CLIMATE CHANGE
19/2017

Synergies and Conflicts between Climate Protection and Adaptation Measures in Countries of Different Development Levels

Final Report

For our Environment

Umwelt Bundesamt

CLIMATE CHANGE 19/2017

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

Project No. (FKZ) 3711 411 09
Report No. (UBA-FB) 002294/ENG

Synergies and Conflicts between Climate Protection and Adaptation Measures in Countries of Different Development Levels

by

Flavio Pinto Siabatto
Potsdam-Institut für Klimafolgenforschung e.V., Potsdam

Lisa Junghans, Lutz Weischer
Germanwatch e.V.m Bonn

On behalf of the German Environment Agency

Imprint

Publisher:
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Study performed by:
Potsdam-Institut für Klimafolgenforschung e.V.
Telegraphenberg A31
14473 Potsdam

Germanwatch e.V.
Kaiserstr. 201
53113 Bonn

Study completed in:
December 2015

Edited by:
Section I 2.1 Climate Protection
Dr. Thomas Voigt

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4359

Dessau-Roßlau, August 2017

The project underlying this report was financed by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear safety under project number 3711 411 09. The responsibility for the content of this publication lies with the author(s).

Kurzbeschreibung

Angesichts einer sich beschleunigenden Erderwärmung wird es für Entwicklungsländer zunehmend bedeutsam, wie sie unter diesen veränderten Bedingungen ihre selbst-definierten Entwicklungsziele beibehalten, mit unvermeidbaren Konsequenzen des Klimawandel umgehen und zudem noch einen Beitrag zum Klimaschutz leisten können. Diese Aufgabenstellung erfordert einen Ansatz, der potentielle Entwicklungspfade für Länder vorzeichnet und Synergien und Zielkonflikte in Bezug auf die oben angemerkten Problemstellungen benennt. Es ist absehbar, dass Maßnahmen zur Bekämpfung des Klimawandels in Zukunft kostenintensiver sein werden und daher Entwicklungsländer verstärkt nach Synergien zwischen Anpassung, Minderung von Treibhausgasen sowie nachhaltigen Entwicklungenzielen suchen müssen. Dies war die Motivation für den vorliegenden Projektbericht, welcher für eine Auswahl von 16 Ländern, Brasilien, Kambodscha, Kolumbien, Grenada, Äthiopien, Indien, Indonesien, Kenia, Mali, Mexiko, Nicaragua, Pakistan, Peru, Philippinen, Südafrika und Vietnam eine solche Untersuchung unternimmt. Natürlich ist eine solche Unternehmung von verschiedenen Herausforderungen begleitet. Soll zum Beispiel ein neuartiger analytischer Modellansatz verwendet werden, oder genügen statistische Ansätze; ja existieren notwendige Daten überhaupt, um vergleichbare Analysen vorlegen zu können? Das Synergien-Projekt folgt hier eher einem pragmatischen Ansatz, der theoretische und datenbasierte Betrachtungen kombiniert und auch mit Datendefiziten umgehen kann. Das Projekt basiert dabei auf folgenden Annahmen: 1) Es wird angenommen, dass eine inadäquate Nutzung von Ressourcen Umweltschäden, soziale Unruhen sowie auch wirtschaftliche Verluste und Risiken verursachen kann. 2) Zur Verfolgung klimafreundlicher Entwicklungspfade wird eine Transformation der Länder vorausgesetzt, die eine höhere Effizienz bei der Ressourcennutzung, eine Verbesserung von Infrastruktur, sozialer und ökonomischer Bedingungen sowie eine bessere Regierungsführung umfasst. 3) Der Modellansatz nimmt ferner an, dass über eine klare Charakterisierung von Zielkonflikten gangbare Wege identifiziert werden können, die ein Land automatisch auf einen klimafreundlichen Entwicklungpfad führen. Auf dieser Basis sowie weiterer theoretischer Überlegungen wurde ein Modellansatz entwickelt, der versucht Länder nach ihrer Anpassungsfähigkeit zu klassifizieren.

Abstract

As global warming is accelerating it becomes essential for developing countries to figure out how they can maintain development targets, cope with unavoidable consequences of climate change and contribute to climate protection in parallel? These questions call for the derivation of climate resilient pathways for developing countries. Developing ideas for these pathways and assessing them in terms of synergies and potential tradeoffs was the major motivation for the actual project report. It is already foreseeable that climate action could become costly, in particular for developing countries. Thus, why not seek for synergies between adaptation, mitigation and sustainable development action? For a selected list of 16 countries, namely Brazil, Cambodia, Colombia, Grenada, Ethiopia, India, Indonesia, Kenya, Mali, Mexico, Nicaragua, Pakistan, Peru, Philippines, South Africa and Vietnam such an undertaking was started and the results are presented in this report. However, such an attempt is associated with a variety of challenges. For example, whether to apply a sound theoretical framework or to rely on existing statistical data? Moreover, when discussing growth targets, mitigation and adaptation challenges, it is immediately clear that countries generally cannot be investigated in an isolated manner, because of mutual dependencies. Thus, the Synergies Project decided to follow a pragmatic approach which combines theoretical and data driven considerations. Accordingly, the project started from the following assumptions: First, an unsuitable utilization of natural resources in economic activities causes environmental disruptions, social unrest and conflicts, economic losses and risks. Second, pursuing climate resilient pathways implies the transformation of countries towards a higher efficiency in the use of natural resources, further development of infrastructure, social conditions and the

economy, as well as better governance. Third, the transformation of tradeoffs into synergies puts countries on track of climate resilient pathways. Based on these assumptions and on further theoretical considerations a matrix approach was developed, which tries to rank countries according to their actual adaptive capacity. In total, more than 40 indicators were used for an evaluation of a country system.

List of Contents

List of Figures

List of Accronyms

ADB:	Asian Development Bank
AFOLU:	Agriculture, Forestry and Land-Use
BAU:	Business as Usual
BID:	Inter-American Development Bank
BRICS:	Brazil, Russia, India, China and South Africa
CCFF:	Climate Change Financing Framework
CCS:	Carbon Capture and Storage
CGCM:	Coupled Global Circulation Models
CGMC	General Coordination on Global Climate Change
CGRE:	Climate-Resilient Green Economy
CICC:	Comisión Intersecretarial de Cambio Climático – Mexico
CIM:	Inter-ministerial Committee on Climate Change
CMIP3:	Coupled Model Inter-Comparison Project 3
CDM:	Clean Development Mechanism
CO_2:	Carbon Dioxide
COP:	Conference of the parties to the UN Framework Convention on Climate Change
CPR:	Conserve-Protect-Restore
CRF:	Common Reporting Format
DEA:	Department of Environmental Affairs – South Africa
DENR:	Department of Environment and Resources – Philippines
DNP:	National Department of Planning in Colombia
DRM:	Disaster Risk Management
ECDBC:	Colombian Strategy of Low Carbon Development
EPA:	Environmental Protection Authority – Ethiopia
EEP:	Energy and Environment Partnership
EPI:	Environmental Protection Index
FAO:	Food and Agriculture Organization
FAOSTAT:	The Statistics Division of FAO

GCM:	General Circulation Models
GDP:	Gross Domestic Product
GGGI:	Global Green Growth Institute
GHG:	Green House Gas
GIZ:	German International Cooperation Agency
GNI:	Gross National Income
CRGE:	Climate-Resilient Green Economy – Ethiopia
GTP:	Growth and Transformation Plan of Ethiopia
HDI:	Human Development Index
IACCC:	Inter Agency Committee on Climate Change – Philippines
IAM:	Integrated Assessment Model
IEA:	International Energy Agency
IF:	Integrating Framework
IMF:	International Monetary Fund
IPCC:	Intergovernmental Panel on Climate Change
IPRI:	International Property Rights Index
IRP:	Integrated Resource Plan
ITCZ:	Inter-tropical Convergence Zone
JPE:	UN Joint Program on Environment
LCDS:	Low Carbon Development Strategies
LDCs:	Least Developed Countries
LTMS:	Long-Term Mitigation Scenario
LULUCF:	Land Use, Land Use and Forestry
MoE:	Ministry of Environment
MWh:	Megawatt hour
MoCC:	Ministry of Climate Change - Pakistan
MRV:	Measurement, Reporting and Verification
MtCO2e:	Million Tons of Carbon Dioxide Equivalent
Mtoe:	Million Tons of Oil Equivalent
NAMAs:	Nationally Appropriate Mitigation Actions

NAPCC:	National Action Plan for Climate Change – India
NASA:	National Aeronautics and Space Administration
NAWASA:	National Water and Sewerage Authority of Grenada
NCs:	National Communications
NCCAP:	National Climate Change Action Plan – Kenya
NCCAP-P:	National Climate Change Action Plan – Philippines
NCCP:	National Climate Change Policy – Pakistan
NCCR:	National Climate Change Response
NCCRS:	National Climate Change Response Strategy – Kenya
NDB:	New Development Bank
NEMA:	National Environment Management Authority – Kenya
NHGGEI:	National Greenhouse Gases Emissions Inventory – Indonesia
NMSA:	National Meteorological Services Agency
NPCC:	National Plan on Climate Change
NREP:	National Renewable Energy Programme – Philippines
NSDP:	National Strategic Development Plan
NSDS:	National Sustainable Development Strategy – Pakistan
ODA:	Official Development Assistance
OECD:	Organisation for Economic Co-operation and Development
OPEC:	Organization of the Petroleum Exporting Countries
PAGASA:	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PoA:	Programme of Activities
PMCCC:	Prime Minister's Council for Climate Change – India
PNMC:	National Policy on Climate Change
POSAF:	Forest Development Social and Environmental Program
PPP:	Purchasing Power Parity
PR:	Property Rights
RAN GRK:	National Action Plan to Reduce Greenhouse Emissions – Indonesia
RAN-API:	National Action Plan for Climate Change Adaptation – Indonesia

RCP:	Representative Concentration Pathways
REDD+:	Mitigation Measures related to "Reducing Emissions from Deforestation and Forest Degradation (REDD)" that also include conservation, sustainable forest management, and enhancement of forest carbon stocks, thus REDD+.
REIPPPP:	Renewable Energy Independent Power Producer Procurement Programme of South Africa
R&D:	Research and Development
SEMARNAT:	Ministry of Environment and Natural Resources – Mexico
SPCR:	Strategic Plan for Climate Resilience of Grenada
SRES:	Special Report on Emission Scenarios
SRM:	Sectoral Reduction Mechanism
TPES:	Total Primary Energy Supply
TC:	Transaction costs
tCO_2:	Tons of CO_2
UNDP:	United Nations Development Program
UNFCCC:	United Nations Framework Convention on Climate Change
UNEP:	United Nations Environmental Program
UN-REDD:	United Nations collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries.
WB:	World Bank
WBGU:	German Advisory Council on Global Change
WFB:	World Fact Book
WGI:	World Governance Indicators
WRI:	World Resource Institute

Foreword

As global warming is accelerating it becomes essential for developing countries to figure out how they can maintain development targets, cope with unavoidable consequences of climate change and contribute to climate protection in parallel. These questions call for the derivation of climate resilient pathways for developing countries, i.e. for a systematic analysis of trade-offs and synergies between adaptation, greenhouse gas mitigation and development measures. Such an undertaking needs to review scientific and governmental literature, employ data from different sources, and develop a semi-empirical approach to analyze major processes on the country level. Seeking for the relevant documents, investigating different data sources and deriving the right conclusions from them was a tremendous undertaking, but it led to a report consisting of two parts. The first volume comprises a brief outline of the methodological basis, more detailed descriptions of country case studies which are concluded by a discussion of potential synergies. The second volume provides a glossary, a more detailed description of the theoretical framework and additional material related to the country investigations.

Apart from this huge amount of material the report still has room for improvements. During the course of the project it was not feasible to develop a comprehensive model approach, which enables to make projections into the future. Moreover, in this study the countries were investigated independently, i.e. it was assumed that a country system and all its internal activities will evolve without any influence from other countries. This assumption, of course, is a simplification, but it was necessary for a structuring of the overwhelming amount of information the project needed to review. The outcome is a matrix, which comprises economic, societal, and financial indicators. This matrix can be used to assess coping capacity in certain sectors and it can serve as a starting point for more detailed investigations. Indeed this holds true also for the underlying methodological framework, which can be further developed into a model which combines environmental, societal, and financial challenges and enables projections and systematic trade-off analyses.

Summing up, the actual study provides a good entry point for further investigations and may provide a blueprint for such undertakings. There is an increasing and urgent need to analyze transition trajectories for countries on a basis of sound and rigorous scientific approaches. Only based on such investigations would it be feasible to make adequate decisions. The framework developed enables the evaluation of the development of the country system. It offers an opportunity to assess the determinants of adaptive capacity and therefore, ideas for future action can be derived, i.e. in the field of adaptation, mitigation and sustainable development.

Due to the fact that various countries, regions and sectors were investigated a lot of colleagues supported the preparation of this report. In particular, the authors are indebted to thank various colleagues for supporting this report, i.e. by figures, text pieces, and data. Furthermore, we generally encountered open ears for more in-depth - sometimes controversial - discussions. In particular, the authors are indebted to acknowledge the following colleagues for their help and support in alphabetical order, i.e. Luis Costa, Thomas Day, Camila Flórez Bossio, Fatima Ghaffarian, Cornelius Grupp, Ramana Guddipudi, Steffen Kriewald, Jürgen Kropp, Linda Krummenauer, David Landholm. Mariana Morena Lemos da Conceição, Stefanie Lynn Becker, Prajal Pradhan, Theresa Rauch, Katja Voigt, Hibba Waheed, and Carsten Walther.

PART I

METHODOLOGICAL OUTLINE

1 Introduction

The Earth is warming. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (IPCC, 2013) and in the last hundred years global mean temperature increased by approx. 0.7 °C. However small changes in the average temperature of the planet can translate to large and potentially dangerous shifts affecting regional climate and weather regimes. Rising temperatures have been accompanied already in serious changes. While many places have experienced changes in rainfall pattern other regions face more frequent and severe droughts. In high altitude region glaciers are rapidly melting causing that melt water driven river run-off decreases threatening freshwater supply for regions (cf. e.g. Rabatel et al., 2013; Vergara et al., 2011). It is obvious that climate change will have a variety of adverse consequences for water availability, forests and biodiversity (IPCC, 2013). In the future these impacts will be more drastically perceived - in developed and under-developed countries. Nevertheless, underdeveloped countries will suffer most from these effects (World Bank, 2013), because of their limited coping capacities. Amongst developing countries are several which are experiencing rapid economic growth, but in many cases social deficits in regard to food security, health, education and infrastructure access are major bottlenecks for better more sustainable growth. Nevertheless, a healthy planet needs a decoupling of natural resource consumption and environmental impacts from economic growth (Fischer-Kowalski & Swilling, 2011) in order to avoid that further planetary boundaries being transgressed (Rockström et al., 2009; Steffen et al., 2015). If this fails mankind will be confronted with a tremendous challenge, namely to tackle environmental and societal disruptions caused by unfavorable weather and climate conditions in parallel. Moreover, accelerated climate change can create even worse the situation, i.e. in a sense that its coping capacity may overstretched by climate related extreme events.

In order to avoid such a scenario countries need gather ideas how they can develop their own sustainability targets. These must include limits for greenhouse gas emissions and have to consider required adaptation needs and sustainable development goals. However, such integrated strategies are difficult to implement, because advantages of one strategy may materialize in shortcomings for other targets. In order to avoid such trade-offs this report makes an attempt to identify synergies between mitigation, adaptation and development activities.

Increasing risks for human development, mainly induced by changing climate conditions, but a still an increasing demand for resources caused by population growth and changes of lifestyles needs more advanced and local ideas how societal transformations may look like and can be implemented. It is important to point out here that cost assessments, although often demanded by policy makers, have clear limitations in terms of valuation of human life and ecosystem components. These shortcomings apply to the valuation of adaptation, due to the uncertainties related to their eventual effectiveness and their actual cost reduction. Ultimately there are environmental assets which can be valued only qualitatively or to a limited extend in quantitative terms. This holds, to a large extend, also for the assessment of synergies between adaptation, mitigation and sustainable development.

Consequently this report develops a semi-quantitative approach which may allow the analysis of synergies of measures for climate protection and adaptation to climate change between countries of different stages of development. The introduced report makes an attempt to provide a clear understanding of the relationships between adaptation and mitigation. In order to provide more detailed insights for policy makers the methodology requires an evaluation of the country situation in regard to adaptation, mitigation and sustainable development. Therefore the report tries to follow a pragmatic approach which uses existing knowledge and combines it with the demands of decision makers.

Based on this approach, the report explores options of potential synergies for 16 countries of very different income and development levels, namely Brazil, Cambodia, Colombia, Ethiopia, Grenada, India, Indonesia, Kenya, Mali, Mexico, Nicaragua, Pakistan, Peru, Philippines, South Africa and Vietnam. For these countries, the actual report developed an appraisal of their vulnerability, and the identification of key adaptation and development needs.

2 Starting Point of this Report

The main goal of this report is to identify potentials for synergies between adaptation needs and mitigation opportunities at a country level under parallel consideration of sustainable development. Consequently, this report tries to pave the road towards a more integrated vision. From a scientific point of view the identification of adaptation needs in the context of climate change has mainly been investigated through vulnerability assessments. However, vulnerability is a very broad concept and applied methodologies are often superimposed by more or less concrete questions. However, results of such undertakings are rarely comparable. Recent decades have shown that different scientific communities independently developed vulnerability concepts targeting particular questions, i.e. individual vulnerability, microeconomic vulnerability, hazard vulnerability, etc.

Roughly speaking actual approaches can be distinguished into two groups: i) concepts within a biophysical tradition and ii) approaches dealing with a human-ecology perspective. The biophysical tradition focuses on the analysis of interactions between natural hazards and their impacts on certain sectors like agriculture, human health, or forestry. To study vulnerability through this perspective one needs to define a specification of the vulnerable system, the hazard it is exposed to, the attributes at risk from this exposure, and a certain time horizon (Füssel, 2009). The human ecology perspective emerged in the 1970s from the inclusion of political and economic causes of vulnerability (O'Keefe et al. 1976) and how micro- and macroeconomic conditions may affect human vulnerability. As these conditions related to e.g. income inequality, the provision of health and basic services are unequally distributed within societies, vulnerability also became a matter of justice and political economy (Adger and Kelly 1999). This report makes an attempt to integrate these two traditions, because the analysis of synergies between adaptation action, mitigation needs, and sustainable development goals affects all dimensions of the above traditions. Consequently, it is desirable that any kind of adaptation action should create co-benefits for mitigation and vice versa. The core of this report is to figure out these potentials. It develops a heuristics, which is more comprehensive, but partly qualitative and enables a ranking of countries of different development levels (common metric). This analysis is based on a review of existing documents dealing with an assessment of current and future climatic risks, actual and potential mitigation and adaptation efforts for countries (cf. also appendix 4).

The current report starts with a brief introduction of the methodological framework (for a detailed description refer to appendices 2 and 3) and an introduction of the underlying assumptions. Subsequently, ideas to describe and assess coping capacity, development levels, and an assessment of mitigation, adaptation and development options on a country level are introduced. Part II provides the detailed country case studies. Part III develops a discussion about common trade-offs found in the country cases.

For further and more detailed reading, five appendices are attached to this report. The first appendix provides the glossary. The second appendix provides the theoretical foundations of the approach, relating growth, impacts and adaptation. Formally, it develops the concept of resilience and introduces the discussion of how the approach can be used in future undertakings in the analysis of climate resilient pathways. Appendix 3 introduces the representation of the country system: its components and their relationships. Here the concept of adaptive capacity and its operationalization is discussed. Appendix 4 offers a summary of the mitigation capacity of ten countries (Brazil, Cambodia, Ethiopia, India, Indonesia, Kenya, Nicaragua, Pakistan, Philippines and South Africa). The fifth appendix offers a graphical evaluation of the adaptive capacity of countries, arranged from the lowest to the highest GNI per capita. It offers evidence of the relationships between the stage of country's development and the adaptive capacity.

3 Conceptual Outline

This section relies on mathematical foundations described in detail in Appendix 2. Text in italics refers to terminology defined in the appendix 1. In general, synergies are understood as adjustments or co-benefits that mitigate GHG emissions, reduce the impacts of climate change on natural environment, the economy and population while at the same time guaranteeing sustainable development. Potential *synergies* are identified via country-based trade-off analyses. In economic terms *trade-off* analyses can also be understood as cost-benefit analysis, but due to the fact that several components are difficult to monetize, the approach applied goes beyond this methodology. For the analysis of synergies in regard to climate protection, trade-offs are situations where an economic activity benefits from the overexploitation or damage of a resource. Thus, climate change itself, deforestation, human health risks, increased poverty, income inequality or high transaction costs, are the result of trade-offs affecting natural, human and financial resources.

The identification of *adaptation* needs is based on an assessment of *vulnerability*. In this report such assessment accounts for three aspects: the sensitivity of natural systems to climate change, the direct impacts of climate change on the provision of economic inputs and the *productive structure* of the country, and the consequences for the population, of direct impacts from e.g. extremes, or indirect impacts from e.g. lower income. In addition to sensitivity and impacts, vulnerability depends on the *adaptive capacity* (Brooks et al. 2005). Resources, social and economic conditions create the adaptive capacity. A country has more adaptive capacity if resources are more available and social and economic conditions are developed. Wealth of resources and high development of socioeconomic conditions create buffers that assimilate impacts. On the other side, scarce resources and lowly developed socioeconomic conditions worsen the adverse consequences of impacts –due to ill management. Therefore, vulnerability depends on impacts on the components of the country system, but also on the development of these components. The assessment of vulnerability requires the combined analysis of impacts and adaptive capacity.

At the country level, adaptation and human development initiatives are often indistinguishable (Smit & Wandel, 2006). Indeed, adaptation actions are often similar to initiatives targeting the Millennium Development Goals (MDG) (Sachs, 2012). The analytical approach applied in this report integrates specific elements of the MDG: health, education and basic services –water supply, water sanitation and energy. For this report, adaptation needs are circumstances and deficits to be adjusted –i.e. developed– for facilitating adaptation of regions, sectors, communities, households and agents.

Adaptation, adaptive capacity and *coping capacity* are related yet not equal concepts. While adaptation measures are concrete adjustments, the adaptive capacity defines the ability to adapt. Thus, successful adaptation action is a manifestation of the adaptive capacity (Smit & Wandel, 2006). Adaptive capacity depends on the coping capacity. The components of the adaptive capacity are also those of the coping capacity. The adaptive capacity refers to structural adjustments which may produce changes in the coping capacity (Berman et al. 2012). These components have been identified from research on the determinants of vulnerability and the adaptive capacity (Brooks et al., 2005). We developed a framework to assess the coping capacity of the country. The work provided in this report is based on the following rationale:

1. An unsuitable utilization of natural resources in economic activities causes environmental disruptions, social unrest and conflicts, economic losses and risks.
2. Pursuing climate resilient pathways implies the transformation of countries for higher efficiency in the use of natural resources, development of infrastructure, social conditions and the economy, and better governance.
3. The transformation of trade-offs into synergies puts countries on track of climate resilient pathways.

3.1 The Definition of a Country System

In the analytical approach the scale of observation is determined by the country. A country is a system defined by a set of components in dynamic interaction, evolving from the transformation of natural, human and financial resources. A country system evolves through economic and societal activities. These activities create outputs, i.e. goods, services, infrastructure, founding of NGOs, etc. The backbone of a country is the *productive structure.* Economic activities may also create effects like environmental pollution, climate change, inefficient and unfair use of human resources, and risks producing financial losses. In order to avoid these environmental, societal and/or economic disruptions, economic and societal action must be steered by governance institutions in a way that it enhances the adaptive capacity (Skjeflo, 2013; Smit & Skinner, 2002).

We identified the essential components of the country system from the determinants of the adaptive capacity in countries (Adger & Kelly, 1999; Adger et al., 2007; Adger, 2003; Brooks et al., 2005; Moss et al., 2008). These determinants include infrastructure and water supply (R. H. Moss, Brenkert, & Malone, 2001), sanitation (R. H. Moss et al., 2001), technological development (Smit & Skinner, 2002), human capital and governance institutions (Berkhout et al., 2006; Brooks et al., 2005; Eriksen & Kelly, 2007; Klein & Smith, 2003; Næss et al., 2005; Tompkins, 2005; Yohe & Tol, 2002), social capital and networks (Adger, 2003; Yohe & Tol, 2002), economic and environmental capacity (Moss et al., 2001), food security and health (Brooks et al., 2005; Moss et al., 2001), education and income (Adger et al., 2007), markets development (Moss et al., 2001; Skjeflo, 2013), property rights (Adger & Kelly, 1999). We further organized the components of country systems according to three integrating factors creating the adaptive capacity:

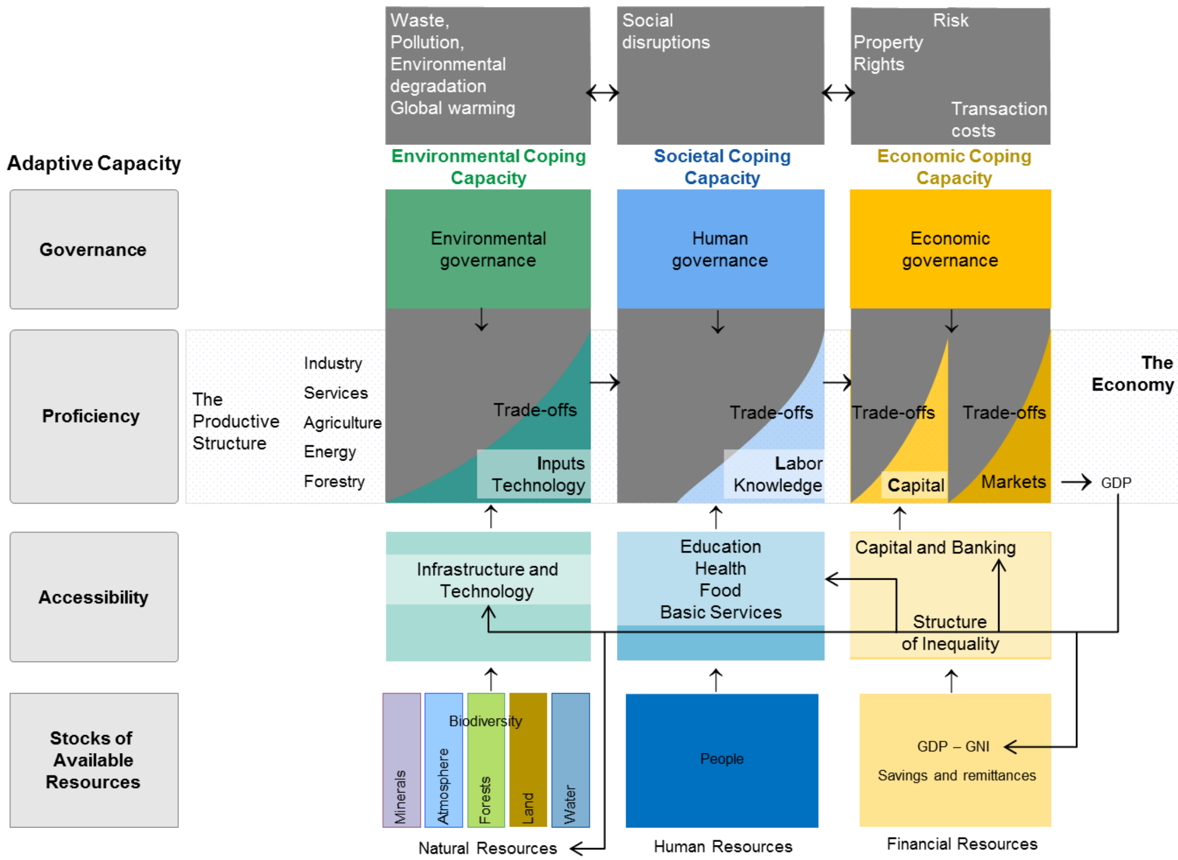
Accessibility: determines the conditions that make resources available for economic activities.

Proficiency: indicates the degree of diversification and specialization of resource use.

Governance: describes the effectiveness of the institutions to control and regulate resource utilization.

Figure 3-1 provides a description of the main elements composing the country system and the relationships between them.

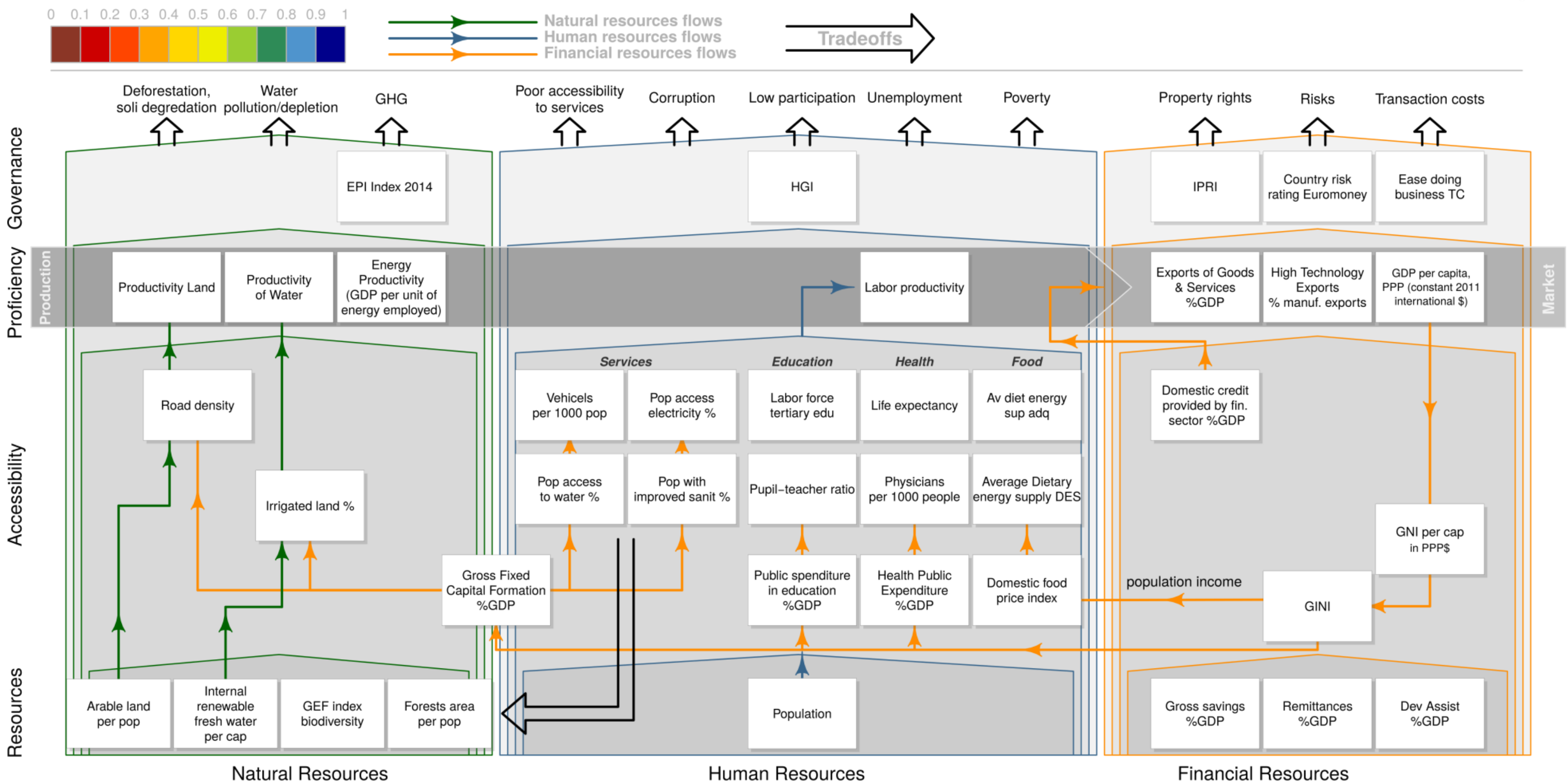
Figure 3-1: Schematic representation of a country system and the factors of the adaptive capacity.



Colored boxes at the right depict the components of country systems specified in the boxes texts. Countries use and transform natural, human and financial resources in economic activities. Arrows denote relationships between components of country systems, determined by the flows of resources within the structures composing country systems. Activities produce trade-offs: flows of goods and services producing economic growth (GDP) and wasted resources producing pollution, environmental degradation on natural resources, social disruptions on human resources, and economic losses from insecure property rights, financial risks and transaction costs. Grey forms refer to the wasted part of resources. Governance structures aim to increase the usable part of the resource and reduce the wasted part, i.e. transform trade-offs into synergies. In natural resources, this waste occurs in all activities and comprises all the resources (for that reason the grey zone starts with the first resources and covers all the activities). For human resources, trade-offs are produced by economic activities (unemployment, bad working conditions, etc.), and by deficient social conditions related to basic services, food, health or education. For that reason the grey zone starts even before the use of human resources in activities. In financial resources trade-offs are produced both at the production side and in markets. The adaptive capacity is a property of the development of the components of country systems.

A formal representation and statistical evidence of the relationships among accessibility, proficiency and governance is presented in Annex 3. For the sake of readability, we excluded these descriptions from the main text of this report. Annex 3 motivates and justifies the selection of the indicators used to assess the adaptive capacity. Figure 3-2 introduces the framework used to assess the adaptive capacity, based on the elements in Figure 3-1. The framework depicts in more detail elements of country system determining the adaptive capacity. The framework introduces additional indicators that show the allocation of financial resources.

Figure 3-2: Framework of indicators used to assess the adaptive capacity and the stage of development of a country.



Each indicator evaluates a component of the country system on an annual basis. For a detailed discussion of the components and their relationships, refer to appendix 3. The value of each indicator is normalized with respect to the rest of the world. A colored scale was created to identify relative values, with brown for very low and blue for very high values. Colored arrows indicate the flows of resources being transformed by the structures of accessibility, to make them available as inputs in economic activities. Some elements can be directly assessed by one indicator, e.g. road density informs adequately the accessibility to land and other natural resources. Similarly it occurs with the indicators of % population with access to electricity, sanitation or improved fresh water. Other elements shaping social conditions (food security, health and education) require more than one indicator. Proficiency was assessed in terms of the productivity of the resource, for natural and human resources. Void arrows indicate potential sources of trade-offs. For a detailed discussion of the used indicators, refer to appendix 3.

4 Assessment of Mitigation, Adaptation and Development Options in Time

4.1 Human Development and Carbon Dioxide Emissions from Fossil Fuel Combustion

Actual studies show that carbon dioxide emissions are clearly related to human development (Costa et al., 2011; Lamb et al., 2014; Steinberger et al., 2013). Consequently, the Human Development Index (UNDP, 2009) can be used as a proxy to investigate carbon emissions for today and in the future (cf. Costa et al. 2011). Moreover, the HDI includes components like life expectancy or school enrolment which are considered to be determinants of adaptive capacity (Brooks et al., 2005). In this study CO_2 emissions and country development were investigated in detail (cf. part II) in particular in regard to determinants of adaptive capacity, i.e. health and education. The study of the relation between CO_2 emissions and the components of the HDI provide an adequate setting to investigate the social trade-offs produced by the increased use of fossil fuels in energy.

4.2 Food Demand, the Evolution of Dietary Patterns and Agricultural Emissions

Population growth and changes in dietary patterns are creating trade-offs in land and water resources. Agriculture creates trade-offs in the atmosphere due to increased emissions from this sector. For studying the dietary patterns of a country, data on countrywide food supply from FAOSTAT were used (FAO, 2014). By examining these data, shifts in dietary patterns for a country during the last five decades can be observed (1961-2011). These shifts can be interpreted as life style changes, because diets move towards more affluent diets consisting of a larger share of animal products (Pradhan et al. 2013). We investigated countrywide agricultural emissions using data from FAOSTAT (FAO, 2014) for the last five decades (1961-2011). It can be clearly shown that this development of dietary life styles causes larger emissions in the respective countries (cf. part II). The detailed methodology is explained in (Pradhan et al., 2013). This approach was used to investigate the trade-offs created by agriculture, driven by dietary life styles changes.

4.3 Peri-Urban Agriculture and Food Self-Sufficiency

Sufficient food supply is a human right. Large parts of human wealth are in the world's cities. Solving the global climate problem requires readjustments in cities in particular, namely intensified action for CO_2 reduction. Cities are also risk prone, i.e. need to adapt. Because of the fact that in this report the focus lies on synergies between adaptation and mitigation, a methodology was developed which exemplifies the effect between adaptation needs and strategies which may reduce carbon emissions.

The massive ongoing urbanization in the 21st century is a major challenge for societies. Crucial developments towards a sustainable future will take place in cities. The potential for local food self-sufficiency for major cities (> 100,000 residents) in the respective countries was analyzed. Today, the necessary transport of food, especially the increasing transport by plane due to the global food supply chain, leads to a significant amount of greenhouse gas emissions. Thus, a reorganization of cities in terms of their food allocation could save a considerable amount of emissions. Country reports rely on results from a model developed by (Kriewald, 2012), able to identify cities and their peri-urban areas as well as the current and possible available harvested areas within the same area.

This model is based on information from the MODIS land cover (NASA, 2014) and the GRUMP population data (NASA, 2015). With regard to national food consumption (FAO, 2014), a linear programming approach calculates the best possible yield in these areas and allows the computation of the fraction of population, which can be potentially nourished. Additionally, future changes on crop yields, under scenarios A2 and B2 based on the MPI ECHAM4 model (IIASA/FAO, 2012) were investigated. Different dietary patterns were considered, namely the current kcal consumption, a maximum with 3500 kcal, a norm with 2800 kcal, and minimum with 2100 kcal/cap and vegan diet (which replaces all animal product kcal by crop kcal) (Kriewald et al. 2015).

5 The Structure of Country Reports

The structure of the country reports follows the rationale of the analytical approach outlined in the previous sections. Each country report starts with a factsheet of relevant information of the country. Afterwards, the country characteristics are described according to the following structure:

5.1 Sensitivity and Vulnerability

The analysis of sensitivity of natural resources indicates how natural resources may respond to changes in temperature and precipitation. Trends and future projections of temperature and precipitation are reported from studies based on the scenario projections calculated for the 4th IPCC Assessment Report (AR4) (IPCC, 2007), because this study started before the release of AR5. The examined resources include water, crop, land use and forestry, and atmosphere. The subsequent sections related to the atmosphere report on the current and trend situation of country based GHG emissions (WRI 2011). This trend is important to appraise targets like emission limits of 2 tCO_2/capita/yr in average up to 2050 (WBGU, 2009) which may keep global warming below 2 $^{\circ}$C, considering an equal burden sharing per capita. Due to globally increasing emissions a 2 t/cap/yr emission budget is still a matter of debate. However, the IPCC-TAR (2001) stated that a world population of about 10 billion people may emit an average of carbon of about 0.3, 0.6, 0.9, and 1.2 tons carbon/capita (equals to 1.1, 2.2, 3.3, 4.4 tCO_2) compatible with 450, 550, 650, and 750ppm limits, respectively by 2100. The reader may imagine that the time horizon for such budget calculations have considerably decreased. Thus, an average emission of 2 t/cap/yr is only a rough estimate for climate protection targets.

5.2 Economic Vulnerability

The assessment of the vulnerability of the economy considers different aspects. First the exposure of the productive structure to damages caused, e.g. by floods, droughts, storms, etc. In general three main economic sectors, namely agriculture, industry and services, and economic activities therein are considered. Increasing scarcities of available resources and additional planning risks defines the vulnerability of economic sectors.

The report discusses the dependence of the country economy on vulnerable sectors. The maturation of an economy is analyzed by considering the level of productive factors, their diversification and the specialization. These productive factors include infrastructure, labor and energy. The specialization and the diversification of the economy are relevant attributes for the coping and the adaptive capacity (Marschke & Berkes, 2006; Pike et al., 2010). Diversification is appraised from the portfolio of exports, in terms of the number of exported products (the set of commodities, goods and services exported by the country (Simoes & Hidalgo, 2014). The specialization of the economy is estimated by the share of exported goods with high added value (Simoes & Hidalgo, 2014), and by the productivity of land, water, energy and labor.

The index of gross fixed capital formation was used as an indicator to measure capitalization and capital formation (World Bank, 2015). It measures %GDP used by the country to invest in infrastructure, e.g. hospitals, schools and other facilities, and private capital. The provision of credits by the financial sector (World Bank, 2015) was used to assess the accessibility to financial resources within the country. If available, an additional indicator is used to depict the number of companies listed in the national stock markets. This number can be considered as a proxy for the concentration or diversification of the economy.

Planning risks may induce an extended vulnerability of an economic system. These, for example, can be created by uncertain property rights or high transaction costs. Consequently, we included the International Property Rights Index (IPRI 2014) and an indicator of ease doing business (World Bank, 2015). In order to account for the governance of additional sources of structural risk, the country risk index was used (Euromoney, 2014).

5.3 Social Vulnerability

Inequality and the structure of entitlements matter for social vulnerability (Adger & Kelly, 1999; Adger, 1999; Kelly & Adger, 2000). Poverty is also an important factor of social vulnerability (Dow & Wilbanks, 2003). The assessment of societal vulnerability in country reports starts by observing the trends of income distribution in the country. Indicators used include the GINI index of income inequality of the World Bank, and the distribution of income among five income shares (World Bank, 2015). For the assessment of poverty trends, the poverty headcount ratio at national poverty lines was used. Comparisons based on the poverty headcount ratio are not possible, as this ratio is defined by national authorities at the country level. However, it provides an estimation of the performance of the country in the reduction of poverty.

Other components of social vulnerability can be measured by food security factors. In addition to the information provided in the evaluation of dietary changes and the potential for peri-urban agriculture (Kriewald et al., 2015; Pradhan et al., 2013), the evaluation of social vulnerability in the country reports includes three indicators that depict the situation of food security in terms of depth of undernourishment, the relative cost of food (the food price ratio), the total food supply in the country, and the adequacy of food (FAO, 2015). Improved livelihood conditions comprise also adequate human health, access to waste sewage and freshwater services (Lissner et al. 2014). These factors are measured by indicators like investments in health infrastructure in percentage of GDP, number of doctors per 1,000 people and life expectancy (World Bank, 2015) as an indicator of outcome of adequate health (Brooks et al., 2005).

Education attainment is one determinant of the adaptive capacity and vulnerability (Adger et al., 2007). We evaluated the situation of education at the country level using three indicators. We used the public expenditure on education as percentage of GDP (World Bank, 2015) as a proxy for the financial resources used in the sector. The indicator of the pupil/teacher ratio in primary school (World Bank, 2015) was used as proxy for human resources in the sector. It approximates the effectiveness and quality of teaching. The appraisal of education at the country level is completed by measuring the output: i.e.

by the percentage of population with a tertiary education in the country (World Bank, 2015).

The provision of basic services determine whether the population is vulnerable to climate change impacts (Moss et al., 2001). Indicators used include the percentage population with access to sanitation services, the percentage population with access to improved water services, and the percentage population with access to electricity (World Bank, 2015).

Before discussing synergies, every country report assesses the adaptive capacity and the stage of development of the country, based on the framework depicted in Figure 3-2. A detailed discussion of the rationale of the assessment is presented in appendix 2 (Climate Resilient Pathways) and 3 (The Country System). The assessment reveals the stage of development of the components of country systems and assesses major bottlenecks and restrictions hindering the development of the country and to implement adaptation and mitigation measure at a high level of efficiency.

The country report ends with an analysis of synergies considering the assessment of vulnerability, adaptation options, and the adaptive capacity. The analysis of synergies departs from the identification of the most relevant trade-offs in the context of vulnerability and adaptation needs and the stage of development of the country.

6 Shortcomings of the Approach

The analytical approach applied to appraise synergies in countries is based on four pillars:

1. Synergies, trade-offs and the relationships between adaptation and mitigation.

   Adaptation and greenhouse gas mitigation policies are inherent aspects of any action initialized by the threat of climate change (Ayers and Huq 2009; Biesbroek et al. 2009; Matocha et al. 2012). While any single actions may have particular effects the opposite may happen if considering joint effects. They are defined as trade-offs in case of negative outcomes and as synergies in case of positive outcomes. In addition the analysis of synergies requires a system approach where the relationships between mitigation, adaptation and sustainable development become evident (Wilbanks & Sathaye, 2007).

2. The description of country systems.

   The country system is the basic entity for the analytical approach. For any of the examined countries relationships between adaptation, mitigation and sustainable development were investigated. The country system exemplifies the emergence of the adaptive capacity.

3. The description and formal representation of the adaptive capacity.

   The potential to transform trade-offs into synergies depends on the adaptive capacity. Several authors have pointed out that the adaptive capacity emerge from the relationships among its determinants (Adger et al., 2007; Moss et al., 2001; Willems & Baumert, 2003). These determinants are indeed the components of country systems, e.g. resource availability, structure of the economic system. It is assumed that a country may develop its adaptive capacity by utilizing resources, if the accessibility to the resource, its proficient use in economic activities and its governance are suitably developed. According to this point of view a formal representation of the adaptive capacity is an essential component for any description, evaluation and modeling of climate resilient pathways.

4. A mathematical framework for resilience of country systems.

   Transforming trade-offs into synergies may create resilience. Climate resilient pathways are trajectories of growth, development associated with a subtle mitigation and adaptation policy (Denton & Wilbanks, 2014). Thus, a mathematical model that integrates the analysis of climate resilient pathways was developed (see appendix 2). The model holds the analysis of trade-offs and synergies.

Despite of the briefly introduced approach several aspects are still unresolved and require further research, namely:

- a framework that analyses mutual dependencies between and amongst countries and with the world market, in particular in regard to economic activities,
- although the approach applied is supported by a comprehensive mathematical description time dimension is not yet considered,
- the underlying mathematical approach is so far analytical, i.e. its implementation as a model will need further time,
- the analysis of institutions and incentives required for synergies is at its beginnings.

PART II

COUNTRY REPORTS

1 BRAZIL

Figure 1-1: Brazil – Factsheet and physical map:

1.1 Sensitivity and Vulnerability

1.1.1 Sensitivity of Natural Resources

Temperature: Although the coverage with meteorological stations of large parts of Brazil is low, a pronounced warming was measured for Brazil during the last 50 years. According to existing empirical measurements mean temperature increased by 0.7 °C which is above the global average for this period (IPCC 2007). Focusing on the winter season alone the warming trend is larger than 1 °C. For the future development temperature changes differ largely depending on the forcing scenarios and the sensitivity of the used models. For three different forcing scenarios (A1FI, A1B, B1) mean temperature increase over Brazil will amount to 4.1-7.7, 3.1-6.0, and 2.0-3.8 °C (reference period 1961-1990) beyond 2090 (Marengo et al. 2011). Moreover, Amazon catchment will become a hot spot for extreme heat, because days with extreme heat will increase from 45-90 d/yr under a 2 °C warming up to 300 d/yr under a 4 °C warming (World Bank 2013a).

Water resources, rainfall and precipitation: Although there is still a missing empirical evidence that rainfall decreased in the Amazon catchment during recent decades (Marengo 2004), certain extreme events indicate that a trend exists towards a drier climate (Li et al. 2008). Marengo (2004) analyzed data for 300 stations from the Amazon catchment (1929-1999) and found that there exists a bipolar behavior. While in the Northern Amazon precipitation is decreasing after the middle of the 1970, it increased in the Southern part. For the whole Amazon catchment there is a trend of decreasing precipitation of 0.15mm/day decade (1949-1999). This trend is also supported by extreme droughts in Southern Amazonia in 2005 and 2010. While the long-term precipitation during the summer season amounts to 200-400mm/month, it decreases to 100mm/month (Marengo et al. 2011). Future projections indicate that this trend may accelerate. Dry periods over the Amazon catchment will be increasingly pronounced beyond 2040 as the Eta-CPTEC model (Marengo et al. 2012) results indicate. Considering the same scenarios as above (A1FI, A1B, B1) the decrease lies between -41% and -11% (2071-2100 in comparison to 1961-1990).

For Southern of Amazonia the opposite will come true, i.e. precipitation increase (Marengo et al. 2011). One reason for this behavior may be a change of wind patterns over the Southern Pacific and Atlantic Ocean which transport moisture over the South-American continent. However, a recent detailed study comparing empirical and simulation data from 19 GCMs data indicate that under accelerated climate change Amazon forest may die-back (Malhi et al. 2009) and the region will develop towards a savannah. Also human induced deforestation is important, because (Marengo et al. 2011) estimated that less than 30% forest reduction will disrupt Amazon's rainfall recycling, i.e. rainfall decreases below a threshold necessary to sustain the forest itself.

River run-off: (Margulis et al. 2011) model estimates for different river catchments calculated mean run-off changes under A2 and B2 forcing scenarios and for a grid resolution of 0.5°x0.5°. To calculate the climate normal (1961-1990) CRU data was used (IPCC 2014). For most of the catchments they found a decrease of river run-off as an overarching trend. This coincides with the projected rain-fall decrease in the Amazon catchment. The only exceptions are the southern regions of Brazil which can expect an increase. Overall, the trend is inconsistent which relates to the fact catchments are large, sometimes overlapping different eco-hydrological zones (see Table 1-1).

Table 1-1: Change of river discharge for different rivers and catchments in Brazil under different climate change forcing scenarios.:

River Catchment Area	Forcing B2/period			Forcing A2/period			Reference 1961-1990
	2011-2040	2041-2070	2071-2100	2011-2040	2041-2070	2071-2100	10^3 m^3/s
Amazon	-7%	-14%	-25%	-6%	-26%	-30%	131.0
Tocantins (T)	-28%	-33%	-46%	-27%	-45%	-53%	13.6
Sao Francisco	-62%	-57%	-53%	-57%	-57%	-47%	2.9
Parana	-15%	-16%	-7%	-6%	-9%	+11%	11.5
South Atlantic Region	+11%	+8%	+16%	+12%	+2%	+9%	4.2

Model runs were performed with the HadRM3P model (after Margulis et al. 2011, cf. for details). (T) indicates a tributary of Amazon river.

Crops yields: By 2012, nine crops covered the 86% of planted area in Brazil, namely cotton, rice, coffee, sugarcane, beans, sunflower, cassava, maize and soybean (WB 2013). Detailed studies have shown that climate change will have different impacts on agriculture in Brazil depending on crop species and region (Assad and Pinto 2008; Pinto et al. 2008; Margulis et al. 2011). The Worldbank (2013) stated that for certain crop species a 2 °C warming may cause a decline of 70% in soybean yield by 2050 (reference period 1989-2009). These challenges can be managed only partly by adaptation strategies e.g. improved crop species, soil management, and/or irrigation. Margulis et al. (2011) estimated that suitable land for soybean cultivation will shrink by 40% (A2 forcing). A decrease in suitable land for crop production holds for the most of the crops except sugarcane. Here an extension of the suitable area for sugarcane production can be expected. The Worldbank (2013) shows that the changes for crops are -4.6% (B2) and -11.7% (A2) for cotton, -9.9% (B2) and -7.4% (A2) for rice, +107% (B2) and +101% (A2) for sugar cane, -13% (B2) and -24% (A2) for soybean by 2020. The increasing need of suitable land for crop can therefore create additional pressure on rainforest, because farmers will probably compensate their losses by new land claimed and obtained after deforestation.

Land Use and Forestry: (Parry et al. 2007) showed that soil erosion may be exacerbated by an increased surface runoff in Brazil’s North-eastern parts. While there are strong indications that increasing temperatures may change the climatologic regime over Amazonia causing significant losses of tropical rain forests or even transform rainforest to savannah in the worst case (Malhi et al. 2009; Margulis et al. 2011), human impacts on Amazonian forest are still high. An important effect is that deforestation still causes high emissions (Song et al. 2015). While in certain regions deforestation and related emissions are still increasing, they are slowing down in others. Moreover, due to moisture losses, forests are becoming more vulnerable to fires which may cause a significant increase in tree mortality (Sampaio et al. 2007).

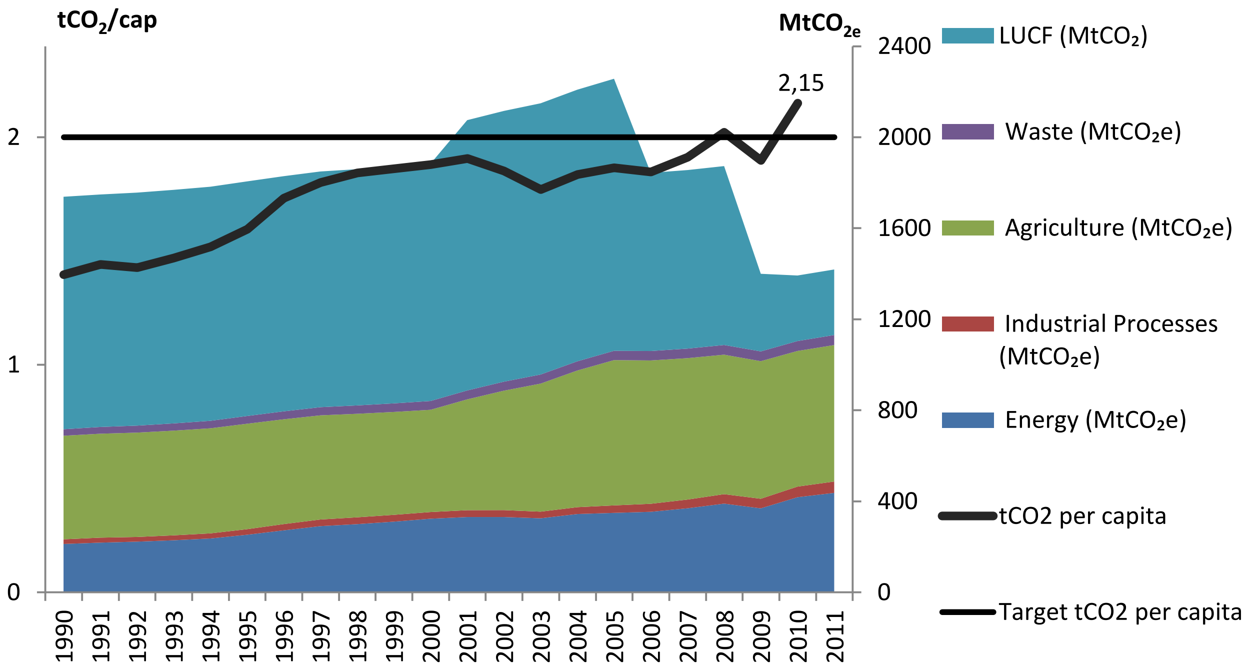
Cattle ranching and land reclamation for soya cultivation are still major drivers of deforestation (Gollnow and Lakes 2014). According to the modeling of the Brazilian Land Use Model (BLUM) under business-as-usual scenario assumptions, cropland would increase to 17 million ha by 2030, compared to the 45.5 million ha of 2009. In the same time, forest area will decrease by 10.6 million ha by 2030 from 238.671 million ha of the BAU scenario (World Bank 2013b). The south region of Brazil will be most impacted, losing 5 million ha by 2030 from the 29.8 million ha (World Bank 2013b). Reaching ~40% of deforestation might trigger reinforcing processes that could produce more climate change (Sampaio et al. 2007).

Atmosphere: Net emissions from deforestation in Brazil are the second highest in the World (288 MtCO_2 by 2011) after Indonesia (1,218 MtCO_2 by 2011) (WRI 2014). As Figure 1-2 show, Brazil has successfully reduced emissions from deforestation. In 2005 emissions from deforestation accounted for 52% of total emissions. In 2011, emissions from deforestation accounted for only 20% of these emissions. On the other hand, emissions from agricultural production and energy and industry have been growing in this century, as Figure 1-2 shows.

The flagship climate legislation is the National Policy on Climate Change (PNMC), adopted in 2009, and its implementation, the National Plan on Climate Change (NPCC) and respective sector plans. It defines the country's low carbon strategy and simultaneously constitutes the voluntary emission reduction targets submitted to the Copenhagen Accord of the UNFCCC as Brazil's 'Nationally Appropriate Mitigation Actions' (NAMAs) (Nachmany et al. 2014). While the Copenhagen pledge is conditional to the provision of adequate financial and technological support, the identical national legislations do not mention any preconditions. The PNMC sets the target of 36.1 - 38.9% emission reductions in 2020 compared to a BAU scenario of 2,704 - 3,236 MtCO_{2e} in 2020 (CAT 2015). It tackles the most obvious potential through reductions in the LULUCF sector as well as in agriculture and energy and would lead to total GHG emissions of 1,977 to 2,068 MtCO_{2e} in 2020 (CAT 2015), which could be in line with the target of an emission cap of under 2 GtCO_{2e}/a and a reduction of 5.8 percent compared to 2005 numbers (Fekete et al., 2013). The PNMC uses several sector plans for implementation such as the 'Action Plan to Prevent and Control Deforestation in the Legal

Amazon', which aims for a 80% reduction of annual deforestation rates in 2020 compared to 1996-2005 or the Forest Code to establish 'Permanent Protected Areas' and for controlling deforestation (Nachmany et al. 2014; "Climate Action Tracker" 2014).

Figure 1-2: GHG sectoral emissions and energy per capita emissions of Brazil.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from bunker fuels are comparatively insignificant and were not included. Lines denote emissions per capita, with black line showing actual emissions and the horizontal line the 2 tCO_2 threshold per capita average to keep under 2°C warming, according to the conditions of fair burden of the Budget Approach (WBGU 2009). As the shares of emissions show, the main sectors for GHG reductions are agriculture, energy and deforestation.

1.1.2 Economic Vulnerability

The Brazilian GNI per capita is low and the inequality of income distribution is very high. Hence, impacts from climate change on GNI will affect the poor more drastically. Based on statistical estimations (Margulis et al. 2011) projections of GDP growth rates amounts to 4.2% per year between 2008 and 2035 and 3.77% between 2035 and 2050 (A2 scenario, without climate change impacts). For a B2 scenario without impacts, the GDP will grow by 4.24% and 3.25%, respectively. Considering climate impacts the Brazilian GDP will lose more under a B2 scenario (2.3% per year) than under an A2 scenario (0.5% per year). Yet, in absolute numbers losses are higher under the A2 scenario.

Productive Factors: The adaptive capacity of any country will be higher if productive factors are developed (Moss et al., 2001). According to (Loman 2014) the performance of the Brazilian economy is burdened by very low stock of infrastructure. While the stock of infrastructure accounts for 58% of GDP in India, and 87% in South Africa, in Brazil it amounted to only 16% in 2013. Brazil is also burdened by the high costs of labor. The percentage of labor force with tertiary education by 2011 was low (17%) compared to neighbor countries (e.g. Colombia 22%, Argentina 34%) (World Bank 2015a). These constraints restrict the availability of human capital and reduce the effectiveness of the economy.

Economic specialization and diversification: Lowly diversified and lowly specialized economies will be more vulnerable to changes in prices and trade conditions. The higher the specialization and the diversification are, the better the adaptive capacity. As the number of commodities exported serves as proxy for diversification, it can be concluded that the economy of Brazil is highly diversified. Brazil exported 1193 commodities in 2012 (Simoes and Hidalgo 2014) similar to Mexico and South Africa. Nevertheless, exports are concentrated in few products. In 2012 only 10 commodities accounted for 48.33% of value of total exports, amongst them 6 were agricultural commodities, namely soybeans, raw sugar, poultry meat, soybean meal, coffee and corn (Simoes and Hidalgo 2014). Therefore, the share of GDP from exports can be affected by impacts of climate change on agriculture.

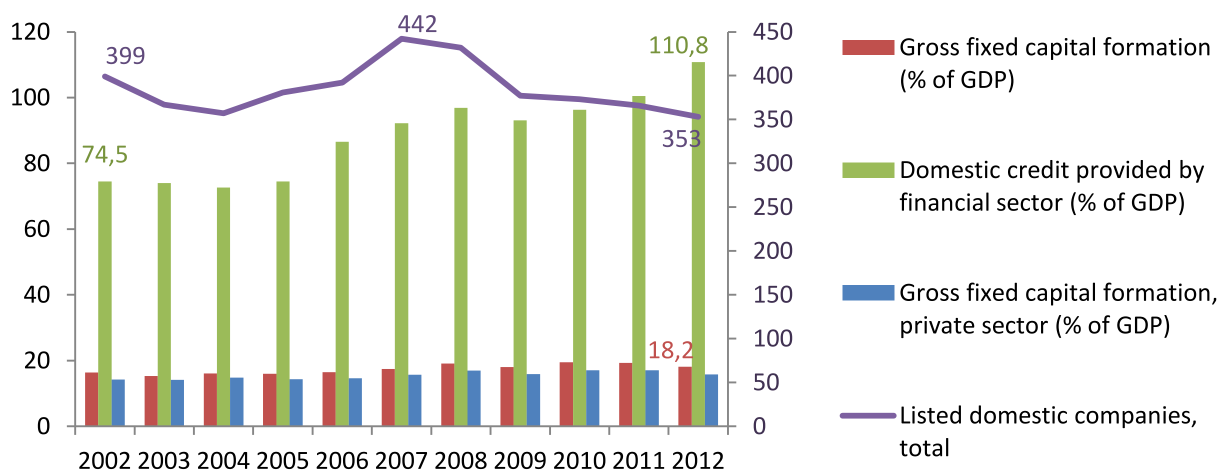
Changes in international trade conditions or impacts from climate change in agricultural commodities exported would not affect the Brazilian economy as severely as other economies. In other countries studied, e.g. Cambodia or Vietnam, exports shares were above 50% of GDP by 2012 making GDP sensitive to changes in international trade conditions. In countries of similar economic status like Mexico or South Africa, revenues from exports account for 33-34% of GDP. The main driver of GDP growth in Brazil is not exports but internal consumption: 63.5% by 2014 (WFB 2015). Exports in Brazil represented only 12.4% of GDP in 2014 (WFB 2015). In regard of international trade the Brazilian economy is relatively resilient.

Capitalization and Capital Formation: High investments in gross fixed capital formation would inform about the commitment to enhance basic infrastructure for adaptive capacity. As Figure 1-3 show the financial system consistently increased the provision of domestic credits from 74.5% to 110.8% of GDP between 2002 and 2012. Therefore, the country has an adequate capacity to provide credit to cope with shocks. It is worth noticing that the financial crisis of 2008 did not severely affect the provision of domestic credit. However, the number of companies listed in the stock market has been reducing since 2007, denoting a process of concentration of capital. It is also indicative of low diversification of the economy. On the other hand, the share of GDP invested in the development of gross fixed capital formation (infrastructure, schools, hospitals, etc.) has kept below 20%. This historical trend is responsible for the low development of infrastructure in Brazil (Loman 2014). These numbers are indicative of a relative high accessibility to financial capital and high development of capital, favoring growth and the capacity to cope with shocks.

Economic Risk and Uncertainties: As it was mentioned in the methods section, the governance of financial resources associated with adaptive capacity is about the ability to reduce the variability of economic flows (Adger et al. 2007). As climate change has an influence on economic outputs; for the assessment of economic vulnerability it is important to trace how the country performs in the control of economic risk and economic uncertainties. Inflation has been kept relatively low, 6.2% in 2013 (WB 2014) and stable around 5.5 with standard deviation 1.08 between 2004 and 2013. This is in contrast to the trend in the last century where inflation reached 2900% in 1990 (World Bank 2015a).

However, Brazil does not perform adequately in transaction costs[1]. As a proxy for transaction costs we used the ease doing business index (World Bank 2015a) which evaluates the environment facilitating development of business. In this index the country ranks 116 (out of 181 countries), i.e. far below Colombia (42) or Peru (43). The country risk index (Euromoney 2014) –which evaluates structural, political and economic risk, places the country in the group below the 70% lower risk countries (62.34 as of 2013). This shows a relatively good governance of financial risk and macroeconomic variables. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). The middle performance in the International Property Right Index (5.4 in 2013) shows inefficiencies and risk associated to property. Insecure land tenure in forests areas may have contributed to this value.

Figure 1-3: The recent evolution of gross fixed capital formation and domestic loans provided by the financial sector in Brazil.



The graphic provides information about domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation, both private and public (World Bank 2015a). For the analysis of the adaptive capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. For growth the country has developed an adequate basis to provide domestic loans, but investments in gross capital formation are insufficient. The decreasing number of companies listed in stock markets indicates an inconvenient concentration of capital.

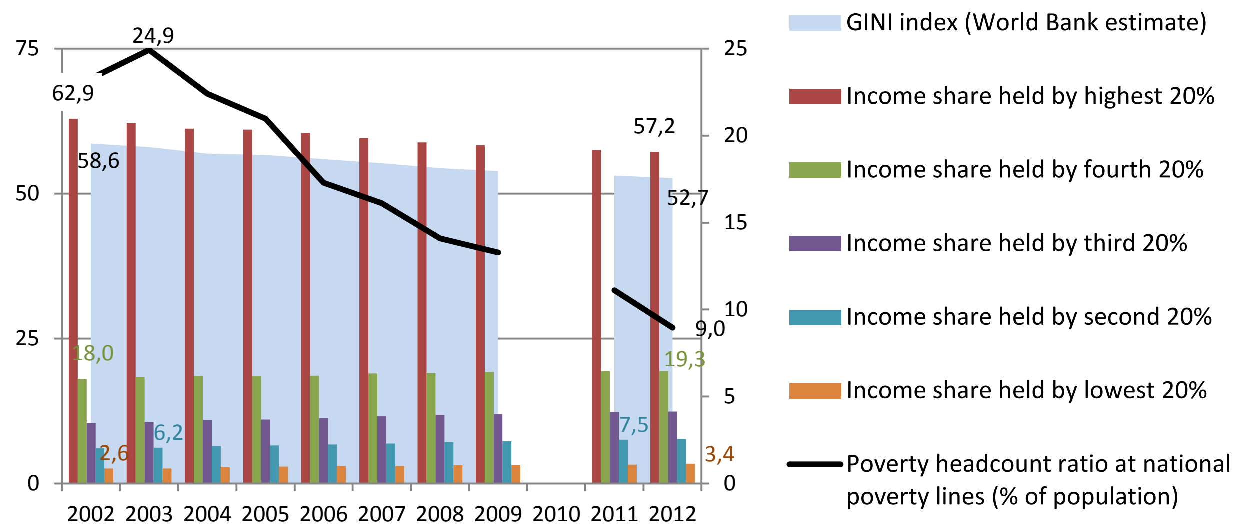
1.1.3 Social Vulnerability

The historical trend of the GINI index of income inequality shows that the Brazilian society has been very unequal. Current inequality in income distribution is still very high. As Figure 1-4 shows, the income share of the highest 20% received 52.7% of the national income, while the income share held by the lowest 20% received only 3.4% by 2012. A tendency to decrease inequality can be observed since 2002, when the richest part of the population received 62.9% of total income, while the poorest received 2.6%. This evolution shows the difficulties of the government to change the status quo in Brazil. With the budget available, the government has reduced the poverty headcount ratio at national poverty line from 24.9% of

1 Transaction costs are the economic costs of searching information for optimal exchange in economic transactions. High transaction costs are typical of lowly developed markets.

total population in 2003 to 9% in 2012 (World Bank 2015a). Income is a determinant of the adaptive capacity of the population (Yohe and Tol 2002). The trends in the reduction of the poverty headcount ratio and income inequality (see Figure 1-4) reflect the efforts of the government to increase the adaptive capacity. However, income inequality is still very high in Brazil.

Figure 1-4: The recent evolution of income distribution, income inequality and poverty in Brazil.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The poverty headcount ratio at national poverty lines (World Bank 2015a) cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Social trade-offs are being reduced in Brazil, as the poverty headcount ratio and income inequality are consistently decreasing.

Food security: Indicators of food adequacy and food supply place Brazil within the 70% higher in the World relative to other countries. Brazil needs to increase in 56 kcal per person per day the average of calories supply (FAO 2015) to provide minimal requirements. 6.9% of people are undernourished and 12% bear food inadequacy (FAO 2015). In regard of minimal supply, undernourishment, and food adequacy, the country faces good conditions. However, these are only average numbers that need to be analyzed in the context of the prevailing inequality of income.

Health, Sanitation and Water Services: Life expectancy in Brazil (73.4 years in 2011) is high relative to the rest of the world (World Bank 2015a). The access to fresh water service reached 97% of total population in 2011, but access to sanitation is rather deficient (81% in the same year); i.e. almost 38 million lack access to sanitation. Moreover, financial support to health care is low. Brazil spent only 4% of GDP in health services in 2012, including private and public expenditure (World Bank 2015a) (European Union: 10.19% of GDP in 2012), below the average in Latin America and the Caribbean (7.7% in 2012) (World Bank 2015a) (for relative values refer to accessibility to human resources in). Dengue and vector-borne diseases will impact human health in Brazil, due to the spread to higher altitudes favored by higher temperatures (Parry et al. 2007). These problems would have incidence in the capacity to cope with impacts of climate change on health.

Education: The pupil teacher ratio in primary education in Brazil was 16 as of 2012, equal to OECD members (WB 2014). But the percentage of labor force with tertiary education (17.2%) is below neighbor countries (Colombia 22%, Ecuador 21% and Argentina 34%). The contrast between the high pupil teacher ratio and the low labor force with tertiary education shows the efforts of the government to correct earlier deficits in education.

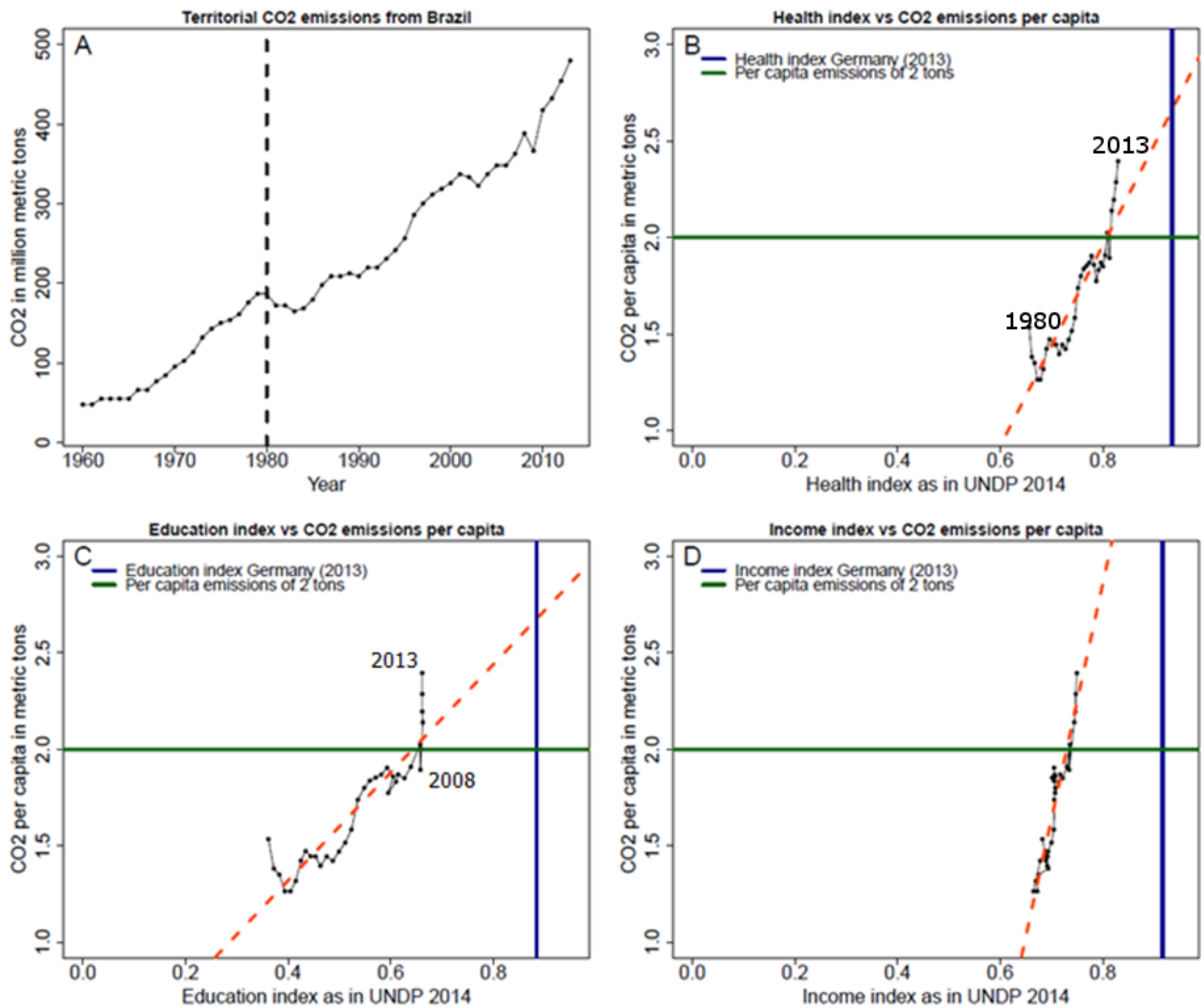
1.2 Links between Adaptation, Development and Mitigation

1.2.1 The Evolution of the HDI and the GHG Emissions

How human development and emissions evolved between 1980 and 2013 is shown in Figure 1-5B, C and D. As Figure 1-5 shows, the linear relationship between observed CO_2 emissions per capita and the HDI components make clear that currently emissions and development are closely interrelated. However, while the education index has been constant since 2009, the emissions grew almost one fourth over the same period (Figure 1-5C). That is, the transference of energy consumed producing higher emissions is not being observed in the development of education outputs reflected in the index. One possible reason is the delay in which investments in education are translated into the outputs of the education index. However, education is partly one result of government investments, partly one of household investments. The indices of health, income and education have remained practically stagnant over the last six years recorded. As Figure 1-3 shows, the country is not allocating adequate shares of investments in the formation of fixed capital –which includes schools, hospitals, roads, etc. As Figure 1-4 also shows, income of the lower income shares have been increasing consistently over the last decade with respect to the income shares of the wealthiest. Therefore, it is evident that the benefits of the redistribution of income in Brazil are being spent in increasing the consumption of goods and services that improve life standards but not health and education.

Assuming the past relations between the HDI components and per capita emissions, Brazil is expected to achieve highly developed standards (HDI>0.9) by 2035 (Costa, Rybski, and Kropp 2011), with associated annual emissions of about 600 million tons also in 2035. It is important still to clarify that despite the rise in per-capita emissions, these are still rather low when compared with big developed-country emitters such as Germany or when compared with fellow emerging economies such as China.

Figure 1-5: Trends of CO_2 emissions and the HDI in Brazil

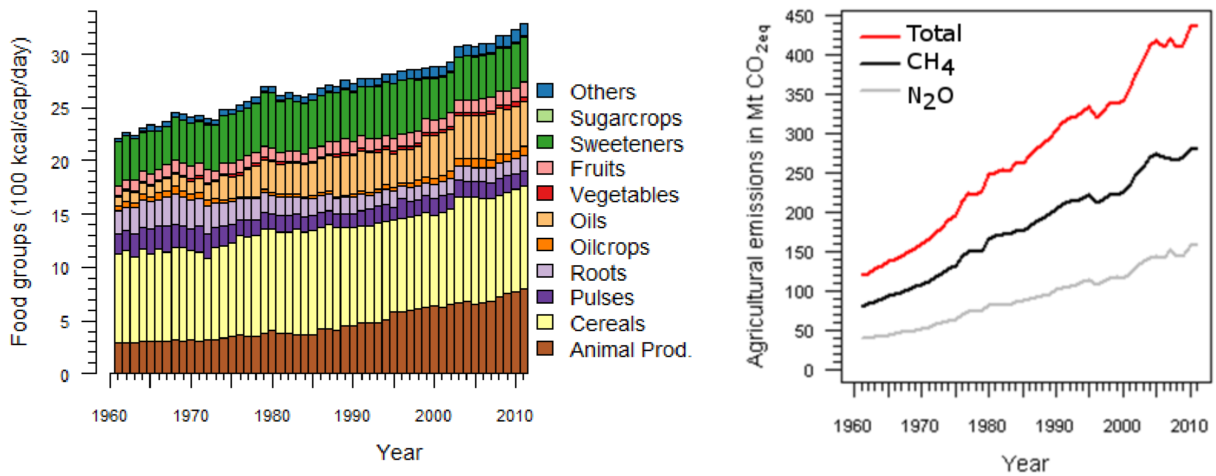


Historical emissions of CO_2 from fossil fuel burning for Brazil obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. Horizontal green line shows the 2t/cap CO_2 target achieving a meaningful climate stabilization policy (WBGU 2009). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. Brazil advances but inconsistently in the indicators composing the HDI, at increasing and variable emissions rates per capita. For synergies, in order to curb the trend, Brazil needs to reduce emissions while improve considerably the performance in education and health.

1.2.2 Dietary Life Styles and Greenhouse Gas Emissions

Figure 1-6 (left panel) shows dietary pattern changes in Brazil between 1961 and 2011 based on 11 different food groups. Brazil's total food supply increased from 2,200 kcal/cap/day to about 3,300 kcal/cap/day during this period. It is remarkable that during the recent decades the amount of cereals was almost constant or increased only slightly, while the amount of animal products tripled in particular after 1990. This clearly indicates an increase in human wealth, i.e. a life style change. However, during the same period GHG emissions from agriculture increased from 120 to 440 $MtCO_{2e}$, i.e. by 267% (Figure 1-6 right panel).

Figure 1-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Brazil.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right —total agricultural non-CO_2 (in CO_{2e}) emissions including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Brazil during the last fifty years. Dietary patterns in Brazil are changing towards affluent diets, reflecting improved nutrient situation whereas greenhouse gas emission from the agriculture has increased in the last 50 years, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

Brazil is a net food and feed exporter (Pradhan et al. 2014) and is playing an important role in supplying global livestock feed demand (Flachsbarth et al. 2015). A recent study that described dietary patterns on a global scale shows that the Brazilian consumption style is characterized by a high calorie diets (Pradhan et al. 2013). Such a diet embodies GHG emissions of approx. 2 tCO_{2e}/cap/yr alone (Pradhan et al. 2013). The over-proportional amount of animal products in this diet (cf. Figure 1-6, left) is met by feeding crops to livestock. In Brazil ˜4 calories of crop products is currently used for livestock growing, i.e. to obtain 1 calorie of animal products (Pradhan et al. 2013a).

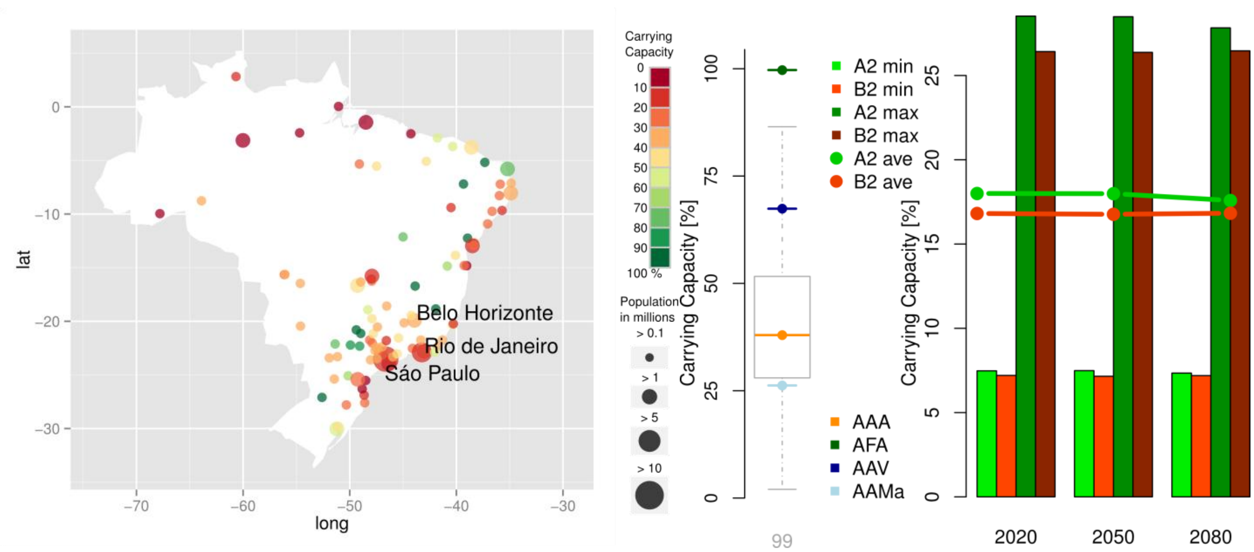
If the individual nourishment style in Brazil changes towards more affluent diets, emissions from the agricultural sector may increase even further. The same holds in the case that Brazil extends agricultural production for the international markets. However, technological progress and adequate management styles in agriculture can change these trade-offs into synergies (cf. e.g. Pradhan et al. 2015), because current emissions per unit of crop and livestock production in Brazil are higher than those for developed countries (Pradhan et al. 2013b). Additionally, certain challenges in the agricultural sector of Brazil are still pressing. Depending on the region the country has only attainted 50% to 70% of the potential crop production (Pradhan et al. 2015). Hence, any efficiency gaining, i.e. yield gap closing by more advanced technology or precise fertilizer usage would lower agricultural emission intensities when the current land use is assumed as constant. If the country decides to produce more food on additional land, i.e. on land obtained by deforestation, this would worsen Brazil's carbon balance in the future.

In the year 2000, around 41 million people in Brazil lived in the regions where local food and feed produced within 10 km x 10 km in cell was sufficient to meet their food and feed demand (Pradhan et al. 2014). Additionally, 72 million Brazilian are food self-sufficient within their states. The country is food self-sufficient, exporting about 114 trillion kcal of food and feed in the year 2000. Furthermore, Brazil could increase its food export by around two and half times by closing yield gaps to attain 90% of the potential crop production.

1.2.3 Peri-Urban Agriculture and Local Food Demand

Currently 85% of in Brazilian residents live in cities and a future growth up to 231 million urban residents by the year 2050 is projected and will raise the fraction of urban population to more than 90% (United Nations 2014). As the UN (2007) stated urban agglomerations are responsible for a large amount of global GHG emissions (approx. 70%). Therefore, solutions for a sustainable urban life are mandatory for the future. One approach can be to produce food in the near vicinity of cities in order to reduce food transport. Such a strategy would also help to use more local products, if feasible. For Brazil 99 cities with a population of 100.000 residents were examined (see Figure 1-7). The analysis shows that today 28% of the surrounding areas are used for agricultural purposes, although 74% could be potentially used. The results implicate that the currently harvested areas can nourish 31% percent of the urban dwellers (Kriewald et al. 2015).

Figure 1-7: The possibility for a food supply from surrounding areas for Brazilian cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV) and an increased kcal-consumption (AAMa). On the right panel the change is shown under different climate change forcing scenarios for the years 2020, 2050, and 2080 (A2, B2) and two yield scenarios (min, max). The values are provided as averages, i.e. for single cities the situation can differ. Brazil has already potential for peri-urban agriculture and could use the surrounding areas of the major cities for agriculture to reduce environmental trade-offs in other regions and due to emissions from transportation.

The largest potential to increase the food self-sufficiency of cities can be achieved by further land-use, i.e. transforming natural land into agricultural area. In this case 100% of urban residents can be nourished by near city food production. However, this may cause unwanted effects, namely carbon emissions from soils. In contrast to such a scenario a vegetarian diet under current land use will increase local food self-sufficiency up to 70%, while increased calorie consumption would meet only 26% self-sufficiency (see Figure 1-7, middle). Climate Change (A2, B2 forcing will have only minor impact on potential of peri-urban agriculture in Brazil. The summed up values decrease from 31% to 28% (A2) respectively to 26% (B2) for the year 2050 and the maximum yield scenario (see Figure 1-7 right).

1.3 The Potential for Synergies and the Stage of Country Development

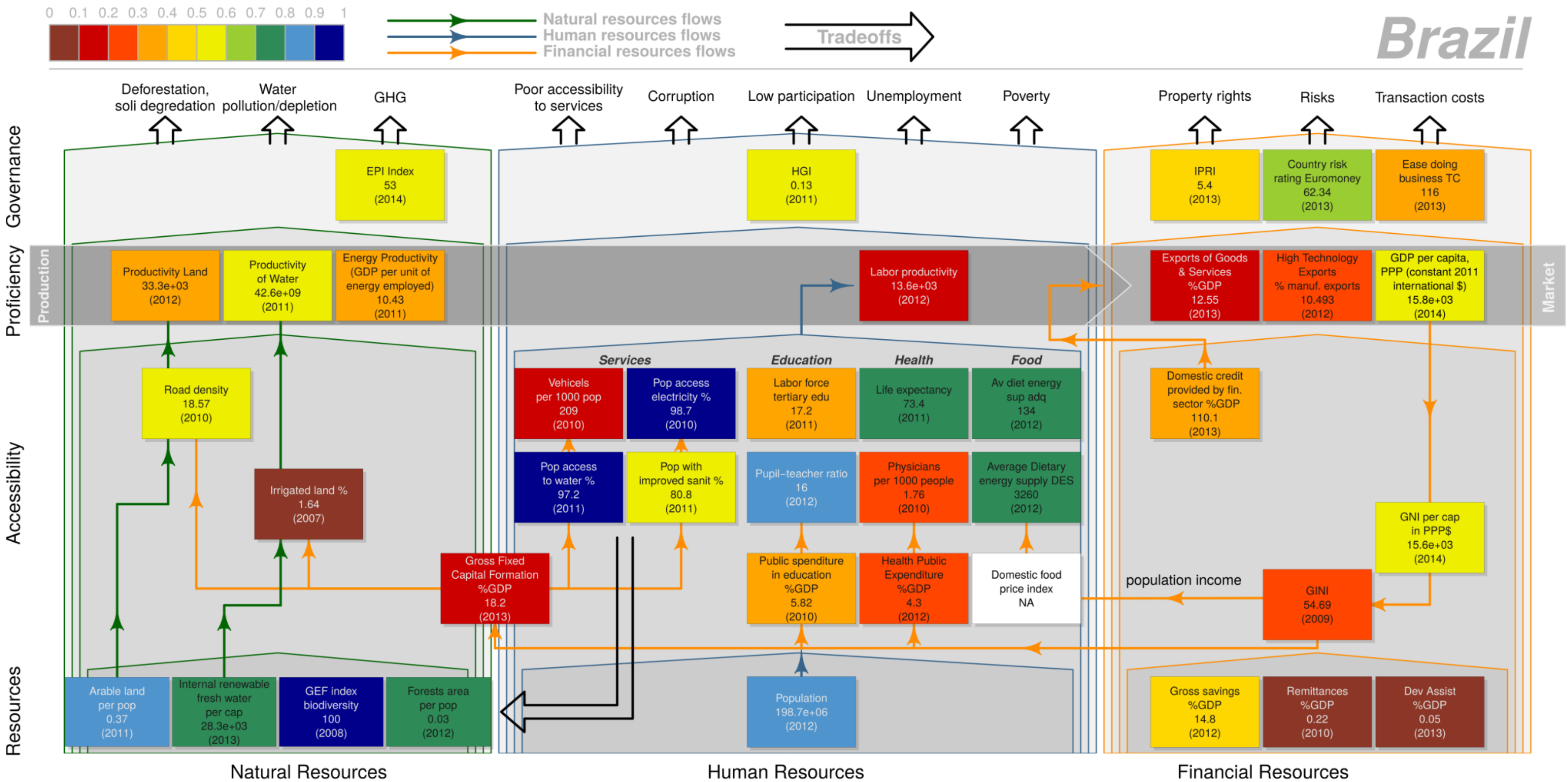
Two trade-offs are obvious in Brazil: the divergent trends between increased GHG emissions and indicators of human development, and the expansion of agricultural production against forest areas. We analyze these trade-offs in the context of the adaptive capacity shown in Figure 1-8 (to keep the narrative simple consider in that brown and dark-red colors represent very low; red and gold, low; yellow colors middle; green colors high; and blue colors, very high performances of the indicator evaluated, with respect to other countries in the world).

1.3.1 Economic Growth, GHG Emissions and Human Development:

As Figure 1-2 shows, GHG emissions have been growing in Brazil in the energy and the agricultural production sectors. As the graphics in Figure 1-5 show the income index, the health index and the education index of the HDI have not grown similarly. This implies that the growth trends in Brazil associated to increased emissions have not been effectively converted and used for human development. The trends of indicators of human development in Figure 1-5 show the deepening of a social trade-off. Options to couple more effectively emissions in the energy sector with indicators of human development require adaptive capacity.

GDP growth is needed for adaptive capacity in Brazil. Financial resources produced by GDP growth are needed to enhance the accessibility to natural resources (see Figure 1-8). Economic growth is also needed to enhance the adaptive capacity of the population (reflected in the indicators of accessibility to human resources in Figure 1-8). The potential for growth in Brazil is constrained by the very low productivity of labor, and medium productivity of natural resources. For growth, the country needs to diversify and to specialize the economy. This is evident in the very low and low performance of the indicators of exports of goods and services as % of GDP and high technology exports as % of manufactured exports (in the proficiency in the use of financial resources). In turn, the medium relative performance in road infrastructure, the low relative performance in education, and the relative low performance in the provision of domestic credits restrict the productivity of the resources. The investment in gross fixed capital formation is low compared to the rest of the world (see Figure 1-8). The Brazilian Government started an improvement program, but it is still lying years behind the planned schedule. Observing the relative development of the determinants of productivity of Brazil in the row of proficiency in Figure 1-8, it becomes evident that labor productivity is the major bottleneck for growth in Brazil, as Loman (2014) shows (refer to section 1.1.2).

Figure 1-8: Indicators of the adaptive capacity of Brazil.

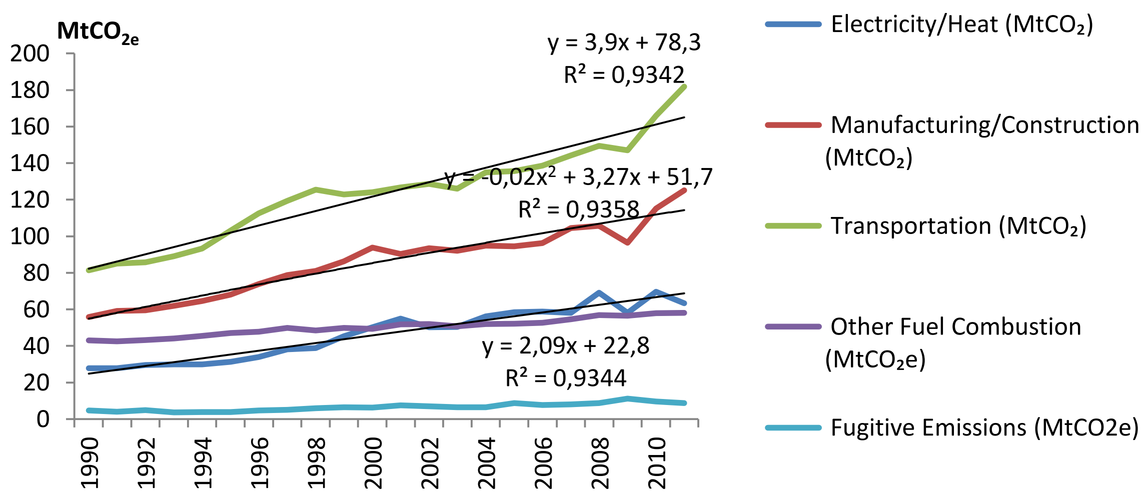


Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. For sustainable development Brazil requires continue reducing inequality, improving human capital and developing its productive structure. The country is on track of developing high standards in social services and creating conditions for growth. For inclusive growth Brazil requires lowering income inequality and improving human capital. The country needs to improve environmental and human governance, property rights and transaction costs mostly rooted in insufficient infrastructure and insufficient human capital.

However, as Figure 1-5C shows, actual trends in education are stagnant while emissions rise steeply. Therefore, for the creation of synergies Brazil needs to develop policies that simultaneously enhance the productivity of resources, enhance social conditions overall, with special attention to education. Growth requires human capital. Low labor productivity is concomitant with high transaction costs, as the indicators in Figure 1-8 show. The government is committed to enhancing human capital. The country has reached OECD standards in the pupil-teacher ratio in primary education (see the subsection on education in section 1.1.3). Despite the efforts on education, the development of the index of education of the HDI in Figure 1-5 has remained almost constant between 2008 and 2013. A similar situation occurs in the health index. Government investments in health are very low, even compared to other countries in the region, and with respect to the world (see Figure 1-8:). In addition the country has reduced income inequality and poverty steadily this century (see Figure 1-4). In summary, whereas the income of the less wealthy has increased consistently and the efforts of the government on education are consistent, the indicators of education and health have not substantially improved. In parallel, as Figure 1-5 shows, the rate of GHG emissions per capita have been rising from nearly 1.8 to nearly 2.4 $MtCO_2$ per capita over the same period (2008-2013).

In order to analyze this trade-off, a relevant question is where GHG emissions from energy are associated to. This is observable in Figure 1-9 and the discussion below.

Figure 1-9: Trends of emissions from energy in Brazil.



Indicators obtained from (WRI 2014). Growth of GHG emissions from energy in Brazil is associated to transportation, manufacturing and electricity. Effective mitigation requires measures to reduce emissions in transport showing the more increasing trend in Brazil.

Growth trends in manufacturing are better fitted by a polynomial regression, while trends from transportation and electricity generation are better fitted by a linear regression (see Figure 1-9). These trends are associated with industrial growth (manufacturing), more trade and higher standards in households (i.e. more cars per capita). The number of vehicles per 1000 people increased from 164 in 2003 to 209 in 2008 (World Bank 2015b), an increase of 27% in 5 years. This trend would explain both increased emissions from transport and increased emissions from manufacturing.

Future economic growth demands more energy and could potentially lead to a more carbon-intensive economy. In 2011 Brazil already needed net energy imports as high as 28.61 Mtoe (mostly refined oil and coal) with an 11% share of Brazil's total primary energy supply (270 Mtoe) (IEA 2014). This included 35,886GWh net electricity imports, a 6% share of the domestic supply. The shares of renewables in energy (43%) and electricity (87%) are high. Brazil's river watershed network offers great potential for hydropower. Although already three quarters of electricity generation is based on this source, the Brazilian government estimates that only 36% of all hydropower potential has been utilized (UNFCCC 2010). Apart from hydropower the country does not produce any solar or geothermal power and only insignificant amounts of wind electricity in 2011. However, scaling up of renewable energy capacities based on biomass, wind, solar, tidal and geothermal is intended (UNFCCC 2010). The country already produces big amounts of biofuels (*Brazil Overview* 2014). Brazil clearly possesses a comparably good mitigation capacity. The development of this potential represents an opportunity for synergies coupling mitigation and human development.

However, measures for coupling reduced GHG emissions and human development also involve the potential contribution of households. In this regard, it is worth noticing how income has been redistributed in Brazil over the last years. As Figure 1-4 shows the redistribution of income has benefited more the 3th and 4th groups, rather than the 2nd richer and the 5th poorest. As the incomes shares in Figure 1-4 show, drivers of higher emissions from transport are rooted in the increased living standards of the lower income shares. Changes in lifestyles would imply the increased demand for cars, more transportation, more energy, and superior goods and services requiring higher energy intensity for their production, among the 3th and 4th income groups. Hence, income redistribution would have enhanced consumerism rather than human development.

Brazil can consider alternative and complementary options to couple human development with mitigations: i) a taxing system that creates incentives to households for investment in education and health and at the same time discourages consumerism, ii) higher investments in education and health care systems, supported by taxes on superfluous consumption, iii) the development of national carbon markets coupled to consumption of superfluous goods and more energy intensive services.

These potential measures affecting the behavior of households and improving labor productivity are more likely to succeed if the country undertakes more aggressive policies for diversification and specialization. As mentioned, the expansion of renewable energy systems represents one branch for diversification and specialization. The country has a good basis to undertake these measures. A low unemployment rate (around 5%) and increasing income supports domestic consumption. The inflation rate for Brazil fluctuates around 6% since 2010, but increased to >7% in the first half of 2015. The share of GDP provided in domestic credit is above 100% of the GDP (see Figure 1-3). But the country needs to perform better in the control of risk, transaction costs, and property rights (see Figure 1-8).

In regard of the overall development of the country Figure 1-8 and Figure 1-5 show that Brazil reaches standards of highly developed countries. As mentioned before, further development are required to support this development further, i.e. in particular in regard the productive structure and the economic conditions as the productivity of resources is still below the standards of developed countries. Growth in Brazil is needed in order to close the gaps in the provision of basic services. As the indicators of Figure 1-8 show the country needs to deploy consistent efforts in the reduction of income inequality and the improvement of health. For a suitable resilience the country also needs to improve in governance of the environment, human governance and the control of sources of financial/economic risks.

1.3.2 Agriculture and Deforestation:

Deforestation has been to a large extent driven by the expansion of soybean crops and cattle ranching (Gollnow and Lakes 2014). Between 2001-2006 soybean agriculture was extended by 1 million hectares in Amazonia leading also to 23% annual deforestation (Morton et al. 2006). Soybean profitability went down, because of disruption in the commodity markets. In 2006 Brazil implemented a soy moratorium in order to intervene in the whole supply chain of soy bean production (Gibbs et al. 2010). This measure reduced deforestation because 30% of soy expansion was produced at expense of deforestation before this agreement came into force. Additionally, it was successful, because of its transparency and simple monitoring mechanism and due to an involvement of a limited number of soy buyers who have control about financing and buying of soy therefore guaranteeing an economic and sustainable management (Gibbs et al. 2010). For the development of a simply and transparent monitoring system, the country developed remote sensing technologies able to detect new deforestation spots over weekly periods. Coordinated actions to effectively reduce deforestation involved the police, local authorities, lawyers' teams and legal instruments combining incentives and penalties.

Brazil possesses a comprehensive framework of legislation and activities to mitigation. It tackles the sectors with most mitigation potential, namely those related to LUCF and agricultural production (Fekete et al., 2013). However, gaps in implementation of reforestation and agricultural measures remain (Fekete et al., 2013). Current policies are likely to overachieve the pledges made and will therefore lead to reduced overall emissions in 2020. The Climate Action Tracker evaluates Brazil's actions as medium, i.e. on the brink of sufficient.

Yet, the country might consider options for halting deforestation. It requires several measures such as: an institutional set up drawing upon the previous successful experiences mentioned, further development of technologies and human capacity for monitoring deforestation in a daily basis, the creation of adequate incentives and local institutions for squatters to become forests guardians, adequate policies for the expansion of soybean and other profitable crops but in savannahs and pastures, long term programs for improving the productivity of land, and other policies for the development of industry and services that create incentives for rural population to safely migrate to urban or semi-urban areas. These measures based on the control of deforestation and the development of agriculture should be complemented with the development of practices and institutions to reduce emissions from agriculture –the second highest after deforestation (see Figure 1-2).

Options to transform trade-offs relating agriculture and forestry into synergies include changes in land use in grasslands and meadows for cultivars in Brazil. Shifting to crops will cut down the production of GHG emissions from enteric fermentation, and GHG emissions associated to grasslands. The share of pastures and meadows in Brazil is above 70%, and the productivity of land is among the lowest in the countries studied. Such land use changes will also have consequences for increased land productivity. Shifting to cultivars will help Brazil to remain food self-sufficient and increase agricultural exports. The conversion of grasslands and meadows into e.g. sugar cane will cool the region by an average of 0.93 (0.78–1.07)°C from changes of the albedo (Loarie et al. 2011). Sugar cane production agriculture might grow even at higher rates in Brazil, due to its importance for biofuel production and its potential for mitigation, and also because climate change will benefit the productivity of sugar cane cultivation in Brazil (Margulis et al. 2011).

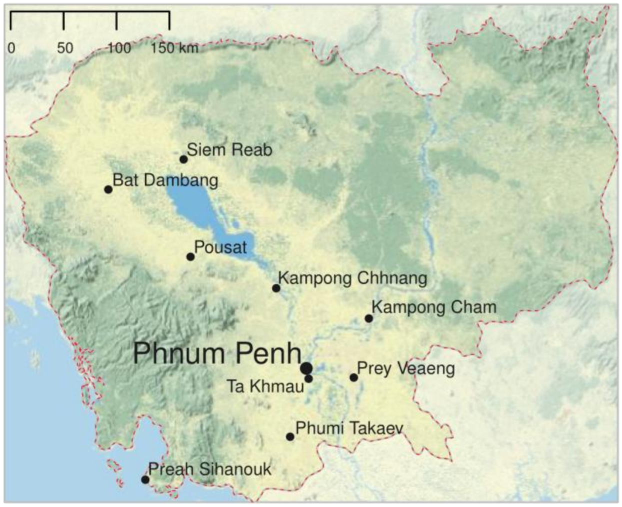
1.4 Conclusions

Brazil has shown its capacity to reduce deforestation rates. Based on the institutions and incentives successfully implemented in the recent pass for transforming trade-offs between agriculture and forestry into synergies, the country needs to further develop technologies, human capital and governance for the effective protection of forests. The Brazilian model offers important examples for other countries. The technologies developed for monitoring deforestation in the short run need to be improved and transferred to other countries. Shifting savannas into cropland is another option to reduce the pressure of agriculture in forests areas. The international community should keep supporting institutional efforts to eliminate deforestation and develop the capacity in forestry.

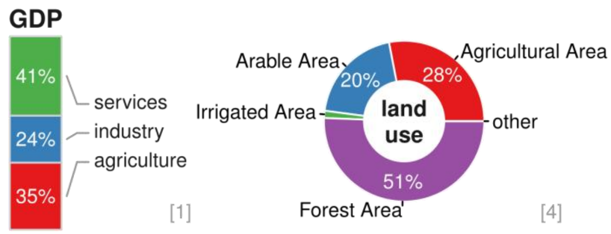
The country is growing but income inequality is still very high. However, for synergies the increasing consumption of electricity and higher demand for transport need to be more effectively transformed into higher standards in education. The country has an adequate income to start the development of carbon markets. The country needs to implement policies that create incentives for households to investment in education and disincentive superfluous consumption.

2. CAMBODIA

Figure 2-1: Cambodia – Factsheet and physical map:



Country size	181,035 sq km	[1]
Coastline	443 km	[1]
Population	15.41 millions	[2]
Rural population (%)	79.5	[2]
Human Development Index	0.58 (136 of 187 – Medium)	[3]
Life expectancy at birth	71.92	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

2.1 Sensitivity and Vulnerability

2.1.1 Sensitivity and Vulnerability of Natural Resources

Cambodia is among the countries that lack detailed studies of climate change projections. To compensate this shortfall, the UNDP developed the Climate Change Country Profiles. For the case of Cambodia, this report relies on the information provided by this study. Climate change projections for Cambodia were calculated considering A2, A1B, and B1 forcing scenarios for the time periods 2030, 2060 and 2090 (McSweeney et al. 2010a).

Temperature: Mean annual temperature has increased by 0.8°C since 1960, at a rate of around 0.18°C per decade. A similar increase rate is observed in all seasons. The mean annual temperature is projected to increase by 0.7 to 2.7°C by 2060, and 1.4 to 4.3 degrees by 2090. The range of projections by the 2090s under any of the emission scenarios is in the 1.0-2.7°C range. The increase is larger in December-January-February, and March-April-May at 0.20-0.23°C per decade, and smaller in June-July-August and September-October-November at a rate 0.13-0.16°C per decade (McSweeney et al. 2010a).

Water resources, rainfall and precipitation: Mean rainfall over Cambodia does not show any consistent increase or decrease since 1960 (McSweeney et al. 2010a). The Mekong River and its tributaries are the major resources of fresh water; approximately 80% of the Cambodian population live along its riverside (Brander et al. 2009). Other sources include a number of small rivers from the Cardamon and Elephant Mountains in the southwest and the Tonle Sap Lake (Brander et al. 2009).

Climate change will modify the Mekong's hydrological regime (Brander et al. 2009). The run-off of the Mekong is clearly correlated with the Indian and East-Asian Monsoon (Xue, Liu, and Ge 2011). Recent results indicate that regime shifts of Monsoon in the region can be expected in the future (Donges et al. 2014). The analysis of CMIP5 runs show a future reduction in the frequency of light rainfall and an increase in high to extreme rainfall for the Indian Summer Monsoon, which would influence the Mekong run-off in the upper catchment (Jayasankar et al., 2015). A higher seasonal rainfall in the Northwest and a decreasing trend in the Northeast are expected. The rainfall period season starts in mid-May and runs until the end of October. During this period Cambodia received three-quarters of the annual precipitation (WB, 2011). Historically, this resulted in large floods along the Mekong River, its tributaries and the Tonle Sape Lake (WB, 2011). In contrast, the time period between November and April is the dry season, often associated with droughts and water scarcity. The region Svay Rieng in the southeast is one of the most drought-prone provinces.

Sea level rise: Simulations under low emission scenarios (SRES B1) predict a rise of about 0.18-0.43m by 2090, while simulations under high emission scenarios (SRES A2) project a sea level rise of 0.23-0.56m for Cambodia (RCG 2014) relative to 1980-1999. A rise of 0.56m would cause a permanent inundated coastal area of about 25,000 ha by 2100 (RCG 2014). Mangrove forests would be likely affected, but also shrimp farms, grassland, populated areas (e.g. Koh Kong town area) and forests (RCG 2014). Rising sea level has a negative impact on the coastal zone and thereby on mangrove forests (IFAD 2013).

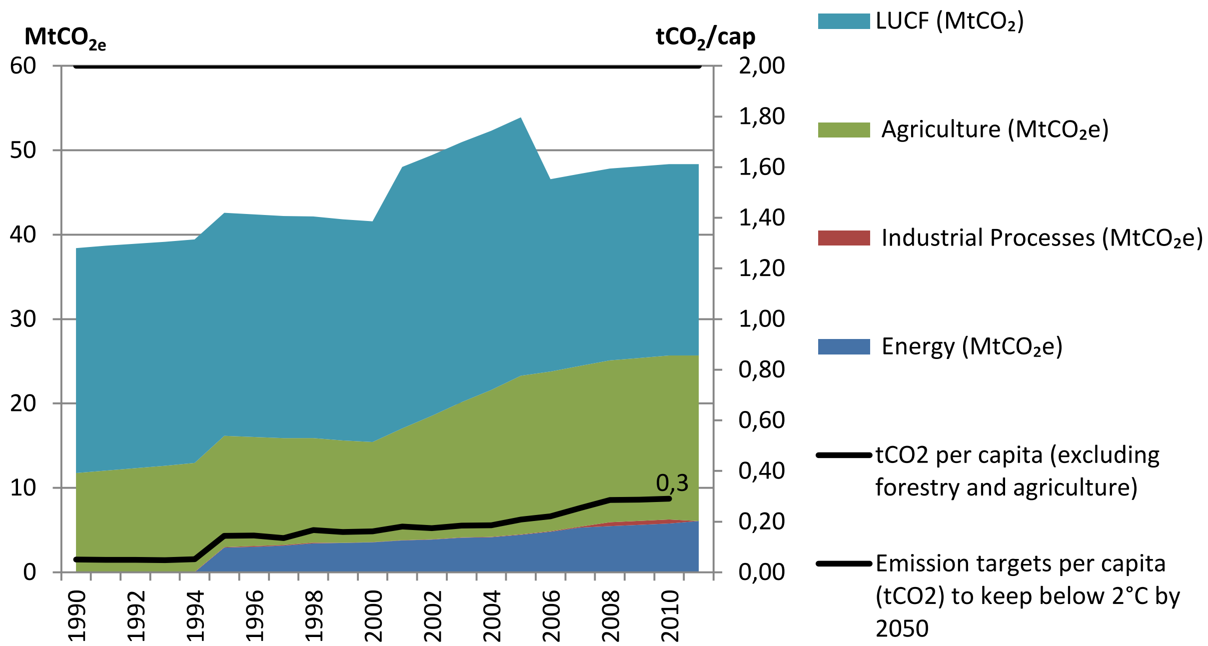
Crop yields: Every increase of growing season minimum temperature by 1°C could lead to a decrease of 10% of rice yield caused by floret sterility during the time of rice flowering (UNDP 2011). For the future, a decrease of rice yield is expected under both high and low emission scenarios. The projected changes in precipitation and temperature will also have a negative effect on the growing and flowering cycles of crops, e.g. on rain-fed and irrigated wheat (WB, 2011). According to the UNDP report (2011) rice is highly dependent on the first rain that occur in May and is consequently vulnerable to changes. Increasing precipitation during wet-seasons might have a beneficial outcome for drier regions. Furthermore, increasing temperatures might have a positive effect on the growth and reproduction rates within a crop cycle, and could lead to migration of new types of insects. Contrastingly, climate change might also lead to increases of pests and diseases.

Land Use and Forestry: 32% of land area was dedicated to agriculture in 2011, while 56% was covered by forests (FAO 2014b). Land under agricultural production increased from 25% of the total area in 1991, to 32% in 2011, and continues to increase (GoK 2014a). Protected forests areas covered 26.21% of the total area in 2012 (FAO 2014b). Climate change will bring changes to the composition of Cambodia's forests (IFAD 2013). With increasing temperatures and droughts, the risk of forest fires will increase, and wet forests will be displaced by deciduous forests; moist forests will expand and dry forests will remain the same (IFAD 2013). Changes in rainfall patterns will further reduce forest productivity (IFAD 2013). According to the UN-REDD (2014) over the last two decades Cambodia lost 2.850 million ha of forests. According to this study, high deforestation is due "mainly to institutional and governance issues and the fast rate of national development". Evidence suggests that large-scale agro-industrial expansions are currently the largest driver of deforestation. Permanent mono-cropping of rubber plantations, illegal logging, and claiming of state land are also reducing the forest area further.

Atmosphere: Total and per capita emissions are both low in comparison to other countries (see Figure 2-2). Cambodia's GHG emissions mostly derive from deforestation and agricultural production, which accounted for about 46.5 and 39.8%, respectively, for 2010 (WRI 2014).

Deforestation rates (2005 – 2010) of around 1.2% per year explain the high portion of emissions in the LUCF sector (FAO 2010a). Emission and removal estimates from the LUCF sector, like in other countries, remain difficult to appreciate due to the forest's significance as carbon sinks.

Figure 2-2: GHG sectoral emissions and energy per capita emissions of Cambodia.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from WRI (2014a). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from waste, bunker fuels and industrial processes are negligible (~1.9%) (WRI 2014) and were not included. Emissions per capita per year from the combustion of fossil fuels (0.3 tCO_2) are very small compared to the 2 tCO_2/cap/year required to keep global warming below 2°C by 2050 under fair burden constraints (WBGU 2009b). As the shares of emissions in the figure show, LUCF, agriculture and energy are the most relevant sectors for mitigation.

To sum up, higher temperatures and changes in water cycles and precipitation regimes will cause changes in agriculture (e.g. crop yield), and forestry (e.g. tree type composition). These projected trends caused by climate change are in contrast with the projected expansion of the agricultural area and further requirements for economic growth.

2.1.2 Economic Vulnerability

Suffering from the Khmer Rouge terror regime in the 70s and ongoing civil war until the late 90s, today Cambodia is one of the least developed countries in Southeast Asia. Agriculture provides an important share for GDP of about 35% by 2013. 80-85% of the Cambodian population derives their income from this sector (ADBI 2013). Between 1995 and 2014 Cambodia had sustained growth rates of 7.6%/yr (World Bank 2015a). Beneficial economic circumstances related to the high demand of rice and garments and stable growth trends in neighboring countries, e.g. Thailand, Vietnam and China, have supported this high average growth (Techo 2014).

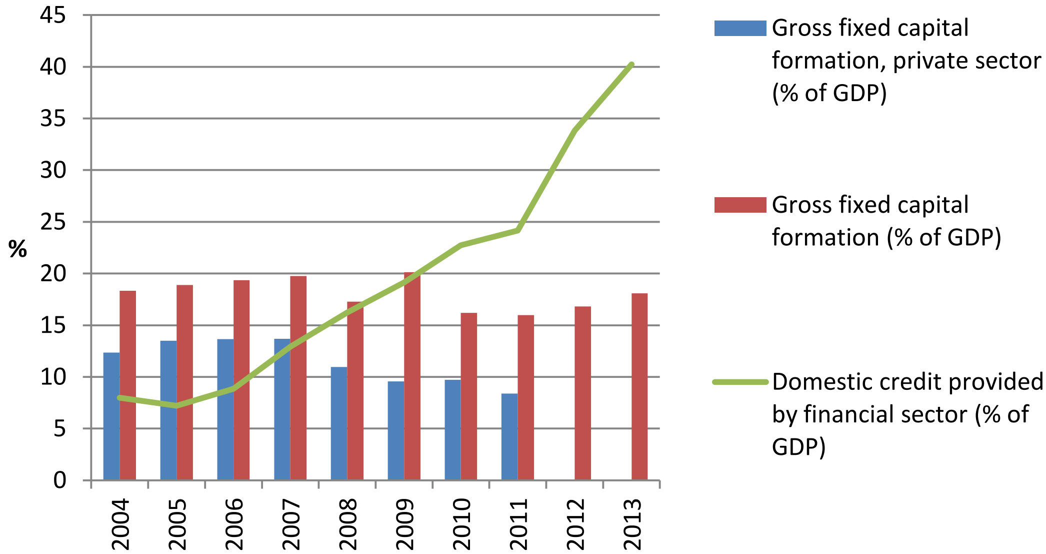
Most agriculture and industry activities take place in the Mekong basin and are severely affected by floods. Floods caused overall losses and damages of US$ 625 million (ADB 2014a), which is equivalent to 4.8% of the total GDP in 2011. In 1997 a drought affected 20% of the total rain-fed area, i.e. approx. 2.2 million ha (Thomas et al., 2013). A flood damaged 20% of total rain-fed rice area in 1996 (Thomas et al., 2013). The country is currently investing more than US$55 million in the reconstruction of irrigation systems in agriculture (ADB 2013).

Economic specialization and diversification: The Cambodian economy relies on very few products and services, namely garments, footwear, tourism, construction sector products and rice production (GoK 2014b). Exports account for 65.3% of the GDP (WFB 2015). Footwear and textiles account for more than 70% of total exports (Simoes and Hidalgo 2014). The sharp decrease of GDP growth in 2009 (0.1%) is attributed to the impact of global economic crisis on garments' exports, tourism, and construction (ADB 2012). Therefore, unfavourable changes in international trade conditions or shocks may considerably affect the economy also in the future. The industry is characterized mainly by family-operated enterprises portrayed by low technology intensity, knowledge, and margins (GoK 2014b).

Capitalization and Capital Formation: As Figure 2-3 shows that loans provided by the national financial system have grown exponentially over the last decade (World Bank 2015a). The share of GDP spent in gross fixed capital formation from the private sector has been decreasing. However, despite the variability of GDP growth the share of public gross capital formation has remained almost constant around 18.1% (standard deviation: 1.47) (World Bank 2015a). Difficulties to access loans in Cambodia for small and medium agribusiness stem from the high informality, high interest rates, low turnover margins, and low assets to back credit (Eliste 2013). This situation pervades the entire production chain.

Economic Risks and Uncertainties: As climate change has an influence on economic outputs it is important for an assessment of economic vulnerability to trace how the country performs in the control of economic risks and economic uncertainties. Despite the high average growth rate (7.57%) for the decade 2005-2014, the Cambodia's annual GDP growth rate has been volatile in the last decade, with an absolute maximum of 13.25 in 2005 and an absolute minimum of minus 0.1% in 2009. Inflation has not been controlled. It approached 25% in 2008 followed by deflation of -0.66% one year later (World Bank 2015a). Average inflation was 6.3% between 2004 and 2013, but standard deviation is high 6.9 (World Bank 2015a). Cambodia has deficits in the governance and management of financial risks and transaction costs. The relative values of the country risk index and the ease doing business are below 0.3. The ease doing business ranks Cambodia 137th within the third decile in comparison to other countries in the world (see indicators of governance of financial resources in Figure 2-8).

Figure 2-3: The recent evolution of capital in Cambodia.



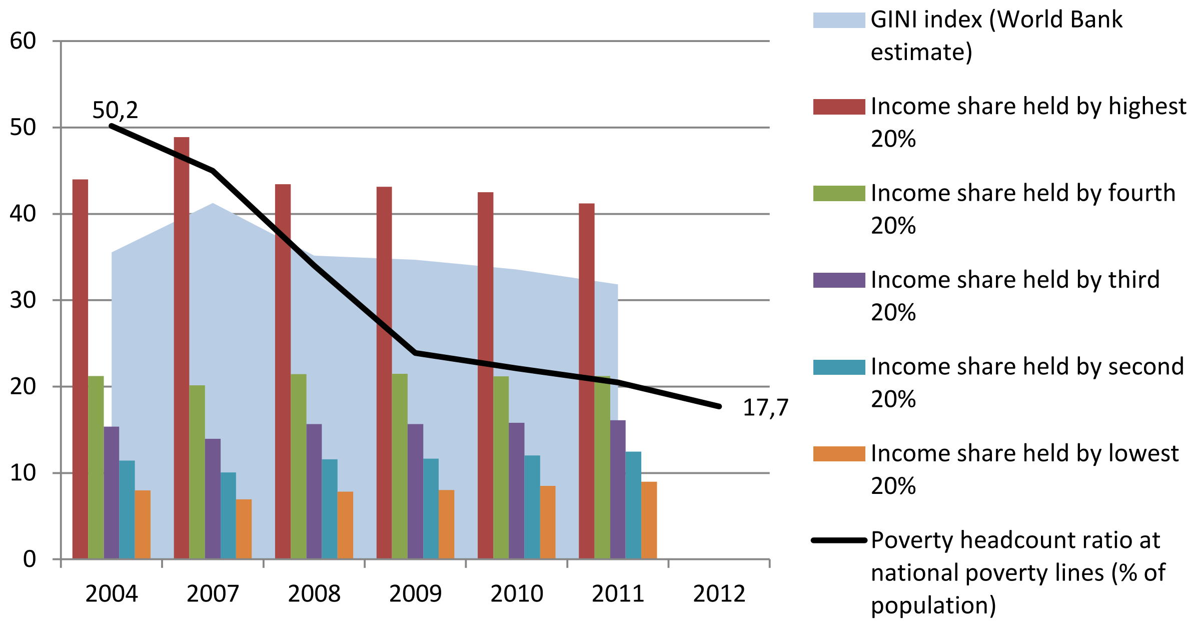
The graphic provides information about domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation (World Bank 2015a). For the analysis of the adaptive capacity, this set of indicators provides a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. For Cambodia information about the number of companies in stock markets is missing. It hinders the relation between capitalization and capital concentration. The trend of the provision of domestic credits favors growth, but it is still low compared to e.g. Vietnam (>100% GDP). Variable investments in gross fixed capital formation in private and public sectors indicate difficulties to keep planed targets.

Summing up, the sources of vulnerability of the Cambodian economy include the high exposure of the productive structure to floods, the expected inundation of coastal areas, increased damages from hazards impacts, and uncontrolled risks and uncertainties in the economic system. Structural problems are related to the size and specialization of economic activities and transaction costs. However, services from the financial sector are growing.

2.1.3 Social Vulnerability

The GDP per capita changed from $297 in 1995 to $731 in 2009 (World Bank 2015a). All indicators of social conditions related to the Millennium Development Goals show positive trends, but the country is still burdened by very low performance in many areas. The national poverty headcount ratio declined from over 45.0% in 2007 to 17.7% in 2011 (World Bank 2015a) although rural poverty remained high at 35%. Poverty in urban areas reached 22% in 2012 (ADB 2012). The gainings in poverty reduction are fragile: if income per day would decrease by US$0.30 (1,200 Cambodians Riels) additional three million Cambodians will be thrown below the poverty line (5,326 Cambodian Riels). This will double the poverty rate to 40% (World Bank 2014a). The GINI index of income inequality tends to decrease. The distribution of income in five income shares shows low differences among the four less wealthy groups. Between 2007 and 2011 the income share of the three poorest shares has increased.

Figure 2-4: The recent evolution of income distribution, income inequality and poverty in Cambodia.



For the assessment of income inequality the GINI index was used (World Bank 2015a). Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Decreasing trends of income inequality and the poverty headcount ratio in Cambodia reduce social vulnerability, but gainings in poverty reduction are still fragile.

Food security: Cambodian food supply of 2400 kcal/cap/day is slightly above its average dietary energy requirement of around 2230 kcal/cap/day (Hiç 2014). However, food security remains an issue, mostly due to the share of income that needs to be spent for food, 46.2% in average as of 2010 (World Bank 2015a). This is a consequence of the vulnerability of income reported and food price volatility. 15.4% of the population is undernourished and the percentage of people suffering from food inadequacy reaches 25% (FAO 2015). According to the Asian Development Bank food price inflation in 2008 disproportionately affected the non-farming rural and urban poor and near-poor. Their welfare was further threatened by the adverse effects of the global economic crisis (ADB 2012).

Health, Sanitation, Water and Energy Services: Life expectancy (71.1 years in 2012) places Cambodia in the sixth decile relative to the rest of the world (World Bank 2015a) (see accessibility to human resources in Figure 2-8). Cambodia spent 5.7% of GDP in health services in 2012, including private and public expenditure (World Bank 2015a). This is low compared to e.g. the European Union −10.19% in 2012 (World Bank 2015a). Access to services is where Cambodia is most burdened; access to improved water supply reached only 67% of total population in 2011, i.e. 4.9 million people had no access to water supply (World Bank 2015a). Access to sanitation reached 33% of the population in 2011, i.e. around 10 million had no access to sanitation as of 2012 (World Bank 2015a). In addition, only 31% of the population had access to electricity in 2010, i.e. 10.25 million people had no access as of 2010 (World Bank 2015a).

Education: Cambodia presents low budget expenditure per student, compared to countries with similar GNI per capita. The government spent only 1.6% of the GDP in education in 2012 (World Bank 2015a), among the lowest in the world (see accessibility to human resources in Figure 2-8). Cambodia lacks human capital; in 2010, only 2.5 in 100 laborers had tertiary education (World Bank 2015a).

2.2 Links between Adaptation, Development and Mitigation

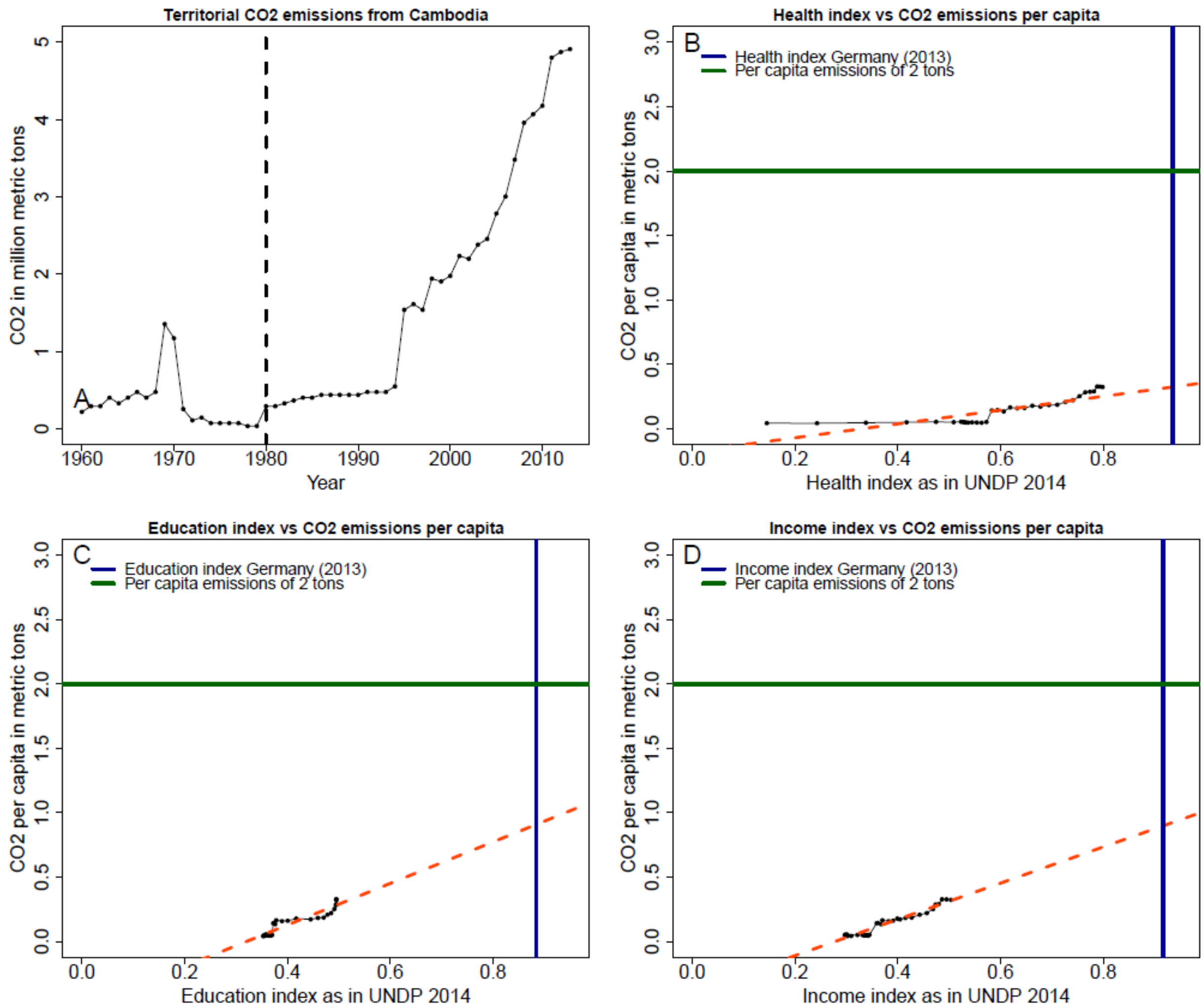
2.2.1 The Evolution of the HDI and the GHG Emissions in Cambodia

Territorial emissions from Cambodia have been modest until the mid-90s. After this time point they sharply increased linearly in time. In 2013 CO_2 emissions reached 4.9 million tons, 8 times higher than that recorded during the 80s (Figure 2-5A). On a per-capita basis CO_2 emissions from Cambodia are low, i.e. not surpassing 0.4 tCO_2 per capita (Figure 2-5B). Cambodia is therefore well below the 2 tCO_2/cap mark required to keep global warming below 2 $^{\circ}$C by 2050 under fair burden constraints (WBGU 2009a).

The relation between the different components of human development and per capita emissions in Cambodia has been a slightly positive one. This holds noticeably for income, although the calculated slopes remain in general very low. For the case of the health index (Figure 2-5B) the relation is stagnant. Fast progress has been achieved in the last 30 years in this respect with the health index in Figure 2-5 increasing from 0.2 to 0.8 under nearly constant emissions. For the cases of education and income achievements development has been slower (Figure 2-5C and D). In these cases a stronger correlation with per-capita emissions is observed. This is particularly noticeable for the case of the income index. In both cases the component score is still far away from the recorded values in high developed countries, e.g. Germany. From a simple extrapolation of current per-capita emissions it can be concluded that emissions do not seem to pose a strong risk of Cambodia moving to per-capita emissions higher than 2 tCO_2cap/year, to keep global warming below 2°C by 2050 under the fair burden constraints (WBGU 2009b).

The progress made by Cambodia to achieve higher levels of Human Development, as measured in terms of the HDI, has been mostly hampered by a poorer performance in education and income when compared to what has been achieved in health. Cambodia is expected to remain below an HDI of 0.9 in the long term (Costa et al. 2011). Under slow but constant human development, long term emissions in Cambodia are estimated to reach 16 $MtCO_2$ by 2050 (Costa et al. 2011). This situation opens a window of opportunity for Cambodia to use its emission budget to grow along activities producing higher added value, requiring higher intensity of energy consumption. However, in order to feed growth and development the country needs to allocate more financial and human resources in education.

Figure 2-5: Trends of CO_2 emissions and the HDI in Cambodia.



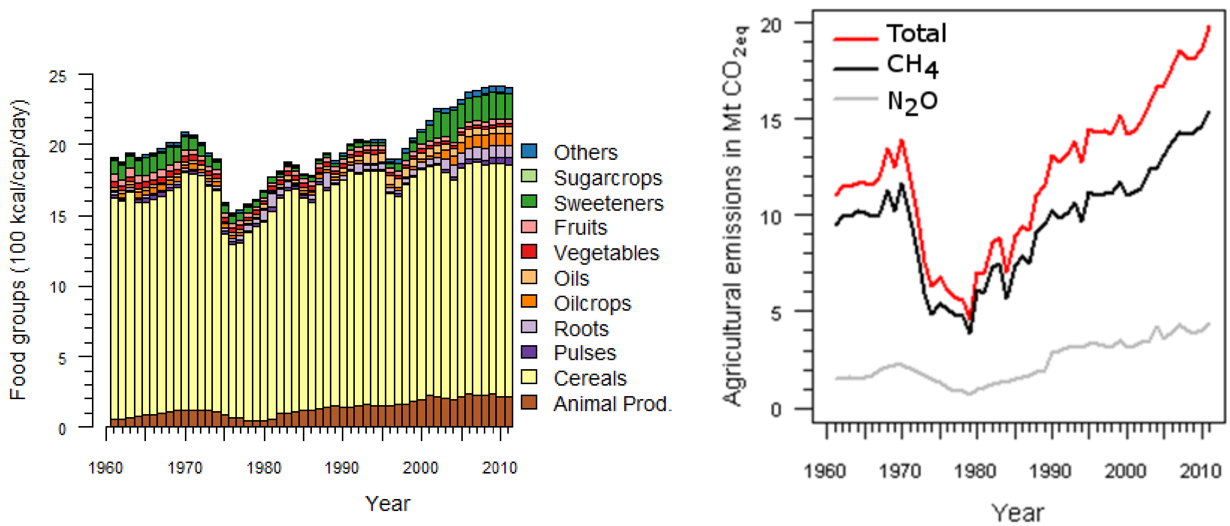
Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project (Le Quéré et al. 2014) (A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs. CO_2 emissions per capita (B). Panels C and D show analogous information as panel B for the education and income index, respectively. Data on population, income, education, and health obtained from the World Bank (2015) database. Horizontal green line shows the 2 t/cap CO_2 target (WBGU 2009a). The vertical blue line highlights the current position (2013) of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. Cambodia has advanced as no other country analyzed in this report in terms of life expectancy, but achievements in education are low.

2.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 2-6 (left) presents the evolution of dietary patterns in Cambodia between 1961 and 2011 based on amount of 11 different food groups supplied in the country. In general, Cambodia’s total food supply has increased from 1,900 kcal/cap/day in 1961 to about 2,400 kcal/cap/day in 2011. The current food supply in the country is below the average food supply of South-East Asia of around 2,700 kcal/cap/day (FAO 2014b). During the last five decades the cereal supply remained almost constant at around 1,600 kcal/cap/day, whereas supplies of sweeteners and oils have almost doubled, and animal products have almost quadrupled. Furthermore, inter-annual variability in supplies of total calories and the different food groups has been observed in Cambodia in the last five decades, with the lowest calorie supply of 1,520 kcal/cap/day in 1976. Total calorie supply has continuously increased in the country since 1998. This depicts changing lifestyles in Cambodia towards calorie-rich and nutritious diets, which are largely based on cereals.

In the year 2000 around 6 million people in Cambodia lived in the regions where local food and feed produced in a 10 km x 10 km in cell was sufficient to meet their food and feed demand (Pradhan et al. 2014a). Cambodia is a net food exporter. The counry is food self-sufficient (Pradhan et al. 2015a). 9.6 million Cambodians can be nourished from the production within their own province. The country exports about 1.6 trillion kcal of food and feed in the year 2000. Major parts of the country so far have attained around 30% of the potential crop production (Pradhan et al. 2015a). Cambodia could increase its food exports to 29 trillion kcal by closing yield gaps to attain 90% of the potential crop production.

Figure 2-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Cambodia.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 (in CO_{2e}) emissions including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Cambodia during the last fifty years. Food supply in Cambodia has increased in the last decade, although it is still below the average global food supply of 2850 kcal/cap/day as of 2010. Additionally, greenhouse gas emissions from agricultural production have increased in the last 20 years. The data was obtained from FAOSTAT (FAO 2014).

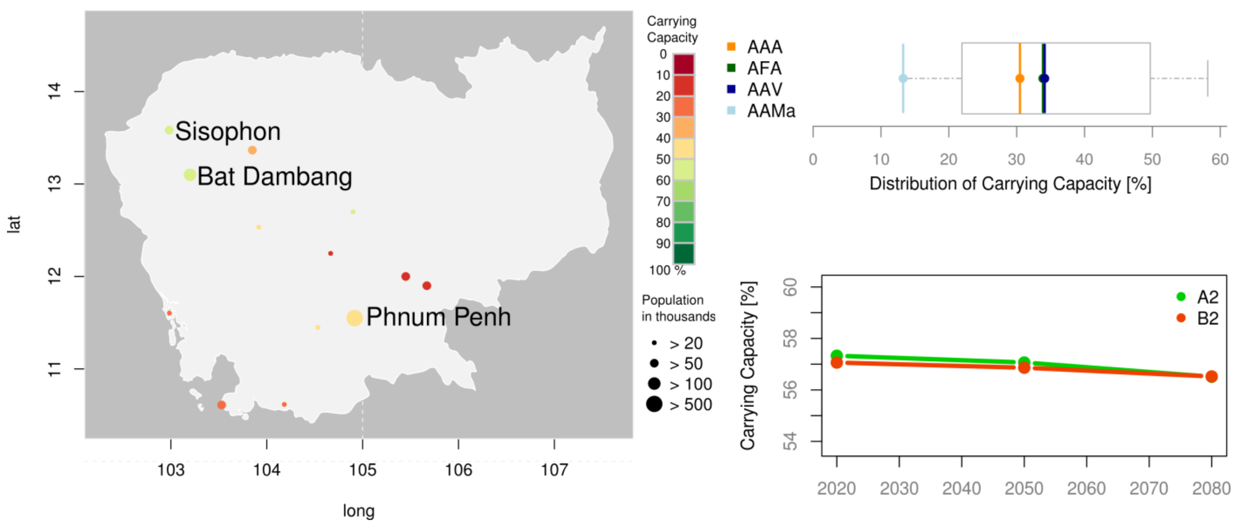
The total agricultural emissions of Cambodia have almost doubled from 11 $MtCO_{2e}$/yr to 20 $MtCO_{2e}$/yr in the last 50 years as shown in Figure 2-6 right. Moreover, agricultural emissions of Cambodia were the lowest in 1979 at around 4.6 $MtCO_{2e}$/yr. However, the emission trend increased particularly in terms of emissions related to agricultural production after 1979. Diets currently consumed in Cambodia embodied emissions of about 0.9 tCO_{2e}/cap/yr (Pradhan et al., 2013). Around 2.3 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013). Dietary patterns in Cambodia may increasingly be calorie and meat rich when the country becomes more developed in the future, resulting in larger volume of GHG emissions. Nevertheless, technological progress may transfer these trade-offs into synergies. Currently, emissions per unit of crop and livestock production in Cambodia are higher than that of developed countries (Pradhan et al., 2013). Hence, technological progress increasing agricultural productivity can also lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al., 2013). Additionally, closing crop yield gaps can increase crop production and ensure the current and future food self-sufficiency in Cambodia even while considering plausible population and diet changes by 2050 (Pradhan et al. 2014b).

Several conclusions can be raised. Dietary patterns in Cambodia are characterized by high consumption of cereals, namely rice (see Figure 2-6). Increased emissions in agriculture would be driven by emissions from rice cultivation rather than from the intensification of agricultural production. Rice is the most exported agricultural product but it only represents 1.2% of total exports (Simoes and Hidalgo 2014). For adaptive capacity and growth it would be desirable for Cambodia to diversify agricultural production, for both internal consumption and exports.

2.2.3 Potential of Peri-Urban Agriculture and Local Food

20% of 15.4 million people in Cambodia live in cities and a future growth up to 22.6 million by the year 2050 will occur mainly in cities (United Nations 2014). 13 cities with population above 20,000 were investigated for the potential of a regionalized food production to increase food security, reduce CO_2 emissions from food transportation, and offer the possibility for an improved food distribution (see Figure 2-7).

Figure 2-7: The possibility for a food supply from surrounding areas for Cambodian cities.



Map for current conditions (AAA) (left) and the summed up carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. The best possibility to minimize environmental trade-offs from agriculture is by closing the yield gap, which will lead to a high productivity of peri-urban agriculture. However, changing climate and especially changing diets can reduce environmental synergies.

Overall, these cities host more than 2 million inhabitants. Today 83.5% of the surrounding areas are used for agricultural purpose, which is nearly all available arable area. From the currently harvested areas 30% percent of the urban dwellers can be nourished (Kriewald et al., 2015). This is relatively small compared with the high fraction of harvested area, and it is the result of a poor *yield gap ratio*[2] of 0.34. Consequently, closing the yield gap is the best option to improve the food self-sufficiency. A dietary pattern with a kcal-consumption of 3,500 kcal/cap/day would reduce the carrying capacity to 14% (see Figure 2-7 top right). All 13 cities will face a decreasing carrying capacity for the year 2080 (B2), as a consequence of climate-induced yield reduction (Kriewald 2012b). For an average yield scenario, the summed up values go down to 56% (see Figure 2-7 bottom right). In conclusion, closing the yield gap should be a political priority for self-sufficiency.

2.3 The Potential for Synergies and the Stage of Country Development

Cambodia is regarded as highly vulnerable to the effects of climate change and therefore focuses mainly on adaptation rather than mitigation. Disasters, i.e. mainly floods and typhons pose major threats to growth and development. The losses and damages caused by floods amounted to US$625 million in 2011, equivalent to 4.8% of the total GDP in 2011 (ADB 2014a). Disaster Risk Managent should be a priority in Cambodia. The development of the capacity in DRM should also be prioritized in international assistance, as the most effective way to protect the economy and the population.

Major trade-offs relating mitigation and adaptation in Cambodia include the expansion of industrial and small farm agriculture against forests areas. Agricultural production, particularly rice production (see emissions from agriculture in Figure 2-6B), is also an important source of GHG emissions (see Figure 2-2). For the transformation of trade-offs into synergies, the country needs to develop its adaptive capacity. It requires economic growth. Therefore, the analysis of the potential for growth and the adaptive capacity is required.

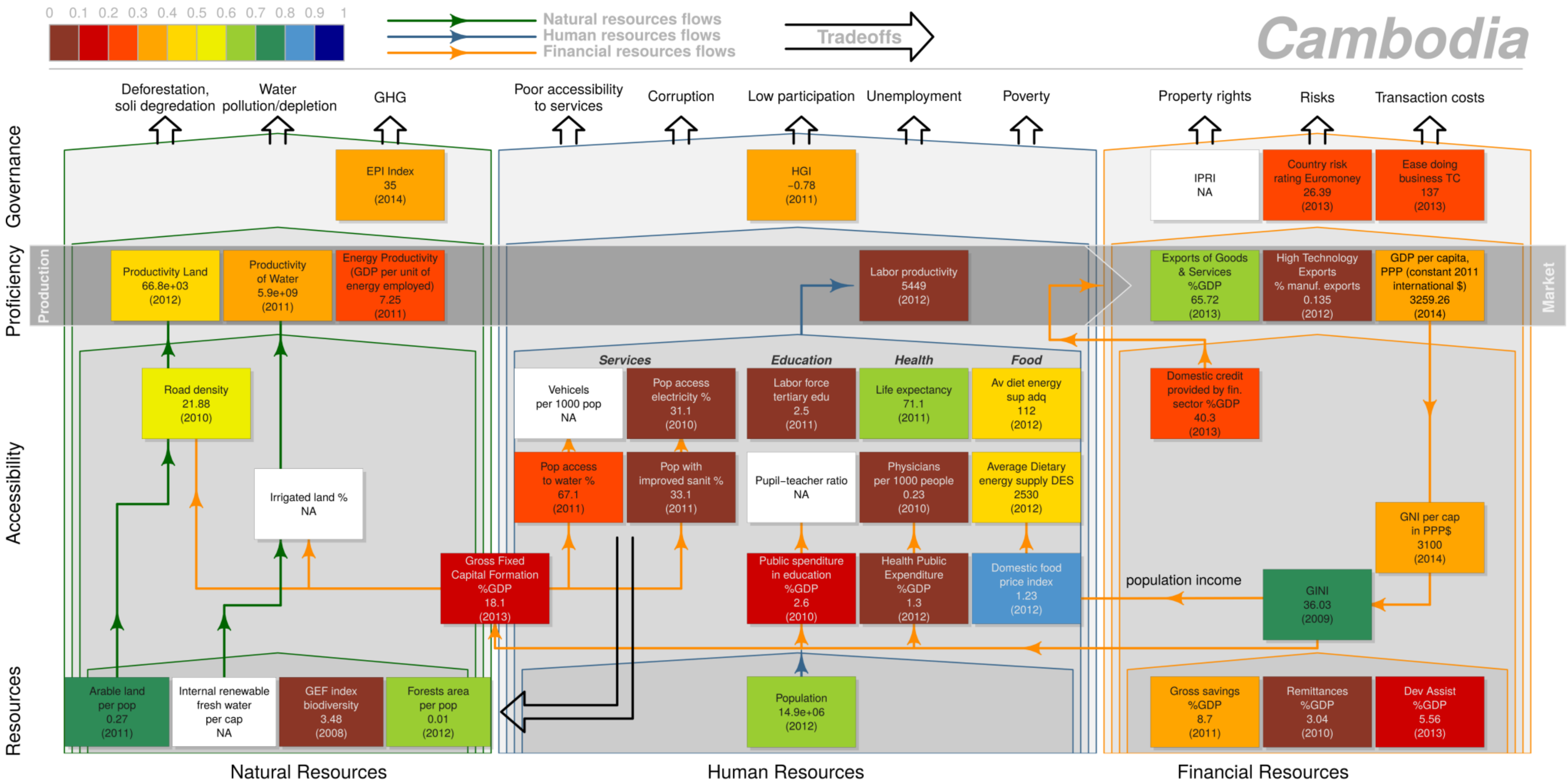
2.3.1 Economic Growth and Adaptive Capacity:

Figure 2-8 offers an evaluation of the relative development of the components of country systems determining the adaptive capacity in Cambodia (to keep the narrative simple consider in Figure 2-8 that brown and dark-red colors represent very low; red and gold, low; yellow colors middle; green colors high; and blue colors, very high performances of the indicator evaluated, with respect to other countries in the world). As it can be seen for adaptive capacity Cambodia needs to develop all its components. This requires growth and adequate long-term policies. Cambodia needs to develop a consistent policy for diversification and specialization. The economy is concentrated in lowly specialized sectors: garments, footwear and rice. The low added value of the activities is evident in the average relative performance in land productivity, low performance in water and energy productivity, and very low performance in labor productivity (see the row of proficiency in Figure 2-8).

---

2 The yield gap ratio results from dividing by the actual and the potential food production per hectare.

Figure 2-8: Indicators of the adaptive capacity of Cambodia.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the methods section. For climate resilient pathways Cambodia requires reducing social vulnerability by improving social conditions, specializing and diversifying the economy, and improving in governance.

For promoting new activities, the country also needs to enhance its financial system −40.3% of GDP provided by the financial system as of 2013 for domestic credit is low (e.g. Vietnam provided >100% GDP for domestic credit in the same year).

For adaptive capacity Cambodia needs to invest in the formation of gross fixed capital, currently low compared to other countries in the world. Improved road infrastructure has been identified as key for better accessibility to markets for agriculture (IFAD 2013). The regional integration with Thailand, Vietnam and China is the main incentive for growth in the future. Cambodia connects Thailand with Vietnam. The main road network in Cambodia is exposed to floods and weather extremes that permanently affect the Mekong delta. The variability of investems in grosss fixed capital formation in Figure 2-3 shows that Cambodia needs to develop its capacity to keep investments plans.

Labor productivity is the major bottleneck for economic productivity. Very low labor productivity correlates with very low performance in the indicator of percentage of labor force with tertirary education. In addition, human resources are burdened by very low access to basic services, very low number of doctors per 1000 people, and very low investments in health. The food price ratio is very low, but in the recent past it was very high. As mentioned in the subsection of food security in section 2.1.3, the share of income that needs to be spent for food amounts to 46.2% in average as of 2010 (World Bank 2015a).

Growth in Cambodia is needed for better income and stronger internal consumption. As shown in Figure 2-8, the % of exports is very high. It reflects the weakness of the internal consumption. Cambodians spent on average 46.2% of their income for food in 2010 (World Bank 2013c). Moreover, the very low share of high tech products in the portfolio of exports indicates the low specialization of the economy.

For a new economic model, Cambodia requires substantial improvements in environmental, human and financial governance. In all the aspects evaluated by the Human Governance Indicators of the World Bank, Cambodia performs negatively. Scores have improved in voice and accountability between 2003 and 2013, political stability and absence of violence, regulatory quality and the rule of law. However, the situation in government effectiveness and control of corruption in 2013 is worse than in 2003. Good governance has been proved a key aspect for cooperation and coordination of stakeholders in Cambodia (Dany, Bowen, and Miller 2014; Bowen et al. 2015).

2.3.1.1 Future GHG Emissions from Energy and Transport

If Cambodia takes advantage of increased trade with Thailand, Vietnam and China countries, energy consumption will grow significantly in the coming decades, increasing the demand from industry and services, but mostly from transport. Future growth, urbanisation and therefore higher energy demand and production will lead to higher overall emissions, particularly in the energy sector. Being extremely dependent on energy imports, the scaling up of the energy supply has been a main focus for Cambodia in recent years, and renewable energy sources and energy efficiency seem to provide both large mitigation potential. This is reflected by various country-wide strategies and frameworks like the National Green Growth Roadmap, and also by individual measures, such as the most recent construction of multiple hydro-power plants. The scaling up of domestic energy supply will likely reduce the high energy prices (Mohammed, Wang, and Kawaguchi 2013; World Bank 2014b).

Oil, gas and coal reserves have been discovered in Cambodia, but are still not being exploited (Ellis et al. 2013). All used fossil fuels are imported with amounts as high as 1.57 Mtoe (almost one third of 5.3 Mtoe total primary energy supply) in 2011, and oil products virtually account for all of them (IEA 2015). Oil is responsible for more than one quarter of Cambodia's total energy supply (excluding electricity trade) and for 90% of all domestic electricity generation in 2011 (IEA 2014a). With respect to electricity supply, Cambodia is highly dependent on imports. In 2011, 1644 GWh were imported from Vietnam, Thailand and Laos and only 1053 GWh were produced domestically (IEA 2014a). However, a hydro-power plant currently under construction (e.g. the Kamchay Hydropower Station operating since late 2011) aims for a decrease of dependency on imported fossil fuels and electricity as well as a better diversification of power sources. Furthermore, its purpose is to solve the country's wide electricity supply shortages and to contribute to the national targets for 100% grid connection of villages in 2030 and 70% of households in 2020 (Kingdom of Cambodia 2012). As Figure 2-8 shows, in 2010, only 31.1% of the population were connected to the grid, while electricity prices remain exceptionally high in comparison to neighboring countries.

Because of the importance of rural lifestyles and consequently the widespread use of fuel wood, the country's current energy mix is comparably clean (73% renewables in TPES in 2011). In the electricity production, renewables only play a minor role (6% in 2011) (IEA 2014a), even though the build-up of hydro-power plants could change this in the future.

For the energy sector, official Cambodian scenarios estimate a reduction potential of 573 to 7,094 $ktCO_{2e}$ in 2050, compared to a baseline scenario, if all preconditions are provided (private sector investment, donor financing and government policy development) (Kamal 2013). Possible mitigation options include energy efficiency, hydro and solar power, gasification and cogeneration, electric vehicles, efficient cook stoves, biogas digesters and ceramic filters. Cambodia has great potential for hydro power generation due to the Mekong River Network and could make use of its tropical location by using solar power. However, currently only small-scale projects of solar PV systems to individual households exist. It is unlikely that Cambodia develop carbon markets in the next decades, due to the very low income per capita and very low emissions per capita.

2.3.2 Agriculture and Deforestation:

Agriculture and deforestation produced 86.4% of the GHG mitigation potential in 2010 (WRI 2011). The reduction of deforestation requires interventions in several fronts, including the control of the expansion of industrial agriculture, better income for population in forests areas, and developing forestry, in which the country presents high potential. Though the tradition in forest management was almost dismantled by the Khmer Rouge, forests communities still possess valuable indigenous knowledge that should be recovered and used to develop the capacity in forestry. Carbon sinks and the sustainable exploitation of forests can curve the current trend of deforestation.

Future use of REDD+ could be a key factor in the country’s mitigation activities. The development of capacity in forestry requires commitment of the government and a decisive support from the international community. REDD+ can play an important role in the transformation of Cambodia in a country able to benefit from the mitigation opportunities in forestry. Three projects in forestry have been registered (the Oddar Meanchey REDD Project, the REDD+ Southern Cardamoms Mountain, and the Lomphat National Wildlife Sanctuary REDD+ project (FCP 2015). Only the Oddar Meanchey REDD Project has established mitigation targets of 7.1 $MtCO_2$ over 30 years, since 2008 (FCP 2014). However, none of these projects is in operation. The projects would provide financial inflows that are important for poverty reduction and for the expansion of services in rural and urban areas in Cambodia, although international commitment is still required.

2.3.3 Agriculture and Rice Production:

Agriculture alone is the second contributor of GHG emissions. The sector has high potential to improve productivity and emissions efficiency. Rice production is responsible for 2/3 of agricultural emissions, more than twice the GHG emissions of the energy sector (Fukui 2014). The country has developed only 30% of the potential yield per hectare, which represents the lowest productivity among the South-east Asian countries studied in this report. In 2013 the CDM adopted the Standardized Baseline Technology Switch in the rice mill sector of Cambodia. The approval of this methodology has paved the path for the exploitation of the mitigation potential. However, the country needs to develop initiatives and institutions for monitoring, reporting and verification of emissions reductions.

2.4 Conclusions

Cambodia needs growth for developing its capacity to adapt. The regional integration with Thailand, Vietnam and China constitutes the axis of growth in the coming years. As Cambodia is the necessary route connecting Thailand and Vietnam, the country needs to develop further its road infrastructure along the Mekong delta. This region is exposed to floods and weather extremes and therefore the country needs to develop more resilient infrastructure and transport systems.

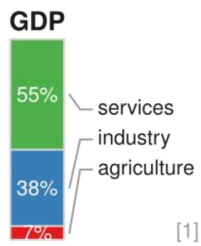
Cambodia possesses limited capacities for mitigation, mostly as a consequence of its low development, but offers, simultaneously, some mitigation potential. While most potential lies in the Agriculture, Forestry and Land-Use (AFOLU) sector, especially in the preservation of Cambodia's valuable forests, also many opportunities are provided by the energy sector, which is expected to grow substantially in the next years. The government already engages climate change mitigation through framework policies, agenda-setting, some individual measures and forest management.

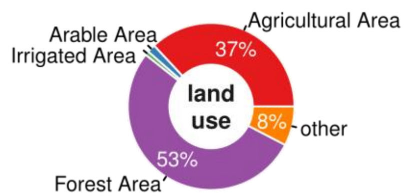
The country needs to diversify its economy towards the services and industry sectors. It requires policies that create incentives for urbanization, education, and the development of human capital. The country needs growth and development for enhancing its environmental, human and economic governance. The development of environmental governance is needed to become attractive for CDM investments in forestry and mitigation.

3. COLOMBIA

Figure 3-1: Colombia – Factsheet and physical map:

Country size	1,138,910 sq km	[1]
Coastline	3,208 km	[1]
Population	48.93 millions	[2]
Rural population (%)	23.8	[2]
Human Development Index	0.71 (98 of 187 – High)	[3]
Life expectancy at birth	74.04	[1]





[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

3.1 Sensitivity and Vulnerability

3.1.1 Sensitivity of Natural Resources

Temperature: Between 1961 and 1990 observed changes in air temperature were +0.1°C to +0.22°C per decade (Villacís 2008). Using SRES A2 scenario assumptions a warming of 1.4–2.5 °C is projected by 2050 (Jarvis et al. 2013). A temperature increase by 1.0 − 1.4°C by 2030 is likely in the Departments of Vaupés, Guainía, and Vichada (Jarvis et al. 2013).

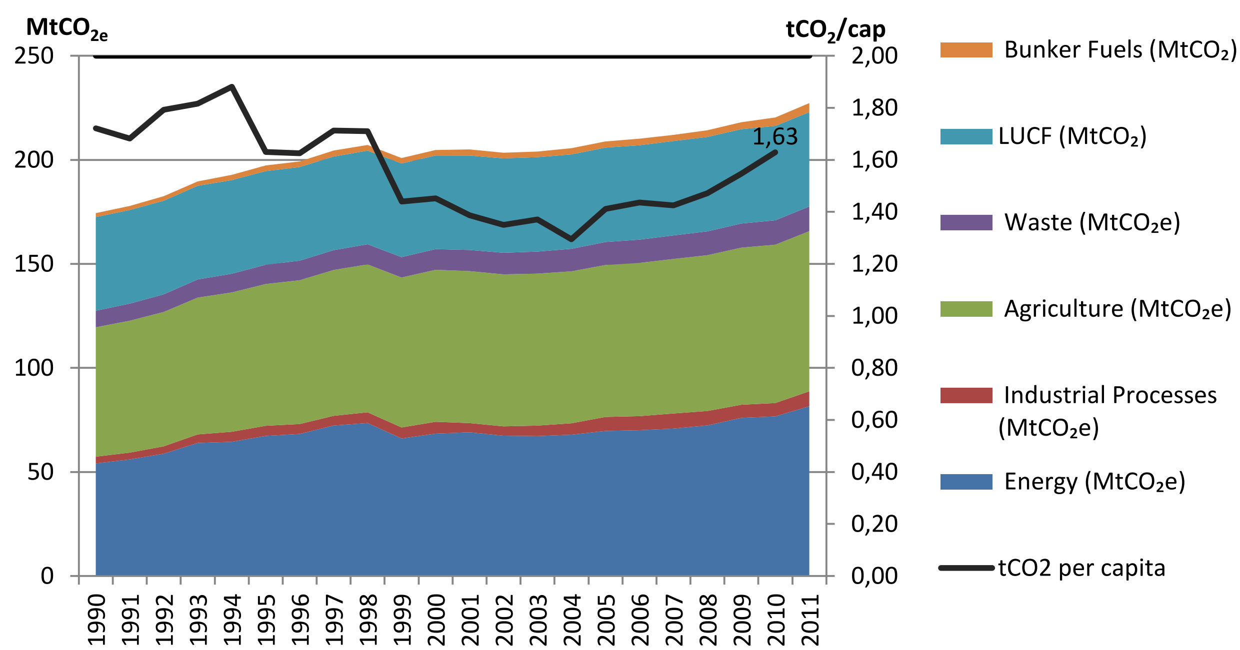
Water resources, rainfall and precipitation: Between 1961 and 1990 precipitation varied between -4% and +4% per decade (Villacís 2008). Rainfall extremes have increased during 1901-2010 (Donat et al. 2013). Precipitation patterns in 2030 and 2050 may be very similar to current patterns, though differing in magnitude with ranges from -3 to +3% in 2030, and -6 to +5% by 2050 (Jarvis et al. 2013). Simulations show a decrease in precipitation in the North by 40 mm/yr by 2030 and 90 mm/yr by 2050. In other regions precipitation will likely increase as much as 80 mm/yr by 2030 and 180 mm/yr by 2050 (Jarvis et al. 2013). The largest decrease in precipitation, up to 60 mm/yr, will likely occur in Atlántico, Norte de Santander, Cesar, Sucre, Arauca, and Magdalena by 2050. The largest increases will likely occur in the Departments of Valle del Cauca, Amazonas, Cauca, Quindío, Nariño, Tolima, Huila, and Caquetá. Pronounced increases are expected for the Amazon region and the coffee-growing zone, namely up to 130 mm/yr (Jarvis et al. 2012).

Crop yields: In a study by Jarvis et al. (2013), 25 crops were selected for their relevance (area and value) in Colombia's agriculture. The crop model Eco Crop was used to calculate impacts on crop yields (SRES A2 scenario) for 2050. 80% of crops will likely be impacted in the majority (>60%) of their current areas of cultivation, with particularly severe impacts on high-value perennial crops. The crop's climatic aptitude was positively affected in 14.4% of the total area, whereas 85.2% was negatively affected (Jarvis et al. 2013).

Land Use and Forestry: The loss of climatic niches suitable for coffee crops in Colombia will force the migration of coffee crops toward higher altitudes by mid-century (Ramirez-Villegas et al. 2012). By 2010 Colombia had 60.49 million hectares of forest covering 55% of its land area (FAO 2014b). From 1990-2010 the average deforestation rate in Colombia reached 0.48% per year resulting in 310,349 ha/yr (Cabrera et al. 2011). In Caquetá deforestation increased by 192% in 2012, the highest rate found in Latin America (Faleiros 2013). Major drivers for deforestation include agriculture and cattle ranching, coca crops, settlement and infrastructure, mining, timber and fires (Mads 2010). Colombia's national development plan (2010-2014) might have contributed to deforestation as it focused on five axes, including agriculture, mining, infrastructure, and housing (DNP 2011).

Atmosphere: Total CO_{2e} emissions –including forestry and agriculture– are increasing in Colombia, while energy, agriculture and forestry being the major contributors. CO_2 emissions per capita (World Bank 2015a) from burning fossil fuels and the manufacture of cement have been decreasing over time (WRI 2014) driven by the reduced share of fossil fuel combustion in the production of electricity. While emissions from electricity generation do not present a significant growth trend emissions from transport are increasing (see Figure 3-2).

Figure 3-2: GHG sectoral emissions and energy per capita emissions of Colombia.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions per capita per year from the combustion of fossil fuels (0.3 tCO_2) are below but close to the 2 tCO_2/cap/year required to keep global warming below 2°C by 2050 under fair burden constraints (WBGU 2009b). As the sectoral shares show the most relevant sectors with mitigation potentials comprise energy, agriculture and forest sector.

3.1.2 Economic Vulnerability

According to the National Planning Department (DNP) 20% increases in losses and damages of human lives during 1980-2010 from weather extremes have resulted in GDP loses of 1.5% (DNP 2014a). Reducing the population exposed to disaster risk by 20% would result in a 4.5% decrease in the mortality and injury rates (DNP 2014a). If investment in disaster risk prevention increases up to 1% of GDP, the economic impacts of disasters would be reduced by 60% (DNP 2014a). For the SRES A2 scenario with no adaptation, projected GDP loses from climate change would amount to 0.50% per year between 2011 and 2100 (DNP 2014a). For the A1B scenario, projected losses in GDP would reach 0.49% per year (DNP 2014a).

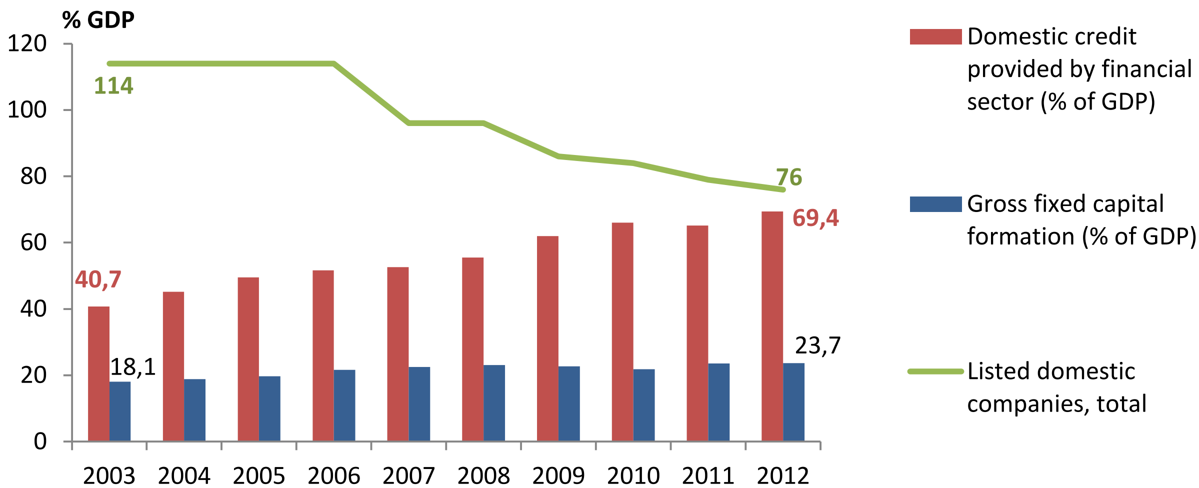
Sectoral impacts: Agriculture contributed 13.94% to GDP in 2013 (World Bank 2015a). The sector represents 17% of the labor force (WFB 2015). The consequences of climate change in agriculture are diverse, yet not adverse in all cases for Colombia (Jarvis et al. 2013; DNP 2014b). In general, corn production will be negatively affected by climate change impacts (DNP 2014b). While the production of corn in Cordoba would be most negatively affected in Norte de Santander and Huila it will benefit (DNP 2014b). Other important commodities like sugar cane would also benefit from changes in precipitation (DNP 2014b).

Impacts on productive factors: Hydroelectric power generation in Colombia amounts to 73% of its total potential (World Bank 2008). The Guavio's river watershed provides 13% of hydropower and would lose 109,961 MWh if the A2 scenario comes true, or 11,809 MWh for the A1B scenario between 2012 and 2050 (DNP 2014a). Other factors negatively affecting the economic productivity in Colombia are labor productivity, poor road infrastructure, and the social conflict (DNP 2014b).

Economic specialization and diversification: Lowly diversified and lowly specialized economies will be more vulnerable to changes in prices and trade conditions. In contrast, a higher specialization and diversification improves the country's adaptive capacity. The Colombian economy is vulnerable to direct and indirect impacts of climate change due to the low specialization and the low diversification of the economy. It is also vulnerable to the dependence of exports on agricultural commodities that will be adversely affected by climate change. With regard to diversification, Colombia exported 1088 commodities by 2012, similar to more diversified economies like Brazil, India and South Africa. 79.2% of the total value exported is produced by only 10 products (Simoes and Hidalgo 2014): 5 raw mineral commodities (crude oil, coal briquettes, gold, ferroalloys and coke), 4 agricultural products (coffee, bananas, raw sugar and flowers), and refined petroleum. The low specialization becomes evident by the fact that mining accounts for 73.46% of total exports (Simoes and Hidalgo 2014). In this respect Colombia performs within in the third decile, i.e. low in the amount of high technology products exported (see proficiency in the use of financial resources in Figure 3-8) relative to the rest of the world (World Bank 2015a). Moreover, crude oil exports account for 42.41% of total exports. In contrast to the mining sector, which would not be adversely affected by climate change, the production of coffee and sugar in the agriculture sector will face adverse consequences for national revenues.

Capital Formation: High investments in gross fixed capital formation are indicative of the commitment to enhance basic infrastructure for adaptive capacity. As shown in Figure 3-3, the provision of domestic credit from the financial sector has been growing steadily since 2003, and was not affected by the 2008 crisis. The decreasing number of companies listed in stock markets show a process of concentration of capital in fewer companies, which is indicative of a low diversification. Other countries in this study (e.g. see the report of VIETNAM) follow a totally different trend, with the number of companies growing steadily. As shown by the index of gross fixed capital formation in Figure 3-3 Colombia shows commitment in infrastructure investment for adaptive capacity. The share of GDP in the creation of gross fixed capital formation in the region is only surpassed by Peru. Overall, these numbers show some resilience of the Colombian economy to changes in the international arena, but also a concentration of capital and low economic diversification that reduces the capacity to cope with financial shocks.

Figure 3-3: The recent evolution of capital in Colombia.



The graphic provides information about domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation (World Bank 2015a). For the analysis of the adaptive capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. Colombia is developing its capacity to provide domestic credit and to invest in infrastructure steadily important for adaptation. However, capital is being concentrated in fewer firms, reducing the social benefits of the economy. This trend of accumulation would need correction to reduce the economic and social trade-offs implied.

Economic Risks and Uncertainties: As it was mentioned in the methods section, the governance of financial resources associated with adaptive capacity is about the ability to reduce the variability of economic flows (Adger et al. 2007). As climate change has an influence on economic outputs; for the assessment of economic vulnerability it is important to trace how the country performs in the control of economic risk and economic uncertainties. Inflation has decreased consistently from 6.9% in 2008 to 2.02% in 2013 (World Bank 2015a). In addition, the country also shows a good performance in transaction costs (see indicators of governance of financial resources in Figure 3-8). In the ease doing business index (World Bank 2015a), which evaluates the environment facilitating development of business associated to transaction costs, the country performs above the seventh decile (43 in 2013 – World Bank 2015a). The country risk index (Euromoney 2014), which evaluates structural, political and economic risk– places Colombia in the seventh lower risk decile (59.34 as of 2013). However, with regard to property rights, the International Property Right Index (5.2 in 2013) places Colombia between 0.4 and 0.5 relative to the rest of the World, mainly as a consequence of land tenure conflicts. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). The numbers for Colombia demonstrate the ability of the government to keep control of macroeconomic sources of risk (inflation, country risk and transaction costs), but show institutional deficits in property rights.

In summary, the sources of vulnerability of the Colombian economy include weather disasters; impacts of climate change in agriculture and, consequently, on exports; impacts of climate change on energy; and the variability of prices of mineral commodities. The economic vulnerability is increased by the low specialization and diversification of the economy and by the concentration of capital. Sources of economic uncertainty include inefficiency of property rights institutions. The economy also shows signs of resilience in regard to inflation, financial turmoil and transaction costs.

3.1.3 Social Vulnerability

Weather disasters are important sources of social vulnerability in Colombia. The country experiences 2.97 disasters per year on average (ALM 2014), with floods and landslides accounting for one third of these disasters between 1970 and 1999 (ALM 2014). During the rainy season of 2010-2011, floods and landslides accounted for death toll of around 450 people and more than 3.3 million people affected (Fog 2013). During the same period 1 million hectares of farmland were flooded and almost 13,000 houses destroyed (Fog 2013).

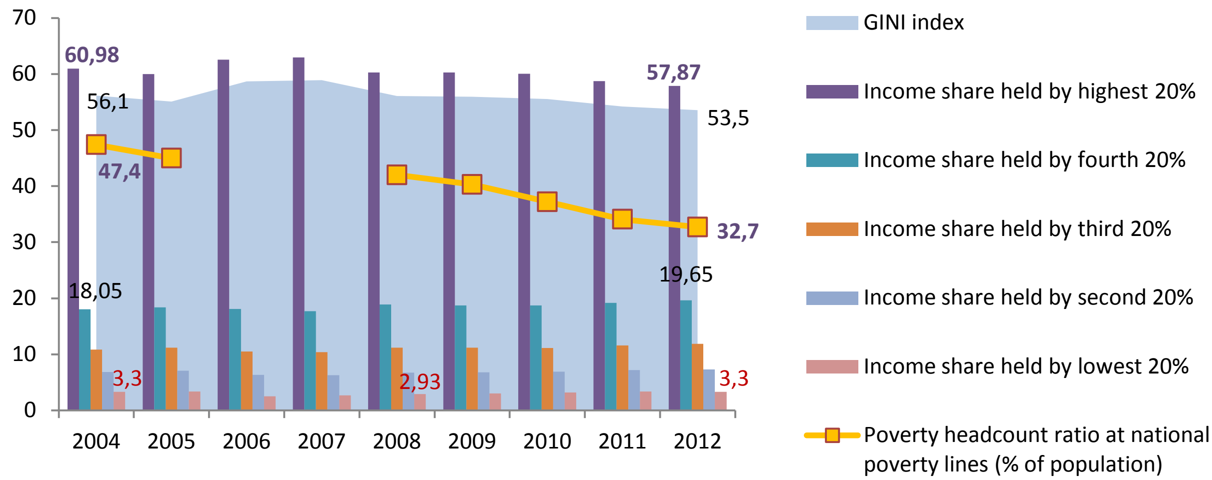
Impacts of climate change on crop yields will affect rural population to a greater extent due to a lower income and lower food availability. Rural population in Colombia represents the 24% of the total population –i.e. 11,653,673 people as of 2013 (World Bank 2015a). Income inequality matters for vulnerability (Adger 1999), and it is particularly high for Colombia, as shown in Figure 3-4. Colombia is among the ten more unequal countries in the world. This implies that wealth is concentrated and most of the population lack financial resources to cope with shocks. As income shares in Figure 3-4 indicates, changes in income distribution have benefited the middle class, but not the poor. In 2012, the fifth income share holding the lowest 20% of national income received the same share as in 2004.

Poverty in Colombia is still high. Nevertheless, policies for alleviating poverty have reduced it from 47.4 in 2004 to 32.7% in 2012. Poverty reduction would be related to programs supporting the poor rather than structural changes securing their long term progress. The poorest continue burdened by income inequality, thus the reduction of social vulnerability in Colombia requires more commitment of the elites.

Food security: In 2012, 10.6% of the Colombian population was undernourished, which represents a decrease from the 14% registered in 2006 (FAO 2015). The food deficit per person in 2012 amounted to 70 kcal per capita per day, similar to Surinam and higher than Honduras (FAO 2015). The prevalence of food inadequacy reaches 17.6% of the population, i.e. 8.4 million (FAO 2015).

Health, Sanitation, Water and Energy Services: Life expectancy (73.6 years in 2012) puts Colombia in the seventh decile –high– relative to the rest of the world (World Bank 2015a) (World Bank 2015a). Colombia spent 5% of GDP in health services in 2012, including private and public expenditure (World Bank 2015a), below the average in Latin America and the Caribbean (7.7% in 2012) (World Bank 2015a). The access to fresh water reached 93% of total population in 2011; i.e. 3.38 million people had no access to water supply. Access to sanitation reached 78% of the population in 2011 i.e. around 1.068 million had no access to sanitation by 2012 (World Bank 2015a). People with no access to electricity amounted to 1.449 million as of 2010 (World Bank 2015a). Despite presenting more positive numbers than Peru, Colombia needs to bridge current gaps in some of these basic services in order to reduce their population's vulnerability.

Figure 3-4: The recent evolution of income distribution, inequality and poverty in Colombia.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poor and their situation in the context of inequality. The high inequality of income distribution in Colombia and high poverty headcount ratio indicate high social vulnerability. This trade-off needs to be considered for the analysis of synergies.

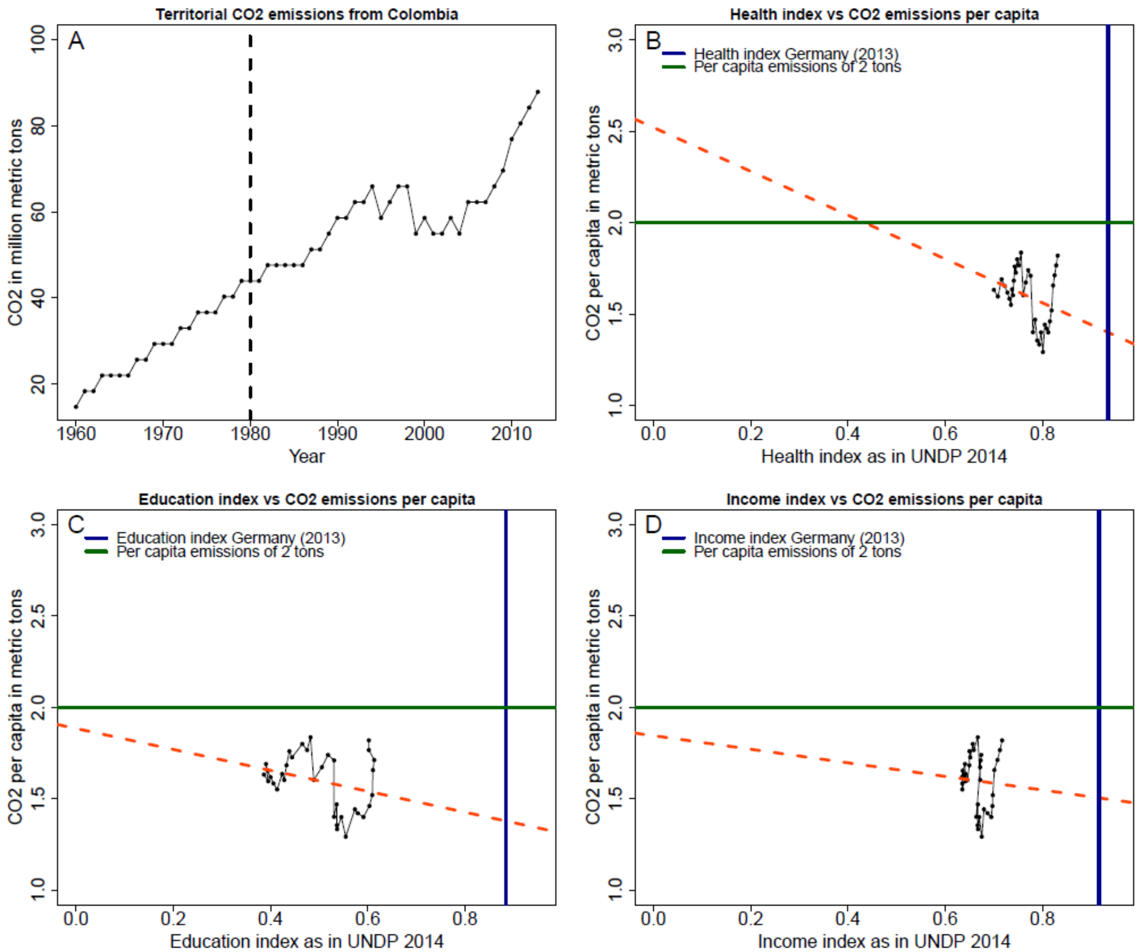
Education: The government spent 6.7% of the GDP in education in 2012 (World Bank 2015a). It places Colombia in the fourth decile relative to the rest of the world. The pupil-teacher ratio in primary education was 25.4 as of 2012, decreasing from 29.4 in 2008. This is still far away from the 16 OECD members (World Bank 2015a). Despite Colombia performed amongst the last in the Program for International Student Assessment PISA in 2012 (OECD 2012) the labor force with tertiary education has increased from 18.3% in 2005 to 22.6% in 2011 (World Bank 2015a). It is now in the range of Costa Rica, Mexico and Ecuador.

3.2 Links between Adaptation, Development and Mitigation

3.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions of Colombia show a continuous growth from 15 $MtCO_2$ in 1960 to 88 $MtCO_2$ in 2013 (Le Quéré et al. 2014). The only exception was a decade-long stagnation in between 1996 and 2006 (Figure 3-5A). On a per-capita basis the picture has been much less consistent. Stagnation throughout the 80s was followed by a drop in the 90s as a consequence of the energy crisis in 1991 leading to per capita emissions of approximately 1.8 tCO_2/cap. Currently, per capita emissions of Colombia are still on the edge of the sustainability limit of 2 tCO_2/cap (WBGU 2009a). However, the sharp increase observed in recent years is likely to change this picture rather soon. As depicted in Figure 3-2 this increase is mostly driven by the energy and transport sectors.

Figure 3-5: Trends of CO_2 emissions and the HDI in Colombia.



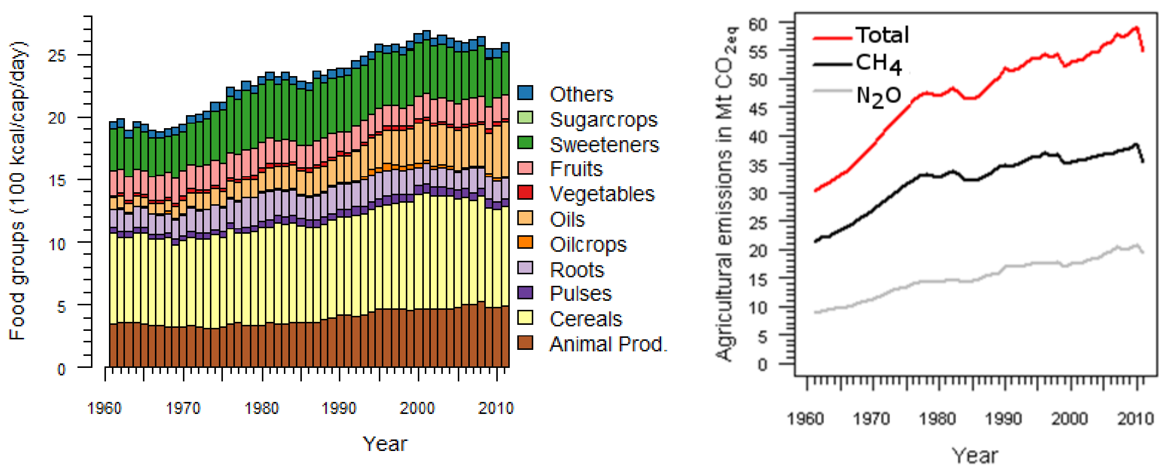
Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project Le Quéré et al. (2013) (A). Health index for the time period of 1980-2013 (calculated according to UNDP 2014 technical notes) vs CO_2 emissions per capita (B). Panels C and D show analogous information as panel B for the Education and Income index, respectively. Data on population, income, education and health was obtained from the World Bank 2014 database. Horizontal green line shows the 2t CO_2/cap target (see WBGU 2009). The vertical blue line highlights the current (2013) position of Germany in regard to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, the dashed vertical line indicates the starting period of analysis for the panels B, C and D. Colombia advances consistently but very slowly in the indices of education and health, while inconsistently reducing CO_2 emissions per capita. The development of elements associated to the HDI does not show an apparent coupling to trends in emissions per capita in Colombia. Hence, policies affecting mitigation have not had significant implications for adaptation and human development in Colombia.

In regard to the evolution of development dimensions such as education, health and income, these are observed to be largely unrelated to per capita emissions over the last 30 years (Figure 3-5B, C and D). The progress made by Colombia towards developed-world standards in the several dimensions analyzed has been a slow one, especially regarding income and education (Figure 3-5C and D). This is also reflected in the fact that Colombia expects to meet an HDI of 0.9 in 2040 or later, with associated annual emissions of 120 million tons (Costa et al. 2011). This is a 40% increase in comparison to 2013. Comparing Figure 3-5B, C and D with Figure 3-3 it is clear that the high increase of GHG emissions in the country has been more related to the accumulation of capital than to the attention of social needs. This reinforces the idea that income inequality in Colombia plays an important role for the allocation of the benefits of GHG emissions.

3.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 3-6 (left) presents the evolution of dietary patterns in Colombia between 1961 and 2011 based on amount of 11 different food groups supplied in the country. In general, Colombia's total food supply has increased from 1,960 kcal/cap/day in 1961 to about 2,600 kcal/cap/day in 2011. During these five decades, amount of sweeteners including sugar supply remained almost constant, whereas supplies of cereals and animal products have increased by 70 and 140 kcal/cap/day, respectively. Furthermore, supply of oils has quintupled in the country. This depicts the changing lifestyles in Colombia towards meat-rich diets.

Figure 3-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Colombia.



The data was obtained from FAOSTAT (FAO 2014).The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (in CO_{2e}), including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Colombia during the last fifty years. Food supply in Colombia has increased in the last few decades, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has decreased in the recent year which needs to be continued to ensure environmental synergies.

In the year 2000, around 8.5 million people in Colombia lived in the regions where local food and feed produced within 5 arc-minute grid (10 km x 10 km in equator) was sufficient to meet their food and feed demand (Pradhan et al. 2014b). Colombia is a net food importer in terms of calories (Pradhan et al. 2015), but a net food exporter in terms of monetary values (FAO 2014b). This is because Colombia exports high value crops such as coffee and flowers (Simoes and Hidalgo 2014). Colombia's net food import was about 14 trillion kcal in the year 2000. The country's food production was sufficient to feed around 14 million people, resulting in around 27 million people depending on international trade for part of their food supply. Major parts of the country so far have attained more than 70% of the potential crop production (Pradhan et al. 2015a). Colombia could become food self-sufficient by closing yield gaps to attain 100% of the potential crop production, resulting in 10 million people relying on local food and the rest of the population depending on intra-country food transfer. Closing crop yield gaps can increase crop production, reducing international food imports. Nevertheless, only closing yield gaps is insufficient for Colombia to ensure its future food self-sufficiency (Pradhan et al. 2014a). Another option consists of shifting land use from grasslands used for cattle ranching to cultivars. Among the countries studied, Colombia presents a very low agricultural productivity and the highest share of agricultural land dedicated to cattle ranching.

The total agricultural emissions of Colombia have almost doubled from 30 $MtCO_{2e}$/yr to 55 Mt CO_{2e}/yr in the last 50 years as shown in Figure 3-6 (right). The increased emissions are related to increases in agricultural production. Furthermore, diets currently consumed in Colombia embodied emissions of about 2 tCO_{2e}/cap/yr (Pradhan et al. 2013b), and around 2 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013a).

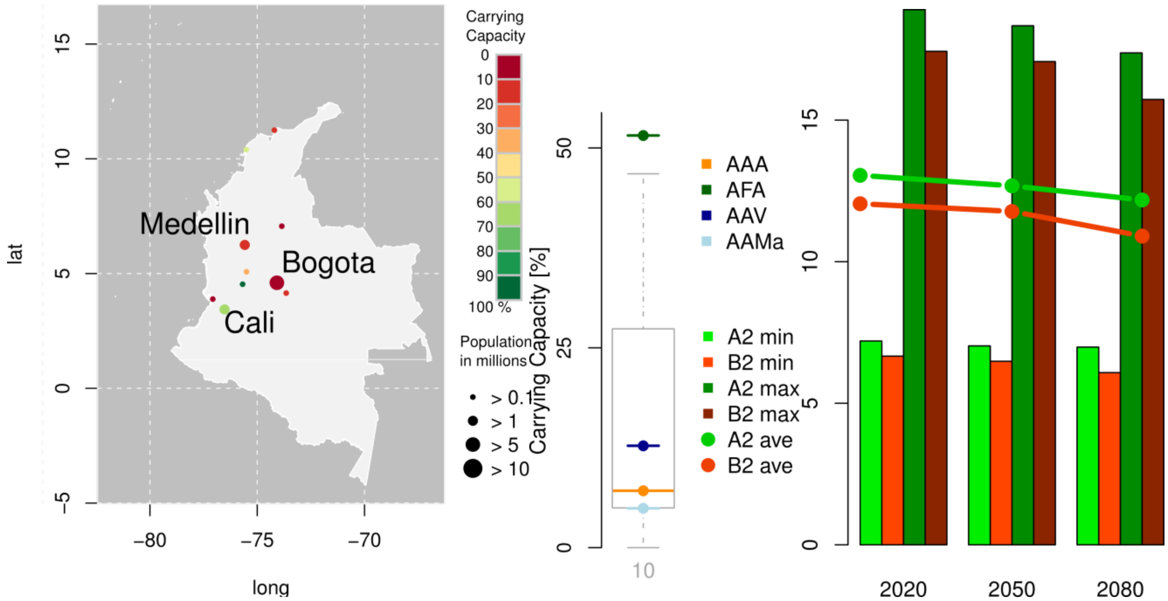
Dietary patterns in Colombia may increasingly be meat-rich when the country becomes more developed in the future, resulting in larger volumes of GHG emissions and food imports. Technological progress can transform these trade-offs into synergies. Currently, emissions per unit of crop and livestock production in Colombia are higher than those of developed countries (Pradhan et al. 2013). Hence, technological progress lowering agricultural emission intensities can lower agricultural GHG emissions of the country (Pradhan et al. 2013). The International Center for Tropical Agriculture CIAT recently launched the program “LivestockPlus consortium”, which investigates alternative cost-effective practices to reduce GHG emissions from cattle in Costa Rica and Colombia (Idupulapati et al. 2015).

3.2.3 Potential of Peri-Urban Agriculture and Local Food

76% of 49.5 million people in Colombia live in cities and a future growth up to 62.9 million by the year 2050 will occur mainly in cities (United Nations 2014). Ten cities with population above 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 3-7). Overall, these cities represent more than 14.4 million people. Today, 20% of the areas surrounding cities are used for agricultural purposes. 19% percent of the urban dwellers can be nourished from the currently harvested areas (Kriewald, Sterzel, Pradhan, García Cantú Ros, et al. 2015).

The biggest potential to increase the food self-sufficiency is by land use change. However, a changed kcal-consumption or diet will have an influence as a further increase up to 3,500 kcal/cap/day will reduce the carrying capacity down to 5% (see Figure 3-7 middle). Nine out of ten cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The summed up values decrease down to 12% (see Figure 3-7 right). Moreover, Colombian food supply of 2600 kcal/cap/day is above its average dietary energy requirement of around 2370 kcal/cap/day (Hiç 2014).

Figure 3-7: The possibility for a food supply from surrounding areas for Colombian cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV) and an increased kcal-consumption (AAMa). On the right the change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and two yield scenarios (min, max) and the averaged values. The current low potential for food self-sufficiency of Colombian cites can be increase by more agricultural areas in the surroundings. Changing climate and diets have just a minor effect.

3.3 The Potential for Synergies and the Stage of Country Development

Two inter-sectoral trade-offs are prominent in Colombia: i) the divergent trends between increased GHG emissions and indicators of human development and ii) between agriculture and deforestation. Intra-sectoral trade-offs relate to the inefficiency of agriculture, where the uncontrolled expansion of cattle ranching plays a predominant role. Moreover, disaster risk management requires special attention as hazards are major sources of losses and damages in Colombia.

3.3.1 Climate Change Policies and Disaster Risk Management

Colombia is highly exposed to weather-related impacts. Economic and human losses are large, and are projected to increase with climate change. In fact, the national strategy for climate change has two main components: mitigation and disaster risk management. The national strategy for climate change is built upon four axis related to mitigation and DRM (DNP 2014b): 1) the design and implementation of the Colombian Strategy of Low Carbon Development (ECDBC), 2) the National Strategy for GHG Emissions Reduction from Deforestation, 3) the National Adaptation Plan −to cope with natural hazards, and 4) a strategy for the financial hedging against natural hazards.

A review of the national strategy (DNP 2014b) summarized in the four points above shows some features worth highlighting:

1. Mitigation and adaptation are separated. Within this conception, the links between adaptation and mitigation would be marginal, restricted to potential co-benefits.
2. The notion of adaptation in the strategy is about disaster risk management. It aims to preserve the competitiveness of economic activities (DNP 2012). A wider perspective on adaptation would include the development of social conditions to reduce social vulnerability in risk-prone regions.
3. The conception of risk management is reactive, not preventive.
4. The identification of the institutional needs and incentives to enhance risk management is not developed.

3.3.2 Economic Growth, GHG Emissions and Human Development:

As Figure 3-5 shows, the development of the education and the health index of the HDI do not follow similar trends with the development of emissions. What are the options to reduce GHG emissions in the energy and transport while enhancing human development? In regard of mitigation, the government has committed to three types of actions (ALM 2014).

1. Unilateral actions: At least 77% of the total energy capacity installed by 2020 will be generated from renewable sources. By 2011, 80% of total electricity production was generated by renewable sources (Mcginn et al. 2013). Several sources offer the possibility to meet this target. As of 2011, the hydropower output represented 30% of the economically exploitable potential (World Energy Council 2013). The country also has the potential to increase the production of biofuels in savannas. By 2020, 20% of fuel consumption will be based on biofuels.
2. Actions with financial support: Colombia will reduce deforestation in the Amazon rainforest to zero by 2020. Recently Colombia signed agreements with Germany and Norway (World Bank 2013d) to meet this target.
3. CDM: Current portfolio of CDM projects has a reduction potential of 17.4 $MtCO_2$. In CDM projects, energy, forests, industry, transport and waste management have a reduction potential of 54.8 $MtCO_2$ by 2020, 66% of BAU emissions (UNFCCC 2014a). In transport, the country has a reduction potential of 6.8-7.6 $MtCO_{2e}$ in 2030, 14-16% of BAU emissions. The strategy does not contemplate the reduction potential of agriculture.

Colombia offers high potential for GHG mitigation in electricity and transport due to its unexploited potential for hydropower and the high potential for the production of biofuels. These potentials can be exploited at very low costs. The development of the biofuel industry in Colombia and the potential for hydropower already being exploited explains the erratic trend of the CO_2 emissions in Figure 3-5A. Figure 3-5 shows also small progress of the income and the health index and even the stagnation of the education index. The high potential for renewables in Colombia and the low costs for their implementation show that the country can develop policies for human development without compromising the future implementation of policies for mitigation.

Other generic options to reduce GHG emissions in the electricity and the transport sector include taxes and abatement targets. Taxes promote the entry of more efficient technologies. However, policies based on taxes would have adverse consequences for GDP (Calderon et al.

2015). For the case of Colombia mitigation policies – associated to taxes and abatement targets – may have adverse consequence for poverty (Hussein 2014). In order to create conditions for the effective implementation of efficient institutions for mitigation – e.g. carbon markets and taxes, the country needs to develop its adaptive capacity. But it requires a more inclusive model of economic growth in Colombia.

A new growth model in Colombia requires long term policies for the diversification of the economy, the promotion of human capital and the development of new enterprises owned by new economic actors, higher income per capita and reducing more effectively the existent inequality in the distribution of income. This requires improving education to achieve higher labor productivity. The productivity of labor is low as shown in Figure 3-8, and reflects the development of the productive structure. Improving human capital requires closing the gaps in the provision of services. In this regard, Colombia is close to bridge the gap (see Figure 3-8).

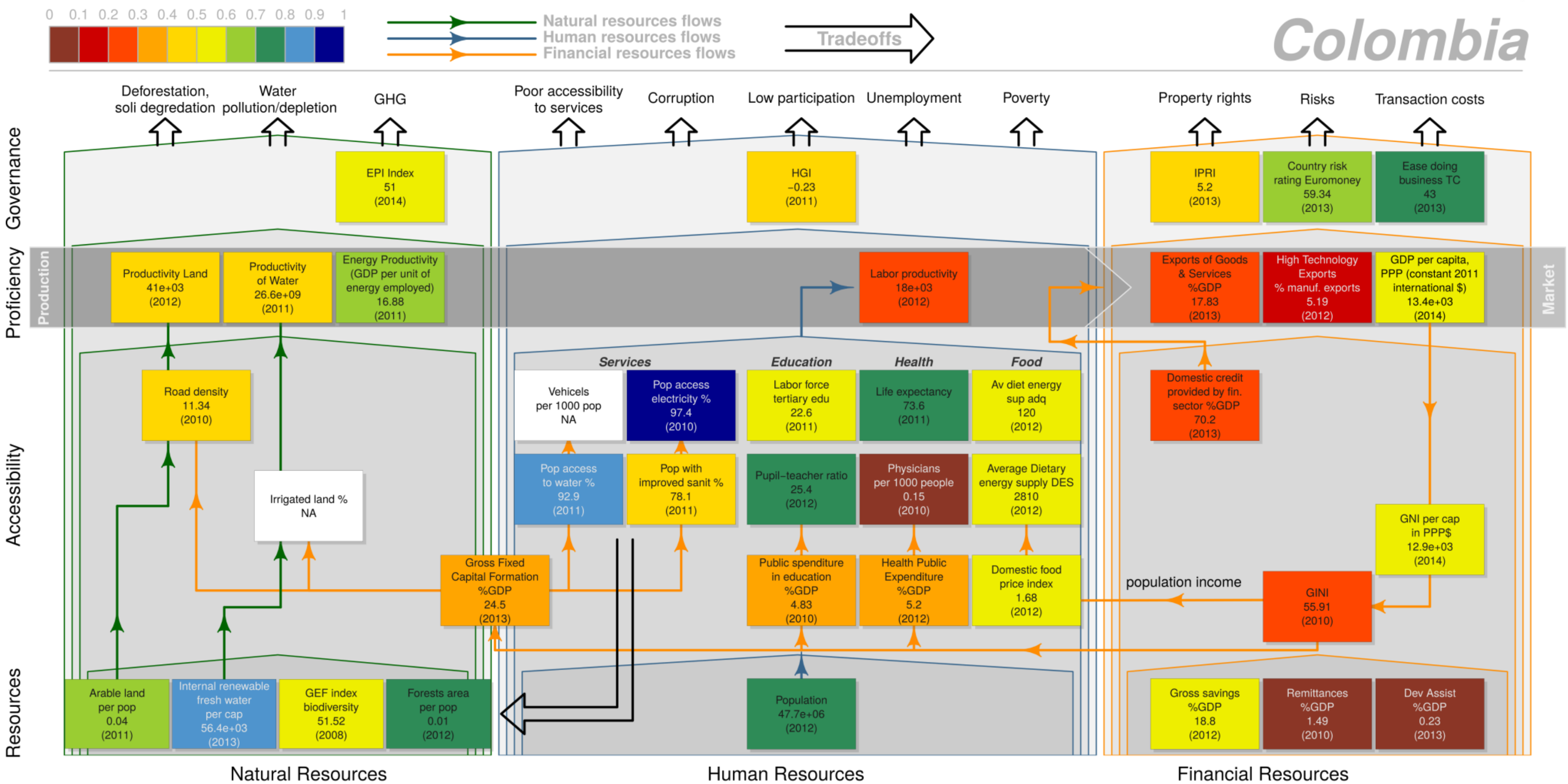
As the indicators of economic governance in Figure 3-8 show (the information crossing the row of governance and the column of financial resources) a positive aspect is the macroeconomic capacity of the country to control risk. In addition, the country has a very healthy banking system (see the trend of domestic credit provided by the financial system in Figure 3-3). As the trend of the number of listed companies in stock markets shows (Figure 3-3), the economic model of Colombia favors the concentration of capital.

The high development of capital in Colombia creates favorable conditions for a growth model based on the diversification and specialization of the economy, and the inclusion of new economic actors in the creation of entrepreneurship. As an indicator of the low specialization, observe in Figure 3-8 (the info crossing the row of proficiency and the column of financial resources) the very low performance in high tech exports compared to the rest of the world. Moreover, mining has a prominent role in exports. Although revenues from mining are being used in the development of road infrastructure, this sector does not promote inclusive growth, and the reduction of inequality and poverty remains to be tackled.

3.3.3 Agriculture, Deforestation and Rural Development:

Deforestation and agriculture together accounted for 53.8% of GHG emissions as of 2011 (WRI 2014). Impacts of climate change on crop yields will drive the increased pressure on forests areas for the expansion of agriculture and cattle ranching, hence exacerbating the production of GHG emissions, if adequate actions are not taken.

Figure 3-8: Indicators of the adaptive capacity of Colombia.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. Compared to other countries in this study, Colombia shows a more developed productive structure, with higher standards in the governance of economic risk and indicators of social development. But the low productivity of labor and the very low share of high technology exports make evident the low specialization of the economy.

The potential for increased deforestation is reinforced by poverty in rural areas. Clearing forests for grasslands represents an income source of poor peasants (Health and Binswanger 1996). Constraints to access land to the poorest in Colombia act as a driver of deforestation (Health and Binswanger 1996). Deforestation is also facilitated by the deficient presence of authorities and the influence of paramilitary and guerrilla forces (Álvarez 2003). In addition, Colombia is a net importer of food, and the production reaches only 70% of the potential yield.

The correction of this trade-off requires the implication of the government in ambitious plans for developing the productivity of agriculture, enhancing the peasants' agriculture and developing the environmental coping capacity for the control of deforestation. For this task there is an important institutional basis consisting of the Colombian Agricultural Institute (ICA according to the national acronym), the Municipal Units of Technical Assistance (UMATAs), the Colombian Corporation for Agricultural Research (CORPOICA), and the Regional Autonomous Corporations. However, institutional coordination is hindered by the seizing of these corporations by politicians and low performance –and decreasing- in the control of corruption.

Improvements in land productivity are needed in Colombia to perform better in terms of food security and agricultural efficiency. By 2000, the country was not self-sufficient (Pradhan et al. 2015), and the country presents a middle-range performance in the control of the costs of food –observable in the high performance of the domestic food price level index. In the total food supply the country presents a middle-range performance (see indicators of food security in Figure 3-8). Minimum energy requirements in Colombia amounted to 1840 kcal/cap/day by 2012 (FAO 2015), and supplies in average 2810. In the average dietary energy supply adequacy the country performs low (120%), i.e. there is a 20% buffer.

Colombia is the country with the highest share of pastures and meadows among the countries studied (90.87% of total agricultural land as of 2011) (FAO 2014b), but land productivity is the lowest among the countries studied. Options to increase agricultural outputs include shifting from grasslands to cultivars. These lands could also be used to promote peasants' agriculture and food security. Peri-urban agriculture would not be priority recourse for reaching self-sufficiency. In regard to the oil palm sector, the government has proposed to increase the cultivation area to three million ha in order to satisfy market demand, which includes the demand for biofuels. However, according to (Castiblanco et al., 2013) this target is unfeasible under current trends. To achieve the 20% blend target in fuel consumption, shifting grasslands into palm oil plantations will have positive consequences in terms of GHG emissions for the transport sector.

Strategies focused on the development of agriculture in grasslands and meadows and halting deforestation is a suitable alternative for mitigation of climate change. According to (A. De Pinto et al. 2014), one additional hectare allocated to agriculture in Colombia increases average GHG emissions by 2.5 Mg CO_{2e} per year, while one hectare of forest lost in the Amazon results in a loss of carbon stock of 367 Mg CO_{2e}. Shifting grasslands into cultivars or forests have implications for cattle ranching. FEDEGAN –the Colombian livestock union, proposes reductions of the total pasture area to 24 million ha from current 34 million by 2019 (A. De Pinto et al. 2014). However, according to these authors, the government proposes further reductions down to 13 million ha. This shows Colombia's potential to reduce GHG emissions in the agricultural sector.

Actions in frontiers of agriculture and forestry with high deforestation rates like in Caquetá require developing incentives for forests protection and additional disincentive mechanisms. International donors established an important agreement with Colombia to achieve mitigation targets in forestry in 2014, within the BioCarbon Fund Initiative for Sustainable Forest Landscapes (World Bank 2013d). Between 2014 and 2018, Germany and Norway will grant 65 US$ million to Colombia to achieve deforestation targets (MoE - 2014). These funds might be used to improve the efficiency of agriculture in order to close the potential yield gap. Increases in land productivity would be more effective by shifting cattle to agricultural crops rather than just developing more efficient technologies for crop production. Changes in land use from cattle to agricultural crops would help Colombia reduce its self-sufficiency deficit and reduce GHG emissions from the agricultural sector.

The country needs to enhance its land tenure system to enforce the protection of its forests through institutional presence, and regulate land use change for agriculture. Programs aimed at increasing agricultural development have also the opportunity to develop and implement technologies that reduce the emission of GHG emissions.

3.4 Conclusions

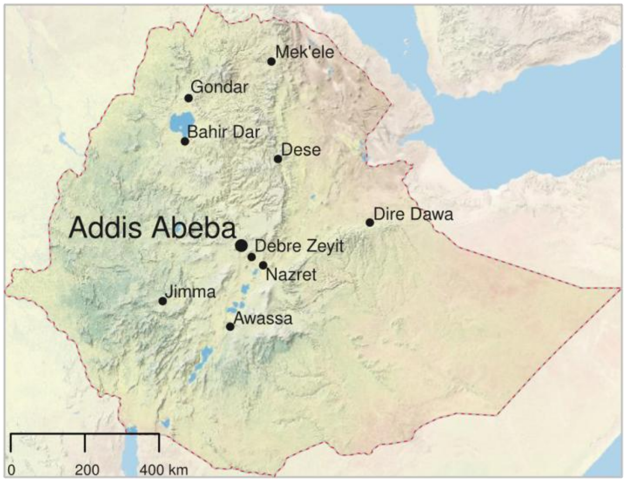
For climate resilient pathways Colombia has a good potential for GHG mitigation in the energy sector. The country is rich in hydropower. Moreover, the country as developed industry for biofuel production, both from sugar cane and oil palm. The country has ambitious and achievable plans to reduce GHG emissions in the energy and the transport sector. Achieving ambitious targets in mitigation do not guarantee that the country is on track of adapting adequately. While ambitious mitigation targets are essential for climate resilient pathways, there also requires a reduction of social vulnerability, protecting natural resources and transiting towards a more inclusive growth model.

For getting on track of climate resilient pathways Colombia needs to develop further its institutions for Disaster Risk Management. Currently, the population and the productive structure are severely affected by weather and human produced disasters. In addition, the country needs to diversify its economy, to reduce its dependency on mining. For a more inclusive growth, the country needs to reduce income inequality.

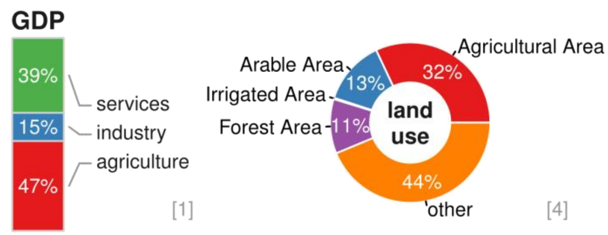
For effective reduction of GHG emission caused by cattle ranching and deforestation, the country needs to develop institutions in forestry. REDD+ and international assistance may play an important role to create incentives in the country for the development of the capacity in the control of deforestation and the capacity for monitoring, reporting and verification of carbon sinks in forestry. In complement, the country needs to develop further institutions for the development of agriculture and rural development, with special emphasis in the development of agricultural productivity of small farms. The country also needs to fix strict targets and develop strong institutions for the control of deforestation from the expansion of cattle ranching.

4. ETHIOPIA

Figure 4-1: Ethiopia – Factsheet and physical map:



Country size	1,104,300 sq km	[1]
Coastline	0 km (landlocked)	[1]
Population	96.51 millions	[2]
Rural population (%)	81	[2]
Human Development Index	0.44 (173 of 187 – Low)	[3]
Life expectancy at birth	63.63	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

4.1 Sensitivity and Vulnerability

4.1.1 Sensitivity and Vulnerability of Natural Resources

For the case of Ethiopia the present report relies mainly on the information provided Climate Change Country Profiles developed by UNDP. The climate change projections for Ethiopia were calculated based on A2, A1B, and B1 SRES forcing scenarios for the years 2030, 2060 and 2090 (McSweeney et al. 2010).

Temperature: Between 1960 and 2006 mean annual temperature has increased by 1.3°C, at a rate of around 0.28°C per decade). The largest increase in temperature in Ethiopia has been observed in the months July/August/September (JAS) at a rate of 0.32°C per decade. The mean annual temperature is projected to increase by 1.1 to 3.1°C by 2060, and 1.5 to 5.1°C by 2090.

Water resources, rainfall and precipitation: The strong inter-annual and inter-decadal variability in Ethiopia's rainfall makes it difficult to detect long-term trends (Mcsweeney et al., 2010). There is no statistically significant trend in observed mean rainfall in any season in Ethiopia between 1960 and 2006 (Mcsweeney et al., 2010). Decreases in JAS rainfall observed in the 1980s have shown recovery in the 1990s and 2000s. There are insufficient daily rainfall records available to identify clear trends in daily rainfall variability.

Climate projections indicate an increase in the annual rainfall amount. This trend is broadly consistent for all ensemble runs performed by the different models (McSweeney et al., 2010). This increase is largely a result of increasing rainfall in the 'short' rainfall season October/November/December (OND) in southern Ethiopia. OND rainfall is projected to change by +10 to +70% as an average over the whole of Ethiopia. Proportional increases in OND rainfall in the driest regions mainly eastern parts of Ethiopia are large. Projections of change in the rainy seasons April/May/June (AMJ) and JAS which affect the larger portions of Ethiopia are more mixed, but tend towards slight increases in the south west and decreases in the north east. Newer results indicate that low lands may become drier while rainfall increases over the highlands according to the CMIP5 runs (Biasutti 2013). Results based on RCP scenarios indicate that climate change will positively affect the runoff of the Didessa catchment, where several water management projects are undertaken (Sintayehu, Kassa, and Bogale 2014).

Crop yields: Ethiopia is an economy dominated by agriculture, i.e. 47% of GDP is achieved by this sector, while 81% of total population live in rural areas (World Bank 2015a). Cereals are the main crops cultivated per area in Ethiopia, with teff (20.9%), maize (14.2%), wheat (12.8%), sorghum (12.8%) and barley (9.1%), averaged over 2004/05–2007/08 (Taffesse et al., 2012). Modeling yield responses obtained by employing stochastic production functions (Kelbore 2012) it was found that the effects of the *belg* and *kremt*[3] rainfall differ across crops and regions. Increases in kremt rainfall increase average yields of all crop items and reduces their variability in the SNNP[4] regional state, while higher *belg* rainfall increases maize yield and reduces its variability in the Oromia region (Kelbore 2012). In order to analyze the effects of future climate on mean crop yields and its variance Kelbore (2012) used crop models forced with climate data obtained from, e.g. CGCM2, PCM, and HadCM3 models (Deressa and Hassan 2009). The results show that negative impacts of future climate change entail serious damage on the production of teff and wheat, but that maize yield will relatively increase by 2050, i.e. benefitting from increased *belg* rainfall. Further simulations indicate that marginally increasing temperatures during summer and winter would significantly reduce crop net revenue per hectare, whereas marginally increasing precipitation during spring would significantly increase net crop revenue per hectare. Moreover, the reduction in net revenue per hectare by the year 2100 would be higher than the reduction by the year 2050 assuming that the damages inflicted through climate change increases with time if negative impacts are not abated through adaptation (Deressa and Hassan 2009).

Land Use and Forestry: At the end of the 19^{th} century, 30% of the Ethiopian land was covered by forests. In 2011 only 12.2% of land was covered by forests (World Bank 2015a). Deforestation drivers are the expansion of small and large scale agricultural farms, illegal logging and forests fires (FDRE-FCPC 2011). Large scale farming has been promoted by the government as a vehicle for rural development and growth. Population growth will likely exert additional pressure on forests (FDRE-FCPC 2011). Mokria et al. (2015) study the dieback in afro-montane forests. Tree dieback affected 1/4 of the total population and affects the 92.2% of *Juniperus procera* and *Olea europaea,* which are main components of these forests. In the study they estimated mean aboveground C-stock was 19.3 (±3.9) Mg C ha^{-1}, with snags contributing to 34.5% of total C-stock. The estimated annual C-sequestration potential of the studied forest was 0.33 (±0.03) Mg C ha^{-1} $year^{-1}$ which is 27% less when compared to the pre-

---

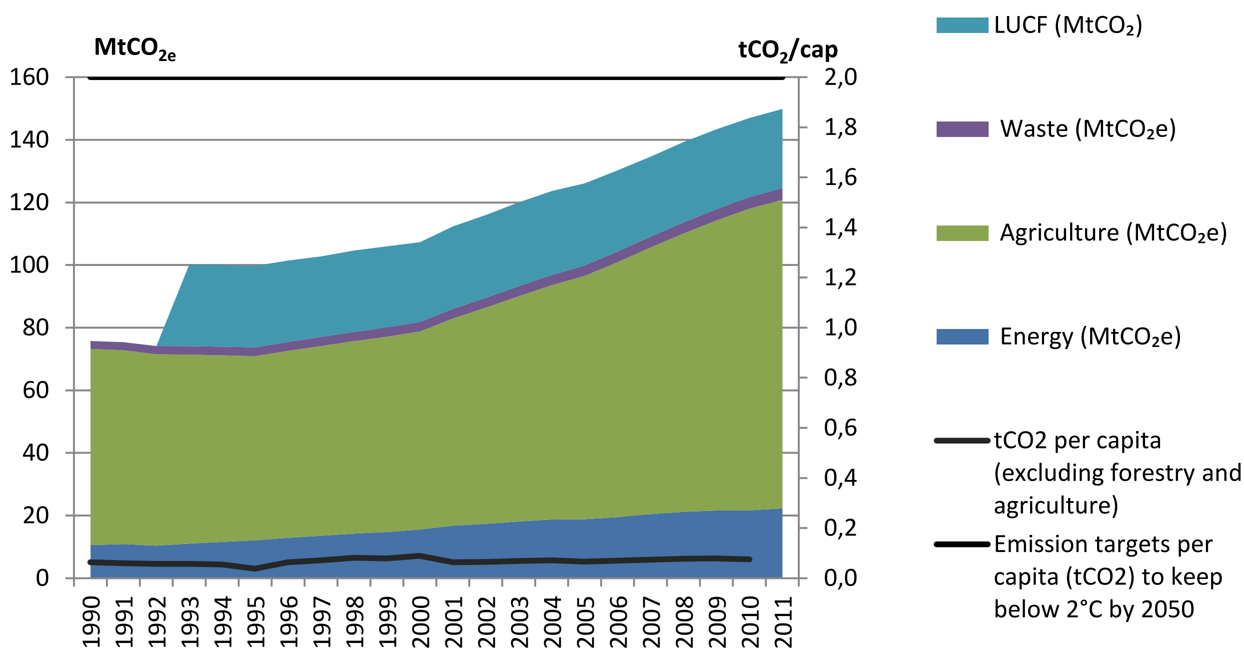
[3] There are three seasons in Ethiopia. From September to February the dry season is known as the bega; this is followed by a short rainy season, the belg, in March and April. May is a hot and dry month preceding the long rainy season (kremt) in June, July, and August. The coldest temperatures generally occur in December or January (bega) and the hottest in March (EB 2014).

[4] Southern Nations Nationalities and Peoples' Regional State (SNNPR)

tree dieback C-sequestration potential. In addition, the study showed that dieback was significantly higher in low altitudes. In addition, tree ring analysis showed that trees reach medium-sized stem diameter (i.e., 20–25 cm) after no less than 100 years, indicating that the effect of forest dieback on C-sequestration potential and ecosystem function is long-lasting.

Atmosphere: In 2010 Ethiopia's GHG emissions mostly derived from agriculture (64.9%) followed by deforestation (17%) and the energy sector (14%) (WRI 2014) (Figure 4-2). The energy consumption pattern in Ethiopia is characterized by a heavy reliance on biomass fuels, which sums up to a share of 93% on total primary energy supply, mainly on account of the household sector (IEA 2014a). As rural population (80%) engages in small-scale agriculture the main sources of energy are still found in the traditional energy sources (UNDP 2014a). Emissions per capita –excluding agriculture and LULUCF are insignificant (0.075 tCO_2/cap).

Figure 4-2: GHG sectoral emissions and energy per capita emissions in Ethiopia.



Emissions from energy include transport. CO_2 emissions per capita (black line) refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from Industrial processes (0.93%) and emissions from bunker fuels (0.68%) and are not included. Total and per capita emissions are extremely low (< 1t/cap/yr) compared to other, in particular, industrialized countries. The currently most relevant sectors for carbon reduction are agricultural production, forestry and energy production.

4.1.2 Economic Vulnerability

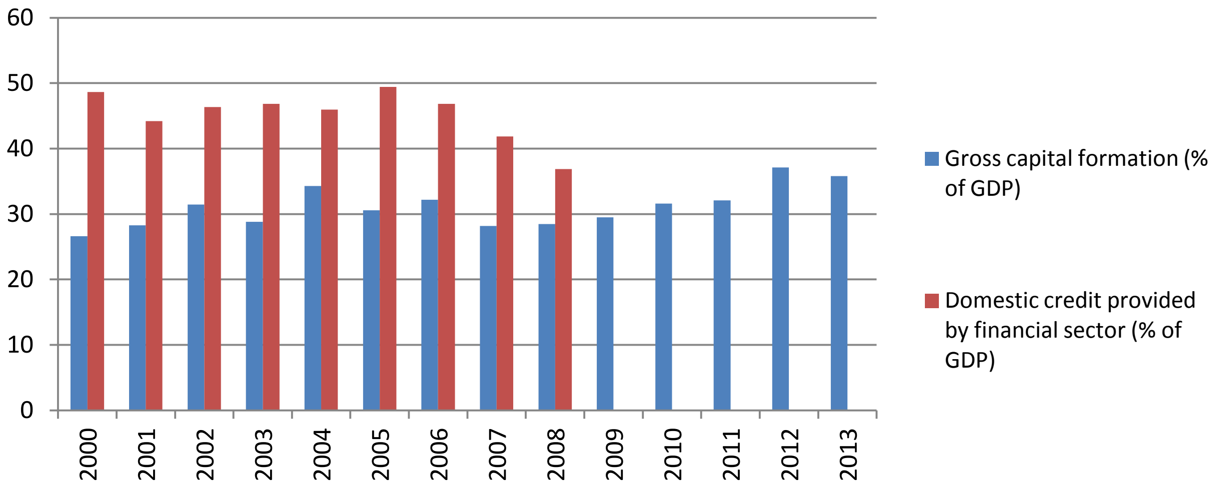
Economic impacts on the agricultural sector: The economy of Ethiopia is highly vulnerable to the variability of weather, due to the high GDP share of agriculture (45% of GDP in 2013, World Bank 2015a). According to the World Bank (2011) droughts and floods are projected to affect considerably the variability of agricultural GDP between 2010 and 2050. Referring to projections the variability of agriculture GDP will rise from 5.2% (BAU without climate change) to 8.4% in a Wet2 scenario (based on A1B SRES forcing scenario). According to the Dry2 scenario based on the B1 SRES scenario, assessing the incidence of droughts, the variability of agricultural GDP will raise to 7.2% in the same period. Considering the range of scenarios, GDP losses will vary between -2% (in a favorable Wet2 scenario) to -6.2% (considering the driest scenario Dry2) by 2025. By 2045, losses vary between -1.5% (in the Wet1 scenario) to -11.6% in the Dry2 scenario (World Bank 2011). Productive factors (in particular road infrastructure and labor) are lowly developed in Ethiopia, contributing to the economic vulnerability. Roads are often affected by floods in Ethiopia (World Bank 2011). The World Bank has encouraged Ethiopia to expand and enhance road infrastructure for higher productivity and for reducing vulnerability to floods (World Bank 2011). According to (Kjellstrom et al. 2015), higher temperatures in Ethiopia will not have significant effects on labor productivity as much of the population lives in high altitudes. The productivity of land is low, similar to the productivity of water (World Bank 2015a). Low usage of inputs leaves room for raising productivity through irrigation, improved seeds, and fertilizers (Taffesse, Dorosh, and Asrat 2012). By 2012 the added value per agricultural worker (constant 2005 US$) was $248, below the average of low income countries ($365.6) (World Bank 2015a).

Economic specialization and diversification: The economy is lowly specialized and diversified, reducing the adaptive capacity: as of 2012, the country exported 592 commodities (much less than Kenya 996), with insignificant share of exports from high technology and machinery (Simoes and Hidalgo 2014). Exports are likely to be impacted by the consequences of climate change, due to the high share of agricultural products. As of 2013, exports represented 11.5% of GDP (WFB 2015). As of 2012 17 agricultural commodities and processed food represented 78.02% of total exports in Ethiopia (Simoes and Hidalgo 2014).

Capitalization and Capital Formation: As Figure 4-3 shows, the loans provided by the financial system have been low and decreasing (World Bank 2015a). The share of GDP spent in gross fixed capital formation is very high compared to neighbor countries. It shows the commitment of the government to the development of infrastructure, hospitals, schools, etc. (World Bank 2015a).

Economic Risks and Uncertainties: As climate change has an influence on economic outputs; for the assessment of economic vulnerability it is important to trace how the country performs in the control of economic risk and economic uncertainties. The economy of Ethiopia is very risk-prone, due to the high variability of agricultural outputs. Inflation in Ethiopia reached 12.9 % in 2005, 44.4% in 2008, and 33.2% in 2012. Explanations for inflation in Ethiopia include domestic demand, higher government spending and increase in government money supply and shift from food aid to cash transfer (Honda et al., 2008; Rashid 2010). Yet, Ethiopia's inflation was concomitant with food price inflation between 1999 and 2009 (Loening, Durevall, and Birru 2009). Since roughly 50% of the GDP is obtained from agriculture the variability of outputs and the volatility of prices would strongly impact the whole economy. Moreover, the economy cannot avail financial resources to better cope with the mentioned variability, due to the lack of money circulation (Atingi-ego et al., 2014).

Figure 4-3: The recent evolution of gross fixed capital formation and domestic credit provided by the financial sector in Ethiopia.



The graphic show information about domestic credit provided by the financial sector (World Bank 2015a) and the investments in gross capital formation (World Bank 2015a). For the analysis of the adaptive capacity, this set of indicators provides a comprehensive view of availability and accessibility to capital, and the commitment in the development of infrastructure. Decreasing financial resources for domestic loans reduces the possibilities to develop the (small scale) economy and the capacity to cope with shocks.

Property Rights constitute an important factor affecting the economy in Ethiopia. The institutional setting of property right in Ethiopia inhibits investments, biases decisions and reduces options. Land belongs to the state and the peoples of Ethiopia, i.e. land owners do not exist in Ethiopia, only claimants and/or proprietors[5]. According to the 1991's constitution, land holders have the right to be compensated for assets and improvements in case of expropriation and rights to inherit. Yet, in reality very often the law cannot be enforced and in many cases it serves politicians to keep control and exert power on land holders (Crewett, Bogale, and Korf 2008). From an economic point of view, the institutionalized architecture of land tenure and property rights has important implications. In principle, land markets are banned. Since land holders have no alienation rights, land cannot be used as liability asset. The only assets available to back loans are infrastructure, crops, and machinery. However, due to the uncertainty created by property rights on land, farmers are reluctant to build assets. The fragility of property rights has created incentives for some strange phenomena. Bluffstone et al. (2008) report that the uncertainty on property rights has spurred the cropping of eucalyptus as this tree grows quick. Eucalyptus is known to consume high amounts of water and to be detrimental to other native species.

Indicators of the governance of risk also show the vulnerability of the Ethiopian economy. Due to the low development of productive factors it does not surprise that transaction costs in Ethiopia are high. In the ease doing business index Ethiopia ranked 125 in 2013 (with 1 being best and 183 worst). The country risk index (33.7 as of 2013), which evaluates

---

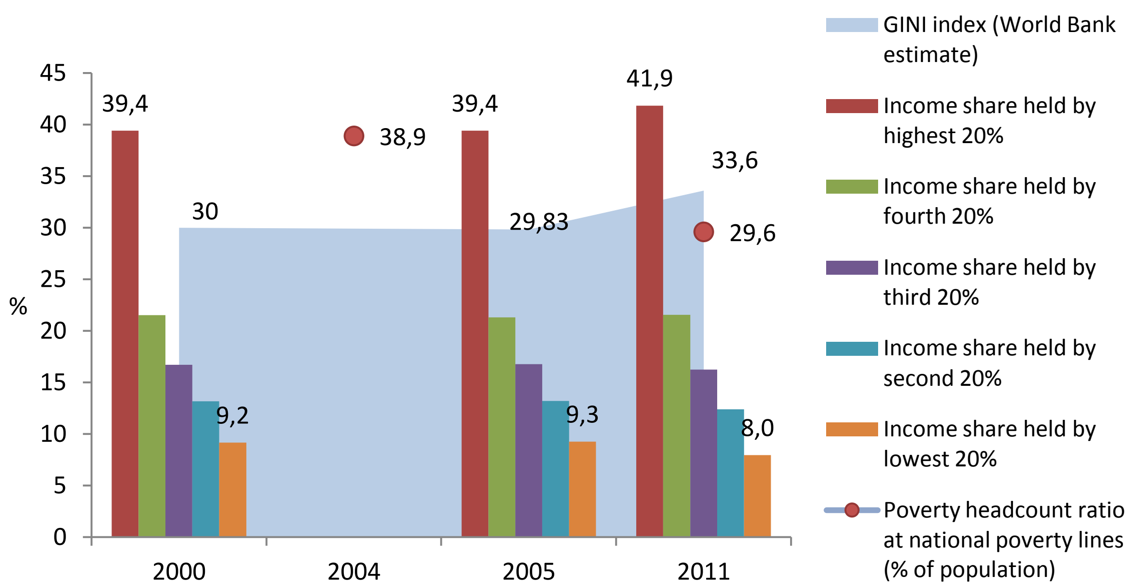
[5] Owners have more rights than proprietors, and proprietors more rights than claimants. Claimants have access rights, withdrawal rights, management rights but they do not have exclusion rights as Proprietors. In turn, owners have alienation rights, i.e. they can transact land in markets (Schlager and Ostrom, 1992; Ostrom and Schlager, 1996).

structural, political and economic risk, places the country in the third decile relative to the rest of the world. In the International Property Right Index (4.5 in 2013) Ethiopia performs only in the second decile relative to the rest of the world.

4.1.3 Social Vulnerability

The Ethiopian population is exposed to weather extremes. Since the 1980s there have been seven major droughts, of which five have led to famines (WB 2010a). Economic impacts on agriculture will affect adversely the population. In 2009 the 85% of the population in Ethiopia derived their income from this sector (WFB 2015). In addition, the very low HDI (rank 173 of 186 in 2010) indicates that Ethiopia is a socially vulnerable country. Poverty has decreased in Ethiopia, but it is still very high. Moreover, income inequality is increasing as the GINI index in Figure 4-4 shows. According to the figure, the income of the richest share of the population has grown from 39.45% of total income in 2000 to 41.9% in 2011, while the income of the poorest share decreased from 9.2% to 8.0% over the same period.

Figure 4-4: The recent evolution of income distribution, income inequality and poverty in Ethiopia.



The GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Increasing inequality of income and a still high poverty headcount ratio in Ethiopia provides an evidence of high social vulnerability and low adaptive capacity of the population. Thus, synergies between adaptation and mitigation action need to consider the reduction of social trade-offs.

Food security: Famine has been recurrent and pervasive in the Ethiopian history. Food insecurity is a major issue, due to direct impacts of changes in average temperature, extremes associated to weather –droughts and floods–, and the share of vulnerable population living in rural areas, depending on agriculture. The prevalence of undernourishment in Ethiopia reached 37.1% by 2013 (FAO 2015). Ethiopia produces 2,240 kcal per person per day and needs 2,220 kcal per person per day. 37.1% of the population is undernourished (FAO 2014b). The depth of undernourishment is 314 kilo calories per person per day. Moreover, the inadequacy of food supply reaches 44% of the total population. These numbers show that the major problem Ethiopia is facing in regard of food security is total food supply. Moreover, in the domestic food price level index (1.92 in 2012) Ethiopia ranks 82 out of 115. Compared to the rest of countries of this study, Ethiopia bears the worse situation on food security.

Health, Sanitation and Water Services: Major health risks associated to climate change in Ethiopia include diseases associated to flooding, malaria diarrheal disease, malnutrition and cardiovascular diseases (Karl and Trenberth 2003). 68% of Ethiopians live in large-scale malaria epidemics prone areas (FDRE 2011a). In 2003 this vulnerability 'resulted in 2 million confirmed cases and 3000 deaths' (FDRE 2011a). Life expectancy (62.5 years) is low. This is not surprising, regarding the very low access to improved water services (49% as of 2012), very low access to sanitation (only 20.7% as of 2012), and very low number of physicians per 1000 people (0.022 as of 2012) (World Bank 2015a). With regard to sanitation and water services, the government has developed initiatives to close these gaps, but the program is burdened by financial shortage, the lack of human capacity, mainly in rural areas, and the lack of financial adsorptive capacity (Calow et al. 2013). In water supply, Ethiopia has provided annual volumes to achieve universal access by 2015 (Calow et al., 2013). Moreover, the country has achieved the Millennium Development Goals (MDGs) for child mortality and is on track for achieving these goals on HIV/AIDS and malaria (WB 2014b).

Education: Ethiopia is committed to enhancing education. The primary school net enrolment reached 82% in 2009, from 77% in 2004 (WB 2011a). For the same period, completion of the primary school increased from 42 to 48%, and enrolment in secondary school improved from 33 to 39% for grades 9 and 10 (Atingi-ego et al. 2014). The enrolment for grades 10 and 11 also increased from 4 to 7% (Atingi-ego et al. 2014).

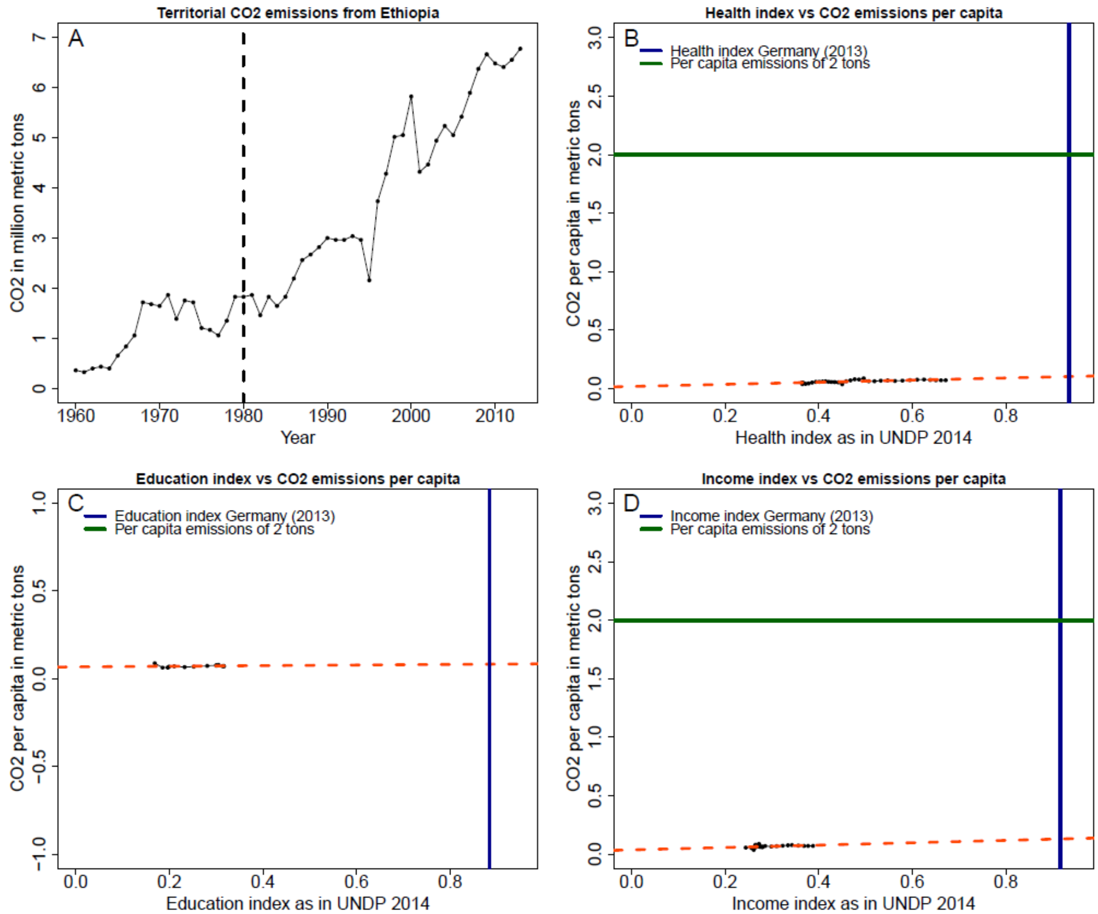
Energy: The percentage of people with access to electricity in Ethiopia was 26.6% in 2012 (World Bank 2015a). The government aims to increase the percentage by 10% over the next decade. It plans to achieve 75% of electricity access in 2015, and 100% in 2030 (CIF 2012). This expansion is needed to attend an increase on demand, but foremost, to close the gap in access to electricity. According to the Growth and Transformation Plan (GTP), Ethiopia aims to expand its power generation capacity from 2,000 MW in 2012, to 10,000 MW in 2015 (CIF 2012a). If this expansion rate is accomplished, the government expects to cover almost 100% of the demand by 2020 (CIF 2012a). Different projects are commissioning or finished.

4.2 Links between Adaptation, Development and Mitigation

4.2.1 The Evolution of the HDI and the GHG Emissions in Ethiopia

Territorial CO_2 emissions from Ethiopia have increased from 0.4 million to about 7 million metric tons between 1960 and 2013 according to the used model, respectively (Figure 4-5A, cf. for comparison World Bank 2015a: in 2011: 7.5 kt).

Figure 4-5: Trends of CO_2 emissions and the HDI in Ethiopia.



Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. Horizontal green line shows the 2t/cap CO_2 target achieving a meaningful climate stabilization policy under fair burden conditions (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. The development of the education and income indices of HDI in Ethiopia do not correlate with emissions per capita, due to the high contribution of agriculture for GDP (Costa et al. 2011). Higher contributions from industry and services would help Ethiopia to increase the pace of development of education and income.

A particularly sharp tendency of higher emissions has been noted since 1980, not without a particularly high inter-decadal variability. On a per-capita basis CO_2 emissions from Ethiopia are extremely low, not overcoming 0.07 tons per habitant (Figure 4-5B) during the time frame investigated. Despite the sharp increase in territorial emissions since 1980 per capita emissions remained very low. Ethiopia's emissions per capita are well below the 2 to. CO_2/cap/year mark required to halt global warming below 2 degrees under the fair burden conditions (WBGU 2009a).

The relation between the different components of human development and per capita emissions in Ethiopia has been a rather flat positive one, regardless if looking at the health, education or income components (Figure 4-5B, C and D). Fast progress has been achieved in the last 30 years with respect to the life expectancy index, from 0.4 to about 0.7 under constant emissions. For the cases of education and income achievements, development has been slower (Figure 4-5C and D). In these cases no correlation with per-capita emissions is observed either. This is because of the high incidence of agriculture in GDP and human development, and low industrial and services growth. In both cases the component score is still far off that recorded in high developed countries, e.g. Germany.

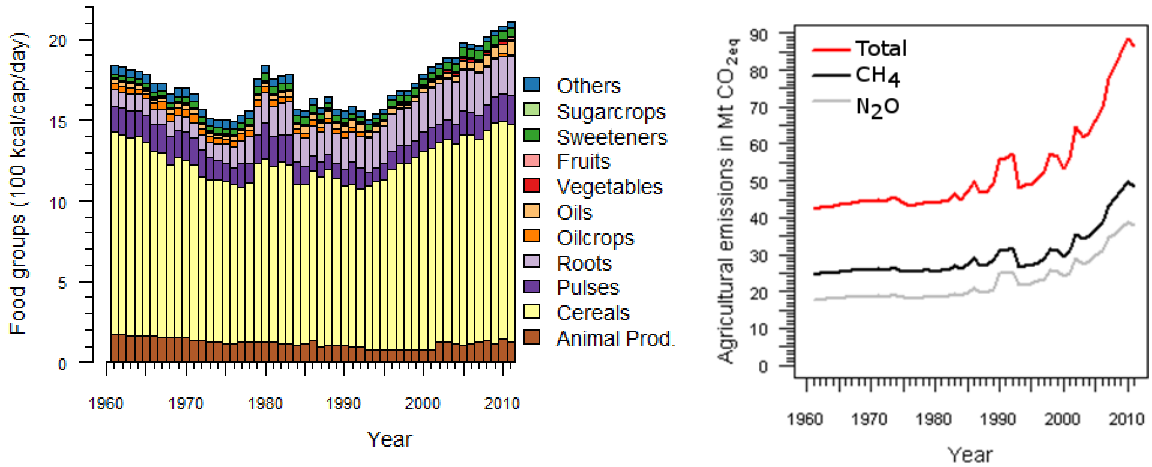
A simple extrapolation of current per-capita emissions trends does not seem to pose a strong risk of Ethiopia moving to per-capita emissions higher than those in line with ambitious climate targets. The progress made by Ethiopia to higher levels of Human Development as measured by the HDI has been mostly hampered by a poorer performance in education and income. Ethiopia is not expected to overcome the 0.9 mark of HDI characteristic of the most developed countries within the first half of the current century (Costa et al. 2011). Emissions by 2050 are estimated at roughly 40 million tCO_2 (Costa et al. 2011).

4.2.2 The Evolution of Dietary Lifestyles in Ethiopia and the Emissions Associated

Figure 4-6 (left) presents the evolution of dietary patterns in Ethiopia between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, Ethiopia's total food supply has increased from 1,840 kcal/cap/day in 1961 to about 2,100 kcal/cap/day in 2011. The current Ethiopian food supply is close to its average dietary requirement of 2,080 kcal/cap/day (Hiç 2014). However, it is still below the average food supply of East Africa of around 2,160 kcal/cap/day (FAO 2014b). During the last five decades the amount of cereals supply per person per day has increased by 100 kcal, whereas supplies of sweeteners and oils have almost tripled. Yet the animal product supply per person has decreased by 50 kcal per day. Furthermore, inter-annual variability in supplies of total calories and the different food groups has been observed in Ethiopia in the last five decades with the lowest calorie supply in 1975 of 1,500 kcal/cap/day. Nonetheless, total calorie supply has continuously increased in the country since 1993. This depicts the increasing food availability in Ethiopia and starting of lifestyle shifts towards calorie rich and nutritious diets, largely based on cereals.

In the year 2000 around 16 million people in Ethiopia lived in the regions where local food and feed produced within 10 x 10 km in cell was sufficient to meet their food and feed demand (Pradhan et al. 2014b). Ethiopia is a net food importer and depends on international trade to meet its food demand (Pradhan et al. 2015). The countries' food production was enough to feed around 24 million people resulting in the rest of the population depending on international trade for parts of their food supply. Ethiopia's net food import was about 6.5 trillion kcal in the year 2000. Ethiopia could become food self-sufficient by closing yield gaps to attain 50% of the potential crop production resulting in 35 million people relying on local food and the rest of the population depending on intra-country food transfer. By 2050 Ethiopian population will reach between 53 and 111 million and will partly depend on international trade to attain 90% of their potential crop production. Closing yield gaps alone is not enough to ensure Ethiopia's future food self-sufficiency when diet shifts are considered.

Figure 4-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Ethiopia.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (in CO_{2e}), including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Ethiopia during the last fifty years. Food supply in Ethiopia has increased in the recent decade, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the last 20 years, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

Correspondingly, the total agricultural emissions of Ethiopia have almost doubled from 42 $MtCO_{2e}$/yr to 87 $MtCO_{2e}$/yr in the last 50 years as shown in Figure 4-6 (right). The emissions increased rapidly after 1995 reflecting increased agricultural production and food supply. Diets currently consumed in Ethiopia embody emissions of about 1.3 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 1.7 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013).

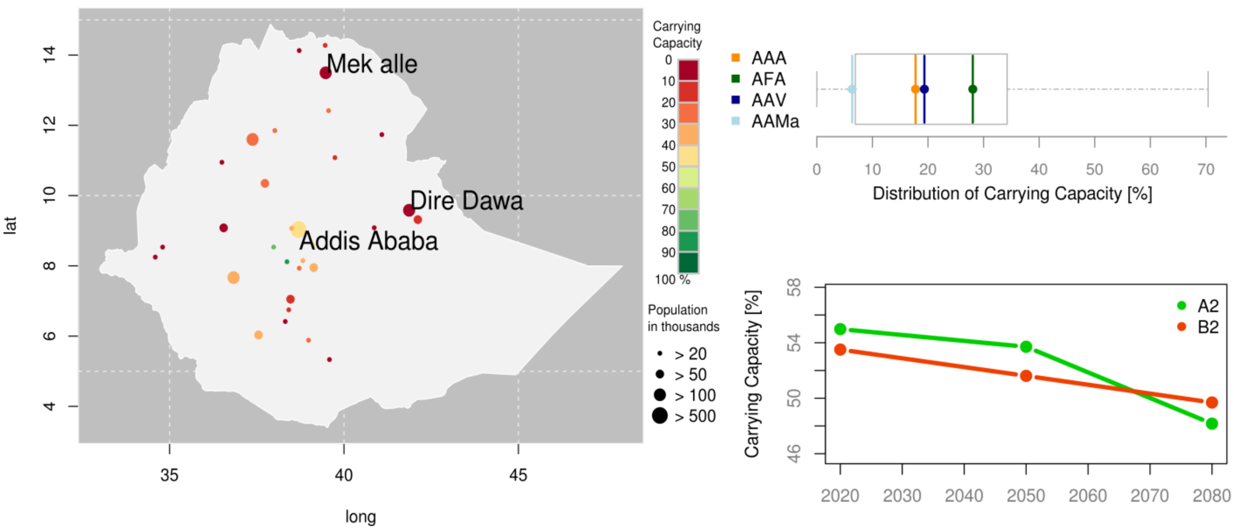
Dietary patterns in Ethiopia may increasingly be calorie and meat rich when the country becomes more developed in the future, resulting in higher GHG emissions. Technological progress may transfer these trade-offs into synergies. Currently, emissions per unit of crop and livestock production in Ethiopia are higher than that of developed countries (Pradhan et al. 2013). Moreover, major parts of the country only have attained up to 30% of the potential crop production so far (Kriewald et al., 2015). Hence, technological progress increasing agricultural productivity can also lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013).

4.2.3 Potential of Peri-Urban Agriculture and Local Food in Ethiopia

Just 19% of the 96 million people in Ethiopia live in cities, but the future growth up to a population of 187.6 million in the year 2050 will occur mainly in cities and raises the percentage of urban population to 37.5% (United Nations 2014). 31 cities with population above 200.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport. Overall, these cities represent more than 4.4 million people. Today 74% of the surrounding areas are used for agricultural purpose, which is 80% of all the available arable area (94%). From the currently harvested areas 36% percent of the urban dwellers can be nourished (Kriewald, Sterzel, Pradhan, García Cantú Ros, et al. 2015).

Today's yield gap ratio is around 0.25. Consequently, closing the yield gap offers the biggest potential to increase the food self-sufficiency. But a changed kcal-consumption or diet will also have an influence as an increase up to 3,500 kcal/cap/day will reduce the carrying capacity down to 6% (see Figure 4-7 – top right). 23 cities or 74% of the investigated cities will face a decreasing carrying capacity by the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012a). The summed up values decrease from 54% down to 50% for an average yield scenario (see Figure 4-7 – bottom right), but are still higher than the current values based on today's low yields. Closing the yield gap must be the first priority.

Figure 4-7: The possibility for a food supply from surrounding areas for Ethiopian cities.



For current conditions (AAA) as a map (left) and the median carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario.

4.3 The Potential for Synergies and the Stage of Country Development

Trade-offs producing GHG emissions in Ethiopia are related to the expansion of agriculture into forests areas. Any transition to an economy with higher participation of industry and services requires the development of agriculture (Rostow 1990). This is particularly true for Ethiopia, because of the high GDP share of the sector (~47%), and the high share of population living in rural areas (~81%). Moreover, food security is a major issue in Ethiopia. Summing up, agriculture is central to the analysis of synergies in Ethiopia. Agriculture itself is the sector with highest emissions (see Figure 4-2). Current emissions from industry, waste, and bunker fuels are insignificant. Contingent future emissions from industry, energy and transport will be conditioned by the development of agriculture.

4.3.1 Economic Growth and Adaptive Capacity:

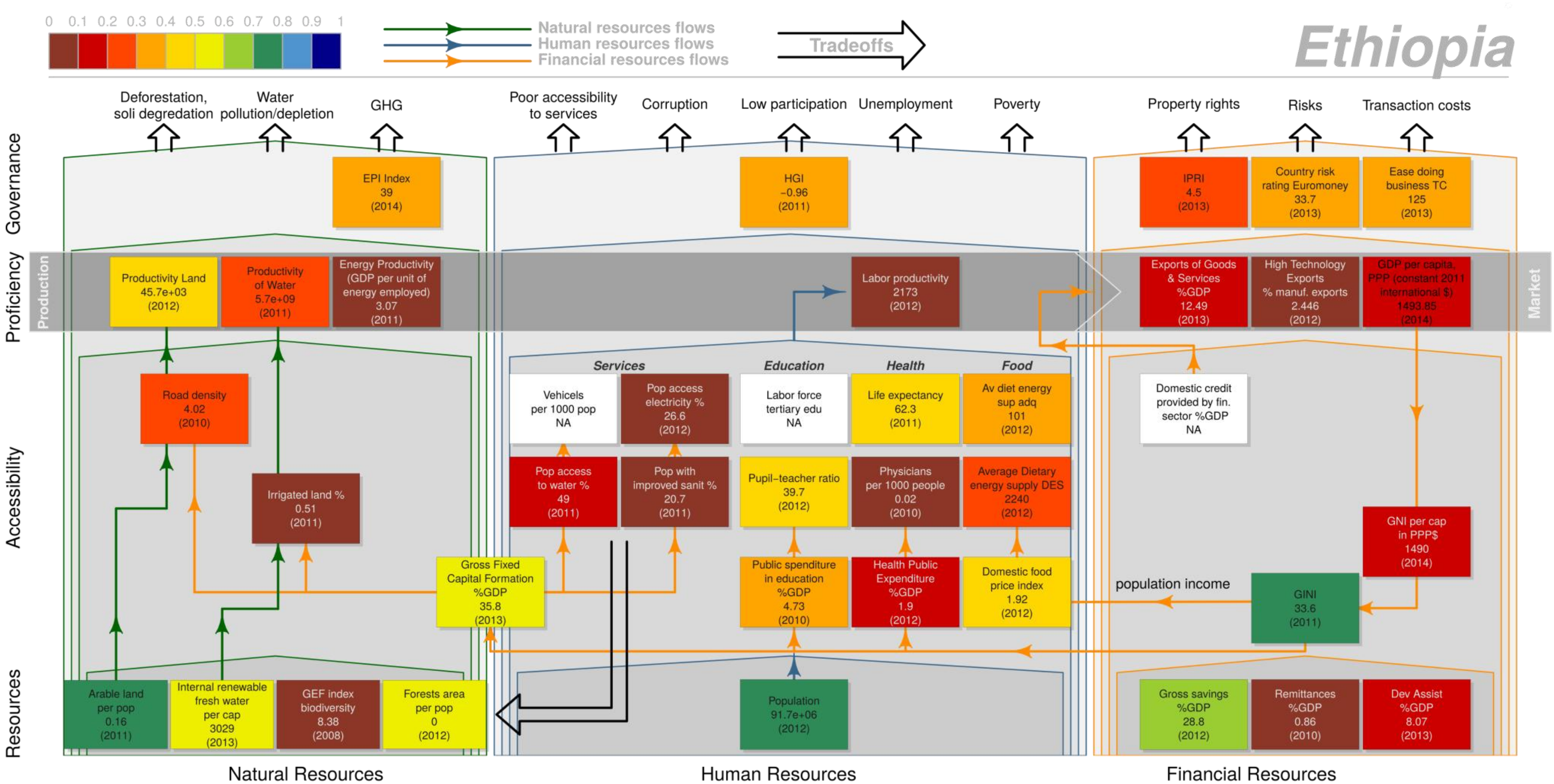
Ethiopia needs growth for adaptive capacity. Figure 4-8 offers an evaluation of the relative development of the adaptive capacity in Ethiopia. A brief observation of the relative development of the indicators in Figure 4-8 shows that Ethiopia needs to improve in all fronts of adaptive capacity: accessibility to resources, their proficient use in economic activities and governance (to keep the narrative simple consider in Figure 4-8 that brown and dark-red colors represent very low; red and gold, low; yellow colors middle; green colors high; and blue colors, very high performances of the indicator evaluated, with respect to other countries in the world). For this purpose, Ethiopia needs growth.

From the indications of Figure 4-8 it is worth observing the urgent need for Ethiopia to protect water resources, biodiversity and forests (see the indicators at the bottom left). For this purpose, the country needs to develop the environmental capacity. The country needs to invest in the development of irrigation systems, technologies and activities that improve the productivity of energy, water and land resources, and the development of the governance (the performance in the environmental part of the EPI index is low compared to other countries in the world). The medium performance in the indicator of gross fixed capital formation shows that the country is committed to the development of infrastructure (see the trend of investments in gross fixed capital formation in Figure 4-3). In 2013, Ethiopia upgraded its department of forestry to the ministry of forestry (Abiye 2013). Similar efforts can be developed in the development of water governance.

A major challenge for the development of the economy in Ethiopia is the very low productivity of labor. This is explained by low specialization of the productive structure, but also by the very low performance in indicators of food security, health, education, and access to basic services. The prevalence of undernourishment in Ethiopia reached 37.1% by 2013 (FAO, 2015). Indicators of food security in Figure 4-8 show that major challenge for food security is food supply. In health, the public expenditure as % of GDP is among the lowest relative to the rest of the world, the number of doctors per 1000 people is very low and life expectancy is low (see Figure 4-8). The country makes efforts to invest more in education. Both in the share of GDP invested in education and the pupil teacher ratio in primary education the performance is middle relative to the rest of the world

Income inequality on Ethiopia is still low but it is growing (see Figure 4-4). However, total GDP is low relative to the rest of the world, and GNI per capita is among the lowest. The domestic credit provided by the financial sector is even reducing (see Figure 4-3). As the indicators of governance of financial resources show in Figure 4-8, Ethiopia needs to improve in property rights, transaction costs and risk.

Figure 4-8: Indicators of the adaptive capacity of Ethiopia.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the methodology refer to the methods section in Part one. The indicators at the left column show the development of the environmental capacity. At the central column, indicators show the societal capacity. Similarly, indicators at the right column show the development of the economic capacity. The very low development of the productive structure and markets (the row of proficiency) make evident the need to link synergies with economic growth. Ethiopia needs economic growth for strengthening adaptive capacity.

4.3.1.1 A Potential Solution

A central question for Ethiopia is how to better allocate its financial and human resources for growth while enhancing the adaptive capacity and protecting natural resources. A climate resilient pathway in Ethiopia should be necessarily rooted in the development of agriculture. It is the sector with potential to produce the financial surpluses required to drive the urbanization process and the enhancement of the industry and the service sectors. Better incomes from agriculture will improve the conditions of rural households, facilitating the migration to urban areas for some of their members. The process of growth based on the development of agriculture should be pursued in parallel with the development of urban markets.

The government is clearly committed to the development of social conditions (see the share of GDP invested in gross fixed capital formation in Figure 4-3). Nevertheless, actual policies do not favor the specialization and the diversification of the economy as desirable. The low development of markets is in part due to the dominant role of the government in the economy, which restricts the availability of capital for the development of the private sector (Atingi-ego, Kees, and Imf 2014). The economic program of the government is crowding out the resources needed by the private sector to foster growth of industry and service sector. These policies have a constraining effect on the performance of the financial system in the provision of domestic loans (see Figure 4-3). According to Atingi-ego et al. (2014) the shortage of circulating money creates negative interest rates. This produces a trap: the government‘s revenues needed for investments are limited by low taxation, tax exemptions, and low private sector growth. Simultaneously, the low liquidity provoked by the government impedes the development of the industry and the service sector.

An alternative to get out of this trap is to reallocate more financial resources for agricultural and rural development, while creating incentives for the development of the industry and service sectors in the short term (approx. 10-15 years). After creating better conditions for agriculture and rural development and the development of industry and services the government can resume the current agenda. After this period, government revenues from taxes to industry and services, the GDP from the agricultural sector, and agricultural incomes would become higher. This change in the policy would have positive consequences for the productivity of resources and GDP. In turn, the government would receive more revenues to improve further social conditions, infrastructure and the provision of domestic loans. This process should be concomitant with the development of environmental, human and economic governance.

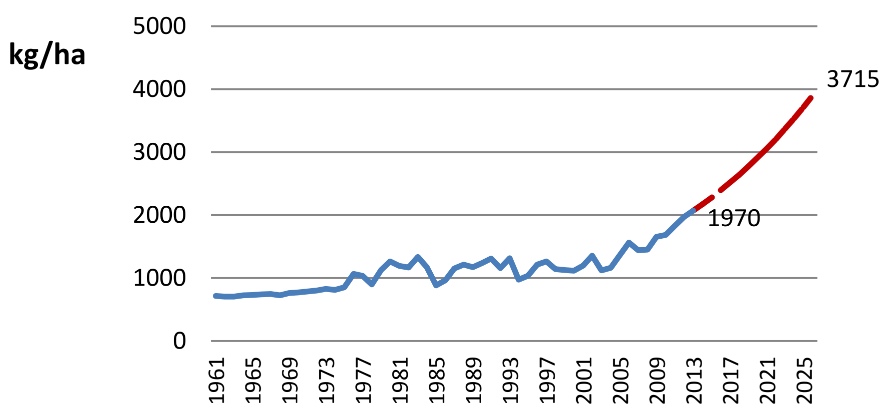
4.3.1.2 Energy

Ethiopia needs to develop its energy system for growth and adaptive capacity. The very low productivity of energy (in the row of proficient use and the column of natural resources in Figure 4-8) correlates with the similar performance of the indicator of accessibility to electricity (in the row of accessibility and the column of human resources in Figure 4-8). While the country largely depends on fossil fuels, Ethiopia recognized the importance of energy-independency and investments in renewables. The government aims to increase the percentage by 10% over the next decade. It plans to achieve 75% of electricity access in 2015, and 100% in 2030 (CIF 2012). To meet this goal, according to the CRGE (FDRE 2011b) it is required to expand electric power supply at a rate more than 14% per year. Yet, there is a gap between the costs and the paying capacity of rural population (CIF 2012a). Therefore, the provision of access to electricity in Ethiopia needs to be complemented with policies and programs to enhance agricultural productivity and increase rural income.

4.3.1.3 Institutions for Agricultural and Rural Development:

The country needs to develop a strategy for agricultural development. Targets of such strategy include increasing agricultural productivity to achieve similar standards with middle income countries. Ethiopia plans to become a middle income country in 2025 − see the next footnote (FDRE 2011b). In middle income countries, the cereal yield per hectare was 3,653 kg/ha in 2012 (World Bank 2015a). The country allocates more than 10% of the total national budget in agriculture and rural development (FDRE 2010). Nevertheless, there is room for improvements. In 2012 the cereal yield per hectare was 1,970.2 kg/ha (World Bank 2015a), comparable to the Arab World, but below the average of low income countries (1,982 kg/ha) (World Bank 2015a). The cereal yield in Ethiopia has to grow by 5.3% on average per year (see Figure 4-9).

Figure 4-9: Cereal yield for Ethiopia.



Data was obtained from World Bank (2015). Ethiopia aims middle income status[6] by 2025. For agricultural productivity, it implies raising cereal productivity from 1970 kg/ha in 2013 to 3715 by 2025.

For increased agricultural productivity the country needs to develop institutions for R+D in agriculture, and for agricultural assistance. Climate change will increase the variability of rainfall in Ethiopia (see the subsection on water resources, rainfall and precipitation, in section 4.1.1). Therefore, institutions responsible for agricultural development also need to develop the capacity in water management. Such institutions should develop varieties more resilient to rainfall variability. Rural farmers should be supported with more efficient technologies. Agricultural assistance should help rural farmers in the adoption of these technologies and more efficient agricultural practices. If the country wants to exploit the potential of agricultural production for the mitigation of GHG emissions, these institutions

[6] "World Bank classifies economies according to 2009 gross national income per capita, calculated using the World Bank Atlas method. Lower middle income starts at USD 996. This report uses GDP per capita equaling USD 1000 to define middle income. 2009 GDP per capita and gross national income per capita in Ethiopia differ by 5%" (FDRE 2011b).

for agricultural assistance should also develop the capacity for monitoring, reporting and verification of GHG emissions reductions in the sector.

As Figure 4-8 shows, the country needs to substantially increase the productivity of land and water (see the information crossing the row of proficient use of resources with the column of natural resources). Key goals for agricultural development in Ethiopia include the diversification of crops, focusing on high added value crops, and the development of the agribusiness sector: food processing industry, textiles, etc. The development of the agribusiness sector will enhance internal consumption and contribute to the development of urban areas at the same time. This will be achieved with more efficient technologies and crops with higher added value. For the development of the agricultural sector the country needs to improve the quantity and the quality of its road network (World Bank 2011). Improving roads network will facilitate the development of rural markets, the access of agricultural products to urban markets, trade and the effective provision of inputs for more efficient and more productive agriculture.

For an effective development of agriculture and for rural development, policies and programs need to involve rural communities. The *kebeles* (village community associations) are essential for this purpose. The development of human capital for the provision of basic services in rural areas, including sanitation, fresh water and electricity, constitutes an alternative for adaptive capacity. However, the kebeles need democratization and better institutions to enforce property rights and avoid the abuse of official servants.

Property rights institutions in Ethiopia are important factors framing the options for development and growth in rural areas. The actual land tenure system restricts land exchange and disincentives investments in capital assets. The institutions of land tenure were ratified in the national constitution of 1995. The government has stated that further discussion on land tenure in Ethiopia is no longer accepted (Rahmato 2004). There is a widespread yet not consensual view about the eventual benefits of giving ownership property rights to peasants. Several authors, agencies (USAID, IMF, WB), and lobby groups (e.g. the Ethiopian Economic Association) have asked the government to grant full ownership on land and create markets for land. The argument is well known: full rights on land assets will enhance the possibilities to cope with shocks. These agencies also encourage the Ethiopian government to open agriculture to private capital. Private capital would improve the productivity of land in agriculture. Liberalizing property rights would expand households' options for investments (Bluffstone et al. 2008). However, the existing institutions of land tenure in Ethiopia have also played an important role in the dynamics of migration. According to the law, a right holder who is absent of his land for prolonged periods (e.g. two years in Tigray), will lose his holdings (Rahmato 2004). This incentive to stay in rural areas has negative effects on the strategy to enhance industry and services and to reduce the role of agriculture (Rahmato 2004). Moreover, the land tenure system plays an important role in reducing inequality and poverty. Given the high variability of agriculture and GDP in Ethiopia, opening up markets for land could create extreme vulnerability to potential landless peasants, and the exacerbation of inequality in rural areas. If peasants were allowed to sell their properties, the private sector would benefit from environmental crises. They would buy land at very convenient prices and the poor would end up with no land. Indeed, several authors have pointed out that the debate about land tenure in Ethiopia has been largely politicized and ideological (Crewett et al. 2008; Rahmato 2004). Indeed, land markets exist, though not in the form that some agents would desire. There are numerous forms of land markets in Ethiopia, related to loans, sharecropping or rental (Rahmato 2004). This informal or hidden form of land markets corrects to some extent the inefficiencies provoked by the inexistence of alienation rights. In summary, thought drastic changes in the land tenure system are not foreseeable, it seems necessary to explore in more detail some adjustments to give rural farmers more flexibility to cope with the uncertainties and impacts of climate change.

4.3.2 Institutions for Climate Resilience in Ethiopia

Ethiopia has committed to develop an institutional architecture for climate resilient growth. In September 2011 the government finalized its “Climate-Resilient Green Economy” (CRGE) strategy. This is the first of its kind in Africa and was established under the leadership of the Prime Minister’s Office, the Environmental Protection Authority and the Ethiopian Development Research Institute (Nachmany, Frankhauser, et al. 2014a). In the process of developing the CRGE strategy, the Ethiopian Government, aided by the Global Green Growth Institute, designed a Climate Resilience strategy for agriculture as well as a Sectoral Reduction Mechanism (SRM) Framework, which outlines the mechanism for implementation of the CRGE (GGGI 2013). The Strategy addresses both climate change adaptation and mitigation objectives and will gradually be fully integrated into the Growth and Transformation Plan (GTP) of Ethiopia to create a green national economic growth plan (GGGI 2013). The very ambitious GTP states the objective of transforming Ethiopia in a mid-income country by 2025 based on carbon-neutral growth (Environmental Protection Authority Ethiopia 2011). To meet the aim of a green economy 150 initiatives have been identified and 60 prioritized based on their local relevance, feasibility, and significant potential for emission reduction. If all the emission reduction initiatives that have been identified were fully implemented Ethiopia would limit emissions to current levels in absolute terms and reduce per capita emissions from 1.8 to 1.1 tCO_{2e} while achieving middle-income status before 2025 (CIF 2012b). The plan covers the six sectors of energy, REDD+, agriculture, building/green city, transport and industry, supporting TC/STCs. The project also puts emphasis on knowledge transfer and capacity building of local stakeholders.

4.3.2.1 Mitigation in Agriculture and Deforestation:

Ethiopia has been active in the registration of CDM projects on GHG mitigation in electricity generation, biofuel development for road transport and household use, electricity generation from renewable energy for off-grid use and direct use of renewable energy, railway projects with trains fed with electricity generated from renewable energy and waste management (UNFCCC 2011a). However, this emphasis on GHG mitigation in energy might have taken place at the cost of neglecting necessary mitigation efforts in agriculture and forestry. Despite the overwhelming evidence about the importance of agriculture, the Climate Resilient Green Economy (CRGE) strategy seems to lack a more decisive approach to exploit the potential of agriculture and forestry for both adaptation and mitigation in the context of development.

A strategy based on synergies also requires targeting GHG mitigation from agricultural production and deforestation. Under adequate systems of incentives at the international level, and the development of the capacity of the country for monitoring, reporting and verification, mitigation in agriculture might provide valuable resources for rural development and sustainable growth in Ethiopia.

Ethiopia has registered a project to apply compost on 80,000 km^2 of agricultural land of rural local communities to increase carbon retention by the soil (UNFCCC 2011a). Another project for implementation of agro-forestry practices and systems on 261,840 km^2 of agricultural land to improve livelihoods and for carbon sequestration has been also registered. If mitigation is quantifiable and verifiable these projects could provide adequate funds for reducing the vulnerability to climate change impacts in agriculture.

There is room to reduce GHG emissions from agriculture and forestry. As of 2012, agriculture and deforestation accounted for 82% of total GHG emissions (WRI 2014). In the forestry sector, Ethiopia has the potential for reducing GHG emissions. Forestry is also an important asset in any strategy to enhance water cycles and reduce the vulnerability of agriculture. But trade-offs with agriculture exist. Business as usual, if other incentives are not provided, deforestation would continue driven by agriculture (FDRE 2011b). There is room to reduce this trade-off. Developments in agriculture have the potential to offset the demand for more land for agriculture. The potential crop production in Ethiopia reaches only 30% (Pradhan et al. 2015b).

Formulated in the Green Growth Strategy of Ethiopia's Growth and Transformation Plan, the most powerful initiative to reach its ambitious aim is the use of more efficient stoves to reduce the burning of fuel wood for cooking. According to the Environmental Protection Authority of Ethiopia this action has the potential to reduce forestry-related emissions by a rate of 50 $MtCO_{2e}$ emissions a year in 2030. In agriculture higher livestock productivity has the potential to reduce 45 $MtCO_{2e}$ emissions a year in 2030. In the industry sector the highest potentials for reducing emissions have been identified in modernizing cement production to achieve higher efficiency and in generating electric power from renewable sources (mostly hydro power) (GGGI 2013). Through the CRGE initiative the country expects to be able to attract additional investment. The country aims to leverage up to US$500 million of additional investment a year by 2025 (GGGI 2013). To implement the CRGE, SRMs will be used. Its purpose is to reduce emissions and vulnerability and build a climate-resilient green economy with zero-net growth in carbon emissions by 2025. A framework of the SRM is currently under revision (Nachmany, Frankhauser, et al. 2014a).

Ethiopia is also active in the area of REDD+: One of the projects in the Great Rift Valley is the Africa's first large-scale CDM project in forestry. The development of a CDM for fuel-efficient stoves is in progress, as well as studies to devise a similar mechanism to support the reduction of emissions from livestock (CIF 2012b).

4.4 Conclusions

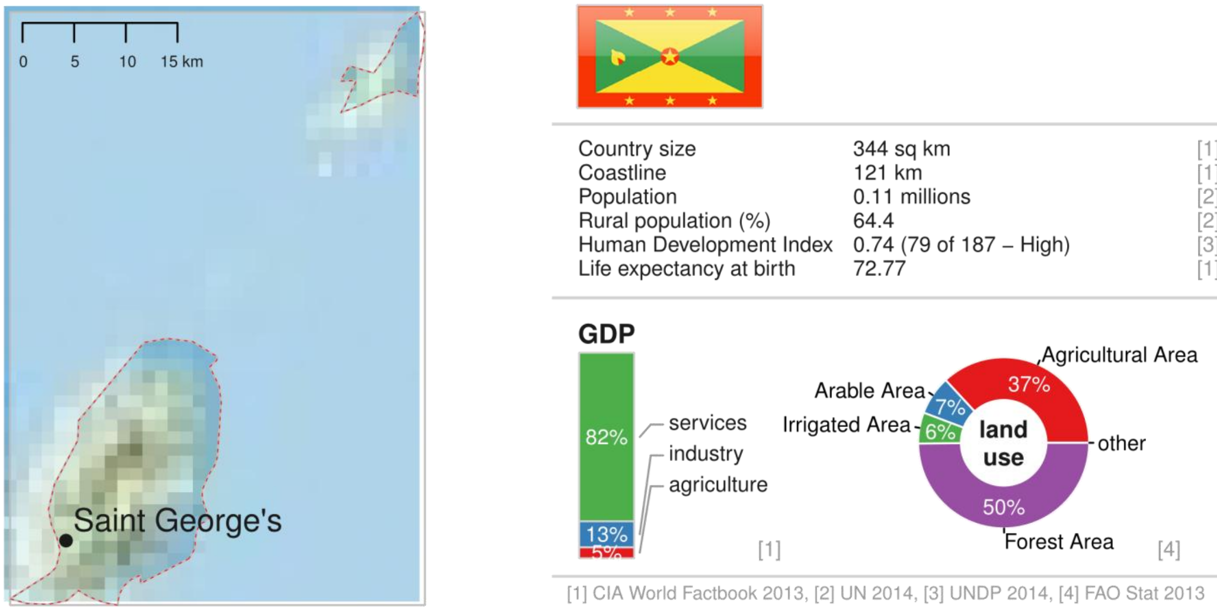
Ethiopia has developed an institutional architecture for climate resilient growth. High and constant investments in capital formation make evident the commitment of the government to increasing adaptive capacity. In 2013 the government created the ministry of forestry, as part of the strategy to make Ethiopia an attractive country for mitigation in the future, for enhancing water cycles and protecting biodiversity.

For developing the capacity to implement synergies, the country needs to develop further its adaptive capacity. In turn, for a suitable adaptive capacity Ethiopia will need further economic growth. Moreover, the country faces important challenges in all fronts. The country needs the development of infrastructure and technologies improving the accessibility to natural resources. Closing the big gap in the provision of basic services in rural and urban areas, education, health, and food security is also mandatory. The country should improve its banking system. By doing so these structures enhance the accessibility to natural resources, knowledge and financial resources will therefore create adequate conditions for the specialization and the diversification of the economy. Ethiopia should also define further incentives for the development of industry and services. For growth of the urban economy the country needs to promote the private sector. The financial capacity of Ethiopia to cope with financial shocks and for growth is restricted, i.e. by the preponderant role of the government and its policy to utilize financial resources.

The improvement of agriculture and rural development are cornerstones for any strategy for growth in Ethiopia. This comprises in particular the establishment and the further development of rural institutions. The kebeles are the key factor for the development of agriculture, the provision of basic services, for mitigation in agriculture, the protection and expansion of forests, the development of REDD+, education and disaster risk management. However, the kebeles still need democratization. It is also required the enhancement of the capacity of the justice to enforce land tenure rights to avoid the abuse of officials. For the reduction of vulnerability of agriculture Ethiopia should improve its capacity in forestry and water management. International assistance can support Ethiopia in the development of its capacity in resources protection, REDD+ and mitigation in agriculture.

5. GRENADA

Figure 5-1: Grenada – Factsheet and physical map:



5.1 Sensitivity and Vulnerability

5.1.1 Sensitivity and Vulnerability of Natural Resources

Grenada is among the countries lacking detailed studies of climate change projections. To compensate this deficit the UNDP developed the Climate Change Country Profiles. For the case of Grenada this report mostly relies on this information. Climate change projections for Grenada were simulated considering A2, A1B, and B1 SRES emissions scenarios for 2030, 2060 and 2090 (McSweeney et al. 2010b).

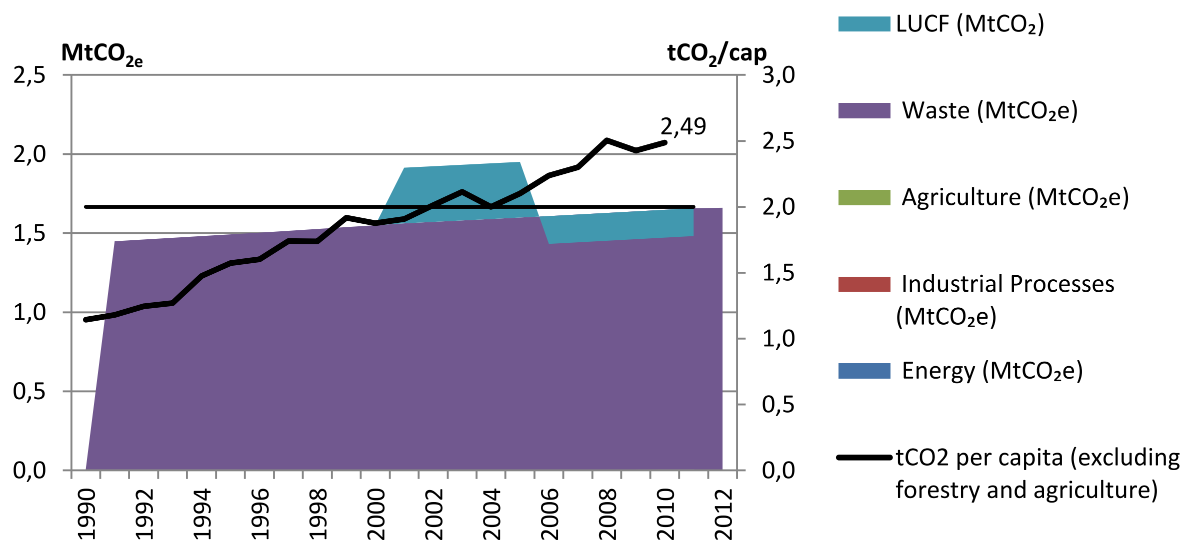
Temperature: Mean annual temperature has increased by 0.6°C since 1960. An increasing rate of around 0.14°C in all seasons per decade is observed (McSweeney et al. 2010b). The mean annual temperature is projected to increase by 0.6 to 2.7°C by 2060, and 1.2 to 4.5°C by 2090. Using A1B as forcing scenario a 1.8°C to 2.3°C median annual increase in surface temperature in the Caribbean Sea small islands regions can be estimated by 2100 (1980–1999 baseline) (Nurse et al. 2014). The projected rate of warming is similar in all seasons, but more rapid in the island's northeast (McSweeney et al. 2010b).

Water resources, rainfall and precipitation: A reduction in rainfall of 0.18 mm/yr is showed in the rainfall records averaged over the Caribbean region for 100 years (1900–2000). This trend is projected to continue. Mean rainfall in Grenada has increased in September, October and November (SON) by 12.0 mm per month since 1960 (6.3% per decade). However, this increase is not statistically significant (McSweeney et al. 2010b). This increase is compensated partially by decreases of around 4.5mm per month (2.5%) per decade in the months of June, July and August (McSweeney et al. 2010b). Using A1B as forcing scenario an overall annual decrease in precipitation of about 12% in the Caribbean small islands regions by 2100 compared to the 1980–1999 baseline (Nurse et al. 2014).

Sea Level Rise: The mean rate of SLR in the Caribbean region over the last 60 years was similar to the global average of approximately 1.8 mm/yr (Palanisamy et al. 2012). Using RCP4.5 as forcing scenario (Church et al. 2013), SLR ranging from 0.5 to 0.6m by 2100 are expected (1986–2005 reference years). Sea-level is expected to rise by 0.13 to 0.56m until the end of the 21st century. As a result of sea level rise saltwater intrusion will reduce the availability of groundwater. An increase in the sea level of half a meter would destroy up to 83% of beaches (Rothenberger 2014).

Atmosphere: Total GHG emissions of Grenada are insignificant compared to developed countries. The main source of GHG emissions is waste. CO_2 emissions per capita are above the emissions targets to keep temperature below 2°C under the fair burden constrains (WBGU 2009a). Since, the country is threatened by the devastating impacts of hurricanes and weather extremes that often hit the island; the disaster risk management is perceived to be more crucial than mitigation of greenhouse gases.

Figure 5-2: GHG sectoral emissions and energy per capita of Grenada.



Emissions from energy are not reported. Emissions from agriculture (0.01 Mt CO_{2e} constant), were not included. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agriculture (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from energy and transport have not been reported by the country. Emissions from agriculture are only 0.01 $MtCO_{2e}$ and were not included. Emissions from energy and transfort are not available in the WRI database. However, emissions per capita from the combustion of fossil fuels (black bold line, 2.49 tCO_2/cap in 2010) reveal high consumption of fossil fuels in transport and energy. The population of Grenada is only 106 thousand inhabitants. Overall, emissions of Grenada are insignificant and do not offer substantial potential for mitigation in the analysis of synergies.

Land Use and Forestry: Grenada has kept its forests area constant over the last 20 years, even though only 14% are primary forests (FAO 2014b). Forests cover 50% of total land area (FAO 2014b). Agricultural growth has not occurred at the expense of deforestation. Indeed, land productivity in agriculture in Grenada is the highest for the countries analyzed in this report;

a trend that is constantly increasing. However, forests are also exposed to extreme weather events (such as hurricane Ivan) that hit the country in the past.

5.1.2 Economic Vulnerability

Grenada has been severely affected by the impacts of hurricanes. After hurricane Ivan in 2004 and Emily in 2005 economic losses of the country are twice its GDP (WB 2009). In addition, heavy rains frequently hit the island. High losses in agriculture caused by droughts and floods (Undesa 2012). Flash flooding and storm events are the primary origin of flood events (GoG, 2012a). The costs caused by Hurricanes Ivan (2004) and Emily (2005) have exceeded by far the financial coping capacity of the country. According to the World Bank, "the financial costs of these disasters were estimated to be more than US$ 900 million. The hurricane damaged more than 80 percent of the country's building structures, and only two of the 75 public schools remained undamaged" (WB 2009).

Sectoral impacts: Tourism is the main source of national income (World Bank 2015a) and will be affected from sea level rise and weather disasters. Services contribute 79.19% to GDP, industry 15.2 and agriculture 5.61% (World Bank 2015a). As of 2008, with regard to population income, the services sector contribution to the GDP was 69% while agriculture sector contribution was 11% (WFB 2015).

Economic diversification and specialization: Less diversified and specialized economies will be more vulnerable to changes in prices and trade conditions. The higher the specialization and the diversification are the better the coping capacity. As of 2013 exports accounted for 21.9% of GDP (WFB 2015). However, six commodities accounted for 82.75% of total exports value in 2012, namely: nutmeg, cocoa beans, non-fillet fresh fish, wheat flours, toilet paper and scrap iron (Simoes and Hidalgo 2014). Impacts of weather and climate related events on agriculture production and their export will pronounce significant economic losses.

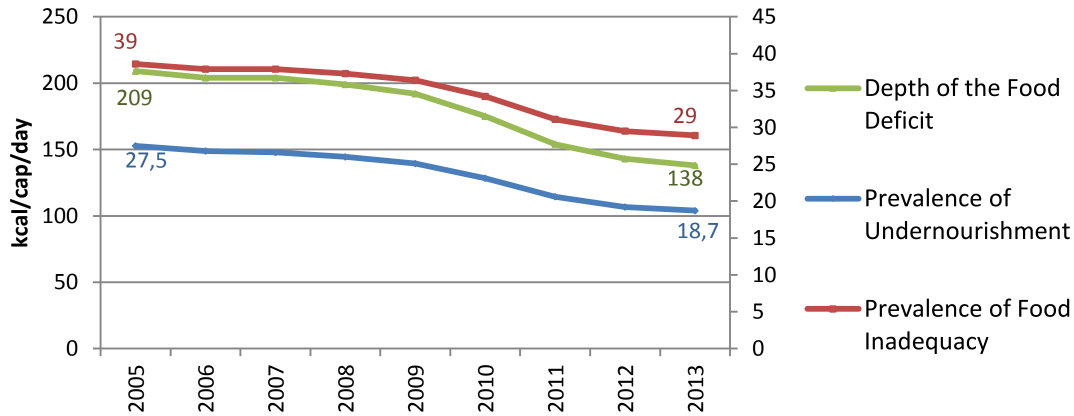
Capital formation: High investments in gross fixed capital formation would inform about the commitment to enhance basic infrastructure for adaptive capacity. Currently, the public debt amounts to 110% the GDP (WFB 2015). It was caused by hurricane related damages in 2004 and 2005. In March 2013 the government stopped making payments to private creditors (Kaiser and Jones 2013). With such a burden the government has jeopardized the investments in socio-economic development and in disasters prevention (WFB 2015). Nevertheless, the domestic credit provided by banking has steadily increased in Grenada from 57.9% in 2003 to 75% in 2012 (World Bank 2015a). Unfortunately information about the development of capital and income distribution is missing.

Economic Risks and Uncertainties: Indicators for governance of financial risks show how risk prone a country is. In Grenada inflation has not been higher than 4.35% over the last ten years, but economic turbulences produced by weather hazards have caused deflation (World Bank 2015a). In the ease of doing business index (World Bank 2015a) which evaluates the environment facilitating development of business associated to transaction costs, the country was ranked 107 in 2013 (World Bank 2015a). The value of the country risk index (Euromoney 2014) which evaluates structural, political and economic risk (19.44 as of 2013) places Grenada in third decile relative to the rest of the world. These numbers reflect the fact that risk pooling institutions are not well developed in small islands (Heger et al., 2008). Overall, the indicators above show a vulnerable economy constrained by high debt, depending on tourism and agriculture exposed to considerable damages from weather events. Extreme weather impacts are evidently the most important challenge to cope with in Grenada.

5.1.3 Social Vulnerability

38% of the Grenadian population lived below the poverty line in 2008 (WFB 2015). As shown in Figure 5-3 indicators of food security show a gradual recovery of food consumption from the values reached after the impacts of hurricanes Ivan (2004) and Emily (2005).

Figure 5-3: Recent evolution of some indicators of food security of Grenada.



After the effects of hurricanes in 2005 and 2006 the country has achieve to reduce the depth of food deficit, undernourishment and prevalence of food inadequacy. Data from (FAO 2014b).

Food security: According to the FAO the prevalence of undernourishment was 18.7% in 2012, after a steady decrease from 30.7% in 1999. However, food deficit is high compared to the rest of the Antilles. In 2012 this deficit was 138 kcal per person per day. This is 7.3% of the minimum energy requirements (1,890 kcal per person per day). In addition 28.9% of the population suffers from food inadequacy. It includes people undernourished (FAO 2014b).

Health, Sanitation, Water and Energy Services: According to the World Bank (2015a) health expenditures are low and decreased from 3.03% of GDP in 2003 to 2.97% in 2012. This is below the average in Latin America and the Caribbean (7.7% in 2012). The access to fresh water reached 96.8% of total population in 2012. Access to sanitation reached 98% of the population in 2012. Health has been a major concern in Grenada, but mostly related to its capacity to cope with disasters (Undesa 2012). Adaptation plans focus on reinforcing health infrastructure and securing energy supply during hurricanes (Undesa 2012).

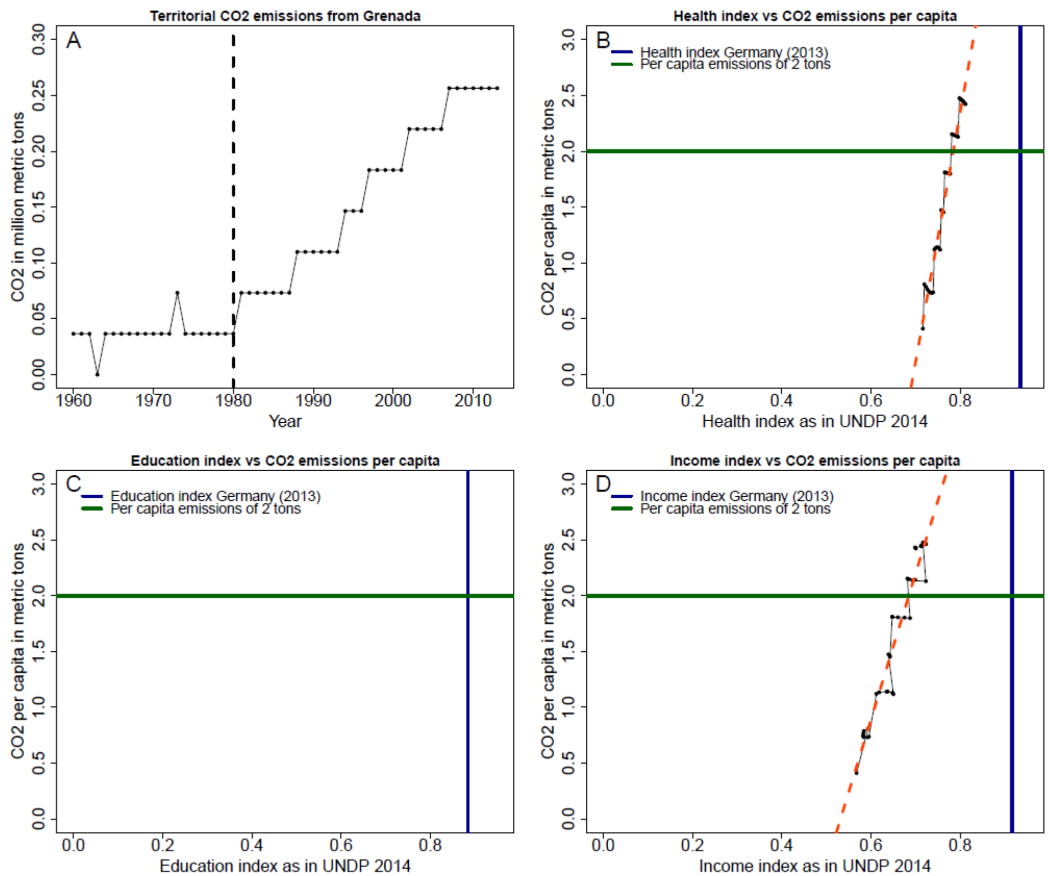
Education: Investments in education are very low in Grenada. Between 2003 and 2012 the % of GNI invested in education has been 3.72% (World Bank 2015a). The pupil teacher ratio amounts to 20.3 for primary (2012) and to 14 for secondary education (2014).

5.2 Links between Adaptation, Development and Mitigation

5.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from fossil fuel combustion in Grenada showed an increase of about 0.05 to 0.25 $MtCO_2$ between 1960 and 2013 respectively (Figure 5-4). A particularly sharp tendency of higher emissions has been noted since 1980, although the emissions data refer to estimated values for many of the years investigated (hence the step-like evolution of emissions). On a per-capita basis, CO_2 emissions in Grenada have increased from 0.5 to 2.5 tons per capita between 1960 and 2013 (Figure 5-4B) following a similar trend of the total emissions. Per-capita emissions currently amounts to 2,5 tCO_2.

Figure 5-4: Trends of CO_2 emissions and the HDI in Grenada.



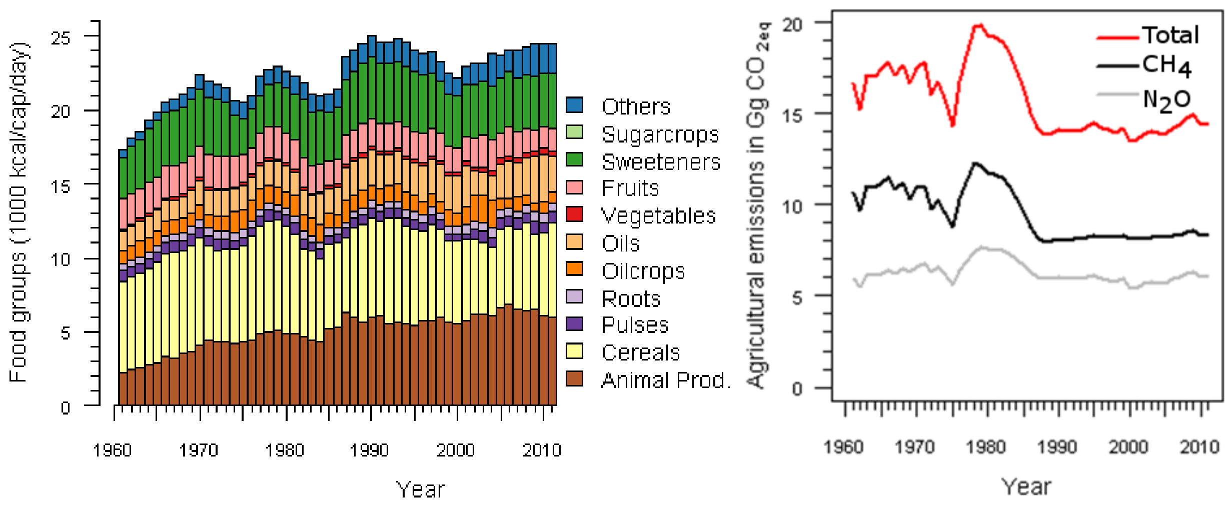
Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. Data for education in figure C was not found. Horizontal green line shows the 2t CO_2/cap target (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Dashed vertical line indicates the starting period of analysis for the panels B, C and D. The stepped trend of emissions might be due to information collected every four years. Elements of human development assessed in the HDI are coupled to emissions per capita in Grenada. CO_2 emissions in Grenada are very low.

The relation between the different components of human development and per capita emissions in Grenada is a positive one for the health and income components (Figure 5-4B and D), while for the education component the lack of data does not allow an analysis. The progress in health standards in the last 30 years has been positive, but slow when compared with the progress made by other countries, e.g. Cambodia and Ethiopia. For the case of the health index, Grenada is only about 0.15 below the index recorded in Germany. For the income index this difference is larger (Figure 5-4B and D).

5.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 5-5 (left) presents the evolution of dietary patterns in Grenada between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, Grenada's total food supply has increased from 1,730 kcal/cap/day in 1961 to about 2,400 kcal/cap/day in 2011. During these five decades the amount of cereals supply per person per day was constant at around 630 kcal whereas per capita supplies of sweeteners and oils have increased by 100 kcal/day. However, per person animal product supply has almost tripled to 600 kcal per day. Furthermore, inter-annual variability in supplies of total calories and the different food groups has been observed in Grenada in the last five decades. However, total calorie supply has continuously increased in the country since 2000. This depicts the increasing food availability in Grenada and lifestyle shifts towards calorie and meat rich diets. The total agricultural emissions of Grenada have decreased from 17 Gg CO_{2e}/yr to 14 Gg CO_2e/yr in the last 50 years as shown in Figure 5-5.

Figure 5-5: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Grenada.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (in CO_{2e}), including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Colombia during the last fifty years. Food supply in Grenada has not changed much in the recent decade, and is below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has also decreased in the recent decades. The data was obtained from FAOSTAT (FAO 2014).

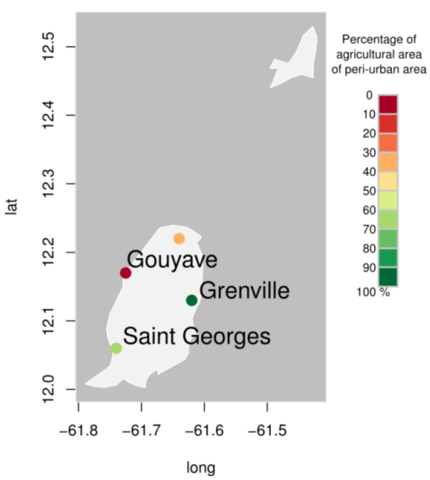
The agricultural emissions of Grenada peaked in 1979 to around 20 Gg CO_{2e}/yr. Then the emissions rapidly decreased to 14 GgCO_{2e}/yr till 1990 and stagnated afterwards. Since

Grenada is an island country depending on food import to meet its food demand (Pradhan et al. 2015a), the changes in agricultural emissions may reflect increase agricultural trade dependency of the country. Furthermore, diets currently consumed in Grenada embodied emissions of about 1.6 tCO_{2e}/cap/yr (Pradhan et al. 2013). Dietary patterns in Grenada may increasingly be calorie and meat rich when the country becomes more developed in the future, resulting in larger volume of food imports and associated emissions.

5.2.3 Potential of Peri-Urban Agriculture and Local Food

35 % of 106.000 people in Grenada live in cities and a future urbanization to 44% will take place until 2050 (United Nations 2014). Four cities were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 5-6). Due to missing yield data it is not possible to compute how many people can be fed by peri-urban agriculture, but the availability of agricultural land near to cities is mandatory (Kriewald et al. 2015). The surroundings of Grenville and Saint Georges consist of 91% resp. 69% agricultural area and could be used as case-study areas.

Figure 5-6: Availability of agricultural areas near to cities in Grenada.



The best possibility to minimise environmental trade-offs due to agriculture is by closing the yield gap, which will lead to high productivity of peri-urban agriculture. However, changing climate and especially changing diets can reduce environmental trade-offs.

5.3 The Potential for Synergies and the Stage of Country Development

Overall, the assessment of the coping capacity and vulnerability shows that the country is highly vulnerable to environmental impacts, with severe financial constraints and high risk. Emissions per capita are growing in Grenada, but reliable information on actual trends of emissions from energy and transport is not available. Emissions per capita by 2010 were high (2.5 tCO_2/year) compared to other countries like Colombia (1.63) or Brazil (2.15). Deforestation has been stopped and the coverage of forests is half of total land area. Emissions of 0.01 $MtCO_{2e}$ in agriculture are insignificant compared to emissions from agriculture in other countries (e.g. 11.33 $MtCO_{2e}$ in Nicaragua) by 2011 (WRI 2014). The mitigation potential of Grenada might be insignificant based on information available (see Figure 5-2). The potential for mitigation would be unfeasible to realize due to more important urgencies to attend, regarding the high debt burden and the costs of weather related disasters hitting the island frequently. In this context, for Grenada the transformation of trade-offs into synergies refer more to the needs and opportunities for coping more effectively with the impacts of weather related impacts. Actual trade-offs affecting Grenada include the debt burden and the consequences of weather related impacts, affecting growth and development.

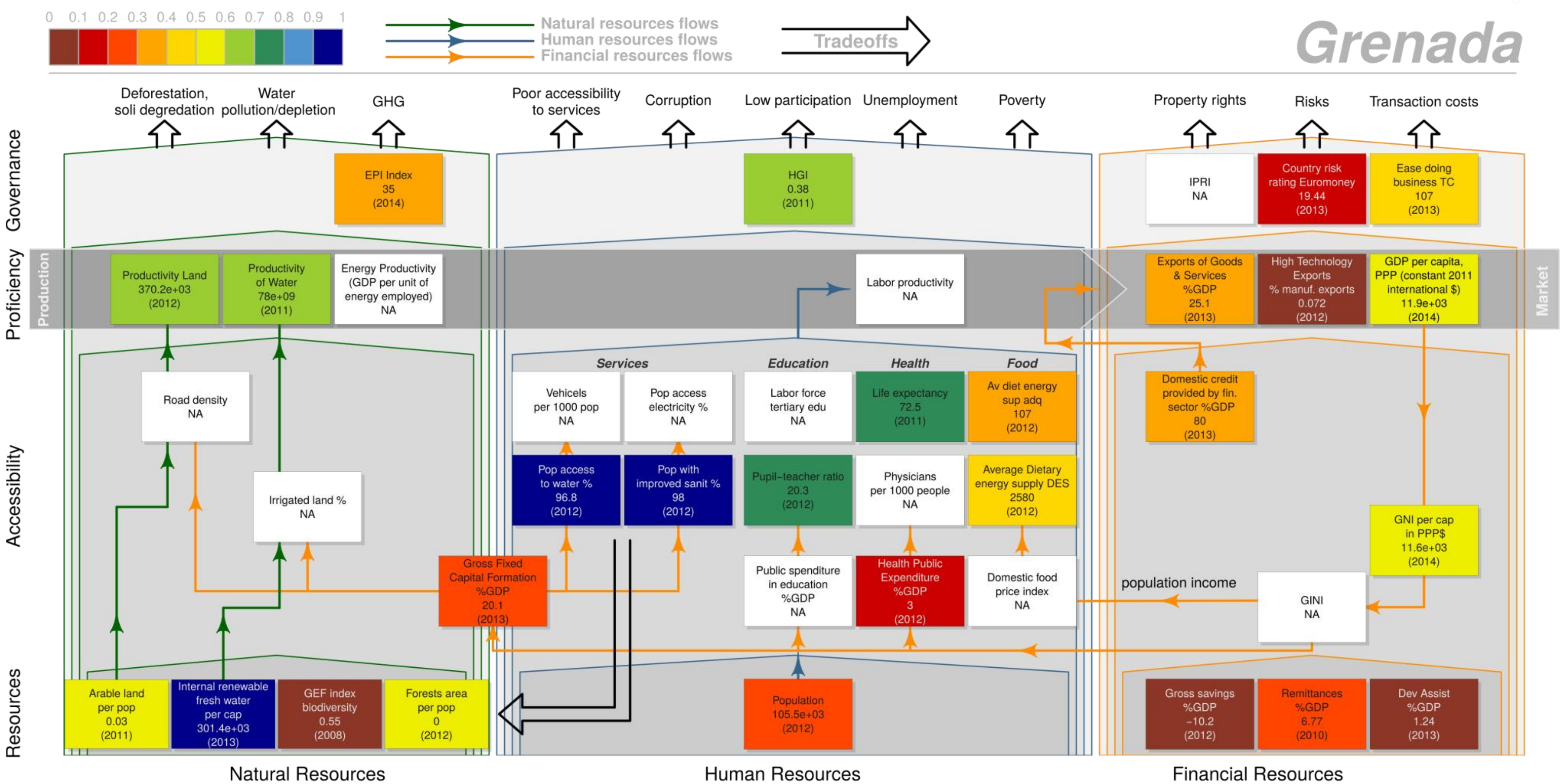
5.3.1 Adaptive Capacity and Disaster Risk Management:

As Figure 5-7 shows, the country is wealthy in renewable fresh water resources per capita, but other natural resources are scarce. Indicators of proficiency in the use of natural resources show that the country has developed its capacity to use water and land resources efficiently. On these issues Grenada outperforms with respect to the rest of countries of this study. The country is very small in size (approx. 1/3 of Berlin's area). As it holds for most of the island countries it is presumably adequately well-endowed with road infrastructure, although for the actual case no data were available. Apart from this road infrastructure is permanently affected by flood flashes (GoG 2014). But the country performs low in the environmental part of the EPI index, showing deficiencies in the institutional architecture in charge of environmental protection.

The economy relies mostly on tourism, agriculture, fishery and exports of some commodities (see subsection on economic diversification in section 5.1.2). The share of GDP from exports is low relative to the rest of the world, but relatively high when compared to other countries of this study –except Vietnam. However, the share of high technology exports in Grenada is very low. The GNI per capita is low with respect to the world, but high when compared to other countries in this study. There is no information of income inequality, but the high score in the indicators of human governance would indicate low inequality. Life expectancy is high and the pupil teacher ratio in primary school is high. Overall these indicators show a clear commitment of the government in social development despite the difficulties. Indeed, for all the indicators composing the human governance index of the World Bank the country performs positive, namely: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption, as of 2013 (World Bank 2015b).

While the indicators for human governance are high, the indicators of governance of financial resources show low performance, i.e. in the control of structural risk (as proxy the country risk index). The performance is middle in terms of transaction costs using the ease doing business as proxy. Available indicators of the economic coping capacity show that the accessibility to financial resources is constrained by low GDP and very low GNI per capita. The financial sector provides 80% of GDP for domestic credit. This is high compared to other countries studied. Overall, these indicators of economic capacity show the need to enhance financial governance. For developoing the economic capcity it is needed more economic diversification. Nevertheless, options to enhance this capacity are limited due to the high debt. Despite the positive signs in many indicators undernourishment in Grenada reached 18.7% of the population by 2012 (FAO 2015).

Figure 5-7: Indicators of the adaptive capacity of Grenada.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. The country performs high in the productivity of land and water resources, but the economy is lowly specialized (performance in high tech manufactured exports is very low). For climate resilient pathways the country needs develop its environmental and economic governance.

By 2000 the country was already not food self-sufficient (Pradhan et al. 2015). As indicators of food in Figure 5-7 show the margin for food surplus is low (only 7% in the indicator of average diet energy supply adequacy).

The country prepares a national plan for adaptation since 2011 (GoG 2012b), supported by international donors. The current version of the national adaptation strategy has identified the following priorities for investments: Disaster vulnerability and climate risk reduction, forest rehabilitation, water resources assessment and management study, roadmap for coastal zone management, improving the use of data & GIS for climate change adaptation, and preparation of a project for rehabilitation of bathway sandstone reef (GoG 2012b).

It is argued that these front lines for adaptation could be better tackled by reforming the institutional architecture. A new design is needed in order to redefine strategic priorities and to improve coordination. According to Wuttge (2012), “Whilst Grenada has developed many policies and strategies over the years relating to adaptation there remain substantial gaps and challenges in a strategic approach to adaptation, implementation of measures and coordination across sectors and scale". The country lacks financial resources needed for the development of monitoring and warning systems, for planning infrastructure and management of water resources and for coordinating action among sectors and communities. So far, neither the plans for adapting to climate change, nor plans and actions for DRM have worked as desired, due to the scarcity of financial and human resources (GoG 2012b).

A consequence of the actual institutional architecture is the responsive nature of the National Disaster Management Agency (GoG 2014). The existing 17 District Disaster Committees have been organized along electoral boundary lines, and not along watershed and basins (GoG 2014). As the government reported (Roberts 2013), despite the recognition of the importance of DRM and adaptation to climate change, the current capacity of the country is far below the challenge posed. The traditional institutional architecture of ministries is designed around activities (i.e. industry, agriculture, tourism), and productive factors (i.e. labor, infrastructure, energy, or finance). Within this design other factors are important but their institutions have less power (Ministry of education, health, housing, social security, or environment). Water issues are not taken over by a specific institution (GoG 2015).

Water related events should gain priority in adaptation in Grenada, at all fronts: water management, hurricanes, flash flood and sea level rise. The country is burdened by an overwhelming vulnerability to weather extremes. Sea level rise is a real threat and the population of Grenada has already experienced it (Wuttge 2012). However, Grenada is even more severely affected by weather and water extremes inland. Hence, synergies in Grenada are about disaster risk management related to water, in the context of adaptation and development. The country requires actions for the development of the adaptive capacity in terms of social and economic conditions and an institutional architecture suited for coping with weather and water related events.

The country has advanced some studies on water management. It provides a basis, for a new institutional architecture. Institutions include the National Water and Sewerage Authority (NAWASA), which is responsible for water quality. Water issues have been addressed under the Strategic Program for Climate Resilience SPCR (GoG 2012b), which emphasizes studies and development of capacity in water governance. In addition, a national water policy incorporating Integrated Water Resource Management principles has been prepared. A multi-sectoral Cabinet-appointed steering committee, chaired by the Permanent Secretary in the Ministry of Agriculture, Lands, Forestry and Fisheries, was set up to manage the drafting of the policy in 2007. Along with the water policy, a water sector review and a framework for water policy implementation has been prepared. In February 2008, a review of the legislation on the water sector was completed.

The development of plans and projects could be more effectively tackled if water governance is institutionalized at the highest possible level. Such institutional embedding requires the participation of the entire society. Fortunately, as the indicators of human governance show, the government enjoys sufficient recognition to lead this process. The country is quite small to organize their population via a consultation process. Politicians should lead this process and be ready to adapt to changes. A new institutional architecture should consider the watersheds as the basic feature for organization. Watersheds based institutions would decide water uses –consumption, agriculture, forestry, energy, industry and services. They should also establish the boundaries for the construction of infrastructure and management for the provision of improved water for human consumption and sanitation.

5.4 Conclusions

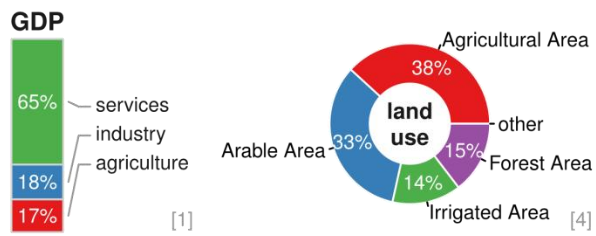
Mitigation has little potential in Grenada. The country is burdened mostly by a high debt, originated by the adverse consequences of hurricanes in 2005 and 2006. The country constantly suffers from losses caused by flash flood. Grenada is further constrained by the low capacity of the government to coordinate actions in disaster risk management.

Grenada could improve its capacity for coping with weather disasters by developing an institutional architecture that suits to the geographical conditions of watersheds. A new organization would help Grenada to coordinate efforts in disaster risk management. It would also help the country to use more effectively its institutional capacity constrained by scarce human capital. A new institutional architecture would help Grenada to integrate government action with the community.

6. INDIA

Figure 6-1: India – Factsheet and physical map:

Country size	3,287,263 sq km	[1]
Coastline	7,000 km	[1]
Population	1267.4 millions	[2]
Rural population (%)	67.6	[2]
Human Development Index	0.59 (135 of 187 – Medium)	[3]
Life expectancy at birth	66.41	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

6.1 Sensitivity and Vulnerability

6.1.1 Sensitivity and Vulnerability of Natural Resources

Temperature: For climate change projections on temperature and rainfall, we rely on recent simulations based on the Representative Concentration Pathways (RCP). In contradiction to other countries these most recent scenarios are available for India. In a preliminary assessment projected temperature increases ranges between 1 and 8°C by 2099 (1860-1990 reference). This range decreases to 0.5-7°C when as reference period 1960-1990 is taken (Chaturvedi et al. 2012). The last range is comparable to other projections based on the Coupled Model Inter-Comparison Project 3 (CMIP3) (Kumar et al. 2011), which provided a range between 2 and 6°C for the same reference period. Under the RCP2.6 scenario the mean temperature increases by approximately 2°C for the period 2070-2099 (based on the 1860-1990 reference). For the RCP8.5 scenario, the increase amounts to 4.8°C (Chaturvedi et al. 2012). For the case of moderate scenarios, i.e. RCP4.5 and RCP6.0, the increase ranges between 2.9°C and 3.3°C (Chaturvedi et al. 2012). A warmer climate will change the temperature regime in the west and southern coast (World Bank 2013a).

Water resources, rainfall and precipitation: For precipitation the projections show a larger uncertainty for all the scenarios ranging from -20% decrease up to 60% increase by 2099 (Chaturvedi et al. 2012). Inter-annual and intra-seasonal variability of monsoon rains is expected to increase (World Bank 2013a). Projections for the mean precipitation in India show an increase of 7% for RCP2.6, 9.4% for RCP4.5, 9.4% for RCP6.0, and 18.7% for RCP8.5 scenarios by 2099 (1961–1990 baseline) (Chaturvedi et al. 2012). For a 4°C global warming threshold an increased precipitation of 10% in annual mean monsoon intensity and 15% increase in year to year variability is expected (World Bank 2013a). Accordingly, an extreme wet monsoon currently occurring every 100 years will occur every ten years (World Bank 2013a).

Higher uncertainties in precipitation are indicative of increased number of droughts, mostly impacting the North-Western (World Bank 2013a). Many regions in India are characterized by water scarcity, especially during summers. The rapidly growing population coupled with urbanization, agricultural intensification and climate change contribute to a greater competition for scarce water resources. The total water consumption in India is expected to rise by 20–40% in the next 20 years (UNFCCC 2012). 20% of households still have no provision of adequate water for domestic use. The per capita availability of water was 5,177 m^3/capita/year in 1951. This value has dropped to 1,654 m^3/capita/year in 2007 and is likely to go further down below 1,140 m^3/year by 2050. The utilization of groundwater for irrigated agriculture, changes in cropping patterns and achievement of national targets of food production will increase manifold and will lead to an overexploitation (UNFCCC 2012) (refer to section 6.2). Changes in water availability and supply also affects sanitation and drainage systems leading to overloading causing floods (UNFCCC 2012).

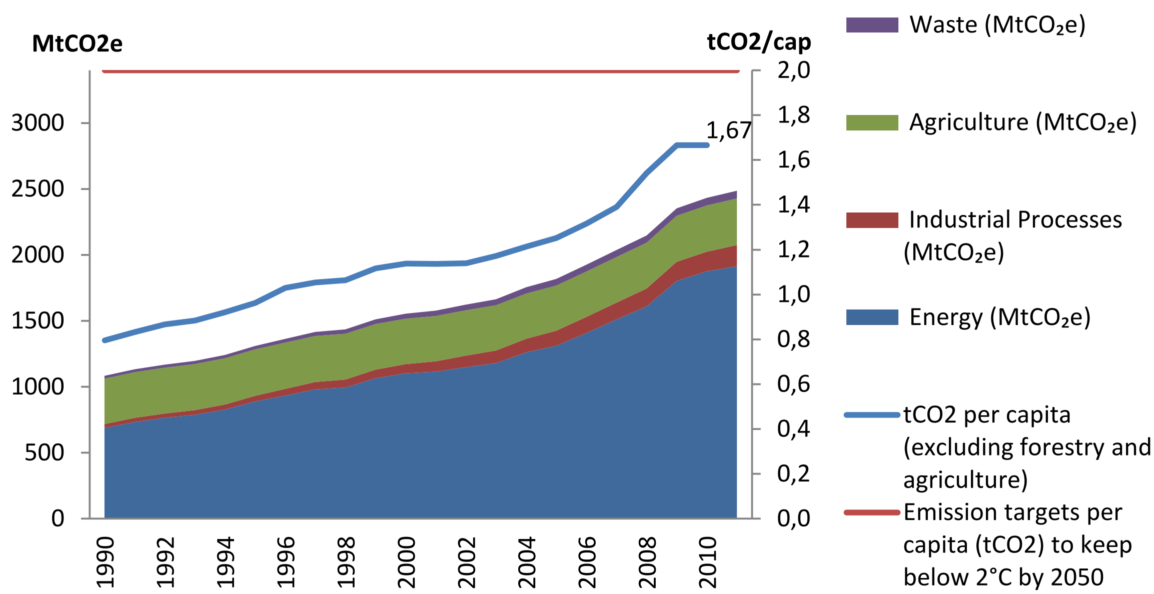
Sea level rise: The projected trends of mean sea level rise for the current century vary depending on the scenario, but are about 4 mm/year on an average (UNFCCC 2012). The most vulnerable stretches along the western Indian coast are Khambat and Kutch in Gujarat, Mumbai and parts of the Konkan coast and south Kerala (UNFCCC 2012). Estimated sea level rise by 3.5 to 34.6 inches between 1990 and 2100 would result in saline coastal groundwater endangering wetlands and inundating valuable land and coastal communities (UNFCCC 2012). The deltas of the Ganga, Krishna, Godavari, Cauvery, and Mahanadi on the East Coast may be threatened along with irrigated land and a number of urban and other settlements that are situated along them (UNFCCC 2012).

Crop yields: Wheat growth is sensitive to temperatures greater than 34°C (Lobell, Schlenker, and Costa-Roberts 2011). Drought and extreme rainfall negatively affected rice yield in predominantly rain-fed areas during 1966–2002 with drought having a much greater impact than extreme rainfall (Auffhammer et al. 2012). Heat stress risks in large suitable cropping areas in India are projected (Teixeira et al. 2013). India accounts for nearly 67% of the total rice production of South Asia (FAO 2013a). Under the climatic conditions before 1960 the India kharif rice yield would have been 8.4% bigger in comparison to 1969–2007 (Pattanayak and Kumar 2014). The C4 millet cultivar will be impacted by increasing temperatures in the 2020-49 and the end of the century (2070-2099) (Berg et al. 2013). The overall decrease of the productivity of the C4 millet will be 6%, with a range between -29 and 11% by the 2080s (World Bank 2013a).

Land Use and Forestry: From simulations forcing a A1B scenario it has been concluded that India has the potential to further increase forests cover (UNFCCC 2012), in particular, in eastern India, Western Ghats and Western parts of India. The vulnerability of forests in India stems more from fragmentation and density, rather than from human interventions (UNFCCC 2012). Only 8.35 Mha are very dense forest. More than 20Mha of forests are monoculture and more than 28.8 Mha are fragmented and have low density (UNFCCC 2012). Most of the land in India is used for agriculture (60%) (FAO 2010b). This percentage was kept constant over the last 20 years. In addition, forest areas have even grown over the same period, from 21% to 23% of the land area of India (FAO 2010b).

Atmosphere: In Copenhagen 2009 India pledged to reduce its GDP's emission intensity by 20-25% by 2020 (excluding agriculture) compared to 2005 levels. India proposed this in an official NAMA, but explicitly voluntary and without legally binding character (UNFCCC 2011a). The government projects overall emissions of 3,500-4,000 $MtCO_{2e}$. The National Action Plan on Climate Change (NAPCC) aims for an electricity production share of renewable energy sources of 15% by 2020 and expanding forest cover from 23 to 33% by 2020 (Nachmany, Frankhauser, et al. 2014a). The country is likely to meet the pledged targets with current policies (CAT 2015). On the opposite expected emissions from 11 energy fuel mix scenarios up to the year 2031 forecasted by the Planning Commission of India have been examined and the results reveal that none of the 11 energy scenarios would help India meet its emissions target if they like to follow the 2 °C pathway (Singh 2011). As Figure 6-2 makes it evident, energy and transport are by far the major source of GHG emissions in India. As of 2011 these sectors represented 77% of total emissions excluding net sinks from forestry.

Figure 6-2: GHG sectoral emissions and energy per capita emissions in India.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production. Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. According to the share of emissions, most relevant sectors for the analysis of synergies are energy –including transport, and agriculture.

The OECD calculated the international assistance having climate change mitigation as a principal or significant objective at US$ 2.9 billion (US$ 2.34 per capita) (OECD 2014a). As of March 2014, India has also hosted 1480 registered CDM projects. Hence, India accounts for nearly 20 per cent of all CDM projects, second only to China (3743, ~50%). Energy security is a significant issue: the country is highly dependent on imports, with 28% (213 Mtoe) of its energy supply based on traded energy sources (mostly crude oil). Additionally, it suffers from frequent electricity shortages and blackouts. The grid-system is often over-stretched and not able to meet electricity demand. India's total energy supply is mostly through fossil-fuel as is its electricity generation, both mainly supplied by coal and oil. Renewable energy sources are currently being scaled up, but accounted for only 17 per cent of total electricity production in 2011 (hydro 12%, biofuels 3% and wind 2%) (IEA 2015).

6.1.2 Economic Vulnerability

Sectoral impacts: The GNI per capita of India is among the lowest in the world (World Bank 2015a). Agriculture is more sensitive to variables affected by climate change: water rainfall and temperature. The large share of population living from agricultural production makes the economy very vulnerable to impacts from sea level rise, higher temperatures, and changes in precipitation. 49% of the population derives income from agriculture (WFB 2015), though the share of GDP from agriculture was only 18.2% by 2013 (World Bank 2015a). According to Jacoby et al. (2014), three decades of warming will reduce agricultural productivity in the range of 7%–13%, with the arid northwest of India especially hit. According to (Pattanayak and Kumar 2014), it is required to compensate the impacts of climate change in agriculture with irrigation facilities for wheat, arhar, rice and millet crops.

Productive Factors: According to Patnaik and Pundit (2014) policy uncertainty plays a role affecting the economic productivity of the country. However, India is currently characterized by high commitment in the development of infrastructure. Labor force with tertiary education was very low (9.8%) by 2010 compared to other countries of this study (e.g. Brazil 17.2%, Colombia 22% (World Bank 2015a). Labor productivity is very low relative to the rest of the world (World Bank 2015a). Therefore, India needs to improve stability and labor productivity for increasing its capacity to cope with shocks affecting economic activities.

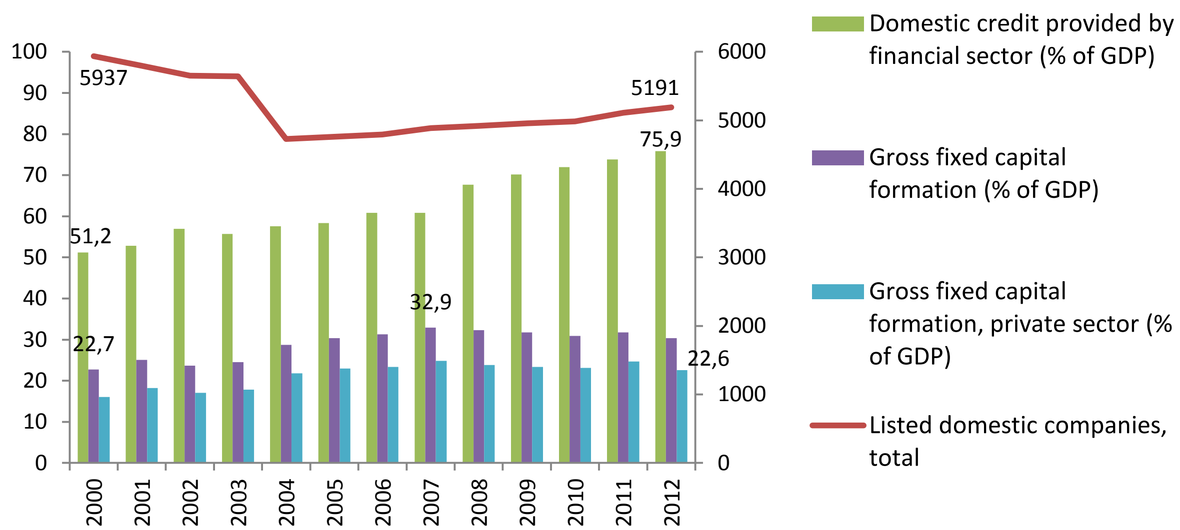
Economic Specialization and Diversification: As the number of commodities exported serves as proxy for diversification, it could be concluded that the economy of India is similarly diversified as those of South Africa, Brazil and Mexico. As of 2012 the country exported 1,211 commodities (Simoes and Hidalgo 2014). Exports are concentrated in relatively few commodities. In 2012 only 128 (nearly 10%) commodities accounted for approximately 80% of value of total exports. In 2012 10.6% of total exports including rice, cotton, corn, wheat soybeans and raw sugar (Simoes and Hidalgo 2014) were depending on climatic pattern. These numbers show that climate change could have an important impact on current exports. Other commodities less vulnerable to climate change impacts include mineral products, cars, machines, medicaments, textiles and plastics. Labor productivity is also low relative to the rest of the world. In summary, numbers show a lowly specialized and lowly diversified economy.

Capitalization and Capital Formation: Investments in gross fixed capital formation can measure the commitment to enhance basic infrastructure for adaptive capacity. As Figure 6-3 shows, the domestic credit provided by the financial system was unaltered by the crisis of 2008 and continues growing. This shows the high capacity of India to allocate financial resources among consumers and companies. Access to credit provides an adequate buffer to cope with climate change impacts. Domestic credit provided by the financial sector has been steadily growing over this century. In addition, the evolution of the number of companies listed in the Indian stock markets shows a steady growth since 2004 indicating a process of further economic diversification. Moreover, the share of GDP invested in the formation of gross fixed capital is high and steady, showing the efforts done to improve infrastructure in roads, education and health facilities. Capital formation in the private sector is also growing.

In short, the Indian economy is being strongly capitalized, creating favorable conditions for long term growth and resilience.

Economic Risks and Uncertainties: The economy is vulnerable to inflation. During this century inflation has been growing reaching 10.9% in 2013 (World Bank 2015a) with standard deviation 3.06% between 2000 and 2013. India does not perform adequately in transaction costs. In the ease doing business index taken as proxy of transaction costs, the country ranks 134 (out of 181 countries). The country risk index (Euromoney 2014), which evaluates structural, political and economic risk, places the country in seventh decile relative to the rest of the world, indicating a low risk country (57.74 as of 2013). With regard to property rights India performs between 0.4 and 0.5 relative to the rest of the world in the International Property Right Index (5.4 in 2013 –similar to Brazil). The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). Overall these values show a disparate situation, where the country performs high in the control of structural risk but low in transaction costs, in the control of inflation and middle in property rights.

Figure 6-3: The recent evolution of capital in India.



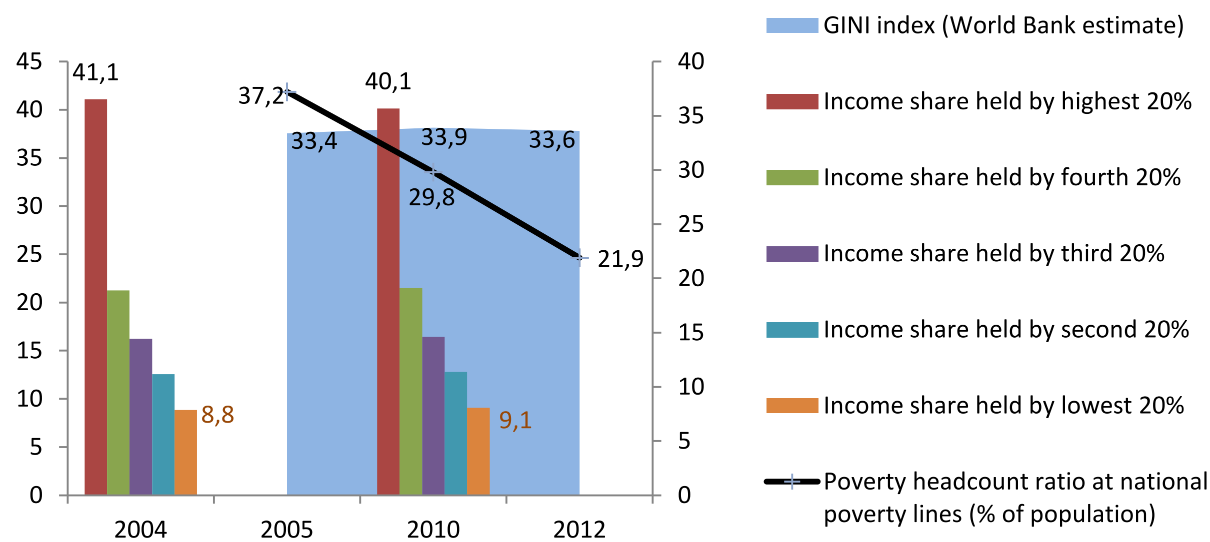
Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation (World Bank 2015a). For growth and development, the country advances consistently in the provision of domestic credit and invests high shares of GDP in the formation of gross fixed capital. However, the low change of listed companies indicates low diversification of the economy, in detriment of adaptive capacity.

6.1.3 Social Vulnerability

The Indian population is highly vulnerable to climate change due to high poverty. The economic vulnerability of the poor leading to malnutrition and food insecurity, high illiteracy, low development of services, the exposure of rural households' economy to weather risk and inflation and the exposure to health impacts. Inequality is not as high as in other countries but it does not decrease. Yet, the headcount poverty line index has been reduced (see Figure 6-4). The overall income per capita is among the lowest in the world, but the poorest 20% receive around 9.1% of total income in 2010. This income share of the poorest is much higher than in other countries of this study showing a similar income per capita.

Food security: By 2014 190.7 million Indians were undernourished (FAO 2015). By 2012 the prevalence of undernourishment reached 17% of the population and the average food deficit reached 121 kcal/person/day (FAO 2015). In addition, in 2012 the prevalence of food inadequacy reached 27% of the population reflecting an unequal distribution of quality food (FAO 2015). By 2010 the poor had to allocate 65% of their incomes for food (FAO 2015). The increasing inflation of the country is therefore affecting the poor more adversely. These numbers show the high vulnerability of the population to food insecurity. These problems will be exacerbated by the expected impacts of climate change on food production reported.

Figure 6-4: The recent evolution of income distribution, inequality and poverty in India.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) cannot be compared between countries but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Income inequality in India is non-decreasing and the poverty headcount ratio is still high. This social trade-off has to be corrected.

Health, Sanitation, Water and Energy Services: India is burdened by the high incidence of heat stress, air pollution, waterborne and vector-borne diseases (Bush et al. 2011), exacerbated by very low development of services. The access to fresh water service reached 90.7% of total population in 2012 in rural areas; i.e. 59.4 million of Indians still lack access to improved water. In urban areas this number amounts to 20.2 million (World Bank 2015a). With regard to access to sanitation services, the situation is even worse, with 480 million people in rural areas without sanitation services and 244 million in urban areas (World Bank 2015a). Moreover, health public expenditure is among the lowest in the world, 1.33% of GDP by 2012 (World Bank 2015a). In fact, life expectancy at birth was only 66.2 years by 2012 (World Bank 2015a). These numbers show that India needs to invest significant resources on the adaptive capacity in health, to cope better with the oncoming impacts of climate change.

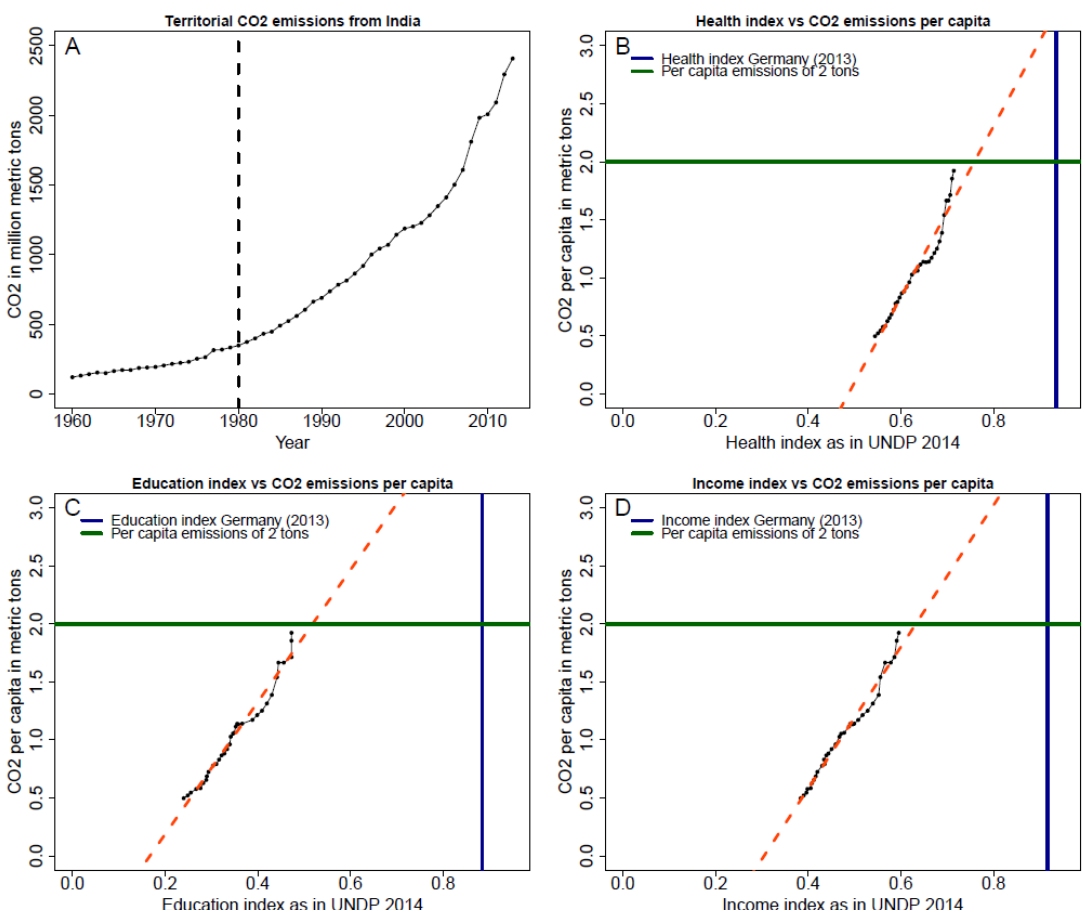
Education: Public expenditure in education in 2012 was only 3.35% of GDP (World Bank 2015a). In 2010 there were only 103 technicians out of one million people in 2010 (1,418 in the Euro area 2005-2010) and 0.8% of the GDP spent on R&D in 2010 (2.1% average 2005-2010 in the Euro area) (World Bank 2015a). The literacy rate for people above 15 was 62.75% by 2006 (World Bank 2015a) implying that 425.8 million Indians were illiterate at that year (World Bank 2015a). Nevertheless, the percentage tertiary students increased from 9.5% in 2000 to 24.7% in 2012 (World Bank 2015a), showing a clear commitment to higher education. But the pupil-teacher ratio in primary education in 2011 was still very high: 35.15 (World Bank 2015a). These indicators show the commitment of the country to raise labor productivity and knowledge, but also the existence of significant gaps to be bridged to increase the adaptive capacity of the country.

6.2 Links between Adaptation, Development and Mitigation

6.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from India show a clear exponential increase from 1960 until 2013 (Figure 6-5A). Accordingly, emissions have soared from 120 to 2400 million tons between 1960 and 2013 respectively.

Figure 6-5: Trends of CO_2 emissions and the HDI in India.



Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2

emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. The green line indicates the 2t/cap CO_2 as an average target not to transgress 2°C the global warming under the fair burden constraints (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. Growth of emissions per capita and the elements of human development assessed in the HDI show coupled trends. Optimal pathways to correct this trade-off in India require reducing emissions per capita from the combustion of fossil fuels while advancing more effectively in the improvement of education and health, and increasing income per capita.

During the last decade, the exponential trend has just been hampered slowly between 2009 and 2010, mimicking the global stagnation in emission caused by the 2009 economic recession (Peters et al. 2011). On a per-capita basis, CO_2 emissions from India are best characterized by a linear increase, from about 0.5 to 2 tCO_2 per-capita in 1980 and 2013 respectively (Figure 6-5B). This development places India at the edge of the suggested 2 tCO_2 per-capita mark required to halt global warming below 2 degrees under the fair burden constraints (WBGU 2009a).

The relation between the different components of human development and per capita emissions in India is strongly linear and positive independently if one looks at the health, education or income components (Figure 6-5B, C and D). From all the components analyzed, the education index is the one that lies more distant from a developed country standards (e.g. Germany) followed by income and health. The strong correlations observed cast doubts about the feasibility of India's ability in staying below 2 tCO_2 per-capita in the near future. Particularly if one attends to the large inertia conferred by the size of the India's economy and population numbers.

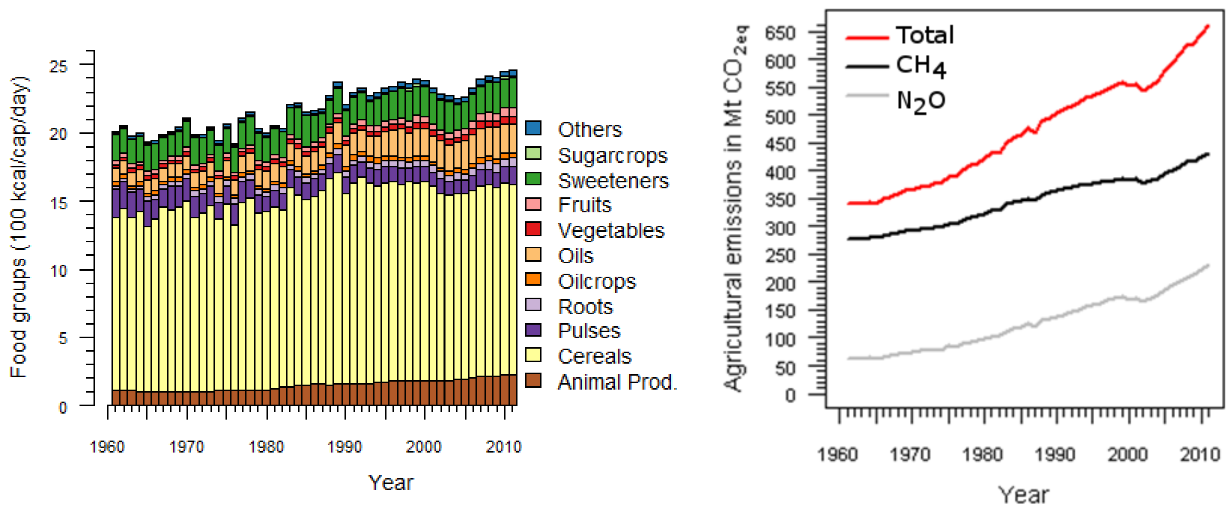
The progress made by India towards higher levels of Human Development as measured by the HDI has been projected to be slow according to previous work. Which means; India is not expected to overcome developed world standards of HDI of 0.9 within the first half of the current century (Costa et al. 2011). It is however expected to achieve 0.8 HDI by 2040, with associated emissions of 5700 million tons for the same year (Costa et al. 2011).

6.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 6-6 (left) presents the evolution of dietary patterns in India between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, India's total food supply has increased from 2010 kcal/cap/day in 1961 to about 2460 kcal/cap/day in 2011. The current Indian food supply is above its average dietary requirement of 2200 kcal/cap/day (Hiç 2014). During these five decades, amount of cereals supply per person per day has increased by 130 kcal, whereas, supplies of oils and animal products have almost doubled. Current per person animal product supply of 230 kcal per day is lower that the global average per person animal product supply of 500 kcal per day. Furthermore, inter-annual variability in supplies of total calories and the different food groups has been observed in India in the last five decades with the lowest calorie supply in 1976 of 1920 kcal/cap/day. However, total calorie supply has continuously increased in the country after 2005. This depicts the increasing food availability in India and starting of lifestyle shifts towards calorie rich and nutritious diets largely based on cereals.

In the year 2000 around 430 million people in India lived in the regions where local food and feed produced within 5 arc-minute grid (10 km x 10 km in equator) was enough to meet their food and feed demand (Pradhan et al. 2014b). India is a net food exporter and is food self-sufficient on the country level (Pradhan et al. 2015a). The country exports about 70 trillion kcal of food and feed in the year 2000. In addition 700 million Indian are food self-sufficient within their states. Furthermore, India could increase its food export to 1140 trillion kcal by closing yield gaps to attain 90% of the potential crop production in 2000.

Figure 6-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in India.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non CO_2 emissions (in CO_{2e}), including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Colombia during the last fifty years. Food supply in India has slightly increased in the recent decade, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the last 50 years, producing environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

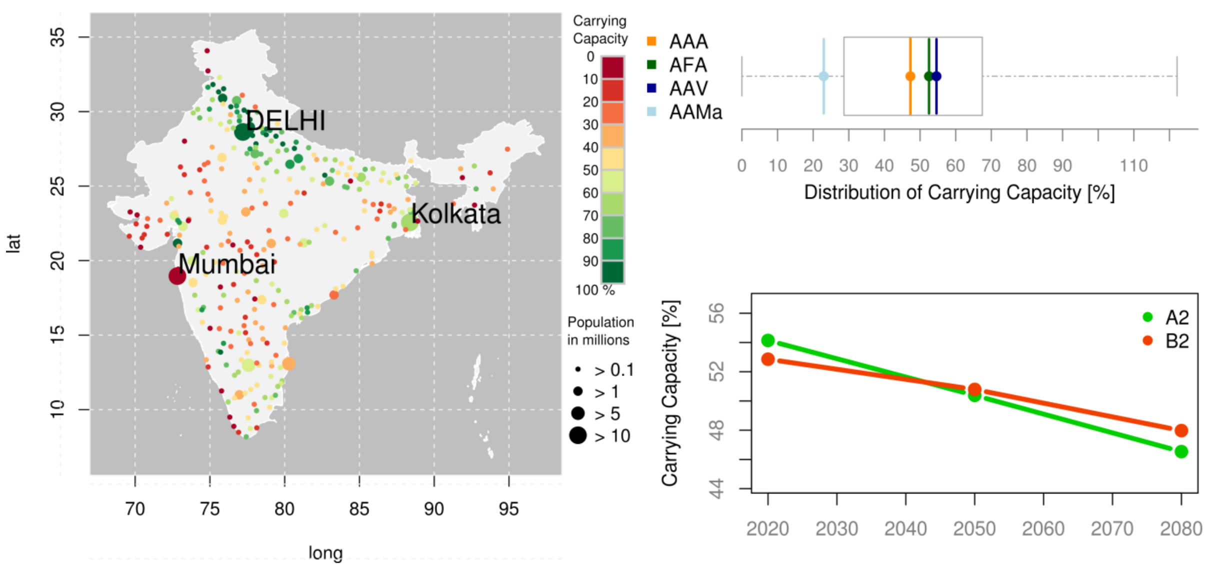
Additionally, the total agricultural emissions of India have almost doubled from 340 Mt CO_{2e}/yr to 660 MtCO_{2e}/yr in the last 50 years as shown in Figure 6-6 (right). The increased emissions are related to increase in agricultural production to meet growing food demand driven by population growth and dietary changes. Furthermore, diets currently consumed in India embodied emissions of about 0.9 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 1.4 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013).

Dietary patterns in India may increasingly be calorie and meat rich when the country becomes more developed in the future, resulting in larger volume of GHG emissions. Technological progress can transfer these trade-offs into synergies. Currently emissions per unit of crop and livestock production in India are higher than that of developed countries (Pradhan et al. 2013). Moreover, major parts of the country so far have attained up to 40% of the potential crop production (Pradhan et al. 2015a). Hence, technological progress increasing agricultural productivity can also lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013). Additionally, closing crop yield gaps can increase crop production and ensure the current and future food self-sufficiency in India even while considering plausible population and diet changes by 2050 (Pradhan et al. 2014b).

6.2.3 Potential of Peri-Urban Agriculture and Local Food

32% of 1267.4 million people in India live in cities and a future growth up to 1620 million by the year 2050 will occur mainly in cities and will raise the percentage of urban population over 50% (United Nations 2014). 307 cities with population above 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport. Overall these cities represent more than 171 million people. Today 89% of the surrounding areas are used for agricultural purpose, which is nearly all of the available arable area (98%). From the currently harvested areas 51.2% of the urban dwellers can be nourished (Kriewald, Sterzel, Pradhan, García Cantú Ros, et al. 2015).

Figure 6-7: The possibility for a food supply from surrounding areas for Indian cities.



For current conditions (AAA) as a map (left) and the median carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. Indian cities offer great potential for food self-sufficiency to improve environmental synergies. However, decreasing yields, due to climate change, should be taken into consideration for further actions.

The yield gap ratio of the investigated cities is 0.58 and offers potential to increase the food self-sufficiency. However, this holds not for the Indo-Gangetic Plain where the yield gap ratio is nearly 1. In this area also the percentage of used agricultural land is nearly at the maximum. An increase of kcal-consumption up to 3500 kcal/cap/day will reduce the carrying capacity down to 23% (see Figure 6-7 –top right). 182 cities (60%) will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The summed up values decrease down to 48% (see Figure 6-7 - bottom right). But the decrease in the Indo-Gangetic Plain is much stronger (up to minus 40%) and cannot be compensated by a changed land-use or improved agriculture.

6.3 The Potential for Synergies and the Stage of Country Development

Population growth, economic growth and development needs will exacerbate the competition for water resources in India. Agriculture will continue to play an important role for rural development, food security and economic growth. The major trade-off in India relates to agriculture and water resources. Another important trade-off relates to growth and development, concerning who is benefiting from increased GHG emissions in energy and transport.

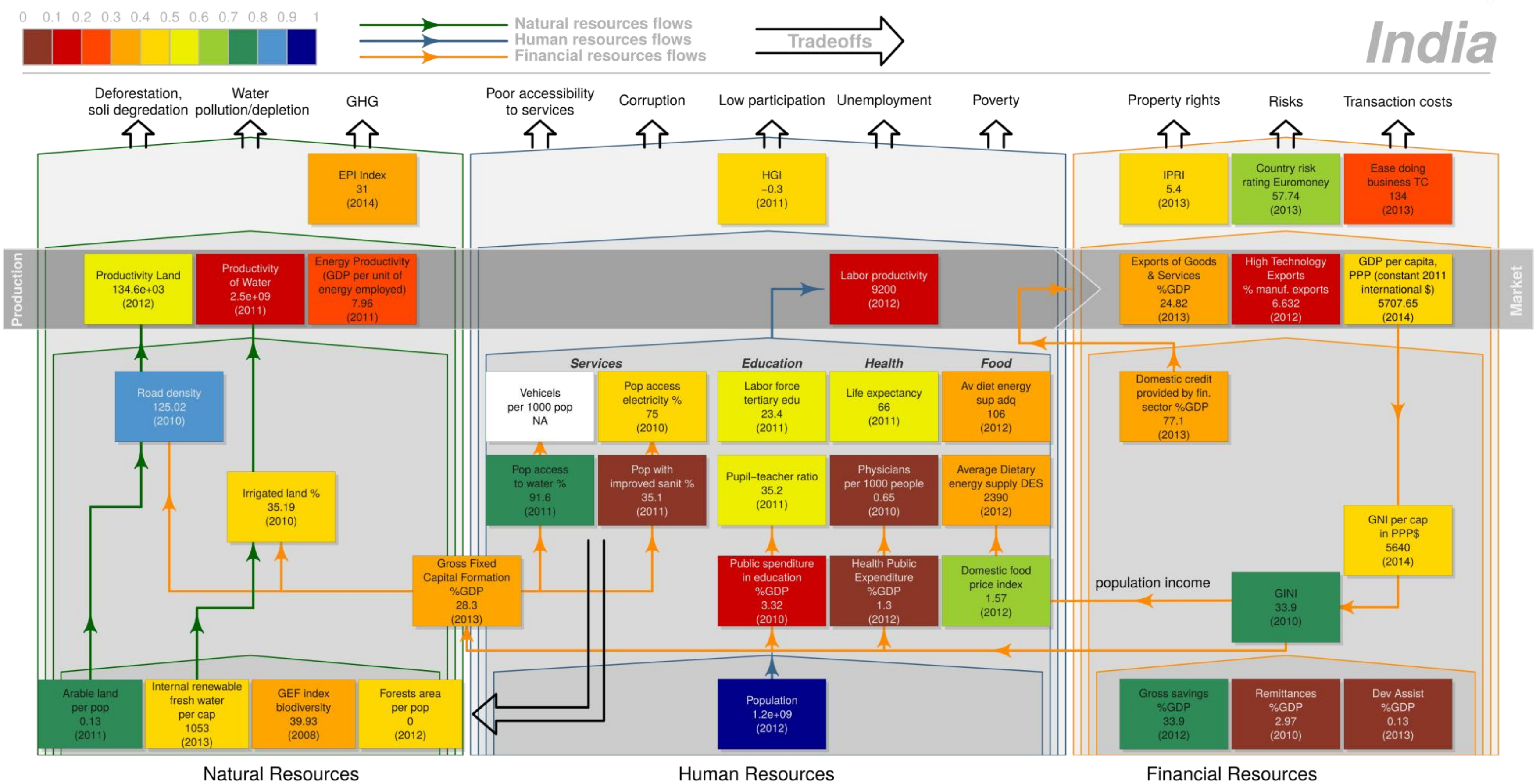
6.3.1 Water, Agriculture and Food Security:

Food security in India is a major issue. The country is self-sufficient, but undernourishment reached 17% by 2012. Minimal energy requirements are too low compared to other countries, even non-developed countries in South Asia. As the indicator of food adequacy (World Bank 2015a) in Figure 6-8 shows, there is only a 6% surplus in production. This shows the low margin to distribute food and the distributional problems existing. But the country performs high in the food price level index (see Figure 6-8). The demand for food is going to increase from changes in dietary lifestyles and population growth. It is expected that there will be an increasing demand of meat (see Figure 6-6) and total calories consumed in general. For sustainable development in regard of food security, India has only one option: to substantially increase the output and quality of food produced for internal consumption.

However, the potential for food security in the middle and long term is challenged by constrains in natural resources endowments. From Figure 6-8 it can be observed that India is rich in arable land per capita, relative to the rest of the world. Yet, the country is restricted to grow the agricultural area indiscriminately. The country is committed to increase forests areas. Forests are threatened by fragmentation (UNFCCC 2012). Forest areas have grown over the last 20 years, from 21% to 23% of the land area of India (FAO 2010b). The productivity of agriculture is constrained by water scarcity. The percentage of total freshwater withdrawal in India reached 90% in 2013 (World Bank 2015a), with 53% being consumed in agriculture (World Bank 2015a). Internal fresh water resources are scarce. Moreover, groundwater levels in south India are falling drastically (Ferrant et al. 2014). The total water consumption in India is expected to rise by 20–40% in the next 20 years (UNFCCC 2014a). Yet, precipitation is expected to increase in India (Schewe 2014). Increased precipitation is accompanied by higher variability, which will be reflected in more and longer extremes. However, water scarcity is not the only factor affecting agriculture. Crop yields will be adversely affected by higher temperatures. As Figure 6-7 shows, under both A2 and B2 scenarios, the carrying capacity is going to be adversely impacted by climate change, at least in areas surrounding cities. Losses of productivity in the Indo-Gangetic Plain are expected (Kriewald 2012b).

A strategy on synergies aims to secure the access to food for the Indian population. The country needs to increase outputs and quality of food consumed within the country. The strategy requires considering all the above aspects: water scarcity, constrained options for land use change for agriculture, competition for water from energy and human consumption and consequences of actions for mitigation.

Figure 6-8: Indicators of the adaptive capacity of India.



White color indicates non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. Sustainable development in India requires improving the productivity of natural resources. Growth is needed in India for bridging the gaps in the provision of basic services of the population for reducing social vulnerability and enhancing environmental protection. For resilient pathways the country needs to improve in governance of natural, human and financial resources.

Actions enhancing water resources include reducing the competition for water from other sectors, enhancing the area and density of forests, developing the capacity in irrigation and increased efficiency in use of water in agriculture. Power generation and agriculture compete for water resources. The pressure on water resources for power generation will be lessened from the increasing number of projects based on solar (the Jawaharlal Nehru National Solar Mission) or wind energy (for e.g. the Jangi 91.8 MW wind farm in Gujarat). For water and food security reasons, the country should advance further in this direction.

Forestation and afforestation might constrain the available area of arable land for agriculture. However, forestry has the potential to regulate and enhance the water cycle. Therefore, programs for carbon sequestration in forestry have the potential to substantially increase water resilience and support programs for food security.

The country should also develop its capacity in irrigation. As the indicator of irrigated land in Figure 6-8 shows, the share of land with irrigation is too small. The increased average precipitation will favor the recharge of aquifers, making irrigation a natural option in some regions. Irrigation based on solar pumping is a possibility to adapt and mitigate. Yet, it requires developing infrastructure, human capital and national institutions for the effective governance in irrigation. Development of the capacity in water management includes also specializing in technologies for storing water. Climate change represents indeed an opportunity, as rainfall is expected to increase. Massive volumes of water from heavy rainfall and increased number of extremes would open the possibility to benefit from more dams for both irrigation and hydropower. Yet, more studies are needed to assess this potential.

Complementary to the development of the capacity in water management, the country needs to substantially improve the productivity of agriculture. As reported the average production is only 40% of the potential crop production (Pradhan et al. 2015a). Though land productivity has evolved within the range of South Asian countries it has still room to improve (US $1,211 per ha by 2011), considering the productivity of Philippines (US $1,948) and Vietnam (US $1,976) in the same year. These numbers show the potential of India to significantly improve the outputs and the value in agriculture. However, it requires national programs for agricultural assistance, further development of agricultural and agro-business markets, and investments in R+D for developing more resistant and more productive crop varieties.

India has the potential to reduce emissions from agriculture. However, emissions from this sector are not the major issue in India. By 2011 these emissions represented only 14% –excluding sinks from forestry (WRI 2014). A national program to increase the productivity and enhance resilience in agriculture could include mitigation as a specific objective. Changes in dietary lifestyles will have for future emissions. Regarding the increase in the consumption of meat expected, i.e. if cattle become the main source of meat this will have a tremendous effect. A dietary change towards meat will also reduce the carrying capacity of peri-urban areas.

6.3.2 Emissions from Energy-Transport and Adaptive Capacity:

As Figure 6-2 shows, emissions per capita are close to reach the $2tCO_{2e}$ threshold required to keep global warming below 2°C by 2050 under fair burden constraints (WBGU 2009a). If India aims to keep emissions per capita under the $2tCO_{2e}$ and at the same time aims to develop, changes on technologies in transport and energy are needed. While emissions from energy and transport are growing more than linearly the health and the education index of the HDI have been growing linearly (see Figure 6-5). For the case of India emissions in energy and transport are coupled to the health and the education index. However, the pace of development of these indexes is slow. Other countries with lower emissions have developed faster and more effectively, e.g. Cambodia in the health index, or Philippines in the education index (see the section on synergies between countries). One question is, if this trend of human development can be at least sustained while reducing emissions. To appraise this possibility consider the installed capacity for electricity generation from their sources, the reserves of coal and fossil fuels and the potential of renewable energy. According to the energy statistics 2014 (CSO 2014) for electricity generation, the total installed capacity in 2013 was 266,644 MW. The installed capacity has grown more for thermal (carbon) 14.71% between 2011-12 and 2012-13 followed by hydropower (1.28%). In March 2013, the installed capacity from thermal amounted 67.16% of total installed capacity. The installed capacity from hydropower amounts to 14.81%. The installed capacity from nuclear reached only 1.79% (CSO 2014). Moreover, the penetration of renewable sources for electricity generation amounts to 28,067.26 MW in March 2013, i.e. growing 12.66% from one year earlier (CSO 2014). Of these renewable sources wind power generation accounted for 67.88%, small hydro power 12.94%, and biomass power 12.83% (CSO 2014). These numbers indicate that the share of renewable sources accounts for 10.52%, but this share is going to decrease, as thermal generation is growing more than renewables.

It is worth to note the allocation of energy across sectors. Industry used 50% of end energy consumption, including iron and steel production accounting for 22.5%, chemical and petrochemicals 9.5%, and construction 6.5% (CSO 2014). The transport sector accounted for 7.6% of total final consumption. The residential and commercial sector accounted for 36.8% (CSO 2014). This numbers show that energy is massively used in the production of steel and iron, associated to the development of infrastructure and machinery, i.e. capital and gross fixed capital formation. Relevant measures to reduce emissions from energy are summarized by Fekete et al. (2013a). Potential mitigation of CDM projects amounts to 617-1435 $MtCO_{2e}$ per year (see appendix 4 on mitigation potential). If this potential is realized, the country would achieve the pledge, and would keep emissions under the $2tCO_2$. However, at the same time demand is growing exponentially and this increased demand is being mostly covered with the installation of thermal plants. In addition, it is worth noticing that coal reserves have grown from 118.15 to 123.19 billion tons (CSO 2014). As the demand for energy increases exponentially, it is evident that the country will raise GHG emissions from coal combustion if adequate incentives on renewables are not offered. The evident consequence is that in the middle term –e.g. beyond 2020, new incentives need to be figured out (Singh 2011).

In the index of gross fixed capital formation in Figure 6-8 observe that India invests 28% of GDP in the development of infrastructure (28%). In this regard, the country have outperformed in the development of road infrastructure (see indicators of accessibility to natural resources in Figure 6-8). The middle performance in land productivity is associated to such development. High density of road infrastructure also creates capacity to cope with eventual impacts from e.g. floods. As Figure 6-3 shows, the share of GDP invested in the formation of gross fixed capital has been growing over this century. This trend will likely continue –given the low development of the country.

Further development of infrastructure requires considerable amounts of iron and steel, and therefore high consumption of energy. Therefore, mitigation efforts need to concentrate on the drastic reduction of emissions in electricity production. If technologies based on more costly renewable energy systems are to be implemented, the country needs to transit to a growth model that diversifies the productive structure towards less pollutant activities and specializes to produce higher added value per capita and per unit of energy employed. This requires improving substantially the development of the productive factors and creating incentives for new activities.

For growth and sustainable development, India has to improve human capital considerably. Labor productivity is low in India, even though the economy is relatively highly diversified. Labor productivity would reflect the middle and low performance in food security, health, education and the provision of basic services.

The capacity to implement long term policies would be hindered by the low performance in the indicators of human governance (World Bank 2015b). The average negative value shows that Indians have a negative perception of human governance in their country. In the recent past (2003 and 2008), the country performed positive but low in the variables 'voice and accountability', and in 'rule of law'. However, it is negative the perception of 'political stability' and 'absence of violence', as well as in 'control of corruption', 'government effectiveness' and 'regulatory quality' (World Bank 2015b). The low value of the environmental part[7] of the EPI index shows the difficulties of the country to control pollution and protect natural resources. Therefore, the country needs to develop more its environmental capacity in order to enforce the improvement of technologies and the reduction of environmental pollution and GHG emissions.

The country also needs to improve its performance in financial capacity. Indicators at the right side of Figure 6-8 show on one side low but non-decreasing inequality (see Figure 6-4), and very low GNI per capita relative to the rest of the world[8]. In regard of the performance of markets indicators show a low development of exports and low share of high technology commodities in the portfolio of exports. The country needs to work on reducing inflation and reducing transaction costs. Economic uncertainties are also related to property rights and political instability (Patnaik and Pundit 2014).

6.4 Conclusions

For synergies India needs to develop institutions and incentives upon two major trade-offs. One relates to water, agriculture and food security. The other one relates to energy (including transport) and human development.

Agriculture is a key sector for development and growth in India. Agricultural development in India is constrained by water scarcity and limited availability of land for agriculture. Climate change will produce changes in land use, though in average these changes are not necessarily associated with increased water scarcity. Water rainfall will increase in some regions, creating opportunities for agriculture and forestry. To take advantages of these new conditions, the country has to develop its capacity in water management: infrastructure, technologies, human capital and institutions focused on the development of irrigation systems, the efficient and sustainable usage of underground

[7] As explained in the introduction of the tool, for the evaluation of environmental governance we disregarded the numeric assessment of health in the EPI index, and kept the environmental part for the assessment.

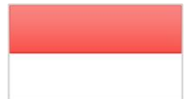
[8] Due to the multi-scalar nature of GNI, for standardization we considered the logarithm of GNI per cap.

water sources, renewable energy technologies for water pumping, and the efficient use of water in agriculture. The development of water management should be accompanied by further development of agricultural productivity. The country should develop technologies that enhance the productive capacity of small and middle size farms. Institutions for agricultural development should include capacity development in mitigation of GHG emissions in the sector. To succeed in this undertaking, the country has to develop its capacity for agricultural assistance.

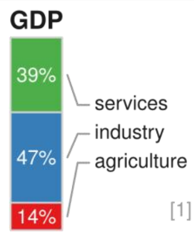
Coal based power plants are the more costs effective alternatives for electricity generation. In fact, the country is rich in coal. The generation of electricity based on renewable energy sources cannot yet compete with coal. The emissions associated to electricity generation are growing non-linearly in India. Under current conditions, the adoption of more costly alternatives based on renewable energies has two possibilities: either receiving massive support from international assistance to make affordable the acquisition and operation of renewable energy technologies, or to raise average income. For higher growth the country needs create human capital and create incentives for the development of industry and services. Without higher life standards in India, the development of e.g. carbon markets or taxing systems for mitigation is not feasible, due to the low paying capacity of most of the population.

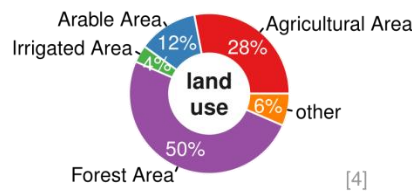
7. INDONESIA

Figure 7-1: Indonesia – Factsheet and physical map:



Country size	1,904,569 sq km	[1]
Coastline	54,716 km	[1]
Population	252.81 millions	[2]
Rural population (%)	47	[2]
Human Development Index	0.68 (108 of 187 – Medium)	[3]
Life expectancy at birth	70.83	[1]





[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

7.1 Sensitivity and Vulnerability

7.1.1 Sensitivity and Vulnerability of Natural Resources

Indonesia is among the countries that lack detailed studies for climate change projections. In order to compensate this deficit, the UNDP developed the Climate Change Country Profiles. The case of Indonesia will be studied relying on information from this report. Climate change projections for Indonesia are available for A2, A1B, and B1 SRES forcing scenarios and for the years 2030, 2060 and 2090 (McSweeney et al. 2010a).

Temperature: The Indonesian climate is strongly influenced by the conditions of the Indian and the Pacific oceans dynamics (McSweeney et al. 2010a). Mean annual temperature has increased by 0.64°C since 1960 implying a rate of around 0.14°C per decade. A similar rate of increase is observed in all seasons, although a faster rate is expected over the western islands (McSweeney et al. 2010a). The mean annual temperature is projected to increase by 0.9 to 2.2°C by 2060, and 1.2 to 3.7°C by 2090. Projected warming is similar in all seasons, but occurs at a faster rate over the larger islands (McSweeney et al. 2010a).

Water resources, rainfall and precipitation: Since 1960, mean annual rainfall has decreased in every season at an average rate of 7.8 mm per month. The largest decreases are reported in the dry season (July-August-September) at -4.8% per decade (McSweeney et al. 2010a). In average the country will become wetter, with changes in range of -28 and +53 mm per month (-12% to +20%) by 2090. Large spatial and seasonal variations in rainfall changes are predicted (McSweeney et al. 2010a). According to the Ministry of Environment (MoE 2007) between 2003 and 2005, about 53.3% of disasters in Indonesia were caused by hydro-meteorological events. Floods occurred most often (34%) followed by landslides (16%).

Sea Level Rise: Sea level in Indonesia has increased by 1–8 mm per year (ADB 2009). 1,500 islands of Indonesia are threatened by inundation. Nearly 98.4% of the population lives within 100 km of the coast (ADB 2009) and approximately 1,600,000 ha of rice harvest area could be endangered by 1m sea level rise (Nicholls and Mimura 1998). By 2050 the area of paddy rice fields could be reduced by 182,556 ha in Java and Bali, 78,701 ha in Sulawesi, 25,372 ha in Kalimantan, 3,170 ha in Sumatra, and 2,123 ha in Lombok (Suroso et al. 2005).

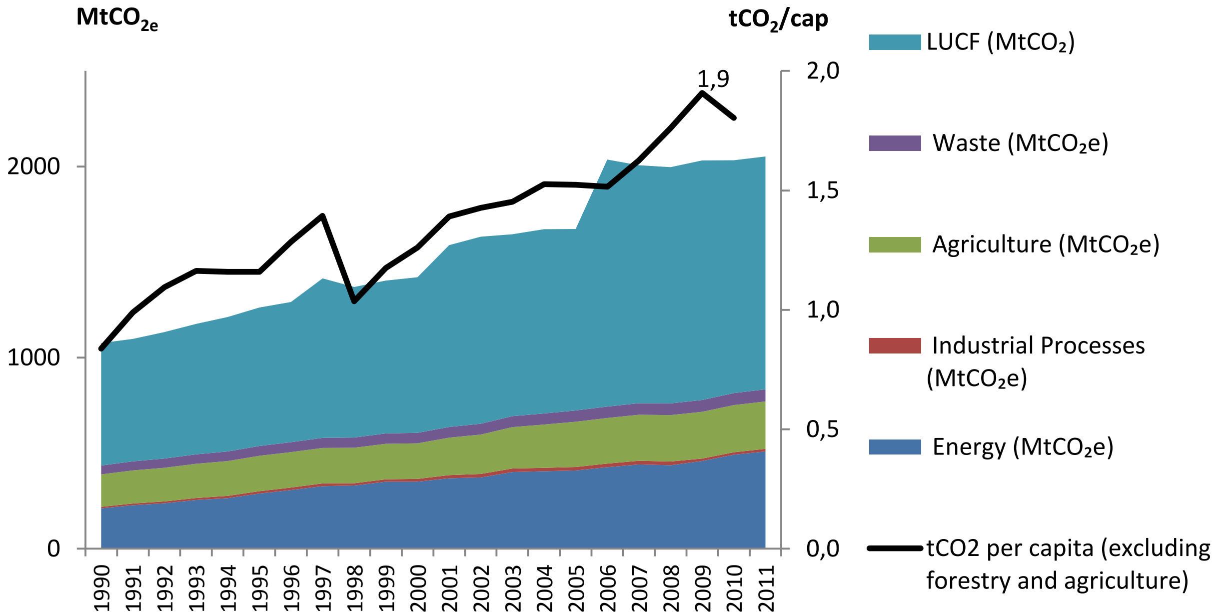
Crop Yields: The risk of reduced food security due to climate change is a major issue in Indonesia. Climate change will affect evaporation, precipitation and run-off, and soil moisture, hence affecting agriculture and food security (UNFCCC 2012). The 1997 El Niño drought affected approximately 426,000 hectares of rice fields (UNFCCC 2012). Climate change will also lower soil fertility by 2 to 8%, which will result in an estimated decrease of rice yields by 4% per year, soya by 10% and maize by 50% per year (Amin et al. 2004).

Land Use and Forestry: Indonesia has the third largest area of tropical rainforest on the planet, i.e. 60% of its landmass covered by forests (FAO 2014b). In terms of biodiversity, it is one of the world's richest countries and hosts a significant part of the planet's tropical deep peat. From a global point of view global view its forests are of highest importance (UN-REDD 2014). Deforestation rates in Indonesia are high. Current estimates are 1.17 million hectares per year (UN-REDD 2014). From 1990-2005 nearly 28 million ha of forests disappeared (FAO 2014b). Between 2000 and 2010 main deforestation drivers were fiber plantations (12.8%), logging (12.5%) and palm-oil plantations (6.8%) (Gilbert 2014). The remaining 67.9% were removed for mixed concessions and mining (Gilbert 2014). The economic costs of the droughts and fires in 1997-1998 were about US$ 9 billion (Case et al. 2007). In the same period, over 2 million hectares of peat swamp forests were burned (Case et al. 2007).

Atmosphere: As shown in Figure 7-2 75% of CO_2 emissions originates from deforestation and land conversion, with 23% associated to forest-related energy consumption, and the remaining to forest-industry related processes (WRI 2014). By far the largest share of Indonesia's GHG emissions derives from peat land activities and from the LULUCF sector. These rates are accountable for approximately 80% of its GHG emissions, mainly due to forest loss. Hence, most activities aimed at the reduction of GHG emissions have to focus on the LULUCF sector (Nachmany, Frankhauser, et al. 2014b). Emission reduction activities in the areas of afforestation and reforestation, sustainable forest management and the prevention of forest fires, especially in peat lands, are most appropriate. Indonesia is committed to reduce between 26 and 41% of BAU emissions by 2020 (UNFCCC 2014a).

Energy production is the second highest emission sector in Indonesia (see Figure 7-2). On the supply side emissions from fossil fuel-based energy production is rapidly growing due to economic growth (Ministry of Finance (MoF) Indonesia 2012). As a result of the rapid economic development, growing electricity demand in rural areas is expected to increase (from 60% in 2010 to 100% in 2020). Nevertheless, Indonesia has ambitious plans to expand renewable energy sources. Amongst them hydro-electric power plants offer the largest emission reduction opportunities. Indonesia also owns a significant share of the world's known conventional geothermal resources. The country's policy to foster renewable energy production is centred on geothermal power and biofuels. The power plant capacity was increased by 317 MW in 2007-2008. However, the Ministry of Forestry reports that 80% of geothermal sources are in forest conservation areas. Thus the exploitation of these resources could lead to further deforestation and degradation. Additionally, solar power and biomass power plants offer further abatement opportunities (Nachmany, Frankhauser, et al. 2014b).

Figure 7-2: GHG sectoral emissions and energy per capita emissions of Indonesia.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from bunker fuels are negligible (WRI 2014) and were not included. Indonesia is close to surpass the 2 tCO_2 per capita per year required to keep global warming below 2°C by 2050 (WBGU 2009a). The shares of sectoral emissions in the figure show that LUCF, energy and agriculture are the most relevant mitigation sectors for the analysis of synergies.

Agricultural production is the third largest emission source in Indonesia (see Figure 7-2). Agricultural carbon emissions accounted for 21.5% of the total in 2009 (WRI 2014) and represent mostly other GHGs than carbon dioxide, namely methane and nitrogen oxide. These emissions originate from three major sources: paddy rice growing, fertilizer application, and burning of crop residues. Main mitigation strategies in this sector are the improvement of water management, advanced fertiliser usage in rice farming, and the restoration of degraded land. In the power sector, emissions are expected to grow sevenfold up to 2030.

7.1.2 Economic Vulnerability

Indonesia is the largest archipelago country in the world and covers an area of 1,910,931 km². It consists of five large islands and about 13,667 small ones (UNFCCC 2011b). Of the 200 million ha of land territory about 50 million ha are used for various agricultural activities. As an archipelago country and with an economy based on natural resources Indonesia is highly vulnerable towards the impacts of climate change.

Between 2000 and 2013 the Indonesian economy grew (World Bank 2015a) from 9.19 to 23.9 US$ billion (PPP constant 2011 international US$). The GNI per capita is still very low, i.e. among the lowest in the world. Since the Asian Financial Crisis in 1997/98 the role of sectors other than oil and gas has become much more important to Indonesian economy. Through a considerable increase in exports and its absorption of unemployed workers, the agriculture sector helped the recovery of Indonesian economy after the crisis (Siregar 2008). Mainly on account of Indonesia's abundant coal and peat resources, the country had an export surplus measuring up to 184,8 Mtoe net imports (IEA 2015). This indicates a positive independence of imports which translates into energy security.

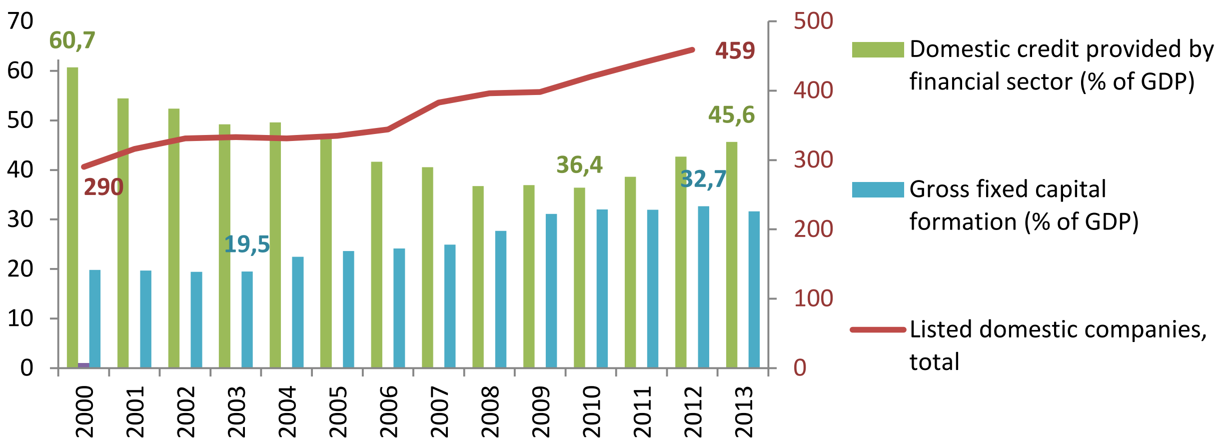
Sectoral Impacts: Climate change will affect agriculture in Indonesia due to sea level rise and reduced crop yields. Agriculture contributed 14.4% to GDP in 2013 (World Bank 2015a) and represented the income of 38.9% of the Indonesians as of 2012 (WFB 2015). Sea level rise will result in the reduction of average income. In the Subang region alone it is estimated that 43,000 farm laborers will lose their jobs. More than 81,000 farmers will have to seek other income sources as a consequence of flooding due to sea level rise (Sari et al. 2007).

Economic specialization and diversification: Lowly diversified and lowly specialized economies will be more vulnerable to changes in prices and trade conditions. The higher the specialization and the diversification are, the better the adaptive capacity. Total number of commodities exported amounted to 1,182 as of 2012 (Simoes and Hidalgo 2014). However, in this portfolio of exports, 87 commodities account for 80% of exports value (Simoes and Hidalgo 2014). The portfolio of exports is diversified. Of the 80%, 37.26% were mineral products, 17.65% agricultural products and fishery, 9.79% technology and machinery, 5.39% chemical products, textiles 5.05%, and other goods and services 4.86% (Simoes and Hidalgo 2014). Mining has the biggest exports share, whereas high technology has a very low share. The numbers presented indicate that the economy is lowly specialized. Finally, it is worth noticing that mining has been identified as responsible for deforestation (Gilbert 2014).

Capitalization and Capital Formation: As shown in Figure 7-3 the formation of gross capital, i.e. infrastructure, schools, hospitals, roads has been growing to reach the 33.6% of GDP in 2013, among the highest in the countries studied. Indonesia is characterized by the decline of the financial system in the provision of credits below 60% of GDP as of 2013. The low spread of financial services constraints credit and expose the poor sector of the population to private lenders that charge interests that could reach up to 20% (World Bank 2014c). During this century the number of companies listed in stock markets has substantially increased. This growth would be indicative of a process of diversification of the economy, concomitant with the diversification of exports reported.

Economic Risks and Uncertainties: Inflation has been problematic in Indonesia. In 1998, inflation picked up to 58%, although it has stayed below 10% (7.84% on average) between 2000 and 2013, with a standard deviation of 3.05 (World Bank 2015a). Moreover, Indonesia does not perform adequately in transaction costs due to the low productivity of labor, agriculture and energy (World Bank 2015a). In the ease doing business, which evaluates the environment facilitating development of business, the country rank is 120 (out of 181 countries), i.e. below China (96) and Philippines (108) (World Bank 2015a). In the country risk index (56.7 as of 2013), which evaluates structural, political, and economic risks (Euromoney 2014), the country holds a middle position with respect to the rest of the world. With regard to property rights Indonesia performs in the third decile in the International Property Right Index (4.8 in 2013), i.e. even worse than Philippines. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). Other sources of macroeconomic instability include high account deficit and fuel subsidies (ADB 2014b). Between 2002 and 2012, the debts doubled to almost US$ 255 billion, and the current account balance is almost minus US$ 24.5 billion (ADB 2014b). Indonesia is a country with difficulties to control the sources of economic uncertainties and risks.

Figure 7-3: The recent evolution of capital in Indonesia.



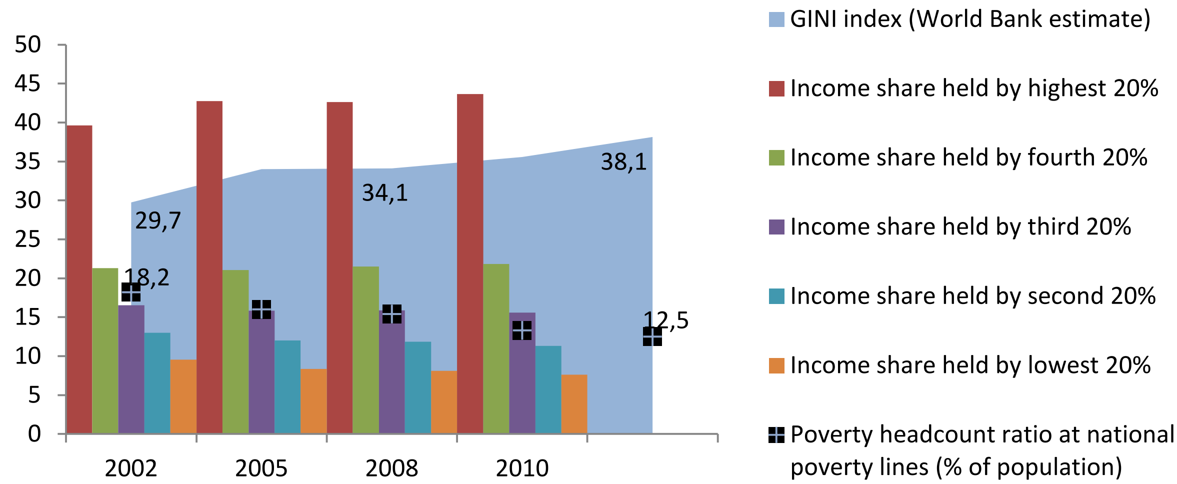
Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation (World Bank 2015a). Indonesia is consistently investing in gross fixed capital formation and recently has positively changed the trend in the provision of domestic credit, for growth, and development. The increased number of companies listed in stock markets indicates economic diversification, for adaptive capacity.

7.1.3 Social Vulnerability

Nearly half of the Indonesian population is vulnerable to economic changes that can force them into poverty (World Bank 2014d). Moreover, income inequality is still growing in Indonesia. Changes in income distribution are benefiting the richest 20% (Figure 7-4). According to the national poverty headcount ratio, poverty has decreased. However, the rate of poverty reduction reached the lowest value in the last decade (0.7% points) in the last two years (World Bank 2014d), which shows the government's lack of commitment. Only 0.7% of the GDP is spent on social assistance programs (World Bank 2014d).

Food security: Indonesia needs 2,300 calories per capita but produces up to 2,820 (FAO 2015). Despite this surplus, 9.1% of the population (23 million) was undernourished by 2013, indicating inequality in the distribution of food. The inadequacy of food supply reaches 15.6% of the total population by 2013 (FAO 2015). Rice is the main staple in Indonesia. Rice self-sufficiency has been achieved since 2008 and maize self-sufficiency in 2005 (FAO 2015). These achievements are threatened by the impacts of climate change on crop yields. The accessibility to food is also being threatened by the increase in the domestic food price level index (FAO 2015), which has grown from 1.6 to 2.0 between 2004 and 2013.

Figure 7-4: The recent evolution of income distribution, inequality and poverty in Indonesia.



The GINI index of income was used to asses inequality. Income shares show the exact distribution of income among five groups (World Bank 2015a). The poverty headcount ratio at national poverty lines (World Bank 2015a) cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. The evident social trade-offs created by income inequality needs to be addressed in the analysis of synergies.

Health, Sanitation, Water and Energy Services: Indonesia spent only 3.02% of GDP in health services in 2012, including private and public (1.19%) expenditure (World Bank 2015a) resulting in a lower performance than the average of South Asia (3.96%) (World Bank 2015a). Public expenditure in health is among the lowest in relation to the rest of the world (see Figure 7-8). Access to fresh water reached 84% of total population in 2011; i.e. nearly 40 million people had no access to water supply as of 2012 (Figure 7-8). Even worse, as of 2012, only 59% of the population had access to sanitation services, i.e. more than 102 million had no access to sanitation (World Bank 2015a). Access to electricity is also low. As of 2012, only 73% of the population had access to electricity (World Bank 2015a) leaving nearly 67.5 million people without this service. These conditions on health expenditure and the accessibility to services represent an additional factor increasing social vulnerability.

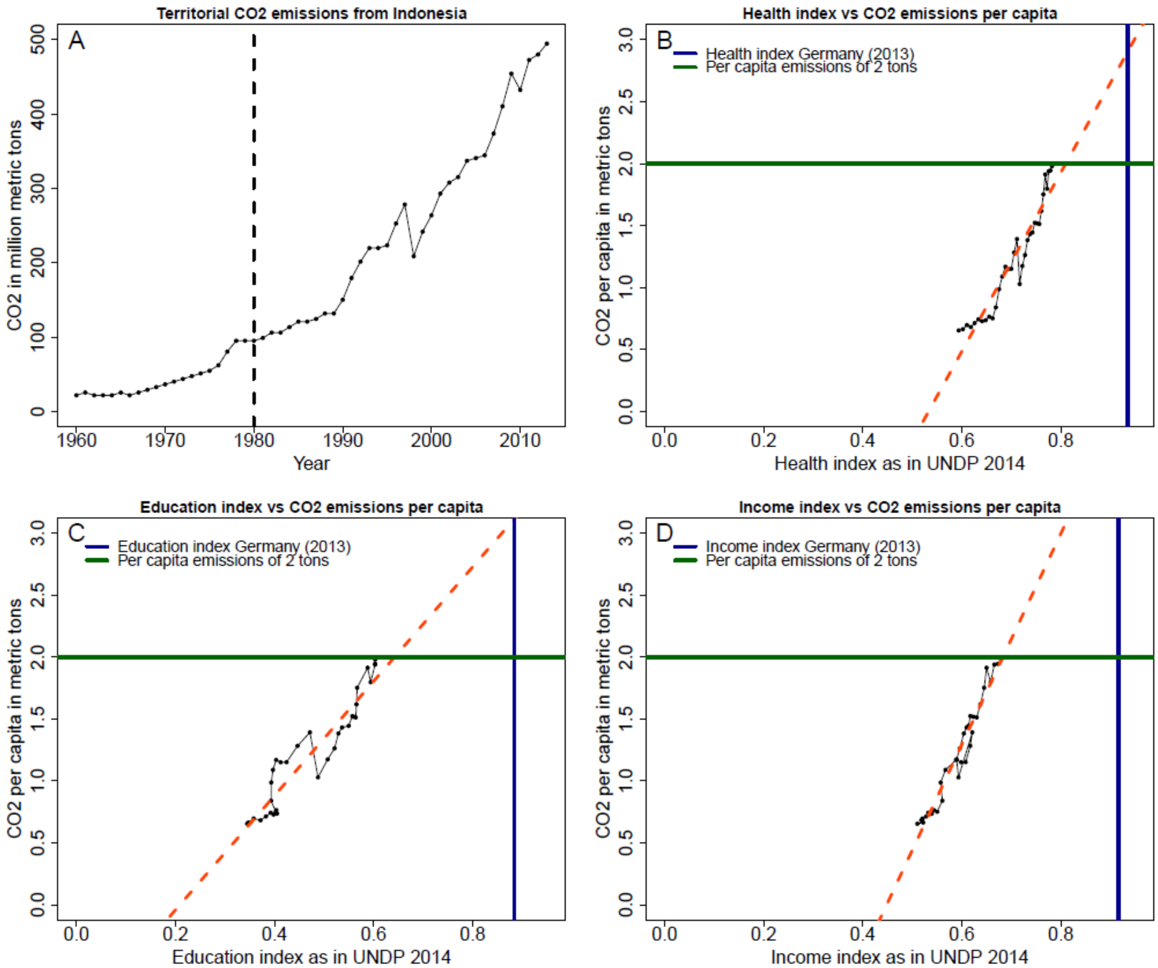
Education: Expenditure in education in 2012 was very low, 2.47% of GNI, and decreased since 2009 (3.27%) (World Bank 2015a). As of 2008, only 7% of the population had tertiary education (World Bank 2015a).

7.2 Links between Adaptation, Development and Mitigation

7.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from Indonesia show a rather exponential increase from about 23 million tons in 1960 to 500 million tons in 2013 (Figure 7-5A). A particularly sharp tendency of acceleration in the overall trend is noted since 1990. On a per-capita basis, CO_2 emissions have risen linearly since 1980 and are currently just below 2 tons per capita (Figure 7-5B). Similarly to India, Indonesia is likely to overcome the reference per-capita emissions required to stabilize climate change in the long term, under the fair burden constraint (WBGU 2009a).

Figure 7-5: Trends of CO_2 emissions and the HDI in Indonesia.



Historical emissions of CO_2 from fossil fuel burning, obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). Panels C and D show analogous information as panel B for the Education and Income index, respectively. Data on population, income, education and health, obtained from the World Bank 2014 database. Horizontal green line shows the 2 t/cap CO_2 target (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. Until 2013, Indonesia has consistently advanced in the development of income, health and education indicators, while emissions have grown consistently, but with a high variability. Optimal trajectories to correct this trade-off require curving the trend of emissions per capita while investing more in education and health, and increasing population income at higher paces.

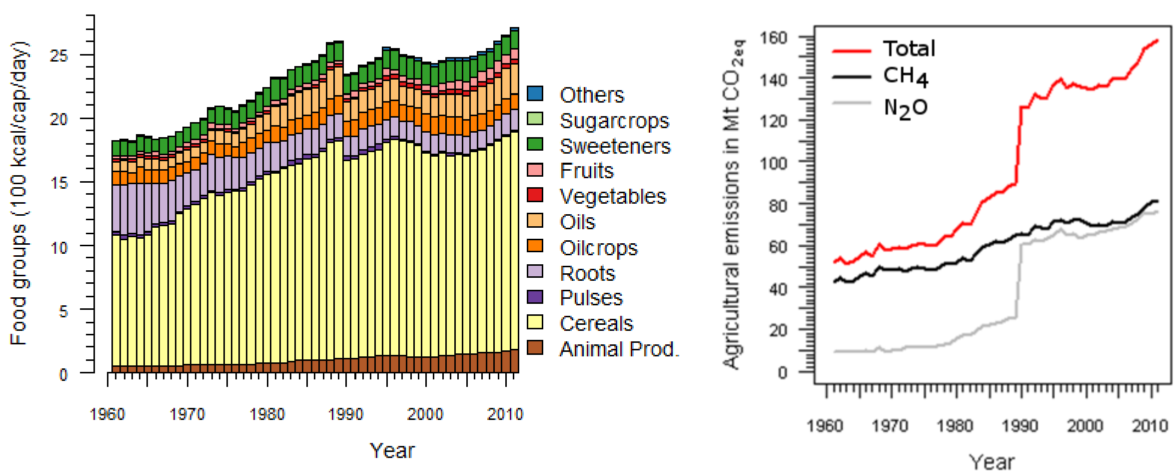
The relation between the different components of human development in Indonesia is observed to be strongly correlated with per capita emissions, regardless of the health, education or income components analyzed (Figure 7-5B, C and D). The progress achieved in the last 2 decades has been slow; in particular, in terms of education and income (far away from developed countries, see vertical blue lines reporting the respective index in Germany in 2013).

An extrapolation of current per capita emissions trends will place per-capita emissions from Indonesia out of the suggested range required by ambitious climate targets. The slow progress made by Indonesia to achieve higher levels of Human Development is further supported by previous research, according to which only by 2045 is the HDI expected to reach 0.9 (indicative of high development) (Costa et al. 2011). Associated emissions with the process are estimated at roughly 1400 million tCO_2 in 2045 (Costa et al. 2011).

7.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 7-6 (left) presents the evolution of dietary patterns in Indonesia between 1961 and 2011, based on the amount of 11 different food groups supplied in the country. In general, Indonesia's total food supply has increased from 1,820 kcal/cap/day in 1961 to about 2,700 kcal/cap/day in 2011. The current Indonesian food supply is above its average dietary requirement of 2,200 kcal/cap/day (Hiç 2014). During these five decades, the amount of cereals supplied per person per day has increased by around 700 kcal, whereas supplies of oil and animal products have almost tripled. Current per person animal product supply of 180 kcal per day is lower than the global average of 500 kcal per day. Furthermore, the different food groups have continuously increased in Indonesia in the last five decades. Despite a slight drop in 1990 the overall calorie supply trend shows an increase in food availability in the country. This depicts a lifestyle shift towards calorie-rich diets, largely based on cereals.

Figure 7-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Indonesia.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (in CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Indonesia during the last fifty years. Food supply in India has increased in the recent decade, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the last 50 years, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

In the year 2000, around 60 million people in Indonesia lived in the regions where local food and feed produced within 10 km x 10 km in cell was sufficient to meet their food and feed demand (Pradhan et al. 2014b). Indonesia is a net food exporter and is food self-sufficient on the country level (Pradhan et al. 2015a). 110 million Indonesian citizens can reach food self-sufficiency within their own provinces. The country exported about 46 trillion kcal of food and feed in the year 2000. Major parts of the country have attained only 50% to 60% of the potential crop production (Pradhan et al. 2015a), which implies Indonesia could increase its food exports to 190 trillion kcal by closing yield gaps to attain 90% of the potential crop production of 2000. Nevertheless, up to 235 million Indonesians will partly depend on international trade by 2050, even by closing yield gaps to attain 90% of their potential crop production, mainly due to diet shifts.

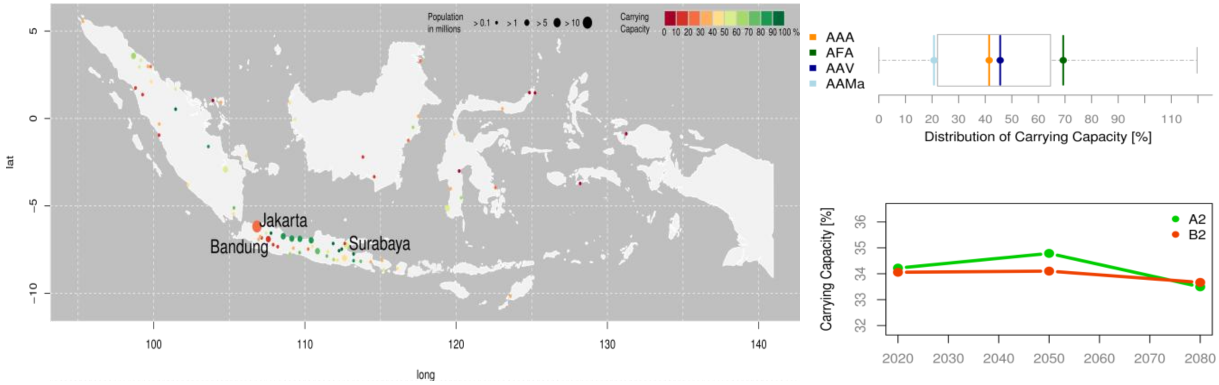
As shown in Figure 7-6 (right) the total agricultural emissions of Indonesia have almost tripled from 51 $MtCO_{2e}$/yr to 160 $MtCO_{2e}$/yr in the last 50 years. The increased emissions are related to an increase in agricultural production, not only to meet growing food demand, but also for international trade. The sharp rise in the emissions between 1989 and 1990 is due to the inclusion of emissions from the burning of savannahs and from the cultivation of organic soils (FAO 2014b). Furthermore, diets currently consumed in Indonesia embodied emissions of about 0.9 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 8 calories of crop products is fed to livestock to obtain 1 calorie of animal product (Pradhan et al. 2013).

Dietary patterns in Indonesia may increasingly be calorie and meat rich when the country becomes more developed in the future. This can also result in a larger volume of GHG emissions. Currently, emissions per unit of crop and livestock production in Indonesia are higher than that of developed countries (Pradhan et al. 2013). Technological progress can transfer these trade-offs into synergies. Increased agricultural productivity can lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013). Additionally, closing crop yield gaps can increase crop production and ensure the current and future food self-sufficiency in Indonesia while considering plausible population growth by 2050 (Pradhan et al. 2014b). Nevertheless, closing yield gaps only is insufficient to ensure future food self-sufficiency when diet shifts are also taken into consideration.

7.2.3 Potential of Peri-Urban Agriculture and Local Food

53% of 252.8 million people in Indonesia live in cities, and a future growth of up to 321 million by the year 2050 will occur mainly in cities, rising the percentage of urban population up to 71% (United Nations 2014). 77 cities with population above 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from the transport of food (see Figure 7-7). Overall, these cities represent more than 63 million people. Today, 60% of the surrounding areas are used for agricultural purpose, which is nearly two third of all available arable areas. Increases in kcal-consumption of diets up to 3,500 kcal/cap/day will reduce the carrying capacity down to 20% (see Figure 7-7 – top right). In this context, the highest potential to increase food self-sufficiency is through land-use change. 45 cities, 58% of the total investigated, will face a decrease in their carrying capacity by the year 2080 (B2), as a consequence of climatic-induced yield reduction (Kriewald 2012b). However, the summed-up values for an average yield scenario decrease only moderately (see Figure 7-7-bottom right).

Figure 7-7: The possibility for a food supply from surrounding areas for Indonesian cities.



Map for current conditions (AAA) (left) and the summed up carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right, the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2), based on an average yield scenario. Indonesia has already potential for peri-urban agriculture and could use the surrounding areas of major cities for food production to reduce environmental trade-offs in other regions and due to emissions from transportation. However, more affluent diets can reduce the effect.

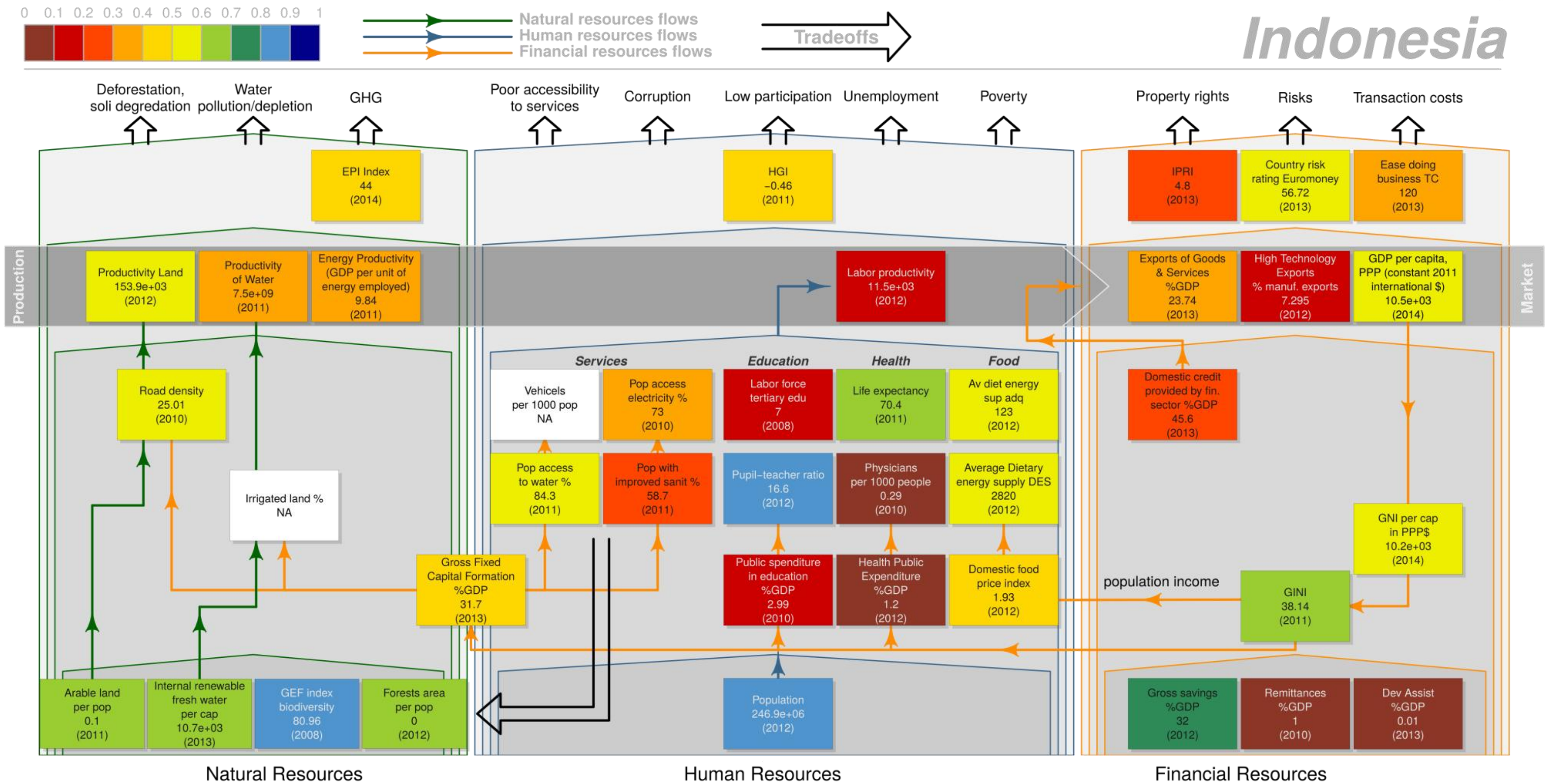
7.3 The Potential for Synergies and the Stage of Country Development

Climate change will impact different sectors in Indonesia. Sea level rise will impact agriculture and the rural population, and higher temperatures will reduce crop yields. Other issues of great importance are the consequences of high deforestation rates, an economic model based on mining, the overexploitation of natural resources, a high share of population deriving their income from agriculture, an increasing inequality and the government's low commitment to social development and environmental protection. Climate change has the potential to exacerbate the trade-offs produced by this model. Inter-sectoral trade-offs producing GHG emissions in Indonesia relate to energy and human development. Indonesia is also burdened by trade-offs between the expansion of industrial agriculture and mining against forests areas. Trade-offs within economic activities relate to the increased demand for energy in transport being supplied with fossil fuels, and peat fires. A strategy for synergies has to consider options for growth and development in an inclusive growth model that halts deforestation, increases agricultural productivity for food security and stops peat fires.

7.3.1 Growth, Energy and Development:

The country is a typical case of the resource curse (Sachs and Warner 2001). In respect to this observe in Figure 7-8 the wealth of Indonesia in natural resources (brown and dark-red colors represent very low; red and gold, low; yellow colors middle; green colors high; and blue colors, very high performances).

Figure 7-8: Indicators of the adaptive capacity of Indonesia.



The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. For climate resilience Indonesia needs to enhance environmental governance to protect its natural resources wealth, specialize more the economy and reduce income inequality –presently growing. Deficits in health and the gap in the provision of basic services are needed for adaptation. White color indicates non-available information.

Countries suffering from the resource curse used to rely on revenues from the exploitation of natural resources and do make commitments to foster development of infrastructure, better productive structures, institutions, markets and social development.

The environmental, economic and social trends mentioned above show that the government is committed to the development of components that benefit some specific sectors. By 2012 the country invested 32% of the GDP in fixed capital formation, i.e. a middle position in comparison to the rest of the world, but in the high range if compared to other countries in this study. The road density 25.01 km/km^2 is high, e.g. in comparison to Brazil which was 18.57 km/km^2 by the same year.

The performance of proficiency indicators shows that the country has not developed its productive structure. The high productivity of land is related to the high revenues of palm oil. The productivity of water and energy are low. The low added value of the economic outputs produced in Indonesia is observable in the very low share of high-technology products in manufactured exports. The portfolio of exports is to a large extent determined by mineral products, gold, palm oil, and rubber (Simoes and Hidalgo 2014). These activities require only low specialization, but an intensive exploitation of natural resources. The labor productivity is very low, while the development of the economy is further constrained by the low development of the financial system in the provision of domestic credit. Indeed, the provision of domestic credit is shrinking (see Figure 7-3).

For the transformation of trade-offs into synergies in the context of sustainable development and growth, the country needs an economic model that shifts from mining and activities driving deforestation, to other industrial and service activities whose added value roots in human capital. For enhancing human capital, the gaps in the provision of basic services need to be bridged. The country also needs to advance in the construction of better institutions for environmental, human and economic governance.

7.3.1.1 GHG Mitigation:

Forestry, agriculture, and the energy sector are the major emitting sectors in Indonesia (see Figure 7-2). In the National Action Plan to Reduce Greenhouse Emissions (RAN GRK) the Indonesian Government made the commitment to cut 26% of the GHG emissions by 2020 compared to projections of BAU scenario. With a range of mitigation strategies, Indonesia aims to achieve an optimal energy mix by 2020. This should be done by an increase of geothermal and biofuel energy production, but also by an intensification of nuclear, hydro, solar, and wind power production (Nachmany, Frankhauser, et al. 2014b). Additionally, in 2010 Indonesia signed a REDD+ partnership with Norway. Norway contributed US$ 1 billion towards REDD+ readiness programme.

There are currently 150 CDM projects registered for Indonesia with approx. 10 million CERs (certified emission reduction, 2014) (UNFCCC 2014a). Out of these 80 deal with waste handling and disposal, i.e. contribution to total emission reduction is limited. 69 deal with energy industries and a few others with agriculture, manufacturing, chemical and metal industries (UNFCCC 2014a). Here the potentials for emission savings are higher. There are also 10 PoAs registered in Indonesia. Furthermore, already three NAMAs are in progress, while two feasibility studies for NAMAs are worked on (NAMA Registry 2014). Indonesia is also undertaking several REDD+ activities 2009-2012 and has carried out phase one of the

UN-REDD programme (UN-REDD 2014). For a comprehensive account of projects, legislation and actions refer to appendix 4.

The main aim of the Action Plan to Respond to Climate Change includes the diversification of the energy mix, the increase in energy efficiency, and the promotion renewable energies (Nachmany et al., 2014b). The government has passed a series of regulations in recent years, including a Presidential Instruction on Biofuel Development in 2006 and a Ministerial Regulation that may foster the role of biodiesel and ethanol-blend fuel in the transportation sector (Nachmany, Frankhauser, et al. 2014b). The intention to promote biofuels might be presented as aligned with mitigation. However, the reality is quite different, since the expansion of plantations for biofuels is responsible for the highest share of GHG emissions in Indonesia. Nevertheless, a lot of work has already been done in mitigation with the National Action Plan as a major step towards climate change-related policy frameworks. In comparison to other Non-Annex I countries, Indonesia has one of the better developed national policy frameworks on climate change and can be therefore classified as a middle league player in terms of its climate change mitigation-related actions. However, the pledge to reduce emissions by 26% below BAU unilaterally and 41% with sufficient additional international support up to 2020 is very ambitious.

7.3.2 Agriculture, Food Security, Deforestation and Peat Fires:

Indonesia is not particularly threatened by food security issues. The country is food self-sufficient, i.e. nearly 60% of peri-urban land is used for agriculture and the country uses only 50-60% of its potential of possible crop production per cultivated area. However, by 2050 the country will need to increase agricultural outputs and increase agricultural land to maintain its self-sufficiency. Demand for increased food outputs is driven by the existing malnutrition 23 million Indonesian in 2013. In addition, 74% of the total population spent 56.21% of their income in food in 2012. Programs for poverty reduction are losing impetus.

Climate change will negatively impact the crop yields of rice, soya and maize (Amin et al. 2004). Indonesia has room to improve the productivity of land in agriculture. Currently, the productivity of land in Indonesia is US$ 1,421. In contrast, Vietnam and the Philippines have a land productivity of US$ 1,976 and US$ 1,948.4. The main staple crop in Indonesia is paddy rice and advanced management needs to be applied in order to limit methane emissions.

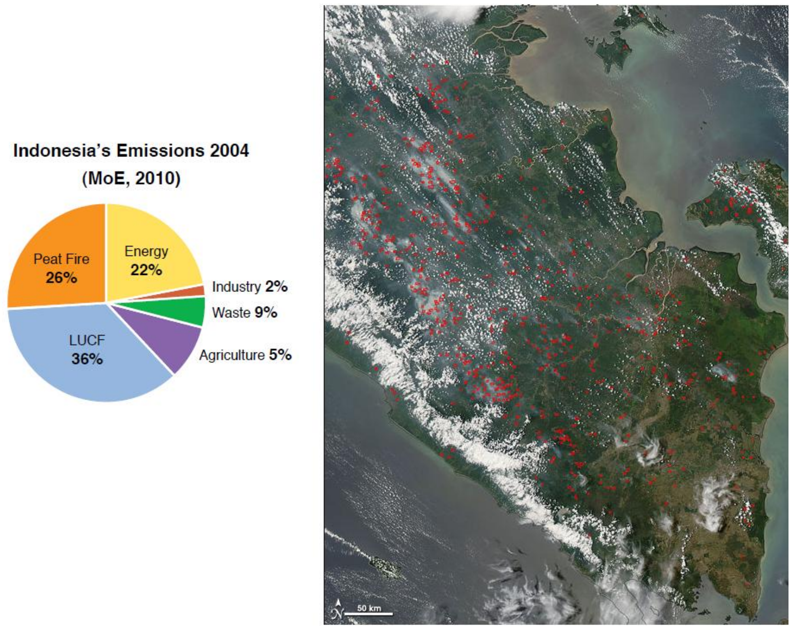
Closing the yield gap and promoting peri-urban agriculture is a second option. Major parts of the country so far have attained around 50% to 60% of the potential crop production (Pradhan et al. 2015). This would enhance food security in the short and middle term, reduce transportation costs and reduce emissions from transport. Shifting pastures into cultivars and improving peri-urban agriculture are not enough to ensure food self-sufficiency. Population growth and changes in dietary lifestyles will reduce the self-sufficiency of Indonesia. In addition, distributional problems need to be addressed, to reduce the high undernourishment of the country.

7.3.3 Deforestation and Peat Fires:

As of 2010 both peat fires (26%) and deforestation (36%) were responsible for 62% of total GHG emissions in the country (GIZ 2012) (see Figure 7-9). Indeed, if Indonesia reduces peat fires to zero by 2020 the country would meet the low commitment target of 2,214.9 $MtCO_{2e}$

by 2020. This is technically achievable and incentives exist. The Indonesia-Norway REDD+ Partnership has offered a strong monetary incentive to meet this target, despite functioning on a payment-for-results basis (P. Smith et al. 2014).

Figure 7-9: GHG and fires in Indonesia Sept 23rd 2007.



Graphic from emissions from BAPPENAS – GIZ (2012). Photograph of Fires in Sumatra from NASA ®[9]

It is unclear how the country will accomplish its targets regarding the elimination of peat fires. The country needs to develop its capacity to control deforestation and to eradicate these events. It requires effective monitoring systems like those developed by Brazil to control deforestation. Further it needs the capacity to mobilize human resources, fire brigades and authorities to any place of the country, and a system of enforceable laws to create disincentives. Despite the country's active legislative response, enforcement and land tenure issues continue to be central challenges when it comes to acting on deforestation, the country's main source of emissions. Experts criticize the legislations as being rather uncommitted, due to a lack of coordination with relevant ministries, a lack of common low-carbon transport vision, and as a consequence of leaving out other important causes for GHG emissions. With current policies and institutions it is unlikely that national targets will be achieved; however the uncertainty of LULUCF emissions makes an evaluation in this regard rather difficult (Hare et al. 2014). For effective action against deforestation and peat fires, high standards on environmental and human governance are required. However, Indonesia performs in the medium range in the environmental part[10] of the Environmental Protection Index.

The country also presents a low performance in human governance. The averaged value of the aggregated human governance indices is slightly negative. In all aspects –voice and

---

[9] http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19129&eocn=related_to&eoci=related_image

[10] As explained in the introduction of the tool, for the evaluation of environmental governance we disregarded the numeric assessment of health in the EPI index, and kept the environmental part for the assessment.

accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption, the country performs negatively but has been improving in the period 2003-2013 (HGI 2015).

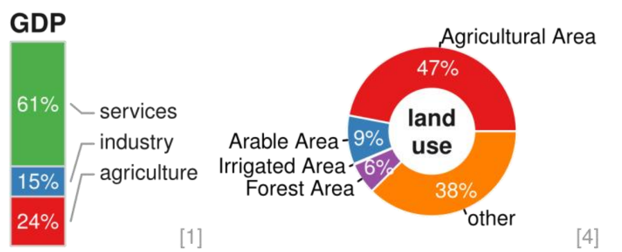
7.4 Conclusions:

The growth model of Indonesia is an archetypical example of a country system sustaining economic growth on the costs of natural and human resources. The economy is mainly based on mining, while deforestation in Indonesia is still the highest in the World. The reduction of trade-offs between the consequences of (no-)management of forests and its effects on the Indonesian population and on natural resources is mandatory. This will have a relevant effect for climate protection as well. Regarding the issue to control fires and deforestation Indonesia may be supported with advanced satellite technologies (cf. Brazil). Further, the country needs to develop its institutions, human capital, laws to promote more sustainable management practices. The country should reduce deforestation, while the international community should redouble its efforts to support Indonesian activities. The country should invest more efforts in the diversification of the economy into industry and services.

8. KENYA

Figure 8-1: Kenya – Factsheet and physical map. Main water towers (stars) and the Lotipiki Basin (orange dashed).

Country size	580,367 sq km	[1]
Coastline	536 km	[1]
Population	45.55 millions	[2]
Rural population (%)	74.8	[2]
Human Development Index	0.54 (147 of 187 – Low)	[3]
Life expectancy at birth	61.72	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

8.1 Sensitivity and Vulnerability

8.1.1 Sensitivity and Vulnerability of Natural Resources

Kenya is among the countries lacking in detailed studies of climate change projections. In order to compensate this deficit the UNDP developed the Climate Change Country Profiles. For the case of Kenya this report relies on the information provided by this study. Climate change projections for Kenya were calculated considering A2, A1B, and B1 SRES forcing scenarios for 2030, 2060, and 2090 (Mcsweeney et al., 2010).

Temperature: Mean annual temperature has increased by 1.0°C since 1960, at a rate of around 0.21°C per decade (Mcsweeney et al., 2010). The mean annual temperature is projected to increase by 1.0 to 2.8°C by 2060 and 1.3 to 4.5°C by 2090 (Mcsweeney et al., 2010).

Water resources, rainfall and precipitation: Observations of rainfall in Kenya since 1960 do not show statistically significant trends (Mcsweeney et al., 2010). Trends in the extreme indices based on daily rainfall data are inconsistent. Only a few areas in the country in the vicinity of the city of Nairobi will experience higher rainfall (SEI 2009). All remaining parts of the country will experience slight decreases in rainfall (SEI 2009).

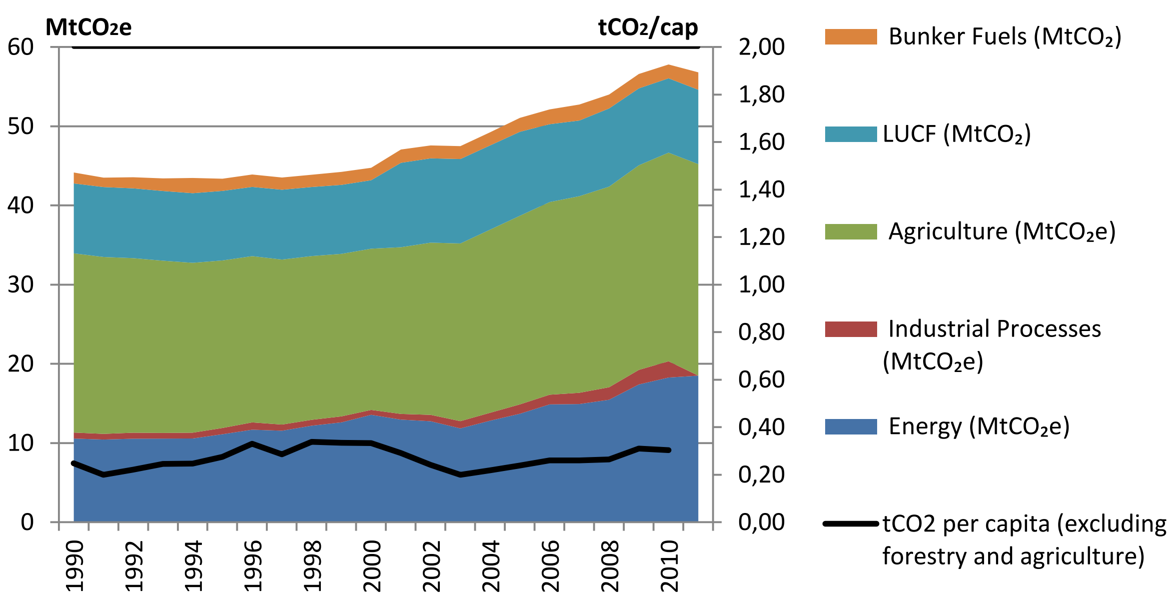
Water scarcity is the major problem for Kenya's people and its economy. Although the number of droughts events have been constant in Kenyan history, in the last thirty years they increased in frequency and intensity (Mateche 2011). The population affected by these droughts have grown exponentially over these years (Mateche 2011). According to the

Ministry of Forestry and Wildlife (UNEP 2012) five water towers provide 75% of total renewable water resources in Kenya: Mau forests, Mont Kenya, the Aberdares, Mont Elgon, and Cherangani (see Figure 8-1). They produce annually 15,800 million cubic meters ~75% of the country's renewable surface water resources (UNEP 2012). Due to the logging of 50,000 ha in these zones, water availability from these towers has been reduced in 62 million cubic meters per year between 2000 and 2010 (UNEP 2012).

The recently discovered aquifer in the northern and central Turkana County (the Lotipiki Basin (see Figure 8-1)) represents an important source of water for development and the mitigation of drought impacts in Kenya. According to estimates, almost 700,000 people can benefit from these resources (UNESCO 2013). The replenishment rate of the aquifer is 1.2 billion cubic meters per year and can supply the needs of entire the Turkana region.

Atmosphere: As Figure 1-2 shows Kenya's per capita CO_2 emissions are among the lowest in the world and did not show a significant rise in recent years. In terms of composition agriculture accounts for about half of all emissions, energy for one third, and LUCF for 10%.

Figure 8-2: GHG sectoral emissions and energy per capita emissions of Kenya.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from waste are negligible (WRI 2014) and were not included. Emissions per capita are far below the 2 2 tCO_2 per capita per year required to keep global warming below 2°C by 2050 (WBGU 2009a). For synergies, relevant sectors for mitigation include energy, agriculture and deforestation (LUCF).

Land Use and Forestry: 48.2% of land in Kenya is used for agriculture (FAO 2014b). Protected areas account for 12.12% of total land (FAO 2014b). Forest areas are only about 6% of total area and decreasing (FAO 2014b). In 1963 around 12% of the Kenya's land surface area was covered by forests (Nema 2013). Agricultural expansion, extraction of wood for charcoal and firewood are the main drivers of deforestation (Ruri 2013). According to the Ministry of Forests and Wildlife, other drivers include logging of indigenous trees, marijuana cultivation, cultivation in the indigenous shamba system practices, livestock grazing, quarry landslides, and human settlements (UNEP 2012). Deforestation in Kenya has been also attributed to past policies, institutional failures and corruption (MoE 2013). The Aberdares, the Mau Complex, and Marsabit forests are under risk (Ruri 2013).

8.1.2 Economic Vulnerability

The Kenyan GNI per capita is very low (US$ 850 in 2012) even compared to sub-Saharan developing countries (US$ 1345 in 2012) (World Bank 2015a). It reduces the capacity to avail funds to buffer shocks. The cost of flooding has reached 2.4% GDP per year (NCCAP 2012). The cost of the droughts in 1998-2000 amounted US $2.8 billion (SEI 2009). The economy in Kenya is highly sensitive to political affairs. Moreover, the slowdown in the manufacturing industry in 2011, was due to political uncertainties (World Bank 2013e).

Economic impacts on agriculture and tourism: The economy of Kenya is highly vulnerable to projected climate change impacts affecting water resources and increasing droughts, due to the high GDP share from agriculture (30% in 2012) (World Bank 2015a). By 2007 75% of the population in Kenya derived their income from agriculture (WFB 2015). Similar holds for the tourism (12.1% in 2013), which can be also affected by adverse consequences of climate change (Knoema 2013). As of 2013 tourism contributed to 10.5% of total employment (Knoema 2013).

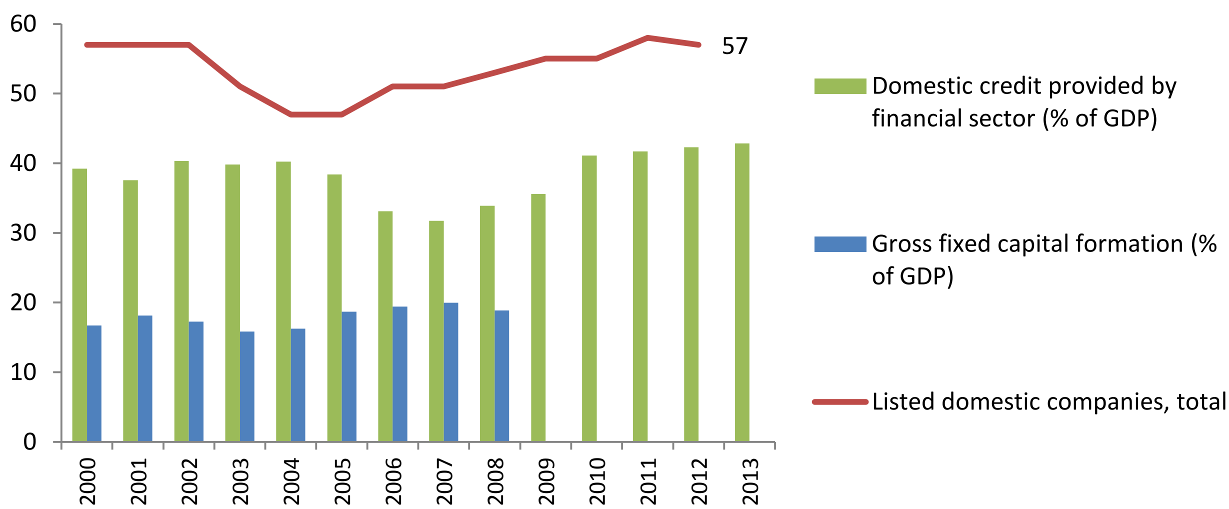
Impacts on productive factors: The low development of electricity, infrastructure, and labor contribute to the low adaptive capacity of Kenya. Electricity is costly and blackouts are frequent (World Bank 2013e). Energy shortages will cause almost 3% of the GDP losses each year until 2030 (Bassi et al. 2011). Moreover, the density of roads (10.67km/km^2) is even lower than in a large country such as Brazil (18.57km/km^2). In addition, Kenya's labor productivity has been falling in the recent past, while at the same time, labor costs have been rising fast compared to their productivity (World Bank 2013e).

Economic specialization and diversification: Economies will low diversification and low specialization will be more vulnerable to changes in prices and trade conditions. The higher the specialization and the diversification are, the better the adaptive capacity. By 2013 exports represented 17.7% of GDP (WFB 2015). Considering the number of commodities exported as a proxy for economic diversification it can be concluded that the Kenyan economy is relatively more diversified than other sub-Saharan countries. As of 2012 the country exported 996 products (more than Mali 537 and Ethiopia 592) (Simoes and Hidalgo 2014). However, the portfolio of exports is concentrated in few agricultural products. In 2012 tea, cut flowers, coffee, and legumes accounted for 46.76% of total exports value in Kenya (Simoes and Hidalgo 2014). This implies that national revenues strongly depend on a few agricultural products, likely to be affected by the impacts of climate change. Thus, Kenya is relying on a lowly diversified and specialized economy.

Capitalization and Capital Formation: High investments in gross fixed capital formation show the commitment to enhancing basic infrastructure for adaptive capacity. For the elements creating the accessibility to capital and financial resources for adaptive capacity, Figure 8-3 shows that the performance of the financial sector in the provision of credit has been relatively poor. Yet, the sector was not affected by the financial crisis in 2008, i.e. afterwards it has maintained growth. However, the share of credit provided is still low. In other countries in this study, domestic credit from the financial sector even surpasses 100% of GDP.

Investments in gross fixed capital formation (infrastructure, schools, hospitals, etc.) have not been consistent showing a low capacity for long-term planning. In addition, the number of listed companies serves to indicate the diversification of the economy. As the trend shows the number of listed companies has varied between 2000 and 2013, but in the end has remained at a similar level. In other countries of this study, e.g. Mexico, Brazil, Colombia or Vietnam, this number has varied significantly, showing either a process of concentration of capital or one of diversification. This number in Kenya would suggest certain stagnation around some fixed number of activities, i.e. no diversification.

Figure 8-3: The recent evolution of capital in Kenya.



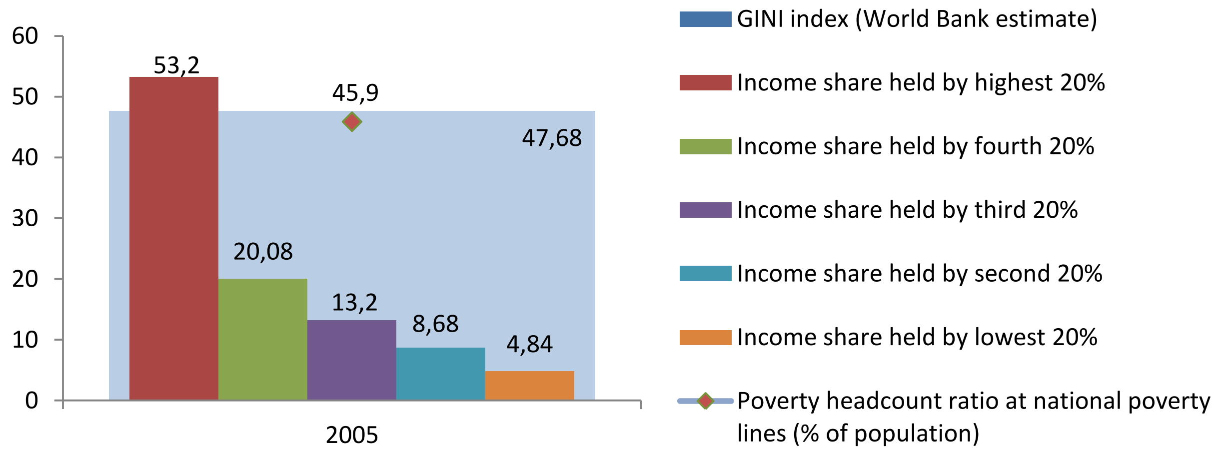
Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a), and investments in gross capital formation (World Bank 2015a). For the analysis of the coping capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. Variable and low GDP shares for the provision of domestic credit and the development of infrastructure reflect the low capacity to maintain policy investments goals. Low and variable shares of GDP for the provision of domestic credit make more difficult to avail funds for coping with shocks. The low and non-changing number of companies listed shows low diversification of the economy. These numbers indicate the inadequacy of the economic model of Kenya for synergies and the pursuit of climate resilient pathways.

Economic Risks and Uncertainties: Indicators of the governance of risk also show the vulnerability of the Kenyan economy. Inflation has been relatively high in this century (10.15% in average), and variable (standard deviation 5.82%) (World Bank 2015a). Due to the low development of productive factors, i.e. electricity, road infrastructure, and human capital, transaction costs in Kenya are high. In the ease doing business, which evaluates the environment facilitating development of business, the country ranks on position 129 (out of 181 countries). The country risk index (38.04 as of 2013), which evaluates structural, political, and economic risks (Euromoney 2014) places the country in the third decile (low). Property rights in Kenya also are important sources of economic uncertainties. The low performance on property rights would indicate social conflicts due to insecure property rights. In the International Property Right Index (6.4 in 2013) Kenya performs in the second decile (very low) relative to the rest of the World. The IPRI index evaluates the strength of property rights on a scale from 0 to 10 (IPRI 2014).

8.1.3 Social Vulnerability

Inequality in Kenya is high (see Figure 8-4) and constitutes a factor in its social vulnerability. Only 0.26% of the population belongs to the higher consumption segment and 1.83% to the middle segment of consumption, whereas 14.3% belongs to the low and 83.6% to the lowest segments of consumption (World Bank 2014e). Within the rural population 28.8 million belong to the lowest segment of consumption, 2.1 million to low consumption segment, and only 61 thousand to middle consumption segment (World Bank 2014e). The total rural and urban population belonging to the lowest segment of consumption amounts 33.5 million. This segment spends 67.3% of their income in food. 45.9% of total population lived below the national poverty line in 2005 (World Bank 2015a). Moreover, food and beverages represent on average 55% of the total expenditure of income in Kenya (World Bank 2014e).

Figure 8-4: The situation of income distribution, income inequality and poverty in Kenya from available information.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The poverty headcount ratio (World Bank 2015a) cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. High inequality and high poverty headcount ratio make evident the existence of social trade-offs that need to be corrected.

People are highly vulnerable to current weather variability in Kenya. Floods in 1997/98 affected almost 1 million people and produced damage related cost to infrastructure, health problems, and loss of crops affecting food security (SEI 2009). The flood in 2006 affected 723,000 people (SEI 2009). Droughts have been even more harmful to the Kenyans.

Food security: Food insecurity is a major issue due to changes in average temperature, extremes associated to weather (droughts and floods), and the share of vulnerable population living in rural areas. 25.8% of the population was undernourished in 2013 (FAO 2014b). Additionally, the inadequacy of food supply reached 36% of the total population (FAO 2014b). The situation of the country in food security is confirmed in the value of food adequacy. Kenya needs to import cereals (Pradhan et al. 2015a).

Health, Sanitation, and Water Services: With no adaptation, the rural population will be impacted from malaria in Kenya, due to the spread of the vector towards high altitude areas (SEI 2009). In 2050, malaria could affect 2.9 to 6.9 million people (SEI 2009). Costs on health would rise to US$144 - US$185 million (SEI 2009). With only 36$ per person invested in health (World Bank 2015a), 0.18 doctors per 1000 people in 2011 (World Bank 2015a) and a low life expectancy (60.4 years) (World Bank 2015a), the country appears very vulnerable to the increase in malaria expected. The rural population with access to improved water resources increased from 43% in 2000 to 55.1% in 2012, but access in urban areas decreased from 87.4% to 83.3% over the same period (World Bank 2015a). As of 2012 nearly 17.3 million Kenyans had no access to improved water resources. In regard to sanitation, between 2000 and 2012, the percentage of rural population with access to improved sanitation facilities increased from 28.5% to only 31.3%; and from 34.6% to 35.3% in urban areas. Nearly 30 million Kenyans had no access to water sanitation (World Bank 2015a) in 2012. In addition, and to worsen the situation, the rural population with access to electricity was only 6.7% in 2012. In urban areas, only 58.2% of the population had access to electricity in 2012. 21 million Kenyans had no access to electricity in 2011 (World Bank 2015a).

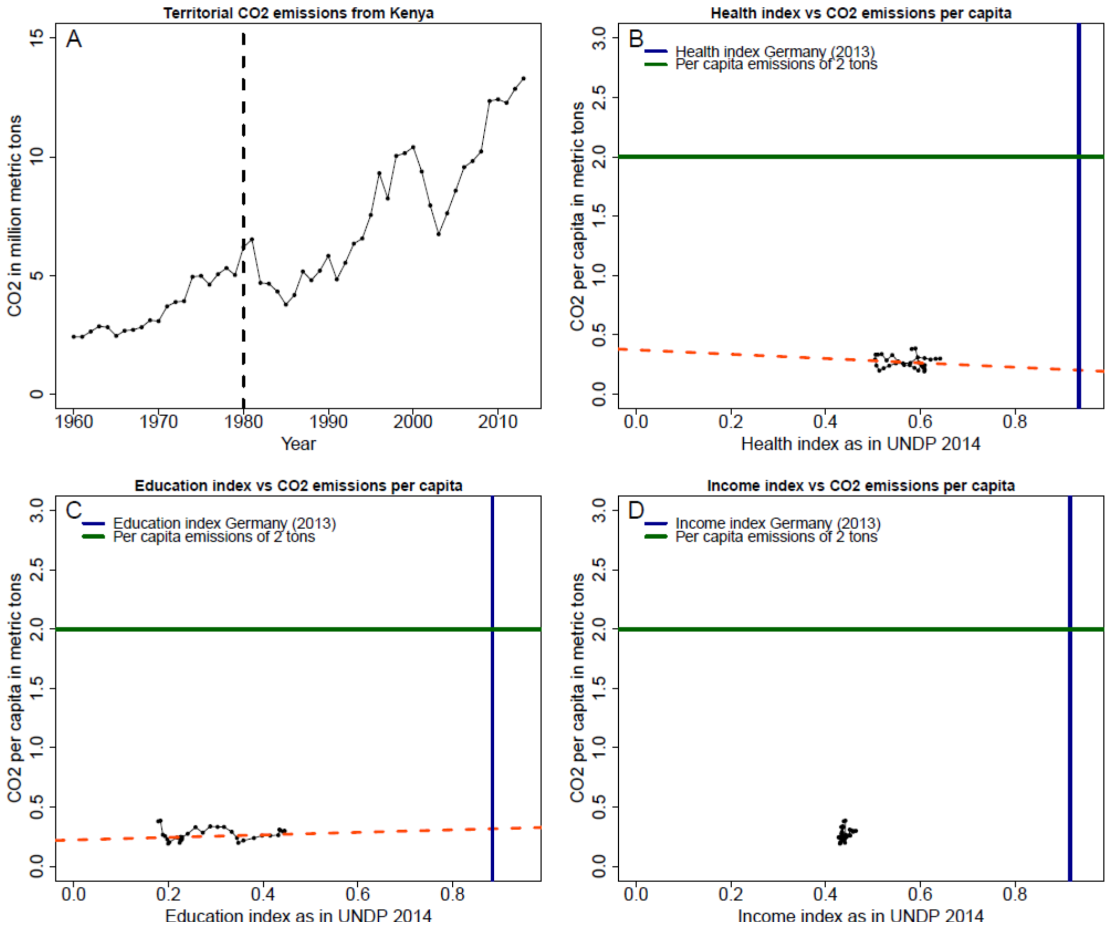
Education: The percentage expenditure in education is very low in Kenya, only 6,6%. It ranks very poorly compared to the rest of the world. Unfortunately, much information about education in Kenya is missing. Average absence from school in Kenya was 15.5%, absence from classroom 42.2%, and time spent in teaching 2h 40min (Martin and Pimhidzai 2013). Private schools' teachers spend more time in teaching (3h 28min) than public schools teachers (2h 19min) (Martin and Pimhidzai 2013). Based on Kenyan official curriculum, only 39.4% of teachers passed the test on minimal knowledge (Martin and Pimhidzai 2013). In terms of infrastructure and availability of inputs, on average there are 3.1 students per textbook. In 95% of the cases there was teaching equipment available, and in 58.8%, infrastructure available (Martin and Pimhidzai 2013).

8.2 Links between Adaptation, Development and Mitigation

8.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from Kenya show a strong inter-decadal variability with a clear tendency to grow. The only exception to this historical development has been a short-term decrease in emissions in the early 2000s. From 1960 to 2013 emissions from Kenya increased from about 2.5 to 13 million tons (Figure 8-5A). On a per capita basis, the CO_2 emissions have remained practically unchanged over the last 3 decades, oscillating between 0.2 and 0.4 tons per capita (Figure 8-5B). The level is below the suggested target of 2 tons per capita to keep global warming below 2°C by 2050 (WBGU 2009a).

Figure 8-5: Trends of CO_2 emissions and the HDI in Kenya.



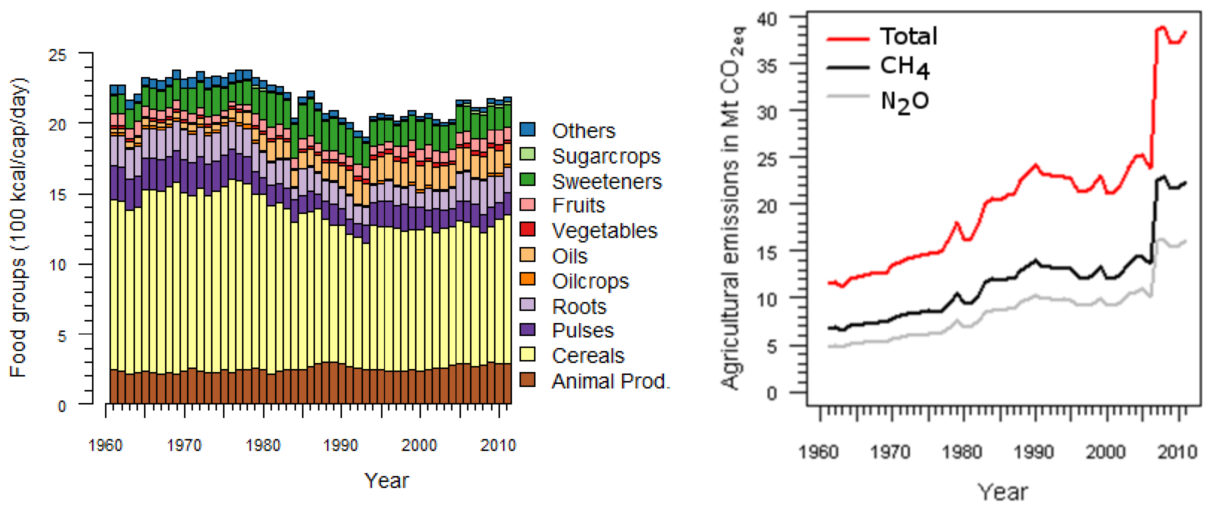
Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education, and health obtained from the World Bank 2014 database. The horizontal green line shows the 2 tCO_2/cap target (WBGU 2009a). The vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. The dashed orange line depicts the trend in average per capita emissions between 1980 and 2013. Finally, the dashed vertical line indicates the starting period of analysis for the panels B, C, and D. The flat trend of emissions per capita shows that the increased GHG in A is driven by population growth. Moreover, the income index has remained stagnant, the index of health does not show a clear trend, and the range of development of the education index is behind the development of the same index in other countries of this study. Increasing overall CO_2 emissions in Kenya are not contributing to the development of the elements of the HDI.

The relation to different components of human development and per capita emissions in Kenya is therefore a flat one, independent if one looks at the health, education or income components (Figure 8-5B, C and D). Progress achieved in the last 2 decades has been slow, remarkably slow in the case of income (see Figure 8-5D). For the cases of health and education some progress has been noted, but it is still very far off the standards reported in developed countries (see vertical blue lines reporting the situation of the respective index in Germany in 2013). The slow progress made by Kenya in Human Development as measured by the HDI is further supported by previous research, according to which Kenya is not expected to pass an HDI of 0.9 (indicative of high development) within the first half of this century (Costa et al. 2011). Despite stagnant per capita emissions, population growth is expected to drive emissions in Kenya to roughly 30 $MtCO_2$ in 2050 (Costa et al. 2011). These numbers show in more detail the dramatic situation of human development in Kenya. Income has remained almost stagnant over the last few decades, and health is not improving.

8.2.2 The Evolution of Dietary Lifestyles in Kenya and the Emissions Associated

Figure 8-6 (left) presents the evolution of dietary patterns in Kenya between 1961 and 2011 based on amount of 11 different food groups supplied in the country. Kenya's total food supply has decreased from 2,270 kcal/cap/day in 1961 to about 2,190 kcal/cap/day in 2011.

Figure 8-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Kenya.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (measured in CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Kenya during the last fifty years. The data was obtained from FAOSTAT (FAO 2014).

The current Kenyan food supply is close to its average dietary requirement of 2,130 kcal/cap/day (Hiç 2014) and slightly above the average food supply of East Africa of around 2,160 kcal/cap/day (FAO 2014b). During these five decades, supplies of cereals per person per day have decreased by around 150 kcal, and oils, sweeteners, and animal products respectively have increased by 110, 30, and 50 kcal/cap/day. Current per person animal product supply of 300 kcal per day is lower than the global average of 500 kcal per day. Supplies of total calories and the different food groups continuously decreased in Kenya until 1993 when it had the lowest calorie supply of 1,900 kcal/cap/day. The total calorie supply has increased after 1993. This depicts increasing food availability in Kenya and beginning of lifestyle shifts towards calorie rich and more nutritious diets.

In contrast, the total agricultural emissions of Kenya have more than tripled from 11 $MtCO_{2e}$/yr to 38 $MtCO_{2e}$/yr in the last 50 years as shown in Figure 8-6 (right). The increased emissions are related to increase in agricultural production to meet growing food demand driven mainly by population growth and the export of cash crops, e.g., tea and coffee. The sharp rise in the emissions between 2006 and 2007 is due to increased emissions from livestock sector (FAO 2014b). Yet, this increase in meat production has not been transferred to higher consumption of meat. Indeed, Kenya is a net food importer in terms of calories (Pradhan et al. 2015) while also being a net food exporter in terms of monetary values (FAO 2014b). This is because Kenya exports high value crop such as tea and coffee. Furthermore, diets currently consumed in Kenya embodied emissions of about 0.9 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 0.8 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013). The livestock production in Kenya is largely based on rangeland (Wint and Robinson 2007).

In the year 2000 approx. 3.6 million people lived in regions where local food and feed produced (model resolution10 km x 10 km) was sufficient to the meet actual food and feed demand (Pradhan et al. 2014b). Moreover, the country's food production was enough to feed around 15.8 million people, resulting in the rest of the population depending on international trade for part of their food supply. Kenya's net food import was about 7.2 trillion kcal in the year 2000. Kenya could become food self-sufficient by closing yield gaps to attain 50% of the potential crop production, resulting in 14 million people relying on local food and the rest of the population depending on intra-country food transfer. Major parts of the country so far have attained less than 30% of the potential crop production (Pradhan et al. 2015). Additionally, closing crop yield gaps, i.e. by better management can increase crop production and ensure current and future food self-sufficiency in Kenya if considering plausible population growth by 2050 (Pradhan et al. 2014b). Nevertheless, only closing yield gaps is insufficient to ensure the future food self-sufficiency if diet shifts will be also considered. The Kenyan population of around 41 million will partly depend on international trade by 2050 even by closing yield gaps to attain 90% of their potential crop production due to population growth and diet shifts.

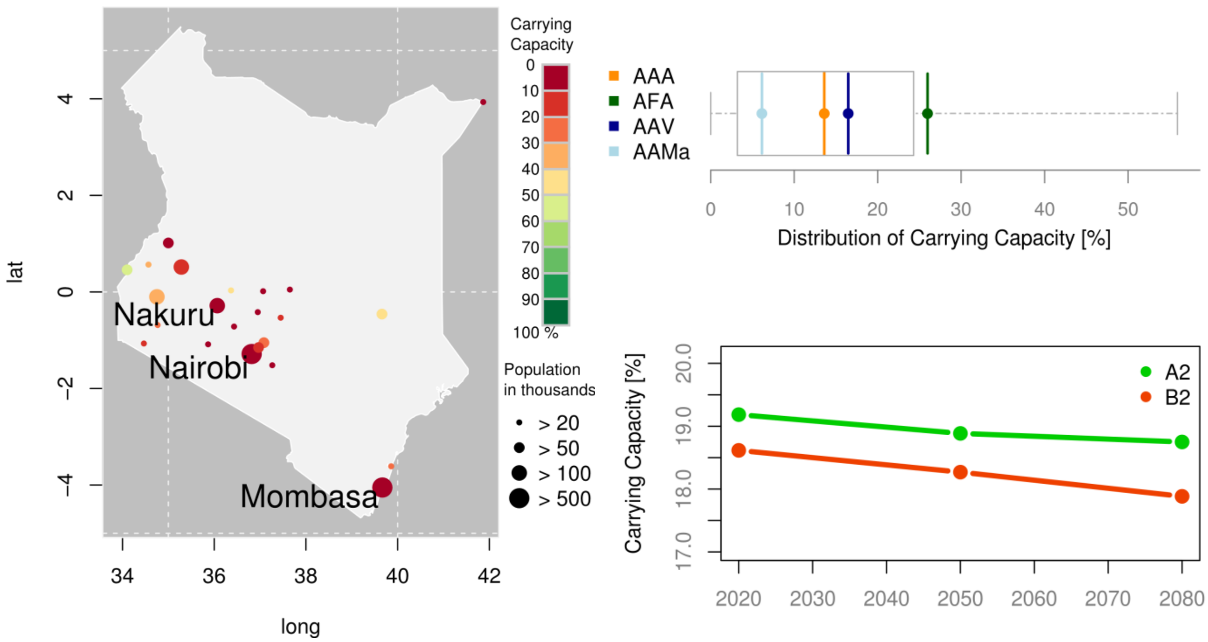
Dietary patterns in Kenya may increasingly be calorie and meat rich as the country becomes increasingly developed in the future, resulting in a larger volume of GHG emissions. Technological progress can transfer these trade-offs into synergies. Currently, emissions per unit of crop and livestock production in Kenya are higher than that of developed countries (Pradhan et al. 2013). Hence, technological progress in increasing agricultural productivity can also lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013).

8.2.3 Potential of Peri-Urban Agriculture and Local Food in Kenya

Just 25% of the 45.5 million people in Kenya live in cities, but the future population growth to 97.2 million in the year 2050 will occur mainly in cities and will raise the fraction of urban population to 44% (United Nations 2014). 23 cities with population above 20,000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 8-7). Overall these cities represent more than 4.2 million people. Today only 34% of the surrounding areas are used for agricultural purposes, although 87% of the surroundings are arable areas. From the currently harvested areas 10% of the urban dwellers can be nourished (Kriewald et al. 2015).

Today's yield gap ratio is around 0.19. Consequently, closing the yield gap offers the largest potential to increase the food self-sufficiency. Also a changed kcal-consumption or diet would have an influence as an increase up to 3,500 kcal/cap/day will reduce the carrying capacity to 6% (see Figure 8-7 – top right). 14 cities will face a decreasing carrying capacity by the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The summed up values decrease moderately from 18.5% down to 17.8% for an average yield scenario assuming an increased yield gap ratio (see Figure 8-7 – bottom right).

Figure 8-7: The possibility for a food supply from surrounding areas for Kenyan cities.



For current conditions (AAA) as a map (left) and the median carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario.

8.3 The Potential for Synergies and the Stage of Country Development

Kenya presents a serious situation. The country is underdeveloped and is highly exposed to weather related impacts –mostly droughts. As of 2013 one quarter of the population was undernourished (FAO 2015). Food supply is decreasing (FAO 2015) and income per capita is stagnant (see Figure 8-5). Moreover, water is scarce and deforestation is uncontrolled. Water towers are threatened by deforestation.

If changes are not undertaken climate change will exacerbate the environmental, economic, and social trade-offs. Two major trade-offs affecting natural resources can be clearly identified in Kenya: the reduction of water availability from deforestation, and the reduction of forests areas from the expansion of agriculture. Major sources of GHG emissions are agriculture and deforestation. As of 2012 agriculture and forestry accounted for 62% of total GHG emissions (WRI 2014). The expansion of cattle ranching is increasing the rate of GHG emissions (see Figure 8-6). Social trade-offs also exist in Kenya. A high share of the population is undernourished and current growth trends are not benefiting the population (see Figure 8-5). The outputs of increased production from agriculture and the expansion of cattle ranching are not being transferred to the population. A strategy for synergies has to consider additional options for growth and development in an inclusive growth model, energy security and human development, food security and the development of agriculture, and its connection with water governance and forests governance.

8.3.1 Growth and Development:

The country needs growth for human development and adaptation to climate change. Observe in Figure 8-8 that the country is wealthy in arable land per capita, but this land is not entirely usable for agriculture due to the scarcity of renewable fresh water resources per capita. Important underground water resources have been found recently in one of the most arid regions (the Lotipiki basin in the Turkana County) which constitute an opportunity for development. The indicators of Figure 8-8 also show that forest resources in the country are scarce. As the report showed, deforestation is still uncontrolled. It is driven by the expansion of agriculture and cattle ranching, illegal crops and charcoal burning.

Upon this resource basis, the country has not developed infrastructure. Road density is only 10.67 km/km^2 (FAO 2015). In addition, the share of irrigate land is very low compared to other countries in the world. This situation will change in the near future, at least in the Lotipiki basin (North-west region). For a successful development of agriculture based on irrigation in this region, the country needs to improve considerably in environmental and human governance. In the environmental part of the EPI index the country performs low. In the averaged indicators of human governance HGI (see Figure 8-8) the country also performs low. The international community has the opportunity to contribute to the development of Kenya by supporting the development of irrigation and development projects based on agriculture in this region, while creating incentives for better governance.

The low development of infrastructure explains in part the low performance in land and water productivity. But low productivity of natural resources is also explained by the overall development of the productive structure evident in the performance of all indicators of proficiency and markets. Indicators show, in addition, very low performance in the productivity of electricity. Blackouts are frequent as reported. Moreover, labor productivity is very low and further decreasing (World Bank 2013e). In addition, the financial system needs to improve the provision of credits. The current quota is low compared to the rest of the world (see accessibility to financial resources in Figure 8-8).

Kenya urgently needs to curb the actual economic trend. As the indicators of accessibility to social resources show in all indicators related to food, health, and basic services, the country needs to improve considerably. Complementary options include a reduction of income inequality (see Figure 8-4) and promotion of the diversification and specialization of the economy. An inclusive growth model requires high investments in education. As reported the performance in education is also very low. In the provision of services, the country performs in the very low and low categories. Under these conditions it is not surprising that labor productivity is very low in Kenya. Closing the gap in the provision of services is also needed. Agriculture still represents the source of income for 74% of the population and therefore a strategy for growth requires the generation of revenues from the increased productivity in agriculture.

Inclusive growth requires improvements in governance. The averaged index of human governance is negative. In every index composing the Human Governance Index (World

Bank 2015b) the country performs negative, without significant positive changes and even a decrease in the control of corruption between 2003 and 2013. The control of economic risks is also deficient. In the three indices used to assess economic uncertainties, the country performs low. Overall the table shows a very low developed country with high social vulnerability, a weak economy, and weak institutions.

8.3.2 Energy Security and Human Development

Kenya needs to substantially increase the production of energy, for growth and human development. As reported, by 2010 only 8% of rural population had access to electricity and 58.2% of urban population enjoyed this service in the same year. Blackouts are frequent (World Bank 2015a) with subsequent damages in productivity.

Kenya has clearly linked climate change action with its development agenda. It is striking that the country underlines the possibility of integrating adaptation and mitigation in future development. The overarching target of becoming a middle-income country laid out by the "Kenya Vision 2030" goes along with a low carbon development pathway emphasized in NCCRS and NCCAP. Although Kenya's focus lies on adaptation to climate change consequences, mitigation measures are carried out through the intention for a low carbon development, and through several CDM and PoA projects.

Despite the difficulties in economic and social issues energy supply in Kenya is to a large extent provided by renewable sources. Nearly 80% of the energy mix is based on renewable sources, and the share of renewables in electricity reaches 67%, with 44% of total domestic electricity supply from hydropower in 2011, 19% from geothermal, 4% from biofuels, and wind 0.2% (IEA 2014a). Oil products account for about 33% of all domestic electricity production (IEA 2014a). Imports of fossil fuels amounted to 4.7Mtoe in 2011 of oil, oil products, coal, and peat (IEA 2014a). These fuels accounted for about one fifth of the total primary energy supply in 2011 (IEA 2014a).

The Kenyan government clearly tries to scale up capacities, connect people to the grid and make use of the country's endowments of clean energy sources, as indicated by a number of recently registered CDM projects and their first NAMA. The country also tries to increase energy capacities by pursuing construction of fossil fuel based electricity and this could be encouraged by recent discoveries of domestic oil, natural gas, and coal.

The country's endowments provide further large potential for renewable energy, especially for geothermal, but also wind and hydro-based power generation (Government of Kenya 2013). In August 2013, the government launched the '5000+ MW in 40 Months Initiative, which includes the build-up of 3,000 MW coal and natural gas as well as 1,500 MW of geothermal capacity (UNFCCC 2014b).

The country can further develop its adaptive capacity in energy based on renewable sources. Most actions towards reducing emissions are conducted through their integration in the general development agenda. Appendix 4 includes the recently published official NAMA and several CDM projects. The country is host to seventeen registered CDM projects with a total emission reduction of 3,143,599 tCO_{2e}/year. Four projects deal with geothermal energy generation, four with wind energy, three with reforestation, two with hydro power, and one each with biomass, biofuel, biogas and energy efficiency. Furthermore, there are eighteen Programmes of Activities (PoAs) under the UNFCCC. In eight of them, Kenya is the only host party, and in ten it takes part along with other countries. The eight PoAs only addressing Kenya provide for 266,754tCO_{2e}/year - three are related to biomass, two to solar power, and one each to biogas, hydro power, and renewables in general. Quantitatively, geothermal and wind energy projects provide the largest emission reductions. Overall, it shows the commitment of Kenya to advance in energy security and mitigation.

8.3.3 Food Security and the Development of Agriculture:

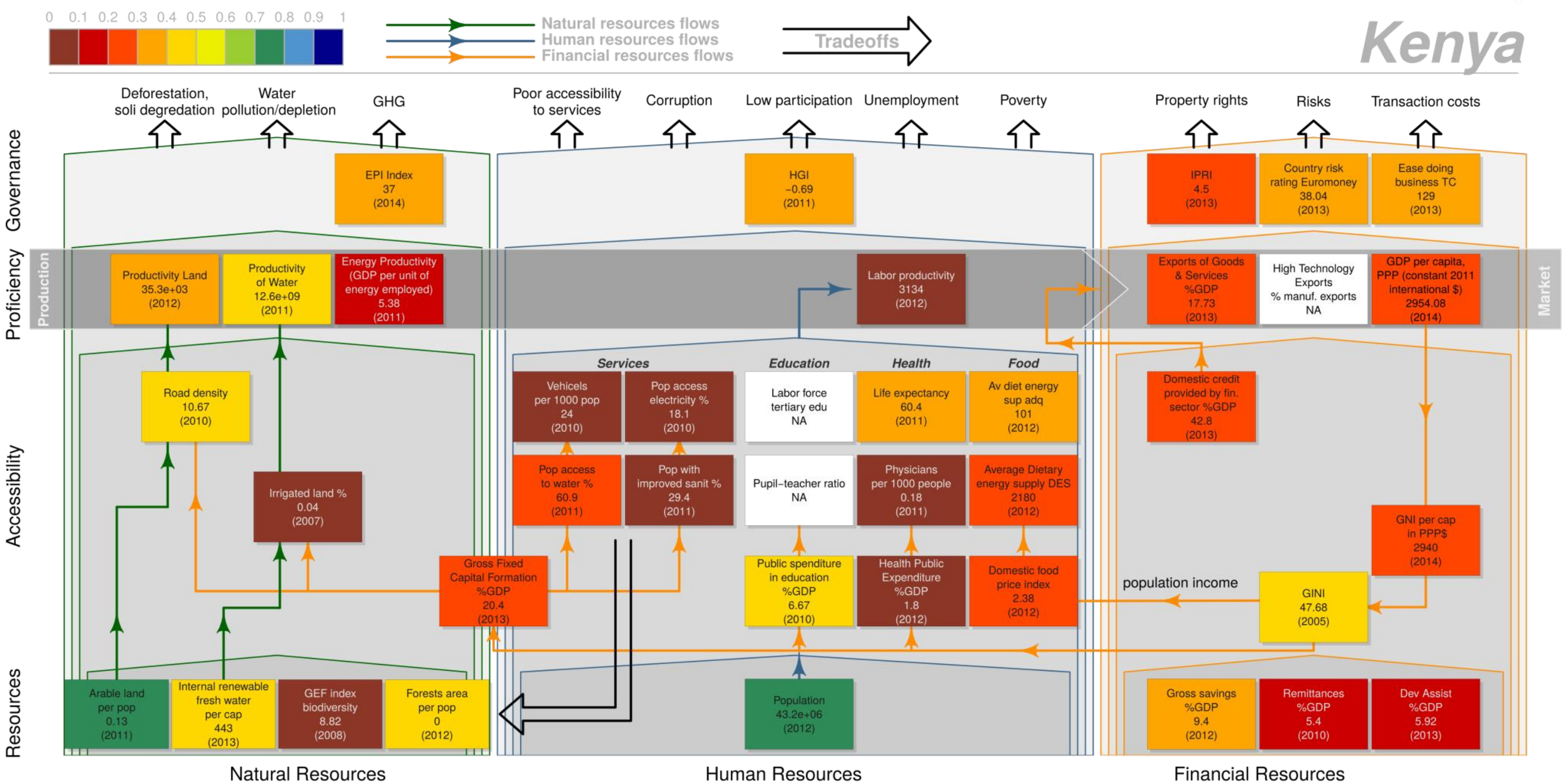
Part of the food insecurity of Kenya stems from the low food supply (see the very low performance of the average dietary energy supply in Figure 8-8). The country needs to work on other areas to increase the accessibility to food, responsible for the high undernourishment in the country (one quarter of the population in 2013). In addition, the performance in the dietary energy supply adequacy shows an insignificant margin of 1% (see accessibility to human resources in Figure 8-8). As reported, 33.5 million Kenyans spend 67.3% of their income in food (World Bank 2014e). The situation in food security is worsened by the low average food supply (2180 kcal/cap/day by 2012, FAO 2015).

Increasing the accessibility to food requires GDP growth and better redistribution of income. Positive GDP growth in this century has not been transformed into human development – especially income and health (see Figure 8-5). Inequality and the poverty headcount ratio are very high (see Figure 8-4). Yet, the ability to develop adequate policies and to implement them for effective changes in inequality is uncertain, due to high corruption and other challenges restricting governance (World Bank 2015b). At present, agriculture accounts for the largest share of emissions and provides for the further reduction potential which is addressed through several CDM projects and PoAs and mentioned in the NCCAP. The country requires a more comprehensive strategy that integrates growth, adaptation, the protection of water and forests resources, and increased agricultural productivity.

8.3.4 Enhancement of Water Sources:

Increased water scarcity from climate change and other drivers needs to be urgently addressed. Climate change will exacerbate water scarcity, but human action is probably more detrimental. The country has two options for improved availability of water resources and precipitation: the adequate management and use of underground water, and the enhancement of water towers. Developing improved water management is also a must in Kenya. Yet, it requires infrastructure, human capital, and enhanced institutions specialized in water management.

Figure 8-8: Indicators of the adaptive capacity of Kenya.



The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. The very low performance in most indicators shows the need to include growth as a basic component for the analysis of synergies in Kenya. Higher productivity and the diversification and specialization of the economy is needed to avail funds for social development and environmental protection. But the country needs to improve considerably in the governance of natural, human and economic resources. White color indicates non-available information.

The recent discovery of important underground water resources in the most arid region (the Lotipiki basin in the Turkana County) constitutes an opportunity to promote agriculture in the region, either crops or cattle. The international community can help Kenya implement efficient technologies and design effective institutions for water management in this deprived region. Financial support and adequate cooperation for enhancing adaptive capacity in water management would open the opportunity to work together in the development of well managed water systems.

8.3.5 Enhancement of Forests:

The NCCAP identified what has the most mitigation potential in the forestry sector. At the moment, this is addressed by the national target of 10 per cent tree cover of all land area and related domestic actions and a couple of CDM projects. In this context, the use of REDD+ could promote forest management. Forestation, reforestation, and afforestation offer the possibility to enhance the catchment of water in water towers. The international community could contribute to actual government plans in five water towers, by integrating REDD+ projects for mitigation into these plans. In order to succeed, local communities have to share benefits of projects targeting the protection and enhancement of water towers (S. Thomas et al. 2010).

8.3.6 Agricultural Productivity:

The country has deployed efforts to increase agricultural outputs. In 2012 agriculture represented 30% of the GDP of Kenya. The share of agriculture has varied between 32% in 1994, and 28% in 2004. Yet, GDP has steadily grown in these years even at high rates: 2.7% in 2009, 5.8% in 2010, 4.4% in 2011, and 4.6% in 2012 (World Bank 2015a). Agricultural area has grown below 1% since 1991 (FAO 2014b), it can be concluded that land productivity in the Kenyan agriculture has clearly increased. However, the productivity of labor in agriculture is still very low (US$369) even below the average of least developed countries (US$438) and Sub-Saharan developing countries (US$774) (World Bank 2015a). There is room to improve productivity, since major parts of the country so far have attained less than 30% of the potential crop production (Pradhan et al. 2015a). Efforts to further improve agricultural productivity could be accompanied by Research and Development, and agricultural assistance to reduce GHG emissions in the sector. Emissions per unit of crop and livestock production are higher than in developed countries (Pradhan et al. 2013). Both emissions and the demand for food will increase in the future due to population growth and changes in dietary patterns.

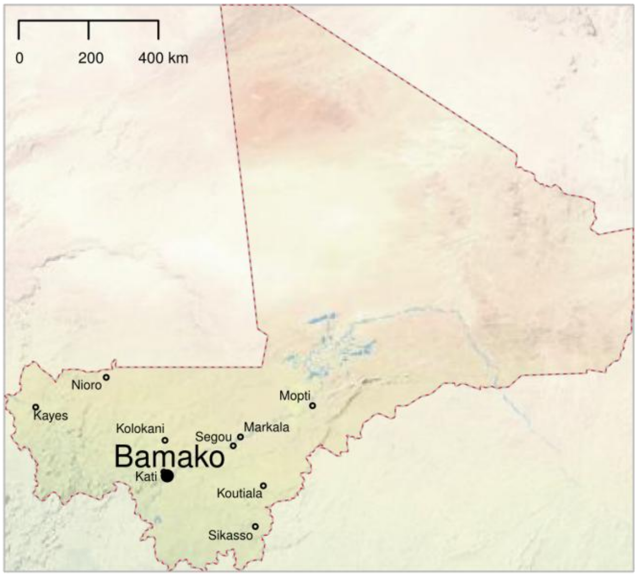
Efficiency in water use in agriculture has also improved. Agriculture used 76.43% of total water withdrawals in 1991. This share increased to 79.16% in 2012 (World Bank 2015a). The lack of irrigation systems restrains potential achievements in higher productivity of water and land. Only 1.9% of arable land is equipped with irrigation (World Bank 2015a). This is a very low score, even compared to the average of the least developed regions (11%).

8.4 Conclusions

Kenya is threatened by increased water scarcity. It is the only country in this study wherein the accessibility to basic services has even decreased in the last years. Food security is a major issue in the country. For synergies three axis need to be developed: increasing the productivity of agriculture, protecting and enhancing water sources, and developing the energy system. For an improvement of agriculture the country needs to invest more efforts and financial resources in Research and Development and in agricultural assistance. The country needs urgently to protect water towers. REDD+ may play a significant role to help Kenya to develop consistent plans for the enhancement of water bodies and water towers. However, there are significant challenges to overcome, i.e. insufficient governance, low environmental capacity and corruption. A new front of hopes for the poor population in the North-West has emerged from the discovery of important reserves of underground water in the Lotipiki basin. The international community can help Kenya to develop the capacity in water management with adequate technologies for water extraction and the design of adequate institutions for water governance and equity in this region. The country advanced in projects taking care for energy security, but remaining gaps are still large, i.e. regarding the large uncovered provision of electricity and the small installed capacity in electricity generation.

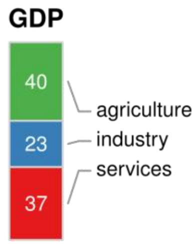
9. MALI

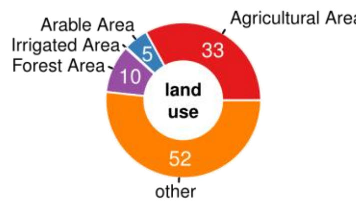
Figure 9-1: Mali – Factsheet and physical map:



Mali

Country size	total: 1,240,192 sq km
Coastline	0 km (landlocked)
Population	15.77 millions
Rural population (%)	60.9
Human Development Index	0.41
Life expectancy at birth	55.03
Child mortality	180
GDP per cap	7286050698.08





9.1 Sensitivity and Vulnerability

9.1.1 Sensitivity and Vulnerability of Natural Resources

Mali is among the countries lacking detailed studies of climate change projections. To compensate this deficit, the UNDP developed the Climate Change Country Profiles. For the case of Mali, this report relies on the information provided by this study. Climate change projections for Mali considered A2, A1B, and B1 SRES emission scenarios, for 2030, 2060, and 2090 (McSweeney et al. 2010a).

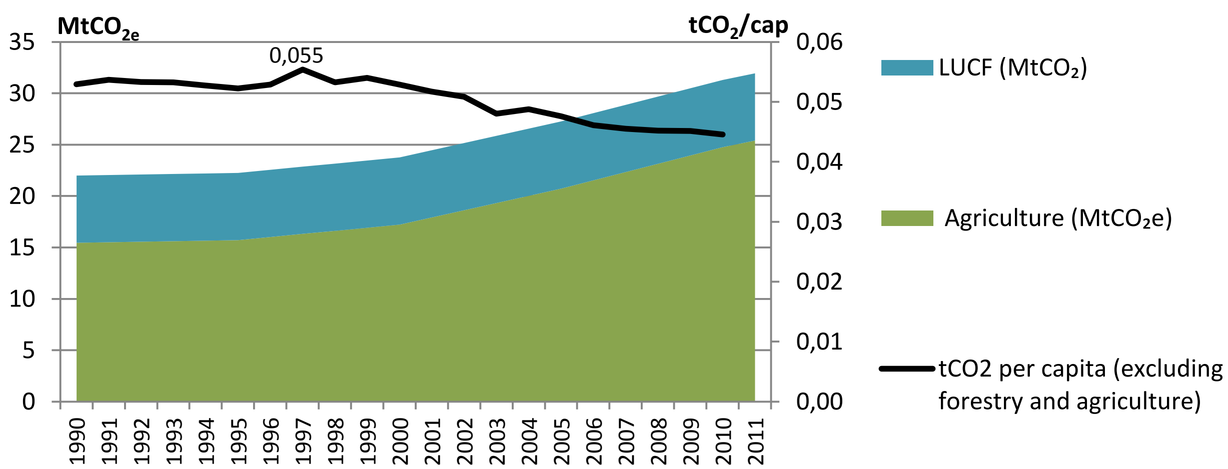
Temperature: Mean annual temperature has increased by 0.7°C since 1960, an average rate of 0.15°C per decade. The rate of increase has been larger in the hot, dry season, i.e. April-May-June, at 0.25°C per decade, but there is no evidence of a warming trend in the driest season, January-February-March (McSweeney et al. 2010a). The mean annual temperature is projected to increase by 1.2 to 3.6°C by the 2060, and 1.8 to 5.9°C by 2090. The projected rate of warming is similar in all seasons and regions.

Water resources, rainfall and precipitation: According to the study by McSweeney et al. (2010) projections on rainfall are more difficult to identify in Sahelian countries, due to high variability on inter-annual and inter-decadal scales. High rainfall occurred in the early 1960 but the early 80s were very dry. Rainfall in Mali has recovered to some extent since the 80s, i.e. the late 90s and early 00s have been relatively wet (McSweeney et al. 2010a). According to this study daily rainfall observations indicate a statistically significant decreasing trend in 5-day rainfall maxima since 1960. Annual 5-day rainfall maxima have decreased by 4.0mm per decade since 1960. The largest decrease was observed in the wet season (June-July-August) amounting to 4.9mm per decade (McSweeney et al. 2010a). Projected changes range from -22 to +25% by the 2090s with ensemble means between 0 and -11%. Decreases are largest in the north (McSweeney, New, and Lizcano 2010). The largest decreases in total rainfall, however, affect the south west of Mali in the wet season (July-August-September).

Crop Yields: Cotton is the main agricultural commodity produced in Mali (Simoes and Hidalgo 2014). Its production will be adversely affected by climate change (Traore et al. 2013). Cotton yields are more sensitive to the number of dry days/season than to other variables (Traore et al. 2013). On average 1 mm of rain is converted into 2 kg of cotton (Traore et al. 2013). An increase of 0.08 $^{\circ}$C of maximum temperature leads to a cotton yield loss of 24 kg/ha. Rainfall is the key limiting factor of in maize yields in the driest districts of Mali (Traore et al. 2013). Climate change will affect agricultural production and food security, mostly in rural areas (Pedercini et al. 2012). The Threshold21 (T21) model based on A1B scenarios (Pedercini et al. 2012) estimates a possible variation of yields due to climate change of -25% by 2050, and a loss of -2% of arid drylands, -1% of semi-arid drylands, and -0.5% of sub-humid drylands due to desertification.

Atmosphere: Total GHG emissions in Mali are mostly driven by agricultural production, land-use changes, and forestry, see Figure 9-2. Emissions per capita (excluding agriculture and LULUCF) are very low and further decreasing.

Figure 9-2. GHG sectoral emissions and energy per capita emissions of Mali.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from industry, waste, and energy are negligible and were not included. According to the emissions shares of the figure, relevant sectors for synergies are agriculture and Land use change in Mali.

Land Use and Forestry: Three climatic zones can be distinguished: the Southern (cultivated Sudanese), the central (semiarid Sahelian), and the northern (arid Saharan) (WFB 2015). Most of the land is desert. Only 6% of total land can be used for agriculture under normal conditions (FAO 2014b). Most of the population lives in the fertile Southern zone (NASA 2014). Climate change will exacerbate water scarcity and increase the number of dry days affecting agricultural zones adversely. Agricultural areas may expand into forests accelerating deforestation. Deforestation drivers include population growth, agriculture and the demand for wood fuel (Rademaekers et al. 2010). Deforestation outpaces by far the efforts in reforestation. Between 1990 and 2010 the country planted 795,000 ha, but deforestation cleared 2,377,000ha (FAO 2014b). Forests losses represent 1.3%, while 11.2% of the total land are forests area of 1990 (FAO 2014b).

9.1.2 Economic Vulnerability

The Malian GNI per capita is among the lowest in the world (World Bank 2015a). Government revenues are low, reducing the capacity of available funds to buffer shocks. The financial situation of Mali has worsened after the coup and an uprising in 2012. The external debt went from 4.4% of the GDP in 2010, to 17.77% in 2013 (World Bank 2015a).

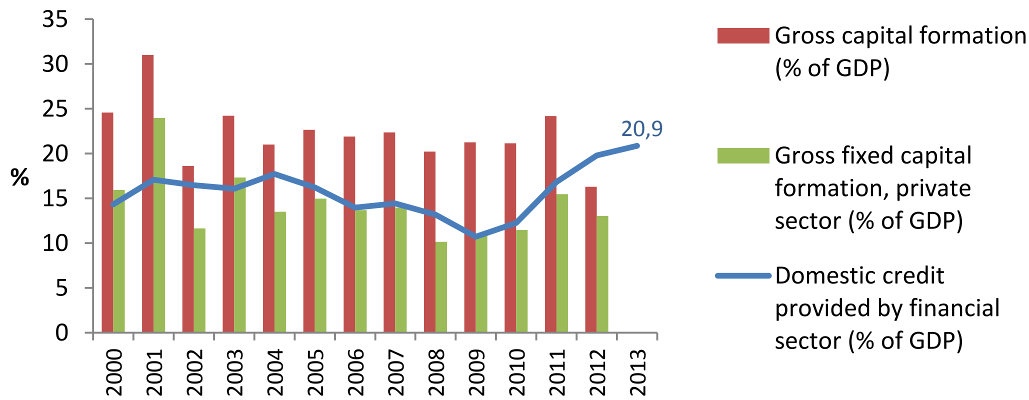
Economic impacts on agriculture: Climate change will affect the crop yields in Mali due to higher temperatures (see section 9.1.1). Climate change will likely exacerbate the scarcity of water further affecting crop production. Agriculture contributed 42.26% to GDP in 2012 (World Bank 2015). The economic contribution of agriculture increases when it is taken into account that the industrial activity is concentrated on processing farm commodities. As of 2005 80% of the population derived their income from agriculture in Mali (WFB 2015). Therefore, climate change has the potential to affect adversely the economy of Mali.

Productive factors: Road infrastructure is insufficient (Briceño-Garmendia et al. 2011) with a road density of only 1.81 km/km^2 as of 2013 (FAO 2014b). Mali is a landlocked country. For international trade it depends on the road infrastructure of neighboring countries. Three international corridors provide access to ports: Tema–Ouagadougou–Bamako, Dakar–Bamako, and Abidjan–Ferkesessedougou–Bamako (Briceño-Garmendia et al. 2011). Mali has paved almost 100% of the regional road network within its boundaries. Mali has signed agreements with China about US$11 billion mostly to finance two major railway projects linking to the coast (AFMI 2014a). For electrification the government as continued the policy of installing thermal power plants with high average prices and ignoring potential interconnection with neighboring countries, mostly West Africa (Briceño-Garmendia et al. 2011). The price of a KWh is high, but still insufficient to cover generation costs (Briceño-Garmendia et al. 2011). The generation of electricity requires massive petroleum imports. Transaction costs of heavy crude oil are high in neighbor countries (Mali 2013). Illiteracy in Mali is still high and labor productivity is among the lowest in the world (World Bank 2015a). But efforts are evident. The literacy rate has steadily grown from 30.54% in 2003 to 47.1% in 2011 (World Bank 2015a). However, it is still an obstacle for diversification, specialization, and growth.

Economic specialization and diversification: As the number of commodities exported serves as proxy for diversification, it can be concluded that the economy of Mali is lowly specialized and lowly diversified. Exports represented 22.5% of the GDP in 2014 (WFB 2015). Six products (gold, raw cotton, prepared cotton, mixed mineral or chemical fertilizers, bovine and oily seeds) accounted for 89.21% of total exports value in 2012 with gold providing 59.09% of the total exports value (Simoes and Hidalgo 2014). Therefore, the revenues of the country are very sensitive to changes in international prices of gold and cotton. The country has made efforts to diversify the economy with investments in tourism. In addition, Mali is developing its iron ore extraction industry to diversify foreign exchange earnings. This diversification strategy would make the country less vulnerable to climate change. In conclusion, the economy is lowly diversified. Moreover, the high share of mineral and agricultural commodities in the portfolio of exports indicates a very low specialization of the economy.

Capitalization and Capital Formation: As Figure 9-3 shows both private and public investments in gross fixed capital formation in Mali are highly variable, denoting deficiencies in planning or execution capacity. In 2012 these investments dropped as a result of the political conflict that year. In addition, the performance of the financial sector in the provision of credit has been very poor (in some other countries of this study it reaches even beyond 100% GDP). The spread of banking services is also low, i.e only 8.2% of people above 15 years old had a bank account in 2011 (World Bank 2015a).

Figure 9-3: The recent evolution of capital in Mali.



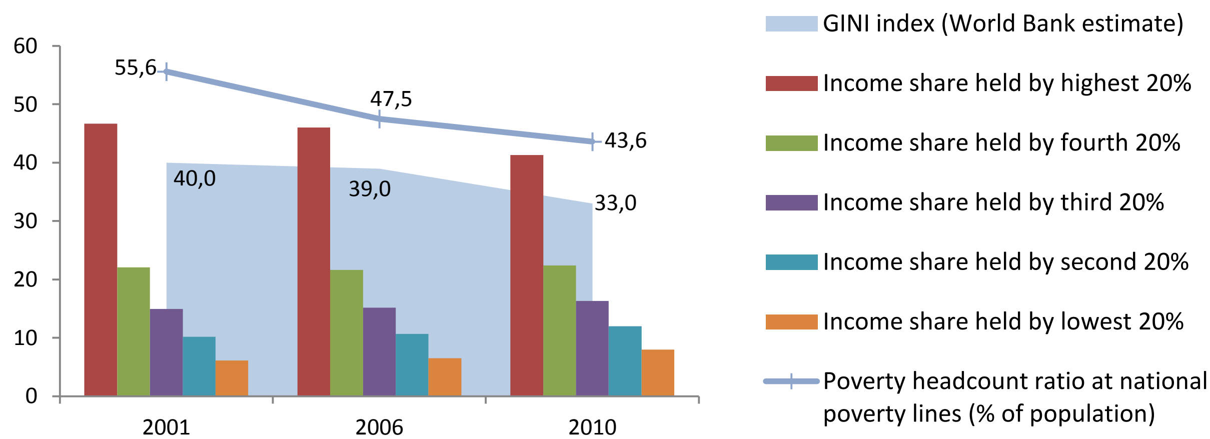
Domestic credit provided by the financial sector (World Bank 2015a), and investments in gross capital formation (World Bank 2015a), private and public. Variable trends of investments on capital formation and the provision of domestic credit indicate the low capacity to develop capital and avail financial resources for growth and development required for synergies.

Economic Risks and Uncertainties: Indicators of the governance of risk also show the vulnerability of the Malian economy. After 2000 the country has suffered from deflation four times, in 2000, 2003, 2004 and 2013 (World Bank 2015a). Average inflation has been 2.49% since 2000, but it is still volatile (standard deviation 3.41%) (World Bank 2015a). Due to the low development of productive factors it is unsurprising that transaction costs in Mali are high. If the ease of doing business is taken as a proxy for transaction costs the country ranks 160 in 2013. The country risk index (Euromoney 2014) which evaluates structural, political and economic risk (32.04 as of 2013) places the country in the third decile. The performance on property rights indicates that social conflict would not be rooted in conflicts with land tenure. In the International Property Right Index (6.4 in 2013) Mali performs in the fifth decile compared to the rest of the World. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). Overall the values of these indicators show low capacity to control inflation, transaction costs and risk.

9.1.3 Social Vulnerability

In 2010 78.78% of the population lived below US$2 per day. Moreover, 50.6% of the Malian population lives with less than US$1.25 per day. The poverty rate has risen to 42.7% in 2012 from 41.7% in 2011 (AfDB 2014). As Figure 9-4 shows, income inequality exists, but decreased between 2001 and 2010, from 40.01 to 33.02 (World Bank 2015a). The GNI per capita is among the 10% lowest in the world (US$1100 in 2012), i.e. biases in income distribution are relatively low. The income from the wealthiest share is being transferred to the poorest shares. However, the Malian population is getting more vulnerable due to political issues, insufficient governance, and the fact that GDP growth does not offset population growth. The GDP grew 3.28% on average between 2008 and 2013, while the population grew at a rate of 3.07% and debt increased over the same period (World Bank 2015a).

Figure 9-4: The recent evolution of income distribution, inequality and poverty in Mali.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. The high poverty headcount ratio shows the high vulnerability of the population and the need to include social trade-offs in the analysis of synergies.

Food security: According to Eozenou et al. (2013) chronic malnutrition is high, with 44% of Malian households and 66% of food poor Malian households having at least one stunted child. A 25% increase in cereal prices and a 25% decrease in cereal production are estimated to increase the number of food poor by 610,000 people. An estimated US$ 5.4 million of extra aid per year will be needed to lift the newly food poor above the food poverty line. About US$ 182 million per year is needed to do this for all existing and new food poor. Vulnerability incidence is in general two to three times higher among the poor than the non-poor, except in urban areas and in the region of Sikasso where the vulnerability incidence is five to six times higher among the poor. According to Pedercini et. al. (2012) Mali will need US$295 million (up from the current US$25 million) as the long-term target level of investment in R&D in agriculture until 2050, to offset the eventual loses caused by climate change (see section on crop yields).

Health, Sanitation, and Water Services: Life expectancy in Mali is among the lowest in the world (54.2 years). Mali's population is exposed to poor health conditions due to low accessibility to water and sanitation services. People suffer from bacterial and protozoal diarrhea, hepatitis A, and typhoid fever (UNPF 2014). In 2010 only 0.08 doctors per 1000 people were available (World Bank 2015a). Efforts to improve health services are consistent. Rural population with access to improved water resources increased from 45% in 2006 to 54.2 in 2012 (World Bank 2015a). Yet, the proportion of total population with access to improved water services is still too low: 67.2% in 2012, i.e. 4.87 million lacked the service. For sanitation the percentage of the rural population with access to improved sanitation facilities increased from 13.3% to only 14.5% between 2006 and 2012, and from 34.6% to

35.3% in urban areas. Mali is among the eight countries that will meet the MDG by 2015 (UN 2013). Mali outperforms in preventive measures such as that 70% of children sleep under insecticide treated mosquito nets (United Nations 2013). Access to electricity more than doubled in the first decade of the century, with the introduction of the AMADER program for rural electrification (Briceño-Garmendia et al. 2011). It widened access to more than 36,000 rural households (Briceño-Garmendia et al. 2011). Nevertheless, only 16.6% of the population had access to electricity by 2010 (World Bank 2015a).

Education: Demand for education is high in Mali, as 47.6% of its population is below 14 (WFB 2015). According to Pearce and Fourmy, despite the efforts of the government, the targets on education for 2015 will not be met in 2009. Nearly 900,000 children aged 7 to 12 are out of school, most of them girls. The pupil teacher ratio was 41 in 2013 - one of the lowest value worldwide. An Oxfam's report estimates more than 45,000 trained teachers are needed to cover the gap. Oxfam recommends increasing the education budget up to 20% of the government budget, and prioritize teacher recruitment and training (Pearce and Fourmy 2009), because this enormous deficit is affecting the potential for the economy to specialize and diversify.

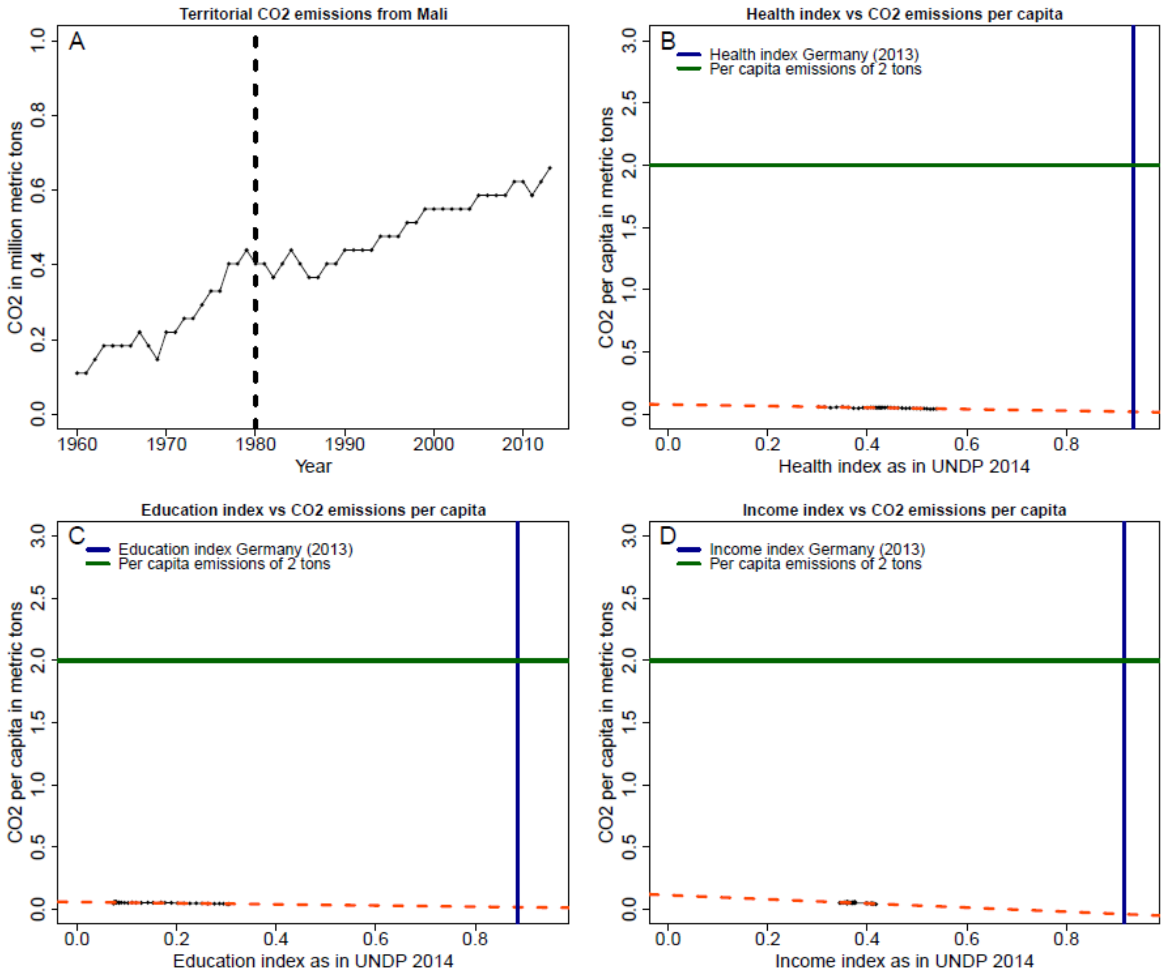
9.2 Links between Adaptation, Development and Mitigation

9.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from Mali have modestly increased from 0.1 to about 0.7 million tons between 1960 and 2013 respectively (Figure 9-5A). On a per capita basis, CO_2 emissions from Mali have been remarkably constant hovering around the 0.05 tCO_2/cap (Figure 9-5B) and well below the 2 tCO_2/cap suggested as reference to keep temperature below 2 degrees (WBGU 2009a). As Figure 9-5B, C, and D show the different components of human development have evolved at nearly constant emissions per capita. The progress towards better standards of living has been remarkably slow and far-off that which is recorded in high developed countries, e.g. Germany.

A simple extrapolation of current per capita emissions trends does not show risk of Mali moving towards per capita emissions higher than 2 tCO_2/cap/year. Mali is not expected to overcome the developed world standards of HDI above 0.9 within the first half of this century (Costa et al. 2011). Population growth is expected to continue driving emission slowly upwards to an estimated level of 1.6 million tCO_2 by 2050 (Costa et al. 2011).

Figure 9-5: Trends of CO_2 emissions and the HDI in Mali.

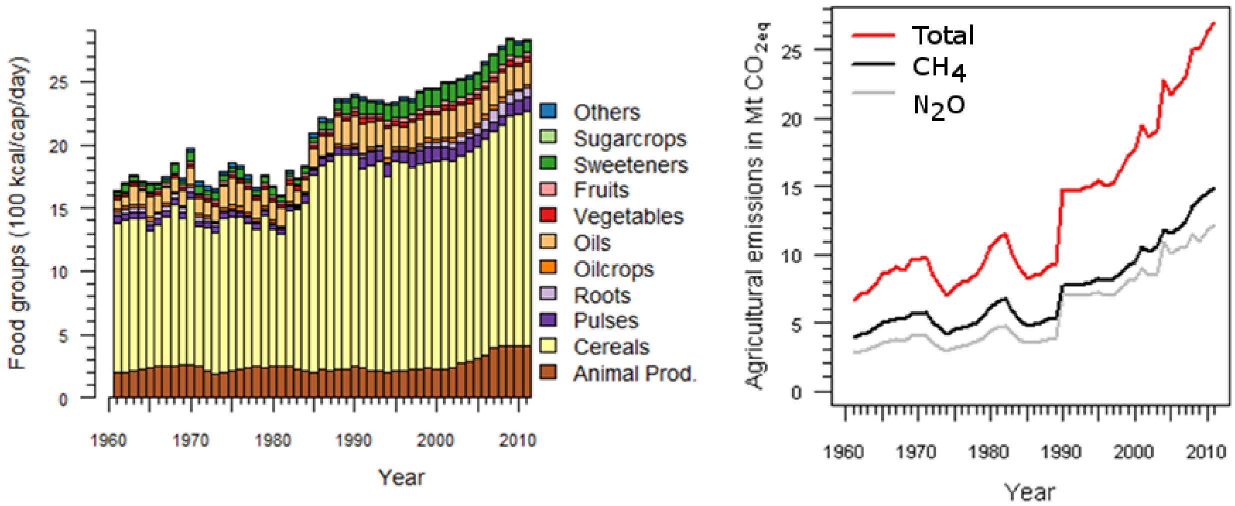


Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education, and health obtained from the World Bank 2014 database. Vertical blue line highlights the situation of Germany (2013) in regards to the corresponding human development dimensions investigated. The green line indicates an average emission burden per capita which may keep global warming below 2°C. Dashed orange line depicts the trend in average per capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C, and D. Indicators of HDI develop consistently but very slowly, at very low emissions per capita levels in Mali. Higher emissions per capita could be used to improve social conditions to correct social trade-offs.

9.2.2 The Evolution of Dietary Lifestyles in Mali and the Emissions Associated

Figure 9-6 (left) presents the evolution of dietary patterns in Mali between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, Mali's total food supply has increased from 1,640 kcal/cap/day in 1961 to about 2,830 kcal/cap/day in 2011. The current Malian food supply is above its average dietary requirement of 2,130 kcal/cap/day (Hiç 2014) and slightly above the average food supply of West Africa of around 2,700 kcal/cap/day (FAO 2014b). During five decades analyzed the amount of cereals supplied per person per day has increased by around 670 kcal, whereas, supplies of oils, sweeteners, and animal products have increased respectively by 110, 60, and 210 kcal/cap/day, respectively. However, the current per person animal product supply of 410 kcal per day is lower than the global average per person animal product supply of 500 kcal per day. Total calorie supply has significantly increased in the country after 1984.

Figure 9-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Mali.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (measured as CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Mali during the last fifty years. Food supply in Mali has increased in the last three decades, however, is still below the global average food consumption of 2850 kcal/cap/day in year 2010. Whereas the total calories have increased, the shares have remained nearly the same. Additionally, greenhouse gas emission from the agriculture has increased in the last decades, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

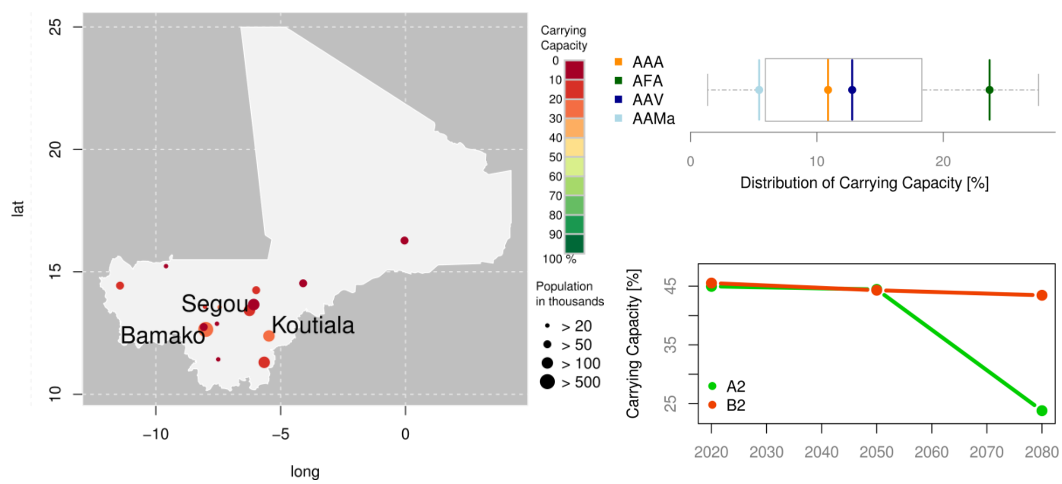
Mali is a net food importer in terms of calories (Pradhan et al. 2015) but a net food exporter in terms of monetary values (FAO 2014b). Mali exports high value crops such as cotton and nuts. This explains the contrast between calories supply and malnutrition. Mali's net food import was around 1 trillion kcal in the year 2000. Major parts of the country so far have attained less than 30% of the potential crop production (Pradhan et al. 2015a). Mali could become food self-sufficient by closing yield gaps to attain 50% of the potential crop production resulting in 4.6 million people relying on local food and the rest of the population depending on intra-country food transfer. Closing crop yield gaps can increase crop production and ensure the current and future food self-sufficiency in Mali even while considering plausible population growth and diet shifts by 2050 (Pradhan et al. 2014b). In the year 2000, around 3 million people in Mali lived in the regions where the local food and feed produced within 5 arc-minute grid (10km x 10km in equator) was sufficient to meet their food and feed demand (Pradhan et al. 2014b).The country's food production can nourish around 5.3 million people sustainably indicating that the rest of the population depends on international food trade.

The total agricultural emissions of Mali have quadrupled from 6.7 Mt CO_{2e}/yr to 27 Mt CO_{2e}/yr in the last 50 years as shown in Figure 9-6 (right). The increased emissions are related to the increase in agricultural production to meet growing food demand and export of cash crops, mainly cotton. The sharp rise in the emissions between 1989 and 1990 is due to the inclusion of emissions from burning savanna (FAO 2014b). Furthermore, diets currently consumed in Mali embody emissions of around 0.9 tCO_{2e}/yr (Pradhan et al. 2013) and around 3 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013). Technological progress increasing agricultural productivity can lower agricultural GHG emissions of the country by reducing agricultural emission intensities (Pradhan et al. 2013). Dietary patterns in Mali may increasine by calorie demand when the country becomes more developed in the future. This results in a larger volume of GHG emissions. Technological progress can transfer these trade-offs into synergies. Currently, emissions per unit of crop and livestock production in Mali are higher than that of developed countries (Pradhan et al. 2013).

9.2.3 Potential of Peri-Urban Agriculture and Local Food

39% of 15.7 million people in Mali live in cities and a future growth of up to 45.2 million by the year 2050 will occur mainly in cities and will raise the fraction of the urban population up to 60% (United Nations 2014). 15 cities with population above 20,000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 9-7).

Figure 9-7: The possibility for a food supply from surrounding areas for Malian cities.



For current conditions (AAA) as a map (left) and the median carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. The best possibility to minimize environmental trade-offs due to agriculture is by closing the yield gap, which will lead to high productivity of peri-urban agriculture.

Overall these cities represent more than 2 million people. Today 56% of the surrounding areas (of 88% available arable area) are used for agricultural purpose. From the currently harvested areas, 20% percent of the urban dwellers can be nourished (Kriewald, Sterzel, Pradhan, García Cantú Ros, et al. 2015).

Today's yield gap ratio is around 0.36 near cities. Consequently, closing the yield gap offers the largest potential to increase food self-sufficiency. Also a changed kcal-consumption or diet will have an influence as an increase up to 3,500 kcal/cap/day will reduce the median carrying capacity down to 5% (see Figure 9-7 – top right). 6 cities or 40% of the investigated cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The A2 scenario shows for an average yield scenario an abrupt decrease starting from 2050. For the B2 scenario, the summed up values are more stable and decreases from 45% down to 43% (see Figure 9-7 – bottom right), but are still higher than the current values based on today's low yields.

9.3 The Potential for Synergies and the Stage of Country Development

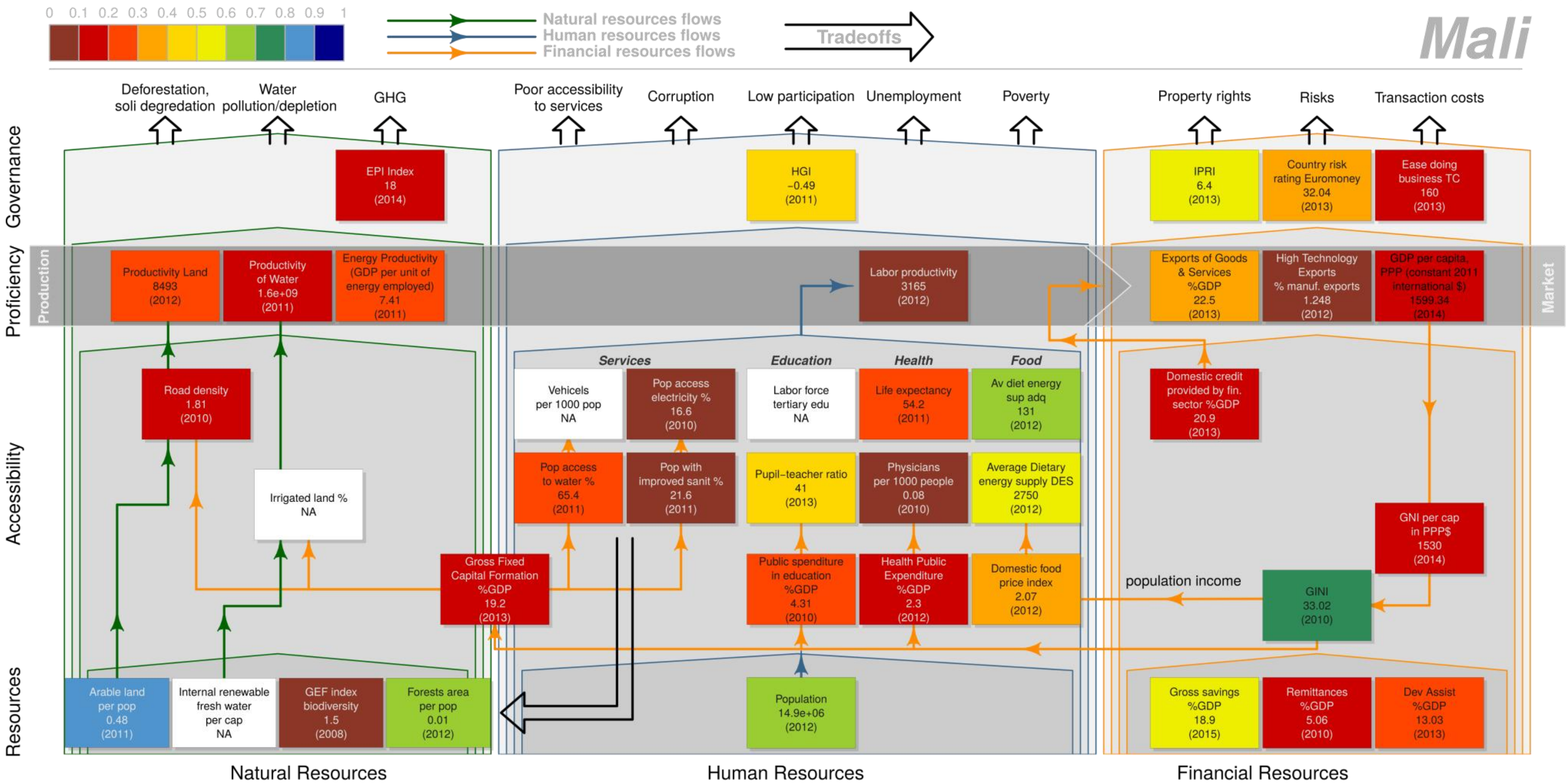
The Malian economy is vulnerable to climate change impacts due to the dependence on cotton for country revenues, the high dependency of population's income on agriculture, and the dependency of industry on agriculture. Country revenues are concentrated on gold and cotton exports. The impacts of climate change on the economy will meet restrictions on energy, labor and infrastructure, and political instability. The population is highly vulnerable, due to chronic undernourishment.

Inter-sectoral trade-offs producing GHG emissions are related to the expansion of agriculture against forests areas. Deforestation drivers also include biomass consumption. Another trade-off producing GHG emissions and economic losses is the costly coal-based generation of electricity. Climate change and development needs will exacerbate these trade-offs if adequate strategies are not developed. As all indicators of Figure 9-8 show, Mali needs to improve all its components if the country wants to develop the capacity to pursuit climate resilient pathways. Therfore, the development of a suitable adaptive capacity in Mali requires growth. Any strategy for growth and development has in agriculture a major axis. The development of synergies in Mali is about a strategy that improves the productivity of agriculture, reduces its vulnerability, increases the food production for internal consumption and for exports, and stops deforestation. We subsume the analysis of these topics in two headlines: one about growth with emphasis in agriculture, and another about deforestation and agriculture.

9.3.1 Growth and Agriculture:

In the short and middle terms agriculture will continue being the major source of growth. Agriculture is the main source of income for 80% of the population. The country needs to improve the productivity of agriculture for food security reasons, for increasing population income, and for producing surpluses to develop industry and services. This challenge meets an economy which is lowly developed. As the indicators of proficiency Figure 9-8 show the productive structure of Mali is insufficiently developed.

Figure 9-8: Indicators of the adaptive capacity of Mali.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section on methods. The low development of the productive structure and markets (in the row of proficiency) shows the need to include growth as a basic component in the analysis of synergies in Mali. The low performance in the indicators of governance shows the need to improve environmental, human and economic governance for the success of policies promoting synergies.

A growth strategy based on the development of agriculture requires higher productivity of water, land and agricultural labor. The productivities of land and water in Mali are low compared to the rest of the world. Agriculture will be severely affected by climate change, due to reduced availability of water and higher temperatures (see sections 9.1.1 and 9.1.2). The development of agriculture requires an exploration of the potential for irrigated agriculture in semiarid or even arid areas. Studies exploring the potential of underground water reservoirs need to be accomplished.

Moreover, the development of agriculture requires road infrastructure improving the accessibility of farmers to markets. Figure 9-8 shows that Mali performs very low in road density. However, Mali is a very large country and most economic activities including agriculture are located in the Southern region. The road network is denser in this region, but still insufficient. The country is investing in road infrastructure. Improved road networks will help to improve land productivity and the capacity to cope with climate related shocks.

The productivity of labor is very low. These low scores are related to the insufficient infrastructure but also to the low diversification and low specialization of the economy. A higher productivity is also related to the technologies in use for agricultural production. The country therefore needs invest in the development of agricultural technologies of small scale farming.

Options to increase the productivity of agriculture include land use changes, shifting from grasslands and meadows areas into cultivars. Mali has the second highest share of meadows and pastures, and the lowest productivity of land among the countries studied. Another option is increasing peri-urban agriculture. Changing land use in peri urban areas can improve food security. It can help reduce emissions from food transportation. Agricultural production in Mali is too concentrated in cotton products and maize production. A natural option to improve the productivity of agriculture includes crop diversification. The country has the opportunity to develop high value agriculture, e.g. coffee, tobacco, flowers, fruits, etc.

The vulnerability of agriculture can be reduced in several ways. Afforestation, reforestation, and the protection of forests will help to regulate the water cycle, reducing the exposure to droughts and even floods. Research and development on resistant varieties rich in calories will also reduce the impacts of droughts and water scarcity. Better practices and the adoption of modern agricultural technologies will also help smooth outputs. Economic vulnerability of agriculture (exposure to price variability) will be reduced with the diversification of crops. All these measures require the commitment of the country to develop knowledge and assistance to farmers. The diversification of crops will also result in better diets and the availability of more food for food security.

Improving agricultural productivity in Mali might follow two different pathways, either promoting industrial agriculture, or developing small scale agriculture. What matters however, are the implications of agricultural growth models for social development. 60% of the population lives in rural areas in Mali. 80% of the population derived their income from agriculture in 2005 (WFB 2015). 50.6% of the Malian population lives with less than US$1.25 per day. The poverty rate has risen to 42.7% in 2012 from 41.7% in 2011 (AfDB 2014). A model for inclusive growth based on the development of agriculture in Mali is about the development of small scale agriculture. For a development strategy fostering small scale agriculture, the country needs to develop research capoacities for higher productivity and institutions for agricultural assistance. Centers with adequate staff of agricultural assistants, social workers, and economists should support the improvement of practices and the use of new technologies.

Increased agricultural outputs should first be conceived for food security. But actions need to include the intervention of food markets and secure an adequate distribution of food. The country needs to reduce the food price level index to make food more accessible to the poorest.

9.3.2 Deforestation and Agriculture:

Water will be scarcer in the fertile southwest corner of Mali in the wet season (McSweeney et al. 2010a). Impacts of climate change on water resources can be reduced by enhancing afforestation. Deforestation needs to be controlled in Mali. Actions to ameliorate the strength of deforestation drivers include the increased productivity of agriculture, but also the development of the potential of forestry for mitigation. The country is involved in REDD+ and the staff working in forestry has increased between 2000 and 2010 (FAO 2010b). If capacity in monitoring, verification and reporting are developed, afforestation, forestation, and reforestation may create opportunities for growth and development in rural areas.

In the environmental part of the Environmental Performance Index11 the country performs insufficiently denoting lack of capacity to control environmental degradation including deforestation. For human governance, the averaged index is negative. In all indexes composing the averaged index the country performs negative and shows a negative trend, since 2003, with higher setbacks in political stability and absence of violence, and control of corruption. In addition, the low performance in the indicators of governance of economic resources shows an economy exposed to uncertainties in terms of property rights, transaction costs, and structural risk.

9.4 Conclusions:

The Malian economy is threatened by climate change, due to the high GDP dependency on agriculture, low economic diversification, and high share of population deriving their income from agriculture. For climate resilient pathways the country needs to develop a strategy based on the development of agricultural productivity. This sector has the potential to produce the financial surpluses required for the development of industry and services and for human development. In the middle term financial and human efforts should be focused on the development of institutions aiming to develop agricultural productivity. This includes institutions enhancing the capacity for agricultural research, institutions for agricultural assistance, and incentives for higher productivity of small scale farming. Mali also has to develop its capacity in forests governance.

The country needs to pay special attention to the development of the energy system taking into account the opportunities offered by neighbor countries. Mali should exploit its potential in solar thermal energy production. The international community has to consider options to support the energy transition in Mali.

Mali needs to develop further its human resources. The current social conflicts are to a large extent rooted in food insecurity. The country needs to develop further in health,

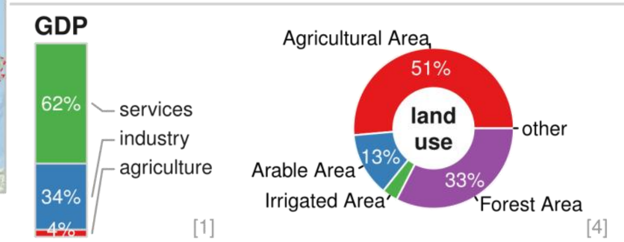
[11] As explained in the introduction of the framework evaluating the adaptive capacity, for the evaluation of environmental governance we disregarded the numeric assessment of health in the EPI index, and kept the environmental part for the assessment.

education, and in in the provision of basic services. The country is burdened by low environmental governance, low human governance and insufficient capacity to cope with financial and economic risks.

10. MEXICO

Figure 10-1: Mexico – Factsheet and physical map:

Country size	1,964,375 sq km	[1]
Coastline	9,330 km	[1]
Population	123.8 millions	[2]
Rural population (%)	21	[2]
Human Development Index	0.76 (71 of 187 – High)	[3]
Life expectancy at birth	77.5	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

10.1 Sensitivity and Vulnerability

10.1.1 Sensitivity of Natural Resources

Temperature: Using A2 and B2 forcing scenarios simulations show an increase of 2 – 4 °C in Mexico by 2050 (UNFCCC 2007). The results indicate that the most continental part of northern Mexico will experience larger increases in temperature as in comparison to the center and the south (UNFCCC 2007).

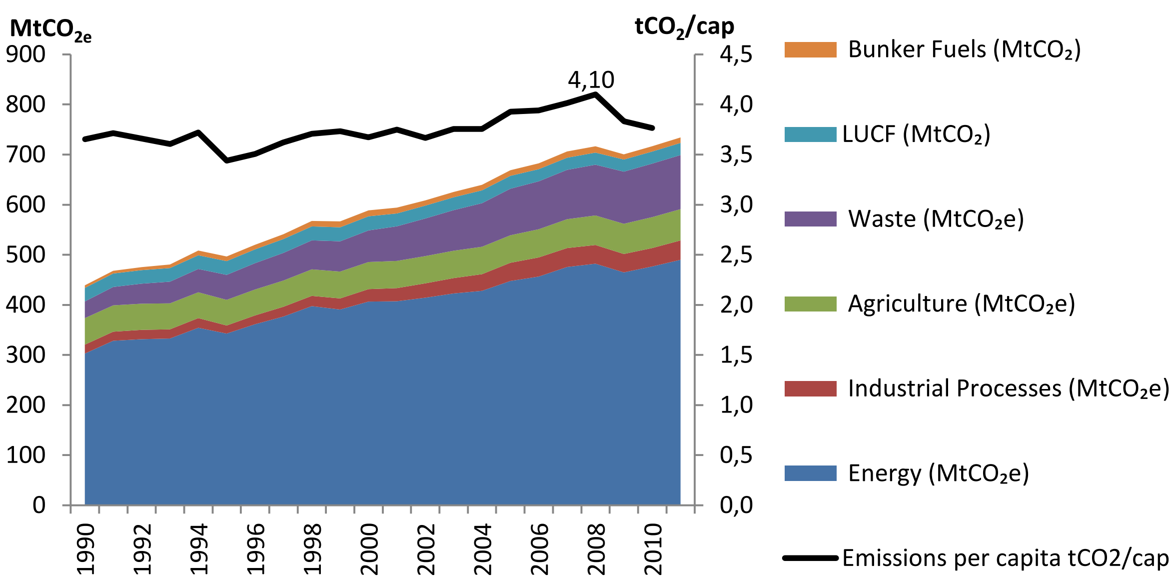
Water resources, rainfall and precipitation: According to the results reported in the Third National Communication (UNFCCC 2007) change in winter rains is expected and the analysis indicates a decrease in precipitation fluctuating between 0 and 0.6 mm/day. A reduction of up to 15% is expected in the regions of Central Mexico and of less than 5% in the Gulf of Mexico water basin, mainly between January and May compared to the period 1960-1990. The summer scenarios for 2020 and 2050 indicate decrease in the average annual precipitation of 5 to 10%. This situation will lead to lower natural water availability, due to an increase in evapotranspiration of between 5 and 15% depending on the region. The hydrologic cycle will become more intense, thus the number of severe storms and the intensity of drought periods will increase. Present conditions suggest a very high degree of pressure on water resources in the northwest part of the country. Overall, nearly 75% of the precipitation is lost by evapotranspiration and 5% recharges the aquifers (UNFCCC 2007). The increasing temperatures will cause an increase of evapotranspiration and a decrease of soil humidity. This will lead to significant decreases in runoff, i.e. 10 to 20% at the national level and over 40% in the coastal wetlands of the Gulf (UNFCCC 2007).

The country is already experiencing longer dry and hotter periods, more droughts, more intense rains, hurricanes, floods and mudslides (World Bank 2013f). The frequency and intensity of hazards are expected to increase with climate change (CICC 2012). Mexico is particularly exposed to weather hazards in the South, in particular in regard to hurricanes and floods. Natural freshwater resources are scarce and polluted in the North, inaccessible and of poor quality in the central regions and are subject to extremes in the Southeast (WFB 2015). Schewe et al. (2014) pointed out that for a business-as-usual scenario (RCP8.5) the central-North arid region will benefit from more rain, while the mountain regions of the west and the central temperate region will suffer from water scarcity. In these regions, forestry would help regulate water cycles and ameliorate the impacts of climate change.

Crop yields: Crop models for 2020 indicate moderate reduction in suitability for rain-fed cereal (corn) crops and an increase of up to 4.2% of surface areas non-suitable for agriculture (UNFCCC 2007). The area of change in corn growing suitability varies 15-40% of the country. 8-29% of the area will have a higher corn growing suitability and 6-29% will face a lower suitability (UNFCCC 2007). Variations in corn growing suitability would imply similar changes in total area for agriculture.

Atmosphere: Mexico is the 12th largest GHG emitter in the world and the second largest in Latin America (World Bank 2013g). Energy and transport are the sectors with the highest shares of emissions. Waste management appears to be an important niche for GHG mitigation (see Figure 10-2).

Figure 10-2: GHG sectoral emissions and energy per capita emissions of Mexico.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agriculture (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from energy include transport. The shares of emissions in the figure make evident that energy is by far the most relevant sector for mitigation in the analysis of synergies.

Land Use and Forestry: Deforestation is considered a national security issue (WFB 2015). Forests area decreased from 36.2% in 1990 to 33.3% in 2010 (FAO 2014b). Mexico lost 7.8% of its forests between 1990 and 2010. Deforestation is concentrated in the southern states (Hansen et al. 2003). Major deforestation drivers are agriculture and cattle ranching, timber, fires, urbanization and diseases (CICC 2012). The demand for wood as fuel and industry also are causing forests degradation.

Disasters: According to the (CICC 2012) weather and extremes (mostly extreme rainfall, floods and hurricanes) have produced severe disasters in Mexico. The costs of damages from hurricanes, floods and heavy rains in 2005 and 2007 have been of the same magnitude of those produced by the earthquake of 1985 (CICC 2012). Mexico is experiencing longer and hotter periods, more droughts, rains, hurricanes, floods and mudslides (World Bank 2013a).

10.1.2 Economic Vulnerability

Sectoral impacts: Losses from droughts amounted 15 billion pesos as of 2010 (CICC 2012) (nearly 1.2 billion US$ in 2010). In the same year, agricultural activities in 1.8 million ha of arable land (out of 21 million ha of arable lands) were damaged. If climate change is not addressed, the Mexican economy is expected to decline by between 3.5 and 4% and suffer significant costs of up to 6.2% of GDP per year (World Bank 2013g).

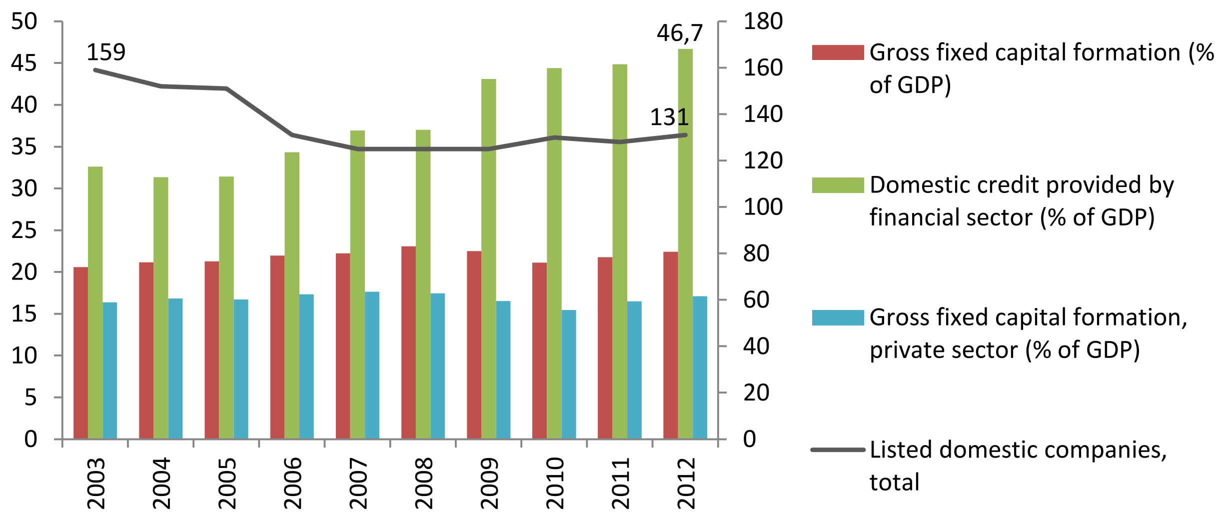
Impacts of climate change on economic activities will be reduced if productive factors are well developed. Factors affecting the productivity in Mexico are labor, infrastructure and energy. Labor productivity is a major issue. While modern economic sectors have increased labor productivity 5.8% per year since 1999, enterprises with less than 10 employees have decreased their productivity by 6.5% per year (Bolio et al. 2014). In addition, mid-size enterprises have grown productivity by roughly 1.0% per year. Employment in middle size enterprises has systematically decreased since 1999 (Bolio et al. 2014). These different trends of productivity are consequences of the tax system (Katz 2014). It creates favorable conditions for large companies, while unfavorable conditions for small and middle enterprises.

Economic specialization and diversification: The diversification index (0.401 in 2012, UNCTAD 2012) places Mexico in the group of countries with the 30% highest economic diversification. As the number of commodities exported serves as proxy for diversification, it can be concluded that the economy of Mexico is highly diversified. The number of commodities exported amounted to 1181 in 2012 (Simoes and Hidalgo 2014). In addition, among the first 100 commodities exported only 11 were agricultural commodities or processed food by 2011 (Simoes and Hidalgo 2014). Therefore, climate change will have marginal impacts on the exports portfolio. Crude oil is the most exported good with 13.16% of total exports (Simoes and Hidalgo 2014). The rest are high technology, industrial products, machinery. This is indicative of a relative high specialization of the economy.

Capitalization and Capital Formation: As Figure 10-3 shows Mexico a high and stable share of GDP is invested in gross fixed capital, i.e. roads, schools and health infrastructure. Investments in private fixed capital formation are also stable showing the permanent renewal and enhancement of private capital. However, the number of companies listed in stock markets has been low and decreases. Countries of similar economic size have more companies (e.g. South Africa 348 by 2012). This characteristic of Latin American countries could be associated to historical inequality. This concentration of capital has implications for the ability of the society to avail financial resources to cope with contingent impacts of climate change. On a positive note since 2003 the provision of domestic credit by the financial system has consistently increased. The economic crisis of 2008 only stopped the growth of domestic credit provided by the financial system. The increase of credit provided displays a better capacity to provide financial resources to the society.

Economic Risks and Uncertainties: Inflation has been kept low (4.18% in average) and smooth (standard deviation 0.82), between 2006 and 2013 (World Bank 2015a). This shows the capacity of the country to control financial uncertainties and a good macroeconomic policy. The International Property Right Index (6.2 in 2013) places Mexico above the fifth decile relative to the rest of the world, showing a relative good capacity to enforce tenure rights. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). In the country risk index, which evaluates structural, political and economic risk, Mexico performs in the sixth decile, indicating relative low risk. With regard to transaction costs, the country also shows a good performance. In the ease doing business which evaluates the business environment facilitating development of business, the country performs above the seventh decile (63 in 2013). Overall, these numbers show a country with good capacity to cope with economic uncertainties.

Figure 10-3: The recent evolution of capital in Mexico.

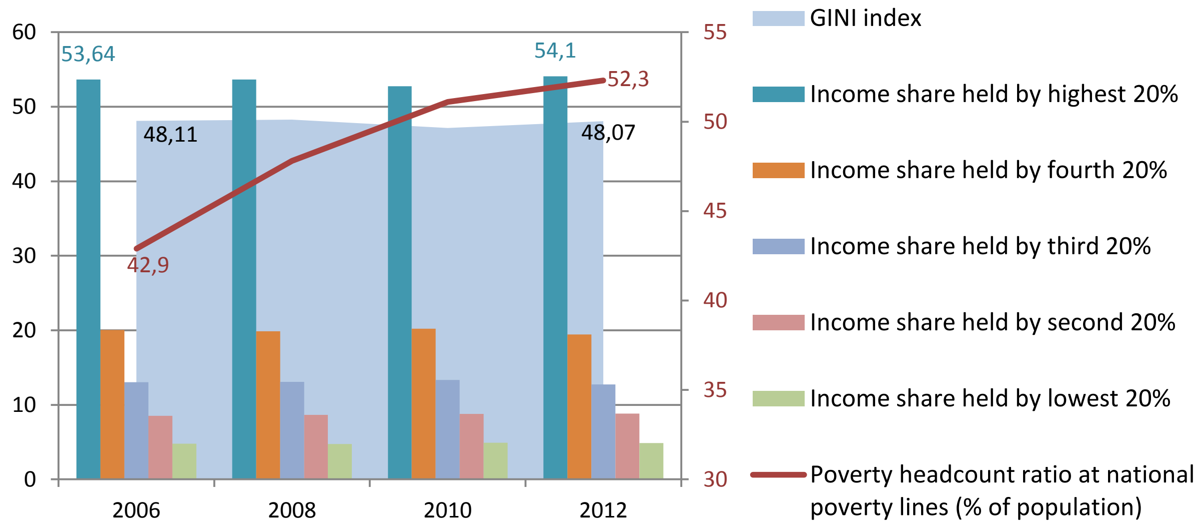


Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies (World Bank 2015a) and investments in gross capital formation (World Bank 2015a), private and public. The country has developed its capacity to provide domestic credit. Shares of GDP invested in fixed capital formation are steady and high showing the commitment of the country in the construction of infrastructure for enhanced adaptive capacity. However, the decreasing number of companies listed in the stock markets shows a process of concentration of capital, inadequate for diversification.

10.1.3 Social Vulnerability

Social vulnerability is high and increasing in Mexico. As Figure 10-4 shows inequality is high and almost constant. In addition, poverty is increasing. These trends are related to the business model of the country favoring the competitiveness of large companies and discouraging formal employment in small and middle enterprises (Bolio et al. 2014). Rural population is even more vulnerable to disasters and weather related impacts. The poverty headcount ratio for rural areas reached 63.6% in 2012 (World Bank 2015a).

Figure 10-4: The recent evolution of income distribution, inequality and poverty in Mexico.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies in social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. High and non-decreasing income inequality and increasing headcount ratio show the higher vulnerability of the society. This deepened trade-off needs to be corrected by synergies.

Food security: Despite the ongoing impoverishment of the Mexicans only 7.2% of the population suffered from food inadequacy and less than 5% from undernourishment in 2012 (FAO 2012). The depth of food deficit was 2 kcal per person per day. The very low domestic food price level index (1.3 in 2012) places Mexico in the seventh decile of high performance. But these are average numbers that need to be contrasted with high inequality. According to a World Bank study (Reddy, Bruhn, and Tan 2013), 70% reported having had regular or occasional difficulties in covering basic expenses, such as food and housing.

Health, Sanitation and Water Services: Life expectancy in Mexico is among the highest in the World (76.9 years in 2011) (World Bank 2015a). Mexico spent 6.14% of GDP in health services including private and public expenditure in 2012 (World Bank 2015a), far below the European Union (10.19% of GDP in 2012) and even the average in Latin America and the Caribbean (7.7% in 2012) (World Bank 2015a). Yet the numbers show a steady growth of health expenditure, from 5.07% in 2000 (World Bank 2015a). The access to fresh water service reached 94% of total population in 2011 and access to sanitation 85% in the same year. This leaves around 7.3 million people with no access to water supply and 18.3 million to sanitation services.

Education: The government spent 5.1% of GDP in education in 2012, a number similar to OECD members (5.27%) (World Bank 2015a). However, 83.1% is spent in teachers' salaries, and 93.3% in wages of the entire education system (Toribio and Hernández 2014). The pupil teacher ratio in primary education in Mexico as of 2012 was 28 far from 16 in OECD member states. The pupil teacher ratio in Mexico (26.6) has kept relatively constant along the last decade. These circumstances show that the education system in Mexico is burdened by unbalances. Such unbalances would restrict the access and the effectiveness of education.

Overall, Mexico shows disparate trends related to the vulnerability of the population. The country performs relatively high in access to improved water and food security, as well as in some indicators of education and health. Yet, inequality and poverty are high, and there are deficits in the provision of water sanitation.

10.2 Links between Adaptation, Development and Mitigation

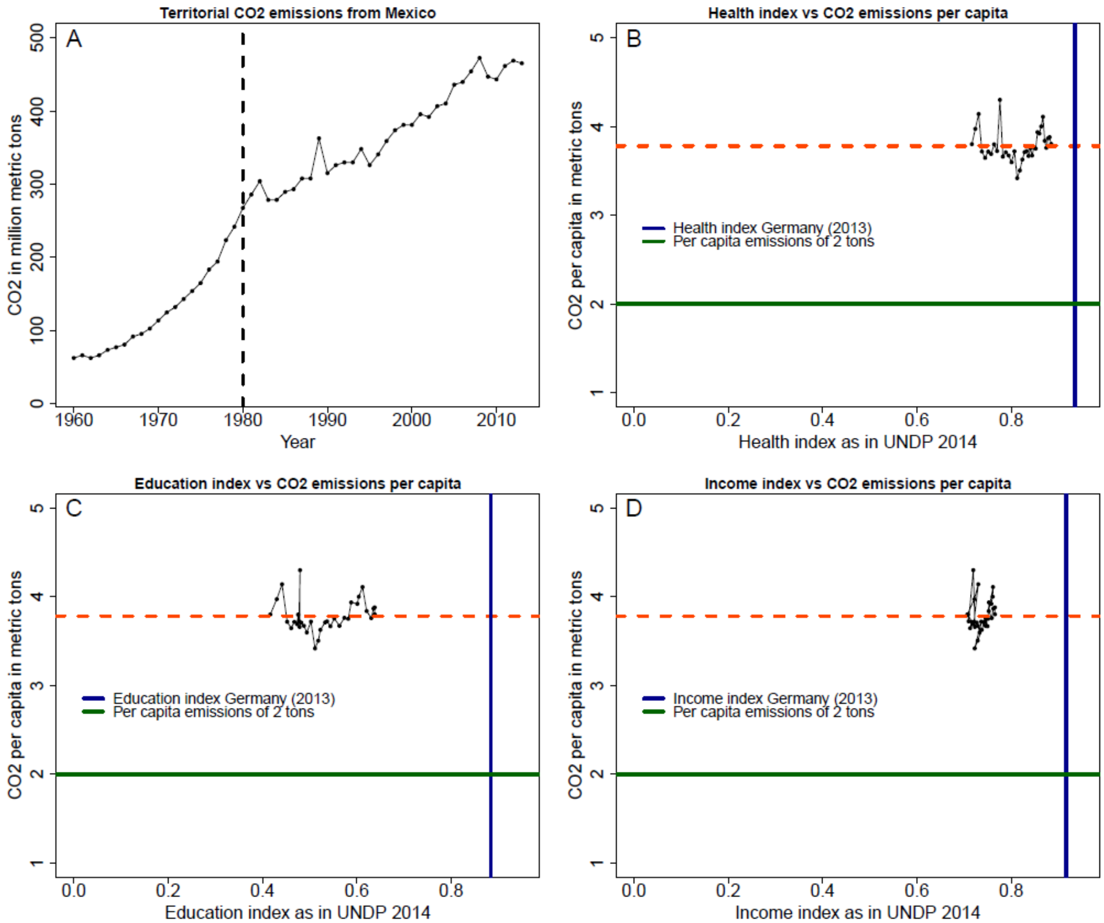
10.2.1 The Evolution of the HDI and the GHG Emissions

For each country the relationship depends on a variety of socio-economic factors (Steinberger et al. 2012), including technology, energy resources, environmental policies or trade (Stern 2004).

The model approach shown in Figure 10-5 makes clear that the territorial emissions of CO_2 grew from approx. 70 million tons in 1960 to approx 465 Mt in 2013 (World Bank 2015a: 467 Mt in 2012). After an exponential growth between 1960 and 1980 emissions have increased more linearly. Although total emissions have risen on per-capita emissions have remained fairly constant from 1980, hovering between 3.4 and 4.3 tons of CO_2/year. Hence, the progress of human development in Mexico has been, in a statistical sense, uncorrelated with per-capita emissions between 1980 and 2013. Same is not true for total emissions. The relatively constant emissions per capita show that the main driver of total emissions growth in Mexico is population growth.

Comparing the recent development of emissions and human development in Mexico it can be inferred that close-to-develop-world standards in the health dimension (Figure 10-5B) have been achieved with emissions that are the double of those required for climate stabilization under the fair burden constraints (WBGU 2009b). Regarding the education and income dimensions (Figure 10-5C and D) progress made by Mexico in the last 30 years appears to be far off developed world standards. Therefore, the future challenge for Mexico lies mostly in bridging the missing gap in the education and income dimensions while reducing the per-capita emissions by the half. This would place the country on a sustainable development path. Due to the weak elasticity verified between per-capita emissions and human development it appears feasible to do so without the risk of increasing emissions. Mexico appears to stand on a steady-state situation in which the slight increase in efficiency (e.g., ever improving health standards with constant emissions) is offset by population growth. However, when inequality is considered as an allocative factor, this average trend would also indicate that the country allocates its emissions budget for the benefit of large companies.

Figure 10-5: Trends of CO_2 emissions and the HDI in Mexico.



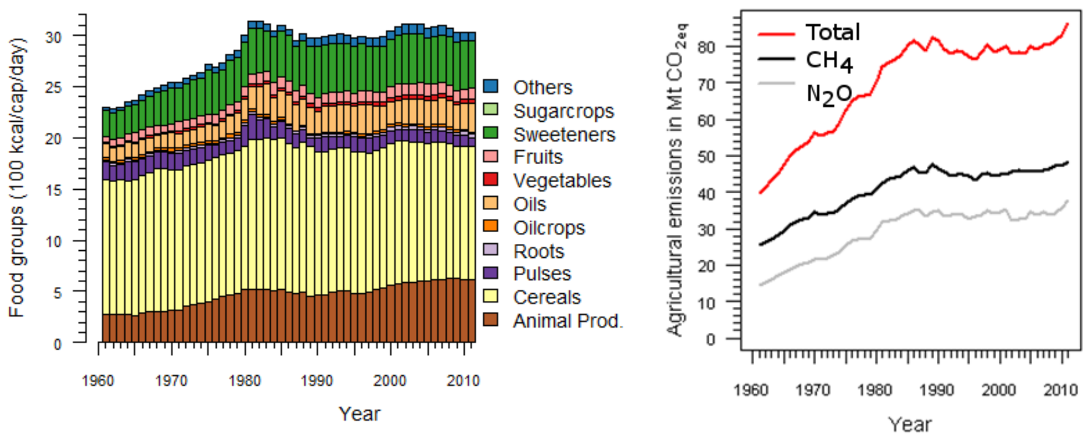
Historical emissions of CO_2 from fossil fuel burning for Mexico (Le Quéré et al. 2013) (B) Health index 1980-2013 (according to (UNDP 2014b)) vs CO_2 emissions per capita in Mexico. Panels C and D show analogous information for Education and Income index as panel B. Data on population, income, education and health obtained from the World Bank 2014 database. Horizontal green line shows the 2 tCO_2/cap target to keep global warming under 2° by 2050. Vertical blue line highlights the current (2013) position of Germany in regard to the corresponding human development dimensions investigated. Dashed orange line depicts the average per-capita emissions of Mexico between 1980 and 2013. The dashed vertical line indicates the starting period of analysis for panels B, C and D. Emissions per capita and trends of elements assessed in the HDI are not coupled in Mexico. However, emissions per capita are high compared to other countries in this study. For synergies, emissions per capita should decrease while increasing income and improving education.

10.2.2 The Evolution of Dietary Lifestyles in Mexico and the Emissions Associated

Dietary changes on a country scale are considered as a proxy for lifestyle shifts. Figure 10-6 (left) presents the evolution of dietary patterns in Mexico between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, Mexico's total food supply has increased from 2,300 kcal/cap/day in 1961 to about 3,000 kcal/cap/day in 2011. During these five decades, amount of cereals supplied remained almost constant, whereas, supplies of animal products, sweeteners including sugar, and oils have almost doubled. This depicts the changing lifestyles in Mexico towards affluent diets.

In the year 2000 around 18 million people in Mexico lived in the regions where local food and feed produced within 10 km x 10 km in cell was sufficient to meet their demand (Pradhan et al. 2014b). On a country scale food for 40 million people can be produced resulting in the fact that 60 million people need to rely on international food trade. Mexico's net food import was about 50 trillion kcal in the year 2000. Mexico could become food self-sufficient by closing yield gaps to attain 75% of the potential crop production, resulting in 27 million people relying on local food and the rest of the population depending on intra-country food transfer. The country has only attainted around 50% of the potential crop production (Pradhan et al. 2015). Mexico may need to close yield gaps to attain more than 90% of their potential crop production to meet food demand by 2050 due to population growth and change in dietary habits.

Figure 10-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Mexico.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (measured as CO_{2e}) including methane (CH4) and nitrogen oxide (N_2O) from the agriculture sector in Mexico during the last fifty years. Dietary patterns in Mexico are changing towards affluent diets, reflecting improved nutrient situation whereas greenhouse gas emission from the agriculture has remained almost constant in the last two decades. Dietary patterns in Mexico are changing towards affluent diets, reflecting improved nutrient situation whereas greenhouse gas emission from the agriculture has remained almost constant in the last two decades, as consequence of increased food imports. The data was obtained from FAOSTAT (FAO 2014).

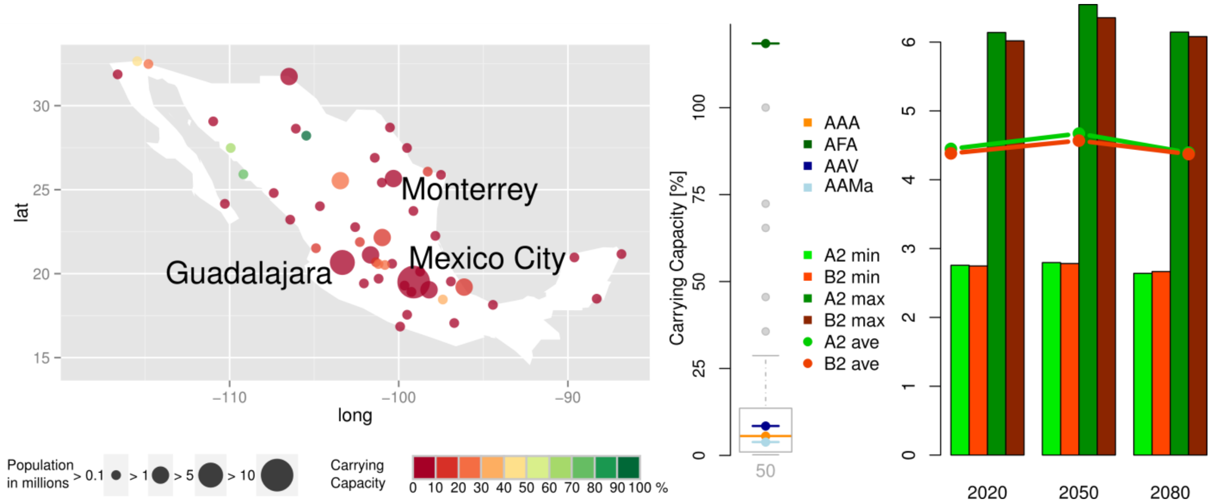
The total agricultural emissions of Mexico have doubled from 40 $MtCO_{2e}$/yr to about 80 $MtCO_{2e}$/yr in the last 50 years (Figure 10-6 right). The increased emissions are related to increase in agricultural production to meet growing food demand driven by population growth and lifestyles changes. The emissions have only slightly increased after 1990. This is because Mexico is a net food importer (Pradhan et al. 2015a) and its growing food demand is increasingly met by international trade in recent decades. Furthermore, such high calorie diets consumed in Mexico embodied emissions of around 2 tCO_{2e}/cap/yr (Pradhan et al. 2013). A high share of animal products in these diets is met by feeding a subsequent amount of crops to livestock (Pradhan et al. 2013). Dietary patterns in Mexico may increasingly be calorie rich when the country becomes more developed, resulting in a larger volume of GHG emissions and food import. Currently, emissions per unit of crop and livestock production in Mexico are higher than that of developed countries (Pradhan et al. 2013).

10.2.3 Potential of Peri-Urban Agriculture and Local Food

80 % of 125 million people in Mexico live in cities and a future growth up to 150 million by the year 2040 will occur mainly in cities (United Nations 2014). Fifty cities with population above 100,000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport. Overall these cities represent more than 54.6 million people. Today only 5% of the surrounding areas are used in agriculture, although 97% could be used. From the currently harvested areas just 6% percent of the urban dwellers can be nourished (Kriewald et al., 2015).

The biggest potential to increase the food self-sufficiency is by a changed land-use. In contrast a changed kcal-consumption or diet will not have a big influence (see Figure 10-7–middle). 76% of the cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). However, the summed up values will not change drastically (see Figure 10-7 – right). Moreover, Mexican food supply of 3,000 kcal/cap/day is already above its average dietary energy requirement of around 2,400 kcal/cap/day (Hiç 2014).

Figure 10-7: The possibility for a food supply from surrounding areas for Mexican cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV) and an increased kcal-consumption (AAMa). On the right the change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and two yield scenarios (min, max) and the averaged values.

10.3 The Potential for Synergies and the Stage of Country Development

Mexico is not only vulnerable to but is also inducing climate change. Mexico is exposed to the impacts of extremes associated to climate change but the economy does not seem structurally exposed: the share of agriculture is low, agricultural exports are minor compared to technologies and mineral commodities. Economic factors of risk are under control. The actual growth model is reducing the adaptive capacity. Climate change will exacerbate social vulnerability, due to changes in land use produced by sea level raise, changes in rainfall patterns and in the suitability of land for agriculture.

Two inter-sectoral trade-offs are prominent in Mexico. One relates emissions from energy and growth, with social development. Emissions from energy and transport accounted for 66.7% of total emissions in 2011 (WRI 2014). Another important trade-off can be observed at the nexus 'expansion of the agricultural frontiers and deforestation'. The combined emissions of agriculture and deforestation accounted for 11.8% of total emissions in 2011 (WRI 2014).

10.3.1 Energy and Human Development:

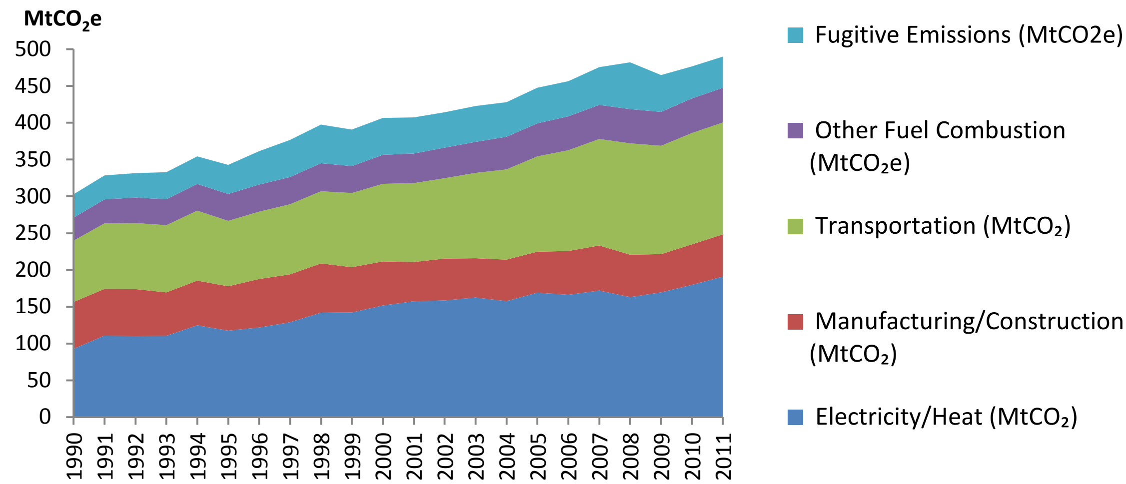
As the flat trend of emissions per capita in Figure 10-5B, C and D show, the human factor affecting total GHG emissions is population growth. With emissions per capita around 3.76 tCO_2 per year the country has progressed in the health index (Figure 10-5B) which is very close to the levels reached by Germany. The pace is not as high as in e.g. Cambodia. The education index in the HDI has also shown progress over the last three decades, but it is still low compared to Germany. Indicators evaluating the performance of the country in education (see Figure 10-9) show the commitment of the government to invest in the sectors, but 83.1% is spent in teachers' salaries, and 93.3% in wages of the entire education system (Toribio and Hernandez 2014). The income index does not show progress (Figure 10-5D). The income of poor population is threatened by decreasing competitiveness of small and middle size companies. The taxing system has created incentives for informal jobs. Trade agreements with North America have had consequences for the income of rural families depending on agriculture, i.e. the country became net food importer (Pradhan et al. 2015a) even though it has the potential to become self-sufficient (Pradhan et al. 2015). Actual policies are affecting the capacity to secure food from the families (Reddy et al. 2013). The national headcount poverty ratio is high and increasing. As Figure 10-4 shows, income inequality is high and non-decreasing. The economic model is deepening the social trade-off in Mexico. Therefore, the increasing total GHG have not been used for human development. Energy per capita is constant but energy consumption is mostly benefiting the richest and large companies. To bring Mexico on a sustainable pathway, strategies must be developed for emissions reductions and for improving significantly human development.

According to the Fifth National Communication to the UNFCCC (CICC 2012), the abatement potential of Mexico in 2020 is 261 $MtCO_{2e}$. 150 $MtCO_{2e}$ should be provided in the energy sector, 34 $MtCO_{2e}$ in public transport and waste management, and 77 $MtCO_{2e}$ in forestry. Energy offers the highest potential for emissions reductions (see Figure 10-2), mostly from electricity production and transportation (see Figure 10-8).

CDM projects portfolio by sector already accounts for 131 $MtCO_{2e}$ up to 2010. Of them, 91 $MtCO_{2e}$ are provided by projects in energy, transportation and waste management and the rest by projects in forestry and agriculture. The costs of implementation will be offset by gains in productivity, energy security, environmental quality, health and social inclusion –i.e. inequality reduction (CICC 2012). Therefore, for synergies in Mexico, the question is policy options to implement mitigation in energy and transport while reducing inequality and improving human development.

With current economic policies shifting electricity systems to technologies based on renewable energies will have negative consequences on social vulnerability. Small and medium size enterprises and poor families would be burdened by higher electricity costs. The correction of social trade-offs needs to consider both, the use of economic instruments like progressive taxes and subsidies to the poorer, and policies to develop the economy towards sectors of services in which small and middle size enterprises can grow.

Figure 10-8: Energy emissions in Mexico.

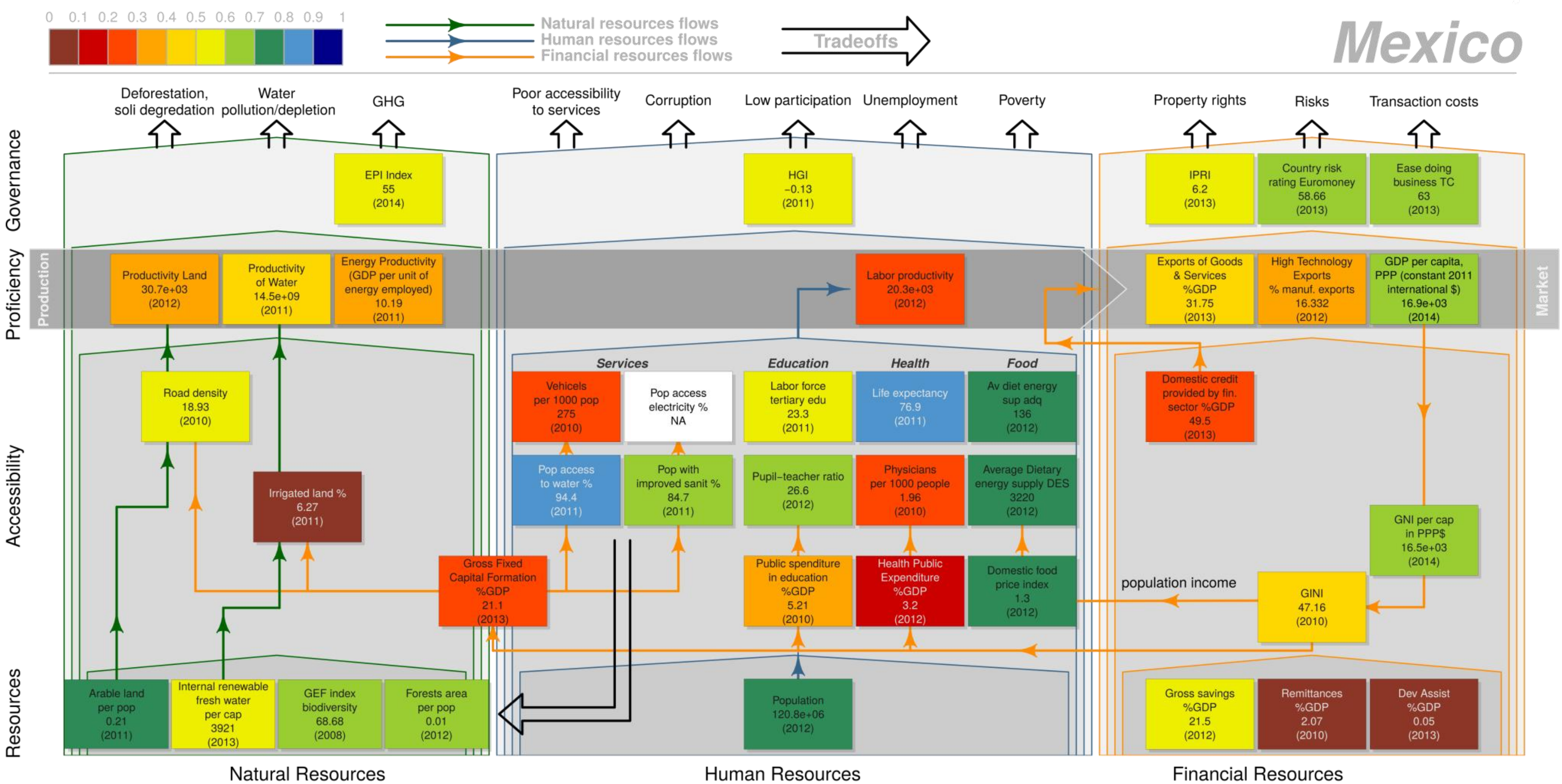


Electricity and transport offer the highest potential for mitigation in Mexico. Data from (WRI 2014).

For inclusive growth Mexico needs to improve productivity of resources, labor and capital. Options to increase the productivity of land and water include increasing road density and the share of irrigated land. This last option may be relevant considering the scarcity of fresh water resources and the middle productivity of water. More land irrigated might help rural population to secure agricultural outputs. Human capital also needs improvements (see labor productivity in Figure 10-9). It requires effective policies to improve human capital. As mentioned a bottleneck is the inertia of the education system and the low share of budget spent in the provision of other means and infrastructure beyond wages. Mexico needs to increase the provision of domestic credit by the financial sector. The share of GDP for credit provided by this sector has increased (see Figure 10-3) but other countries of similar economic status provide much more (e.g. South Africa 190%, or India 77%).

However, the feasibility to pursue adequate policies for resilience depends on the capacity to govern resources. Indicators of governance show high developments in the governance of financial risks and uncertainties, but middle performance in property rights, human governance and environmental governance (see Figure 10-9). These differences are indicative of the emphasis of the Mexican governments on the development of the economy, but the lower commitment in social and environmental issues. The averaged indicator of human governance is negative (World Bank 2015b). In the indicators composing the averaged index, Mexico performs slightly positive but decreasing in voice and accountability (from 0.30 in 2003 to 0.08 in 2013), government effectiveness (0.31 by 2013) and regulatory quality (0.46 in 2013). However, the country performs negative and decreasing in political stability and the absence of violence, rule of law, and the control of corruption. The middle value of the environmental part of the EPI index shows the difficulties of the country to control deforestation and environmental pollution.

Figure 10-9: Indicators of the adaptive capacity of Mexico.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. Mexico is rich in natural resources, has an average development of road infrastructure and low-average productivity of water, land and energy.

10.3.2 Agriculture, Food Security, Deforestation and the Water Cycle:

As reported in section 10.1 results from GCM are not conclusive about the future changes on water cycles from climate change in Mexico. Some regions will benefit from higher rainfall, while others will have increased water scarcity. In any case, impacts of climate change will cause land use changes from changes in rainfall patterns. Climate change will also produce more intense and frequent extremes like storms, droughts and heavy rainfall. These changes have the potential to exacerbate environmental and social trade-offs. A strategy for synergies in Mexico has to consider utilizing the potential land use changes from climate change for enhancing food security, benefiting the poor, halting deforestation and reducing GHG emissions.

The country has the potential to become food self-sufficient. Yet, policies need to be readjusted, as currently Mexico is a net importer of food. The strategy for synergies implies enhancing the production technologies and practices of small farm agriculture in Mexico. According to the projections of the Third National Communication, changes in water cycles and crop yields from climate change will demand widening the agricultural area 15-40% at least potentially against forest areas. This widening can be partially offset by improving agricultural efficiency. As reported only 50% of the potential crop production is used. A simple extrapolation shows that if the crop production index (2004-2006 = 100)[12] continues growing as today it will increase only 8% in 2020. Therefore, more investments for developing agricultural productivity are needed.

A combination of measures to improve agricultural efficiency and reduce the share of grasslands for agriculture might bring about net emissions reductions. The potential of grasslands and meadows is further constrained by the scarcity of water in Mexico. The country would need to develop strategies to enhance and optimize the use of water. Climate change might increase water availability in those areas where increased rain in the coming future is expected, in the central North part of Mexico (Schewe et al. 2014). These areas could be eventually used to further enhance the regulation of the water cycle by developing programs on forestation and afforestation.

10.4 Conclusions:

Mexico is not only vulnerable to, but is also fostering climate change. Mexico is exposed to the impacts of extremes associated to climate change, but the economy does not seem structurally exposed, i.e. the share of agriculture is low, agricultural exports are minor compared to technologies and mineral commodities. Economic factors of risk are under control. The growth model is increasing social vulnerability. Climate change will exacerbate social vulnerability, due to changes in land use produced by sea level raise, changes in rainfall patterns and in the suitability of land for agriculture.

For synergies Mexico needs to revise its economic model, which is based on the promotion of the competitiveness of large size companies, and the lack of incentives for middle and small scale enterprises. A more inclusive growth model requires decreasing

---

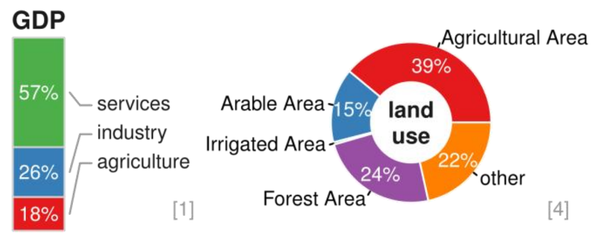
[12] Crop production index shows agricultural production for each year relative to the base period 2004-2006. It includes all crops except fodder crops. Regional and income group aggregates for the FAO's production indexes are calculated from the underlying values in international dollars, normalized to the base period 2004-2006 (WB 2014).

poverty and inequality, for reduced social vulnerability. If poverty is reduced the pressure on forests will be decreased. A combination of measures to improve agricultural efficiency and reduce the share of grasslands for agriculture might bring about net emissions reductions. The country has the potential to become food self-sufficient. Due to the high income inequality, the adoption of renewable energy systems with higher costs would burden even more the poor and the small and medium enterprises. Progressive taxes and subsidies are useful instruments to correct this tradeoff. Mexico also needs policies to develop the economy towards sectors of services in which small and middle size enterprises can grow.

11. NICARAGUA

Figure 11-1: Nicaragua – Factsheet and physical map:

Country size	130,370 sq km	[1]
Coastline	910 km	[1]
Population	6.17 millions	[2]
Rural population (%)	41.5	[2]
Human Development Index	0.61 (132 of 187 – Medium)	[3]
Life expectancy at birth	74.84	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

11.1 SENSITIVITY AND VULNERABILITY

11.1.1 Sensitivity of Natural Resources

Climate change scenarios for Nicaragua are rare. The examinations in this section is based on UNDP country profiles (McSweeney et al. 2010b). These provide temperature and precipitation projections considering A2, A1B, and B1 forcing scenarios.

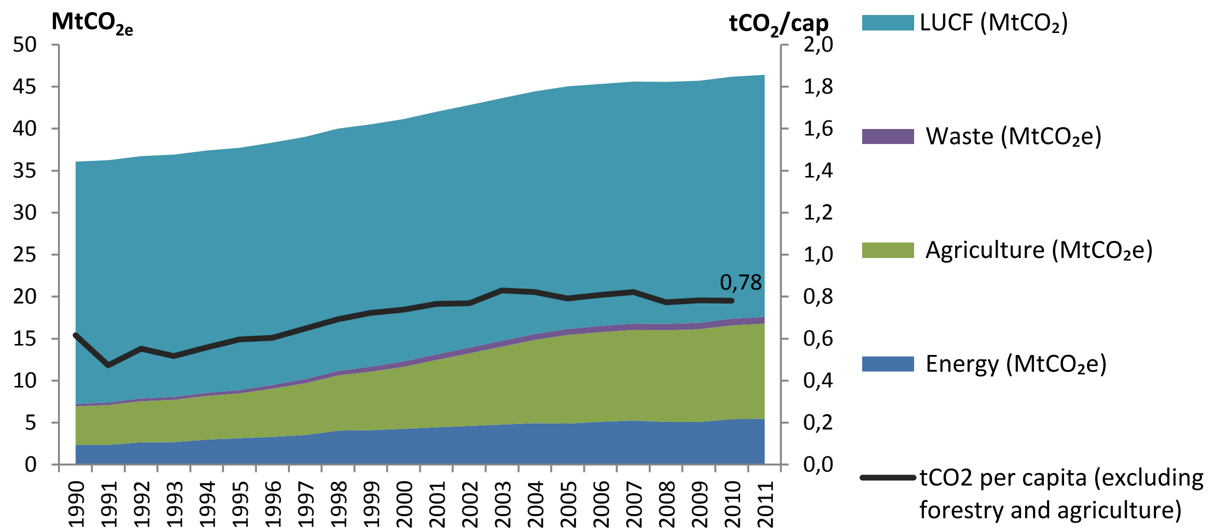
Temperature: According to the country profile, the mean annual temperature has increased by 0.9°C since 1960, at a rate of around 0.2°C per decade. The mean annual temperature is projected to further increase by 0.6 to 2.7°C by 2060 and 1.2 to 4.5°C by 2090. The most rapid changes are expected for the North-east (McSweeney et al. 2010b).

Water resources, rainfall and precipitation: Mean annual rainfall has declined within the last 15 years. This is mainly due to lower rainfall during the wet season (June-July-August and September-October-November). The observed average trend since 1960 has decreased 5-6% on average per decade. Projections of mean annual rainfall do not show a consistent direction of change, but the median values are consistently negative for all seasons and emissions scenarios. Projections vary between -63% and +16% by the 2090s (McSweeney et al. 2010b). The most significant decline in precipitation is expected in dry regions, mostly western and northern parts of the country and mainly during June-July-August in the middle of the wet season (World Bank 2009a). While in the Atlantic region there is no vulnerability in the context of water availability and hazards the Pacific and Central regions are highly vulnerable to climatic variability by 2050 and 2100 (World Bank 2009a). Furthermore, strong reductions in underground water are projected in the mid-century with a 75% decline in the base water flow until 2050 and up to 90% by 2100 (World Bank 2009a). Climate change may produce conflicts induced by increased water scarcity, shortages in fresh water in urban areas, reductions of water recharges due to an unsustainable use of freshwater resources, lower water tables caused by recurrent droughts, and more water pollution (UNDP 2010).

Crop yields: Climate change will affect agriculture in general, but the production of coffee most specially (Laderach et al. 2011). Coffee could even be impossible to grow towards the end of the century (World Bank 2009a). The production of maize, beans and coffee, three of the key subsistence and export crops, could decrease rapidly (Ramirez et al. 2010). The 'suitability for coffee crops in Nicaragua, and Costa Rica and El Salvador will be reduced by more than 40%' (Porter et al. 2014).

Atmosphere: Most GHG emissions in Nicaragua are produced from deforestation (nearly 63%), followed by agriculture (24%) and energy (11%) (see Figure 11-2). The government did not make significant progress to stop the loss of forests, although it has introduced a National Strategy for Avoided Deforestation and Forest Degradation which is linked to REDD+ programs. The country has not committed to reduce GHG emissions, adducing political reasons. Excluding LULUCF and agriculture GHG emissions are very low −0.78 tCO_2 per capita as of 2010 (World Bank 2015a).

Figure 11-2: GHG Sectorial Emissions (WRI 2014) and energy per capita emissions (World Bank 2015a) of Nicaragua.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agricultural production (World Bank 2015a). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from industry and bunker fuels are negligible and were not included. According to the shares of emissions in the figure, deforestation, agriculture and energy are the main mitigation sectors for the analysis of synergies.

Land use and Forestry: According to the Global Forests Assessment of (FAO 2014b) the forest area in Nicaragua decreased from 37.2% to 25.7 between 1990 and 2010%. 50% of forests resources have been transformed into crops and pastures since 1950 (FSP 2012). Deforestation is driven by a mixture of uncontrolled expansion of cattle ranchers, commercial logging, mining, and intensive agriculture (FSP 2012), but as a survival response of landless peasants (López-Carr and Burgdorfer 2013).

11.1.2 Economic Vulnerability

Nicaragua was the third most affected country in the world by the impacts of extreme weather events between 1991 and 2010 (UNDP 2013a). Over these 20 years more than 40 events occurred in Nicaragua. As result over 150 people per year died on average and annual economic losses nearly reached 2% of GDP (Harmeling 2012).

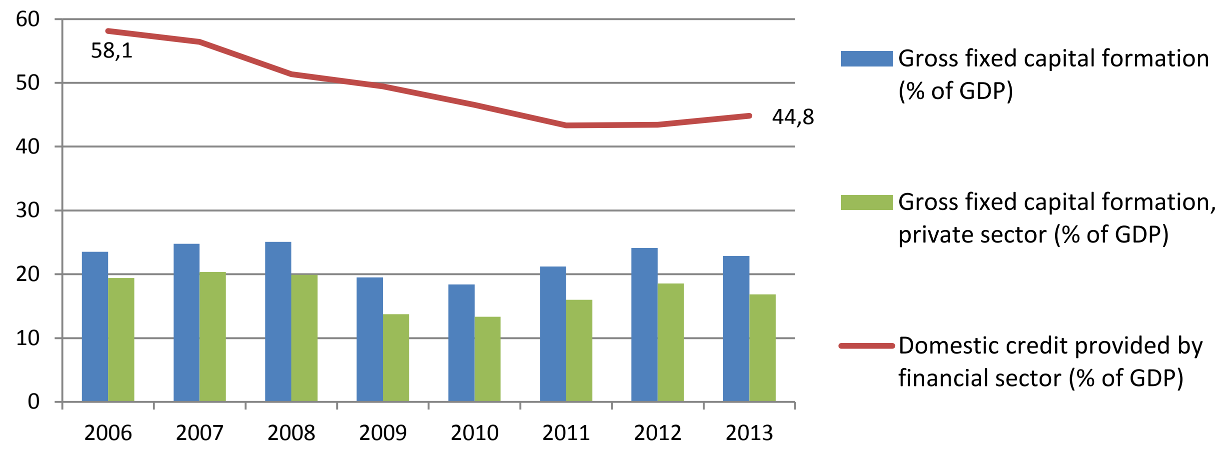
Economic impacts on the agricultural sector: Its GDP grew by 3.4% per year between 2000 and 2012 (World Bank 2015a). Impacts on crop yields and changes in water cycles imply damages in agriculture. In 2012 the agricultural sector contributed 20% of GDP, industry and services contributed 27% and 53% respectively. While the share of the service sector decreased over the last years, agricultural and industrial sectors have grown (World Bank 2015a). Regarding population income 31% of the population rely on income from agriculture by 2011 (WFB 2015).

Economic specialization and diversification: As the number of commodities exported serves as proxy for diversification it can be concluded that the economy of Nicaragua is lowly diversified. Exports are the main source of revenues, and represents 38.6% of the GDP in Nicaragua as of 2014 (WFB 2015). In 2012 46 commodities accounted for 89.94% of exports value; 18 agricultural commodities produced 46.29% of total exports (Simoes and Hidalgo 2014), and coffee represented the most exported good (14.4%). With low diversification and specialization and high reliance on agricultural commodities for revenues climate change may cause considerable damages to the economy of Nicaragua.

Capitalization and Capital Formation: Figure 11-3 shows the 2006-2013 trends indicating investments in infrastructure, roads, buildings, etc.. Investments in gross fixed capital formation are higher than the average of Latin America (close to 20% of GDP between 2011 and 2013) (World Bank 2015a). Investments from the private sector in fixed capital formation are lower but within the range of other countries in this study (between 15 and 20%). Both private and public investments in gross fixed capital formation are very variable denoting the influence of external events in the planning of investment budgets in Nicaragua. The provision of domestic credit from the financial system in Nicaragua is decreasing. This is important due to the fact that the country's economic structure is based on small and low-productivity enterprises, i.e. 90% of all businesses are micro, small and medium sized enterprises, contributing 40% of the GDP. About 60% of jobs in Nicaragua are based on these companies (IADB 2013).

Economic Risk and Uncertainties: Losses from risks and economic uncertainties reduce the capacity to use financial capital. Nicaragua's annual GDP growth rate was volatile during the last decade, with an absolute minimum of minus 2.8% in 2009, indicating that even Nicaragua was affected by the economic crisis in 2008/2009. Average inflation between 2000 and 2013 was 7.98%, with standard deviation of 4.02 (World Bank 2015a) and a peak of 19.8% in 2008, indicating that the government does not had an effective program for active inflation control. Nicaragua has deficits in the governance of financial risk and transaction costs. The ease doing business indicator of transaction costs ranks Nicaragua 124th (out of 188 countries). With regard to property rights Nicaragua's Property Rights Index (8.2 in 2013) places the country among the highest in the world. Liscow (2013) has empirically shown that more secure property rights in Nicaragua have exacerbated deforestation. The country risk index (Euromoney 2014), which evaluates structural, political and economic risk, places the country in the third decile (32.59/100 as of 2013).

Figure 11-3: The recent evolution of capital in Nicaragua.



Domestic credit provided by the financial sector (World Bank 2015a), and investments in gross capital formation, private and public. For growth and development, the country invests similar shares of GDP in the formation of gross fixed capital with other countries in the region studied (Mexico, Peru and Colombia). The potential for growth is increasingly restricted by the shrinking provision of domestic credit.

11.1.3 Social Vulnerability

Consequences of climate change for social vulnerability are given by economic impacts of climate change, but by inequality and other conditions affecting the population. In 2008 almost half (46.5%) of the workers were underemployed, while 7.2% of the potential working force in 2013 was unemployed (WFB 2015). As shown in Figure 11-4 the poverty headcount ratio has but only slightly decreased between 2005 and 2009, while later information is not available. In addition, inequality has increased significantly in the same period (World Bank 2015a). Increased inequality has negatively affected the three lower income groups, while affecting positively, but insignificantly the second income group and benefiting the richest segment.

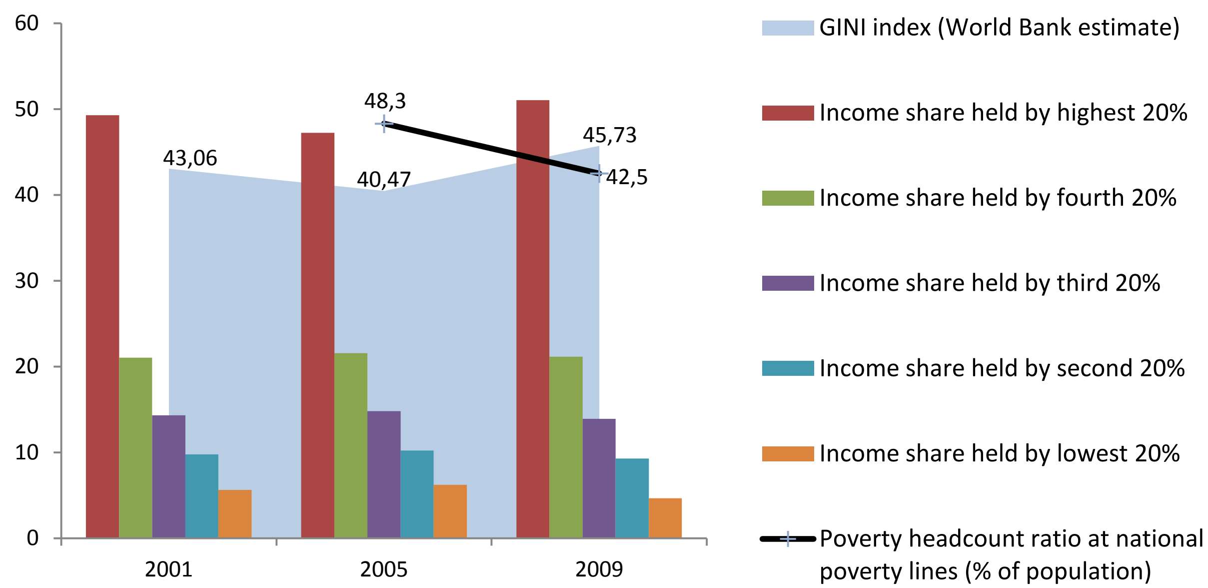
Food security: In 2013 41.85% of the Nicaraguan population lived in rural areas. 25% of farming households experience chronic or temporary food insecurity (FAO 2013b). In these poor rural households more than 50% of income is generated through rain-fed agriculture (World Bank 2009b). Nicaragua reduced the prevalence of undernourishment from 55.1% to 20.1% between 1990 and 2010 (FAO 2014b). Nevertheless, the food deficit was still very high in 2012 (144 kcal/cap/day). If the prevalence of food inadequacy is considered 30% of the population would have suffered from inadequate diets.

Health, Sanitation and Water Services: Health vulnerability has been indicated to be the most important issue in social vulnerability to climate change in Nicaragua (UNDP 2013a). The prevalence of diarrhea, dengue, and leptospirosis (Keller 2013) is related to seasonal rainfall patterns and extreme events that increase the emergence of standing water sources, which facilitate disease transmission.

According to the UNDP (Keller 2013) impacts from climate change on health include an increase in cases of malaria, hydric, allergic and respiratory diseases (Keller 2013). The Nicaraguan population is exposed to serious health conditions due to low accessibility to water and sanitation services. As of 2011 the access to fresh water was only available to 85%

of the population. Access to sanitation is even worse (52% in the same year), i.e. almost 2.87 million are suffering from lacking service. Closing the gap in sanitation and water is needed to reduce health vulnerability. Furthermore, financial support to health care is low. Nicaragua spent only 4% of GDP in health services in 2012 including private and public expenditure (World Bank 2015a). This is below the average in Latin America and the Caribbean (7.7% in 2012) (World Bank 2015a). In spite of this efforts to improve are consistent and Nicaragua is systematically increasing the share of GDP in the health sector (World Bank 2015a).

Figure 11-4: The recent evolution of income distribution, inequality and poverty in Nicaragua.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The poverty headcount ratio (World Bank 2015a) is an national measure of the efforts of the government to reduce poverty via subsidies of social programs. These indicators offer a view of the vulnerability of the poor and their situation in the context of inequality. Increasing inequality of income and high poverty headcount ratio reveal the current deepening of social trade-offs that need correction.

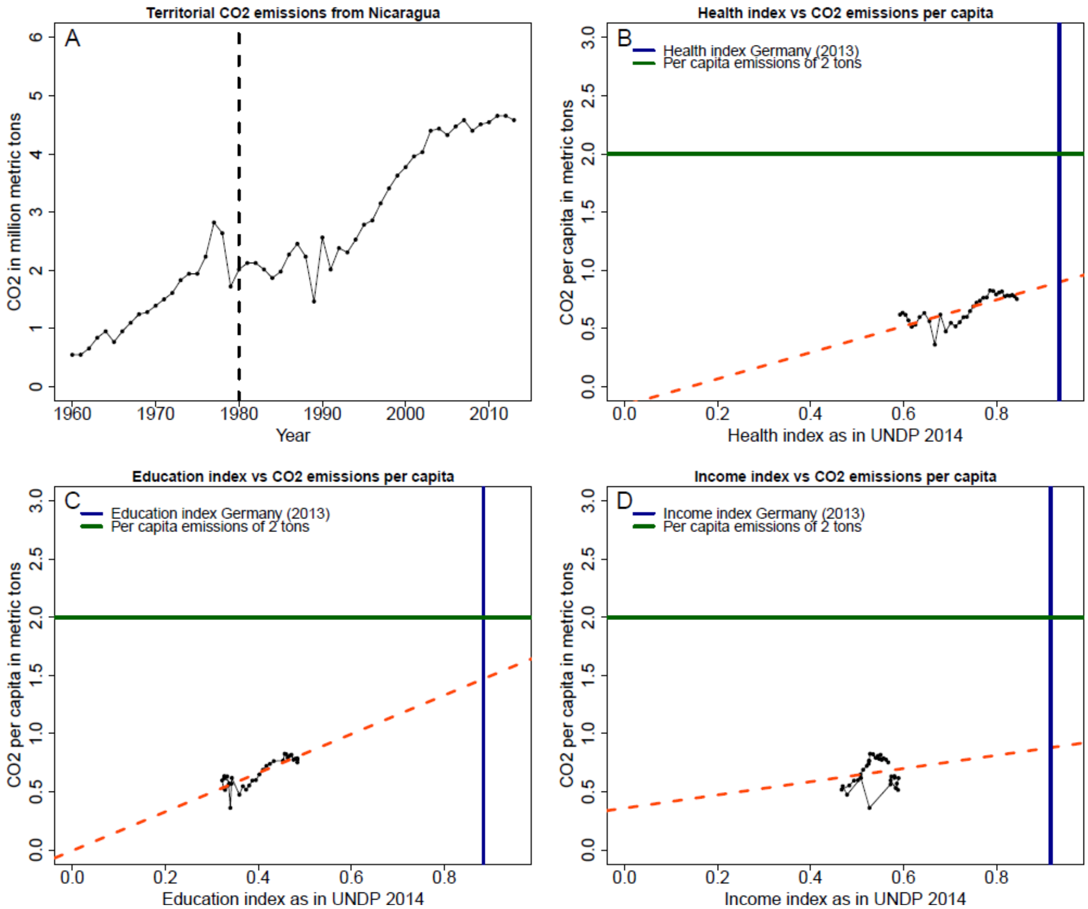
Education: The pupil-teacher ratio in primary education in Nicaragua was 29.6 as of 2012. This is far below OECD countries (16) (World Bank 2015a), but increases in education expenditure were observable in the last years. However, the labor force with tertiary education has decreased from 13.5 in 2006 to 12.89 in 2010 (World Bank 2015a).

11.2 LINKS BETWEEN ADAPTATION, DEVELOPMENT AND MITIGATION

11.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from fossil fuel combustion in Nicaragua are characterized by a steady increase between 1960 and 1977, a stagnation throughout the 80s, a second rise throughout 90s, and stagnation at about 4.5 $MtCO_2$ since early 2000s (Figure 11-5A).

Figure 11-5: Trends of CO_2 emissions and the HDI in Nicaragua.



Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). Panels C and D show analogous information as panel B for the Education and Income index, respectively. Data on population, income, education and health are obtained from the World Bank 2014 database. Horizontal green line shows the 2t/cap CO_2 target. Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. The trends do not allow significant conclusions about the coupling of increasing emissions per capita from energy and human development in Nicaragua, due to the omission of LUCF and agriculture emissions.

On a per-capita basis, CO_2 emissions in Nicaragua have increased slightly from 0.6 in 1980 to about 0.8 tCO_2 per-capita in 2013 (Figure 11-5B). Correspondingly, the relation between per-capita emissions and the different components of human development is a positive one, but with rather low slopes (Figure 11-5B, C and D). The progress in health standards in the last 30 years has been characterized by a steady approximation towards developed-world standards (2013 health index for Nicaragua = 0.84, 2013 health index for Germany = 0.93). Regarding the remaining components progress has been slower and still distant from developed-world standards, especially regarding the education index.

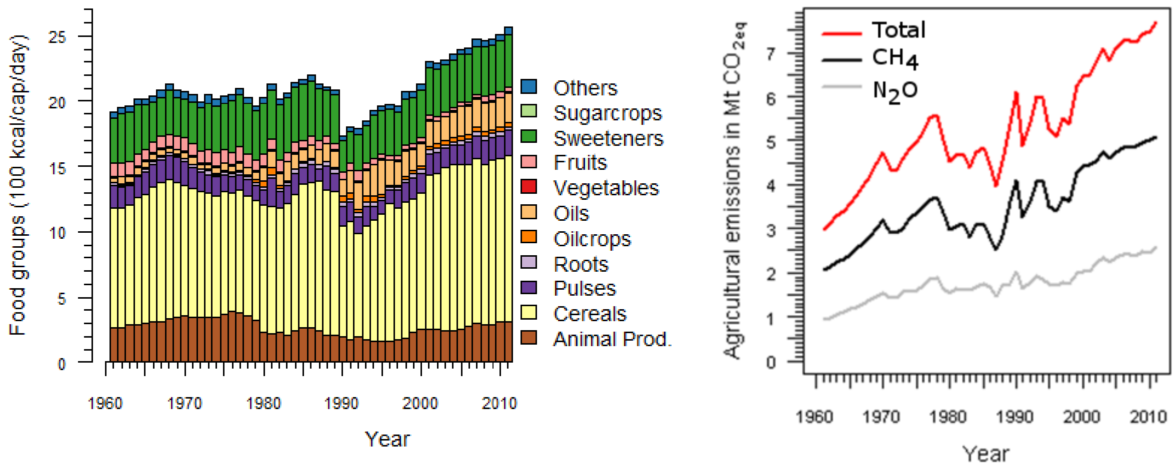
Despite the progress increasing good health standards, the low performance of Nicaragua in education and income levels are expected to slow down the progress of the country towards higher scores of Human Development. An HDI above 0.9 for Nicaragua cannot be expected within the first half of this century (Costa et al., 2011). By 2050 CO_2 emissions in Nicaragua are projected to range at about 17 $MtCO_2$ (Costa et al. 2011).

11.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 11-6 (left) presents the evolution of dietary patterns in Nicaragua between 1961 and 2011. The total food supply has increased from 1,910 kcal/cap/day in 1961 to about 2,560 kcal/cap/day in 2011, but malnutrition in rural areas and food inadequacy remains still unresolved. The current Nicaraguan food supply is above its average dietary requirement of 2,390 kcal/cap/day (Hiç 2014). During the last five decades the amount of cereals supply per person per day has increased by around 370 kcal, the supply of oils, sweeteners, and animal products have increased by 190, 60, and 40 kcal/cap/day respectively. Current per person animal product supply of 310 kcal per day is lower than the global average per person animal product supply of 500 kcal per day. Supply of total calories and the different food groups have slightly changed between 1961 and 1989. The food supply dropped heavily in 1990 due to the internal war, with the lowest calorie supply of 1,730 kcal/cap/day, but has continuously increased in the Nicaragua ever since. This depicts the increasing food availability of the country and the start of lifestyle shifts towards calorie-rich and nutritious diets largely based on cereals.

In the year 2000 around 1.4 million people in Nicaragua lived in the regions which are self-sufficient in terms of food production within 10 km x 10 km grid (Pradhan et al. 2014b). The country's food production was enough to feed approx. 2.4 million people resulting on a high dependence on international trade for food supply. Nicaragua's net food import was about 8 billion kcal in the year 2000. The country is a net food importer in terms of calories (Pradhan et al. 2015a), although a net food exporter in terms of monetary values (FAO 2014b). The later is a consequence of high value crops exported like coffee and beef. Major parts of the country have attained less than 30% of the potential crop production (Pradhan et al. 2015a). Nicaragua could become food self-sufficient by closing yield gaps to attain 50% of the potential crop production. Closing crop yield gaps can increase crop production and ensure the future food self-sufficiency in Nicaragua while considering plausible population growth and diet shifts by 2050 (Pradhan et al. 2014b).

Figure 11-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Nicaragua.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions during the last fifty years in Nicaragua, including methane (CH_4) and nitrogen oxide (N_2O) emissions from the agriculture sector. Food supply in Nicaragua has improved in the last two decades; however, it is still below the global food consumption average of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emissions from agriculture have increased in the last decades, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

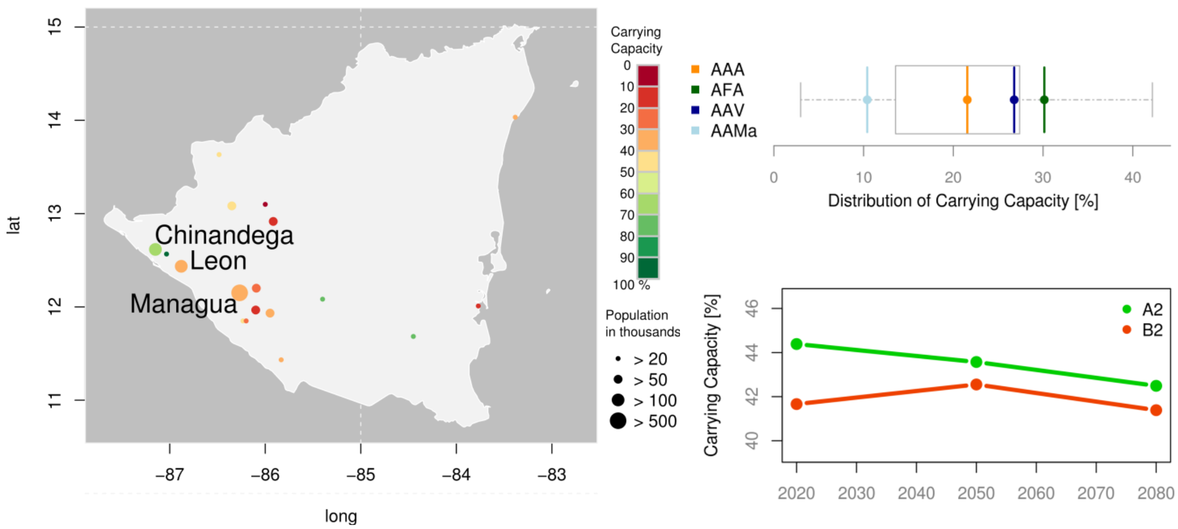
The total agricultural emissions of Nicaragua have more than doubled from 3 $MtCO_{2e}$/yr to 7.7 $MtCO_{2e}$/yr in the last 50 years (Figure 11-6 right). The increased emissions are related to increases in agricultural production to meet growing food demand and exports of food products, e.g., coffee and beef. Current diets consumed in Nicaragua embody emissions of about 0.9 tCO_{2e}/yr (Pradhan et al. 2013), and approx. 1.4 calories of crop product is fed to livestock to obtain 1 calorie of animal product (Pradhan et al. 2013). Currently, emissions per crop unit and livestock production in Nicaragua are higher than in developed countries (Pradhan et al. 2013). Technological progress may increase agricultural productivity and lower agricultural GHG emissions by lowering emission intensities (Pradhan et al. 2013).

11.2.3 Potential of Peri-Urban Agriculture and Local Food

58% of Nicaragua's 6.2 million population live in cities, and a future growth up to 8.4 million by the year 2050 will occur mainly in cities, which will result in 72% of the population living in urban areas (United Nations 2014). 18 cities with a population above 20.000 were investigated for the potential of regionalized food production to increase food security and reduce CO_2 emissions from the food transportation. Overall, these cities represent more than 1.9 million people. Today, already 62% of the surrounding areas are used for agricultural purpose, which is nearly two third of the arable area. 22% percent of the urban dwellers can be nourished from the currently harvested areas (Kriewald et al., 2015).

The largest potential to increase food self-sufficiency is produced by closing the yield gaps. Nevertheless, one has to take into account that changes in lifestyles may cause additional calorie demand up to 3500 kcal/cap/day common in North America will reduce the carrying capacity down to 10% (see Figure 11-7 – top right). Nine out of 18 cities will face a decreasing carrying capacity for the year 2080 (B2 scenario) due to climatic induced yield reduction (Kriewald 2012b). However, the summed up values for an average yield scenario would be still over 40% (see Figure 11-7 bottom right). Summing up, closing the yield gap must be the first priority for agricultural policy.

Figure 11-7: The possibility for a food supply from surrounding areas for Nicaraguan cities.

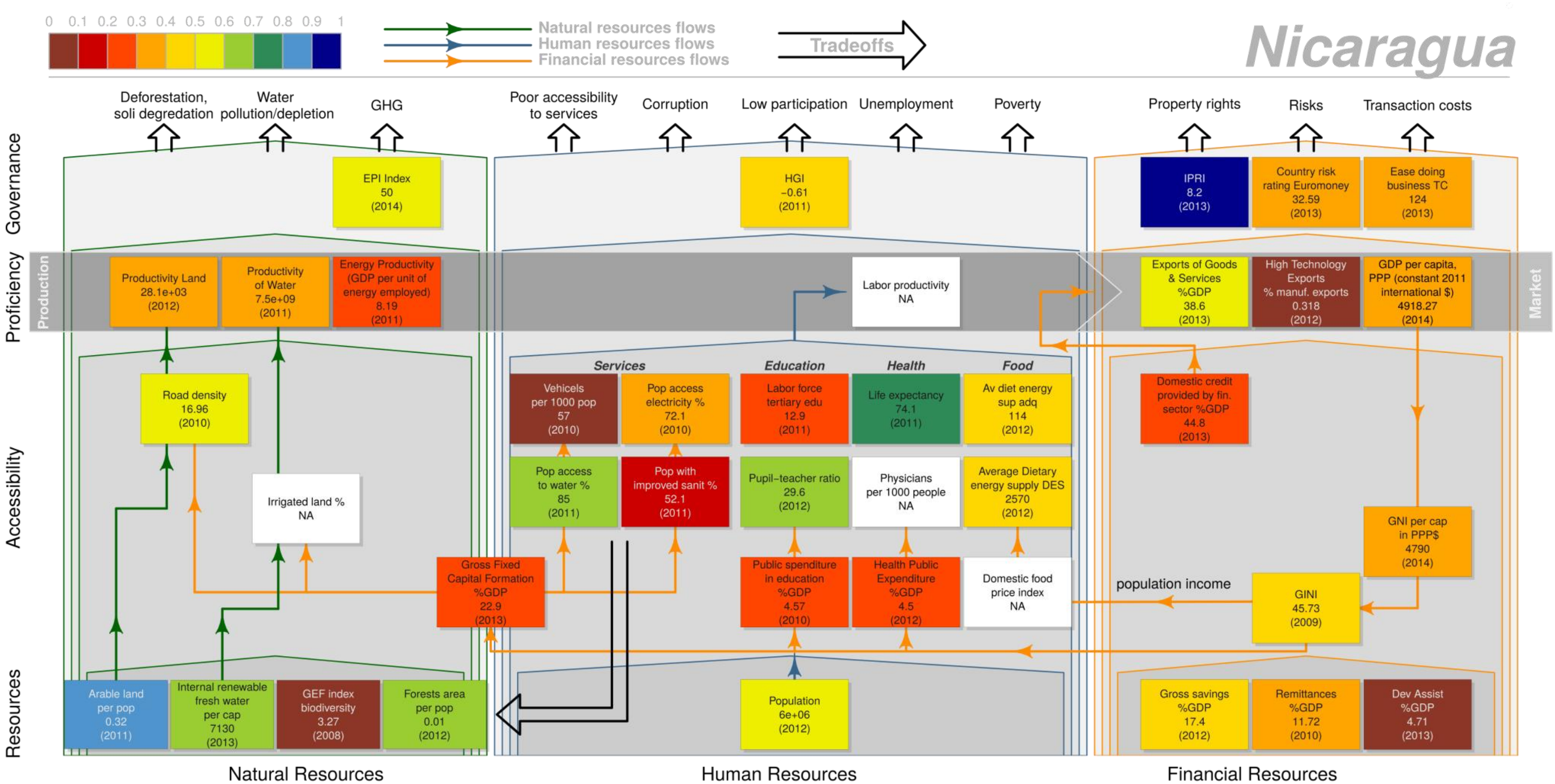


Map for current conditions (AAA) (left) and summed up carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right, the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2), based on an average yield scenario. The best possibility to minimize environmental trade-offs due to agriculture is by closing the yield gap, leading to high productivity of peri-urban agriculture. However, changing climate and diets can reduce the effect.

11.3 The Potential for Synergies and the Stage of Country Development

Nicaragua is burdened by environmental, social and economic trade-offs. The economic model based on the expansion of agriculture against forests areas is responsible for the reinforcement of such trade-offs. An important trade-off producing GHG emissions is deforestation driven by the expansion of crops and cattle ranching. Deforestation and the uncontrolled exploitation of water resources is also affecting water availability. Biomass consumption is another source of forests degradation. The social trade-off is reflected in the high and increasing inequality, and high poverty (see Figure 11-4). The country is not food self-sufficient. The population is burdened by food insecurity and malnutrition. As indicators of accessibility to human resources in Figure 11-8 show the population is affected by insufficient access to fresh water, sanitation and electricity. The economic model does not promote the development of industry and services. The share of GDP from services has decreased over the last years. Investments in the formation of capital are not consistent (see Figure 11-3). For climate resilient pathways, the country needs to reconsider its economic growth model. A new model of growth is needed for developing the adaptive capacity.

Figure 11-8: Indicators of the adaptive capacity of Nicaragua.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the methods section. The low performance in most indicators indicate that growth is an essential component for any strategy which may deploy synergies between adaptation and mitigation in Nicaragua.

11.3.1 Economic Growth and Adaptive Capacity:

Policies for the diversification and the specialization of the economy are required to reduce the dependency of agriculture and to increase the capacity to cope with economic shocks of climate change. This requires investments in the development of infrastructure and policies for the development of industry and services. The financial resources needed for such development have to be provided by progressive taxes. Exports represent an important source of revenues for the country, but are dominated by agricultural commodities. This reliance on agricultural commodities and the very low share of high technology manufactures is indicative of low specialization. The country will improve the productivity of land by investing more in the creation of transport infrastructure, which has a lower density than in other countries such as Mexico (18.93 km/km^2).

Nevertheless, the increasing inequality of income distribution and the negative performance in indicators of governance shed doubts about capacity of the government to promote such policies. The lack of capacity includes environmental, human and economic governance. In the environmental part of the Environmental Performance Index[13] (EPI 2015a) the country presents a medium performance. This medium value is questionable, due to the fact that Nicaragua has the highest deforestation per capita rate within the countries studied (see Part 3). Uncontrolled deforestation is linked to the lack of environmental and human governance and to an economic structure based on small and non-specialized activities. With regard to human governance the averaged index is negative. The country performs negatively and shows a negative trend in the variables 'voice and accountability', 'government effectiveness', 'rule of law' and 'control of corruption' since 2003. With regard to the control of economic uncertaintis and risks, the country has a low performance and in transaction costs evaluated with the ease doing business (see the the governance of financial resources in Figure 11-8). The high rank in the Property Rights Index (see Figure 11-8) is misleading as institutions of property rights in Nicaragua are responsible for increased deforestation (Liscow 2013). Property rights are not only about granting rights to private agents to decide land uses, but about establishing and enforcing limits. These indicators show that Nicaragua faces important challenges to overcome in the governance of the environment, the society and the economy, if the country aims to cope with the tremendous challenges posed by climate change.

There is no information about labor productivity in Figure 11-8. However, other indicators of productivity and the very low share of high technology in manufactured exports allow concluding that labor productivity in Nicaragua is quite low. As a fact, the labor force with tertiary education has decreased from 13.5 in 2006 to 12.89 in 2010 (World Bank 2015a). For the diversification and the specialization of the economy, Nicaragua needs to develop consistent policies for the human capital formation. Professionals need incentives to remain in their country.

The country does not perform adequately in social issues. Income inequality is growing and the national poverty head count ratio is high (see Figure 11-4). Undernourishment affected 20.1% of the population in 2010 (FAO 2015). The average dietary energy supply

---

[13] As explained in the introduction of the methodological framework, for the evaluation of environmental governance we disregarded the numeric assessment of health in the EPI index, and kept the environmental part for the assessment.

adequacy (114%)[14] shows that distributional issues are to some extent responsible for undernourishment. In education, the share of GDP invested is still low compared to other countries (see education in section 180). Nicaragua needs to bridge the gap in the provision of basic services in order to increase the adaptive capacity of the population.

11.3.1.1 Agriculture and Deforestation:

Agriculture is the sector from which financial surpluses for industrial and services development can be produced. Improving agriculture should not imply producing more deforestation. For synergies, policies promoting deforestation and the expansion of cattle can be replaced by policies increasing the efficiency of agriculture. As Figure 11-8 shows, land productivity in Nicaragua is low. Crop production is only 30% of its potential (Pradhan et al. 2015a). Given the big potential of Nicaragua to reduce the yield gap and improve land productivity, the country could consider not only the reduction of deforestation, but even to increase the forest area again. International cooperation could play an important role by supporting projects for developing the capacity in agriculture.

Emissions per capita from deforestation are the highest among the countries studied. As of 2010, 60.8% of GHG emissions in Nicaragua were produced by LUCF (WRI 2014) (see Figure 11-2). In addition, agriculture is the second sector producing GHG emissions. This sector shows the highest emissions growth rate (0.38 $MtCO_{2e}$ per year (WRI 2014). Adaptation actions in forestry, under the umbrella of the Forest Development Social and Environmental Program (POSAF) focus on economic productivity of small and middle producers in forest frontiers. Projects include infrastructure for water collection, improved biomass cooking stoves and education. Nevertheless, major drivers of deforestation are not being addressed. Transforming this trade-off into synergies requires stopping deforestation.

Options to improve agricultural productivity while enhancing environmental governance in forests areas demand investments, political strength, coordinated efforts and institutions. REDD+ may play an important role to help the country develop these requirements.

The country needs to develop reseach and development capacities in agriculture to achieve a higher productivity in small and middle-size farms. Agricultural assistance in these farms is needed to reduce risks and to assist farmers to incorporate new and more efficient technologies. Major needs to increase agricultural productivity in Nicaragua include improved soil quality management, improved management of pests, diseases and weeds, improving accessibility to markets, and adequate application of fertilizers (Pradhan et al. 2015a).

The National Environmental Strategy and Climate Action Plan 2010-2015 targets reducing vulnerability, but mentions concurrent mitigation effects, for instance in the National Strategy for Avoided Deforestation and Forest Degradation (MARENA 2011a). A number of voluntary mitigation measures are listed focusing on projects in the agriculture and the forest sector. The measures include training, awareness-raising and pilot projects for sustainable activities.

14 The indicator expresses the Dietary Energy Supply (DES) as a percentage of the Average Dietary Energy Requirement (ADER) in each country.

11.3.1.2 Energy:

To foster growth in the industrial and service sector an increased provision of sustainable energy is needed. The country has to bridge the gap in the provision of energy to the population (see Figure 11-8). Policies for the development of industry and services would increase emissions from energy and transport although these increases would still keep Nicaragua under the range of 2 tCO_2/cap. in the long term (see Figure 11-2).

The potential for renewable energies in Nicaragua is excellent, due to possible utilization of geothermal, hydroelectric, wind, solar and biomass energy. PRONicaragua, the official investment agency of Nicaragua estimates a potential of about 4,500 MW in the renewable energy sector (PRONicaragua 2012) and the World Bank an even larger number, up to 5,800 MW (World Bank 2013h). In this regard, the Inter-American Development Bank credits Nicaragua excellent climate fund-raising (Inter-American Development Bank 2013). Electricity prices are comparably high there seem to be great incentives for establishing clean energy. In 2010 72.1% of the total population had access to the electricity grid (World Bank 2014f). The country does not possess any identified domestic fossil fuels. Fossil fuels imports account for about half of its total primary energy supply (1.58 Mtoe of crude oil and oil products). In terms of energy security it is therefore highly dependent on international oil supply and its respective prices. In 2010 the National Program for Sustainable Electrification and Renewable Energy was introduced. The country was remarkably successful in developing micro-credits for small-scale renewable energy projects and attracting large-scale credits from foreign investors and donors.

The most noteworthy mitigation policy would be the aim for a 94% renewable energy share in 2017 (IADB 2013). In recent years, the government has focused strongly on improving electricity access through renewable resources, aiming to bring down electricity prices and to become more independent from imported fossil fuels. In recent years, the government has attracted international financing on renewable energy projects (US$1.5bn since 2006) (IADB 2013). In terms of emissions from the energy sector, which are usually growing fast when pursuing carbon-based development Nicaragua has made significant progress in recent years to diversify its energy mix on renewable energy sources. The aim for a 94% renewable energy share in 2017 is very ambitious as the country could become a role model for low-carbon development in the energy sector. However, mitigation in other areas is not engaged from a large-scale perspective, since adaptation gets the most attention with regard to climate change action. Representing one of the least developed countries covered in this study, Nicaragua needs to scale up its capacities to fully exploit its mitigation potential and obtain the benefits of a low-carbon development model.

Poor domestic, economic and societal assets diminish Nicaragua's overall mitigation capacity owing to its low development status. Implementing measures solely targeting mitigation might be challenging. The country’s mitigation potential is high as it seems capable of attracting international finance as a result of remarkable opportunities in the forestry renewable energy sectors.

Eleven CDM projects registered in Nicaragua accounted for a combined emission reduction of 999,059 tCO_2/year (UNFCCC 2014c). Four projects are related to wind power, two to hydropower, one to biomass and energy, one to geothermal energy, two to waste management, and one to reforestation. Additionally, there are five PoAs under CDM, in which Nicaragua is participating (together with other countries). Quantitatively, most of the reductions in emissions are provided by wind power projects, with three of them reducing emissions by more than 100,000tCO_2/year. The Vinasse Anaerobic Treatment Project provides big potential, while other projects such as the Southern Nicaragua CDM Reforestation Project and the Biogas Programme Nicaragua present more limited reduction potentials.

11.3.2 Disaster Risk Management

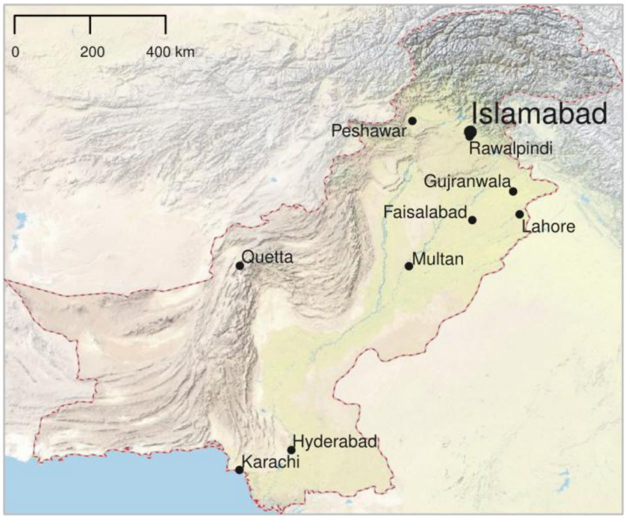
It is important to stress the role of Disaster Risk Management for development in Nicaragua. The main focus of climate change related policies focuses on adaptation, what is emphasized in its second National Communication to the UNFCCC (MARENA 2011b). Climate related hazards considered so far in adaptation plans include drought and water scarcity, weather extremes, floods, land degradation and deforestation, public health and sea level rise (ALM 2011). The development of the capacity in Disaster Risk Management is crucial, as the high costs associated to frequent and intense exposures to weather extremes are ~2% of GDP (Harmeling 2012). DRM constitutes the most effective way to reduce long term damages in Nicaragua.

11.4 Conclusions:

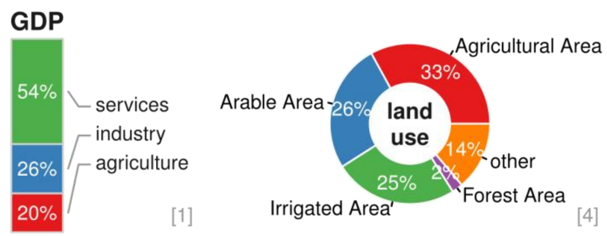
Nicaragua is severely threatened by extremes. The current economic policy setting of the country is exacerbating the adverse consequences of climate change. It is mainly based on the dismantling of forests for cattle ranching and crops. The expansion of agriculture is not being used to reduce inequality or to set the basis for industrial or service sectors growth. The country is burdened by corruption. For synergies the country needs to foster growth towards services and industry. Deforestations should be stopped and the expansion of cattle ranching controlled. The country needs to invest in the development of agriculture, for rural development, and for guranteeing future food security. The country has large potentials in renewable energy production, i.e. for GHG mitigation and energy security.

12. PAKISTAN

Figure 12-1: Pakistan – Factsheet and physical map:



Country size	796,095 sq km	[1]
Coastline	1,046 km	[1]
Population	185.13 millions	[2]
Rural population (%)	61.7	[2]
Human Development Index	0.54 (146 of 187 – Low)	[3]
Life expectancy at birth	66.57	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

12.1 Sensitivity and Vulnerability

12.1.1 Sensitivity and Vulnerability of Natural Resources

Pakistan is among the countries lacking detailed studies of climate change projections. To compensate this deficit the UNDP developed the Climate Change Country Profiles. Climate change projections for Pakistan were provided considering A2, A1B, and B1 forcing scenarios for 2030, 2060 and 2090 (Mcsweeney et al. 2010).

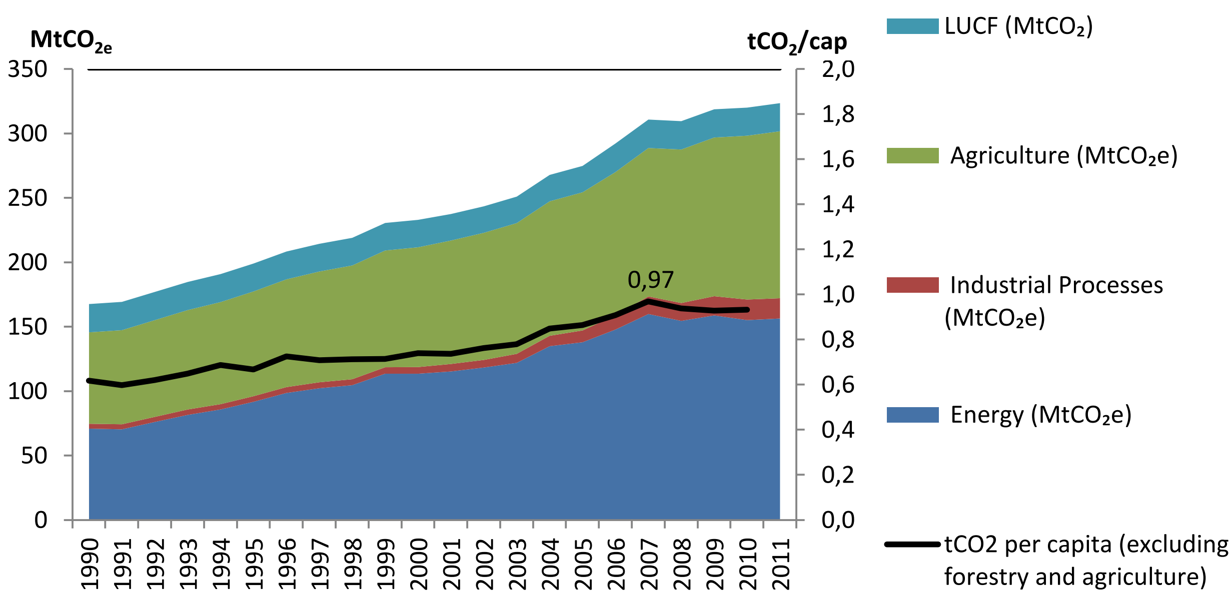
Temperature: According to this study mean annual temperature has increased by 0.35°C between 1960 and 2006, at a rate of 0.08°C per decade. The increase in temperature in Pakistan has been most rapid in October-November-December at a rate of 0.19°C per decade. There is no evidence of a warming trend in the summer season July-August-September. The mean annual temperature is projected to increase by 1.4 to 3.7°C by 2060, and 1.9 to 6.0°C by 2090 in respect to the reference period 1960 - 1990. The projected rate of warming is most rapid in the most northern regions of Pakistan likely affecting the remaining forests spots of the country. Increased temperature will decrease water availability and accelerate glaciers melting, causing flash floods. This will have serious consequences for agriculture, the economy and the population, as for example in 2010.

Water resources, rainfall and precipitation: Trends on change in mean annual rainfall over Pakistan have not been detected since 1960. Averaged mean annual rainfall over Pakistan considering different model trends project a wide range of both positive and negative changes in precipitation. Projected changes range from -9 to +20mm per month (-20 to +41%) by 2090s (McSweeney et al. 2010). According to Malik et al. (2011) the Indus River and its tributaries are the major water sources of Pakistan. More than 70% of river flow consists of the melted glacial run-off. The remaining is partly added by unpredictable monsoon rains in the summer. The rate of glaciers retreat has increased and glacial lakes are forming in the northern part of Pakistan.

Crop yields: Impacts of climate change on crop yields show different tendencies. Using crop growth simulation models CERES-Wheat and CERES-Rice the impacts of climatic parameters on wheat and rice productivity in Pakistan were analyzed (Iqbal 2013). For wheat an increase in temperature resulted in reduction of growing season length in all the regions, but at a faster rate in the Mountainous region compared to arid and semiarid plains (Iqbal 2013). Yield increased in the mountainous region but decreased in the sub-mountainous, arid and semi-arid regions (Hussain and Mudasser 2007). For rice production the results showed that a temperature rise by 1 and 5°C the length of the growing season is shortened from 108 days to 102 and 89 days, respectively in the semi-arid Sheikhupura district (Iqbal 2013).

Atmosphere: The energy sector is the largest source of GHG emissions as Figure 12-2 shows. Most promising mitigation opportunities can be provided by an increase of the renewable energy use in the electricity mix. One focus of the National Climate Change Policy (NCCP) is on energy efficiency requirements in building codes and long-term transport planning (MoCC 2012). Emissions from agriculture are caused mainly by methane and nitrous oxide originated particularly from the four sub-sectors, i.e. enteric fermentation in cattle, rice cultivation, release of N_2O from soils through fertilizers and manure management. Hence, possible mitigation actions should focus on these issues (MoCC 2012).

Figure 12-2: GHG sectorial emissions and energy per capita emissions of Pakistan.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agriculture (World Bank 2015a). Sectorial emissions obtained from (WRI 2014). Emissions from bunker fuels and waste are negligible and were not included. As the shares of emissions show, the most relevant sectors for the analysis of synergies are energy and agriculture.

Considerable mitigation potential exists in the Pakistan's forestry sector through carbon sequestration via afforestation, forestation and reforestation measures as well as preventing deforestation (MoCC 2012). The forestry sector is in focus of Pakistan's Vision 2030 document.

As an example, the Forestry Policy sets out to restore existing forests in addition to reforesting some deforested and degraded areas with a strong focus on watershed reforestation (Globe 2013). With a GDP growth of 6.1% in 2013 (compared to a South Asian GDP growth of 4.6%) a significant growth of emissions in the near future can be expected, particularly in the energy and transport sectors. Emissions per capita were (0.93tCO_2/cap in 2010) (World Bank 2015a) below the 2.0tCO_2/cap (WBGU 2009b).

Land Use and Forestry: The country is characterized by large variations in topography across its territory, as well as by climatic, socioeconomic and environmental diversities. Around 92 percent of the country's area is classified as semi-arid to arid facing extreme shortage of precipitation. Pakistan forest resources consist, among others, of one of the oldest and second largest Juniper forests in the world (Khan 2014). Most forests are located in the northern part of the country. Deforestation rate in Pakistan is very high. Current rates estimated 1.66% or an average of 42,000 ha per year (FAO 2014b). In last two decades Pakistan lost around 840,000 ha or 33.2 % of its forest. This is the highest value in Asia (FAO 2014b). Deforestation drivers include poverty (Shehzad et al. 2014) and fuel wood consumption (Ali et al. 2006).

12.1.2 Economic Vulnerability

The frequency of glacial hazards (e.g. glacial outbursts) in the Himalayas and Hindu-Kush region of Pakistan has increased considerably in the past decades (Malik et al. 2011). The floods in 2010 caused by extraordinary rainfalls provoked more than 1,900 casualties, affected more than 20 million people, and resulted in damages for $9.5 billion, the highest number of people affected and the largest economic damages from natural disaster in Pakistan (World Bank 2013a). Homes, farms and key infrastructure such as bridges were washed away in the area affected (UNISDR 2011). Floods of unprecedented scale in Southern Pakistan in 2010 affected 23 districts of Sindh Province and adjoining areas of northern Balochistan causing damages to crops, infrastructure and human settlements. The damages estimated in agriculture, energy, health, transport, environment, forestry, water supply and sanitation amounted to US$ 3.7 billion (Government of Pakistan 2012). The costs of recovery were estimated at US$ 2.8 billion.

Economic impacts on agriculture and other sectors: Increasing water scarcity, glacial melting, higher temperatures and extremes will produce direct impacts on the economy of Pakistan. Agriculture represents an important economic sector (25% of GDP as of 2013). In 2013, 44% of labor force was employed in agriculture (WFB 2015), but climate change will impact other sectors in Pakistan as well. Most of the productive structure is located in the Indus River delta, frequently and intensely affected by floods (World Bank 2013a).

The development of the productive factors: Impacts of climate change on economic activities can be reduced if productive factors become well developed. Climate change impacts will meet an economy constrained by the low development of productive factors in Pakistan. Major problems affecting productive factors include the overexploitation of water resources, the low installed capacity on electricity, lack of infrastructure, the low literacy rate and the high expenditures in defense.

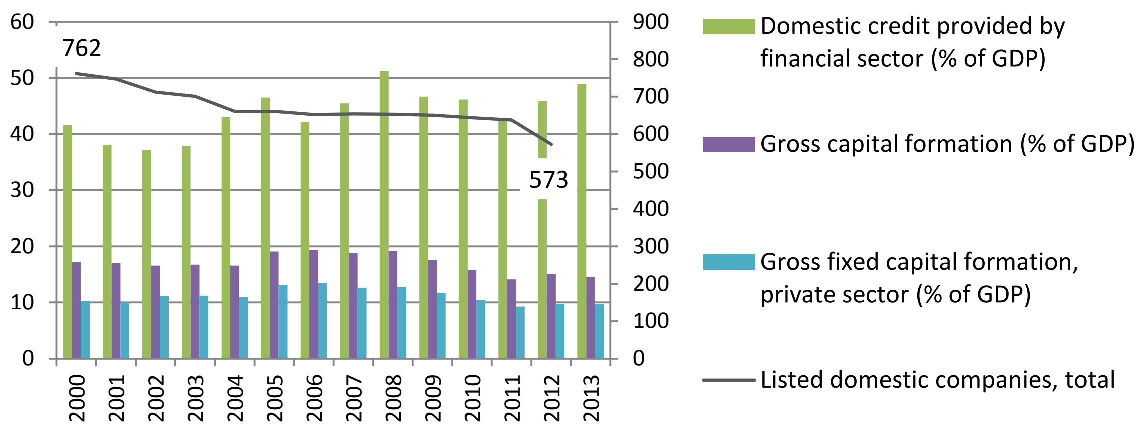
Water withdrawal in agriculture amounts to 94% of total internal renewable fresh water resources. Residential consumption accounts for 5% and industry only 1% (World Bank 2015a). Moreover, the annual freshwater withdrawals reached 333.63% of renewable resources in 2013, i.e. underground water resources increasingly being depleted (World Bank 2015a). The percentage of irrigated agricultural land in Pakistan is the highest in the World (73.5% as of 2009) (World Bank 2015a). If the groundwater reserves in Pakistan are depleted the economy may collapse. Pakistan suffers from an endemic energy crisis since last century. By 2013, the share of electricity generated by hydro and nuclear sources amounted 36%, furnace oil-fired sources 35%, gas-fired plants 29%, and coal-fired plants 0.1% (Shoaib 2013). Electricity from imported petroleum costs approximately Rs.12-17 (0.12-0.17 US$) per unit of oil power generation, while electricity generated by hydropower costs about Rs.1 (0.01 US$) per unit (GoP 2013). As of 2012 72% of energy consumed for residential purposes was biomass, 18% natural gas and 9% electricity (IEA 2014b). Labor force in agriculture is mostly illiterate (World Bank 2015a). The overall literacy rate in Pakistan is 55% (World Bank 2015a). Another burden on the economy of Pakistan is the war against terror. Since its independence Pakistan has spent a huge amount of the national budget for defense and security measures. The government budget share for defense is 18% (2.36 % of GDP), as of 2013-14 (Afzal and Yusuf 2013).

Economic specialization and diversification: As the number of commodities exported serves as proxy for diversification, it can be concluded that the economy of Pakistan is lowly diversified. In 2013 only 49 commodities accounted for nearly 80% of total exports value 17.42% of them are agricultural commodities and 47.49% from textile industry (Simoes and Hidalgo 2014). The major productive basis of agriculture and exports is located in areas vulnerable to floods. Yet, exports contributed only 12% to the GDP (WFB 2015). The economy is lowly specialized. Only 1.66% of manufactured exports were high technology in 2013 (World Bank 2015a).

Capitalization and Capital Formation: The share of GDP invested in gross fixed capital formation in Pakistan is very low compared to the mean of other countries studied around 20%. These investments reached just 14.6% in 2013 as Figure 12-3 shows. The variability of investments in gross capital formation makes the difficulty to keep long term targets evident. The adaptive capacity is determined by the ability to avail financial resources. The provision of loans by the financial sector is below 50% of the GDP. In other countries of this study, the provision of domestic credit by the financial sector reaches even more than 100% of GDP, e.g. in Vietnam. Moreover, the decreased number of listed companies in the stock markets indicates a process of capital concentration or loss of economic diversification.

Economic Risk and Uncertainties: The performance in the governance of risks is disparate. The economy of Pakistan is vulnerable to inflation. Over this century inflation has been high (average 8.7%) and volatile (standard deviation 4.9) (World Bank 2015a). The country does not perform adequately in transaction costs. In the ease doing business index, used as proxy for transaction costs, the country ranks 110 in 2013 (with 1 being best and 183 worst). Moreover, in the country risk index (Euromoney 2014), which evaluates structural, political and economic risk the country reaches a value of 32.34 (as of 2013). This index provides a maximum value of 100 for minimal risk. Yet, in the International Property Right Index (IPRI) the country performs better (6.6 in 2013). The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). These numbers show that economy of Pakistan is highly vulnerable to economic risks and inefficient in the control of transaction costs.

Figure 12-3: The recent evolution of capital in Pakistan.



Domestic credit provided by the financial sector, number of listed domestic companies and investments in gross capital formation (World Bank 2015a), private and public. For the analysis of the coping capacity, these set of indicators give a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. Pakistan shows difficulties to invest consistently in capital formation and to avail financial resources for domestic credit.

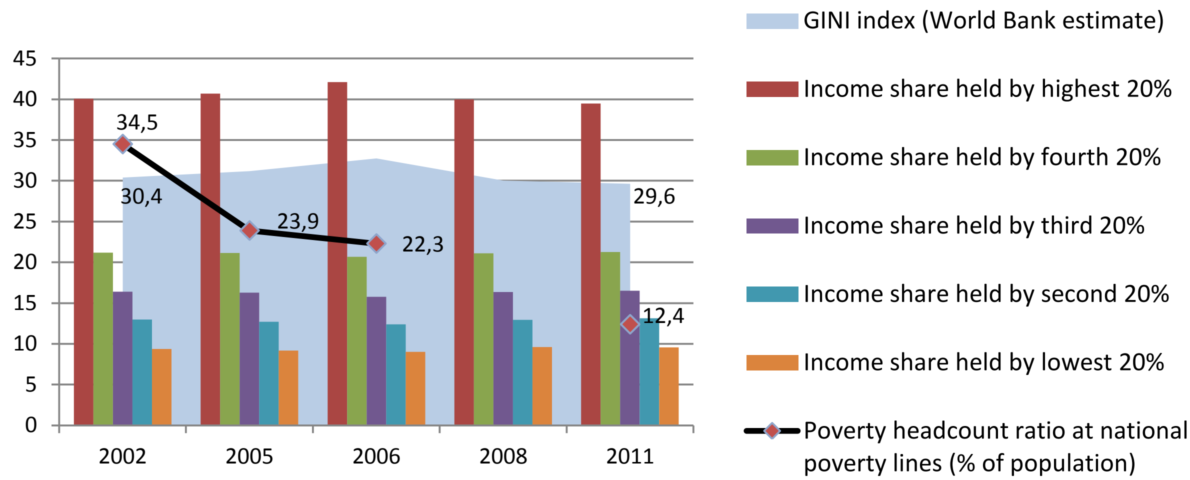
12.1.3 Social Vulnerability

The major sources of social instability in Pakistan are flooding crises, but corruption, conflicts, lack of transparency and accountability and abuse by governmental agents and agencies (Hippler 2008). As Figure 12-4 shows, income inequality has been reduced from 30.4 in 2002 to 29.6 in 2011 (World Bank 2015a). The national poverty headcount ratio decreased from 34.5% in 2002 to 12.4% in 2011 (World Bank 2015a). Nevertheless, as of 2010 the proportion of people living below US$ 2 per day was 78.8% (World Bank 2015a). In addition, 21% of the Pakistani population lives with less than US$ 1.25 per day (World Bank 2015a).

Food security: It is a key issue in Pakistan. The 17.2% of the population is undernourished and 24.3% bear food inadequacy (FAO 2015). The depth of undernourishment is 131 kcal/cap/day (FAO 2015). Around 72 million people consume less than 2,100 kcal per day (National Nutrition Survey of Pakistan 2011). Around 7 million households were severely under insecure food availability and 45 million people were vulnerable to food shortage (National Nutrition Survey of Pakistan 2011). The prevalence of chronic malnutrition is high, i.e. 43.7% percent of children undernourished. The 35% of deaths under-five is due to malnutrition (GoP 2011). Food insecurity in Pakistan is worsened by high food prices (FAO 2015). The food price index in Pakistan has been rising continuously (FAO 2015) since 2003.

Health, Sanitation and Water Services: Climate change threatens the population and health facilities. The floods caused by heavy rains in 2011 resulted in damage to the public health infrastructure in Sindh and Balochistan provinces for US$4.9 million (Government of Pakistan 2012). The estimated amount required to meet short-term needs has been taken as proxy of indirect losses and amounted to US$9.4 million (Government of Pakistan 2012). The total cost of reconstruction for this sector is estimated at US$9.8 million for the fully and partially damaged health facilities (Government of Pakistan 2012). These numbers give an estimate of the overall costs of climate change in health.

Figure 12-4: The recent evolution of income distribution, inequality and poverty in Pakistan.



For assessment of income inequality the GINI index of income inequality of the World Bank was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Income redistribution and the reduction of poverty levels in Pakistan are needed.

The Pakistani population is exposed to poor health conditions, due to low accessibility of health services and sanitation services. People suffer from bacterial and viral diseases, cardiac diseases, influenza, tuberculosis, diarrhea, hepatitis and typhoid fever (Afzal and Yusuf 2013). Life expectancy in Pakistan is among the lowest in the World (66.03 years) (World Bank 2015a). In 2011 there were only 0.8 doctors per 1000 people (World Bank 2015a). Current efforts to fulfill the Millennium Development Goals till 2015 are not sufficient.

In 2010 67.4% of the people had access to electricity. There is an evident effort to improve water services in Pakistan from 85% in 1991 to 91% in 2011 (World Bank 2015a). Agriculture is the sector with the highest water consumption. The withdrawal of water among 3 sectors amounts to 5% domestic, 1% industrial and 94% agriculture (World Bank 2015a). Efforts in sanitation could not be ignored because only 37% population had access to sanitation facilities in 2000 and even after 12 years (in 2012) only 47% of the population had access.

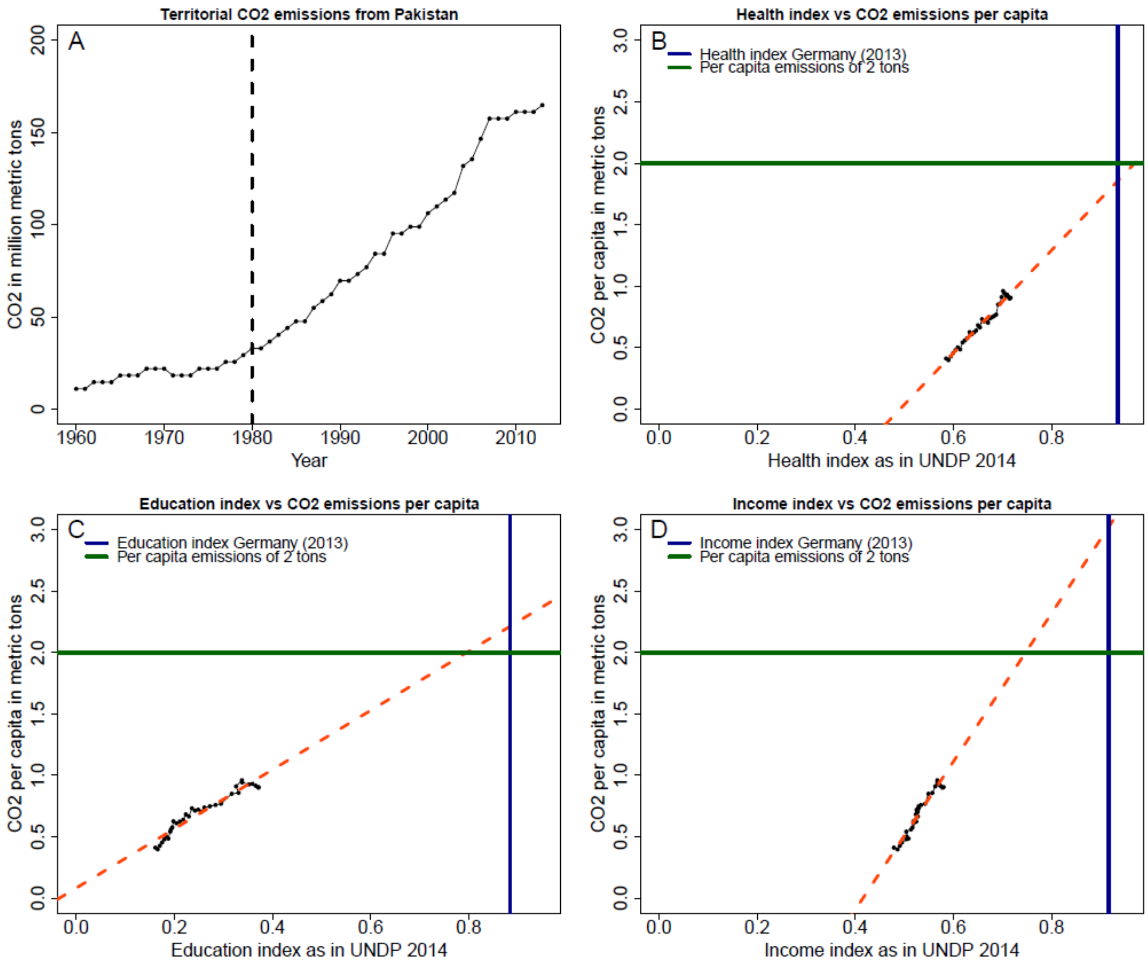
Education: The expenditure in education was 2.1 % of GDP in 2012 ranking Pakistan 164 in the World (WFB 2015). Demand for education is very high in Pakistan as only 5.1% of the population (17 – 23 years) secured a higher education (ICEF 2015). 33.3 % of Pakistani population is below 14 (WFB 2015).

12.2 Links between Adaptation, Development and Mitigation

12.2.1 The Evolution of the HDI and the GHG Emissions

Territorial CO_2 emissions from Pakistan have grown without interruption between 1960 and 2013 from about 10 to about 165 million tons (Figure 12-5A). On a per-capita basis this tendency of growth is observed at a slower rate than for total emissions. As of 2013 per-capita emissions of Pakistan range at about 0.9 tons per habitant (Figure 12-5B).

Figure 12-5: Trends of CO_2 emissions and the HDI in Pakistan.



Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. Horizontal green line shows the $2tCO_2$/cap. Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. The increased emissions per capita are statistically significantly coupled to all the indices composing the HDI (Costa et al. 2011), but the pace of HDI in all its components is low compared to other even less developed countries in this study. Trajectories to correct the trade-off suggest reducing the production of fossil fuels while improving income and health and mainly education at higher paces.

The correlations between the different components of human development and per-capita emissions in Pakistan are positive (Figure 12-5B, 6C and 6D), with a particularly high slope observed for the case of income (Figure 12-5D). In relation to the growth observed in both total and per-capita emissions, progress in all human development components investigated has been slow, notoriously in the case of education. In all cases the component score is still far-off that recorded in high developed countries.

A simple extrapolation of current per-capita emissions trends would put Pakistan on an unsustainable path towards emission higher than the limit required for ambitious climate targets. This is particularly noticeable, due to the great inefficiency in transforming emissions into income for the population. As reported, this is due to the inefficiency in electricity generation. The progress of Pakistan towards higher levels of Human Development (measured by the HDI) is expected to be slow. HDI scores above 0.9 are apparently unachievable within the first half of this century (Costa et al. 2011). Under a slow human development, fast population growth, and an inefficient transformation of emissions to income, emissions in Pakistan in the year 2050 are expected to be of about 1000 million tCO_2 (Costa et al. 2011).

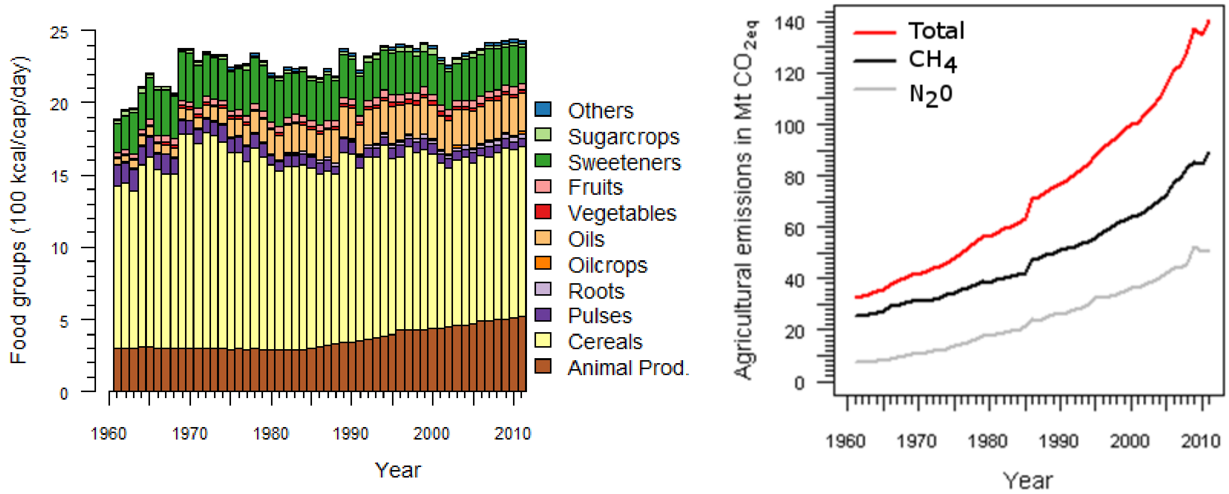
12.2.2 The Evolution of Dietary Lifestyles in Pakistan and the Emissions Associated

Figure 12-6 (left) presents the evolution of dietary patterns in Pakistan between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, Pakistan's total food supply has increased from 1,880 kcal/cap/day in 1961 to about 2,430 kcal/cap/day in 2011. The current food supply in Pakistan is above its average dietary requirement of 2,210 kcal/cap/day (Hiç 2014). During these five decades amount of cereals supply per person per day has increased by around 50 kcal, whereas, supplies of oils, sweeteners, and animal products have increased by 220, 60, and 210 kcal/cap/day, respectively. Moreover, current animal product supply of 520 kcal per person per day is above to the global average animal product supply of 500 kcal per person per day. This depicts lifestyle shifts towards more calorie and meat rich diets.

In the year 2000 around 55.4 million people in Pakistan lived in the regions which are self-sufficient in terms of food production (10 km x 10 km in grid cell) (Pradhan et al. 2014b). The country food production was sufficient to feed around 100 million people. Pakistan is a net food importer (Pradhan et al. 2015). The net food import amounted to 4 trillion kcal in the year 2000. Major parts of the country so far have attained between 40% and 70% of the potential crop production (Pradhan et al. 2015). Closing crop yield gaps by 50% can increase crop production and ensure higher current food self-sufficiency in Pakistan (Pradhan et al. 2014b). This will result additional 60 million people relying on local food. Nevertheless, Pakistan population of around 240 million will partly depend on international trade by 2050 even by closing yield gaps to attain 90% of their potential crop production due to population growth and potential diet shifts.

The total agricultural emissions of Pakistan have more than quadrupled from 32 $MtCO_{2e}$/yr to 140 $MtCO_{2e}$/yr in the last 50 years (Figure 12-6 right). The increased emissions are related to increases in agricultural production to meet growing food demand driven by population growth and dietary changes. Diets currently consumed in Pakistan embodied emissions of about 0.9 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 0.7 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013). The livestock production in Pakistan is largely based on rangeland (Wint and Robinson 2007).

Figure 12-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Pakistan



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Pakistan during the last fifty years. Food supply in Pakistan has slightly increased in the recent decade, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the last 50 years, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

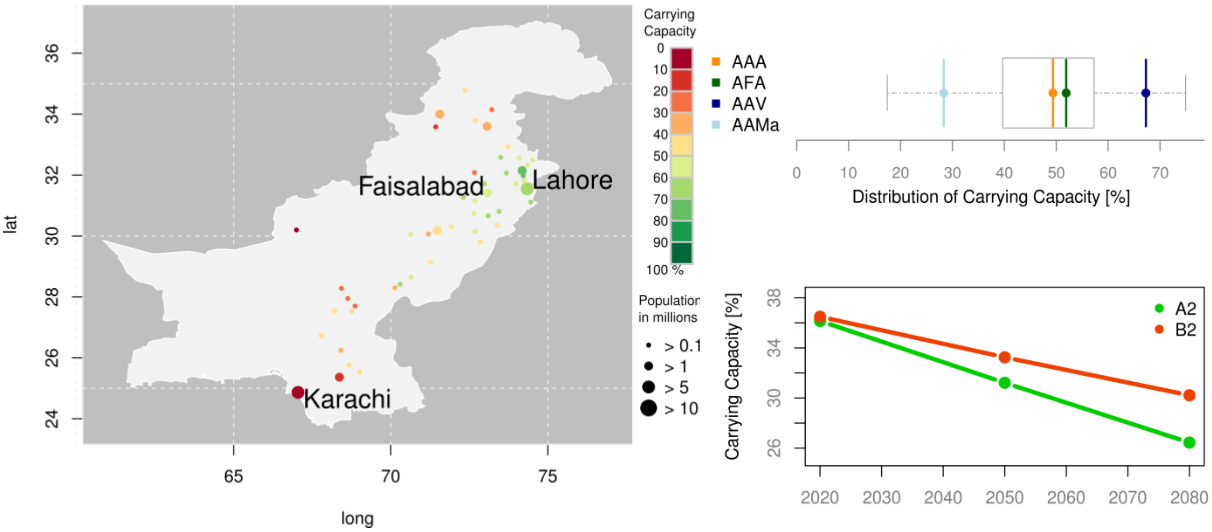
Technological progress increasing agricultural productivity can lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013). However, only closing yield gaps is not enough to ensure future food self-sufficiency by 2050 due to population growth and diet shifts.

12.2.3 Potential of Peri-Urban Agriculture and Local Food

38% of 185 million people in Pakistan live in cities, but the future population growth up to 271 million in the year 2050. Urban population will raise to 57% (United Nations 2014). 49 cities with population above 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 12-7). Overall these cities represent more than 32.9 million people. Today 70% of the surrounding areas are used for agriculture, which is nearly 80% of all available arable area (90%). From the currently harvested areas 36% percent of all the urban dwellers in the investigated cities can be nourished (Kriewald et al., 2015).

Due to the already high yield gap ratio (0.91) and the intensive agricultural use of the surrounding areas there is not much more possibility to increase the food self-sufficiency. Consequently climate induced yield changes or dietary changes cannot be compensated. An increased kcal-consumption up to 3500 kcal/cap/day will reduce the median carrying capacity down to 28% (see Figure 12-7 top right). All 49 cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The summed up values decrease drastically from 36% today down to 26% (A2, averaged yield) in the year 2080 (see Figure 12-7–bottom right).

Figure 12-7: The possibility for a food supply from surrounding areas for Pakistani cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV), and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. Pakistan has good potential for peri-urban agriculture and could use the surrounding areas of major cities for food production to reduce environmental trade-offs. However, climate change will reduce yields drastically and there is not much possibility to improve the good yield gap ratio or to open new agricultural areas.

12.3 The Potential for Synergies and the Stage of Country Development

Pakistan is highly vulnerable to climate change. Consequences of climate change include the diverse impacts of future melting of glaciers. This can cause sudden glacial outbursts and more run-offs in the short and less run-off in the Indus River in the long term accompanied by extreme weather situations. This situation is even worsened by an uncontrolled deforestation in the North. Sources of vulnerability of the Pakistani economy include weather disasters and impacts of climate change in agriculture and energy. The adaptive capacity is constrained by the low installed capacity of electricity, lack of infrastructure, the low literacy rate and the high expenditure for security measures. The adaptive capacity is further restricted by the low economic specialization, diversification and low research and development capacities in terms of climate and environmental change. Uncontrolled sources of economic uncertainties include inflation, high transaction costs and high risk. Pakistan is highly constrained in terms of natural resources. Moreover, the capacity to increase crop yields per hectare is small.

A major trade-off in Pakistan relates to the overexploitation of water resources from agriculture. This trade-off may be exacerbated by climate change due to the increasing water scarcity projected (see section 12.1.1). This environmental trade-off will have direct repercussions for agriculture. The agricultural sector contributed to about 24% of the GDP and provided employment to 48.8% of the labor force in 2013 (WFB 2015). Therefore, economic and social trade-offs will be reinforced. In order to work out these trade-offs, Pakistan requires an economic model that develops the industry and services sectors.

There exists an additional trade-off created by the production of GHG emissions from the intense usage of coal in the production of energy and the trends of human development. Coal-based thermal plants for electricity generation are being installed to meet the increasing demands for electricity. However, the increasing use of energy with the increasing production of GHG gases is not being effectively used for enhancing social conditions and developing the adaptive capacity. Figure 12-8 offers an overview of the stage of development of the determinants of adaptive capacity in Pakistan. As the figure shows Pakistan performs deficiently in the development of the infrastructure, social condition, the development of accessibility to financial resources, productivity, markets and governance. Energy plays an important role for growth in Pakistan. It is crucial that the country receive incentives to develop its energy systems based on renewable energy technologies.

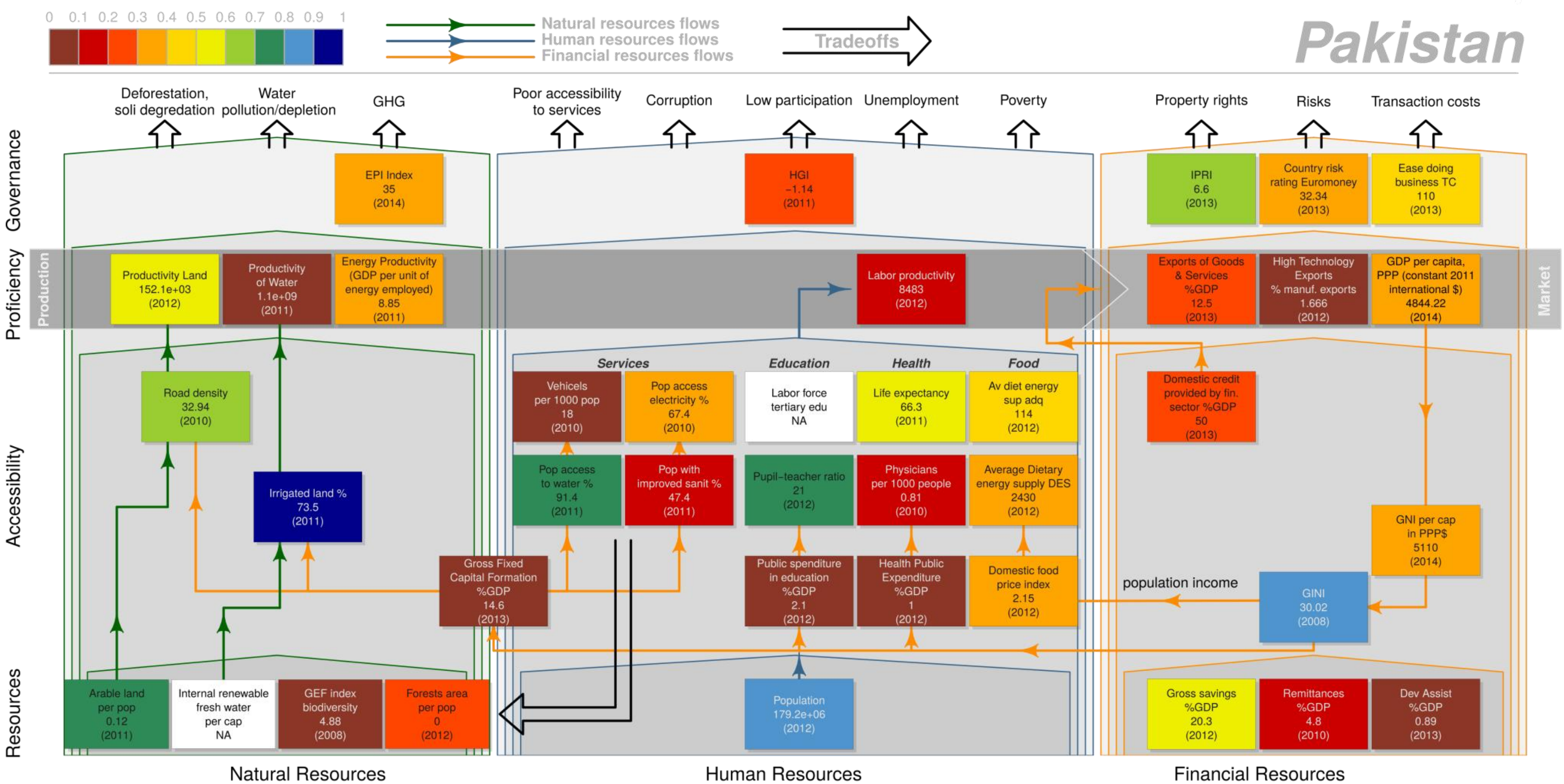
Other trade-offs exist. The potential for hydropower generation creates competition for water resources in Pakistan. It may exacerbate the overexploitation of water resources. In addition, there is an ongoing process of deforestation of the remaining forests in the North, driven by the expansion of agriculture. Pakistan needs to further enhance its adaptive capacity for developing Disaster Risk Management.

12.3.1 Growth and Adaptive Capacity:

Climate resilient pathways in Pakistan require economic growth. The current growth model in which agriculture provides the main source of income of the population is unsustainable due to the exhaustion of water resources. Pakistan has to transit from an agriculture-based economy to one where industry and services play major roles as income sources for the majority of the Pakistanis. The new growth model is needed for economic development, but also for developing the adaptive capacity. Pakistan is challenged by severe restrictions in water availability. In order to cope with the threats of a potential collapse of agriculture the country has to develop its capacity in water management. The country also needs to develop urgently the governance in forestry. For adaptive capacity Pakistan has to design and follow consistent plans in human capital formation, knowledge and expertise in the usage of modern and efficient technologies in agriculture, management of financial resources, and the further development of institutions.

The economy is lowly developed. In the row of proficiency in Figure 12-8 it can be observed that the productivity of water, energy and labor are low. The low specialization of the economy is observable in the very low share of high technology products in the manufactured products exported. This situation can only be corrected by diversifying and by specializing the economy. Currently the financial surpluses required to foster this economic trend can be provided by all sectors (see the shares of agriculture, services, and industry in Figure 12-1).

Figure 12-8: Indicators of the adaptive capacity of Pakistan.



The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the methods section. To improve adaptive capacity Pakistan needs to diversify its economy, i.e. in industry and service sector. The country needs to close the gaps in the provision of basic services. White color indicates non-available information.

However, the very low performance on the indicators of human governance in Figure 12-8 casts doubts on the adequate use of additional revenues and the willingness of the society to pay more taxes. For developing the adaptive capacity Pakistan requires changes in governance.

The development of the industry and services sectors requires highly qualified human resources. Investments in education are required. But human capital also depends on social conditions. As the indicators of accessibility to human resources in Figure 12-8 show consistent and long-term investment in social development are required. The share of GDP invested in gross fixed capital formation is very low compared to other countries. This share needs to be substantially increased for closing the gaps in the provision of sanitation and fresh water services. These investments are also required for the development infrastructure in health and education. Pakistan also has to invest more in health services and food security.

12.3.1.1 Agriculture and Food Security:

Agriculture is not the main GDP source but is the major source of income for most of the Pakistani population. Performance on food security is serious in Pakistan. The depth of undernourishment reached 131 kcal/cap/day on average by 2013 (FAO 2015). The prevalence of chronic malnutrition is high in Pakistan, i.e. with 43.7 % percent of children undernourished (FAO 2015). Around 72 million people consume less than 2,100 kcal per day (National Nutrition Survey of Pakistan 2011). Around 7 million households face severely food insecurity and 45 million people are vulnerable to food shortage (National Nutrition Survey of Pakistan 2011). The country is not self-sufficient in terms of food production (see section 12.2.2).

Options to grow in agriculture are limited due to the low carrying capacity of land. Even by achieving its maximum capacity the country will become more dependent on food imports in the future (see section 12.2.2). This capacity will be further reduced by future warming (see Figure 12-7-right) and by future shortening of water availability due to glacial melting. Moreover, agriculture is the sector with the second highest GHG emission rates after the energy sector. Almost a third of Pakistan’s total area is classified as rangeland with livestock farming playing a significant role in the economy and the GHG emission rate.

Any climate resilient pathway in Pakistan has in agriculture a source of economic growth, a potential for food security and a source of income for the population. The country has the potential to improve agricultural productivity. In this context, the country needs to devote consistent efforts to radically improve agricultural productivity. It demands research and development for the development of crop varieties, the control of emissions mostly from enteric fermentation, the development of capacity in agricultural assistance, and supporting the technological transformation of small scale farms. Agricultural development in Pakistan requires the adoption of modern technologies for the optimal use of water. Other options to improve agricultural productivity in Pakistan include adequate use of fertilizers in the Indus’ delta and the North-east, improving accessibility to markets, managing yield variability in the North-west, and to a lesser extent managing soil quality (Pradhan et al. 2015b).

12.3.1.2 Energy

As Figure 12-5 shows emissions per capita from the combustion of fossil fuels were low 0.93 tCO_2/year in 2011. These emissions are expected to grow due to sustained growth rates projected. The construction of synergies requires the reduction of GHG emissions from fossil fuel combustion. As Figure 12-8 shows human development in Pakistan requires closing the existing gaps in the provision of electricity.

The energy sector is the largest source of GHG emissions. Most promising mitigation options can be provided by this sector primarily through an increase in the share of renewable energy in the future electricity mix. Pakistan needed net energy imports of 19.82 Mtoe 2011 mainly on account of crude oil, oil products and coal in 2011. The net imports amounts up to a 23% share of the country's total primary energy supply (84.84 Mtoe) (IEA 2015). Primary energy supplies in Pakistan comprise biofuels and waste (35%), natural gas (32%), oil (24%), coal/peat (5%), hydro, and nuclear electricity in 2011 (IEA 2015). The only fossil fuel resource available in Pakistan is coal, with an estimated resource base of 185 billion tons (UNFCCC 2003). Existing resources for renewable energy like hydropower, wind, and solar energy are underdeveloped in regard to its potential (UNFCCC 2003). A number of private companies are trying to promote solar power in Pakistan (Murphy et al. 2013).

To meet the needs of Pakistan's lack of financial capacity and development, the World Bank estimated net ODA of US$ 3.5 billion (US$ 20 per capita) in 2011 (World Bank 2015a). Only a minor part of ODA received by Pakistan is related to climate change mitigation. The OECD calculated international assistance having climate change mitigation as principal or significant objective of US$ 23.1 million (US$ 0.13 per capita) (OECD 2015). The country needs further financial support that could disincentive the use of coal for electricity generation.

12.3.2 Climate Change Institutions:

Pakistan has currently a total of seven climate change related policies in place. Five of them directly address mitigation aspects, while the remaining two have a broader climate change scope, taking up some mitigation as well as adaptation issues. The main focus is on addressing institutions and administrative arrangements, while pricing carbon is not covered yet by any of the legislations. The most important policy drafted by the Pakistani Planning commission is the National Climate Change Policy (NCCP) funded by the UN Joint Program on Environment (JPE) in 2012. In 2015 Pakistan subsumed all climate change related issues on the rooftop of a new Ministry for Climate Change. The main foci of the policy include energy efficiency, renewable energy production, disaster preparedness, capacity building and technology transfer, e.g. for adaptation measures. The policy provides a comprehensive framework for the National Action Plan, which is designed to implement the Policy for national efforts on adaptation and mitigation. Its goals are envisioned in the Planning Commission's Vision 2030 document. The main focus of this document is adaptation taking into account of Pakistan's high vulnerability to the impacts of climate change. Nonetheless, mitigation measures for the sectors, energy efficiency and conservation, transport, forestry, industry, agriculture, livestock and town planning are part of the policy. Important topics of the NCCP include energy efficiency requirements in building codes and long-term transport planning (Ministry of Climate Change (MoCC) Pakistan 2012). Up to date over 60 CDMs are registered in Pakistan (UNFCCC 2014c).

12.3.2.1 Forestry:

Pakistan has the potential to reduce its vulnerability to climate change and to mitigate emissions through the forestry sector. Forestry in the North can further help reduce poverty and increase the biomass yield to satisfy energy needs of the poor. Better forests coverage in the North will help to regulate the water cycle and to reduce impacts of increased flows from glaciers. The country still needs to develop further capacities in forestry, i.e. for monitoring, reporting, and verifying forestation and sinks. Deforestation needs to be stopped. The international community could and should help Pakistan to grow forests area and develop the country's forests governance.

In the forest sector the country targets are the substitution of firewood and timber, and the active prevention of encroachment on remaining forest lands through regulations on grazing, and the doubling of forest cover by 2030 (Nachmany et al. 2014). Pakistan's forestry and other land-use sector contributed only to estimated 6% of GHG emissions in 2009 (see Figure 12-2), but considerable mitigation potential exists in the sector through carbon sequestration via afforestation and reforestation measures as well as preventing deforestation. The forestry sector is in focus of Pakistan's Vision 2030 document (see appendix 5). The Forestry Policy sets out to restore existing forests in addition to reforesting some deforested and degraded areas with a strong focus on watershed reforestation (Nachmany et al. 2014).

12.4 Conclusions

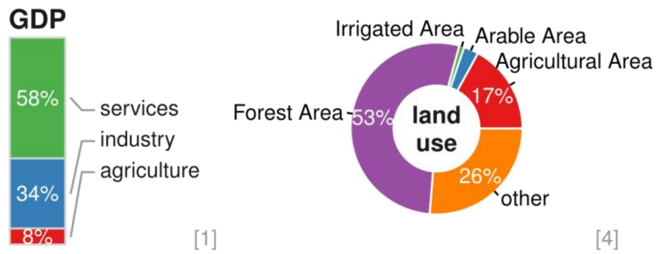
Pakistan is increasingly threatened by glacial melting, less precipitation and extreme weather conditions and one of the most vulnerable countries in Asia. In parallel, clears signs are observable that monsoon pattern are changing causing tremendous threats for the agricultural sector. Forced by historic water scarcity, Pakistan has already developed its capacity in irrigation. But this capacity has not resulted in significant increases in water productivity. This shows the lack of commitment in the development of agriculture. Options to regulate water cycles include forestry in the North. However, the resulting regulation of the water cycle and the eventual capture of water from trees in mountain areas do not seem sufficient to provide the amounts of water needed. If other options are not available, Pakistan would be forced to develop more costly technologies for the production of fresh water.

The country needs urgently to develop institutions in agriculture for better productivity and crop diversification. In parallel, Pakistan needs to develop plans for economic diversification in industry and services. The country needs to invest much more in human development. It is needed to improve considerably human governance. The international community can help Pakistan to develop institutions in forestry and water management, as well as in larger research and development capacities. This would enable Pakistan to avoid a rapid increase in future GHG emissions, i.e. by effective energy management, and help the country to cope with adverse consequences of climate change by developing tailor made smart solutions for their actual and future problems.

13. PERU

Figure 13-1: Peru – Factsheet and physical map:

Country size	1,285,216 sq km	[1]
Coastline	2,414 km	[1]
Population	30.77 millions	[2]
Rural population (%)	21.7	[2]
Human Development Index	0.74 (82 of 187 – High)	[3]
Life expectancy at birth	74.83	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

13.1 Sensitivity and Vulnerability

13.1.1 Sensitivity of Natural Resources

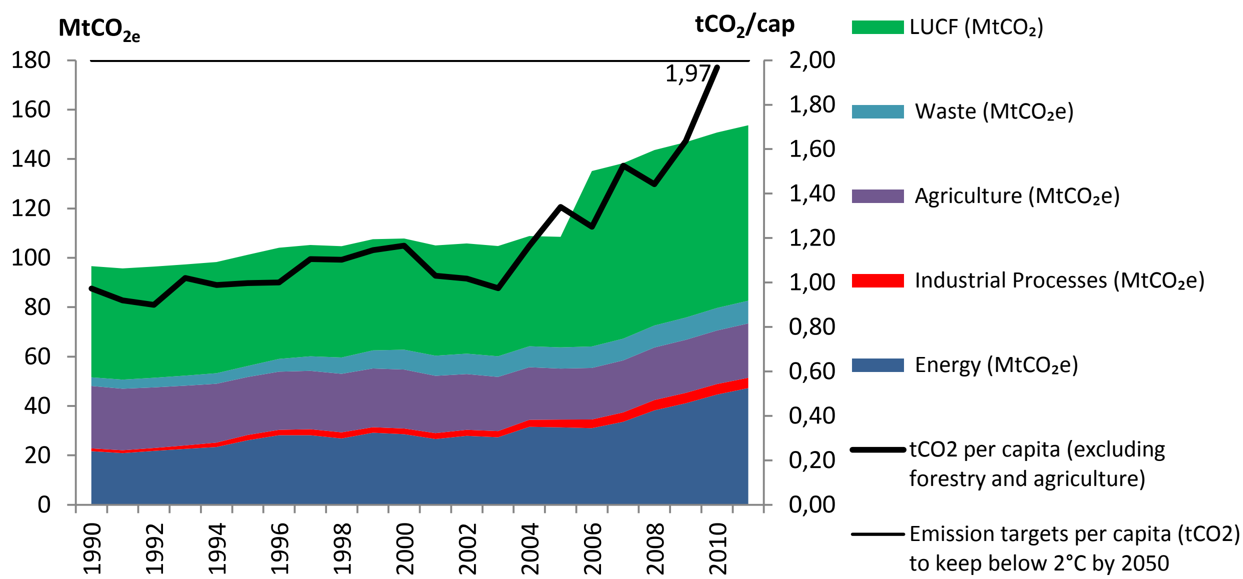
Temperature: Report on trends and projections of temperature are based on information from (SENAMHI 2005a, 2007, 2009a, 2009b; Obregón et al. 2009). Temperature in the southern Andes of Peru have increased between +0.2°C and +0.6°C per decade for the period 1964 – 2006 (Marengo et al. 2012). The dry season average temperature increases of between 0.7°C and 1.8°C by 2020 and between 1°C and 4°C by 2050 are expected. The greatest increases in temperature are expected in the northern coast and the northern mountains, the northern jungle, the central highlands and the south.

Water resources, rainfall and precipitation: The distribution of rainfall presents large contrasts between the Amazon basin with an average between 2000 and 3000 mm/year and the drier coast which receives only 200 mm/year (Sanabria et al. 2009; Urrutia and Vuille 2009). In the central Andes rainfall is expected to decrease and accompanied by more extreme rain and consecutive dry days (Sanabria et al. 2009; Urrutia and Vuille 2009). The river discharge decreased during the dry seasons between 1950 and 1990 (Baraer et al. 2012). Almost all glaciers in the tropical Andes are shrinking rapidly since the 1980s (Rabassa 2009; Rabatel et al. 2013). Peru has already lost 39% of its glaciers, due to a 0.7°C temperature rise in the Andes between 1939 and 2006 (UNDP 2014). Changes of −20% to −30% in precipitation in the northern and central Andes of Peru between 1963 and 2006 have been observed (Obregón et al. 2009; SENAMHI, 2005b, 2007, 2009b, 2009c). In absolute terms rainfall decreased 44 mm per decade in the Mantaro Valley and in the central Andes of Peru between 1970 and 2005 (SENAMHI 2009a). In the Southern Andes the decrease ranges between −11 and +2 mm per decade (SENAMHI 2005b; SENAMHI 2007; SENAMHI 2009c; Marengo et al. 2012).

Crop yields: Potatoes represent one of the most consumed staples in Peru. Studies on two main varieties of potato, *Solanum tuberosum* and *Solanum juzepczukii* were carried out for the A2 and B2 SRES scenario and for 2071–2100 (Sanabria and Lhomme 2013). Changes projected include earlier planting dates, less planting failures, and shorter crop cycles in all four investigated locations and for both scenarios. Yield deficits will increase under climate change (Lobell et al. 2011). There will be a strong negative impact on yields for *S. tuberosum* (stronger under A2 scenario than under B2), while *S. juzepczukii* yields is less impacted (Sanabria and Lhomme 2013).

Atmosphere: By 2007 Peru released 0.1% of the global CO_2 emissions (Stern 2007). Emissions from energy and waste are growing (Figure 13-2). The Peruvian Amazon became a source of CO_2 emissions in 2012 as result of the droughts in the western Amazon in 2005 and 2010 (UNDP 2013). GHG emissions from deforestation reached 53 $MtCO_{2e}$ between 1990 and 2000 (UNDP 2013). Excluding emissions from agriculture and LUCF, emissions per capita from the combustion of fossil fuels are reaching the $2tCO_2$/cap.

Figure 13-2: GHG sectoral emissions and energy per capita emissions of Peru.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agriculture (World Bank 2015). Sectoral emissions obtained from (WRI 2014). Emissions from LUCF contain CO_2 but not N_2O and CH_4. Emissions from bunker fuels are negligible and were not included. The shares of the figure make evident that deforestation, energy, and agriculture are the most relevant sectors for the analysis of synergies.

Land Use and Forestry: Deforestation rates are high (FAO 2014). Main deforestation drivers are agriculture, livestock production (The Redd Desk 2013), mining, logging, and coca cropping (UNDP 2013). Deforestation rates are still increasing from 2005 and remain on a high level (UNDP 2013). Deforestation is fostered by the weakness of land tenure rights (Ministerio del Ambiente 2010).

13.1.2 Economic Vulnerability

During the 1983/83 and 1997/98 ENSO events and the droughts of 2003-2004 the country lost 73,047 ha of agricultural production. Up to 97% of the production of key crops was lost in some regions affected (UNDP 2013). The damages caused by climate hazards have been estimated at US$390 million per year for the period 1995 to 2007. The two El Niño events and following droughts in 2003–2004 had the worst impacts. Cold waves left 260,505 livestock dead in 2006 (Sanabria et al. 2009).

Economic impacts on the agricultural sector: Reliable studies of projected impacts of climate change on agriculture in Peru have not been identified. Agriculture accounts for 80% of the total water demand and it will be affected by changing temperature and rainfall (UNDP 2013). Agriculture contributed 7.4% to the Peruvian GDP in 2007 (World Bank 2015). Impacts of climate change on agriculture would not only affect the GDP, but the income of 25.8% of the population employed by it as of 2011 (WFB 2015).

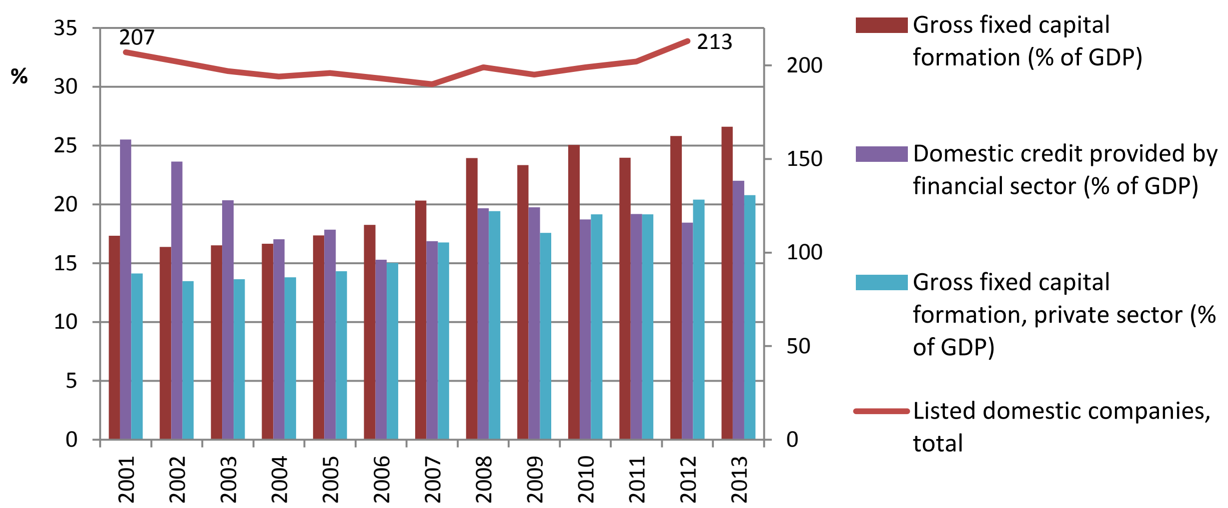
Economic specialization and diversification: The economy of Peru is lowly diversified. 80% of revenues from exports are generated by only 22 commodities in 2012, i.e. 14 raw mineral products, refined crude oil, 6 vegetal products, and Knit T-shirts (Simoes and Hidalgo 2014). These numbers differ from other countries of this study. For example, in Kenya 49 commodities compose the 80% mark of total exports. In Peru mining accounted for 69.71% of total exports in 2012 (Simoes and Hidalgo 2014). The diversification index (0.708 in 2012 (UNCTAD 2012)) places Peru in the third decile relative to the rest of the world. Though mining would not be directly impacted from climate change, the high dependency on mining and the low diversification make Peru highly vulnerable to changes in commodity prices. In fact, Peru belongs to the 10% lowest performing countries on the number of high technology products exported (World Bank 2015). Peru is vulnerable to impacts affecting agriculture of prices of mineral commodities, due to the low diversification and low specialization of its economy.

Capitalization and Capital Formation: The share of investments in gross fixed capital formation has been and is still high in Peru (Figure 13-3). These shares are the highest in Latin America (World Bank 2015). This shows the interest of the government to transform the capital rents of mining into the infrastructure required for sustained growth. Investments in gross fixed capital formation in the private sector are high and growing. The number of listed companies in the stock market (213) in 2013 has recovered from a decline between 2001 and 2007. The number of listed companies is much higher than in Colombia (only 76) by 2012. However, the share of GDP for domestic credit provided by the financial sector is too low, i.e. only 22% of GDP by 2013. Therefore, the financial capacity to cope with shocks is constrained by low accessibility to financial capital.

Economic Risks and Uncertainties: Peru shows disparate trends in the control of economic uncertainties and risk. Inflation has been kept low (2.9%) and it has remained below 4% over the last decade (World Bank 2015). The country shows a good performance in the control of transaction costs. The ease doing business index ranked the country 42 in 2013 (out of 183). The ease doing business evaluates the environment facilitating development of business. It is used as proxy of transaction costs. Less promising, the country's risk index, which evaluates structural, political, and economic risk (Euromoney 2014), places the country in the fifth decile (55.76 as of 2013). Peru has historically suffered from weak property rights, mostly in rural areas. These inefficiencies are captured in the low performance of the IPRI index (4.1 in

2013). The International Property Right Index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). Overall, these numbers show the ability of the government to preserve macroeconomic stability (transaction costs and inflation), but in addition the existence of structural challenges related to property rights.

Figure 13-3: The recent evolution of capital in Peru.



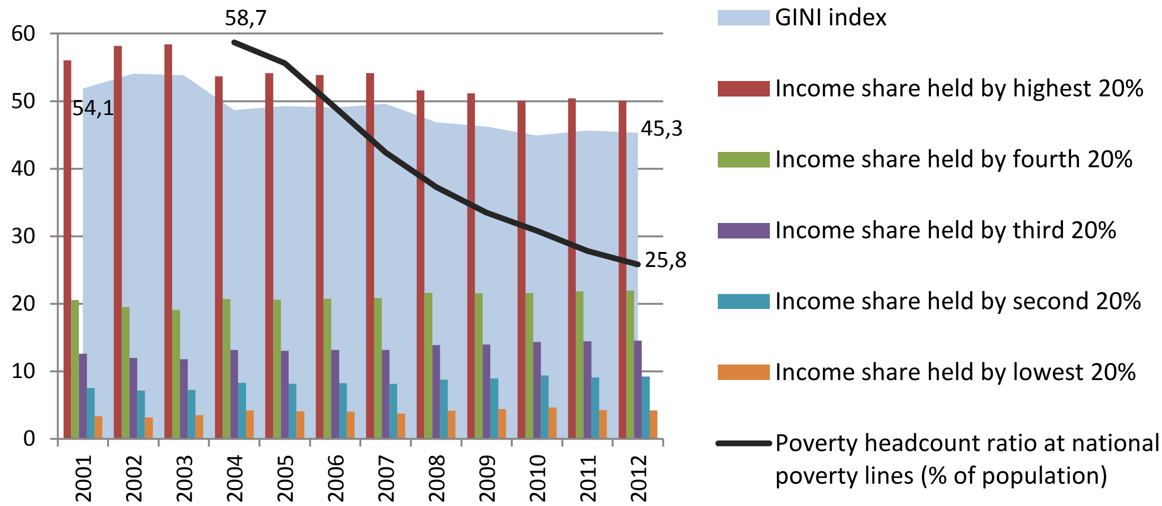
Domestic credit provided by the financial sector (World Bank 2015), number of listed domestic companies, and investments in gross capital formation, private and public. For the analysis of the adaptive capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. The country is investing high shares of GDP in gross fixed capital formation, but the provision of credit is very low compared to other countries in this study. The number of listed companies does not grow, indicating low diversification.

13.1.3 Social Vulnerability

The rural population in Peru represents 22% of the total population, i.e. around 6,7 million people as of 2013 (World Bank 2015). The impacts of climate change on crop yields and agriculture will affect rural population more than the urban population. However, other factors will affect the capacity of the population to cope with the impacts of climate change. As Figure 13-4 shows inequality in Peru is very high. It has decreased, but not significantly. Changes in income distribution have benefited more the middle class. Yet, policies for alleviating poverty have reduced it by more than half. The reduction of social vulnerability in Peru requires the commitment of the elite and the government to reduce inequality.

Food security: Undernourishment in Peru is experienced by 11.8% of the population in 2012 (FAO 2015). The food deficit was 70 kcal per person per day. This number decreased steadily from 167 kcal in 2004 (FAO 2015). The food deficit problem is less critical than in neighbor countries like Bolivia with 189 kcal or Ecuador with 128 in 2012 (FAO 2015). The domestic food price level index is very low (1.66 in 2012). Yet, food security is threatened by climate change, as crop yields are projected to suffer reductions.

Figure 13-4: The recent evolution of income distribution, inequality and poverty in Peru.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015). The national poverty headcount ratio (World Bank 2015) is not comparable, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. High income inequality and high poverty head count ratio indicate the existence of a social trade-off that needs to be corrected.

Health, Sanitation, Water, and Energy Services: Life expectancy in Peru (74.5 years in 2011 (World Bank 2015)) places the county in the seventh decile with higher life expectancy relative to the rest of the world. According to indicators of the World Bank Peru spends only 2.76% of GDP in health services, including private and public expenditure. This number is below the average in Latin America and the Caribbean (7.7% in 2012). The access to improved water services reached 86.8% of total population in 2011; i.e. 4 million people had no access to water supply. Access to sanitation reached 73.1% of the population in 2011, i.e. around 8.6 million had no access to sanitation as of 2012. People with no access to electricity amounted to 4.4 million as of 2010. Peru needs to bridge current gaps in services and health to improve its human resilience to climate change impacts.

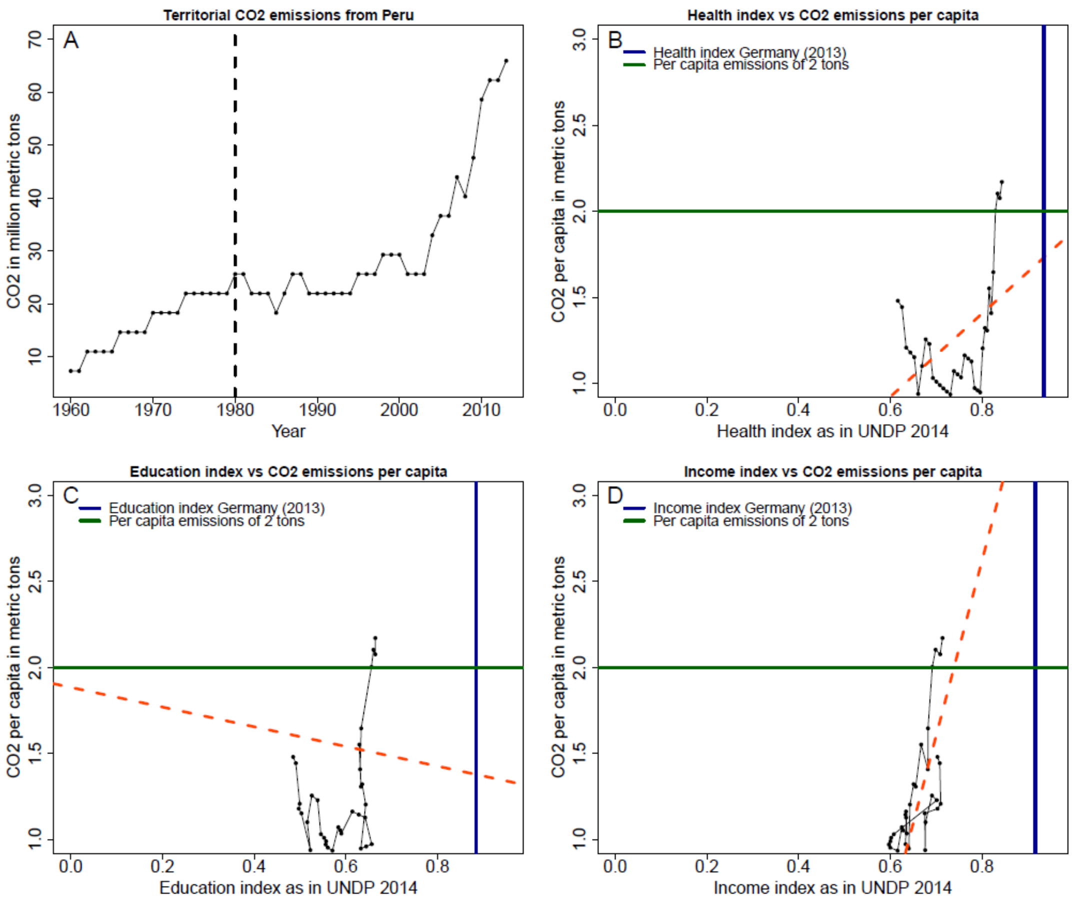
Education: The government spent 2.76% of the GDP in education in 2012. This ranks Peru among the lowest 20% in the World (World Bank 2015). The pupil teacher ratio in primary education in Peru was 19.2 among the highest 20% in the world in 2012 (World Bank 2015). This indicates the commitment of the government to enhance human capital. According to the World Bank, the labor force with tertiary education was 33% in 2004, but this number dropped to 11.8% in 2005 due to emigration. Since then this number has increased to 15.1% in 2011 (World Bank 2015).

13.2 Links between Adaptation, Development and Mitigation

13.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from Peru highlight the existence of two distinct periods (Figure 13-5). The first lasted until the early 2000s and was characterized by a rather slow increase in CO_2 emissions.

Figure 13-5: Trends of CO_2 emissions and the HDI in Peru.



Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project (Le Quéré et al. 2013) (A). Health index for the time period of 1980-2013 (calculated according to UNDP 2014 technical notes) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education, and health obtained from the World Bank 2014 database. Horizontal green line shows the 2 tCO_2/cap target (WBGU 2009). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the statistical trend in average per-capita emissions between 1980 and 2013. Finally, the dashed vertical line indicates the starting period of analysis for the panels B, C and D. Over the last 11 years (2002-2013) the development of indices of human development correlate positively with higher emissions from fuel combustion in Peru. However, while emissions grew from nearly 1 to 2.2 tCO_2/cap, indices of income, education and health remained nearly stagnant, indicating the deepening of a social trade-off that needs to be corrected.

In contrast, during the last decade emissions doubled from about 32 million tons in 2003 to 65 in 2013. In per capita terms, emissions have been decreasing from 1980 to 2003, the year with the lowest per capita value of emission was recorded at about 0.95 tCO_2. Since 2003 per capita emissions grew sharply and surpassed the 2 tons per capita mark in 2010.

The progress in human development dimensions in Peru and its relation to CO_2 emissions shows a diverse picture. As Figure 13-5B shows the health index progressed 0.07 over the eleven years before 2003 (from 0.72 to 0.79). Between 2003 and 2013 the health index increased by 0.05 points from 0.79 to 0.84. Similar changes have occurred at very different rates for CO_2 emissions which are decreasing over the first period. For the education index the situation has been even more contrasting (see Figure 13-5C). The value of the education index in 2013 is almost the same as it was in 2003, while emissions per capita from fossil fuels over the same period have more than doubled.

Average income levels are strongly correlated with per capita emissions. The evolution has been a circular one. During the period when emissions per capita decayed, the income index followed this trend. The economic growth afterwards was strongly associated with a sharp rise in emissions. This offers a clear indication for the strong correlation of the two indicators. The current path of economic development in Peru makes it largely incompatible with long-term climate protection goals. Despite the fast rise in emissions, Peru is projected to achieve an HDI above 0.9 by 2040 (Costa et al. 2011). These trends show a trade-off between the production of GHG emissions and social development.

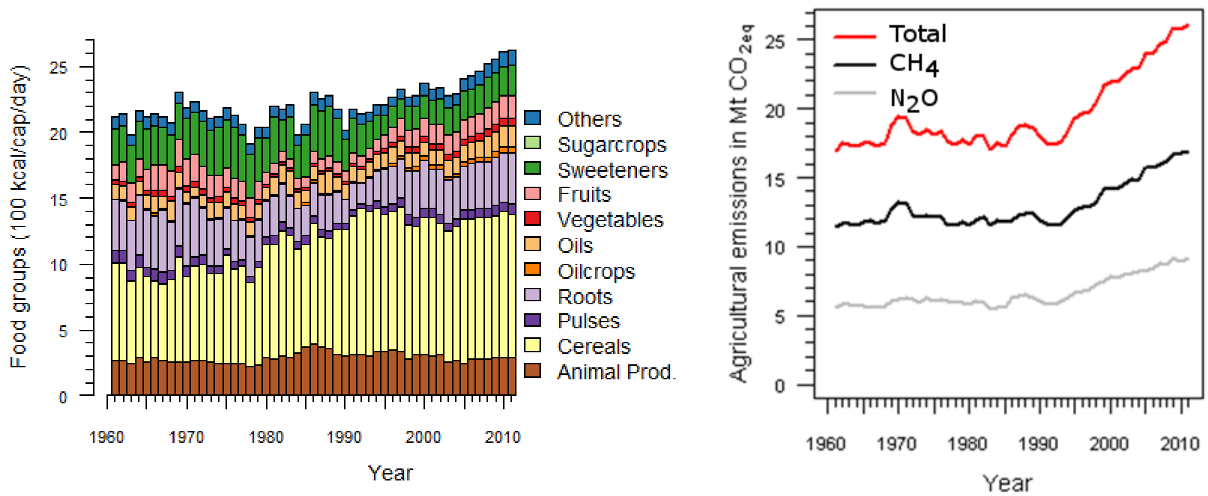
13.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 13-6 (left) presents the evolution of dietary patterns in Peru between 1961 and 2011. In general, Peru's total food supply has increased from 2,100 kcal/cap/day in 1961 to about 2,600 kcal/cap/day in 2011. During these five decades, the amount of animal product supplied remained almost constant (around 300 kcal/cap/day), whereas, supplies of cereals and oils increased by 350 and 50 kcal/cap/day respectively. Furthermore, the inter-annual variability in supplies of total calories and the different food groups has been observed in Peru during the last five decades. Overall this depicts the changing lifestyles in Peru towards calorie rich diets, largely based on cereals.

Food self-sufficiency in Peru allowed nourishing approx. 4 million people by food produced within a 10 km x 10 km grid (Pradhan et al. 2014). Considering a larger scale food production was sufficient to feed around 10 million people, resulting in around 15 million people. This results in the fact that still 15 million people depend on international trade for food supply. Peru's net food import was around 7 trillion kcal in the year 2000. The country so far has attained around 40% to 70% of the potential crop production (Pradhan et al. 2015a). Peru could become food self-sufficient by closing yield gaps to attain 90% of the potential crop production, i.e. resulting in 5 million people relying on local food and the rest of the population depending on intra-country food transfer. Nevertheless, the Peruvian population between 29 and 34 million will partly depend on international trade by 2050 even by closing yield gaps to attain 100% of their potential crop production due to population growth and change in dietary habits.

The total agricultural emissions of Peru have increased from 17 $MtCO_{2e}$/yr to 26 $MtCO_{2e}$/yr in the last 50 years as shown in Figure 13-6 (right). The increased emissions correspond to an increase in food supply in the country after 1990, and hence, related to increase in total agricultural production. Moreover, Peru is a net food importer in terms of calories (Pradhan et al. 2015a) but a net food exporter in terms of monetary values (FAO 2014). This is due to the fact that Peru exports high value crop such as coffee and fruits. Furthermore, diets currently consumed in Peru embody emissions of about 1 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 3 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013).

Figure 13-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Peru.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (in CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Peru during the last fifty years. Food supply in Peru has slightly increased in the last few decades, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the recent decades, indicating environmental trade-offs. The data was obtained from FAO (2014).

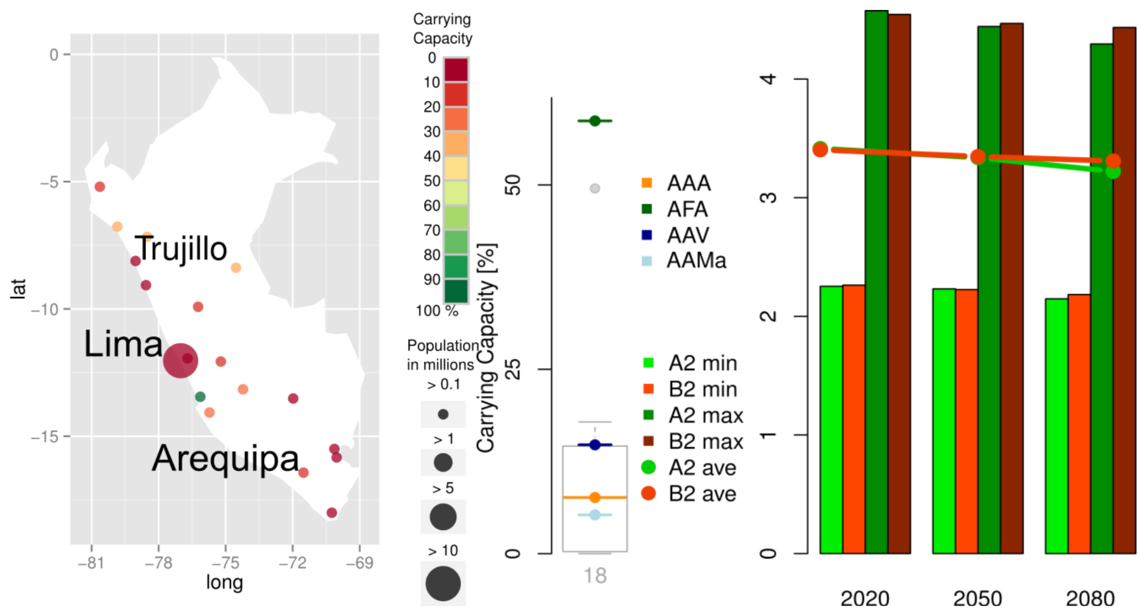
Dietary patterns in Peru may increasingly be calorie rich when the country becomes more developed in the future. This will result in larger volumes of GHG emissions and food import. Currently, emissions per unit of crop and livestock production in Peru are higher than that of developed countries (Pradhan et al. 2013). Technological progress lowering agricultural emission intensities can lower agricultural GHG emissions of the country (Pradhan et al. 2013). Closing crop yield gaps can increase crop production, reducing the need for international food trade.

13.2.3 Potential of Peri-Urban Agriculture and Local Food

78% of the 30.8 million people in Peru live in cities and a future population growth up to 41 million by the year 2050 will occur mainly in cities (United Nations 2014). 18 cities with a population above 100.000 were investigated for the potential of regional food production to increase food security and reduce CO_2 emissions from food transport (see Figure 13-7). Overall, these cities represent more than 10.6 million people. Today only 4% of the surrounding area is used in agriculture, although 56% could be used. From currently harvested areas just 4% of the urban dwellers can be nourished (Kriewald et al. 2015).

The highest potential to increase the food self-sufficiency is by changing the land-use. In contrast a changed kcal-consumption or diet will not have a large influence (see Figure 13-7-middle). 13 of the 18 cities investigated will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012). The summed values decrease from 4% to nearly 3% (see Figure 13-7-right). Moreover, the Peruvian food supply of 2,600 kcal/cap/day is above its average dietary energy requirement of around 2,300 kcal/cap/day (Hiç 2014).

Figure 13-7: The possibility for a food supply from surrounding areas for Peruvian cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV), and an increased kcal-consumption (AAMa). On the right the change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and two yield scenarios (min, max) and the averaged values. Minimizing environmental trade-offs with the help of peri-urban agriculture is only possible by increasing the fraction of agricultural area in the surroundings.

13.3 The Potential for Synergies and the Stage of Country Development

Climate change is going to affect natural resources in Peru considerably. Effects of increased temperature include more droughts, lower rainfall, and more GHG emissions from deforestation. Crop yields will be reduced and therefore, affect food security. The sources of vulnerability of the Peruvian economy include weather extremes, i.e. droughts and floods from El Niño and la Niña, increasing water scarcity and decreased crop yields. Almost 70% of the Peruvian population and most of its economic activity is concentrated along the Pacific coast. The Pacific coast is a desert. 95% of the Peruvian population depends on water sources from glaciers. Recent studies show that inter-tropical glaciers are in rapid decline (cf. e.g. Rabassa 2009, Rabatel et al. 2013, IPCC 2014). Thus, it is very likely that reduced fresh water availability and the potential for hydropower generation will affect the country seriously (Parry et al. 2007; Ministerio del Ambiente 2010, Lemke et al. 2007). The average demand for electricity is projected to increase 4% per year between 2002 and 2030 (APEC 2006). Glacier retreat can make the hydropower potential drop from the current 48% to 43% by 2030 (APEC

2006). So far, power plants based on natural gas are considered the most cost effective technologies to cover the expected gaps in electricity generation (Union of Concerned Scientists 2011). The adaptive capacity is constrained by the high dependency of the economy on mining, the low specialization and low diversification of the economy, and the low capacity of the financial system to provide domestic credit. Sources of uncertainties include inefficient institutions on property rights. Nevertheless, the economy shows signs of resilience in regard to inflation and transaction costs.

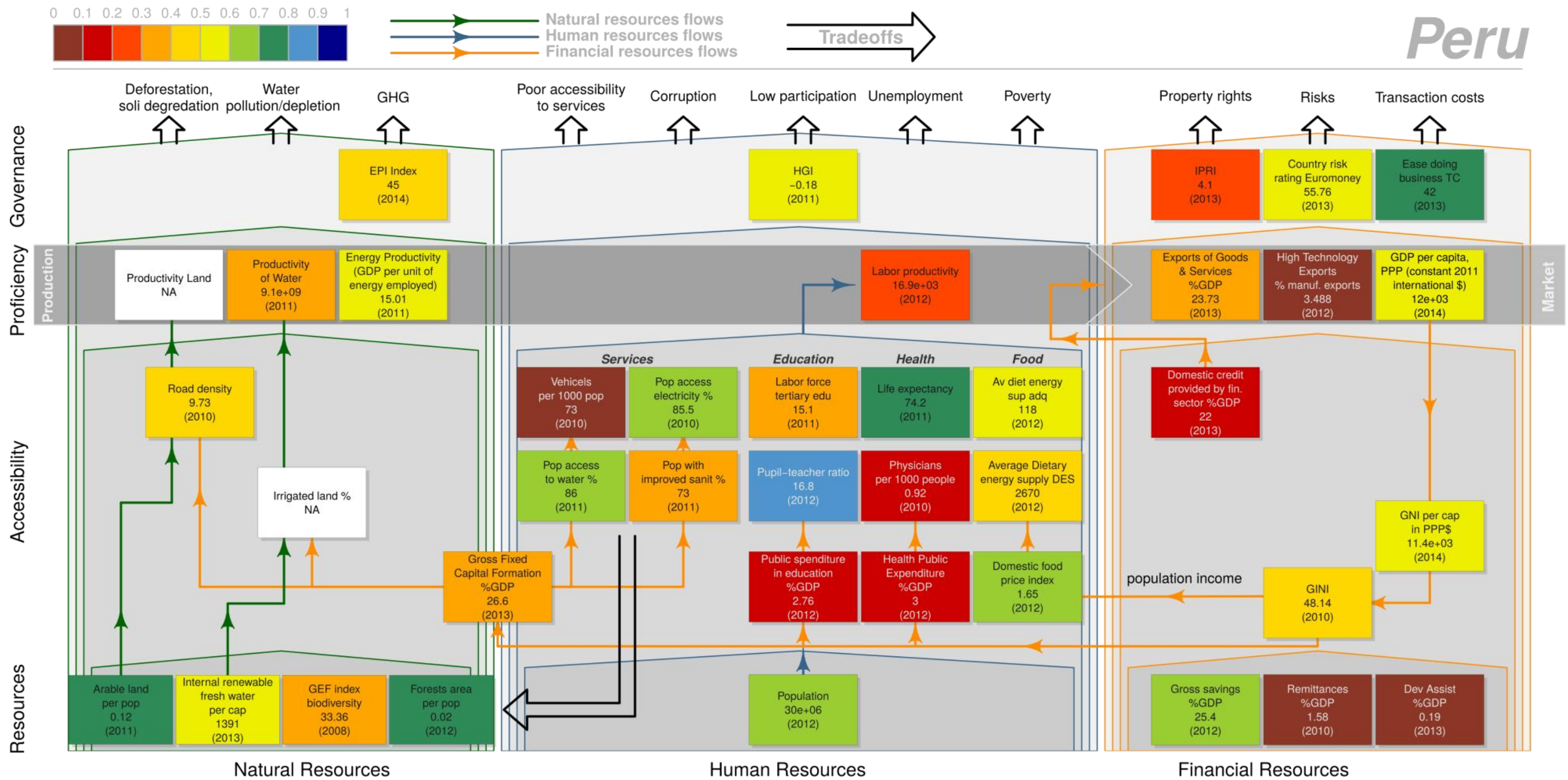
13.3.1 Growth, Human Development and Adaptive Capacity:

Trade-offs between economic activities and resources producing GHG emissions in Peru relate to the expansion of agriculture, cattle ranching, and mining. All these activities force deforestation. Other trade-offs relate to the increased demand for energy in transport, which is supplied by fossil fuels. Peru is burdened by trade-offs between energy-intensive growth and human development. Another trade-off affecting natural resources relate to the increased demand of water for human consumption and electricity generation. These trade-offs are related to the growth model of the country based on mining and the overexploitation of natural resources. Social trade-offs are further exacerbated by the structure of income distribution prevailing, which is responsible for the high inequality (see Figure 13-4). For pursuing climate resilient pathways Peru needs to develop the adaptive capacity based a new model of growth.

As Figure 13-8 makes evident the development of the adaptive capacity in Peru requires coordinated and long-term plans to develop at all fronts. The relative values of the indicators of productivity (in the row of proficiency) show that the economic structure of Peru is lowly developed. The low development of the economic structure is reflected in the very low performance in % of high technology exports and in the high reliance on mining. The diversification and the specialization of the economy demand the use of better technologies in agriculture for increased productivity of land and water. The country is doing efforts to improve in some aspects of capacity. In road density Peru performs middle relative to the rest of the world, but very low compared with Brazil (18.57) or Ecuador (17.03 km/km^2). But Peru ranks first among its neighbors in investments in gross fixed capital formation. Nevertheless the country has to find a balance between the high investments on infrastructure and investments in services and human development.

Labor productivity is low in Peru. This is determined by the low productivity of the economy in general. It is further constrained by the low coverage of basic services, low number of labor force with tertiary education and inadequate performance in food security. As the indicators of Figure 13-8 show the shares of GDP in education and health are among the lowest in the world. For increased labor productivity the country needs to follow consistent and long term plans for human development. The low performance of the financial services in the provision of domestic loans also restrained the development of the economy.

Figure 13-8: Indicators of the adaptive capacity of Peru.



Blank cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. For growth and development the country needs to improve labor and resources productivity by diversifying and specializing the economy – currently based on mining. Growth requires important investments in infrastructure and human capital. The provision of credits also needs to improve. The country needs to close the gaps in the provision of basic services and to improve in governance.

The low development of the structures of accessibility to resources and the low development of the economy create mutual restrictions. Therefore it is required to develop consistent policies for both developing the economy and enhancing the productive factors. The country needs to close the gaps in the provision of basic services in order to enhance the adaptive capacity of the population.

However, the possibilities to coordinate the development of the factors of accessibility and proficiency are constrained by the high inequality of income distribution. Reducing structural inequality requires changes in governance. Peru needs to develop further its governance capacity especially in environmental and human governance. In the environmental part of the Environmental Performance Index the country performs middle. Such performance is in line with the low performance in the GEF index of environmental protection and high deforestation rates (see Figure 13-2).

With regard to human governance the averaged index of the indicators of human governance of the World Bank is slightly negative (HGI = - 0.18 in Figure 13-8). In the variables of the HGI the country performs positive though low in ‘voice and accountability’, and ‘regulatory quality’, but negative in ‘political stability and absence of violence’, ‘government effectiveness’, ‘rule of law’, and ‘control of corruption’. Negative trends between 2003 and 2013 include ‘rule of law’ and ‘control of corruption’. But the country shows better development of institutions to control economic risk, with high performance in the ease doing business (related to transaction costs), and middle performance in the indicator of country risk, measuring structural risk.

Food security is an important issue in Peru, in regard to the projected impacts of climate change on water resources and crop yields. Currently the country is not self-sufficient (Pradhan et al. 2015). The country performs adequately in the control of the costs of food, indicated by the domestic food price level index. In the average dietary energy supply adequacy the country performs middle (118%). As undernourishment was 11.8% by 2012 (FAO 2015) this indicator makes evident distributional problems in the provision of food.

13.3.1.1 Mitigation:

According to the Action Plan on Adaptation and Mitigation (Ministerio del Ambiente 2010), mitigation measures should focus on diversifying the energy matrix, improving the energy efficiency in industry and residential consumption, and improving fuels quality. Peru aims to modify its energy matrix with up to 40% of renewable sources (NAMA Database 2012). Moreover, the mitigation potential from waste management amounts to 7MtCO_{2e} (NAMA Database 2012). There is an ongoing plan for modernizing solid waste management in municipalities. In the industry sector the country aims to reduce 20% GHG emissions in the production of brick by 2020 and achieve a 10% reduction in GHG emissions in the cement sector by 2020, among other activities (NAMA Database 2012). Following a business as usual track these plans would reduce GHG emissions without contributing to sustainable development in Peru. For synergies, these plans need to be institutionally coupled to human development targets.

13.3.2 Water Scarcity, Drinking Water and Electricity Generation:

Peru is rich in arable land and forests. However, stocks of renewable fresh water resources are not as abundant (lower than in Colombia, Ecuador, and Bolivia). The middle value of the indicator of internal renewable fresh water resources averages the high scarcity in the coast and abundant water resources in the Amazon catchment (Sanabria et al. 2009; Urrutia and Vuille 2009). Climate change will have important consequences for water resources that need to be addressed. This holds for an increased availability of water in most populated areas, for economic uses, and for closing the gap in the provision of water and sanitation services.

Water resources are important for agriculture and electricity generation. The supply of drinking water and water for electricity are under imminent threat in Peru. Population growth will increase the demand for water resources. As of 2012 only 86% of the population had access to improved fresh water resources, and only 75% to sanitation (World Bank 2014). The country needs to develop a clear strategy that optimizes the use of water because of increasing water scarcity. Increases in the demand for electricity can be compensated with the exploitation of other renewable resources. A strategy for the optimal use of scarce water resources requires efficient provision of improved water for human consumption, closing the gap in the provision of water and sanitation, reducing the use of water in electricity generation, exploring the potential of underground water for irrigation, and the enhancement of forests and water towers.

Options to bridge the gap in electricity generation considered so far are based on fossil fuels. Solutions based on solar thermal power and wind power have the potential to compete with gas-based solutions. Additional investments increasing the installed capacity in electricity generation with renewable energy should be considered by CDM projects. This option may gain support from international donors supporting social development, if the country commits to investing steadily in the enhancement of social conditions for adaptation. Reducing further the use of water resources for electricity generation can help Peru to cover the projected gap in the provision of improved water for human consumption. The country needs to develop its capacity in water management and irrigation. Water reservoirs and irrigation can help reduce the impacts of water scarcity. Water bodies can be further enhanced by an effective control of deforestation, forestation, afforestation, and reforestation. However, the current trends of deforestation are also fostered by actual policies.

13.3.3 Agriculture, Food Security and Deforestation:

There are trade-offs between agriculture, cattle ranching, and forests. Together, deforestation and agriculture accounted for 59.33% of GHG emissions in Peru as of 2011 (WRI 2014). The projected impacts of increased water scarcity, higher temperature, lower crop yields, and hazards will exacerbate the pressure of agriculture on forests areas in Peru. Moreover, as the low performance in the IPRI index indicates, land tenure institutions have played an important role in incentivizing deforestation. Effective policies for the protection and enhancement of forests require that the country solve the endemic inefficiency of institutions of property rights.

Agriculture is the third larger emitting sector in Peru. In addition, the productivity of land (see appendix 5) is among the lowest within the countries studied. Peru is not self-sufficient in terms of food production (Pradhan et al. 2015). Peru has the potential to increase the productivity of agriculture and become self-sufficient in the middle term, without affecting forests areas. To make this happen, the country needs to develop research capacities and enhance countrywide agricultural assistance, for example to close the yield gap, which amounts to 40% to 70% of the potential crop production (Pradhan et al. 2015). In addition, peri-urban agriculture has the potential to reduce GHG emissions from transport, and the potential to reduce social vulnerability.

Programs improving agricultural productivity may be conceived in two different ways, either by promoting industrial agriculture, or by enhancing small farms and making them more productive. The first option may be more productive in terms of yield outputs, but it would increase inequality. The second option requires more commitment by the government, as it entails developing institutions, allocating and maintaining important budget shares of government revenues for the development of capacity in agriculture. Yet, this option has the potential to significantly reduce social vulnerability, mostly in rural areas, and to produce for and consume more from local markets. Actions required to improve agricultural productivity in Peru include more sustainable use of fertilizers in areas near the coast, management of yield variability due to changes in weather, improving accessibility to markets in the cordillera, improved management of pests, diseases, and weeds in the Northern Amazon region, among others (Pradhan et al. 2015b).

Peru faces a challenging situation requiring urgent, lasting, and decisive actions. A strategy to control deforestation in Peru requires different actions fronts that should include the protection and enhancement of water bodies, the development of high-yield crop varieties, the creation of economic incentives for the protection of forests in frontier areas, and the regulation of cattle ranching. Peru is active in GHG mitigation by avoiding deforestation. Peru aims to preserve 54 million hectares of forest and reduce deforestation rates to zero by 2021 (REDD+ Peru 2015). This should meet a 47.5% reduction of national GHG emissions compared to the year 2000 (Che Piu and Menton 2013). Carbon sinks from afforestation, forestation, and reforestation could provide financial flows for sustainable development in frontier agricultural zones in Peru.

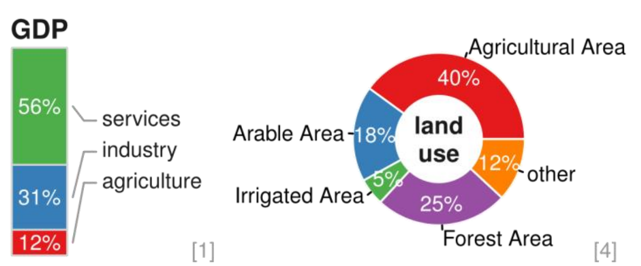
13.4 Conclusions:

Peru is challenged by climate change impacts. In the coming years the country will suffer from severe water scarcity due to the melting of glaciers. The country is actually not prepared to cope with the impacts of water scarcity. Peru needs to commit to the development of its adaptive capacity in water management. However, the country moves into an opposite direction. Deforestation is still uncontrolled. The country relies on mining as main activity, with subsequent consequences for low specialization and diversification of the economy. The transition to renewable energies needs support to avoid the adoption of coal power plants. This will reduce the pressure on water sources for hydropower. The country also needs to prioritize the development of agriculture. Research and development capacities can support improvements in agricultural productivity. The country needs to develop robust institutions for agricultural assistance to make small and poor farmers more productive.

14. PHILIPPINES

Figure 14-1: The Philippines – Factsheet and physical map:

Country size	300,000 sq km	[1]
Coastline	36,289 km	[1]
Population	100.1 millions	[2]
Rural population (%)	55.5	[2]
Human Development Index	0.66 (117 of 187 – Medium)	[3]
Life expectancy at birth	68.7	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

14.1 Sensitivity and Vulnerability

14.1.1 Sensitivity of Natural Resources

The observations and projections of temperature and precipitation used here are those reported by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The climate trends were analyzed using available observed data from 1951 to 2009 using 1971 – 2000 as reference period (PAGASA 2011). Simulations of temperature and rainfall in the Philippines in 2020 and 2050 employed the PRECIS model (Providing Regional Climates for Impact Studies) and the A2, B2, and A1B forcing scenarios (PAGASA 2011).

Temperature: There has been an increase in annual mean temperature by 0.65°C between 1951 and 2009 (PAGASA 2011). In terms of maximum and minimum temperatures, the increases have been 0.36 °C and 0.1°C respectively (PAGASA 2011). All areas of the Philippines will get warmer, with larger increases during the warmer summer months (PAGASA 2011). Annual mean temperatures (average of maximum and minimum temperatures) in all areas in the country are expected to rise by 0.9 °C to 1.1 °C in 2020 and by 1.8 °C to 2.2 °C in 2050 (PAGASA 2011).

Water, rainfall and precipitation: There is a substantial spatial difference in the projected changes in rainfall in 2020 and 2050. A reduction is expected for most provinces during the summer season (MAM) (PAGASA 2011), i.e. the usually dry season becomes drier. Rainfall increases are likely in most areas of Luzon and Visayas during the southwest monsoon (JJA) and the SON seasons making these seasons wetter. Thus, the likelihood of both droughts and floods in these areas is also increasing (PAGASA 2011). The northeast rainfall is projected to increase (PAGASA 2011) in DJF. During the southwest monsoon season (JJA), larger increase in rainfall is expected in the provinces of Luzon (0.9% to 63%) and Visayas (2% to 22%), but generally decreasing trends in most of the provinces in Mindanao by 2050 (PAGASA 2011).

Sea level rise: Though sea level rise is seen as a real threat sound studies about the potential damages from sea level rise in the Philippines are missing. According to the Philippine Strategy on Climate Change Adaptation sea level rise is already perceived by coastal communities of small, flat islands off southern Palawan and in Central Visayas (ACCBIO 2009). In addition, there are serious concerns about the potential damages of sea level rise and coastal storm surges on power transmission and distribution systems (ACCBio 2009). A total of 703 municipalities across the country will be vulnerable to a one-meter sea level raise. These areas are where the poor are at greater risks (ACCBio 2009).

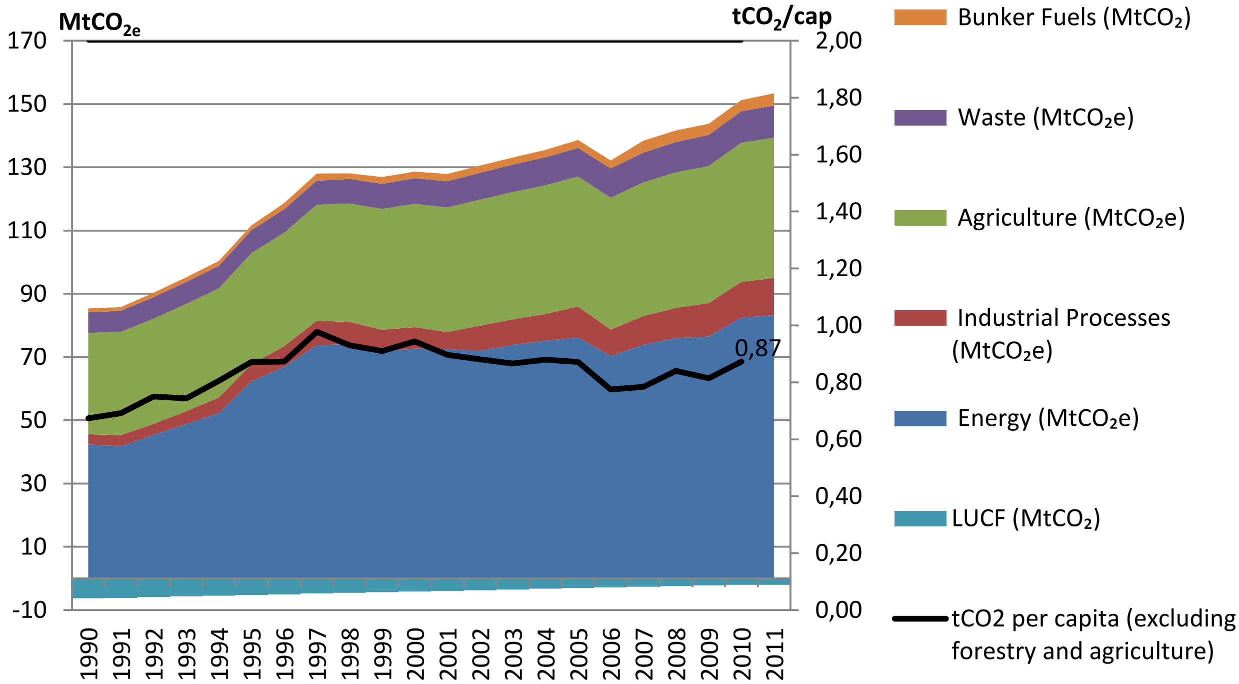
Crop yields: During 2012 the production of palay and sugarcane declined due to floods that severely affected some palay farms in Davao. Changes in harvest schedules in Western Visayas and Cagayan Valley were observed in the same year (UNFCCC 2012). The production of sugar cane declined in the provinces of Bukidnon, Davao del Sur, and Lanao del Sur (UNFCCC 2012) due to frequent rains in 2012. Crop shifting from sugarcane to palay in Tarlac and from sugarcane to oil palm in Mindanao contributed to the decline (UNFCCC 2012). Projections on future crop yields in South Asia face high uncertainties (Li et al. 2015). Changes in temperature and rainfall will affect the incidence/outbreaks of pests and diseases, both for plants and animals (PAGASA 2011).

Land Use and Forestry: Forest areas in the Philippines have been gradually increasing in the last years to a share of 30.8% of the total land area in 2010 (FAO 2014b) even with some expansion of the agricultural area. In total, it covers 40.6% of the total land area in 2010 (FAO 2014b). Protected areas have grown (FAO 2014b). The Philippines are active in REDD+. The National REDD-plus Strategy covers a horizon of ten years (2010-2020). It aims to develop the capacity in forests management to pursue REDD+ programs in the future (UN-REDD 2015).

The country has a total of 15 million ha forest land. The Philippines' forests are among the most diverse forests in the world, but also among the most endangered, because the conversion of forest lands into farmlands and the extraction of forest resources were major economic policies during the last century. Two decades ago the forestry policy was amended to encourage more sustainable forest practices, e.g. with an overall logging ban on primary forests in 1990 and logging concessions under the timber license agreement system (UNFCCC 2000).

Atmosphere: The energy sector is by far the largest emitter of GHG emissions with over 50% (Figure 14-2). The Philippines' total energy supply is by 60% fossil-fuel based (IEA 2014a). Fossil fuels make up the largest share of electricity generation (IEA 2014a). Both are mainly provided by coal/peat, natural gas, and oil (IEA 2014a). Agriculture is the second contributor of GHG emissions (see Figure 14-2). Agriculture contributes mainly by CH_4 and N_2O (WRI 2014); mostly induced by rice cultivation, domestic livestock, and soils (WRI 2014).

Figure 14-2: GHG sectoral emissions and energy per capita emissions of the Philippines.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LULF and agriculture (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). The shares of emissions show that energy and agriculture are the most relevant sectors for the analysis of synergies.

Renewable energy sources accounted for 40% of the total electricity production in 2011, i.e. geothermal/solar/wind 21%, biofuels 17%, and hydro 2% (IEA 2014a). Imported coal and crude oil provide more than half of the country's energy supply (IEA 2014a). The largest part of energy emissions derives from electricity and heat production followed by manufacturing and construction (IEA 2014a), i.e. mainly from the cement and metal industries (IEA 2014a). The fuel types used in these subsectors are conventional fuels such as oil and coal, which contribute substantially to GHG emissions (IEA 2014a). The Asian Development Bank estimates the total potential mitigation options in the energy sector at 157 $MtCO_2$, out of which 68 $MtCO_2$ could be implemented at a negative cost (ADB 2009). GHG emissions from the industry sector, which are the third highest emission rates after energy and agriculture (WRI 2014) are largely based on the production and transformation of raw materials.

14.1.2 Economic Vulnerability

The GDP of the Philippines has almost doubled between 2001 and 2013, from 3.29 to 6.22 US$ billion (PPP constant 2011 international US$) (World Bank 2015a). The economy is today experiencing one of the fastest growth rates in the world. The Filipino economy has been transitioning from an agricultural based to one relying more on services and manufacturing. However, the lack of competitiveness in key sectors, insecurity of property rights, complex regulations, and severe underinvestment by the government and the private sector have led to an unsatisfactory growth pattern, atypical for the East Asia region (Crepin 2013). This growth pattern has failed to provide good jobs to the majority of Filipinos and led to substantial outmigration. In addition, corruption has been identified as a major source of low governance in the Philippines. Good governance and anticorruption are top priorities for the Philippine Development Plan 2011-2016 (NEDA 2011).

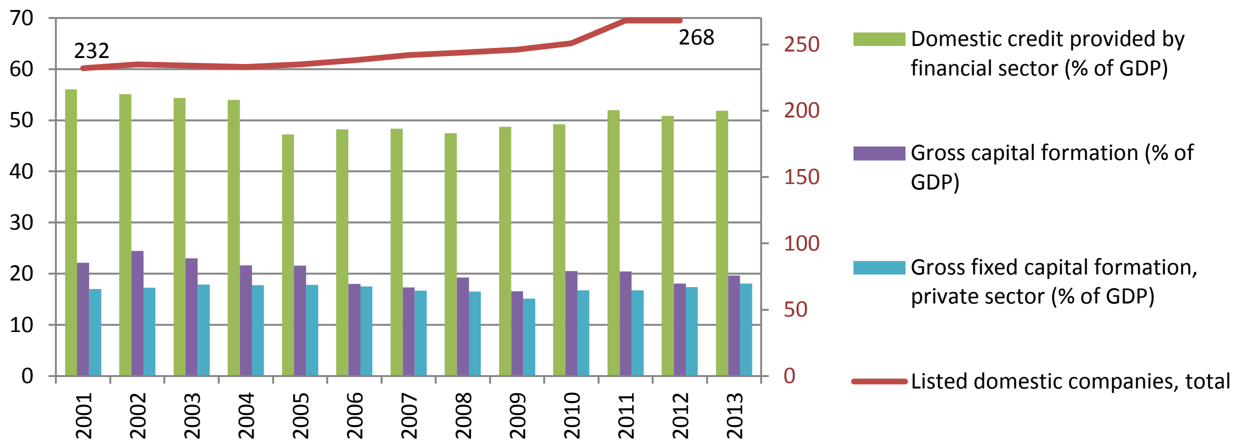
Economic impacts on the agricultural sector: Agriculture is still seen as 'the country's economic lifeline' (UNFCCC 2000). Agriculture contributed 11.23% of GDP in 2013, and represented the income of 32% of the Filipinos in 2012 (WFB 2015). Agriculture has been traditionally focused on a few main crops, namely rice and corn. Coconut and sugar cane are important commodities for export (Simoes and Hidalgo 2014). Climate change will affect agriculture more severely in the Philippines, due to temperature changes and changes in rainfall regimes (PAGASA 2011). Decreasing yields and inadequate job opportunities in the agricultural sector could lead to migration and shifts in population resulting in an increasing pressure for urban areas, particularly for mega cities (PAGASA 2011).

Economic specialization and diversification: The total number of commodities and services exported amounted to 1096 in 2012 (Simoes and Hidalgo 2014), similar to Mexico, Brazil, Indonesia, and South Africa. 55 commodities cover nearly 80% of exports in value (Simoes and Hidalgo 2014). Moreover, exports are not concentrated in specific sectors. Of those 55 products 7.13% were mineral products, 5.73% were obtained from agriculture and fishery, 63.41% from technology and machinery, 0.69% chemical products, textiles 1.16%, and other goods and services 1.67%. These numbers shows a varied portfolio of exports. With regard to economic specialization high technology exports are very high in the Philippines (see Figure 14-9). However, these exports are not the result of national innovation processes, but more of mass production based on innovations developed abroad.

Capitalization and Capital Formation: As Figure 14-3 shows in the last decades the formation of gross capital, i.e. infrastructure, school, hospital, roads, has not been constant. It varied from 16.6% of GDP (in 2009) to 24.5% (in 2002) with an average of 20.2%. As many countries try to keep constant the percentage of GDP for investments in infrastructure the variability of investments in the Philippines reflects some lack of planning. The private sector has kept investments in capital formation at 17.1% on average. In addition, the Philippines are characterized by the stagnation of the financial system in the provision of credit below 60% of GDP (in contrast with e.g. Vietnam above 100% of GDP as of 2013). The number of listed companies in the national stock markets has slightly increased during this century reflecting the diversification of the economy. The country needs to enhance opportunities for the provision of domestic credit and continue with the diversification of the economy.

Economic Risk and Uncertainties: Between 2003 and 2013 inflation has been kept low (average 4.4%) and under control (standard deviation 1.77) (World Bank 2015a). However, the country does not perform adequately in transaction costs. In the ease doing business index taken as proxy of transaction costs the country ranks 108 behind China (96). The ease doing business index evaluates the environment facilitating the development of business. The country risk index (Euromoney 2014), which evaluates structural, political, and economic risk, places the Philippines in the fifth decile in 2013. With regard to the index of property rights the Philippines is ranked in the fourth decile (5.0 in 2013), low, but better than neighboring countries like Vietnam. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014).

Figure 14-3: The recent evolution of capital in the Philippines.



Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies and investments in gross capital formation, private and public. For the analysis of the adaptive capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. Being one of the most populated countries in the world, the number of listed companies is low compared to other countries. The provision of domestic credit is deficient and investments in infrastructure are variable, below 20% of GDP. Overall, it shows inadequate formation and availability of capital for growth.

14.1.3 Social Vulnerability

The Philippines as an archipelago country is highly vulnerable to the threats of climate change, especially since a major part of its population lives in coastal areas. According to the World Risk Report 2011, the Philippines is the third most endangered country by climate change impacts (UNU-EHS 2011).

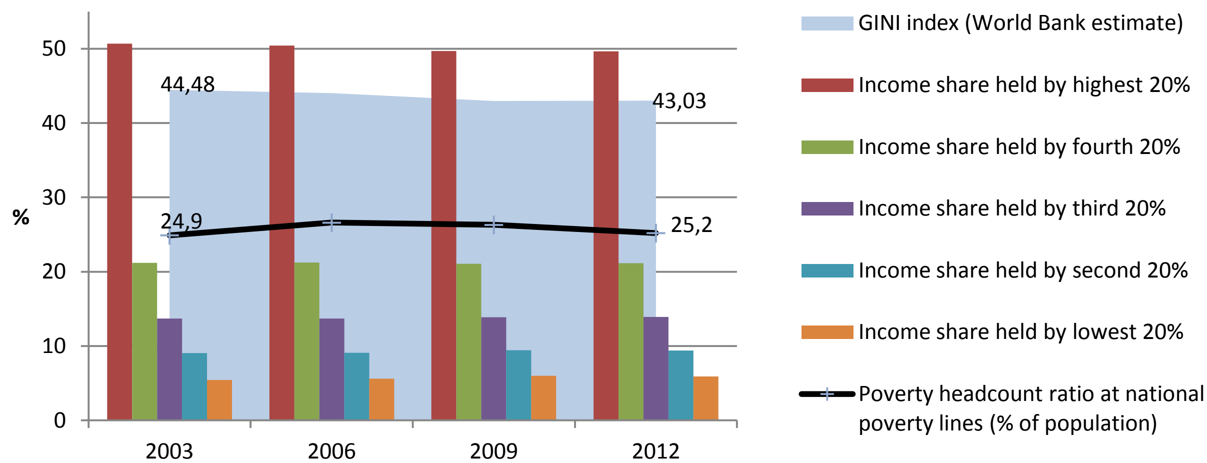
Income inequality in the Philippines does not decrease and is high (World Bank 2015a). Moreover, the poverty headcount ratio has even increased (see Figure 14-4). In 2009 18.4% of the population lived on less than $1.25 a day (World Bank 2015a). This share amounts to 16.9 million persons (more than the total number of citizens in Cambodia) (World Bank 2015a). However, the percentage of people living in poverty declined by 12.3% over the last 20 years, as in 1990 the share of people living with less than $1.25 a day was 30.7% - 19.5 million persons.

Food security: The National Climate Change Action Plan of Philippines (NCCAP-P) ranks food security first as a priority for action (Philippines Climate Change Commission 2011). The objective of the national strategic priority on food security is to ensure availability, stability, accessibility, and affordability of safe and healthy food amidst climate change (Philippines Climate Change Commission 2011). Almost 51% of the population lives in rural areas (World Bank 2015a). 16.2% of people were undernourished by 2013 (FAO 2015). Moreover, the inadequacy of food supply reached 23% of the total population by the same year (FAO 2015). Yet, the volatility of food price index in the Philippines has not been historically as high as for Indonesia and Cambodia.

Health, Sanitation, Water, and Energy Services: Life expectancy in the Philippines (68.4 years in 2012) is 7.3 years shorter than in Vietnam (World Bank 2015a). The Philippines spent 4.59% of GDP in health services in 2012 including private and public expenditure (World

Bank 2015a). This is higher than average in South Asia (3.96 as of 2013) (World Bank 2015a). Public expenditure in health is among the lowest compared to the rest of the world. Health issues would be partially explained by the low performance of the Philippines in the provision of services. Access to fresh water reached only 92% of total population in 2011; i.e. nearly 8.6 million people had no access to the water supply as of 2012 (World Bank 2015a). However in 2012, only 74% of the population had access to sanitation services, i.e. nearly 28 million had no access to sanitation (World Bank 2015a). 83% of the population had access to electricity by 2010 (World Bank 2015a) leaving nearly 18.3 million people without this service. These conditions on health expenditure and the accessibility to services represent a factor of social vulnerability in the Philippines.

Figure 14-4: The recent evolution of income distribution, inequality and poverty in the Philippines.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups. The national poverty headcount ratio cannot be compared between countries, but offers a measure of the efforts of the government to reduce poverty via subsidies of social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Income inequality and poverty headcount ratio are high and non-decreasing. This trade-off has to be considered in the analysis of synergies.

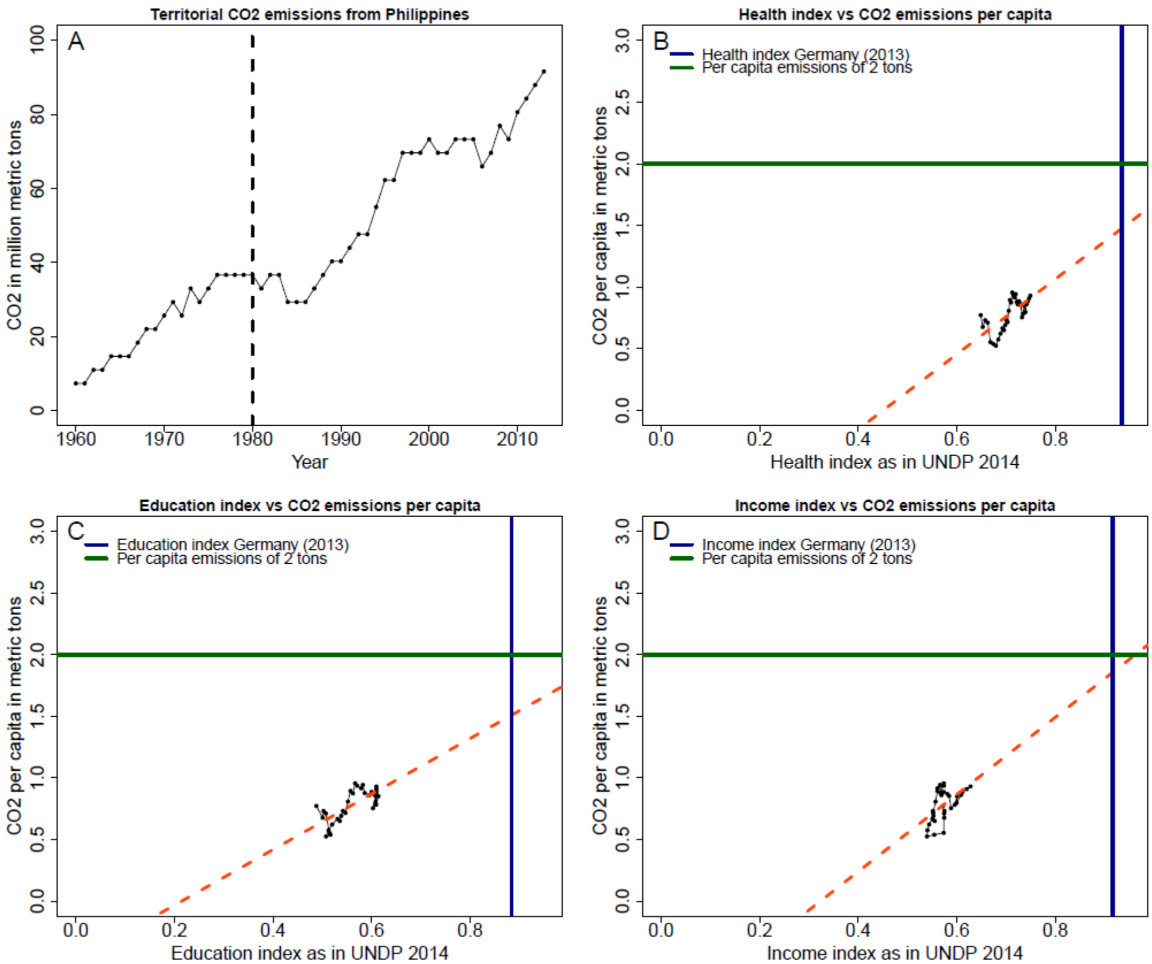
Education: Expenditure in education was 2.44 % of GDP by 2011, stable over the last decade (World Bank 2015a). It is below the South Asia average (2.8%) and Vietnam (5.86%). The country lacks reliable information on education. There were only 11 technicians per one million people in 2007 (1,418 in the Euro area 2005-2010) and only 0.11% of GDP was spent in Research and Development in 2007 (2.1% average 2005-2010 in the Euro area), indicating a very poor proficiency (World Bank 2014f).

14.2 Links between Adaptation, Development and Mitigation

14.2.1 The Evolution of the HDI and the GHG Emissions

Territorial CO_2 emissions from the Philippines have grown from 7 to 91 $MtCO_2$ between 1960 and 2013. On a per capita basis the picture is less clear, varying between periods of growth and decrease. Per capita emissions within the last 3 decades ranged between a minimum of 0.5 and a maximum of 1 tCO_2 per-capita (Figure 14-5B).

Figure 14-5: Trends of CO_2 emissions and the HDI in the Philippines.



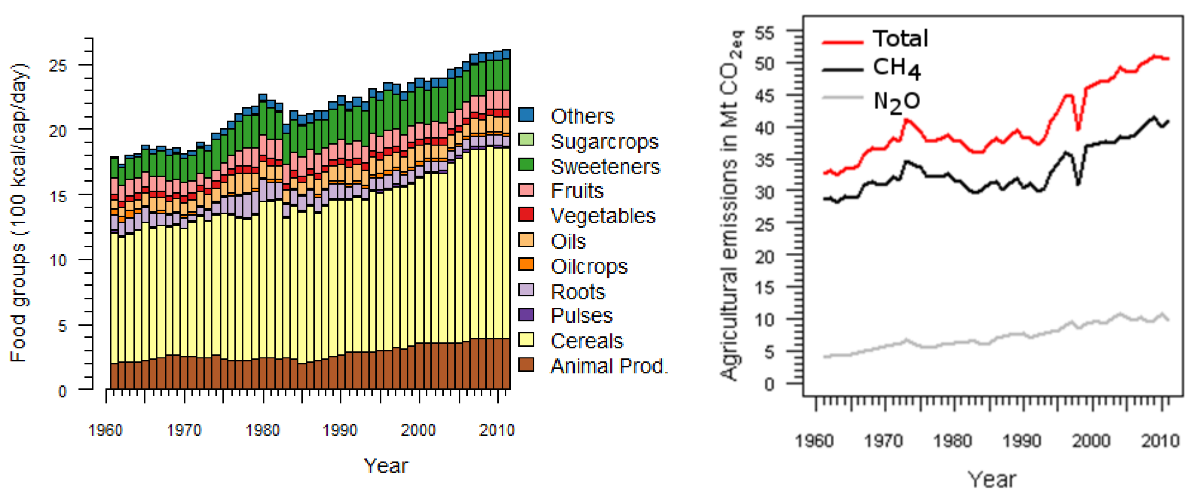
Historical emissions of CO_2 from fossil fuel burning obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education, and health obtained from the World Bank 2014 database. Horizontal green line shows the 2 tCO_2/cap target achieving a meaningful climate stabilization policy (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany. Dashed orange line depicts the trend in average per capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C, and D. Emissions per capita are growing, but the pace of development of the indices composing the HDI is the lowest compared to the other countries of this study. The increased emissions per capita in the Philippines are not effectively being transferred to human development.

The correlations between the different components of human development and per capita emissions in the Philippines are erratic (Figure 14-5B, C and D), particularly in the case of income (Figure 14-5D). The progress in all human development components which have been investigated is still slow. An extrapolation of current per capita emissions trends would probably keep the Philippines below the limit required for climate targets under the fair burden constraint to keep global warming below 2°C (WBGU 2009a). Nevertheless, due to the erratic trend observed in past few trends, more robust statements are hindered. The progress of the Philippines towards higher levels of Human Development (measured by the HDI) is expected to be slow. HDI scores above 0.9 are unachievable within the first half of this century (Costa et al. 2011). Under a slow human development and fast population growth, emissions by the year 2050 are expected to be of about 240 $MtCO_2$ (Costa et al. 2011).

14.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 14-6 (left) presents the evolution of dietary patterns in the Philippines between 1961 and 2011 based on amount of 11 different food group supplied in the country. In general, the Philippines' total food supply has increased from 1,790 kcal/cap/day in 1961 to about 2,600 kcal/cap/day in 2011. The current food supply in the Philippines is above its average dietary requirement of 2,210 kcal/cap/day (Hiç 2014). During the past five decades the amount of cereals supplied per person per day has increased by around 460 kcal, whereas, supplies of oils, sweeteners, and animal products have increased by 70, 90, and 190 kcal/cap/day, respectively. Moreover, current per person animal product supply of 390 kcal per day is below the global average per person animal product supply of 500 kcal per day. However, the food supply in the Philippines has continuously increased during the last decades. This depicts lifestyle shifts in the Philippines towards calorie and meat rich diets.

Figure 14-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Philippines.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural emissions including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in the Philippines during the last fifty years. Food supply in the Philippines has increased in the last five decades, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the recent decades, indicating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

In the year 2000 around 21 million people in the Philippines lived in regions where local food self-sufficiency can be guaranteed on a 10 km x 10 km grid (Pradhan et al. 2014b). The Philippines are a net food importer (Pradhan et al. 2015). It amounted to 16 trillion kcal in the year 2000. Major parts of the country so far have attained less than 40% of the potential crop production (Pradhan et al. 2015). The countrywide food production was sufficient to feed around 31 million people. The remaining part of the population depends on international food trade. However, the Philippines could still become food self-sufficient by closing yield gaps to attain 50% of the potential crop production resulting in 33 million people relying on local food, but the rest of the food demand can be satisfied on the country scale. Nevertheless, the Philippines population of around 108 million will partly depend on international trade by 2050, even by closing yield gaps to attain 90% of their potential crop production due to population growth and diet shifts.

The total agricultural emissions of the Philippines have increased from 33 $MtCO_{2e}$/yr to 51 $MtCO_{2e}$/yr between 1961 and 2011 (Figure 14-6 right). The increased emissions are related to an increase in agricultural production to meet growing food demand driven by population growth and dietary changes. Furthermore, diets currently consumed in the Philippines embodied emissions of around 0.9 tCO_{2e}/yr (Pradhan et al. 2013) and around 4 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013).

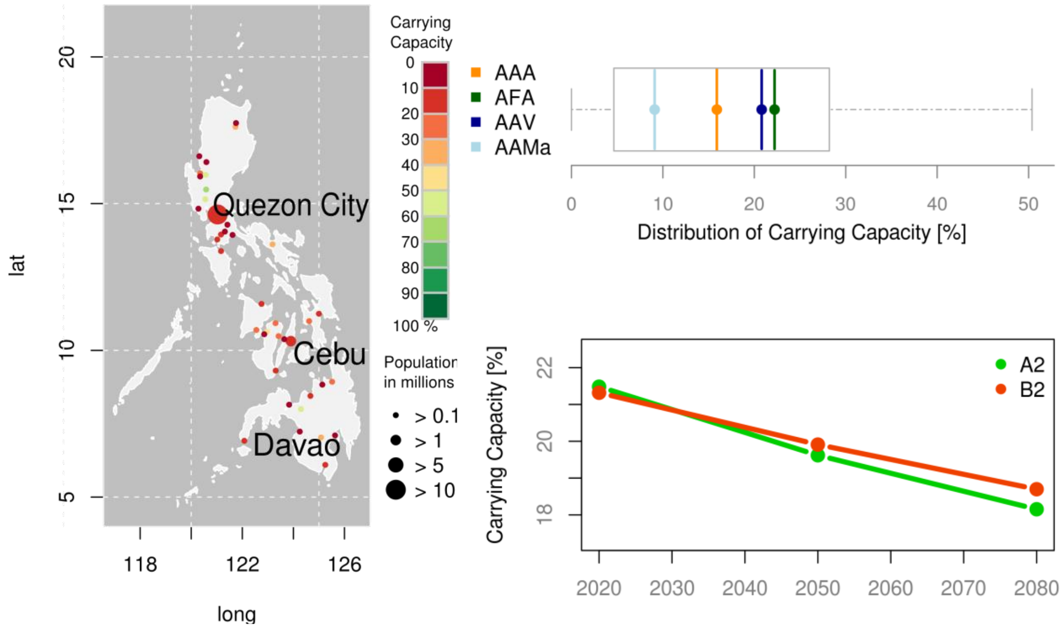
Currently, emissions per unit of crop and livestock production in the Philippines are higher than that of developed countries (Pradhan et al. 2013). Hence, technological progress increasing agricultural productivity can lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013). Additionally, closing crop yield gaps can increase crop production and ensure the current and future food self-sufficiency in the Philippines, while considering further population growth by 2050 (Pradhan et al. 2014b). However, only closing yield gaps is not sufficient to ensure the future food self-sufficiency when diet shifts are considered.

14.2.3 Potential of Peri-Urban Agriculture and Local Food

44.5% of the 100 million people in the Philippines live in cities and a future growth up to 157 million by the year 2050 will occur mainly in cities (United Nations 2014). 39 cities with population above 100,000 were investigated for the potential of regionalized food production to increase food security and reduce CO_2 emissions from transport. Overall these cities represent more than 21 million people. Today 55% of the surrounding areas are used for agricultural purpose, which is nearly 60% of all available arable area (94%). From the currently harvested areas 19% of the urban dwellers can be nourished (Kriewald et al., 2015).

Today's yield gap ratio for the investigated cities is around 0.52. Consequently, the biggest potential to increase the food self-sufficiency is by closing the yield gap. But a changed kcal-consumption or diet will have an influence as a further increase up to 3,500 kcal/cap/day will reduce the carrying capacity down to 9% (see Figure 14-7 – top right). 32 cities equal to 82% of the investigated cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). However, the summed values for an average yield scenario decrease from 21.5% down to 19% (see Figure 14-7 – bottom right). In conclusion, closing the yield gap must be the first priority in policy making.

Figure 14-7: The possibility for a food supply from surrounding areas for the Philippine cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. The best possibility to minimize environmental trade-offs due to agriculture is by closing the yield gap, also leading to high productivity of peri-urban agriculture. However, changing climate and more affluent diets can reduce the effect.

14.3 The Potential for Synergies and the Stage of Country Development

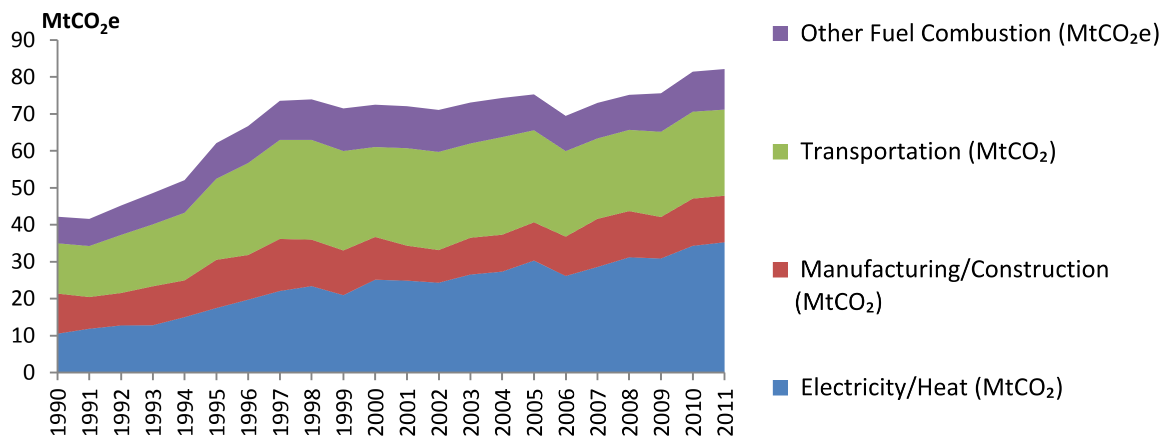
Two major trade-offs exist in the Philippines. First, increasing energy consumption producing GHG emissions from fossil fuels is not adequately being transformed into higher standards of human development. CO_2 emissions from fossil fuels are still low (see Figure 14-5), but high GDP growth rates suggest increasing emissions rates in the near future. Second, intra-sectoral trade-offs exist in agriculture. This activity is the second largest emitter. Associated to agriculture, there are concerns on food security. Due to the exposure to weather extremes and sea level raise, Disaster Risk Management deserves special attention in the Philippines.

14.3.1 Energy and Human Development:

Strategies for synergies need to couple more effectively the development of the energy system with human development. The pace of improvements in human development is slow (see Figure 14-5). These trends are in contrast with the relative high share of emissions from energy and transport (see Figure 14-2).

Energy security is an issue. The actual demand is not met. 83% of the population had access to electricity in 2010 (World Bank 2015a) leaving nearly 18.3 million people without this service (World Bank 2014f). The increasing demand for electricity has been driven by households and services. A closer observation of emissions from energy in Figure 14-8 shows that the trends of emissions growth are driven by electricity generation. Since 1998 emissions from transport have even decreased (WRI 2011). This is not the result of technological change in the transport sector, but the outcome of similar trends in energy consumption in this sector (IEA 2014a). Emissions from manufacturing do not show a significant growth trend. Relatively constant emissions in manufacturing (of e.g. steel and cement) are concomitant with low investments in infrastructure (see Figure 14-3).

Figure 14-8: Emissions trends from Transportation, Electricity and Manufacturing and the Cement industry in the Philippines.



Coal is responsible for the increasing emissions in electricity generation. Emissions from manufacturing and transport are stable. Data was obtained from (WRI 2014).

Of the 10.28 Mtoe of coal consumed in 2012 only 1.73 Mtoe were used by industry directly, and the rest transferred to power plants. 79% of electricity is produced by coal (IEA 2014a). Most of the coal is imported (7.1 Mtoe, out of 10.98 Mtoe in 2012). Losses from transformation in power plants are significant. Of the 20.75 Mtoe delivered to power plants in 2012 14.29 Mtoe were lost (IEA 2014a), i.e. 71%. Energy efficiency in electricity generation offers big potential for reducing emissions and lowering coal imports.

The Philippines import energy fuels of 18.56 Mtoe, mostly in the form of crude oil and oil products (IEA 2014a). This comprises 46% of the total percentage of energy supply (40.45 Mtoe) (IEA 2014a). However, the total consumption of oil products by industry has decreased since 1997, while biofuels and electricity has steadily increased over this century (IEA 2014a). Renewable energy sources accounted for 40% of total electricity production in 2011 (geothermal/solar/wind 21%, biofuels 17% and hydro 2%) (IEA 2015). Geothermal energy is entirely used for electricity generation. The use of geothermal energy reached a peak in 2000, and stabilized around 8.1 Mtoe in 2012. Therefore, current investments in the enhancement of renewable energy sources will help reduce the country's dependence on imported fossil fuels and reduce emissions from coal.

Clean Development Mechanism (CDM) projects in the Philippines are biased to waste management with 57% of total projects involved in this sector (NFSCC 2010). Total abatement potential of CDM projects amounts to 0,55 $MtCO_2$/yr (WRI 2014). For higher efficiency in mitigation, international assistance and CDM projects should prioritize electricity generation.

The NCCAP with the ambitious target of doubling renewable energy capacity in the next 20 years comprises a number of significant aims. Furthermore, the country has energy efficiency and conservation programs in place and pursues a low carbon transportation pathway (Nachmany et al. 2014). The country has already implemented seven policies related to climate change mitigation. Four of them address mitigation matters, one adaptation, and two are broader legislations that address both issues. The main focus among these is on the sector of institutions and administrative arrangements, while carbon pricing is not addressed in any of them (Nachmany et al. 2014).

The Asian Development Bank calculated that, compared to a BAU scenario, the country would have a fairly large CO_2 reduction potential at a relatively low cost. A number of net negative cost options exist in the power, industry, transport, and residential and commercial sectors, with total potential of 68 $MtCO_2$ (amounting to 37% of the BAU emissions) in 2020 (ADB 2009). A further increase in renewable energy production could help in terms of energy security, since currently 46% of the country's energy is being imported (IEA 2015).

Among the main problems of the Philippines in terms of mitigation action is the affordability of the technologies needed, e.g. utilization of renewables in power production. Regarding this interventions in terms of overcoming market barriers for the widespread use of renewables need to be undertaken. Moreover, it would be very useful to agree upon one mitigation strategy, comprising all the steps and strategies necessary. To this end, the various GHG abatement efforts being proposed and contemplated under the various sectoral plans should be integrated.

14.3.2 Adaptive Capacity

Pricing carbon, increasing the share of more costly renewable energies, overcoming other market barriers, and improving the capacity of coordination among different institutions require a wealthier economy, higher population income, institutional development, and enhanced governance, i.e. adaptive capacity. For an adequate adaptive capacity the country requires growth. The industry is stagnant in the Philippines. The economy is not being diversified and it is not specialized (refer to section 14.1.2). The economic model of the Philippines requires diversification, specialization, reducing income inequality, and improving social conditions. With the help of Figure 14-9 consider the overall situation of the country that needs to be addressed for adaptive capacity.

As the indicators of natural resources show, the Philippines is wealthy in arable land per capita, but fresh water and forests resources per capita are scarce, compared to other countries in the world. These natural resources are less abundant, though the situation is not as dramatic as Pakistan or the African countries studied. Forests areas per capita are low, but increasing. The country participates in REDD+ program. The low performance in the GEF index of biodiversity protection would correlate with the low share of forests per capita.

For productivity of natural resources the road density in the Philippines is high compared to other countries. For the row of proficiency in Figure 14-9 consider the stage of development of the productive structure, the performance of markets and the GDP. Numbers show a country with middle and low productivity of natural and human resources indicating low specialization.

The low specialization of the economy is not evident in the high performance in high technology exports Figure 14-9, as these high tech products are produced but not invented in the Philippines. In any case exports can provide important revenues for the country.

For growth the country needs to enhance the provision of domestic credit, which is lower in comparison to countries like India and Vietnam as of 2013. The productivity of land would not be determined by constraints on land access because transport infrastructure is good, but more by the technologies used in agriculture and the low value products produced. Similarly, low labor productivity would reflect the low specialization of the productive structure and the constraints on human capital imposed by low human development.

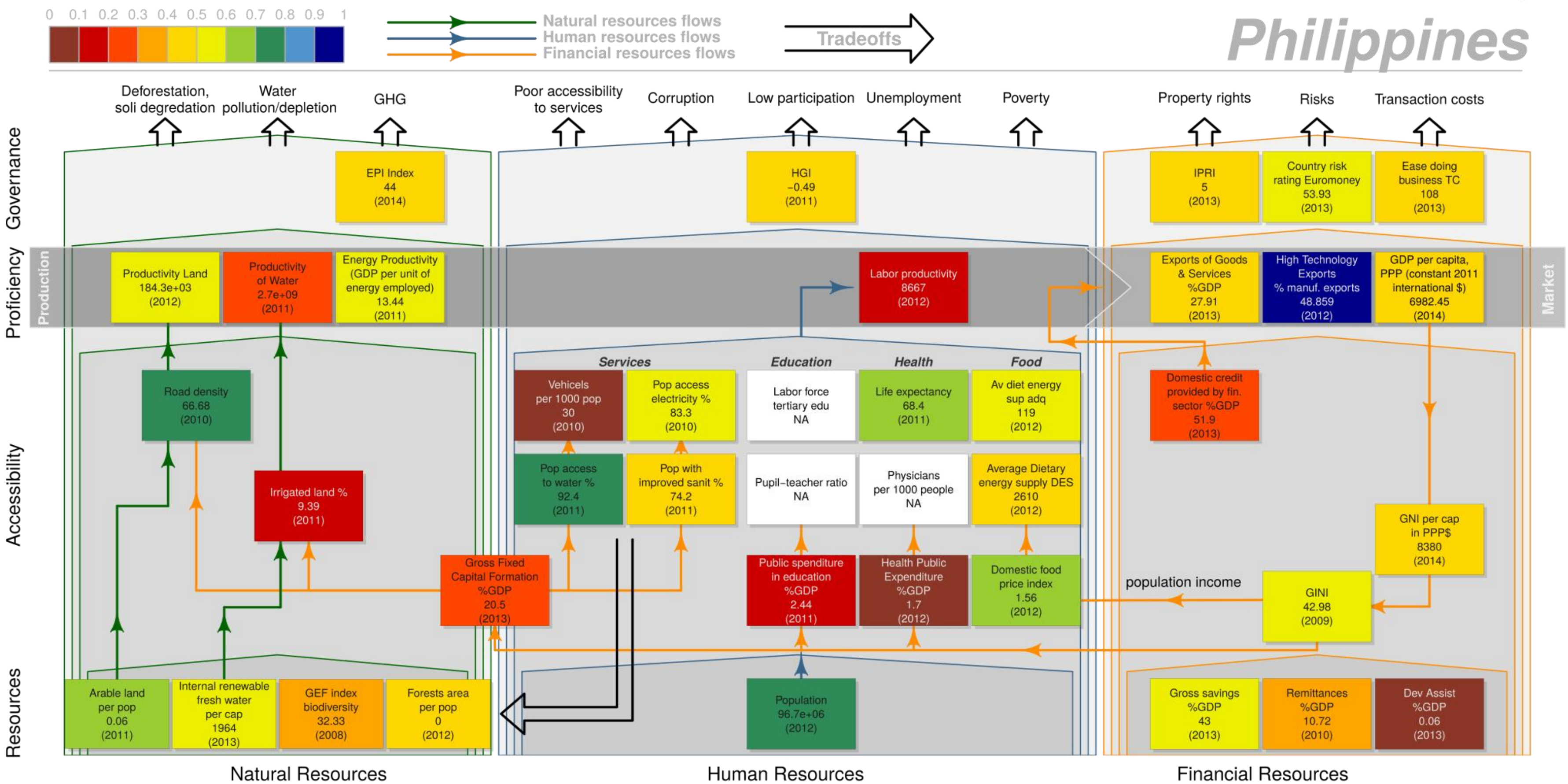
As Figure 14-9 shows the gaps in the provision of basic services need to be bridged. Food security is priority in the National Climate Change Action Plan of Philippines (NCCAP-P) (Philippines Climate Change Commission 2011). Human capital formation is not effective when people are undernourished (16.2% of the population was undernourished) or suffer from food inadequacy (23% in 2013 (FAO 2015)). The contrast between the trends of energy emissions and trends of health and education indices in the HDI (see Figure 14-5) reveals the outcome of the current policy settings. While Cambodia increased the health index from nearly 0.1 to 0.8 in the Philippines this index has grown from nearly 0.64 to 0.76 during the same period. The low commitment to reduce social vulnerability is evident in the very low share of GDP spent in health (see accessibility to human resources in Figure 14-9).

These numbers show that the Philippines need to develop a balanced plan to diversify and specialize the economy while enhancing social conditions and reinforcing the financial system. Such balance requires governance. With regard to human governance, the averaged index of human governance is negative (see human governance in Figure 14-9 World Bank 2015b). Except in the variable ‘government effectiveness’ where the country performs positive but low, in all other variable composing the averaged index of human governance the country performs negative since 2003: ‘voice and accountability’, ‘political stability and absence of violence’, ‘rule of law’ and ‘control of corruption’. In all indicators of governance of economic uncertainties, the country performs middle, i.e. in structural risk (the country risk index), in transaction costs (the ease doing business), and in property rights (the International Property Rights Index). In the environmental part of the Environmental Performance Index, the country performs middle, mainly due to the country’s partly unsustainable performance in agriculture, water resources, and climate and energy policy (EPI 2015b).

14.3.3 Agriculture and Food Security:

There are concerns on the current and future food insecurity in the Philippines. The country is not food self-sufficient (Pradhan et al. 2014b). Climate change will significantly affect the carrying capacity of the Philippines (see Figure 14-7). Major parts of the country have attained less than 40% of the potential crop production (Pradhan et al. 2015a). The potential to increase land productivity is to some extent limited. There is yet room to improve food security by closing the yield gap.

Figure 14-9: Indicators of the adaptive capacity of the Philippines.



White cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. The Philippines need to develop governance, the productive structure and social conditions for adaptive capacity.

In order to transform the trade-offs of agriculture into synergies the country needs to develop its capacity in agriculture. Agriculture offers the opportunity to reduce GHG emissions to levels of more developed countries. Emissions have been steadily increasing in the Philippines with the constant increase of calories consumption. The share of meat in diets is below the average (see Figure 14-6). Moreover, the ratio of 4 calories needed to produce 1 calorie of meat is too high, compared to other countries of this study.

Research and development is needed, as well as the incorporation of modern technologies in agriculture. Options to improve agricultural productivity in the Philippines mainly include management of pests, diseases, and weeds, and technical application of chemical inputs, and improving accessibility to markets (Pradhan et al. 2015a).

The international community can support efforts in this direction by developing programs to enhance the national capacity in research and from the development of new crop varieties, which are more resistant to droughts and higher temperatures. International initiatives for climate change can support the Philippines in developing these varieties, while reducing sectoral emissions per calorie produced. In addition, the country needs to develop further its capacity in agricultural assistance. As 51% of the population lives in rural areas, the development of the capacity in agriculture requires massive financial efforts, the development of national and regional institutions and continuity in the plans. The high share of rural population in the Philippines demands a more aggressive policy to develop agriculture for food security and for economic growth.

14.3.4 Sea Level Rise and Disaster Risk Management:

According to the World Risk Report 2011 the Philippines are among the most endangered countries by climate change impacts (Birkmann et al. 2014). The vulnerability of the Philippines to climate change is the result of expected changes in natural resources, high exposure to weather extremes, sea level rise, and adverse consequences of higher temperatures and changes in rainfall for agriculture and food security. Ramping up support for disaster risk reduction projects and programs would therefore have large benefits.

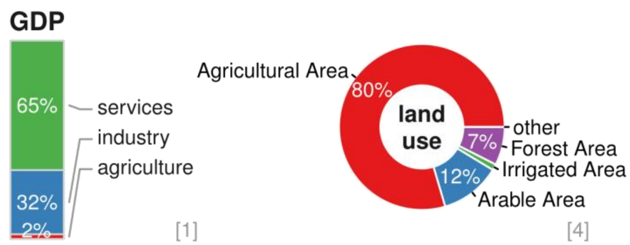
14.4 Conclusions:

The Philippines is highly vulnerable to climate change impacts. Disaster Risk Management (DRM) and food security are the major challenges for adaptation. The country needs to develop adequate institutions in DRM. It also needs to define a clear and long-term strategy to enhance agriculture. This requires the development of institutions for Research and Development and for agricultural assistance. However, the adaptive capacity of the Philippines is low. The Philippines do not follow a clear strategy for growth and development. This is evident in the unclear trend of GHG emissions, the stagnation in the income index of the HDI, and the variability of investments in the formation of gross fixed capital. For adaptive capacity the country needs to define a strategy for growth, to invest in human capital, and to bridge the high gap in the provision of basic services for the population. The energy system is very inefficient in Philippines. Losses in energy production generation (14.29 Mtoe) are higher than the total energy contents of the coal imported (7.1 Mtoe) in 2012.

15.SOUTH AFRICA

Figure 15-1: South Africa – Factsheet and physical map:

Country size	1,219,090 sq km	[1]
Coastline	2,798 km	[1]
Population	53.14 millions	[2]
Rural population (%)	35.7	[2]
Human Development Index	0.66 (118 of 187 – Medium)	[3]
Life expectancy at birth	56.92	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

15.1 Sensitivity and Vulnerability

15.1.1 Sensitivity of Natural Resources

Temperature: The Department of Environmental Affairs has completed a detailed and comprehensive assessment of climate change trends and projections in South Africa (Department of Environmental Affairs 2014). For the period 1961-2100 different SRES scenarios were considered in ten Coupled Global Circulation Models (CGCM). For a B1-SRES scenario a moderate temperature increase over the interior part of South Africa of about 2-2.5°C for 2040-2060, and 3°C in 2100 will be expected (Department of Environmental Affairs 2014). Projections considering A1B as forcing scenario indicate different warming among regions of South Africa ranging from 0.5°C to 3.5°C (Jalloh et al. 2013).

Water: Precipitation patterns are unequally distributed in South Africa. While some areas have exhibited a significant increase in rainfall since 1950, neighboring areas that are 50 km away have shown a significant decrease (MacKellar et al. 2014). In a study of the Dept. of Environ. Affairs (2014) the country was divided in subregions, namely Western, West, Central, East and Eastern. According to the projections of the downscaled ensembles of CGCMs the eastern South Africa will become wetter, with a projected increase of more than 20 mm/month. The east will become drier, with rainfall decrease of more than 20 mm/month. Slight to moderate increase in autumn rainfall is expected in the South-western Cape (Department of Environmental Affairs 2014). For the south-western Cape a moderate to strong increase in winter precipitation is projected (Department of Environmental Affairs 2014). Rainfall will also increase for the south-western Cape during spring (Department of Environmental Affairs 2014). In another study based on A1FI, A2, B1, and B2 scenarios it was found that in the arid regions of South Africa, i.e. the northern regions show the largest increase in the number of wet days during winter and spring months for both >2 and >10 mm/d rainfall events, by 2040 (Faramarzi et al. 2013). Overall, precipitation patterns will become more uncertain (Department of Environmental Affairs 2014). In summary, some parts of South Africa will be drier, but in general rainfall will increase.

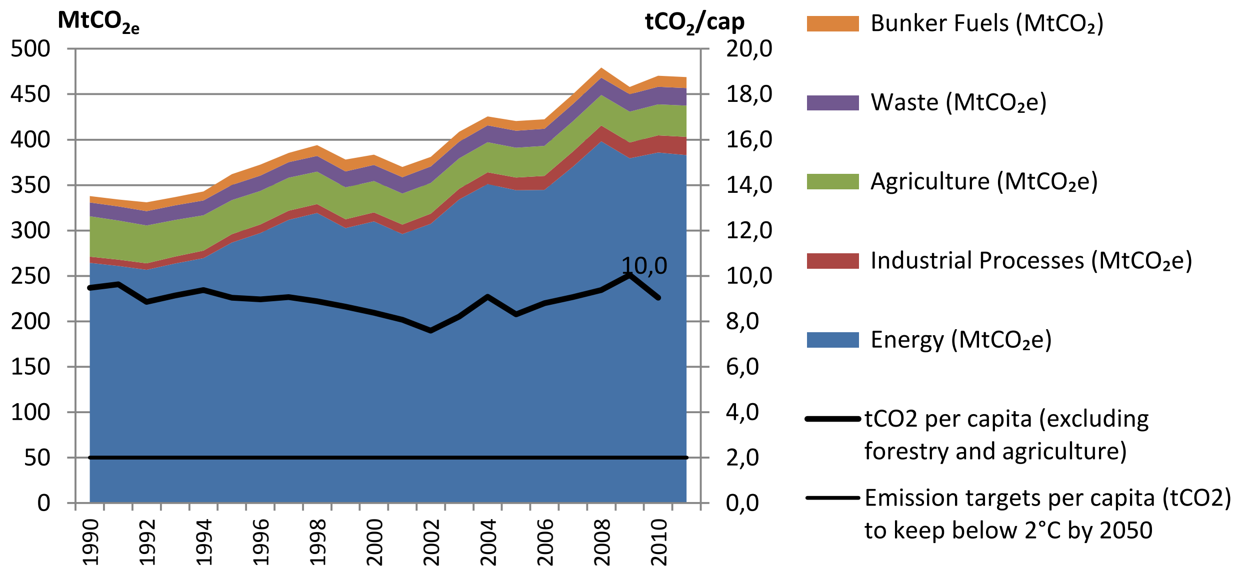
Crop yields: Main high value crops produced in South Africa include maize, wheat and sugar cane. Based on temperatures and precipitation projected by the model under an A1B scenario, the Decision Support Software for Agro-technology Transfer crop model predicts more losses than gains in the production of maize (Jalloh et al. 2013). The MIROC 3.2 predicts losses above 25% of current production in most parts of the country, but partially compensated by high gains in some other regions. The situation for wheat is different, as the models predict much more gains than losses (Jalloh et al. 2013).

Nearly 85% of the total wheat area is rain-fed additional the other 15% is irrigated (Jalloh et al. 2013). The crop is highly sensitive to changes in rainfall and the production in the Western Cape shows high variability (Jalloh et al. 2013). The increased uncertainty of rainfall will have further consequences for the variability of wheat yields. On the opposite, the production of sugar cane is projected to increase with climate change (Jalloh et al. 2013).

Land Use and Forestry: According to the second national communication, deserts are only about 1% of the total land in South Africa, while shrub lands cover nearly 40%, savannah woodlands nearly 33% and grasslands 27% (UNFCCC 2012). Almost 90% of the land in South Africa is cultivable land (FAO 2014b). Only 11% of land is continuously cultivated (UNFCCC 2012). Deforestation has been controlled, but the share of forests lands is only 7.6% (FAO 2014b).

Atmosphere: South Africa is the 12th largest emitter in the world (WRI 2014) and the largest GHG emitter on the African continent. Emissions have risen from 350 $MtCO_{2e}$/a in 1990 by more than 50% to 559.7 $MtCO_{2e}$/a in 2012 (OECD 2014b). In global comparison it ranks at number 15 in terms of its total GHG emissions. As Figure 15-2 shows energy and transport are the major emitter sectors in South Africa, followed by agriculture. According to the Department of Energy about 77% of South Africa's primary energy needs were provided by coal (DoE 2014) in 2013. The production and consumption of coal is expected to increase, due to the increasing demand for electricity and the low cost of coal. In the country 62% of the coal production is allocated to the production of electricity (DoE 2014). By2020 emissions growth mainly stems from industry and the increased electrification and electricity use of households. From a longer-term perspective, transport will contribute significantly to emission growth (Fekete et al. 2013). South Africa plans to produce 42% of electricity from renewable sources by 2030 (DoE 2013). The country committed to reduce 34% of BAU emissions by 2020, and 42% by 2025. According to the Climate Action Tracker, the country will not meet these targets (CAT 2015). In addition, South Africa’s emissions per capita have by far trespassed the 2 tCO_2 per capita average required to keep global average temperature growth below 2°C under fair burden conditions (WBGU 2009a).

Figure 15-2: GHG sectoral emissions and energy per capita emissions of South Africa.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LULUCF and agriculture (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). As the shares of the figure shows, energy and transport are the most relevant mitigation sectors for the analysis of synergies.

15.1.2 Economic Vulnerability

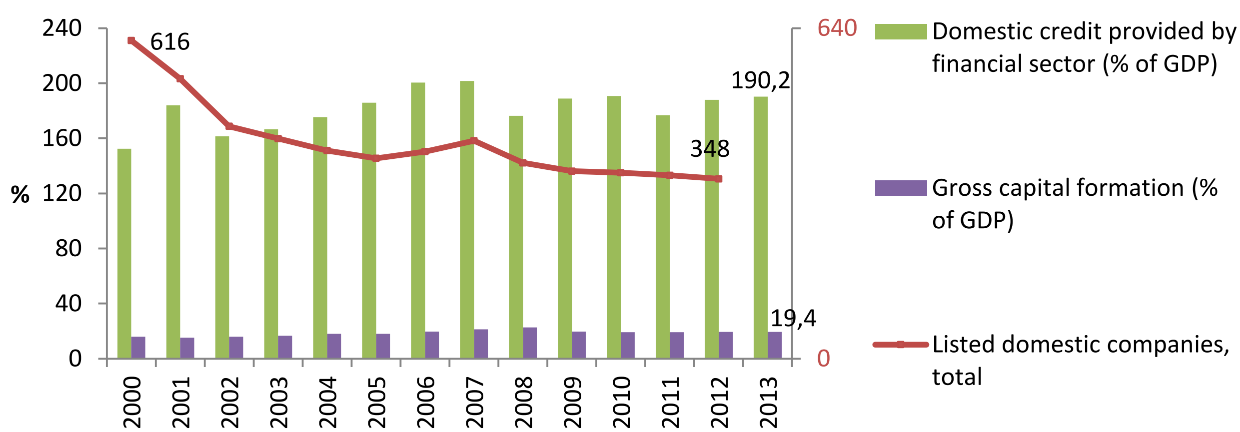
South Africa is the largest economy in Africa and has grown rapidly since the end of the apartheid era in 1994. It is an emerging economy and the most developed nation in Africa (World Bank 2014f). Despite rapid growth, economic problems from the apartheid era remain, particularly poverty and a lack of economic participation among disadvantaged groups (EIA 2014). The economy of South Africa has been seriously affected by the global economic crisis over the last years inducing a slowdown in rate of economic growth. So the average growth rate of South Africa was about 5% between 2004 and 2007. Between 2008 and 2012, however, it was just above 2% (World Bank 2015a).

Sectoral impacts: Climate change will produce changes in land use, with consequences for agriculture. According to the Department of National Treasury, climate change will impact more adversely agriculture. Overall impacts will be felt more drastically after 2050 (Ziervogel et al. 2014). Until that year losses will amount up to 10% of GDP of 2010 in net present value. Due to water scarcity more vulnerable regions will be more harshly affected (Ziervogel et al. 2014). These areas are inhabited by the most vulnerable population.

Economic specialization and diversification: The country will be more able to cope with these impacts if the economy is diversified and specialized. The economy of South Africa is diversified. In 2014, exports represented 34% of GDP (WFB 2015). Following statistics of trade of Simoes and Hidalgo (2014) the country exported 1,214 products in 2011, more than Mexico. Exports include agricultural commodities, technology and chemicals, but principally mineral products. Only 60 commodities represented nearly 80% of total exported value as of 2011 (Simoes and Hidalgo 2014). Exports are concentrated in a few products, mainly mineral commodities, i.e. gold, platinum, coal briquettes, diamonds, iron ore and ferroalloys (48% of total exports value in 2012). Agricultural commodities which are more vulnerable to climate change impacts contribute to 5% of exports value. The economy is not highly specialized. The share of high technology products exported is only 4.5% (World Bank 2015a). Overall, these numbers show an economy highly dependent on revenues from mineral products with little contribution from agriculture. The portfolio of exports in South Africa is not sensitive to climate change impacts. The economy is exposed more to changes in trade and prices of mineral products.

Capitalization and Capital Formation: Figure 15-3 shows the evolution of a set of indicators of capitalization. Between 2000 and 2012 the number of companies listed in national stock markets dropped from 616 to 348 indicating a process of capital concentration, and affecting the availability of capital for the whole society. This concentration of capital has consequences for income inequality (cf. below). The percentage of GDP provided as domestic credits in South Africa is the highest among the countries studied showing a high capacity to make financial resources for growth available. However, the share of GDP invested in gross fixed capital formation (infrastructure, health, education, etc.) is low compared to less developed countries in this study. Overall, these numbers show that the South African economy is wealthy but capital is highly concentrated.

Figure 15-3: The recent evolution of capital in South Africa.



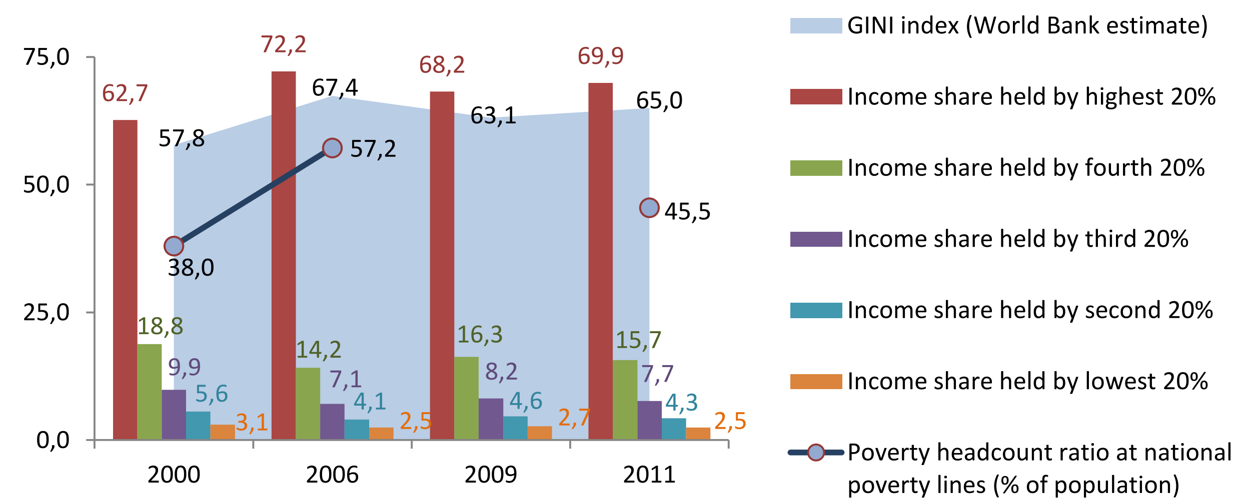
Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies and investments in gross capital formation. For the analysis of the adaptive capacity, this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. South Africa shows a contrast between the wealth of the financial system and the share of GDP for infrastructure. The wealth of the financial system is concomitant with the process of capital concentration indicated by the decreasing number of companies listed in stock markets.

Economic Risks and Uncertainties: Inflation is not under control in South Africa. The average inflation rate over this century is 5.9% (World Bank 2015a) with standard deviation of 3.06. The country shows a good performance in transaction costs. We used the ease doing business index as proxy for transaction costs. The index evaluates the environment facilitating development of business. In this index the country ranks 41 (out of 183 countries) in 2013 (World Bank 2015a). In the country risk index (Euromoney 2014) which evaluates structural, political and economic risks places South Africa in the group above the 60% lower risk countries (58.73 as of 2013). These numbers show a low risk country with adequate business environment. However, the country does not perform similarly in property rights. The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). The IPRI index (5.9 in 2013) places South Africa in the sixth decile showing relative insecurity related to land tenure. Overall, these numbers show an unbalanced situation related to the capacity of the country to cope with risk and uncertainties. The country shows some insecurity in property rights and low capacity to control inflation while it performs well in transaction costs and in structural, political and economic risks.

15.1.3 Social Vulnerability

The population is highly vulnerable due to high unemployment (25% in 2014) (WFB 2015), low coverage of basic services, poor performance in health and deficits in education (World Bank 2015a). Social vulnerability is associated to high inequality of income distribution. As Figure 15-4 shows income inequality in South Africa is very high (the second highest in the world). It has even increased over this century (World Bank 2015a). Except the richest, all other income groups had to face reduced income shares. Moreover, the poverty head count is very high. These trends are concomitant with capital concentration and the wealth of the financial sector (see Figure 15-3).

Figure 15-4: The recent evolution of income distribution, income inequality and poverty in South Africa.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) cannot be compared between countries. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Social trade-offs indicated by increased income inequality and very high poverty headcount ration need to be considered in the analysis of synergies for South Africa.

Food security: South Africa performs adequately in several indicators of food security. The lowest consumption segment in South Africa spent 38.7% of their income in food and beverages in 2010 (The World Bank 2015). For Nicaragua the same consumption segment spent 54% and 53.27% in India. The average food deficit per capita is only 13 kcal/cap/day (FAO 2014b), and the prevalence of food inadequacy is below 5% (FAO 2014b). Yet, these numbers need to be pondered by high inequality.

Health, Sanitation, Water and Energy Services: Life expectancy in South Africa is among the lowest in the world (55.3 years in 2012) (World Bank 2015a). The government has made efforts to improve the situation. Indicators of the World Bank show that public and private health expenditure in South Africa amounts to 8.78% of GDP in 2012. This is above the average in Latin America and the Caribbean (7.7% in 2012). The provision of basic services in South Africa is deficient. Access to fresh water reached 95.1% of total population in 2012 (99.2% in urban areas and 88.3% in rural areas). Access to sanitation reached 82.7% of the population in 2012. South Africa needs to bridge current gaps in services and health to improve its resilience to climate change impacts.

Education: Total public spending in education amounts to 6.6% of GDP 2012 (World Bank 2015a) in the sixth decile relative to the rest of the world. The pupil teacher ratio in primary education in South Africa was 29.5 as of 2012 World (World Bank 2015a). Labor force with tertiary education has increased from 11.9 in 2001, to 16.5% in 2011 (World Bank 2015a). The trend confirms the commitment of the new government to improve education, i.e. for adaptive capacity of the population.

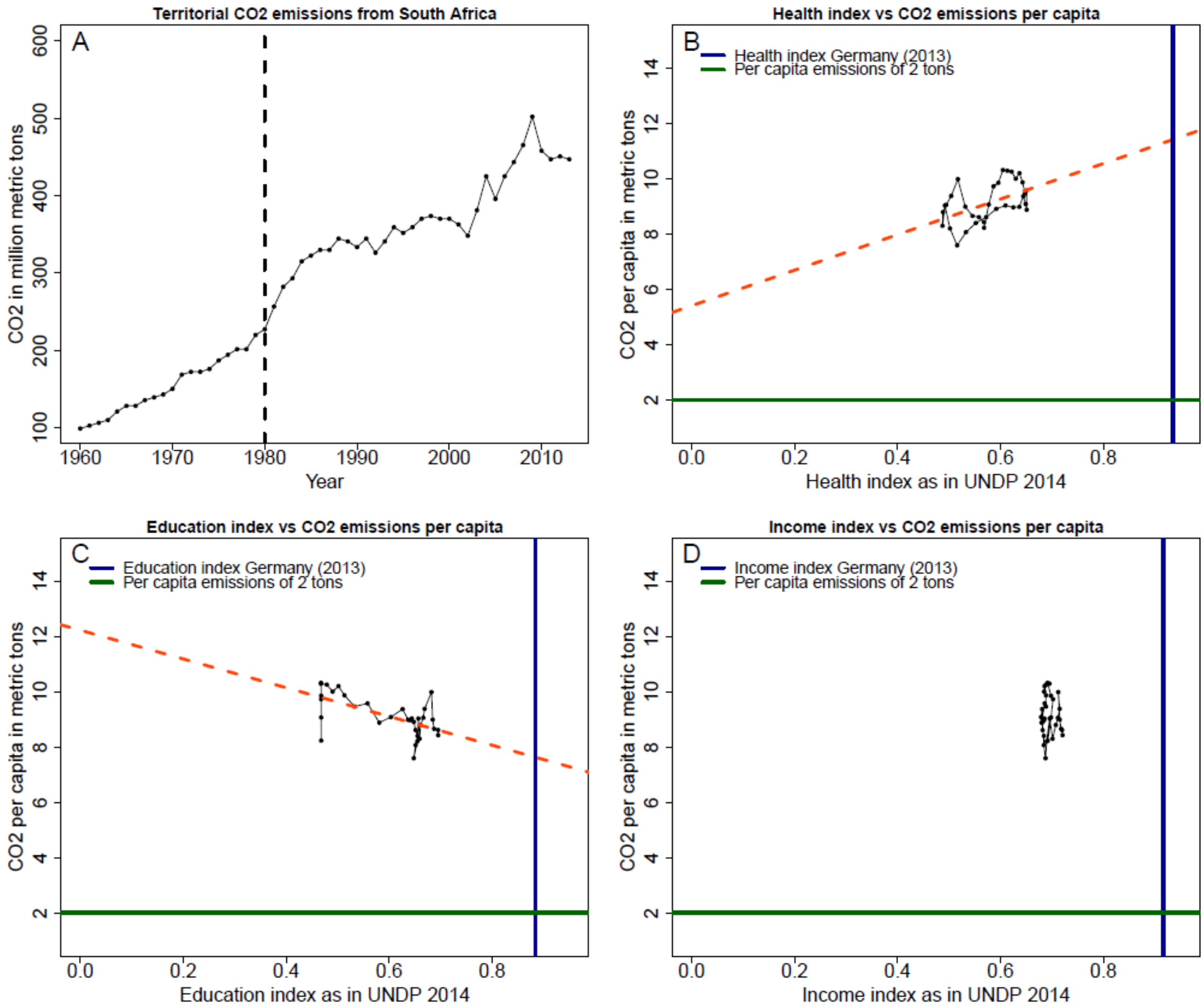
15.2 Links between Adaptation, Development and Mitigation

15.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from South Africa have increased from 100 to 450 million tCO_2 between the years to 1960 and 2013 respectively (Figure 15-5A). In per-capita terms, emissions show a rather erratic behavior with negative tendency, oscillating between 10 and 7.5 tCO_2 over the last 3 decades (Figure 15-5B). Per-capita emissions in South Africa have been consistently developing far above the limit of 2 tCO_2/year suggested by the WBGU (2009).

With the exception of the education index all other components investigated show an erratic trend in relation with per-capita emissions. This is particularly true for the case of the income index (Figure 15-5D). The only significant correlation was obtained for the education index. In this particular case, the education standards in South Africa show a relative decoupling to per-capita emissions (Figure 15-5C). A simple extrapolation of past per-capita trends in South Africa is not convincing, especially for the case of the income index. Due to the past inertia in development gains and emissions, it is likely that South Africa will remain with per-capita emissions above 2 tCO_2 in the near future. Hampered by a slow progress in income levels and a recovering health index the progress of South Africa towards higher levels of HDI is expected to linger below 0.9 over the coming decades (Costa et al. 2011).

Figure 15-5: Trends of CO_2 emissions and the HDI in South Africa.



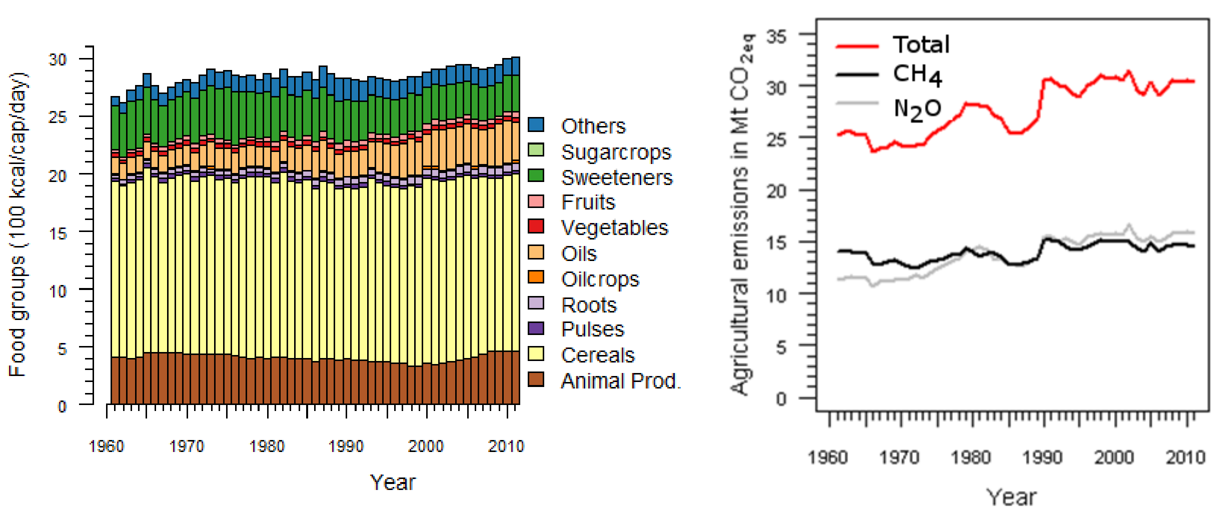
Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database. Horizontal green line shows the 2t/cap CO_2 (WBGU 2009a). Vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. Dashed orange line depicts the trend in average per-capita emissions between 1980 and 2013. Finally, dashed vertical line indicates the starting period of analysis for the panels B, C and D. Increasing energy consumption based on coal is not being transferred into higher income per capita in South Africa, indicating a trade-off between climate change and development.

15.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 15-6 (left) presents the evolution of dietary patterns in South Africa between 1961 and 2011. In general, South Africa's total food supply has increased from 2,671 kcal/cap/day in 1961 to about 3,000 kcal/cap/day in 2011. The current food supply in South Africa is above its average dietary requirement of 2,310 kcal/cap/day (Hiç 2014). During these five decades amount of cereals supply in South Africa remained almost constant at 1,530 kcal/cap/day, whereas supply of sweeteners has decreased by 70 kcal/cap/day. However, supplies of oils and animal products have increased by 200 and 50 kcal/cap/day respectively. The current per person animal product supply of 560 kcal per day is above the global average per person animal product supply of 500 kcal per day.

In the year 2000 approx. 4.7 million people in South Africa lived in the regions where local food and feed produced within 10 km x 10 km grid was sufficient to meet their food and feed demand (Pradhan et al. 2014b). The country food production was sufficient to feed around 18 million people. The rest of the population still depends on international trade for parts of their food supply. South Africa's net food import was about 7 trillion kcal in the year 2000. Major parts of the country so far have attained between 40% and 70% of the potential crop production (Pradhan et al. 2015). South Africa could become food self-sufficient by closing yield gaps to attain 50% of the potential crop production. Closing crop yield gaps can increase crop ensure the current and future food self-sufficiency in South Africa even while considering population growth and diet shifts by 2050 (Pradhan et al. 2014b).

Figure 15-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in South Africa.



The graphic at the left shows the amount of eleven different food groups including animal products (Animal Prod.) supplied per person per day. Right — total agricultural non-CO_2 emissions (measured as CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in South Africa during the last fifty years. Food supply in South Africa has slightly increased in the recent decade, which is above the global average food supply of 2850 kcal/cap/day in year 2010. This reflects improved nutrient situation. Additionally, greenhouse gas emission from the agriculture has slightly increased in the last 50 years. The data was obtained from FAOSTAT (FAO 2014).

The total agricultural emissions of South Africa have increased from 25 MtCO_{2e}/yr to 30 MtCO_{2e}/yr between 1961 and 2011 as shown in Figure 15-6 (right). The slight increased emissions are related to the small increase of food supply. Moreover, South Africa is a net food importer (Pradhan et al. 2015). Diets currently consumed in South Africa embodied emissions of about 1.3 tCO_{2e}/cap/yr (Pradhan et al. 2013) and around 4 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013).

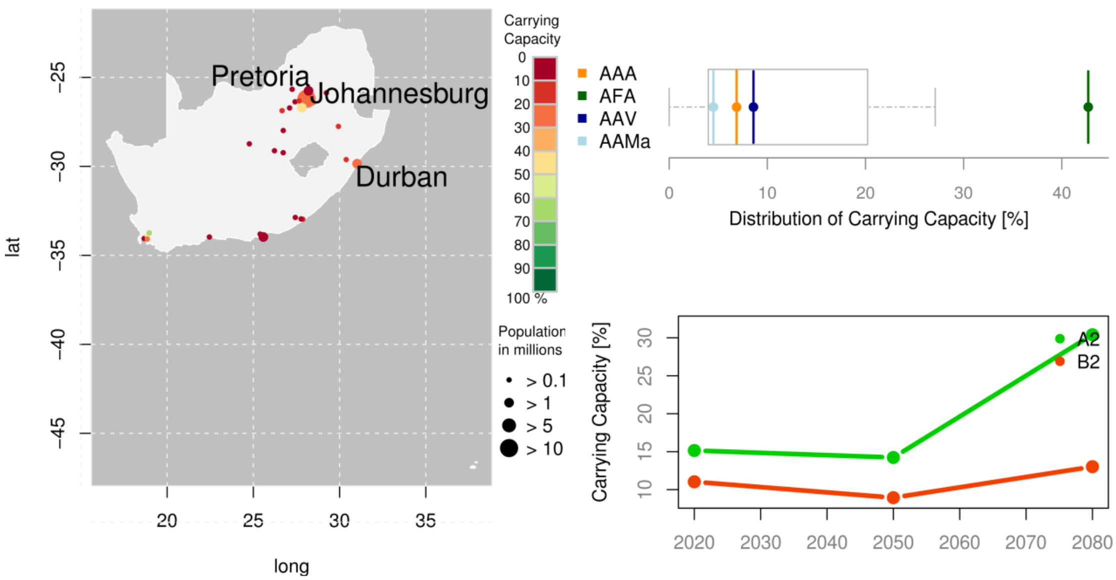
Although South African diet is already calorie rich, share of animal products and total calorie in the diet may further increase when the country becomes more developed in the future.

Currently, emissions per unit of crop and livestock production in South Africa are lower that of most developing countries, however, still higher than that of developed countries (Pradhan et al. 2013). Technological progress increasing agricultural productivity can further lower agricultural GHG emissions of the country by lowering agricultural emission intensities (Pradhan et al. 2013).

15.2.3 Potential of Peri-Urban Agriculture and Local Food

64% of 53.1 million people in South Africa live in cities and a future growth up to 63.4 million by the year 2050 will occur mainly in cities and raises the fraction of urban population up to 77% (United Nations 2014). 27 cities with population above 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 15-7).

Figure 15-7: The possibility for a food supply from surrounding areas for South African cities.



For current conditions (AAA) as a map (left) and the median carrying capacities (top right) for the use of all arable land (AFA), a vegan diet (AAV) and an increased kcal-consumption (AAMa). On the bottom right the future change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and based on an average yield scenario. The best possibility to minimize environmental trade-offs with the help of peri-urban agriculture is by increasing the fraction of agricultural areas in the surroundings of the major cities.

Overall these cities represent more than 23.1 million people. Today 34% of the surrounding areas are used for agricultural purpose, which is nearly 40% of all available arable area (83%). From the currently harvested areas 19% percent of the urban dwellers could be nourished (Kriewald et al. 2015). This relatively high number is brightened by the influence of Johannesburg with a Carrying Capacity of 24%. The median value is with 8% much lower.

Today's yield gap ratio is around 0.63 and consequently, closing the yield gap offers much potential to increase the food self-sufficiency. But a changed kcal-consumption or diet will have an influence as an increase up to 3500 kcal/cap/day will reduce the median carrying capacity down to 4% (see Figure 15-7 – top right). 12 cities or 44% of the investigated cities will face a decreasing carrying capacity for the year 2080 (B2) due to climatic induced yield reduction (Kriewald 2012b). The A2 scenario shows for an average yield scenario an abrupt increase ongoing from 2050. Again, brighten by the influence of Johannesburg, for which the data indicates higher yields for 2080. For the B2 scenario the summed up values are more stable (see Figure 15-7 – bottom right), but they are still higher than the current values based on today's relative low yields.

15.3 The Potential for Synergies and the Stage of Country Development

Climate change may represent more an opportunity for South Africa's development. Climate change will drive changes in land use due to the new patterns of rainfall projected (see section 15.1). Changes in rainfall will make some regions drier, but in general, average rainfall will increase. As Figure 15-7 shows the carrying capacity of arable land will increase with climate change. However, global warming will increase the variability of rainfall producing more extremes. Therefore, adaptation to climate change in South Africa entails taking advantage of both, improved conditions related to higher average rainfalls and creating adaptive capacity for coping with increasing variability of the water cycle.

The major trade-off is caused by the high inequality of South Africa. Mitigation and adaptation may produce more inequality or may help the county to pursue a more inclusive growth model. Climate change is an opportunity for developing the capacity in agriculture. Another trade-off in South Africa relates GHG emissions from energy with human development.

15.3.1 Energy:

South Africa is a significant contributor to GHG gases causing global warming. The country accounts for about 30% of total primary energy consumption on the entire continent. The country relies heavily on its large-scale, energy-intensive coal mining industry. The largest proportion of GHG emissions in South Africa stems from the energy sector (see Figure 15-2).

South Africa has limited reserves of oil and natural gas and uses its large coal deposits to meet most of its energy needs. Electricity is mostly produced by coal fired plants using domestic coal (DoE 2014). Energy consumption in the industrial and construction sectors relies largely on electricity (EIA 2014). Most of the oil consumed in the country is used in the transportation sector. It is imported from Middle Eastern and West African producers in the Organization of the Petroleum Exporting Countries (OPEC) and is locally refined. Import products in the energy sector are mainly crude oil and oil products, but South Africa had an overall energy export surplus of 17,31 Mtoe from coal exports in 2011 (IEA 2015).

Concerning renewable energy fuel wood is currently the most widely used form in South Africa. More than one third of the population is relying on it for their energy needs (UNFCCC 2011c). About 2% of South Africa's current energy mix is provided by hydroelectric and pumped storage schemes (UNFCCC 2011c). Theoretical renewable energy potential in South Africa is vast, with about 280 TW of solar energy. Wind energy resources of South Africa are estimated by the South African Wind Energy Association to exceed 30 GW, though only 700 MW were utilized in 2013. Therefore, South Africa has the physical potential to transform its electricity system based on coal into one based on renewables. The country aims to increase the installed capacity of electricity generation to 40,000 MW by 2030, with at least 20,000

MW from renewable energy sources (Ziervogel et al. 2014). The country has advanced to meet this target with the South Africa's Renewable Energy Independent Power Producer Procurement Program (REIPPPP).

South Africa has made a conditional pledge to reduce its GHG emissions below the BAU emission development by approximately 34% by 2020 (and 42% by 2025). The target was proposed during the Copenhagen negotiations and submitted to the UNFCCC Secretariat in 2010. This is adopted in the flagship policy of South Africa, the National Climate Change Response White Paper (NCCR) of 2011. The NCCR addresses both mitigation and adaptation and provides planning goals for the short- (5 years), medium- (20 years), and long-term (up to 2050). Based on this South Africa's emissions should peak between 2020 and 2025, increasing constant for approximately a decade and then decline in absolute terms thereafter (Hare et al. 2014). The NCCR reiterates that the emission reduction pledge is conditional on international support. The strategy contains a number of general measures and activities that serve to reach the country's reduction goal. In particular, the NCCR calls for the development of carbon budgets for each sector (Fekete, Mersmann, and Vieweg 2013). The South African Department of Energy has taken up GHG mitigation in its mission aiming to have 30% clean energy by 2025. In the Integrated Resource Plan (IRP), which is the key governmental document for power generation planning in South Africa, reducing carbon emissions has been labeled as a key constraint for energy planning. Despite these efforts the pledge of South Africa to reduce GHG emissions 34% of BAU by 2020 is considered as inadequate (CAT 2015). Current policies will have no significant impacts on reversing the BAU trend (CAT 2015).

Only four legislation frameworks directly concerning climate change have been adopted in South Africa. This is rather poor compared to international standards. South Africa has almost exclusively dealt with climate change through policies, strategies, and regulations. Legislation on market-based mitigation mechanisms has been rather scarce until a proposal on carbon tax has been introduced in 2012 (Nachmany, Frankhauser, et al. 2014a). In 2008 the strategic framework for climate policy was announced. It defines a framework for a long-term net zero-carbon electricity sector and establishes general guidelines for tackling climate change: inter alia it includes the introduction of a carbon tax, renewable energy feed-in tariffs, a carbon capture and storage system, energy efficiency and transportation (Nachmany, Frankhauser, et al. 2014a).

In regard to short-term actions the NCCR proposes so-called Flagship Programs that should show immediate results in various sectors, such as water protection and demand management, transport, waste management, energy efficiency in the industry sector. In addition, a transportation plan will be implemented that promotes lower carbon mobility in five larger and ten smaller cities. Further, there is a policy on promoting a transport modal shift (road to rail, private to public transport) and to alternative vehicles (e.g. electric and hybrid vehicles). However, the ambitious NCCR has the character of a general White Paper and still needs to be underpinned by strong legislation (Fekete et al. 2013).

Out of the existing efforts, the NCCR is certainly at the forefront but considering the country's high energy intensity, especially for electricity, strategies such as the Integrated Resource Plan play an important role for South Africa's future low-carbon development (Fekete et al. 2013). A point of criticism is that the policies fall short of their potential. This is shown by the fact that the government is still giving prominence to coal fired power stations.

There exists significant room for improvement and ambition in the transportation and manufacturing sectors (Nachmany, Frankhauser, et al. 2014a). The design of the carbon tax sends a positive signal, as it cuts across most sectors and has a large potential to lead to low carbon development in the medium term, if it is adopted as timely as currently envisaged. For shorter term benefits in climate protection the flagship programs laid out in the NCCR should be implemented. These projects can showcase the country's ambitions and may serve to attract international funding that is necessary to fulfill South Africa's mitigation goal inscribed as a NAMA under the UNFCCC (Fekete et al. 2013).

Regarding international assistance the OECD calculated the international assistance having climate change mitigation as principal or significant objective at US$ 108.24 million (US$ 2.3 per capita). The World Bank estimated net ODA in 2011 of US$ 1.398 billion (US$ 28 per capita) (OECD 2014a; World Bank 2014f).

15.3.2 Carbon Markets and the Effects of Inequality for Adaptive Capacity

Developing market-based mitigation mechanisms, promoting more costly renewable energy and energy efficiency, and changes in transportation systems require adaptive capacity, i.e. a wealthy economy, higher population income, institutional development and enhanced governance. South Africa is an emerging economy with an average income per capita higher than most countries of this study. In principle, the country would be prepared for the adoption of carbon markets. However, inequality matters for adaptive capacity.

In regard of the adaptive capacity evaluated in Figure 15-8 South Africa exhibits unbalances created by the unequal distribution of income. As the block of indicators at the right shows the economic capacity of South Africa is developed. This can be observed in the high performance relative to the rest of the world in issues like the governance of financial risk (the country risk index), or in transaction costs (the ease doing business index). These high scores indicate high development of financial and other institutions for the governance of risk and macroeconomic variables. The relatively high GDP shows that the country has the capacity to produce the financial resources required for developing the adaptive capacity. The structure of accessibility to financial resources is also developed. In the provision of domestic credit by the financial system the country performs middle compared to the rest of the world, but very high compared to the other countries studied in this report. These indicators of accessibility, proficiency and governance of financial resources would indicate that the country has developed adequate conditions for the development of carbon markets.

However, the wealth derived by a high economic capacity is not being transferred into human development. As the indicators of societal capacity in the central block show (Figure 15-8) the population is still burdened by considerable gaps in the provision of basic services. As Figure 15-4 show the richest 20% receives nearly twice the income of the other 80%. The contrast between the high economic capacity and the development of the adaptive capacity of the population is a consequence of the prevailing inequality of income distribution. These imbalances created by inequality restrict the possibilities to use instruments like taxes on fuels and electricity consumption.

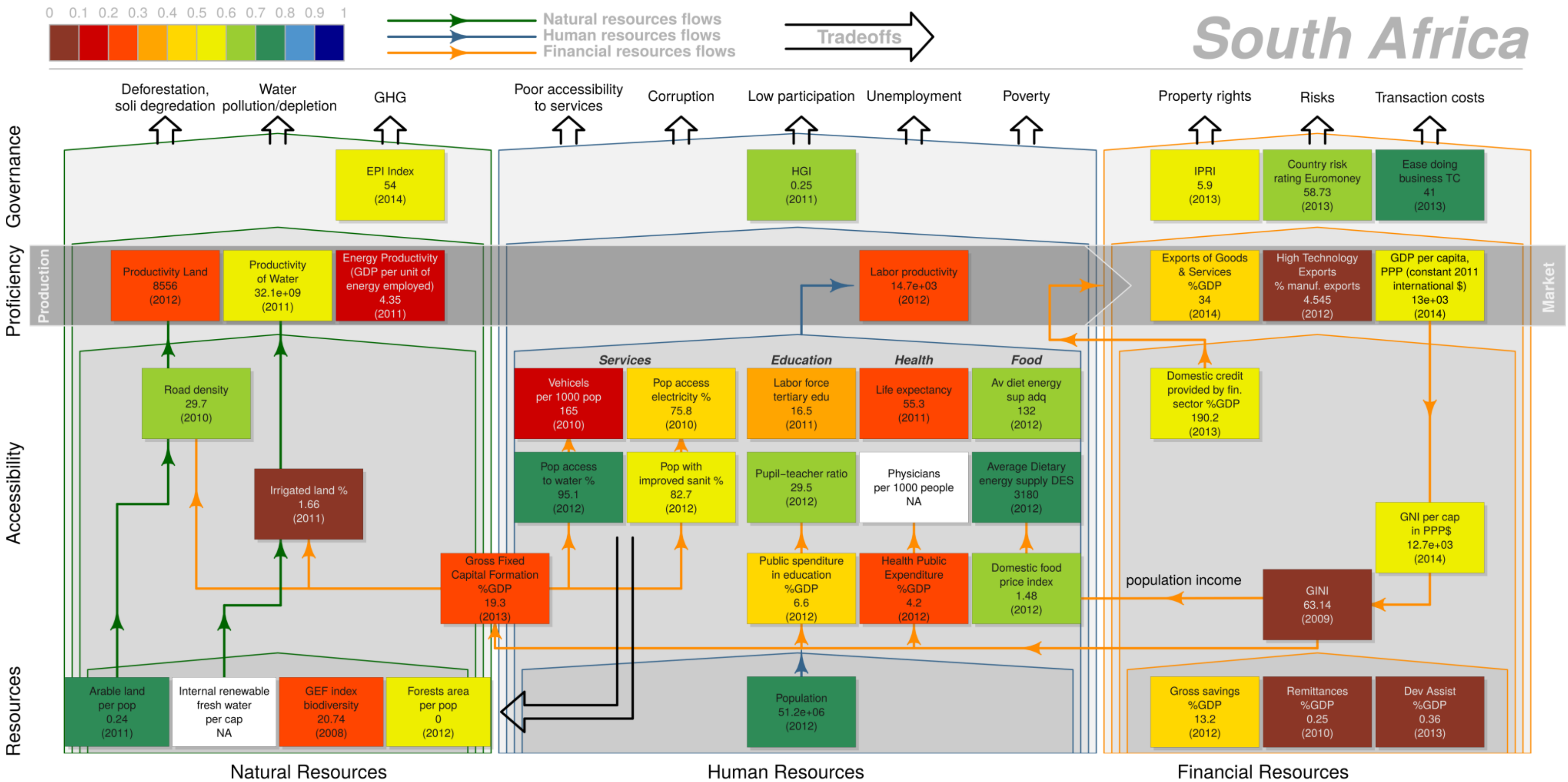
For adaptive capacity and the creation of conditions enabling the implementation of carbon markets South Africa requires a more inclusive growth model. South Africa has not developed its productive structure adequately. South Africa has to develop its productive structure, diversify and specialize the economy, and enhance human capital. Currently mining is the sector that most contributes to GDP. However, this activity does not demand qualified labor. The low specialization of the South African economy is also observable in the very low performance in the % of high technology exports as percentage of manufactured exports (Figure 15-8). The low productivity of factors (see the row of proficiency in Figure 15-8) also offers evidence of the low specialization of the economy. The productivity of land of South Africa is comparable to Mali. The productivity of energy is very low compared to the rest of the world. There is room to improve the efficiency of energy use in South Africa. By 2012 the energy delivered to power stations amounted to 63.73 Mtoe, but 41.8 Mtoe were lost in the generation process (IEA 2014a). The low development of the productive structure is also observable in the low performance in the index of labor force with tertiary education. As reported, unemployment is very high. Labor productivity is low due to the low demand for specialized labor. Higher labor productivity is restricted by deficiencies in the provision of basic services, health, education and food security. Inclusive growth requires better conditions for the population, for higher productivity.

The government would have the capacity and the legitimacy to set a new course. In the averaged sum of the indicators of human governance of the World Bank (see governance of human resources in Figure 15-8) South Africa performs high compared to other countries of the world. But improvements are needed even in governance. The medium performance in the environmental part of the EPI index shows the difficulties of the country to control pollution and protect natural resources. The country needs to develop its environmental capacity in order to enforce the improvement of technologies and the reduction of environmental pollution and GHG emissions.

15.3.3 Agriculture and Water:

Global warming will cause changes in the spatial distribution of crops in South Africa, i.e. favoring the west and the central regions (see section 15.1.1). Weather extremes are projected to increase. The uncertainty of rainfall patterns creates large uncertainties in agricultural production. Despite these uncertainties in agricultural outputs, the increased average rainfall projected offers the opportunity to take advantage of climate change. Improved agriculture would not require major efforts in the development of irrigation, but the creation of reservoirs is needed.

Figure 15-8: Indicators of the adaptive capacity of South Africa.



White colored cells indicate non-available information. The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. For adaptive capacity and synergies, South Africa needs to adjust the high inequality in income distribution, close the gaps in the provision of basic services –with higher share of GDP invested in these services, and to invest more in the health sector.

If an inclusive model is to be pursued land use changes would help South Africa to develop the agricultural sector and improve the economy of rural population. The agricultural sector in South Africa is lowly diversified (see section 15.1.2). The country has the possibility to venture into the production of crops beyond maize, wheat and sugar, the main agricultural commodities produced at the moment.. The country is a net importer of food, even though it has the potential to become self-sufficient. The country has attained 40% - 70% of the potential crop production, yet it needs to meet only the 50% of the potential to become self-sufficient (Pradhan et al. 2015a). To meet the potential yield South Africa requires developing agricultural assistance, the implementation of modern agricultural technologies and practices (Pradhan et al. 2015a).

The development of the agricultural sector for sustainable development can be the source of economic progress for the 35% of the population living in rural areas. But South Africa has to develop its capacity for research and development in agriculture. The adoption of more productive technologies and better practices by small and medium size farmers requires capacity building, financial support, technology transfer and the development of markets for agricultural inputs. This requires the development of institutions for agricultural assistance.

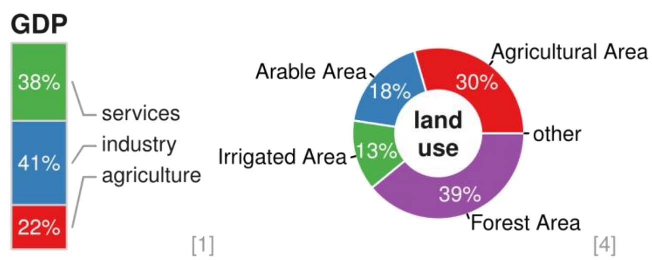
15.4 Conclusions:

Climate change offers an opportunity for developing the adaptive capacity of South Africa further. Global warming will drive changes in land use that may be used to develop the agricultural sector and enhance rural population. For taking advantage of climate change South Africa therefore needs to develop its capacity in water management due to the increased variability of water flows projected from climate change. For rural development the country also needs to develop its institutions for agricultural assistance. The development of the adaptive capacity of South Africa has to concern the high inequality of income distribution as a major bottleneck. It makes most of the population vulnerable to the environmental and economic changes that global warming will drive in the coming future. It also hinders the development of carbon markets. Due to the high inequality of income distribution, the development of carbon markets or carbon taxes would produce social trade-offs affecting mainly the poor. The implementation of progressive taxes would be the best solution to reduce GHG emissions by market mechanisms. For adaptive capacity the country needs to diversify and specialize its economy highly dependent on mining at the moment.

16. VIETNAM

Figure 16-1: Vietnam – Factsheet and physical map:

Country size	331,210 sq km	[1]
Coastline	3,444 km	[1]
Population	92.55 millions	[2]
Rural population (%)	67	[2]
Human Development Index	0.64 (121 of 187 – Medium)	[3]
Life expectancy at birth	75.94	[1]



[1] CIA World Factbook 2013, [2] UN 2014, [3] UNDP 2014, [4] FAO Stat 2013

16.1 Sensitivity and Vulnerability

16.1.1 Sensitivity of Natural Resources

Vietnam is among the countries lacking in diverse studies on climate change projections. To compensate this deficit, the UNDP developed the Climate Change Country Profiles. Climate change projections for Vietnam were calculated considering A2, A1B, and B1 forcing scenarios, for 2030, 2060, and 2090 (Mcsweeney etr al. 2010).

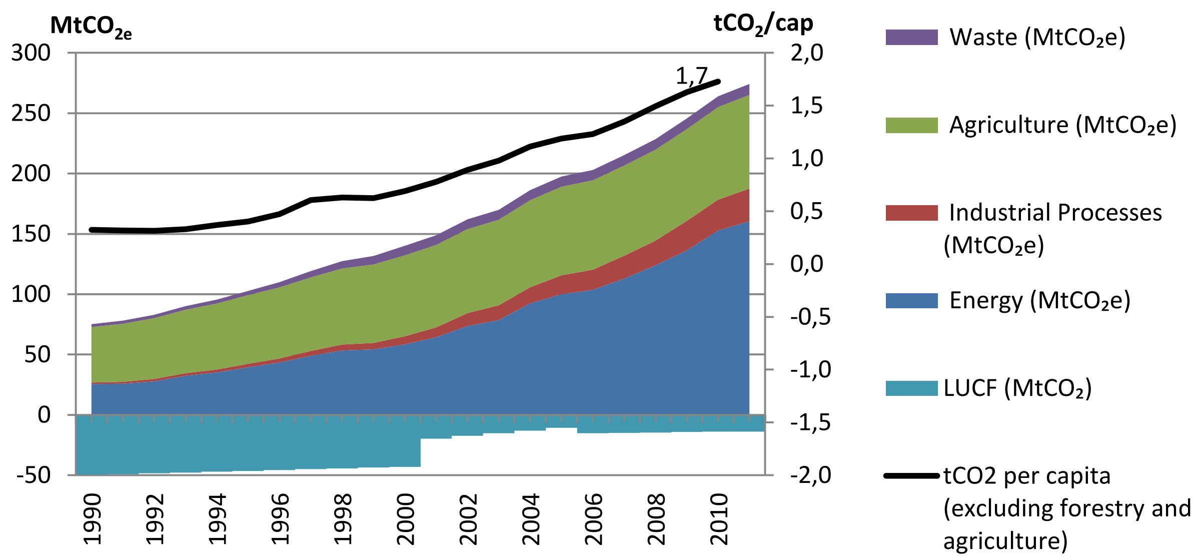
Temperature: Mean annual temperature has increased by 0.4°C since 1960, at a rate of around 0.09°C per decade. A faster increase of 0.14-0.15°C per decade has been observed for the dry seasons (November-December-January, and February-March-April), and a slower increase of 0.08-0.11 °C per decade for the wet seasons (May-June-July, and August-September-October). The warming is more pronounced in the southern parts of the country. In the long-term, the mean annual temperature is projected to increase by 0.8 to 2.7°C by 2060, and between 1.4 and 4.2°C by 2090.

Water resources, rainfall and precipitation: The mean rainfall in Vietnam has not shown any consistent increase or decrease since 1960 (Mcsweeney etr al. 2010). Precipitation is expected to increase by about 10% during the dry season (December-January-February) for a 2°C scenario, and by more than 20% for a 4°C scenario. In absolute terms these increases are small compared to a very low precipitation amount during the dry season (World Bank 2013a). A more focal study based on the APHRODITE gridded dataset (Souvignet et al. 2014) shows an intensification of rainfall (+15%/decade) in central Vietnam accompanied with longer and an increased number of extremes. River discharge trends show an increase in mean discharge (31 to 35%/decade) between 1980 and 2009.

Sea level rise: For the B1, B2, and A1F1 forcing scenarios sea level may rise 28 to 33cm by 2050, and 65 to 100cm by 2100, considering a baseline of 1980-1999 (UNFCCC 2012). Changes of 1m in sea level may result in around 5 million people being displaced (Carew-Reid 2008). Vietnam is also expected to lose 8,533 square kilometers of freshwater marshes (a 65% loss) from sea level rise (Dasgupta et al. 2009).

Atmosphere: Current emissions are relatively low for Vietnam (see Figure 16-2). As of 2010 total emissions were below 300 $MtCO_2e$ (compared to 1439 $MtCO_2e$ of Brazil for the same year) (WRI 2014). However, if actions are not being taken Vietnam will reach similar levels as Brazil very soon. This boost is induced by the current exponential growth of emissions from energy production. Emissions from industry are also growing. In addition, emissions from agriculture are still growing but tend to stabilize. Current CO_2 emissions per capita were below the $2tCO_2$ per capita in 2010. Yet, these emissions will probably grow beyond this threshold. As emissions per capita are essentially related to energy, these emissions will grow exponentially if adequate actions are not taken. Vietnam is controlling deforestation and increasing the forests area (FAO 2014b) (Figure 16-2), which may help to mitigate GHG emissions. However, the forests sinks cannot compensate increasing emissions from energy production, industry and agriculture.

Figure 16-2: GHG sectoral emissions and energy per capita emissions of Vietnam.



Emissions from energy include transport. CO_2 emissions per capita refer to the combustion of fossil fuels and exclude LUCF and agriculture (World Bank 2015a). Sectoral emissions obtained from (WRI 2014). Emissions from bunker fuels are insignificant and were not included. According to the share of emissions, relevant sectors for the analysis of synergies include energy, agriculture and to lesser extent industry.

Crop yields and aquaculture: According to the Second National Communication, a 1°C increase in temperature would correspond to a shortening of the growth cycle by 5 to 8 days for rice, and 3 to 5 days for potatoes and soybean (UNFCCC 2012). Similarly, coffee and other tropical crops will tend to shift to higher elevations in the mountains and further north (UNFCCC 2012). Increased intensity of tropical cyclones, salinity intrusion produced by sea level rise, and higher temperatures will create increased stress for aqua farms (World Bank 2013a). Aquaculture accounts for 5% of the GDP of Vietnam (World Bank 2013a). Projected changes in the maximum catch potential in reef fishery will amount to a 16% decrease in Vietnam (World Bank 2013a). In 2040 Sea level rise of 30cm will produce losses of 12% of crop production in the Mekong delta due to inundation and salinity intrusion (World Bank 2013a). Yu et al (2010) used climate projections of 3 global circulation models of wet, medium and dry projections, and included the effects of a 30 cm sea level rise by 2050, to assess the impacts of climate change on rice production (Yu et al. 2010). A 13% decrease of paddy rice production by 2050 largely due to sea level rise is projected.

Land Use and Forestry: Vietnam plans to reforest 14.1 million ha by 2020 and 14.5 million ha by 2030. The primary forests should be kept constant at a level of 9.7 million ha. 4.4 million ha of planted forests are planned for 2020 and 4.8 million ha for 2030. Savannahs areas will be reduced from 3.4 million ha in 2010 to 1.0 in 2020 and 0.2 in 2030 (UNFCCC 2012). On the impacts side, tropical crops may be found at elevations of 100 to 550m and will move 100 to 200km northward by 2100. The cultivation area for subtropical crops may decline by 2100 (UNFCCC 2012).

16.1.2 Economic Vulnerability

Vietnam can be considered a success story. Over the period 2004-2013 real GDP grew steadily (standard deviation 0.849) by an average of 6.2% per year (World Bank 2015a). During this century the GNI per capita (constant 2005 US$) has grown from US$524 in 2000 to US$983 in 2013 (World Bank 2015a). However, Vietnam is highly vulnerable to climate change impacts. Causes of vulnerability include the high exposure to sea level rise and cyclones, and the relevance of agriculture and the income of the rural population (67%). Climate change will likely affect agriculture, road infrastructure, hydropower generation and economic activities in areas below 1m exposed to sea level raise (Arndt et al. 2012).

Sectoral Impacts: The Mekong Delta produces around 50% of Vietnam's total agricultural production (WB 2013). The Mekong Delta province is home to approximately 47% of the farms in Vietnam (Government of Vietnam 2015). In 2011 the Delta produced 23.2 million tons of rice paddy, i.e. 55% of national rice production (Government of Vietnam 2015). Most of the production, nearly 18.4 million tons, was used for internal consumption. Furthermore, 72.4% of the aquaculture was located in the Delta province in 2010 (Government of Vietnam 2015). Between 1996 and 2011 aquaculture outputs multiplied by 24 and its share of GDP increased from 2.6% to about 4.8% (Government of Vietnam 2015). Since 2001 aquaculture production has yielded higher outputs than capture fisheries (Government of Vietnam 2015). Both, agriculture in the Mekong Delta and aquaculture will be affected by climate change though the quantification of projected damages is still uncertain.

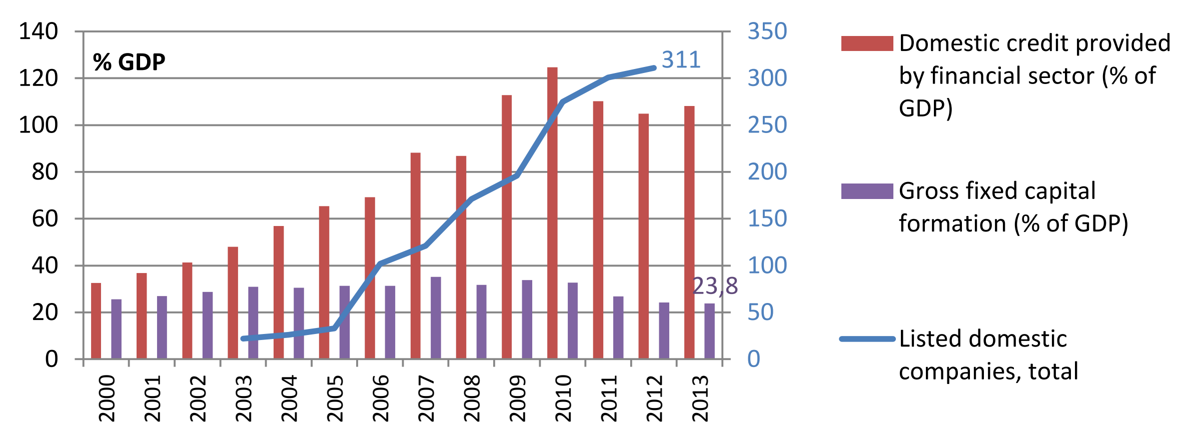
Future impacts on transportation were estimated based on A2, A1B, and B1 forcing scenarios (Chinowsky et al. 2012). Results show that in the worst case scenario a total damage costs amount of US$ 55 billion can be expected for the period 2010-2050 (2010 prices without discounting). Estimates of damages on road infrastructure mostly caused by flooding range between US$4 and US$9 billion (Chinowsky et al. 2012). Cost effective adaptation consists of sealing unpaved roads and making roads more resistant to precipitation and flooding.

Impacts on productive factors: Labor productivity in Vietnam is among the lowest in the World. Labor productivity needs to grow by more than 50% by 2020 in Vietnam in order to maintain rapid growth (Breu et al. 2012). Productivity is affected by low agricultural productivity, energy inefficiency, and low added value of manufacturing (Breu et al. 2012).

Economic specialization and diversification: The economy of Vietnam is highly diversified. By 2012 the country exported 1,117 commodities, similar to Indonesia and South Africa (Simoes and Hidalgo 2014). The country's economy is focused on exports. By 2013 exports represented 84.7% of the GDP, higher than any other country in this study (WFB 2015). Exports are diversified in terms of sectors. Considering the set of commodities accounting for 80% of total exports value, 27.97% were technology and machinery, 16.78 agriculture and fishery, 9.7 minerals, 4.03 other goods and services, and 20.5% textiles (Simoes and Hidalgo 2014). This diversified portfolio makes the Vietnamese economy less vulnerable to impacts on agriculture. These numbers show that the economy of Vietnam cope much better with climate change impacts due to high diversification.

Capitalization and Capital Formation: As Figure 16-3 shows the financial system consistently improved the provision of domestic credit in Vietnam between 2000 and 2010 and it has remained high afterwards. It is worth noticing that the financial crisis of 2008 did not severely affect the provision of domestic credit. In parallel the number of companies listed in the stock market has consistently grown since 2003. This high growth is indicative of the diversification of the economy. Investments in gross fixed capital formation, i.e. infrastructure, schools, hospitals, etc., have decreased though the share remains high compared to other countries in this study. These numbers are indicative of a relative high accessibility to financial capital and high development of capital favoring growth.

Figure 16-3: The recent evolution of capital in Vietnam.



Domestic credit provided by the financial sector (World Bank 2015a), number of listed domestic companies and investments in gross capital formation public. For the analysis of the coping capacity this set of indicators gives a comprehensive view of availability and accessibility to capital, commitment in the development of infrastructure and trends of capital concentration or diversification. Vietnam is consistently developing infrastructure and the capacity to attend the demands for domestic credit. The increasing number of listed companies in stock markets shows the tendency to diversify the economy.

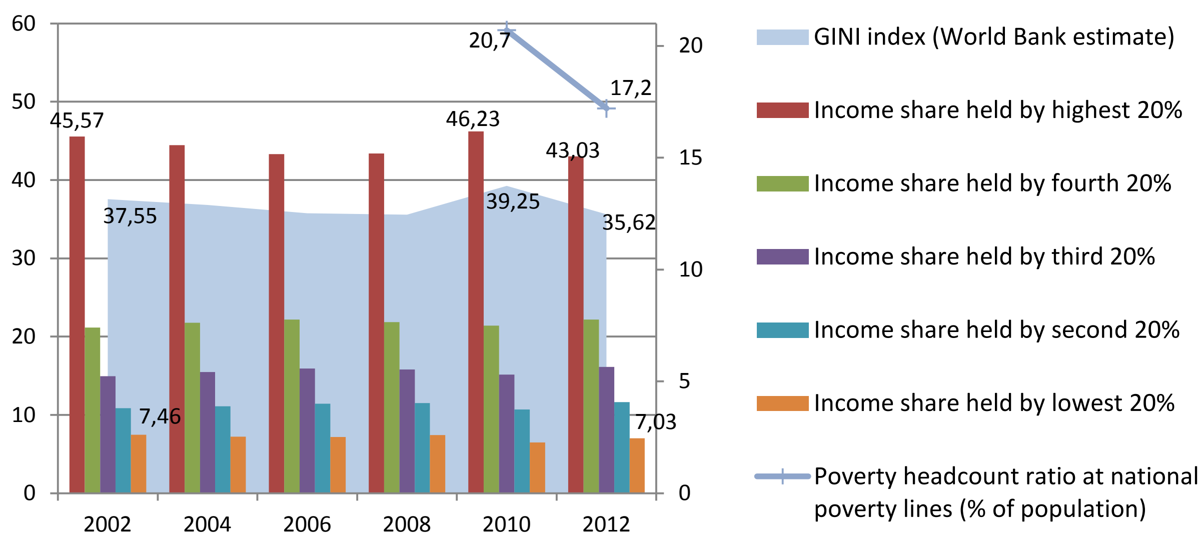
Economic Risks and Uncertainties: Inflation is an issue in Vietnam. Though inflation was only 6.59% in 2013 the average between 2004 and 2013 was 10.5% (World Bank 2015a). Moreover

Vietnam does not perform adequately in transaction costs. In the ease doing business index, which evaluates the environment facilitating development of business associated to transaction costs the country ranks on position 99 (out of 181 countries). This is close to China (96), though better than Philippines (108). The country risk index (Euromoney 2014), which evaluates structural, political, and economic risk, places the country in the fourth decile (48.16 in 2013). With regard to property rights Vietnam performs in the second decile in the International Property Right Index (4.7 in 2013). The IPRI index evaluates the strength of property rights in a scale from 0 to 10 (IPRI 2014). For adaptive capacity Vietnam has to develop further its economic institutions.

16.1.3 Social Vulnerability

More than 15 million persons in Vietnam have been severely affected by weather related disasters during the last 10 years (Mendoza et al. 2012). 13,000 lives have been lost over the past 20 years from natural disasters (Rocklo et al. 2014). In regard of the adaptive capacity of the population, income inequality has been slightly reduced in Vietnam (Figure 16-4). Income inequality is not as high as for African or Latin American countries of this study. It is also lower than in Philippines. However, the share of income of the poorest has been reduced. The country outperforms in the reduction of poverty and is on track to achieve its Millennium Development Goals (UNDP 2015).

Figure 16-4: The recent evolution of income distribution, inequality and poverty in Vietnam.



For assessment of income inequality the GINI index of income inequality of the WB (2014) was used. Income shares show the exact distribution of income among five groups (World Bank 2015a). The national poverty headcount ratio (World Bank 2015a) offers a measure of the efforts of the government to reduce poverty via subsidies and social programs. Overall, these indicators offer a view of the vulnerability of the poorer and their situation in the context of inequality. Income inequality is not consistently decreasing in Vietnam and the income share of the poorest is even decreasing. This trends need to be corrected for improved adaptive capacity of the population.

Food security: Nearly 40% of the dietary animal protein intake in South East Asia comes from fish (World Bank 2013a) substantially reducing the production from GHG emissions compared to countries providing meat from livestock. The sector will be affected by climate change. Four main regions groups are burdened with high vulnerability to food security: small farmers in the Red River and Mekong delta, small farmers in the Northern Region, artisanal fisher-folk in Central Coastal Region, and urban workers without stable employment (FAO 2004). According to the FAO 13.7% of the population suffered from food inadequacy, and 8.3% from undernourishment in 2012. The food deficit was 63 kcal per person per day on average (FAO 2015). This number decreased from 103 kcal per capita per day as of 2011-2013 (FAO 2015). The domestic food price level index (1.69 in 2010) is very low (FAO 2015). These numbers show the slight influence of distributional issues affecting food security for the poorer and the existence of economic policies keeping food prices low.

Health, Sanitation, Water and Energy Services: Life expectancy in Vietnam (75.7 years in 2012) is high relative to the rest of the World (World Bank 2015a). Vietnam spent 6.57% of its GDP in health services in 2012, including private and public expenditure (World Bank 2015a). Vietnam performs much better than its neighboring countries in access to basic service. However, deficits are still high. Access to improved fresh water sources reached 96% of total population in 2011 leaving nearly 3.6 million people with no access to a water supply. In the same year 75% of the population had access to sanitation services, i.e. nearly 22 million had no access to sanitation (World Bank 2015a). But 97.6% of the population had access to electricity by 2010 (World Bank 2015a). The impacts of heat extremes will mostly affect the elderly population. In Vietnam, people aged 60 and over are projected to increase 22%. They will account for 31% of the total population by 2050 (WB 2013).

Education: Public expenditure in education in 2012 was 6.9 % of GDP and increasing (World Bank 2015a). The literacy rate for people over 15 is 94% (World Bank 2015a). The percentage of tertiary students increased from 10% in 2003 to 24.4% in 2011. The pupil-teacher ratio has decreased positively from 24.6 in 2003 to 19.6 in 2011. This indicators show a commitment to raise labor productivity and knowledge.

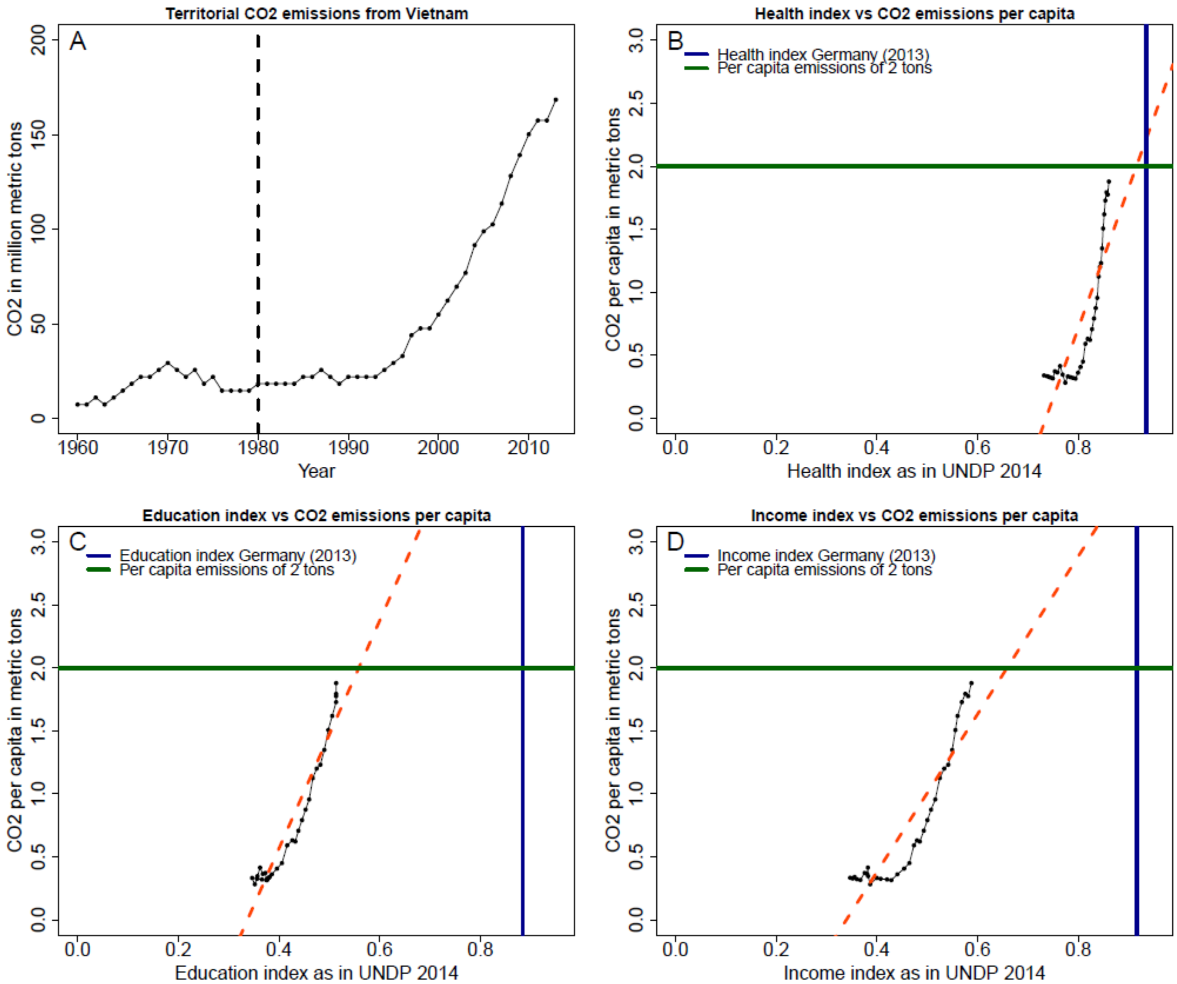
16.2 Links between Adaptation, Development and Mitigation

16.2.1 The Evolution of the HDI and the GHG Emissions

Territorial emissions from fossil fuel combustion in Vietnam show an increase from about 7 to about 170 million tons between 1960 and 2013 respectively (Figure 16-5A). A particularly sharp tendency of higher emissions can be observed since 1990; the point up to which historical emission have remained fairly constant. On a per-capita basis, the evolution of CO_2 emissions in Vietnam mimicked that observed for the territorial ones. Over the past 20 years, per capita emissions have rapidly increased from 0.4 to about 1.8 (Figure 16-5B).

A strong correlation can be observed between the different components of human development and per capita emissions in Vietnam (Figure 16-5B, and D). The progress in individual components appears nevertheless to be slower than the fast increase observed in per-capita emissions suggesting some inefficiency of the country in converting resources into development, especially when compared to countries such as Cambodia and Ethiopia. If Vietnam follows the current growth path it can be expected that the 2 tCO_2/cap/year (WBGU 2009a) will be transgressed in the near future. Vietnam is expected to move into the developed world standards (HDI>0.9) by 2045 (Costa et al. 2011). Associated emissions in 2045 are estimated at about 690 $MtCO_2$ (Costa et al. 2011).

Figure 16-5: Trends of CO_2 emissions and the HDI in Vietnam.

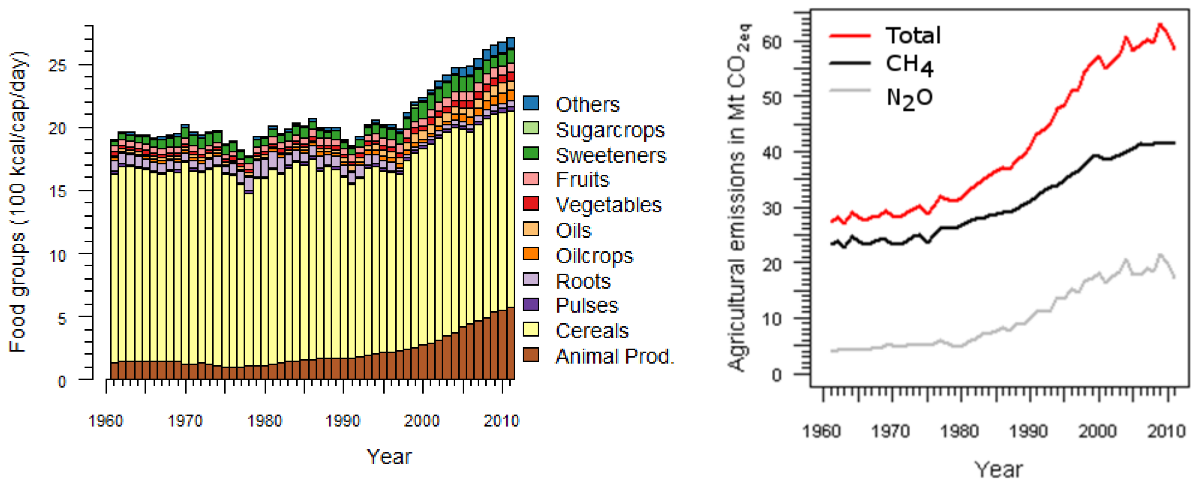


Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education, and health obtained from the World Bank 2014 database. The horizontal green line shows the 2 tCO_2/cap target. The vertical blue line highlights the current (2013) position of Germany in regards to the corresponding human development dimensions investigated. The dashed orange line depicts the trend in average per capita emissions between 1980 and 2013. Finally, the dashed vertical line indicates the starting period of analysis for the panels B, C, and D. The flat trend of emissions per capita shows that the increased GHG in A is driven by population growth. Indices of the HDI have improved consistently in Vietnam, but the concave form of the graphics make evident that the rate of CO_2 emissions growth per capita is higher. The increasing emissions per capita are coupled in Vietnam, but the trend is deepening the trade-off between energy and development, that needs to be corrected by synergies.

16.2.2 The Evolution of Dietary Lifestyles and the Emissions Associated

Figure 16-6 (left) presents the evolution of dietary patterns in Vietnam between 1961 and 2011. In general, Vietnam's total food supply has increased from 1,910 kcal/cap/day in 1961 to about 2,700 kcal/cap/day in 2011. The current food supply in Vietnam is above its average dietary requirement of 2,300 kcal/cap/day (Hiç 2014). During these five decades, supplies of cereals, oils, and sweeteners per person per day have increased by around 60 kcal each, whereas animal product supply has increased by 440 kcal/cap/day. Current per person animal product supply of 574 kcal per day is above the global average per person animal product supply of 500 kcal per day. Supplies of total calories and the different food groups have slightly changed between 1961 and 1997 with the lowest calorie supply of 1,820 kcal/cap/day in 1977. The total calorie supply has continuously increased in the country since 1998. This depicts lifestyle shifts in Vietnam towards calorie and meat rich diets.

Figure 16-6: Evolution of dietary compositions (left) and agricultural emissions (right) for the last fifty years in Vietnam.



The graphic at the left shows the amount of eleven different food groups including animal products supplied per person per day. Right — total agricultural non-CO_2 emissions (as CO_{2e}) including methane (CH_4) and nitrogen oxide (N_2O) from the agriculture sector in Vietnam during the last fifty years. Food supply in Viet Nam has improved in the recent decade, however, still below the global average food supply of 2850 kcal/cap/day in year 2010. Additionally, greenhouse gas emission from the agriculture has increased in the last two decades, demonstrating environmental trade-offs. The data was obtained from FAOSTAT (FAO 2014).

In the year 2000, around 37 million people in Vietnam lived in regions where the local food self-sufficiency can be guaranteed within a 10 km x 10 km grid (Pradhan et al. 2014b). 51 million people in Vietnam are food self-sufficient within their provinces. The country is food self-sufficient. In addition, the country exports around 24 trillion kcal of food and feed in the year 2000. Parts of the country have thus far attained up to 80% the potential crop production (Pradhan et al. 2015). Considering future population growth and diet shifts, around 60 to 70 million Vietnamese will partly depend on international trade by 2050 even when closing yield gaps to attain 90% of their potential crop production. Vietnam could increase its food export to 74 trillion kcal by closing yield gaps to attain 90% of the potential crop production in 2000 (Pradhan et al. 2014b).

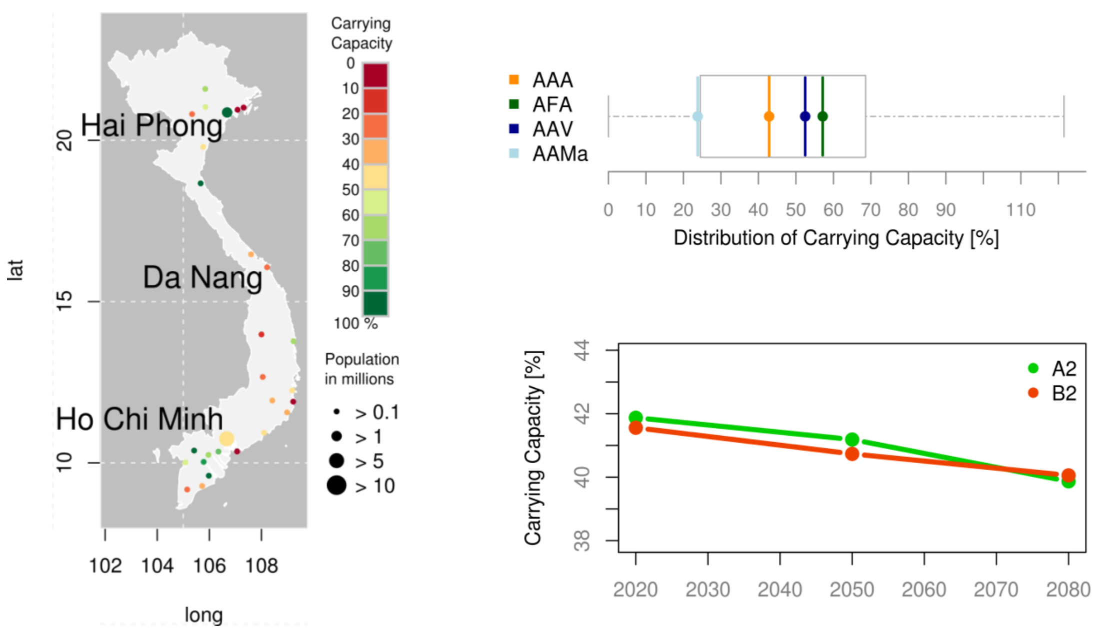
Dietary patterns in Vietnam may increasingly be calorie and meat rich as the country develops in the future resulting in larger GHG emissions. However, technological progress can transform these trade-offs into synergies by increasing agricultural productivity and also lowering agricultural emission intensities (Pradhan et al. 2013).

The total agricultural emissions of Vietnam have doubled from 27 $MtCO_2e/yr$ to 58 $MtCO_2e/yr$ in the last 50 years as shown in Figure 16-6 (right). The increased emissions are related to increases in agricultural production to meet growing food demand driven by population growth and dietary changes. Furthermore, diets currently consumed in Vietnam embodied emissions of about 0.9 $tCO_2e/cap/yr$ (Pradhan et al. 2013) and around 3.5 calories of crop products is fed to livestock to obtain 1 calorie of animal products (Pradhan et al. 2013). Emissions per unit of crop and livestock production in Vietnam are higher than that of developed countries (Pradhan et al. 2013).

16.2.3 Potential of Peri-Urban Agriculture and Local Food

32.9 % of the 92.5 million people in Vietnam live in cities and in the future will grow up to 103.7 million by the year 2050, with most of the growth happening in cities (United Nations 2014). 28 cities with population over 100.000 were investigated for the potential of a regionalized food production to increase food security and reduce CO_2 emissions from food transport (see Figure 16-7).

Figure 16-7: The possibility for a food supply from surrounding areas for Vietnamese cities.



For current conditions (AAA) as a map (left) and the summed up carrying capacities (middle) for the use of all arable land (AFA), a vegetarian diet (AAV) and an increased kcal-consumption (AAMa). On the right the change due to climate change for the years 2020, 2050, and 2080 for two different climate scenarios (A2, B2) and two yield scenarios (min, max) and the averaged values. Vietnam offers goof potential for peri-urban agriculture and could use the surrounding areas of major cities for food production to reduce environmental trade-offs in other regions and due to emissions from transportation. More affluent diets and climate change can reduce the effect in future.

Overall these cities represent more than 11.2 million people. Today 67% of the surrounding areas are used for agricultural purposes. This is equal to 76% of all available arable area (88% of the surrounding area). From the currently harvested areas 53% percent of the urban dwellers can be nourished (Kriewald et al., 2015).

16.3 The Potential for Synergies and the Stage of Country Development

Two featured trade-offs relating to adaptation and mitigation exist in Vietnam. One connects growth producing increasing emissions from energy, and human development. The other one relates the development of agriculture, GHG emissions from agricultural production and food security. A strategy for climate resilient pathways in Vietnam needs to take into account the threats posed by climate change in the context of the strengths and weaknesses of the adaptive capacity (Figure 16-8).

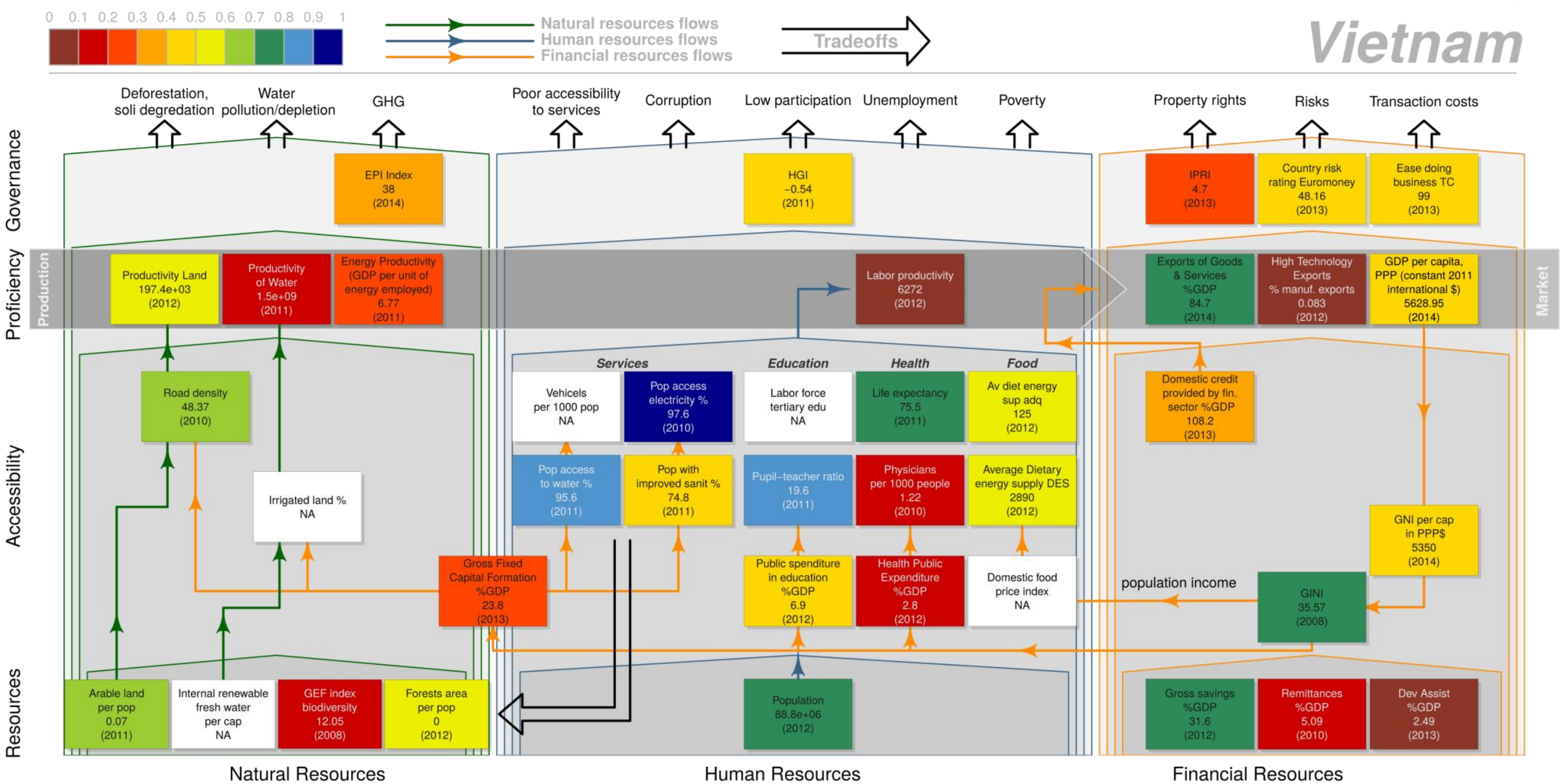
16.3.1 Growth and Adaptive Capacity:

Vietnam has grown consistently over the last decades. Economic growth has been used to enhance the economic coping capacity. The capacity of the financial system to provide credit is low compared to the rest of the world but the highest amongst the countries studied in this report. Growth has also been associated to the increasing number of companies listed in stock markets (see Figure 16-3). In addition the country has achieved to develop consistently based on exports, which is the main source of revenues (83,9%) in 2013 (World Bank 2015a). It can be concluded that Vietnam has created adequate conditions for further economic growth based on the diversification of the economy over the last decades.

Nevertheless, the country still needs to develop further its productivity and its economy. As the indicators of proficiency show the productivity of water, land and labor are very low compared to the rest of the world. This low performance of the productive factors (except capital) is concomitant with the low specialization observable in the very low performance in the indicator of high technology exports. The high share of exports is positive for economic resilience. However, it also shows the weakness of internal consumption. In order to make the economy stronger Vietnam needs to improve the average income per capita. The GNI is very low compared to the rest of the world.

For enhancing the adaptive capacity of the population Vietnam needs to close the gaps in the provision of basic services. As the section on social vulnerability reports the country has been working consistently to meet the Millennium Development Goals targets. The gap in the accessibility to improved fresh water and electricity is very low. But access to sanitation needs to be improved. There is no information available to assess the adaptive capacity in education. However it should be very low in line with the very low productivity of labor. The relative value of the indicators of proficiency shows clearly that labor productivity represents the major bottleneck for economic development in Vietnam.

Figure 16-8: Indicators of the adaptive capacity of Vietnam.



The color of each cell reveals the stage of development of the element assessed. For a detailed description of the tool refer to the section of methods. The country exhibits a high performance in exports as sources of GDP and high land productivity compared to other countries of this study. The labor productivity is quite low. The share of high technology manufactured exports makes indicates a low diversification of the economy. For adaptive capacity the country needs to diversify the economy, enhance human capital, improve in governance and invest more in social aspects. White colored cells indicate non-available information.

In regard of other productive factors it is worth to note the high performance in road infrastructure. However, the country needs to invest in road maintenance to mitigate losses from climate change impacts (Arndt et al. 2012). This would demand more investments in gross fixed capital formation. The medium performance in land productivity is supported by the high road density. It is also the result of consistent efforts to improve agricultural productivity (cf. the analysis below). Yet, the productivity of water and energy are very low.

The capacity to pursue climate resilient pathways requires high governance. For higher productivity of water, land, and energy, the country needs to improve environmental governance. The country also needs to improve macroeconomic policies and financial institutions to reduce risk and transaction costs (see indicators of governance in Figure 16-8). In human governance, the country also requires improvement. The averaged index of human governance is negative. In the indices composing the averaged index of human governance, the country performs positive and improving only in 'political stability and the absence of violence'. In the other indices composing the HGI ('voice and accountability', 'regulatory quality', 'control of corruption'), the country performs negative, but with positive trends. However in 'rule of law' the situation is stagnant and the perception negative (World Bank 2015b).

As Figure 16-4 makes evident income inequality in Vietnam is not a major issue. In the GINI index the country performs high, i.e. inequality is low. As Figure 16-4 shows, the income share of the lowest income group is 7.3%, much higher than in other countries –e.g. Brazil, Colombia, Peru, Mexico or South Africa. However, there is an imbalance between the development of the economic capacity and human development. This is observable in the concave trends of Figure 16-5 B, C and D. The concave shape of these graphics makes evident that the rate of growth of emissions are greater than the rate of growth of the indices of education, health, and income per capita. The trade-off between growth and human development is being reinforced in Vietnam.

16.3.2 Energy, Growth and Development:

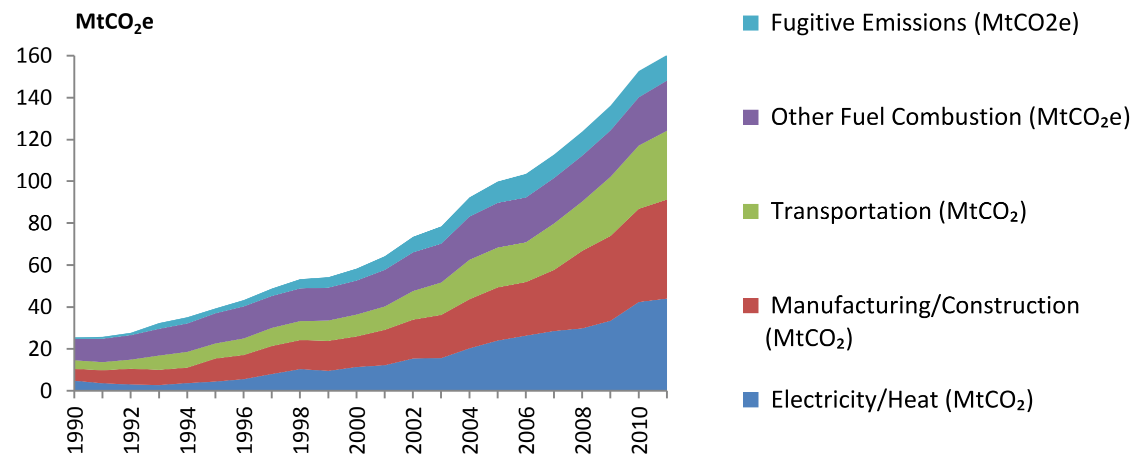
Energy and transport will drive the exponential growth of emissions if adequate actions are not taken. Emissions from energy and transport have largely exceeded the commitment expressed in the Second National Communication (UNFCCC 2012). The emissions by 2030 would be more than the double in comparison to the planned emissions of 470 $MtCO_2e$. These emissions will not be offset by emissions reductions from forestry. Consequently, emissions per capita will surpass the $2tCO_2$ per capita very soon. Options to transform this trade-off are evident from Figure 16-5B, C, and D. It requires reducing GHG emissions from an increased share of renewable energy sources without compromising the efforts on human development.

Climate change policies in developing countries in tropical regions tend to prioritize adaptation. Vietnam is not an exception, due to the actual impacts of climate change. The country has expressed concerns about the trade-offs that the costs of renewable energy solutions would imply for development and growth (UNFCCC 2012). Considering the urgency for adaptation, Vietnam should not spend its financial resources on the acquisition of costly technologies based on renewable energies. Disaster mitigation should have a high priority in order to keep and improve human livelihood conditions. However, despite the apparent lack of interest in costly mitigation actions, Vietnam has recently developed a mitigation policy.

There are two important motivations for this policy: the need to address the reduced stocks of fossil fuels reserves, and the realization that the model of high economic growth rate at expense of environmental degradation cannot be sustained (Zimmer et al. 2010).

Vietnam is the country with the 4th largest portfolio of CDM projects worldwide. As Figure 16-9 shows, transport, manufacturing, and electricity generation drive the exponential trend of GHG emissions growth in Vietnam. As of 2013, 9 PoAs and 14 Verified Carbon Standard (VCS) projects have been registered. In the same year, 4 Gold Standard projects have been registered (Government of Vietnam 2014). However, none of these projects are currently being implemented (Government of Vietnam 2014). Figure 16-9 shows that most important niches for mitigation in energy are transport, manufacturing, and electricity. These niches should be considered with priority by CDM projects.

Figure 16-9: GHG emissions of Vietnam excluding agriculture and LUCF (WRI 2014)



Other sectors' emissions, apart from energy, will grow as well. As Figure 16-2 shows, emissions from industry are growing more than linearly. Yet, the share of GDP from industry has remained constant in Vietnam over the last decade. If this tendency remains, emissions from industry will increase proportional to GDP growth, if mitigation actions are not taken.

Observing the connection between the niches of mitigation of GHG emissions in the energy system (represented by the indicator of energy productivity in Figure 16-8) and the niches of human development (represented in the set of indicators of the accessibility to human resources in Figure 16-8) it becomes apparent that a strategy to finance both mitigation and human development requires the transformation of the productive structure, from one based on low productivity and low technologies to a more specialized based on renewable sources of energy. Measures to promote inclusive growth and mitigation would require systems of incentives that reward low polluting economic activities and the use of clean technologies and fine the use of polluting technologies. The international community should consider options that support these growth paths, as they have considered rewards for deforestation reduction targets e.g. for Indonesia, Brazil, and Colombia. Such incentives would harmonize with the intentions of the Vietnamese government to promote energy security via renewable technologies.

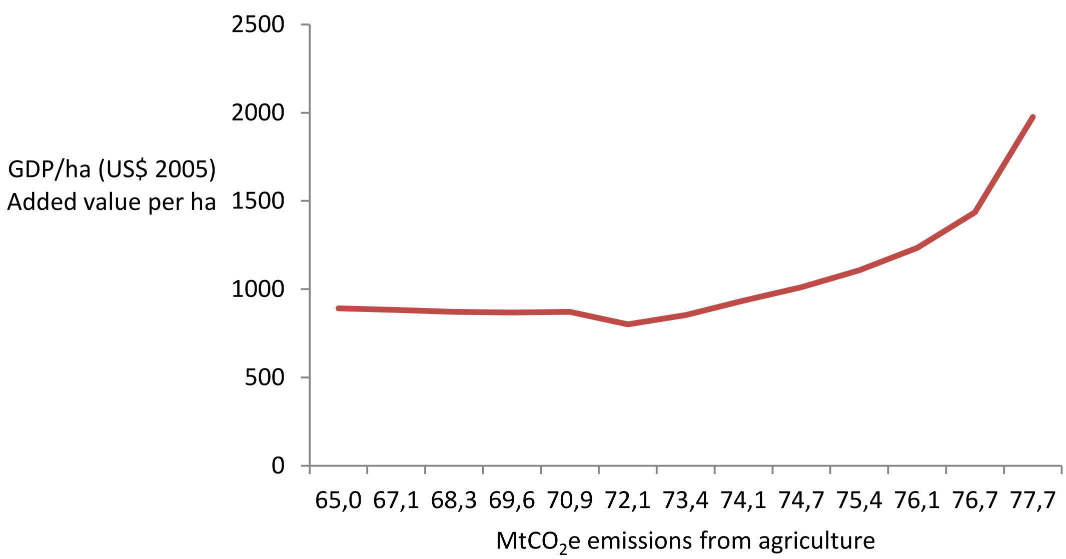
16.3.3 Agriculture and Food Security:

Though agriculture represents the second large emission sector Vietnam already tends to transform trade-offs into synergies. First, the country has worked to correct past trade-offs from agriculture in forests areas over the last few years. Currently the country has a positive growth rate of forests areas and plans to expand these areas.

Trade-offs of agriculture producing GHG emissions have also been reduced. As Figure 16-2 shows Vietnam is one country where the growth rate of emissions from agriculture has been consistently decreasing from 2.2 in 1991 to 0.7 $MtCO_2e$/year in 2010 (WRI 2014). As Figure 16-10 shows the increase of total emissions from agriculture (from 65$MtCO_2e$ in 1999 to 77.7$MtCO_2e$ in 2011) is concomitant with an impressive growth of added value per hectare. Among the countries studied the productivity of the land in Vietnam is equal to the Philippines and it is only surpassed by Grenada. Despite this success Vietnam still has challenges to face the expected impacts of climate change. The country needs to continue investing in research and development in agriculture, to attend the needs, and to compensate the impacts of climate change.

Agriculture in Vietnam has the potential to reduce emissions to some extent by developing peri-urban agriculture to attain 90% of the potential crop. Options to raise the production of calories include a higher share of fish in the dietary lifestyles. The reduction of GHG emissions from agriculture could largely benefit from the further application of methodologies like that developed by Cambodia for rice cultivation (Fukui 2014). Overall, these trends provide evidence of the efforts of Vietnam to transform trade-offs into synergies in agriculture.

Figure 16-10: The evolution of emissions from agriculture and added value per hectare in Vietnam, between 1999 and 2011.



With information from (World Bank 2015a) and FAO (2015).

16.4 Conclusions:

Vietnam shows evidence of high relative capacity to pursue ambitious goals towards sustainability. The country has been able to stop deforestation and increase forests areas. The productivity of agriculture has doubled between 1999 and 2011. The country still grows following an economic model based on low labor productivity. This model is also responsible for exponential growth of GHG emissions in electricity, manufacturing and transport.

Agriculture is and will remain an important economic sector, due to the high contribution to GDP and high share of population living in rural areas. It is therefore expected that in the next years the process of urbanization will play an important role in the economic development of Vietnam.

In this context, the country needs to develop long-term policies that link the development of cities and agriculture to low emission technologies. The country requires international support to reduce significantly the use of coal in electricity generation.

PART 3

Climate Resilient Pathways and Synergies between Countries

1. A Brief Summary:

For an effective implementation of policies maximizing climate protection, adaptation to the unavoidable consequences of climate change, resources protection and human development, countries need to invest efforts in human capital development, strengthening governance bodies and stabilization and improvement of the financial sector. It can be synthesized that for adaptive capacity, economic growth and societal development are urgently needed. Nevertheless, the question remains what kind of growth in each country suits to the demands of more effective adaptation, more effective environmental protection and GHG mitigation, and adequate growth targets.

In this project it has been argued that pursuing climate resilient pathways requires new institutions and adequate incentives at international, national and local levels. In addition it was stated that new institutions have to be established to transform trade-offs into synergies. For example, transforming the trade-off created by deforestation from agriculture in countries with high share of rural population needs institutions that integrate different goals. These institutions need to be endowed with capacities and technical skills related to forests protection, monitoring, reporting and verification of carbon sinks, the application of advanced technologies for higher agricultural productivity and for less-emitting production styles. These bodies should increase the capacity for research and development and provide permanent and effective agricultural assistance. A similar rationale applies to the correction of other widespread trade-offs reported. Therefore, a more detailed analysis of synergies at the country level would need specific evaluations of how existing institutions (national and international) can be effectively involved in particular issues, or re-shaped. Further incentives need to be identified and/or developed in order to foster adequate transformation of trade-offs into synergies.

Some issues are common in the studied countries:

5. Pakistan, Peru and Kenya are suffering from a current and also future scarcity of fresh water. Large amount of river runoff in Pakistan and Peru are supplied by glaciers. While currently an increase can be observed due to an accelerating melting, in the future the runoff will substantially decrease. Pakistan, India, Ethiopia, South Africa, Mexico, Peru and some desert parts of Colombia suffer from severe water scarcity. These countries need to develop technologies and practices for inter-seasonal water harvesting. Moreover, disaster risk management strategies are needed in these countries in order to cope with extreme events. The population impacted by severe droughts in Kenya has grown exponentially over the last two decades, but effective response mechanisms have not been implemented. International development assistance may play an important role helping these countries to develop their capacity in water management. This should be accompanied by the development of the adequate governance in the forest sector.

6. Food security is of central importance in a number of countries like Pakistan, Kenya, India, Mali and Peru. Under current agricultural production standards the necessary future minimal locally produced food supply is not achievable in Grenada, Ethiopia, Kenya, Pakistan and Peru. Moreover, due to the rapid introduction of western lifestyle and further population growth, the future food demand will grow considerably. National food self-sufficiency cannot achieved in countries like Grenada, Ethiopia, Kenya,

Indonesia, Pakistan, Peru, and the Philippines, even if current advanced agricultural practices for closing potential yield gaps are to be applied.

7. The agricultural sector will remain the main source for further economic growth and human development in Nicaragua, Kenya, Ethiopia, Mali, Pakistan, India, Indonesia and Cambodia. These countries should develop coherent policies to improve the productivity of small and medium sized farms. These countries need to develop long term plans for capital formation of rural communities in the use of modern agricultural technologies and practices. International programs like REDD+ or CDM should be accompanied by regional institutions to create incentives for the integration of agricultural development, carbon sinks and GHG mitigation in agriculture.
8. Cambodia, Nicaragua, Grenada, Colombia, Pakistan and Mexico require developing their capacity in water governance. Disaster Risk Management (DRM) strategies need to be improved, to enhance the capacity to cope with extrem events.
9. Forestry is in the most of the investigated countries the sector to achieve the largest synergies. In Kenya the protection and the expansion of forest areas in water towers is almost the only means to enhance water resources. In Pakistan the enhancement of forests in the North is crucial to regulate regional water cycles. REDD+ should be enhanced in these countries due to water security reasons. International assistance should prioritize the development of national capacities in countries with the highest potential for GHG mitigation provided by forests, i.e. Cambodia, Nicaragua, Mexico, Philippines, Vietnam, India, Indonesia, Brazil, South Africa, Colombia, Peru, Nicaragua, Mali and Ethiopia.
10. For the creation of synergetic processes and the development of adaptive capacity potential growth paths need to be investigated in all countries. Higher income per capita and the development of markets are required for an increased adaptive capacity. The effective functioning of institutions like, e.g. carbon markets, REDD+ or CDM requires more educated people with better incomes. In many of the countries studied emissions from the combustion of fossil fuels are growing fast while indicators of human development remain almost stagnant. This disparity has been shown to correlate with high inequality and low governance. For climate resilient pathways these countries need an inclusive growth model, based on knowledge, equity, technology, and good governance.
11. Some more developed countries e.g. South Africa, India, Brazil and Mexico have developed conditions for the development of carbon markets, but these should be further supported by international programs. However, inequality in Brazil, South Africa and Mexico represent a bottleneck for the implementation of carbon markets. Low human governance and corruption further restrict the potential for the implementation of progressive taxes in these countries.

2. Climate Change, Food Security and Forests Governance

Climate change will force changes in land use everywhere (Kang et al. 2009). Except in South Africa climate change will have adverse consequences for agriculture. Projected impacts of climate change on crop yields may further drive changes on land use and deforestation subsequently. Crop yields will be further affected by more intense droughts and extreme floods. In some countries, e.g. Vietnam, Philippines, Indonesia, and Cambodia sea level rise will reduce the total agricultural area. Population growth and changes in dietary patterns will reinforce the demand for more food production, in particular for more meat. Increasing uncertainties in terms expected rainfall will intensify the pressure to use more land in order to offset the variability of agricultural outputs. While this pressure is closely linked to deforestation in many countries, climate change may have also direct impacts on forest covers. In Peru drier conditions in the North Amazonian region show already changes in the forest cover and composition (UNDP 2013c). If adequate management strategies are not implemented land use change will exacerbate deforestation and accelerate local and global climate change. The transformation of these trade-offs into synergies requires efforts on three fronts: food security, agricultural productivity and environmental (mainly forests and water) governance.

2.1 Food Security:

Food security is important for developing countries, in particular for the poor. It needs long-term planning, because climate change may threat current food supply in the future. Furthermore, globally there exists a tendency toward more meat rich diets. This will even increase food demand. Consumption patterns have been changing towards more animal products in Brazil, Colombia, Grenada, Vietnam, Pakistan, South Africa and Mexico. The actual global average consumption per cap per day of animal products amounts to 500 kcal. This amount is transgressed in these countries. Subsequently it can be expected that the expansion of cattle ranching will continue, increasing the pressure on forests areas.

Only wealthier countries have performed relatively well in food security. The population of most of the countries in this study suffers from undernourishment and malnutrition. Poorer countries need to produce more food for domestic consumption. Only India, Indonesia, Vietnam and Cambodia are currently food self-sufficient measuring there actual domestic food production capacities. Other countries can become self-sufficient by closing their yield gaps ranges between 40% and 100% by applying more advanced production styles in agriculture.

Major drivers for food demand are population growth and changing diet styles. Peri-urban agriculture can nourish large amounts of residents in cities, but only under optimal management practices. This may reduce long distance food transport. Climate change will reduce this option tremendously, in particular in India and Pakistan.

Food security requires an increase and diversification of food production, although this is only one aspect of the problem. In parallel, countries need to develop agricultural markets for an effective allocation of food, and policies for an adequate distribution. International assistance should consider food security at national levels as an important factor for climate change policy. Efforts to reduce the pressure from agriculture on forests or efforts to reduce the production of GHG emission in agriculture require that countries improve governance in this sector.

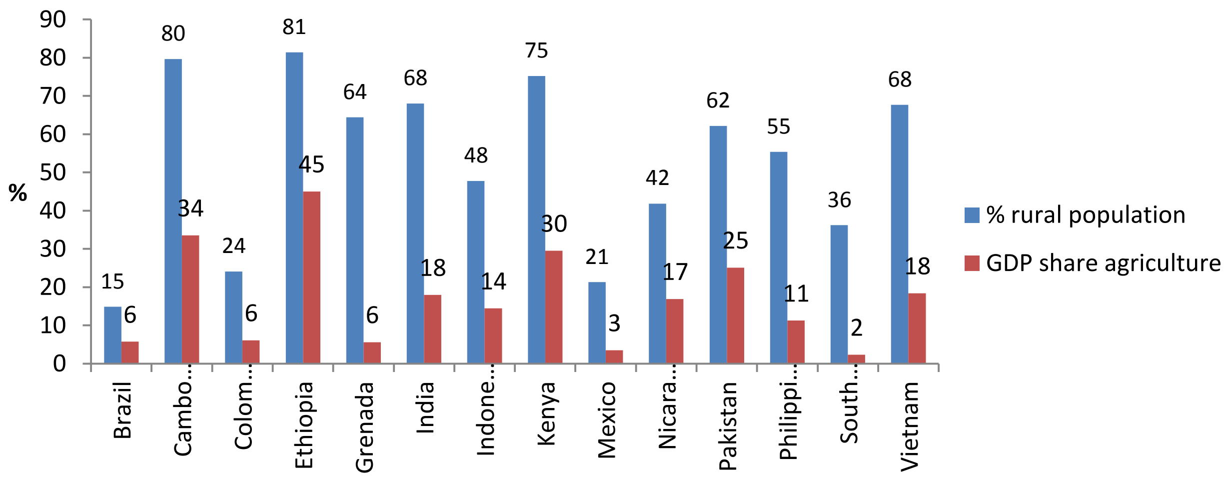
2.2 Deforestation:

Forestation, afforestation, and reforestation offer high potential for GHG mitigation, carbon sinks and the development of rural communities. If higher incentives for carbon sinks and GHG mitigation are institutionalized forestry may emerge as a sector for growth.

Deforestation is a widespread phenomenon relevant in most countries in this study. Agriculture is the major driver of deforestation, due to increasing demands for food, GDP growth and population income. In Brazil, for example, deforestation is driven by prices of soya (Aide et al. 2012) and cattle ranching (De las Heras et al. 2012). According to the country reports, in Peru, Colombia and Indonesia, industry and mining are direct drivers, while in Ethiopia, Kenya, Nicaragua, Colombia, Peru, Mexico, Pakistan, and Cambodia deforestation provides income to the rural poor. In Cambodia agricultural expansion and military are important drivers of deforestation. The demand for biomass has been identified as a key driver in Kenya and Ethiopia. In any case climate change has the potential to reinforce deforestation.

Figure 2-1 shows the share of population living in rural areas and the share of agriculture in GDP for fourteen countries (Peru and Mali were not included due to lack of information). It can be assumed that the above factors drive deforestation more strongly, if high shares of population live in rural areas. Furthermore, deforestation would be higher if agriculture is an important sector for GDP. Thus, deforestation would be higher in Cambodia, Ethiopia, Kenya, Vietnam, Pakistan, Indonesia and Nicaragua. Considering the share of agriculture in GDP deforestation would be higher in Ethiopia, Cambodia, Kenya, Pakistan India and Vietnam. On the contrary, if the share of rural population and GDP share from agriculture are small, deforestation rates would be small in countries like Colombia, Mexico or Brazil. In reality however, deforestation has been stopped in India, Philippines and Vietnam. In fact, these countries have increased the forests areas.

Figure 2-1: The relevance of agriculture in fourteen countries studied.



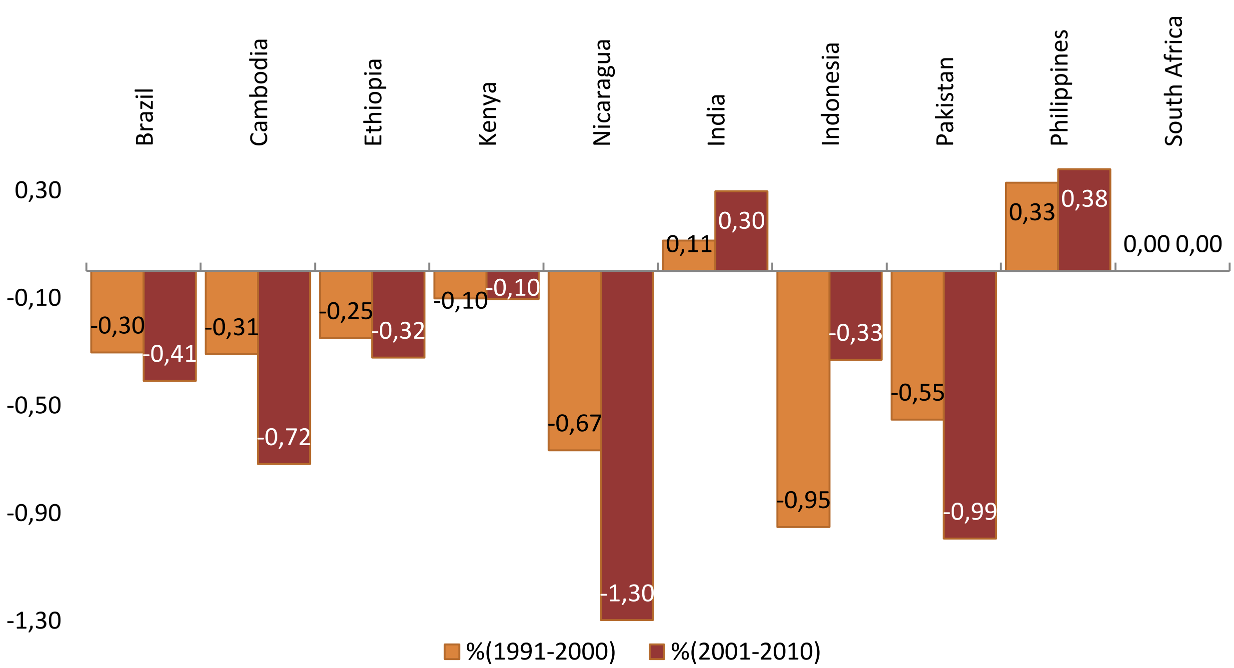
Information from the (World Bank 2015a). The percentage GDP from agriculture does not include agro-business or industry related sectors –e.g. textiles.

On the opposite, deforestation is high in Mexico, Colombia and Brazil. The values of deforestation in Nicaragua are very high compared to the share of rural population. The case of Brazil reveals the influence of other drivers rather than population growth. In this country, cattle ranching and the expansion of soya crops are major drivers of deforestation. The above figure make evident that deforestation rates in the countries studied are not only driven by some factors associated to the extent of rural population and the importance of agriculture for GDP, but also by other factors restraining –or promoting– deforestation.

2.2.1 Forest Governance and Adaptive Capacity:

The influence of population growth on deforestation can be more closely analyzed by considering the forest area elasticity of population growth in ten countries (Figure 2-2). The elasticity explains how forest cover would respond if (rural) population changes in a country. A large negative elasticity would indicate that forests governance is insufficient or ineffective to cope with actual needs (e.g. Kenya, Cambodia, Nicaragua). While India, Vietnam, the Philippines and South Africa have stopped deforestation or increased the forests areas, in Nicaragua, Pakistan and Cambodia deforestation is highly sensitive to population growth. In these countries the situation has even worsened between 2001 and 2010. Deforestation in Nicaragua is even facilitated by laws assigning property rights to deforesters (Liscow 2013). In Pakistan the remaining forests in the North are threatened by lack of capacity in forestry (Muhammad et al. 2011). In addition, an outdated design of forest governance is considered as a factor facilitating deforestation (Ali et al. 2006). In Cambodia poverty, the military, and the expansion of industrial agriculture are drivers of deforestation. The cases of India and Philippines are characteristic of the high capacity in forests governance.

Figure 2-2: Forest area elasticity of population growth. Information from FAO (2010)



The percentage change of population and forests area were calculated for the periods 1991-2000 and 2001-2010. The elasticity function is defined as $e_{forest,pop}$ = (Δ *f.cover change/f.area*)/(Δ *pop. change/total pop.*).

Property rights (PR) are cornerstones for forests governance. If PRs are enforced deforestation could be effectively controlled. Different circumstances explain the low capacity to enforce PRs in the countries studied. In Ethiopia land holders have some rights to decide upon land use and rights, i.e. to develop some sharing contracts, but alienation rights still belong to the state (Rahmato 2004). Conflicts originated in the fuzziness of PR also exist in Brazil, Indonesia and Kenya. Nevertheless, property rights need to be handled carefully, because granting absolute property rights has also set conditions for deforestation in Nicaragua (Liscow 2013).

To sum up, to stop deforestation the countries need to develop their capacities in sustainable management of forests, because dealing with forests is a multidimensional issue. For example, deforestation is affecting other natural resources. In Nicaragua, water scarcity is sensitive to deforestation (Ray 2013). Water scarcity is also a major challenge in Ethiopia and Kenya. It is being increased by deforestation (see the respective country reports). In Cambodia, Nicaragua, Mexico, Colombia, Indonesia and Brazil forests are invaluable as biodiversity hotspots and this asset is threatened by deforestation. It also affects other economic sectors, e.g. in Nicaragua, Ethiopia and Kenya forests are important sources of biomass for energy production.

Despite the relevance of forests for climate change mitigation and adaptation only 0.6% of total registered CDM projects related to afforestation and 2.5% to reforestation and agriculture by 2013 (P. Smith et al. 2014). Crucial factors affecting the performance of the forest sector in GHG mitigation is the lack of financial support, know-how for the implementation of plans, property rights on afforested or reforested land, and the participation of benefits of local communities (S. Thomas et al. 2010).

According to the hypothesis of the analytical approach developed in this project an adequate and sustainable utilization of forests require the development and use of sustainable technologies, a suitable infrastructure for accessibility (in the case of forests governance for monitoring deforestation), specialized human capital and the provision of financial support for the development of capacities in forests governance.

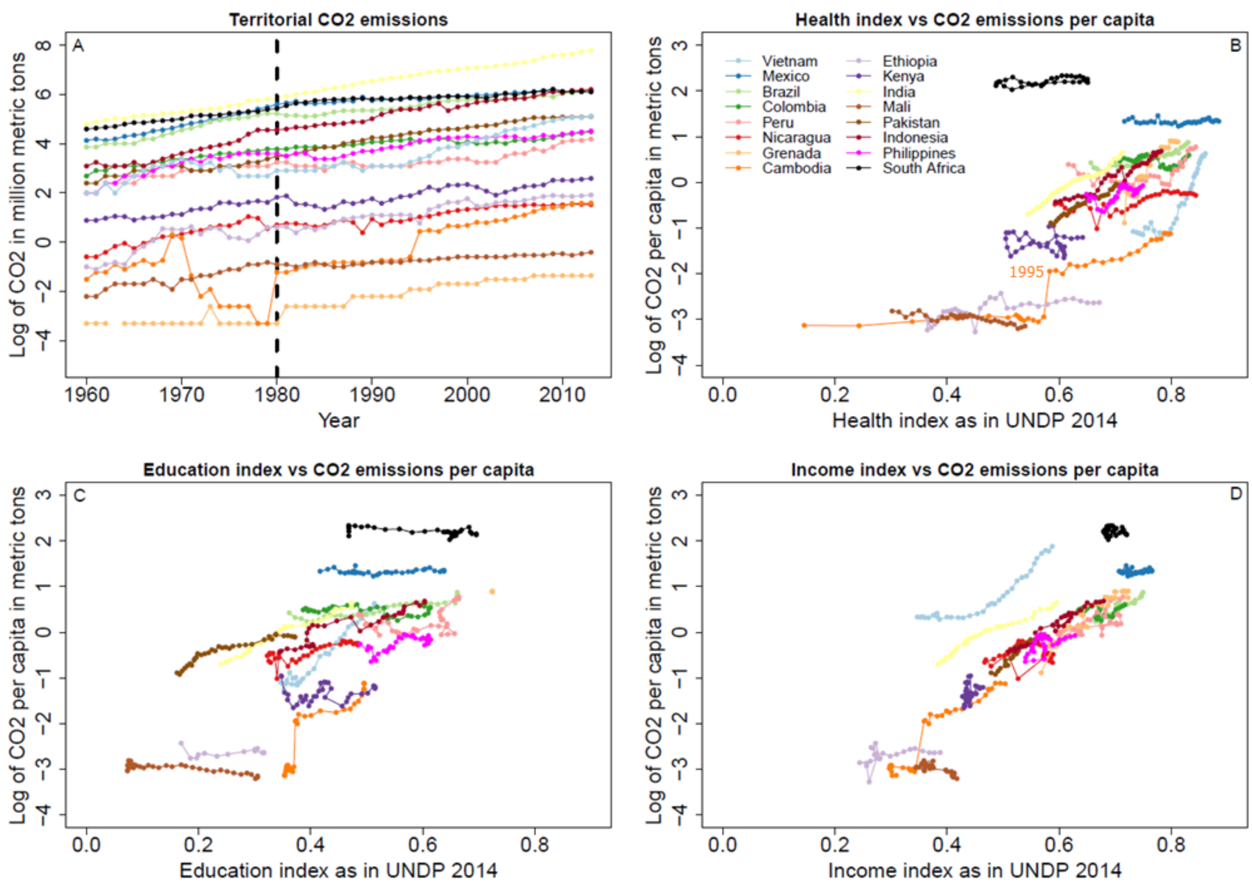
3. Energy, Growth, Human Development and Inequality

The increased consumption of fossil fuels in the generation of energy and transport produces environmental pollution and climate change. However, does this trade-off produce higher standards of human development and more adaptive capacity? This is a core question if synergies are to be evaluated.

The evolution of the HDI over time shows an overall correlation with increased GHG emissions from the combustion of fossil fuels (Costa et al. 2011). For the countries analyzed in this study it becomes evident (Figure 3-1D) that GHG emissions per capita are coupled to average income per capita, i.e. the higher the emissions are, the higher is the average income. South Africa and Mexico show the highest emissions per capita and also the highest average income per capita. However, poverty is increasing in Mexico and in South Africa the poverty headcount ratio was 45.5% in 2011 (World Bank 2015a). Thus, in both countries inequality is high. For a real sustainable pathway livelihood, here measured by the HDI, need to be decoupled from fossil fuel emissions. This, of course, will affect all dimensions of human life. For better health an even exponential growth can be globally observed. For education and income a similar behavior can be observed. While for single countries the development of the education index over time is only slightly increasing or constant, globally a linear dependence between education and emissions can be observed (Costa et al. 2011). The income, indeed, shows the clearest dependence of emissions on income even for the single countries. While for the health index (Figure 3-1B) the development is diverse for the respective countries.

Summing up, it is evident (Figure 3-1D) that GNI per capita and emissions co-evolve, the way how economic growth (indicated by CO_2 as proxy) translates into human development is not. The above analysis calls for more careful considerations of the role of emissions in human development and how countries may decouple growth from emissions.

Figure 3-1: Trends of health, education and income in the HDI, in the sixteen countries studied.



Historical emissions of CO_2 from fossil fuel burning for obtained from the global carbon budget project (Le Quéré et al. 2014)(A). Health index for the time period of 1980-2013 (Byrne and Macfarlane 2014) vs CO_2 emissions per capita (B). C and D panels show analogous information as panel B for the Education and Income index respectively. Data on population, income, education and health obtained from the World Bank 2014 database.

Inequality matters for synergies between energy usage and human development. Countries with high or increasing inequality (South Africa, Mexico, Indonesia, Colombia and Peru) are characterized by high emissions per capita from energy, concentration of capital in fewer hands (Mexico, Colombia and South Africa), increasing or high poverty, and deficits in services. Increasing emissions in these countries are produced by higher consumption of fossil fuels in the energy and transport sector. However, the economic growth implies that higher energy consumption is not effectively transferred into better social conditions.

Prevailing economic models of growth in these countries favor inequality. Therefore, inequality is one major factor for social vulnerability in those countries. The implications for synergies are straightforward. Policies aiming to reduce GHG emissions while in parallel developing require measures to reduce inequality. A variety of actions and mechanisms can be taken that could work in this direction. In countries relying on activities like mining, which produce massive financial flows, but require low specialization and non-skilled labor, taxes on production would create financial resources. These can be further invested in education, health and infrastructure (the cases of Peru, Colombia, Indonesia and South Africa). In other countries, like in Brazil, policies and taxes could create incentives to invest more in education and reduce incentives to superfluous consumption. Progressive taxes are the most efficient instrument to correct these trade-offs.

4. Brazil, India, South Africa - Cross-Country Synergy Analysis

4.1 Synergies and Economic Strength:

Brazil, India and South Africa are emerging economies. They have seen significant economic growth in recent years along with strong sectoral development. However, the three countries continue to face significant challenges, including poverty, social inequality and increasing GHG emissions. In addition, they are divergent in economic strength. While India is among the poorer lower-middle-income countries according to the World Bank, South Africa is well within the upper-middle-income group. Brazil is situated at the upper end of the latter group (World Bank 2015a).

While the countries are situated in different regional contexts their shared status as emerging economies calls for a comparative analysis. Accordingly, they may be able to work together towards approaching climate change mitigation and adaptation in a synergetic manner. South Africa has made particular progress by making climate synergies a policy priority. Both in regard to general policy design and specific issues, Brazil, India and South Africa would benefit from greater cooperation to increase the global effort against climate change and set a positive example for other governments while profiting from the developmental co-benefits that synergetic approaches should aim to create.

The approach of this section is twofold. On the one hand, we seek to find how the three countries can learn from each other, i.e. how they might develop similar approaches to facilitate a synergetic approach to tackling climate change. On the other hand, we explore the possibilities for the countries to work together and develop common approaches. This way, we hope to locate the most viable options for cross-country cooperation in relation to synergies between climate change mitigation and adaptation. Subsequently, it will be explored how the three countries' may increase financial capacities that may create opportunities for cooperation, in particular through the New Development Bank. Finally, the prospects for creating carbon markets within Brazil, India and South Africa is investigated.

4.1.1 Synergies by Sector

The three countries' economic strength is related to the development of particular sectors. Some of these have become significant GHG emitters, but also provide opportunities for mitigation and adaptation. In the following it is investigated how the three countries can promote synergy-based climate policies in the energy and forestry sectors.

4.1.1.1 Energy:

Brazil, India and South Africa have developed significant energy sectors that fuel their economic growth. Brazil possesses a large renewable energy sector based primarily on biofuel and hydropower, but this has had significant trade-offs. India and South Africa largely rely on conventional energy such as oil and coal. Renewable energy expansion mitigates GHG emissions, while helping to adapt to the decreased viability and availability of conventional energy as a result of climate change. In addition, it can help increase overall electricity access. We must bear in mind that energy supply, in particular access to electricity, is an important developmental issue. The individual countries' progress differs significantly: while 99.3% of the Brazilian population had access to electricity in 2011, only 84.7% of South Africans and 75.3% of Indians enjoyed the same privilege (World Bank 2015a).

Brazil has achieved widespread electricity integration based on renewable energy, but at a significant cost to people and environment. While Brazil's hydropower facilities have a low carbon footprint, their construction caused the destruction of natural environments and removal of local populations. Brazil's public investment approach and biofuel quota are admirable, but its policy implementation is a negative example that India and South Africa can seek to avoid.

In developing new approaches the countries must determine, which types of renewable energy are the most viable in their respective countries based on their geographic and social circumstances. India and South Africa can aim to both increase the share of renewable energy in the national grid and promote decentralised electrification. In seeking synergetic policy approaches decentralized energy rather than grid expansion may be the most feasible and partly also the cheapest approach for all three countries.

Decentralised renewable energy production is a particularly attractive synergy-based policy approach, as it has the co-benefit of promoting inclusive growth and development in isolated rural areas that are not connected to the national electricity grid. This could help to address existing disparities of electricity access, particularly in India and South Africa. India has launched a major initiative to this end, the Jawaharlal Nehru National Solar Mission, which promotes grid-based and off-grid solar energy production. South Africa could investigate the possibility of implementing a similar approach to promote climate mitigation and adaptation as well as rural electricity access. In Brazil private initiatives have promoted rural electrification through decentralized solar energy production (Oregon Public Broadcasting 2005). The government may consider promoting and expanding such programs to increase electricity access and further decrease conventional energy use. This may be a viable approach to deal with an increasing energy demand in Brazil that existing hydropower and biofuel facilities will not be able to handle. Finally, the three countries would benefit from long-term energy plans that build on decentralized renewable energy and consider both household and industrial energy demand.

4.1.1.2 Forestry:

Deforestation is a significant contributor to climate change at a global scale. Reducing deforestation, as well as reforestation and afforestation, can create synergies between climate mitigation and adaption as forests mitigate GHG emissions and help people and ecosystems adapt to climate change. Forestry is a significant issue in Brazil, a lesser issue in India and a small issue in South Africa.

While deforestation continues to be a serious problem in Brazil, the country has taken exemplary action against it. Effective monitoring systems must be in place to measure and control forest cover. The Brazilian National Space Research Institute has developed systems which are already being adopted in other countries and could be used in India and South Africa. The countries could further follow Brazil and implement direct control measures, such as requiring land holders to report on land use. A combined strategy may be appropriate which also provides economic incentives against deforestation. To create effective climate synergies, local stakeholders must receive economic benefits from conservation.

An additional strategy that the states may consider is agroforestry, which involves planting trees or shrubs in or around agricultural lands. This mitigates GHG emissions while increasing the land's resilience to climate change. This synergy-based approach is being promoted by the Indian government through the National Agroforestry Policy, which was launched in 2014. Smaller initiatives have been taken by state and non-state actors in Brazil and South Africa. The latter countries would benefit from monitoring India's implementation of its agroforestry policy as this would be valuable input for creating such a public initiative in their respective countries. The developmental co-benefits of agroforestry are immense, particularly for poor rural inhabitants, making it an ideal synergy-based approach that can simultaneously help tackle poverty and inequality.

4.2 Financial Capacity:

Brazil, India and South Africa have seen immense economic growth in recent years, but poverty and inequality persist in all three countries. Common approaches to synergetic climate policy may be developed based on the countries' strong and increasing financial capacity. This can be achieved through direct project financing, by providing economic incentives to relevant actors and by promoting scientific research and cooperation. If such actions were successful, it would provide a positive example for other countries to follow, particularly to advanced industrialized countries.

The New Development Bank (NDB) is a potential forum for promoting synergy-based climate change policy. It was established in July 2014 by the BRICS group which comprises Brazil, India and South Africa along with China and Russia, and is intended to provide development financing much like the World Bank and International Monetary Fund, but under alternative conditions (The Economist 2013). Article 1 of the NDB agreement states that '[t]he Bank shall mobilize resources for infrastructure and sustainable development projects in BRICS and other emerging economies and developing countries'15. The bank has been provided with

[15] The full text of the agreement can be found at http://brics6.itamaraty.gov.br/media2/press-releases/219-agreement-on-the-new-development-bank-fortaleza-july-15

US$50 billion initial capital as well as US$100 billion in guarantees. The establishment of the NDB is an opportunity to create a new financial initiative against climate change. Accordingly, 'investing in environmental sustainability and building resilience to climate change could be a strategic area of the BRICS Bank's portfolio' (Oxfam International 2014). The bank could focus on projects that aim to create synergy between climate mitigation and adaptation.

Within and beyond the NDB, Brazil, India and South Africa (or the BRICS group) can take a coordinated approach in the financial effort against climate change. While they rightly point out that the Annex I countries under the UNFCCC are primarily responsible for climate change e.g. (Environmental Defense Fund 2013), they can set a positive example by using their newly attained economic strength to implement a synergetic response to climate change. This would set a positive example for other countries to follow suit. Such financial initiatives may be a climate change strategy that complements negotiations under the UNFCCC, taking concrete action before an agreement is reached or to help implement an agreement when it is achieved.

Climate change policies require a sound scientific basis. Brazil, India and South Africa could use their financial capacity to expand climate change research. This can help the countries find adequate strategies for implementing synergetic policies at a local, national and international level. In addition, the countries would benefit from increased scientific exchange to share knowledge and strategies. Overall approaches are likely to differ by country due to different geographic and social circumstances, but it may be possible to adapt local approaches from one country to another. This requires a dynamic scientific exchange between universities and policy implementers.

4.3 Carbon Markets:

Carbon markets create a mechanism through which GHG emissions are measured, bought and sold as a commodity, i.e. 'carbon credits' are traded on a market. Carbon markets aim to mitigate GHG emissions. Proceeds from market schemes can, in principle, be used to finance adaptation measures, creating synergy between mitigation and adaptation. The most common forms of carbon markets are cap-and-trade schemes and project-based offset mechanisms. In cap-and-trade schemes, a central authority at a local, national or international level sets an overall emissions cap and allows emissions below the cap to be traded. Emissions allowances are allocated to emitters in the form of carbon credits either for free or in auctions. If they receive credits below their current emissions, the emitters must choose whether to reduce their emissions or buy more allowances. As surplus credits can be sold, there is an economic incentive to reduce emissions. The goal is to encourage flexible and innovative emissions reductions where they are most economically viable. In project-based offset mechanisms, emitters 'offset' their emissions by financing mitigation projects elsewhere (Gledhill, Grant, and Low 2008). An example of this is the Clean Development Mechanism (CDM) which was established by the Kyoto Protocol. Under this initiative, industrialized countries finance mitigation projects in developing and emerging economies. There are currently 1521 CDM projects registered in India, 327 in Brazil and 55 in South Africa (UNFCCC 2014c).

Carbon markets may create difficulties and have been criticized for various reasons. Cap-and-trade systems do not necessarily reduce GHG emissions, but create a flexibility of emissions below a particular threshold. This threshold can be gradually lowered to create an overall emissions reduction. Carbon offset mechanisms do not reduce emissions in absolute terms, but merely finance emissions reduction measures elsewhere, whereby the add-on of GHG mitigation – whether mitigation would have taken place without the given project – may be difficult to determine. The commoditization of emissions will not necessarily lead to their reduction in absence of structural change (Gilbertson T 2009). Furthermore, the market prices for carbon credits can be volatile. The two largest carbon markets, the European Union Emissions Trading System (EU ETS) and the CDM, have seen a dramatic price drop per carbon credit in recent years. This reduces the economic incentives for mitigation (The Economist 2013). The EU ETS has been criticised in particular for handing out carbon permits too freely based on past pollution, thereby creating little incentive to reduce emissions (Gilbertson T 2009). Finally, carbon markets are viable to manipulation and fraud (Interpol 2013).

If carbon markets are to be used as a mechanism to combat climate change, they must be carefully set in place within a functional institutional context, and they will likely need to be supplemented with other mechanisms. Various parallel approaches may be required to create a structural economic shift towards sustainable development. Carbon markets can only be considered a synergetic approach to climate change if they support adaptation, whether directly or indirectly. This can be achieved through various strategies. If carbon credits are auctioned off in a cap-and-trade system, the proceeds can go towards adaptation. If such systems are established at an international level, governments may collect emissions credits based on the carbon storage capability of large ecosystems such as forests if measures are taken to protect them; these credits can be sold to GHG emitters, using the proceeds for adaptation. Carbon offset mechanisms can foster synergetic approaches to climate change more directly if they finance projects that contribute to both mitigation and adaptation.

The German Energy and Climate Fund is exemplary of how revenue from carbon markets can be used to finance, among other things, adaptation measures. Carbon credits within the EU ETS are auctioned off by the German authorities to companies and the proceeds are deposited in the fund which finances climate change mitigation and adaptation measures in Germany and elsewhere. The fund has faced financial difficulties and required additional public support due to the market price drop for carbon certificates (Stefan 2013; BMF 2013). If carbon markets were established in Brazil, India and South Africa, such a fund could be used to channel mitigation revenues towards adaption, though additional mechanisms may be required to maintain a stable carbon credit price.

4.4 Nationwide Carbon Markets:

Brazil, India and South Africa are presently exploring their options for creating national carbon markets (Partnership for Market readiness 2013). In South Africa, a pilot emissions trading program is in planning to help companies comply by a newly established carbon tax (Reuters 2014). In Brazil, the regional governments of São Paolo and Rio de Janeiro are planning to implement ETS schemes, though plans have currently been placed on hold (ICAP 2014). India already has a market-based energy efficiency scheme in place in which energy savings certificates are traded to achieve energy intensity targets. This is not an emissions trading system as the goal is not emissions mitigation, but a relative energy saving (EDFIETA

2013). Neither country has plans to use proceeds from carbon credit allocation to support climate adaptation.

Potential exists in all three countries to implement cap-and-trade systems. Such schemes could be implemented in the electricity generation and industrial sectors as these are large and produce significant emissions. The carbon market could possibly be expanded to include the forestry and agricultural sectors, though enforcement may be more difficult as these sectors include large numbers of actors such as small-scale farmers. Furthermore, persisting illegal deforestation complicates implementation.

For carbon markets to be successful, they require a robust institutional framework, including functioning financial markets, 'minimum standards for monitoring, reporting and verification of emissions' (Stern 2007). Further research and institutional development is required in the three countries to create an effective framework for implementing carbon markets. If the necessary precautions are put in place, national carbon markets could be developed. Further mechanisms would need to implemented place to ensure that their establishment leads to climate adaptation financing. Additional measures may be required to ensure the stability of the carbon price.

4.5 Carbon Markets between Countries:

It may be possible to achieve a greater benefit for mitigation and adaptation if carbon certificates could be sold on an international market. This would allow emissions to be offset in other countries. For example, Brazil would possess an immense economic potential if it could sell carbon certificates acquired through GHG mitigation based on decreased deforestation. This could be used to finance adaptation measures if a functioning market were in place and the carbon price were sufficiently high. Similar potential may exist in India and South Africa.

International carbon markets can build on the institutional foundations of national markets. Developing a global carbon market may be difficult at this time, but smaller initiatives are possible, as the EU ETS has shown. Besides regional initiatives, similar economic development could create a positive environment for implementing a common carbon market. This may be possible between Brazil, India and South Africa, or among the BRICS countries. These countries possess similar financial capabilities, but different emissions sources and mitigation potentials. This may provide an opportunity to mitigate emissions where it is most efficient, going beyond the CDM's limited project-based approach. Such an initiative would require the given countries to cooperate and agree on a fixed emissions reduction target. This may be politically difficult, but would provide a positive example for other countries and blocs to follow. A cap-and-trade scheme could be launched that builds on its members' strengths and bears in mind the lessons learned from existing schemes such as the EU ETS. Effective mechanisms would also be required to ensure that the funds generated contribute to climate change adaptation. Finally, such a scheme would require an ambitious emissions cap that is gradually lowered to ensure that emissions are not only restructured, but significantly reduced overall.

4.6 Concluding Remarks

A number of approaches are possible to promote a synergy-based climate change policy within and between Brazil, India and South Africa. The countries can learn from each other in the implementation of energy and forestry policy. In all three countries, further efforts are possible and necessary to tackle climate change mitigation and adaptation. The countries' financial capacity can be a basis for cooperation to promote synergy-based policies and projects. The establishment of the NDB may be a particular opportunity to foster cooperation. Finally, policy makers may consider establishing carbon markets within and between Brazil, India and South Africa. Such efforts will only be viable if the necessary institutional framework is put in place along with sufficient safeguards to ensure that carbon markets benefit adaptation. Governments must consider that carbon markets do not necessarily contribute to adaptation, nor do they even create significant emissions reductions if mitigation targets are low. Synergy-based climate policy requires effective coordination at national level, but would greatly benefit from international cooperation. Brazil, India and South Africa could set a positive example for the world to follow.

Synergetic climate change policy requires ambitious plans and effective implementation. Policy design must account for diverging local needs and allow for flexibility. Brazil, India and South Africa continue to face significant developmental challenges such as poverty and inequality. An effective long-term climate change policy should take these into consideration. Brazil, India and South Africa share an immense potential: as emerging economies with significant financial capacity, they can choose which type of development they want to undergo. The countries can seize the present opportunity and embark upon a sustainable route that builds on synergy-based climate change policy and inclusive growth. Environmental and social issues are inherently interlinked; effective policy must address both.

References

Abiye, Yonas. 2013. “New Ministry for Environment, Forest.” *The Reporter*. http://www.thereporterethiopia.com/index.php/news-headlines/item/639-new-ministry-for-environment-forest.

ACCBio. 2009. “An Institutional Collaboration for the Formulation of the Philippine Strategy on Climate Change Adaptation,” 1–24.

ADB. 2009. “The Economics of Climate Change in Southeast Asia: A Regional Review.” *Asian Development Bank (ADB)*, no. April: 255.

———. 2012. “Cambodia - Water Supply and Sanitation Sector Assessment, Strategy, and Road Map.” *Asian Development Bank*.

———. 2013. “Asian Development Bank and Cambodia: Fact Sheet,” no. December: 0–3.

———. 2014a. “Cambodia: Flood Damage Emergency Reconstruction Project.” *Asian Development Bank*.

———. 2014b. *Indonesia Needs to Pursue Structural Reforms Amid Widening Current Account Deficit*. http://www.adb.org/news/indonesia/indonesia-needs-pursue-structural-reforms-amid-widening-current-account-deficit.

ADBI. 2013. “Country Paper on Climate Change Mitigation in Agriculture in Cambodia.” *Workshop on Developing Farming Systems for Climate Change Mitigation 26-30 August 2013 , Colombo , Sri Lanka*.

Adger, N. 1999. “Social Vulnerability to Climate Change and Extremes in Costal Vietnam.” *World Development* 27 (2): 249–69.

Adger, N., S. Agrawala, M.M.Q. Mirza, C. Conde, K O’Brien, R. Pulhin, B. Smit, and K. Takahashi. 2007. *Assessment of Adaptation Practices, Options, Constraints and Capacity*. Edited by M L Parry, O F Canziani, J P Palutikof, P J Van Der Linden, and C E Hanson. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

Adger, N., and P. Kelly. 1999. “Social Vulnerability to Climate Change and the Architecture of Entitlements.” *Mitigation and Adaptation Strategies for Global Change* 4: 253–66.

Adger, Neil W., Shardul. Agrawala, M. Monirul Qader. Miraz, Cecillia. Conde, Karen. O’Brien, J. Pulhin, R. Pulwarty, B. Smit, and K. Takahashi. 2007. “Assessment of Adaptation Practices, Options, Constraints and Capacity.” In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by M L Parry, O F Canziani, J P Palutikof, P J Van Der Linden, and C E Hanson, 717–43. Cambridge University Press, Cambridge, UK.

Adger, W Neil. 2003. “Social Capital , Collective Action , and Adaptation to Climate Change.” *Economic Geography* 79 (4): 387–404.

Adger, W. N. 2003. “Social Aspects of Adaptive Capacity.” In *Climate Change, Adaptive Capacity and Development*, edited by J. B. Smith, R. J. T. Klein, and S. Huq, 29–50.

AfDB. 2014. “Mali Economic Outlook.” http://www.afdb.org/en/countries/west-africa/mali/.

Afzal, Uzma, and Anam Yusuf. 2013. “The State of Health in Pakistan: An Overview.” *Lahore Journal of Economics*, no. September 2013: 233–47. http://ideas.repec.org/a/lje/journl/v18y2013ispp233-247.html.

Aide, T Mitchell, Matthew L Clark, H Ricardo Grau, David Lopez-Carr, Marc a Levy, Daniel Redo, Martha Bonilla-Moheno, George Riner, Maria J Andrade-Nuñez, and Maria Muñiz. 2012. “Deforestation and Reforestation of Latin America and the Caribbean (2001 – 2010).” *Biotropica* 45 (2): 262–71. doi:10.1111/j.1744-7429.2012.00908.x.

Aldred, Jonathan. 2009. “Ethics and Climate Change Cost-Benefit Analysis: Stern and after.” *New Political Economy* 14 (4): 469–88. doi:10.1080/13563460903288221.

Ali, Tanvir, Babar Shahbaz, and Abid Q. Suleri. 2006. “Analysis of Myths and Realities of Deforestation in Northwest Pakistan : Implications for Forestry Extension.” *International Journal of Agriculture and Biology*, no. 2003: 2004–7.

ALM. 2011. “Nicaragua’s Second National Communication - Project.” *Adaptation Learning Mechanism*.

———. 2014. “Colombia Nama.” *Adaptation Learning Mechanism; UNDP*. http://www.undp-alm.org/projects/bf-colombia-nama.

Álvarez, María D. 2003. “Forests in the Time of Violence Conservation Implications of the Colombian War.” *Journal of Sustainable Forestry* 16 (3-4). http://www.tandfonline.com/toc/wjsf20/16/3-4.

APEC. 2006. “PEC Energy Demand and Supply Outlook 2006: Projections to 2030 Economy Review.” *Asia Pacific Energy Research Centre*.

Arndt, Channing, Finn Tarp, and J Thurlow. 2012. “The Economic Costs of Climate Change: A Multi-Sector Impact Assessment for Vietnam,” 4131–45. doi:10.3390/su7044131.

Assad, Eduardo Delgado, and Hilton Silveira Pinto. 2008. “Global Warming and the New Geography of Agricultural Production in Brazil.” *Design*, no. August.

Atingi-ego, Michael, Jan Kees, and Martijn Imf. 2014. “The Federal Democratic Republic of Ethiopia : Joint Staff Advisory Note on the Growth International Monetary Fund Joint Staff Advisory Note on Prepared by the Staffs of the International Development Association (IDA) and International Monetary Fund (IM,” no. 11.

Auffhammer, Maximilian, V. Ramanathan, and Jeffrey R. Vincent. 2012. “Climate Change, the Monsoon, and Rice Yield in India.” *Climatic Change* 111 (2): 411–24. doi:10.1007/s10584-011-0208-4.

Ayers, Jessica M., and Saleemul Huq. 2009. “The Value of Linking Mitigation and Adaptation: A Case Study of Bangladesh.” *Environmental Management* 43: 753–64. doi:10.1007/s00267-008-9223-2.

Bank, World. 2011. “Climate Risk and Adapation Country Profiles.” *World Development*, no. April.

Baraer, Michel, Bryan G Mark, Jeffrey M McKenzie, Thomas Condom, Jeffrey Bury, Kyung-In Huh, Cesar Portocarrero, Jesús Gómez, and Sarah Rathay. 2012. “Glacier Recession and Water Resources in Peru’s Cordillera Blanca.” *Journal of Glaciology* 58 (207). International Glaciological Society: 134–50.

Bassi, Andrea M, Cleopus Wang, Gilbert Kirui, Lucy Nyambura Njaramba, Douglas Otunga, Joel Nzioka Muema, Stephen N Ngugi, et al. 2011. *Strengthening Institutional Capacity for Integrated Climate Change Adaptation Comprehensive National Development Planning in Kenya Final Report*. http://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCcQFjAA&url=ftp://ftp.earthobservations.org/ID-Board/20140917-19_IDIB_meeting_Enschede/Meeting_documents/Kenya/Kenya Final Report v5.pdf&ei=wTBXVbPNKcmnsAGIw4GYCw&usg=AFQjCNG_uoWF4r.

Berg, a., N. De Noblet-Ducoudré, B. Sultan, M. Lengaigne, and M. Guimberteau. 2013. "Projections of Climate Change Impacts on Potential C4 Crop Productivity over Tropical Regions." *Agricultural and Forest Meteorology* 170. Elsevier B.V.: 89–102. doi:10.1016/j.agrformet.2011.12.003.

Berkhout, Frans, Julia Hertin, and David M. Gann. 2006. "Learning to Adapt: Organisational Adaptation to Climate Change Impacts." *Climatic Change* 78: 135–56. doi:10.1007/s10584-006-9089-3.

Berman, Rachel, Claire Quinn, and Jouni Paavola. 2012. "The Role of Institutions in the Transformation of Coping Capacity to Sustainable Adaptive Capacity." *Environmental Development* 2. Elsevier: 86–100. doi:10.1016/j.envdev.2012.03.017.

Biasutti, M. 2013. "Forced Sahel Rainfall Trends in the CMIP5 Archive." *Journal of Geophysical Research: Atmospheres* 118 (4): 1613–23. doi:10.1002/jgrd.50206.

Biesbroek, G. Robbert, Rob J. Swart, and Wim G M van der Knaap. 2009. "The Mitigation-Adaptation Dichotomy and the Role of Spatial Planning." *Habitat International* 33 (3). Elsevier Ltd: 230–37. doi:10.1016/j.habitatint.2008.10.001.

Birkmann, Joern, Matthias Garschagen, Peter Mucke, Almuth Schauder, Thomas Seibert, T. Welle, Jakob Rhyner, et al. 2014. "World Risk Report 2014," September. Bündnis Entwicklung Hilft and UNU-EHS. http://collections.unu.edu/view/UNU:2753#.VVh8DE4T0jM.mendeley.

Bluffstone, R, M Yesuf, B Bushie, and D Damite. 2008. "Rural Livelihoods, Poverty, and the Millennium Development Goals: Evidence from Ethiopian Survey Data." *Environment for Development Discussion Paper Series*, no. June: 38.

BMF. 2013. "BMF Schafft Planungssicherheit Beim Energie- Und Klimafonds (EKF)." http://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Oeffentliche_Finanzen/Bundeshaushalt/2013-04-25-ekf.html.

Bolio, Eduardo, Jaana Remes, Tomás Lajous, James Manyika, Morten Rossé, and Eugenia Ramirez. 2014. "A Tale of Two Mexicos: Growth and Prosperity in a Two-Speed Economy." *McKinsey Global Institute*, 92.

Bowen, Kathryn J, Fiona P Miller, Va Dany, and Sonia Graham. 2015. "The Relevance of a Coproductive Capacity Framework to Climate Change Adaptation : Investigating the Health and Water Sectors in Cambodia" 20 (1).

Brander, Luke, Pushpam Kumar, Makiko Yashiro, Greg Miles, Els Breet, Jens Burau, Paulo Nunes, and Lisa Brander. 2009. *FRESHWATER under THREAT SOUTH EAST ASIA*. Edited by UNEP.

Brazil Overview. 2014.

Breu, Marco, Richard Dobbs, Jaana Remes, Jaana Skilling, and Jinwook Kim. 2012. *Sustaining Vietnam ' S Growth : The Productivity Challenge. McKinsey Global Institute, McKinsey & Company.*

Briceño-Garmendia, C., C. Dominguez, and N. Pushak. 2011. *Mali's Infrastructure: A Continental Perspective*. doi:doi:10.1596/1813-9450-5599.

Brooks, N., N. Adger, and P. Kelly. 2005. "The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation." *Global Environmental Change* 15 (2): 151–63. doi:10.1016/j.gloenvcha.2004.12.006.

Brooks, Nick, W. Neil Adger, and P. Mick Kelly. 2005. "The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation." *Global Environmental Change* 15: 151–63. doi:10.1016/j.gloenvcha.2004.12.006.

Bush, Kathleen F., George Luber, S. Rani Kotha, R. S. Dhaliwal, Vikas Kapil, Mercedes Pascual, Daniel G. Brown, et al. 2011. "Impacts of Climate Change on Public Health in India: Future Research Directions." *Environmental Health Perspectives* 119 (6): 765–70. doi:10.1289/ehp.1003000.

Byrne, Dale M, and Duncan L Macfarlane. 2014. *Human Development Index 2013: Technical Notes*. *Report*. Vol. 30.

Cabrera, Edersson, Diana Marcela Vargas, Gustavo Galindo, María Claudia García, María Fernanda Ordóñez, Lina Katherine Vergara, Ana María Pachecho, Juan Carlos Rubiano, and Paola Giraldo. 2011. *Memoria Técnica de La Cuantificación de La Deforestación Histórica Nacional - Escalas Gruesa Y Fina*. *Director*.

Calderon, Silvia., Andrés Camilo. Alvarez, Ana María. Loboguerrero, Santiago. Arango, Katherine. Calvin, Tom. Kober, Kathryn. Daenzer, and Karen. Fisher-Vanden. 2015. "Achieving co2 Reductions in Colombia: Effects of Carbon Taxes and Abatement Targets." *Energy Economics*. Elsevier B.V. doi:10.1016/j.eneco.2015.05.010.

Calow, J, Ludi, E, Tucker, J. 2013. *Achieving Water Security: Lessons from Research in Water Supply, Sanitation, and Hygiene in Ethiopia*. Edited by Josephine Tucker Roger Calow, Eva Ludi.

Carew-Reid, Jeremy. 2008. *Rapid Assessment of the Extent and Impact of Sea Level Rise in Viet Nam*. http://www.icem.com.au/documents/climatechange/icem_slr/ICEM_SLR_final_report.pdf.

Case, Michael, Fitrian Ardiansyah, and Emily Spector. 2007. *Climate Change in Indonesia Implications for Humans and Nature*. *WWF*. http://assets.panda.org/downloads/inodesian_climate_change_impacts_report_14nov07.pdf.

Castiblanco, C., A. Ettera, and M. Aidec. 2013. "Oil Palm Plantations in Colombia: A Model of Future Expansion." *Environmental Science & Policy* 27: 172–83.

CAT. 2015. "Climate Action Tracker." at http://climateactiontracker.org/countries/india.html.

Chaturvedi, Rajiv Kumar, Jaideep Joshi, Mathangi Jayaraman, G. Bala, and N. H. Ravindranath. 2012. "Multi-Model Climate Change Projections for India under Representative Concentration Pathways." *Current Science* 103 (7): 791–802.

Chinowsky, Paul S, E Amy, Niko L Strzepek, and Kenneth Strzepek. 2012. "Working Paper No . 2012 / 80 Road Infrastructure and Climate Change in Vietnam."

Church, J.a., P.U. Clark, a. Cazenave, J.M. Gregory, S. Jevrejeva, a. Levermann, M.a. Merrifield, et al. 2013. "Sea Level Change." *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 1137–1216.

CICC. 2012. "Mexico's 5th National Communication."

CIF. 2012a. *Ethiopia SREP Fact Sheet*. doi:10.1016/S0140-6736(48)91584-0.

———. 2012b. *Scaling-Up Renewable Energy Program – Ethiopia Investment Plan (Final Draft)*.

"Climate Action Tracker." 2014.

Costa, L., D. Rybski, and J. P. Kropp. 2011. "A Human Development Framework for CO2 Reductions." *PLoS ONE* 6 (12): e29262.

Costa, Luís, Diego Rybski, and Jürgen P. Kropp. 2011. "A Human Development Framework for CO2 Reductions." *PLoS ONE*. doi:10.1371/journal.pone.0029262.

Crepin, Cristophe. 2013. *Getting a Grip on Climate Change in the Philippines: Executive Report*. http://www.worldbank.org/content/dam/Worldbank/document/EAP/Philippines/Final ExReport.pdf.

Crewett, W, a Bogale, and B Korf. 2008. "Land Tenure in Ethiopia: Continuity and Change, Shifting Rulers, and the Quest for State Control." *CAPRi Working Paper*, no. 91: 35.

CSO. 2014. *Energy Statistics*.

Dany, Va, Kathryn J. Bowen, and Fiona Miller. 2014. "Assessing the Institutional Capacity to Adapt to Climate Change: A Case Study in the Cambodian Health and Water Sectors." *Climate Policy* 14 (June): xx. doi:10.1080/14693062.2014.937385.

Dasgupta, Susmita, Benoit Laplante, Craig Meisner, David Wheeler, and Jianping Yan. 2009. "The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis." *Climatic Change* 93 (3-4): 379–88. doi:10.1007/s10584-008-9499-5.

De las Heras, A., I. Lake, A. Lovett, and C. Peres. 2012. "Future Deforestation Drivers in an Amazonian Ranching Frontier." *Journal of Land Use Science* 7 (4). http://www.tandfonline.com/doi/abs/10.1080/1747423X.2011.590234.

De Pinto, A., A. Haruna, Creamer. B., G. Hyman, M. Li, H-Y. Kwon, J. Valencia Garcia, et al. 2014. *Low Emission Development Strategies for Agriculture and Other Land Uses : The Case of*.

Denton, Fatima, and Thomas J. Wilbanks. 2014. "Climate-Resilient Pathways: Adaptation, Mitigation, and Sustainable Development," 1101–31.

Department of Environmental Affairs. 2014. *Long Term Adaptation Scenarios - South Africa*.

Deressa, Temesgen Tadesse, and Rashid M. Hassan. 2009. "Economic Impact of Climate Change on Crop Production in Ethiopia: Evidence from Cross-Section Measures." *Journal of African Economies* 18 (4): 529–54. doi:10.1093/jae/ejp002.

DNP. 2011. "Plan Nacional de Desarrollo 2010-2014, Mas Empleo, Menos Pobreza Y Mas Seguridad." *Prosperidad Para Todos, Departmento Nacional de Planeacion, Republica de Colombia*.

——. 2012. “Plan Naional de Adpatación Al Cambio Climático. ABC: Adaptación Bases Conceptuales. Marco Conceptual Y Lineamientos. Resumen Ejecutivo,” 12. http://www.sigpad.gov.co/sigpad/archivos/ABC_Cambio_Climatico.pdf.

——. 2014a. “Impactos Económicos Del Cambio Climático En Colombia – Síntesis.” *Departmento Nacional de Planeacion, Comision Economica Para America Latina Y El Caribe, Bianco Inter Americano de Dedesarrollo*.

——. 2014b. “Bases Del Plan Nacional de Desarrollo 2014-2018.” *Todos Por Un Nuevo Pais Paz Equidad Educacion - Department Nacional de Planeacion*.

DoE. 2013. *ANNUAL REPORT 2013/14 - Energy - South Africa*.

——. 2014. *Coal Resources - South Africa*. http://www.energy.gov.za/files/coal_frame.html.

Donat, M. G., L. V. Alexander, H. Yang, I. Durre, R. Vose, R. J H Dunn, K. M. Willett, et al. 2013. “Updated Analyses of Temperature and Precipitation Extreme Indices since the Beginning of the Twentieth Century: The HadEX2 Dataset.” *Journal of Geophysical Research: Atmospheres* 118 (5): 2098–2118. doi:10.1002/jgrd.50150.

Donges, J. F., R. V. Donner, N. Marwan, S. F. M. Breitenbach, K. Rehfeld, and J. Kurths. 2014. “Nonlinear Regime Shifts in Holocene Asian Monsoon Variability: Potential Impacts on Cultural Change and Migratory Patterns.” *Climate of the Past Discussions* 10 (2): 895–975. doi:10.5194/cpd-10-895-2014.

Dow, Kirstin., and T. Wilbanks. 2003. *Poverty And Vulnerabilities To Climate Change*. *Stockholm Enviroment Institute*. Vol. 2002.

EDFIETA. 2013. “Brazil - The World’s Carbon Markets: A Case Study Guide to Emissions Trading,” 1–8.

EIA. 2014. *South Africa Overview*.

Eliste, Paavo. 2013. 2013. “Cambodia - Study on Access to Financial Services for Small and Medium Agribusiness Enterprises in Cambodia (English).” *WB - Documents & Reports*, no. 82585. http://documents.worldbank.org/curated/en/2013/11/19122704/cambodia-study-access-financial-services-small-medium-agribusiness-enterprises-cambodia.

Ellis, K., J. Keane, A. Lemma, and L. Pichdara. 2013. *Low-Carbon Competitiveness in Cambodia*.

Environmental Defense Fund. 2013. *India The World’s Carbon Markets: A Case Study Guide to Emissions Trading*.

Environmental Protection Authority Ethiopia. 2011. *The Path to Sustainable Development – Ethiopia’s Climate-Resilient Green Economy Strategy*.

Eozenou, Patrick, Dorsati Madani, and Rob Swinkels. 2013. “Poverty , Malnutrition and Vulnerability in Mali,” no. August.

EPI. 2015a. “Environmental Performance Index.” *Yale University* Online: ht.

——. 2015b. “Environmental Performance Index.” *Yale University*.

Eriksen, S. H., and P. M. Kelly. 2007. “Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment.” *Mitigation and Adaptation Strategies for Global Change* 12: 495–524. doi:10.1007/s11027-006-3460-6.

Euromoney. 2014. “World Risk Average.” http://www.euromoneycountryrisk.com.

Faleiros, Gustavo. 2013. “Incremento de 24% En La Deforestación de La Amazonía.” http://oeco.org.br/mapas/27291-incremento-de-24-en-la-deforestacion-de-la-amazonia.

FAO. 2004. “Food Insecurity and Vulnerability in Viet Nam : Profiles of Four Vulnerable Groups Food Insecurity and Vulnerability in Viet Nam : Profiles of Four Vulnerable Groups,” no. 04.

——. 2010a. “Cambodia Forestry Outlook Study.” *The Forestry Administration, Phnom Penh, Food and Agriculture Organization of the United Nations - Regional Office for Asia and the Pacific.*

——. 2010b. “Global Forest Resources Assessment 2010 - Country Report Cambodia.” *Food and Agricultural Organization of the UN* 34.

——. 2013a. *FAO STATISTICAL YEARBOOK.*

——. 2013b. “Climate Change and Food Security in Nicaragua - Addressing the Linkages between Climate Change and Vulnerability to Food Insecurity.” http://www.fao.org/climatechange/59732/en/.

——. 2014a. “FAO Statistival Databases: Agriculture, Fisheries, Forestry, Nutrition.” *Food and Agricultural Organization of the UN.*

——. 2014b. “FAOSTAT 2014, FAO Statistical Databases: Agriculture, Fisheries, Forestry, Nutrition. Rome: FAO.” http://faostat.fao.org/.

——. 2015. “FAO - Food Security Indicators.” http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.VPSkKuFv9DQ.

Faramarzi, Monireh, Karim C. Abbaspour, Saeid Ashraf Vaghefi, Mohammad Reza Farzaneh, Alexander J.B. Zehnder, Raghavan Srinivasan, and Hong Yang. 2013. “Modeling Impacts of Climate Change on Freshwater Availability in Africa.” *Journal of Hydrology* 480 (February): 85–101. http://www.sciencedirect.com/science/article/pii/S0022169412010761.

FCP. 2014. “Oddar Meanchey REDD Project (Cambodia).” http://www.forestcarbonportal.com/project/oddar-meanchey-forest-carbon-project.

——. 2015. “Forest Carbon Portal.” http://www.forestcarbonportal.com/project/?KEYWORD=&PROJECT_STATUS=&PROJECT_TYPE=&PROJECT_SEEKING_SUPPORT=&PROPOSED_MARKET=&COUNTRY=Cambodia&PROJECT_STANDARD=.

FDRE. 2010. *ETHIOPIA’S AGRICULTURAL SECTOR POLICY AND INVESTMENT FRAMEWORK (PIF) 2010-2020. World Health.*

——. 2011a. *Crge Vision.* http://www.undp-aap.org/sites/undp-aap.org/files/Ethiopia_Climate Resilient Green Economy Vision.pdf.

——. 2011b. *Ethiopia’s Climate-Resilient Green Economy.* https://www.undp-aap.org/sites/undp-aap.org/files/Ethiopia CRGE Strategy Final.pdf.

FDRE-FCPC. 2011. “Forest Carbon Partnership Facility (FCPF) Readiness Preparation Proposal (R-PP) Country Submitting the Proposal : Federal Democratic Republic of Ethiopia,” 1–229.

Fekete, H., N. Höhne, M. Hagemann, T. Wehnert, F. Mersmann, M. Vieweg, M. Rocha, M. Schaeffer, and W. Hare. 2013. “Emerging Economies - Potentials, Pledges and Fair Shares of Greenhouse Gas Reductions.” *Umweltbundesamt, Climate Change* 6.

Fekete, H., F. Mersmann, and M. Vieweg. 2013. *Climate Change Mitigation in Emerging Economies: From Potentials to Actions*.

Ferrant, Sylvain, Yvan Caballero, Jérome Perrin, Simon Gascoin, Benoit Dewandel, Stéphanie Aulong, Fabrice Dazin, Shakeel Ahmed, and Jean-Christophe Maréchal. 2014. "Projected Impacts of Climate Change on Farmers' Extraction of Groundwater from Crystalline Aquifers in South India." *Scientific Reports* 4: 3697. doi:10.1038/srep03697.

Fischer-Kowalski, Marina, and Mark Swilling. 2011. *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*.

Flachsbarth, Insa, Bárbara Willaarts, Hua Xie, Gauthier Pitois, Nathaniel D. Mueller, Claudia Ringler, and Alberto Garrido. 2015. "The Role of Latin America's Land and Water Resources for Global Food Security: Environmental Trade-Offs of Future Food Production Pathways." *Plos One* 10: e0116733. doi:10.1371/journal.pone.0116733.

Fog, Lisbeth. 2013. "Colombia Failing to Put Climate Policy into Action - Scientists." *Thomson Reuters Foundation*.

FSP. 2012. *Environmental Sustainability Issues in Nicaragua*. http://www.fsdinternational.org/country/nicaragua/envissues.

Fukui, Akiko. 2014. "Market Mechanism Country Fact Sheet : Cambodia National Climate Change Policy in Cambodia." *IGES Climate and Energy Area, Cambodia's Climate Change Strategic Plan*.

Füssel, Hans-Martin. 2009. "Development and Climate Change - Review and Quantitative Analysis of Indices of Climate Change Exposure, Adaptive Capacity, Sensitivity, and Impacts." *Backgroundnote - World Development Report*. doi:10.1126/science.1183876.

GGGI. 2013. *Ethiopia Unveils Sectoral Reduction Mechanism Framework and Operational Manual for CRGE Facility*. http://gggi.org/ethiopia-unveils-sectoral-reduction-mechanism-framework-and-operational-manual-for-the-crge-facility/.

Gibbs, H K, a S Ruesch, F Achard, M K Clayton, P Holmgren, N Ramankutty, and J a Foley. 2010. "Tropical Forests Were the Primary Sources of New Agricultural Land in the 1980s and 1990s." *Proceedings of the National Academy of Sciences of the United States of America* 107 (38): 16732–37. doi:10.1073/pnas.0910275107.

Gilbert, Natasha. 2014. *Fibre Production Drives Deforestation in Indonesia*. http://www.nature.com/news/fibre-production-drives-deforestation-in-indonesia-1.15589.

Gilbertson T, Reyes O. 2009. "Carbon Trading How It Works and Why It Fails." *Critical Currents* 7: 210–11. doi:10.1038/343210a0.

GIZ, BAPPENAS –. 2012. *Development of the Indonesian NAMAs Framework*.

Gledhill, Richard, Jonathan Grant, and Lit Ping Low. 2008. *Review of Carbon Markets*. http://www.theclimategroup.org/_assets/files/carbon-markets-review.pdf.

GoG. 2011. "Government of Grenada. Government Officials Meet Flash Flood Victims of St.John." http://www.gov.gd/egov/news/2011/apr11/18_04_11/item_4/government_officals_meet_flood_victims.html.

———. 2012a. *Caribbean Regional Strategic Program for Climate Resilience (SPCR)*.

———. 2012b. *Grenada Strategic Program for Climate Resilience (SPCR)*.

———. 2014. “National Disaster Management.” http://www.gov.gd/departments/nadma.html.

———. 2015. “Government of Grenada.” http://www.gov.gd/.

GoK. 2014a. “Demining and Development.” http://cmac.gov.kh/en/article/demining-and-development.html.

———. 2014b. *Industrial Development Policy 2014-2024*. http://www.sa-asia.com/home/alert_perspective/pdf/industrial_development_policy_2014to2024.pdf.

Gollnow, Florian, and Tobia Lakes. 2014. “Policy Change, Land Use, and Agriculture: The Case of Soy Production and Cattle Ranching in Brazil, 2001–2012.” *Applied Geography* 55 (December): 203–11. http://www.sciencedirect.com/science/article/pii/S0143622814002045.

GoP. 2011. *National Nutrition Survey 2011 Government of Pakistan*.

———. 2013. *National Power Policy - Pakistan*. http://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCIQFjAA&url=http://www.ppib.gov.pk/National Power Policy 2013.pdf&ei=43tXVa2MMMyrsAG67YHQCQ&usg=AFQjCNEwCkghvV-NBYJcpTqcd8W00KYMrw&sig2=k0sZN7RCdTz_rGuPo9NZmQ&bvm=bv.93564037,d.bGg.

Government of Pakistan. 2012. “Pakistan: Flood Impact Assessment.” *Pakistan Economic Survey 2011-12*, 247–58.

Government of Vietnam. 2014. *SOCIALIST REPUBLIC OF VIETNAM MARKET READINESS PROPOSAL (MRP) Version October 10 , 2014*.

———. 2015. “GENERAL STATISTICS OFFICE of VIETNAM.” http://www.gso.gov.vn/Default_en.aspx?tabid=766.

Hansen, M C, R S DeFries, J R G Townshend, M Carroll, C Dimiceli, and R A Sohlberg. 2003. “Global Percent Tree Cover at a Spatial Resolution of 500 Meters: First Results of the MODIS Vegetation Continuous Fields Algorithm.” *Earth Interactions* 7 (10): 1–15.

Hare, B., N. Höhne, K. Blok, L. Jeffrey, J. Gütschow, and M. Schaeffer. 2014. “Climate Action Tracker.” Brazil.

Harmeling, Sven. 2012. “Global Climate Risk Index 2012: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2010 and 1991 to 2010.” *Germanwatch - Briefing Paper*.

Heger, Martin, Alex Julca, and Oliver Paddison. 2008. “Analysing the Impact of Natural Hazards in Small Economies The Caribbean Case.” *Natural Hazards*.

Hiç, C. 2014. “An Estimation of Food Waste and Its Implications on Food Security and Environment.” Humboldt University.

Hippler, Jochen. 2008. “Violence, Governance and Islam in Pakistan.” http://www.jochenhippler.de/html/violence-_governance-_islam_in_pakistan.html.

Hussein, Zekarias M. 2014. “Three Essays on Climate Change, Mitigation Policy, and Poverty in Developing Countries.” *Theses and Dissertations Available from ProQuest*. http://docs.lib.purdue.edu/dissertations/AAI3636134.

IADB. 2013. “Nicaragua - Access to Credit in Rural Production Chains.” *Inter-American Development Bank*.

ICAP. 2014. “International Carbon Action Partnership.” https://icapcarbonaction.com/ets-map.

ICEF. 2015. “ICEF - Monitor - Pakistan.” http://monitor.icef.com/category/regions/asia/pakistan.

Idupulapati, Rao., Jenet. Andreas, Tapasco. Jeimar, Chirinda. Ngonidzashe, and Rosenstock. Todd. 2015. “LivestockPlus : Supporting Low Emission Development for Livestock Sector in.”

IEA. 2014a. “International Energy Agency.” Brazil.

———. 2014b. “International Energy Agency.” http://www.iea.org/statistics.

———. 2015. “International Energy Agency Data.”

IFAD. 2013. “Cambodia - Environmental and Climate Change Assessment.” *Prepared for IFAD’s Country Strategic Opportunities Programme 2013-2018*, no. 3215- KH.

IIASA/FAO. 2012. *Global Agro-Ecological Zones (GAEZ v3.0)*. IIASA, Laxenburg and FAO, Rome.

Inter-American Development Bank. 2013. *Climatescope 2013*.

Interpol. 2013. “Guide to Carbon Trading Crime,” no. June.

IPCC. 2007. *Climate Change 2007: Working Group I: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. https://www.ipcc.ch/report/ar4/wg1/.

———. 2013. “Summary for Policymakers. In:” doi:10.1017/CBO9781107415324.

———. 2014. “The Climatic Research Unit Global Climate Dataset.” http://www.ipcc-data.org/observ/clim/cru_climatologies.html.

IPCC. 2013. *Climate Change 2013: Working Group I: The Physical Science Basis Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013*.

IPRI. 2014. *APPENDIX II : DETAILED METHODOLOGY AND DATA SOURCE INFORMATION Appendix II : Detailed Methodology and Data Source Information. Victoria*. http://internationalpropertyrightsindex.org/about.

Iqbal, Mohsin. 2013. “Climate Change Impacts on Agriculture and Building Resilience in Pakistan,” no. August.

Jacoby, Hanan., Mariano. Rabassa, and Emmanuel. Skoufias. 2014. “Distributional Implications of Climate Change in India.” *American J. of Agricultural Economics*, no. April: 1–56. doi:10.1093/ajae/aau084.

Jalloh, Abdulai, Gerald C Nelson, Timothy S Thomas, and Harold Roy-macauley. 2013. “Southern African Agriculture and Climate Change A Comprehensive Analysis.”

Jarvis, Andy, Julián Ramírez-villegas, Jeimar Tapasco, Carlos Navarro, Caitlin a Peterson, Emmanuel Zapata-caldas, and Myles J Fisher. 2013. "Are Climate Change Adaptation and Mitigation Options Eco-Efficient?" *Eco-Efficiency: From Vision to Reality (Issues in Tropical Agriculture Series)*, 252.

Jayasankar, C B, Sajani Surendran, and Kavirajan Rajendran. 2015. "Robust Signals of Future Projections of Indian Summer Monsoon Rainfall by IPCC AR5 Climate Models: Role of Seasonal Cycle and Interannual Variability." *Geophysical Research Letters*, 1–8. doi:10.1002/2015GL063659.Received.

Jiro Honda, Zaijin Zhan, and Alun Thomas. 2008. *The Federal Democratic Republic of Ethiopia : Selected Issues International Monetary Fund Washington , D . C . Selected Issues*.

Kamal, Uy. 2013. "Mitigation Potential, Progress and Way Forward." *3rd National Forum on Climate Change, Cambodia*.

Kang, Yinhong, Shahbaz Khan, and Xiaoyi Ma. 2009. "Climate Change Impacts on Crop Yield, Crop Water Productivity and Food Security - A Review." *Progress in Natural Science* 19 (12). National Natural Science Foundation of China and Chinese Academy of Sciences: 1665–74. doi:10.1016/j.pnsc.2009.08.001.

Karl, T R, and K E Trenberth. 2003. "Modern Global Climate Change." *Science* 302 (5651): 1719–23. doi:10.1126/science.1090228.

Katz, I. 2014. "México: Productividad – Por Isaac Katz." *HACER Latin American News*.

Kelbore, Zerihun Getachew. 2012. "An Analysis of the Impacts of Climate Change on Crop Yield and Yield Variability in Ethiopia." *Munich Personal RePEc Archive*, no. 39944. http://mpra.ub.uni-muenchen.de/49466/.

Keller, Marius. 2013. "CLIMATE RISK MANAGEMENT FOR THE HEALTH SECTOR IN NICARAGUA," no. January: 1–11. https://www.iisd.org/publications/climate-risk-management-health-sector-nicaragua.

Kelly, P M, and W N Adger. 2000. "Theory and Practice in Assessing Vulnerability To." *Climatic Change* 47: 325–52.

Kingdom of Cambodia. 2012. *The Cambodian Government's Achievements and Future Direction in Sustainable Development*.

Kjellstrom, Tord., Bruno. Lemke, Matthias. Otto, Olivia. Hyatt, David. Briggs, and Chris. Freyberg. 2015. *Climate Change and Increasing Heat Impacts on Labor Productivity Estimating Impacts on Labor Productivity*.

Klein, R., S. Huq, F. Denton, T. Downing, R. Richels, J. Robinson, and F. Toth. 2007. "Inter-Relationships between Adaptation and Mitigation." *Climate Policy*, 745–77.

Klein, R.J.T., and J. B. Smith. 2003. "Enhancing the Capacity of Developing Countries to Adapt to Climate Change-a Policy Relevant Research Agenda.pdf." In *Climate Change, Adaptive Capacity and Development*, edited by J. B. Smith, R.J.T. Klein, and S. Huq, 317–34. Imperial College Press.

Klein, Richard J T, E. Lisa F Schipper, and Suraje Dessai. 2005. "Integrating Mitigation and Adaptation into Climate and Development Policy: Three Research Questions." *Environmental Science and Policy* 8 (6): 579–88. doi:10.1016/j.envsci.2005.06.010.

Knoema. 2013. "World Travel and Tourism Council Data, 2013." http://knoema.com/WTTC2013/world-travel-and-tourism-council-data-2013.

Kriewald, S. 2012a. “A Dynamical Coupled Model for a Sustainable Urban-Bio-Region.” University of Potsdam.

———. 2012b. “A Dynamical Coupled Model for a Sustainable Urban-Bio-Region.” University of Potsdam.

Kriewald, S., T. Sterzel, P. Pradhan, A. García Cantú Ros, and J. Kropp. 2015. “The Contribution of the Urban Hinterland to Food Self-Sufficiency in Large Cities: A Global Overview.” *In Preparation*.

Kriewald, S., T. Sterzel, P. Pradhan, A. G. C. Ros, and J. P. Kropp. 2015. “The Contribution of the Urban Hinterland to Food Self-Sufficiency in Large Cities: A Global Overview.” *In Preparation*.

Kumar, K. Krishna, K. Kamala, Balaji Rajagopalan, Martin P. Hoerling, Jon K. Eischeid, S. K. Patwardhan, G. Srinivasan, B. N. Goswami, and Ramakrishna Nemani. 2011. “The Once and Future Pulse of Indian Monsoonal Climate.” *Climate Dynamics* 36 (11-12): 2159–70. doi:10.1007/s00382-010-0974-0.

Laderach, Peter, Mark Lundy, Andy Jarvis, Julian Ramirez, Emiliano Perez Portilla, Kathleen Schepp, and Anton Eitzinger. 2011. “The Economic, Social and Political Elements of Climate Change.” In *The Economic, Social and Political Elements of Climate Change*, edited by W. L. Filho, 703–23. Springer-Verlag Berlin Heidelberg. doi:10.1007/978-3-642-14776-0.

Lamb, W F, J K Steinberger, a Bows-Larkin, G P Peters, J T Roberts, and F R Wood. 2014. “Transitions in Pathways of Human Development and Carbon Emissions.” *Environmental Research Letters* 9 (1): 014011. doi:10.1088/1748-9326/9/1/014011.

Le Quéré, C., G. P. Peters, R. J. Andres, R. M. Andrew, T. a. Boden, P. Ciais, P. Friedlingstein, et al. 2014. “Global Carbon Budget 2013.” *Earth System Science Data* 6: 235–63. doi:10.5194/essd-6-235-2014.

Le Quéré, C., G. P. Peters, R. J. Andres, R. M. Andrew, T. Boden, P. Ciais, P. Friedlingstein, et al. 2013. “Global Carbon Budget 2013.” *Earth System Science Data Discussions* 6: 689–760. doi:10.5194/essdd-6-689-2013.

Lemke, Peter, Jian Ren, Richard B Alley, Ian Allison, Jorge Carrasco, Gregory Flato, Yoshiyuki Fujii, et al. 2007. “Observations: Changes in Snow, Ice and Frozen Ground.” In *Climate Change 2007: The Physical Science Basis; Summary for Policymakers, Technical Summary and Frequently Asked Questions. Part of the Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, 337–83. Cambridge University Press, Cambridge, UK.

Li, W., R. Fu, N. Negrón Juárez, and K. Fernandes. 2008. “Observed Change of the Standardized Precipitation Index, Its Potential Cause and Implications to Future Climate Change in the Amazon Region.” *Phil. Trans. R. Soc. B* 363: 1767–72.

Liscow, Zachary D. 2013. “Do Property Rights Promote Investment but Cause Deforestation? Quasi-Experimental Evidence from Nicaragua.” *Journal of Environmental Economics and Management* 65 (2). Elsevier: 241–61. doi:10.1016/j.jeem.2012.07.001.

Lissner, Tabea K., Dominik E. Reusser, Tobia Lakes, and Jürgen P. Kropp. 2014. “A Systematic Approach to Assess Human Wellbeing Demonstrated for Impacts of

Climate Change." *Change and Adaptation in Socio-Ecological Systems* 1 (1): 98–110. doi:10.2478/cass-2014-0010.

Loarie, Scott R., David B. Lobell, Gregory P. Asner, Qiaozhen Mu, and Christopher B. Field. 2011. "Direct Impacts on Local Climate of Sugar-Cane Expansion in Brazil." *Nature Climate Change* 1 (2). Nature Publishing Group: 105–9. doi:10.1038/nclimate1067.

Lobell, David B, Wolfram Schlenker, and Justin Costa-Roberts. 2011. "Climate Trends and Global Crop Production since 1980." *Science* 333 (6042). American Association for the Advancement of Science: 616–20.

Loening, Josef L., Dick Durevall, and Yohannes a. Birru. 2009. "Inflation Dynamics and Food Prices in an Agricultural Economy The Case of Ethiopia," no. June: 4969.

Loman, Herwin. 2014. *How to Tackle the " Custo Brasil " Tax System and Red Tape. Rabobank | Economic Research Department*. Vol. 135.

López-Carr, David, and Jason Burgdorfer. 2013. "Deforestation Drivers: Population, Migration, and Tropical Land Use." *Environment* 55 (1): 37–41. doi:10.1080/00139157.2013.748385.

MacKellar, Neil., Mark. New, and Chris. Jack. 2014. "Observed and Modelled Trends in Rainfall and Temperature for South Africa: 1960-2010." *South African Journal of Science* 110 (7-8): 1–13. doi:10.1590/sajs.2014/20130353.

Mads. 2010. "Estrategia Colombiana de Desarrollo Bajo En Carbono ECDBC." *Ministerio de Ambiente Y Desarrollo Sostenible*, 7.

Malhi, Yadvinder., Luiz. Aragão, David. Galbraith, Chris. Huntingford, Rosie. Fisher, Przemyslaw. Zelazowski, Stephen Sitch, Carol McSweeney, and Patrick Meir. 2009. "Exploring the Likelihood and Mechanism of a Climate-Change-Induced Dieback of the Amazon Rainforest." *Proceedings of the National Academy of Sciences of the United States of America* 106 (49): 20610–15. doi:10.1073/pnas.0804619106.

Mali, World Bank and the Republic of. 2013. *JOINT IDA-IMF STAFF ADVISORY NOTE ON THE GROWTH AND POVERTY REDUCTION STRATEGY PAPER 2012–17*. http://documentos.bancomundial.org/curated/es/2013/04/17629300/mali-joint-ida-imf-staff-advisory-note-growth-poverty-reduction-strategy-paper-2012-17.

Malik, Amin Aslam, Pervez Amir, Shakeel Ahmad Ramay, and Vaqar Ahmad. 2011. *National Economic and Environment Development Study - Pakistan*. http://unfccc.int/files/adaptation/application/pdf/pakistanneeds.pdf.

MARENA. 2011a. *Estrategia Nacional Ambiental Y Del Cambio Climático Plan de Acción 2010-2015*.

———. 2011b. *Segunda Comunicación Nacional Sobre Cambio Climático Nicaragua (Second National Communication on Climate Change Nicaragua)*.

Marengo, J. 2004. "Interdecadal Variability and Trends of Rainfall across the Amazon Basin." *Theoretical and Applied Climatology* 78 (1-3): 79–96. doi:10.1007/s00704-004-0045-8.

Marengo, J., Sin. Chou, Gillian. Kay, Lincoln. Alves, José. Pesquero, Wagner. Soares, Daniel. Santos, et al. 2012. "Development of Regional Future Climate Change Scenarios in South America Using the Eta CPTEC/HadCM3 Climate Change Projections: Climatology and Regional Analyses for the Amazon, S{ã}o Francisco and the Paran{á} River Basins." *Climate Dynamics - Observational, Theoretical and Computational Research on the Climate System* 38 (9-10). Springer: 1829–48.

Marengo, J., C. Nobre, S. Chou, J. Tomasella, G. Sampaio, L. Alves, G. Obregón, W. Soares, R. Betts, and G. Kay. 2011. “Dangerous Climate Change in Brazil: A Brazil-UK Analysis of Climate Change and Deforestation Impacts in the Amazon.” *INPE, Met Office Hadley Centre*, 56. http://www.ccst.inpe.br/relatorio_eng.pdf.

Margulis, Sergio, Carolina Burle Schmidt Dubeux, J. Marcovitch, A. Barbieri, A. Szklo, B. B. N. Strassburg, C. Azzoni, et al. 2011. *The Economics of Climate Change in Brazil: Costs and Opportunities*. FEAUSP Sao Paulo.

Marschke, Melissa J., and Fikret Berkes. 2006. “Exploring Strategies That Build Livelihood Resilience: A Case from Cambodia.” *Ecology and Society* 11 (1). doi:42.

Martin, Gayle H., and Obert Pimhidzai. 2013. *Education and Health Services in Kenya. Data for Results and Accountability*.

Mateche, Damaris. 2011. *The Cycle of Drought in Kenya a Looming Humanitarian Crisis*. http://www.issafrica.org/iss-today/the-cycle-of-drought-in-kenya-a-looming-humanitarian-crisis.

Matocha, J., G. Schroth, T. Hills, and D. Hole. 2012. “Integrating Climate Change Adaptation and Mitigation through Agroforestry and Ecosystem Conservation.” *Advances in Agroforestry* 9: 31–67. doi:10.1007/978-94-007-4676-3.

Mcginn, Dennis., David. Green, Rainer. Hinrichs-rahlwes, Steve. Sawyer, Marietta. Sander, Richard Taylor, Irene Giner-reichl, Sven. Teske, Harry. Lehmann, and David. Hales. 2013. *Renewables 2013 GLOBAL STATUS REPORT 2013*.

Mcsweeney, C, M New, and G Lizcano. 2010. “UNDP Climate Change Country Profiles: Mali,” 1–27.

McSweeney, C., M. New, G. Lizcano, and X. Lu. 2010a. “The UNDP Climate Change Country Profiles.” *Bulletin of the American Meteorological Society* 91 (2): 157–66. doi:10.1175/2009BAMS2826.1.

———. 2010b. “The UNDP Climate Change Country Profiles - Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries.” *Bulletin of the American Meteorological Society* 91: 157–66. doi:10.1175/2009BAMS2826.1.

Mendoza, Maria Emilinda T, Bui Dung The, Heng Naret, Vicente G Ballaran, and Kim B Arias. 2012. “Assessing Vulnerability to Climate Change Impacts in Cambodia , the Philippines and Vietnam: An Analysis at the Commune and Household Level,” no. November: 21–22.

Ministerio del Ambiente. 2010. “Plan de Acción de Adaptación Y Mitigación Frente Al Cambio Climático,” 148. http://sinia.minam.gob.pe/index.php?accion=verElemento&idElementoInformacion=1064&verPor=&idTipoElemento=8&idTipoFuente=#.

Ministry of Climate Change (MoCC) Pakistan. 2012. *National Climate Change Policy*.

Ministry of Finance (MoF) Indonesia. 2012. *Indonesia’s First Mitigation Fiscal Framework – Full Report*.

MoCC. 2012. *National Climate Change Policy Government of Pakistan*. http://www.mocc.gov.pk/gop/index.php?q=aHR0cDovLzE5Mi4xNjguNzAuMTM2L21vY2xjL2ZybURldGFpbHMuYXNweD9pZD0xMyZhbXA7b3B0PXBvbGljaWVz.

MoE. 2013. *A Corruption Risk Assessment for REDD + in Kenya*. http://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCcQFjAA&url=http://www.unredd.net/index.php?option=com_docman&task=doc_download&gid=11014&Itemid=53&ei=YiZXVfrMM4WqU7evgLgF&usg=AFQjCNFIZj0YB3wiwUXXRtq71TOfIbRI5g&sig2=jTz5p99f8bOq1kSovPR.

MoE -. 2014. "Colombia Contará Con Recursos Cercanos a Los 64 Millones de Dólares Para Invertir En La Reducción de La Deforestación En La Amazonía." https://www.minambiente.gov.co/index.php/component/content/article/2-noticias/1130-colombia-contara-con-recursos-cercanos-64-millones-dolares-para-invertir-en-planes-de-reforestacion.

Mohammed, E., S. Wang, and G. Kawaguchi. 2013. *Making Growth Green and Inclusive: The Case of Cambodia*. Paris.

Mokria, Mulugeta, Aster Gebrekirstos, Ermias Aynekulu, and Achim Bräuning. 2015. "Tree Dieback Affects Climate Change Mitigation Potential of a Dry Afromontane Forest in Northern Ethiopia." *Forest Ecology and Management* 344. Elsevier B.V.: 73–83. doi:10.1016/j.foreco.2015.02.008.

Morton, Douglas C, Ruth S DeFries, Yosio E Shimabukuro, Liana O Anderson, Egidio Arai, Fernando del Bon Espirito-Santo, Ramon Freitas, and Jeff Morisette. 2006. "Cropland Expansion Changes Deforestation Dynamics in the Southern Brazilian Amazon." *Proceedings of the National Academy of Sciences of the United States of America* 103 (39): 14637–41. doi:10.1073/pnas.0606377103.

Moss, R H, a L Brenkert, and E L Malone. 2001. "Vulnerability to Climate Change: A Quantitative Approach." *Prepared for the U.S. Department of Energy*, no. September: 88. www.globalchange.umd.edu.

Moss, R., M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgiziuli, et al. 2008. "Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts and Response Strategies." *Technical Summary. Intergovernmental Panel of Climate Change, Geneva*, 132. http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=940991.

Muhammad, Kanwar, Javed Iqbal, and Maqsood Ahmad. 2011. "Mainstreaming Pakistan for Reducing Emissions from Deforestation and Forest Degradation Plus (REDD +): The Way Forward to Readiness Phase," no. September.

Murphy, D, J Parry, and M Keller. 2013. "FEATURE: Priority CCD Actions for Pakistan." http://cdkn.org/2013/04/climate-change-adaptation-and-mitigation-options-for-pakistan/.

Nachmany, M., S. Fankhauser, T. Townshend, M. Collins, T. Landesman, A. Matthews, C. Pavese, K. Rietig, P. Schleifer, and J. Setzer. 2014a. *The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 33 Countries*.

Nachmany, M., Samuel Fankhauser, T. Townshend, M. Collins, T. Landesman, A. Matthews, C. Pavese, K. Rietig, P. Schleifer, and J. Setzer. 2014b. *The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries*. London.

Nachmany, M., S. Frankhauser, T. Townshend, M. Collins, T. Landesman, A. Matthews, C. Pavese, K. Rietig, P. Schleifer, and J. Setzer. 2014a. *The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries. GLOBE International and the Grantham Research Institute*. Vol. 4. London School of Economics.

———. 2014b. "The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries. Fourth Edition." *London: GLOBE International and the Grantham Research Institute, London School of Economics* 4.

Næss, Lars Otto, Guri Bang, Siri Eriksen, and Jonas Vevatne. 2005. "Institutional Adaptation to Climate Change: Flood Responses at the Municipal Level in Norway." *Global Environmental Change* 15: 125–38. doi:10.1016/j.gloenvcha.2004.10.003.

NAMA Database. 2012. "NAMAs in the Energy Generation and End-Use Sectors in Peru."

NAMA Registry. 2014. *NAMA Indonesia*.

NASA. 2014. "Maps » Population Density Grid, v3 (1990, 1995, 2000)." http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density/maps?facets=region:africa&facets=theme:population.

———. 2015. "Socioeconomic Data and Applications Center (sedac)." http://sedac.ciesin.columbia.edu/data/set/grump-v1-settlement-points.

NEDA. 2011. *National Economic and Development Authority - Philippines*. http://www.neda.gov.ph/?p=1128.

Nema. 2013. "Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation, Kenya," no. March: 58. http://www.tech-action.org/index.php?option=com_k2&view=item&task=download&id=50_d71ec22bdb343fe8ece6db565338feac.

NFSCC. 2010. *The Phil National Climate Change Policy*.

Nicholls, R J, and N Mimura. 1998. "Regional Issues Raised by Sea Level Rise and Their Policy Implications." *Climate Research* Vol. 11: 5–18.

Nisar Ahmad Khan. 2014. "Pakistan Forest Resources." http://pakistangeographic.com/forests.html.

Nurse, L.A., R. McLean, J. Agard, L. Briguglio, V. Duvat-Magnan, N. Pelesikoti, E. Tompkins, and A. Webb. 2014. "Chapter 29. Small Islands." *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandre*, 1613–54. http://www.ipcc.ch/report/ar5/wg2/.

O'Keefe, P., K. Westgate, and B. Wisner. 1976. "Taking the Naturalness out of Natural Disasters." *Nature* 260: 566–67.

Obregón, G., A. Díaz, G. Rosas, G. Avalos, D. Acuña, C. Oria, A. Llacza, and R. Miguel. 2009. *ESCENARIOS CLIMÁTICOS EN LA CUENCA DEL RÍO SANTA PARA EL AÑO 2030 SENAMHI Servicio Nacional de Meteorología E Hidrología Amelia Díaz Gabriela Rosas Grinia Avalos Delia Acuña Clara Oria Alan Llacza La Presente Publicación Forma Parte Del El Marco de La Seg*.

OECD. 2014a. *OECD StatExtracts*.

———. 2014b. "OECD Stat Extracts." *Organisation for Economic Co-Operation and Development*.

———. 2015. "Aid Activities Targeting Global Environmental Objectives." http://stats.oecd.org/Index.aspx?DataSetCode=RIOMARKERS.

Oregon Public Broadcasting. 2005. “Meet the New Heroes: Fabio Rosa.” http://www.pbs.org/opb/thenewheroes/meet/rosa.html.

Ostrom, e. Schlager, E. 1996. *Rights to Nature - Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment*. Edited by and Karl-Goran Maler Susan Hanna, Carl Folke. IslandPress. http://islandpress.org/rights-nature.

Oxfam International. 2014. “The BRICS Development Bank: Why the World’s Newest Global Bank Must Adopt a Pro-Poor Agenda.” http://www.policyinnovations.org/ideas/policy_library/data/01686.

PAGASA. 2011. *Climate Change Scenarios in the Philippines*.

Palanisamy, H., M. Becker, B. Meyssignac, O. Henry, and a. Cazenave. 2012. “Regional Sea Level Change and Variability in the Caribbean Sea since 1950.” *Journal of Geodetic Science* 2 (2): 125–33. doi:10.2478/v10156-011-0029-4.

Parry, M., O. Canziani, J. Palutikof, and Co-authors. 2007. “Technical Summary.” In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by M. L. Parry, O. F. Canziani, J. P. Palutikof, P J Van Der Linden, and C E Hanson, 23–78. Cambridge University Press, Cambridge, UK.

Partnership for Market readiness. 2013. “Participants.” https://www.thepmr.org/content/participants.

Patnaik, Ila, and Madhavi Pundit. 2014. “Is InDIA ’ S LonG-Term TrenD GrowTh DecLInInG ? Adb Economics Working Paper Series,” no. 424.

Pattanayak, Anubhab, and K. S. Kavi Kumar. 2014. “Weather Sensitivity of Rice Yield: Evidence From India.” *Climate Change Economics* 05 (04): 1450011. doi:10.1142/S2010007814500110.

Pearce, Caroline, and Sébastien Fourmy. 2009. *Delivering Education For All in Mali*. https://www.oxfam.org/en/research/delivering-education-all-mali-report.

Pedercini, M., H. Kanamaru, and S. Derwisch. 2012. “Potential Impacts of Climate Change on Food Security in Mali Potential Impacts of Climate Change on Food Security in Mali,” 36.

Peters, Glen P., Gregg Marland, Corinne Le Quéré, Thomas Boden, Josep G. Canadell, and Michael R. Raupach. 2011. “Rapid Growth in CO2 Emissions after the 2008–2009 Global Financial Crisis.” *Nature Climate Change* 2 (January): 2–4. doi:10.1038/nclimate1332.

Philippines Climate Change Commission. 2011. *National Climate Change Action Plan 2011-2028*. http://www.emb.gov.ph/portal/Portals/54/Images/NCCAP.pdf.

Pike, Andy, Stuart Dawley, and John Tomaney. 2010. “Resilience, Adaptation and Adaptability.” *Cambridge Journal of Regions, Economy and Society* 3 (1): 59–70. doi:10.1093/cjres/rsq001.

Pinto, Hilton Silveira, Eduardo Delgado Assad, J. Zullo Jr., S. R. de M. Evangelista, A. F. Otavian, A. M. H. de Avian, B. A. Evangelista, et al. 2008. *Global Warming and the New Geography of Agricultural Production in Brazil. The British Embassy*.

Porter, J.R., L. Xie, a.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso. 2014. “Climate Change 2014: Impacts, Adaptations, and Vulnerability. Food Security and Food Production Systems,” 485–533.

Pradhan, P., G. Fischer, H. van Velthuizen, D. E. Reusser, and J. P. Kropp. 2015a. “Closing Yield Gaps: How Sustainable Can We Be?” *PLoS ONE* 10 (6). doi:10.1371/journal.pone.0129487.

———. 2015b. “Closing Yield Gaps: How Sustainable Can We Be?” *PloS One* Under-Revi.

Pradhan, P., M. Lüdeke, D. Reusser, and J. Kropp. 2013. “Embodied Crop Calories in Animal Products.” *Environmental Research Letters* 8 (4): 044044. doi:10.1088/1748-9326/8/4/044044.

———. 2014a. “Food Self-Sufficiency across Scales: How Local Can We Go?” *Environmental Science & Technology* 48 (16): 9463–70. doi:10.1021/es5005939.

———. 2014b. “Food Self-Sufficiency across Scales: How Local Can We Go?” *Environmental Science & Technology* 48 (16): 9463–70. doi:10.1021/es5005939.

Pradhan, P., D. E. Reusser, and J. P. Kropp. 2013. “Embodied Greenhouse Gas Emissions in Diets.” *PLoS ONE* 8 (5): e62228.

PRONicaragua. 2012. *Nicaragua Powers up on Green Energy*.

Rabassa, J. 2009. “Impact of Global Climate Change on Glaciers and Permafrost of South America, with Emphasis on Patagonia, Tierra Del Fuego, and the Antarctic Peninsula.” *Developments in Earth Surface Processes* 13. Elsevier: 415–38.

Rabatel, Antoine, Bernard Francou, A Soruco, J Gomez, B Cáceres, J L Ceballos, R Basantes, et al. 2013. “Current State of Glaciers in the Tropical Andes: A Multi-Century Perspective on Glacier Evolution and Climate Change.” *The Cryosphere* 7 (1). Copernicus GmbH: 81–102.

Rademaekers, K., L. Eichler, J. Berg, M. Obersteiner, and P. Havlik. 2010. *Study on the Evolution of Some Deforestation Drivers and Their Potential Impacts on the Costs of an Avoiding Deforestation Scheme Authors :* http://bookshop.europa.eu/en/study-on-the-evolution-of-some-deforestation-drivers-and-their-potential-impacts-on-the-costs-of-an-avoiding-deforestation-scheme-pbKH3013413/.

Rahmato, D. 2004. “Searching for Tenure Security? The Land System and New Policy Initiatives in Ethiopia.” *Discussion Paper*.

Ramirez, Di, J. Ordaz, J. Mora, A. Acosta, and B. Serna. 2010. “Nicaragua : Efectos Del Cambio Climático Sobre La Agricultura.” *Comision Economica Para America Latina Y El Caribe (CEPAL)*, 1–91.

Ramirez-Villegas, J., M. Salazar, A. Jarvis, and C. Navarro-Racines. 2012. “A Way Forward on Adaptation to Climate Change in Colombian Agriculture: Perspectives towards 2050.” *Climatic Change* 115: 611–28. doi:10.1007/s10584-012-0500-y.

Rashid, Shahidur. 2010. “Staple Food Prices in Ethiopia.” *Variation in Staple Food Prices: Causes, Consequence, and Policy Options*, no. January.

Ray, Deepak K. 2013. “Dry Season Precipitation over the Mesoamerican Biological Corridor Is More Sensitive to Deforestation than to Greenhouse Gas Driven Climate Change.” *Climatic Change* 119 (3-4): 775–83. doi:10.1007/s10584-013-0753-0.

RCG. 2014. “Cambodia Climate Change Strategic Plan 2014 – 2023 2013.” http://www.camclimate.org.kh/en/policies/nccc-news/197-cccsp-2014-2023-kh-en-final.html.

Reddy, R., M. Bruhn, and C. Tan. 2013. "Financial Capability in Mexico: Results from a National Survey on Financial Behaviors, Attitudes, and Knowledge." *The World Bank* 82134.

Reuters. 2014. "Britain to Fund South African Carbon Trading Experiment." http://www.reuters.com/article/2014/07/14/safrica-carbontrading-idUSL6N0PP3F220140714.

Roberts, Dianne. 2013. *Status of Disaster Status of Disaster*.

Rocklo, J., K. Bao Giang, H. Van Minh, K. Ebi, M. Nilsson, K. Sahlen, and Weinehall. L. 2014. "Local Research Evidence for Public Health Interventions against Climate Change in Vietnam." *Global Health Action - Climate Change and Health in Vietnam* 1: 1–3. http://www.globalhealthaction.net.

Rockström, Johan, W L Steffen, Kevin Noone, Åsa Persson, F Stuart Chapin Iii, J Rockstrom, W Steffen, et al. 2009. "Planetary Boundaries: Exploring the Safe Operating Space for Humanity Recommended Citation" 14 (2). http://pdxscholar.library.pdx.edu/iss_pub.

Rostow, W.W. 1990. *The Stages of Economic Growth*. Cambridge University Press, Cambridge, UK.

Rothenberger, Dieter. 2014. *Integrated Climate Change Adaptation Strategies in Grenada*. https://www.giz.de/en/worldwide/27030.html.

Ruri, Consultants. 2013. *Analysis of Drivers and Underlying Causes of Forest Cover Change in the Various Forest Types*. www.kenyaforestservice.org/documents/redd/Analysis of Drivers of Deforestation &forest Degradation in Kenya.pdf.

Sachs, Jeffrey D. 2012. "From Millennium Development Goals to Sustainable Development Goals." *The Lancet* 379 (9832): 2206–11. doi:10.1016/S0140-6736(12)60685-0.

Sachs, Jeffrey D., and Andrew M. Warner. 2001. "The Curse of Natural Resources." *European Economic Review* 45 (4-6): 827–38. doi:10.1016/S0014-2921(01)00125-8.

Sampaio, Gilvan, Carlos Nobre, Marcos Heil Costa, Prakki Satyamurty, Britaldo Silveira Soares-Filho, and Manoel Cardoso. 2007. "Regional Climate Change over Eastern Amazonia Caused by Pasture and Soybean Cropland Expansion." *Geophysical Research Letters* 34: L17709. doi:10.1029/2007GL030612.

Sanabria, J, and Jean-Paul Lhomme. 2013. "Climate Change and Potato Cropping in the Peruvian Altiplano." *Theoretical and Applied Climatology* 112 (3-4). Springer: 683–95.

Sanabria, J, J Marengo, and M Valverde. 2009. "Escenarios de Cambio Climático Con Modelos Regionales Sobre El Altiplano Peruano (Departamento de Puno)." *Rev Peruana Geo-Atmosf{é}rica* 1: 133–48.

Sari, Agus P., Martha Maulidya, Ria N. Butarbutar, Rizka E. Sari, and Wisnu Rusmantoro. 2007. "Executive Summary: Indonesia and Climate Change," no. March: 1–9.

Schewe, J., J. Heinke, D. Gerten, I. Haddeland, N. W. Arnell, D. B. Clark, R. Dankers, et al. 2014. "Multimodel Assessment of Water Scarcity under Climate Change." *Proceedings of the National Academy of Sciences of the United States of America* 111 (9): 3245–50. doi:10.1073/pnas.1222460110.

Schlager, E., Ostrom, E. 1992. "Property-Rights Regimes and Natural Resources: A Conceptual Analysis." *Land Economics* 68 (3): 249–62. http://www.jstor.org/stable/3146375?seq=1#page_scan_tab_contents.

SEI. 2009. "Economics of Climate Change Kenya," 82. doi:doi:10.1201/b16969-7.

SENAMHI. 2005a. *Escenarios Del Cambio Climático En El Perú Al 2050: Cuenca Del Río Piura [Climate Change Scenarios in Peru for 2050: The Piura River Basin]. Programa de Cambio Climático Y Calidad de Aire (PROCLIM) and Servicio Nacional de Meteorología E Hidrología (SENAM.* http://ipcc-wg2.gov/AR5/report/njlite?chapter=&page=60.

———. 2005b. "Escenarios Del Cambio Climático En El Perú Al 2050: Cuenca Del Río Piura." *Programa de Cambio Climático Y Caladidad de Aire & Servicio Nacional de Meteorología E Hidrología*.

———. 2007. *Escenarios de Cambio Climático En La Cuenca Del Río Urubamba Para El Año 2100 [Climate Change Scenarios in the Urubamba River Basin by 2100] [Rosas, G., G. Avalos, A. Díaz, C. Oria, L. Metzger, D. Acuña, and R.M. San Martin (eds.)]. Parte Del Proyecto Reg.* http://ipcc-wg2.gov/AR5/report/njlite?chapter=&page=60.

———. 2009a. "Escenarios de Cambio Climático En La Cuenca Del Río Mantaro Para 2100." *Servicio Nacional de Meteorología E Hidrología & Centro de Predicción Numérica – CPN*.

———. 2009b. "Escenarios de Cambio Climático En La Cuenca Del Río Urubamba Para El Año 2100." *Servicio Nacional de Meteorología E Hidrología & Centro de Predicción Numérica – CPN*.

———. 2009c. "Climate Scenarios for Peru to 2030." *National Meteorology and Hydrology Service & Numerical Prediction Center – CPN*, 1–136.

Shehzad, Khuram, Faisal M. Qamer, M. S. R. Murthy, Sawaid Abbas, and Laxmi D. Bhatta. 2014. "Deforestation Trends and Spatial Modelling of Its Drivers in the Dry Temperate Forests of Northern Pakistan — A Case Study of Chitral." *Journal of Mountain Science* 11 (5): 1192–1207. doi:10.1007/s11629-013-2932-x.

Shoaib, Muhammad. 2013. *PAKISTAN ECONOMIC SURVEY 2012-13 Chapter 14 - Energy*. http://www.finance.gov.pk/survey_1213.html.

Simoes, A, and C Hidalgo. 2014. "Products Exported by Countries in 2012 - The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence." https://atlas.media.mit.edu/en/.

Singh, Kartikeya. 2011. "India's Emissions in a Climate Constrained World." *Energy Policy* 39 (6). Elsevier: 3476–82. doi:10.1016/j.enpol.2011.03.046.

Sintayehu, G., T. Kassa, and M. Bogale. 2014. "Potential Impacts of Climate Change on the Hydrology and Water Resources Availability of Didessa Catchment, Blue Nile River Basin, Ethiopia." *Journal of Geology & Geosciences*. http://www.omicsgroup.org/journals/potential-impacts-of-climate-change-on-the-hydrology-and-water-resources-availability-of-didessa-catchment-blue-nile-river-basin-ethiopia-2329-6755.1000193.php&&aid=39046.

Siregar, H. 2008. *Problems Facing the Indonesian Economy and Current Policy Responses for Agriculture*. Hanoi.

Skjeflo, Sofie. 2013. "Measuring Household Vulnerability to Climate Change-Why Markets Matter." *Global Environmental Change* 23 (6). Elsevier Ltd: 1694–1701. doi:10.1016/j.gloenvcha.2013.08.011.

Smit, Barry, and Mark W Skinner. 2002. "Adaptation Options in Agriculture To Climate Change : A." *Mitigation and Adaptation Strategies for Global Change* 7 (UNFCCC 1992): 85–114. doi:10.1023/A:1015862228270.

Smit, Barry, and Johanna Wandel. 2006. "Adaptation, Adaptive Capacity and Vulnerability." *Global Environmental Change* 16: 282–92. doi:10.1016/j.gloenvcha.2006.03.008.

Smith, P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E. A. Elsiddig, H. Haberl, et al. 2014. "Agriculture, Forestry and Other Land Use (AFOLU)." In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by R. Edenhofer, O., J. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, and T. Zwickel and J.C. Minx (Savolainen, S. Schlömer, C. von Stechow, 811–922. Cambridge University Press, Cambridge, UK. doi:10.1016/j.phrs.2011.03.002.

Song, Xiao-Peng, Chengquan Huang, Sassan S. Saatchi, Matthew C. Hansen, and John R. Townshend. 2015. "Annual Carbon Emissions from Deforestation in the Amazon Basin between 2000 and 2010." *Plos One* 10 (5): e0126754. doi:10.1371/journal.pone.0126754.

Souvignet, Maxime, Patrick Laux, Jim Freer, Hannah Cloke, Dang Quang Thinh, Tran Thuc, Johannes Cullmann, et al. 2014. "Recent Climatic Trends and Linkages to River Discharge in Central Vietnam." *Hydrological Processes* 28 (4): 1587–1601. doi:10.1002/hyp.9693.

Stefan, Schultz. 2013. "Energiewende-Fonds: Crash Des Emissionshandels Verursacht Milliardenloch." *Spiegel Online*. http://www.spiegel.de/wirtschaft/soziales/energiewende-fonds-milliardenloch-durch-emissionshandel-a-888415.html.

Steffen, Will, Katherine Richardson, Johan Rockström, Sarah Cornell, Ingo Fetzer, Elena Bennett, R. Biggs, et al. 2015. "Planetary Boundaries: Guiding Human Development on a Changing Planet." *Science* 347 (6223). doi:10.1126/science.1259855.

Steinberger, Julia K, J Timmons Roberts, Glen P Peters, and Giovanni Baiocchi. 2012. "Pathways of Human Development and Carbon Emissions Embodied in Trade." *Nature Climate Change* 2 (2). Nature Publishing Group: 81–85.

Steinberger, Julia K., Fridolin Krausmann, Michael Getzner, Heinz Schandl, and Jim West. 2013. "Development and Dematerialization: An International Study." *PLoS ONE* 8 (10). doi:10.1371/journal.pone.0070385.

Stern, D. I. 2004. "The Rise and Fall of the Environmental Kuznets Curve." *World Development* 32 (8): 1419–39.

Stern, N H. 2007. "The Economics of Climate Change: The Stern Review," 712. doi:10.1257/aer.98.2.1.

Suroso, Djoko, Tri Wahyu Hadi, Ibnu Sofian, Hamzah Latief, Oman Abdurahman, Hendra Julianto, and Budhi Setiawan. 2005. "VULNERABILITY OF SMALL ISLANDS TO

CLIMATE CHANGE IN INDONESIA : A Case Study of Lombok Island , Province of Nusa Tenggara Barat."

Taffesse, Alemayehu Seyoum, Paul Dorosh, and Sinafikeh Asrat. 2012. "Crop Production in Ethiopia: Regional Patterns and Trends." *ESSP II Research Note* 11 (Essp Ii). http://essp.ifpri.info/publications/.

Techo, Samdech Akka Moha Sena Padei. 2014. "Cambodia Outlook Brief Brief* 2014,."

Teixeira, Edmar I., Guenther Fischer, Harrij van Velthuizen, Christof Walter, and Frank Ewert. 2013. "Global Hot-Spots of Heat Stress on Agricultural Crops due to Climate Change." *Agricultural and Forest Meteorology* 170 (March): 206–15. http://www.sciencedirect.com/science/article/pii/S0168192311002784.

The Economist. 2013. "Carbon Trading ETS, RIP?" *The Economist*. http://www.economist.com/news/finance-and-economics/21576388-failure-reform-europes-carbon-market-will-reverberate-round-world-ets.

The Redd Desk. 2013. "REDD in Peru," http://theredddesk.org/countries/peru/.

The World Bank. 2015. "Global Consumption Database South Africa." Global Consumption Database.

Thomas, S., P. Dargusch, S. Harrison, and J. Herbohn. 2010. "Why Are There so Few Afforestation and Reforestation Clean Development Mechanism Projects?" *Land Use Policy* 27 (3): 880–87.

Thomas, Timothy S, Ros Bansok, and Cathy Chiang. 2013. "Cambodian Agriculture Adaptation to Climate Change Impact," no. August.

Tompkins, Emma L. 2005. "Planning for Climate Change in Small Islands: Insights from National Hurricane Preparedness in the Cayman Islands." *Global Environmental Change* 15: 139–49. doi:10.1016/j.gloenvcha.2004.11.002.

Toribio, Laura, and Lilian Hernandez. 2014. "El Gasto No Refleja Mejor Educación." *Excelsior*.

Traore, Bouba., Marc. Corbeels, Mark T. van Wijk, Mariana C. Rufino, and Ken E. Giller. 2013. "Effects of Climate Variability and Climate Change on Crop Production in Southern Mali." *European Journal of Agronomy* 49 (August): 115–25. http://www.sciencedirect.com/science/article/pii/S1161030113000518.

Undesa. 2012. "Climate Change Adaptation in Grenada: Water Resources, Coastal Exosystems and Renewable Energy."

UNDP. 2009. *Human Development Report - 2009 Overcoming Barriers : Human Mobility and Development. Human Development*. Vol. 331. New York: Palgrave Macmillan. doi:10.1016/S0883-153X(98)80004-0.

———. 2010. "Mainstreaming Climate Change in Nicaragua - Screening for Risks and Opportunities." *Integracion Del Cambio Climatico; UNDP Nicaragua*.

———. 2011. "Cambodia Human Development Report 2011. Building Resilience: The Future of Rural Livelihoods in the Face of Climate Change," 224. http://hdr.undp.org/en/content/building-resilience.

———. 2013a. "Climate Risk Management for the Health Sector in Nicaragua." *Bureau for Crisis Prevention and Recovery*, 1–11.

———. 2013b. "Cambio Climático Puede Poner En Riesgo El Progreso En El Desarrollo Humano Del Perú. Available."

———. 2013c. *Cambio Climático Puede Poner En Riesgo El Progreso En El Desarrollo Humano Del Perú*. http://www.pe.undp.org/content/peru/es/home/presscenter/articles/2013/11/28/cambio-clim-tico-puede-poner-en-riesgo-el-progreso-en-el-desarrollo-humano-del-per-/.

———. 2014a. "CDM Opportunities and Challenges in Ethiopia | UNDP's Capacity Development in Ethiopia." http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/strategic_themes/climate_change/carbon_finance/CDM/ethiopia.html.

———. 2014b. "Human Development Report 2014 - Sustaining Human Progress: Reducing Vulnerability and Building Resilience." *United Nations Development Programme*.

UNEP. 2012. "Deforestation Costing Kenyan Economy Millions of Dollars Each Year and Increasing Water Shortage Risk." *Press Releases November 2012*.

UNESCO. 2013. *Strategic Groundwater Reserves Found in Northern Kenya*. http://www.unesco.org/new/en/media-services/single-view/news/strategic_groundwater_reserves_found_in_northern_kenya/#.VVckN0bK5e9.

UNFCCC. 2000. *The Philippine's Initial National Communication on Climate Change*.

———. 2003. *Pakistan ' S Initial National Communication on Climate Change*. http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=3928#beg.

———. 2007. *Mexico's Third National Communication to the United Nations Framework Convention on Climate Change*.

———. 2010. *Second National Communications of Brazil to the United Nation's Framework Convention on Climate Change*.

———. 2011a. "Compilation of Information on Nationally Appropriate Mitigation Actions to Be Implemented by Parties Not Included in Annex I to the Convention." *Unfccc* AWGLCA/201: 1–49.

———. 2011b. *Indonesia Second National Communication under the United Nations Framework Convention on Climate Change*.

———. 2011c. *South Africa's Second National Communication on Climate Change*.

———. 2012. "Non-Annex I National Communications." http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php.

———. 2014a. "Appendix II - Nationally Appropriate Mitigation Actions of Developing Country Parties." http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php.

———. 2014b. *NAMA Registry*.

———. 2014c. "CDM Registry." https://cdm.unfccc.int.

Union of Concerned Scientists. 2011. "Climate Hot Map - Peru." *Climate Hot Map - Global Warming Effects around the World*.

UNISDR. 2011. "Global Assessment Report on Disaster Risk Reduction: Revealing Risk , Redefining Development," 178. http://www.preventionweb.net/english/hyogo/gar/2011/en/home/download.html.

United Nations. 2013. *The Millennium Development Goals Report 2013*. doi:ISBN 978-92-1-101284-2.

———. 2014. *World Urbanization Prospects: The 2014 Revision*.

Un-REDD. 2014. "UN-REDD Cambodia." http://www.un-redd.org/AboutUNREDDProgramme/NationalProgrammes/Cambodia/tabid/6896/Default.

UN-REDD. 2014. "UN-REDD in Indonesia." http://www.un-redd.org/CountryActions/Indonesia/tabid/987/language/en-US/Default.aspx.

———. 2015. "UN-REDD - Phillipines." http://www.un-redd.org/NationalProgrammes/Philippines/tabid/6897/Default.aspx.

UNU-EHS. 2011. *World Risk Report 2011*.

Urrutia, Rocío, and Mathias Vuille. 2009. "Climate Change Projections for the Tropical Andes Using a Regional Climate Model: Temperature and Precipitation Simulations for the End of the 21st Century." *Journal of Geophysical Research: Atmospheres (1984–2012)* 114 (D2). Wiley Online Library.

Villacís, Marcos. 2008. "Ressources En Eau Glaciaire Dans Les Andes d'Equateur En Relation Avec Les Variations Du Climat : Le Cas Du Volcan Antisana." *Docteur de l'UNiversite Mintpellier II*.

WB. 2009. *Grenada: Dealing with the Aftermath of Hurricane Ivan.* http://reliefweb.int/report/grenada/grenada-dealing-aftermath-hurricane-ivan.

WBGU. 2009a. *Solving the Climate Dilemma: The Budget Approach*. *Special Report*. http://www.wbgu.de/en/special-reports/sr-2009-budget-approach/.

———. 2009b. *Solving the Climate Dilemma: The Budget Approach*. *Special Report*. http://www.wbgu.de/wbgu_sn2009_en.pdf.

WFB. 2015. "Country Reports." https://www.cia.gov/library/publications/resources/the-world-factbook/.

Wilbanks, Thomas J., and Jayant Sathaye. 2007. "Integrating Mitigation and Adaptation as Responses to Climate Change: A Synthesis." *Mitigation and Adaptation Strategies for Global Change* 12: 957–62. doi:10.1007/s11027-007-9108-3.

Willems, Stéphane, and Kevin Baumert. 2003. "Institutional Capacity and Climate Actions." *OECD Environment Directorate International Energy Agency* 5. OECD.

Wint, W., and R. Robinson. 2007. *Gridded Livestock of the World*. Edited by FAO. *Organization*.

World Bank. 2008. "Retracting Glacier Impacts Economic Outlook in the Tropical Andes." *Latin America & Caribbean*.

———. 2009a. "Country Note on Climate Change Aspects in Agriculture." *Climate Change Aspects in Agriculture*, 2000–2007. http://siteresources.worldbank.org/INTLAC/Resources/Climate_HondurasWeb.pdf.

———. 2009b. *Country Note on Climate Change Aspects in Agriculture - Nicaragua. Context*. http://siteresources.worldbank.org/INTLAC/Resources/Climate_HondurasWeb.pdf.

———. 2011. *Economics of Adaptation to Climate Change*. http://climatechange.worldbank.org/sites/default/files/documents/EACC_Ethiopia.pdf.

———. 2013a. *Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience*.

———. 2013b. "Impacts of Climate Change on Brazilian Agriculture" 68774.

———. 2013c. "Global Consumption Database - Cambodia."

———. 2013d. "BioCarbon Fund Initiative for Sustainable Forest Landscapes."

———. 2013e. "Kenya Economic Update: Time to Shift Gears," no. No. 8: 106. www.worldbank.org/kenya/keu.

———. 2013f. *Mexico Seeks to Adapt to Climate Change and Mitigate Its Effects*. http://www.worldbank.org/en/results/2013/04/17/mexico-seeks-to-adapt-to-climate-change-and-mitigate-its-effects.

———. 2013g. "Mexico Seeks to Adapt to Climate Change and Mitigate Its Effects."

———. 2013h. *Nicaragua: A Renewable Energy Paradise in Central America*.

———. 2014a. "A WORLD BANK COUNTRY STUDY Where Have All The Poor Gone ? Cambodia Poverty Assessment 2013," no. 2nd Edition, April 2014.

———. 2014b. *Worldwide Governance Indicator*.

———. 2014c. *New Poverty Frontier in Indonesia: Reduction Slows, Inequality Rises*. http://www.worldbank.org/en/news/feature/2014/09/23/new-poverty-frontier-in-indonesia-reduction-slows-inequality-rises.

———. 2014d. *Poverty Reduction in Indonesia Slows, Inequality Increases: World Bank Reports*. http://www.worldbank.org/en/news/press-release/2014/09/23/poverty-reduction-slows-inequality-increases-world-bank-reports.

———. 2014e. "Global Consumption Database Kenya." http://datatopics.worldbank.org/consumption/country/Kenya.

———. 2014f. "World Bank Data."

———. 2015a. "The World Bank - Data." *The World Bank Group*.

———. 2015b. "Worldwide Governance Indicators." http://info.worldbank.org/governance/wgi/index.aspx#home.

World Energy Council. 2013. "Hydropower in Colombia."

WRI. 2011. "CAIT 2.0 - WRI's Climate Data Explorer." *World Resource Institute*. http://cait2.wri.org.

———. 2014. "CAIT Data Explorer." *World Resource Institute*. http://cait2.wri.org.

Wuttge, Eva. 2012. "Programme on Integrated Climate Change Adaptation Strategies." http://cigrasp.pik-potsdam.de/adaptations/programme-on-integrated-climate-change-adaptation-strategies.

Xue, Zuo., J. Paul. Liu, and Qian. Ge. 2011. “Changes in Hydrology and Sediment Delivery of the Mekong River in the Last 50 Years: Connection to Damming, Monsoon, and ENSO.” *Earth Surface Processes and Landforms* 36 (3): 296–308. doi:10.1002/esp.2036.

Yohe, Gary, and Richard S J Tol. 2002. “Indicators for Social and Economic Coping capacityF Moving toward a Working de Nition of Adaptive Capacity.” *Global Environmental Change* 12: 25–40.

Yu, Bingxin, Tingju Zhu, Clemens Breisinger, and Nguyen Manh Hai. 2010. “Impacts of Climate Change on Agriculture and Policy Options for Adaptation The Case of Vietnam.” *IFPRI Discussion*, no. August: 1–23.

Ziervogel, Gina, Mark New, Emma Archer van Garderen, Guy Midgley, Anna Taylor, Ralph Hamann, Sabine Stuart-Hill, Jonny Myers, and Michele Warburton. 2014. “Climate Change Impacts and Adaptation in South Africa.” *Wiley Interdisciplinary Reviews: Climate Change* 5 (5): 605–20. doi:10.1002/wcc.295.

Zimmer, Anne, Michael Jakob, and Jan Steckel. 2010. “What Motivates Vietnam to Strive for a Low-Carbon Economy?” *Energy for Sustainable Development* 24 (1995): 19–32.