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Status, potential and challenges

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Abstract: Mitigating agricultural greenhouse gas emissions in Argentina

This report describes the current state of agriculture in Argentina with regard to the greenhouse gas (GHG) emissions it produces and the climate and other socio-economic policies that it faces. We identify options that could reduce agricultural emissions and estimate the mitigation potential of those options. Finally, we identify barriers to adopting these mitigation strategies and some possible solutions to overcoming those barriers.

Kurzbeschreibung: Länderbericht Argentinien

Dieser Bericht beschreibt den aktuellen Stand der Landwirtschaft in Argentinien im Hinblick auf die von ihr verursachten Treibhausgasemissionen sowie den aktuellen sozioökonomischen und klimapolitischen Rahmen für den landwirtschaftlichen Sektor. Wir identifizieren Optionen für Maßnahmen, die die landwirtschaftlichen Emissionen reduzieren könnten, und diskutieren das Minderungspotenzial dieser Optionen. Abschließend werden Hindernisse für die Umsetzung dieser Minderungsoptionen und einige mögliche Lösungen zur Überwindung dieser Hindernisse aufgezeigt.

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List of abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
BAU	Business as usual
CBAM	Carbon Border Adjustment Mechanism
CH_4	Methane
CO_2	Carbon dioxide
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross domestic product
GHG	Greenhouse gas
GNCC	National Climate Change Cabinet
IPCC	Intergovernmental Panel on Climate Change
LTS	Long-Term Strategy
LULUCF	Land Use, Land-Use Change and Forestry
NDC	Nationally Determined Contributions (in Paris Agreement)
NUE	Nitrogen Use Efficiency
N_2O	Nitrous oxide
MAGyP	Ministry of Agriculture, Livestock and Fisheries
MAyDS	Ministry of Environment and Sustainable Development
MBGI	National Forest Management Plan with Integrated Livestock
MRV	Measurement, reporting and verification
$MtCO_2e$	Mega tonnes of CO_2 equivalent
OECD	Organisation for Economic Co-operation and Development
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax

Summary

The aim of this report is to identify possible emission mitigation options in the agricultural sector, the barriers towards implementing those options and provide some recommendations on how to overcome those barriers. The report begins with a description of the current state of agriculture in Argentina with regard to the GHG emissions it produces, and the climate and socioeconomic policies that shape the sector. We then identify three key options that could reduce agricultural emissions and estimate their mitigation potential. Finally, we identify barriers that act at the farm, national, international and consumer level along with possible steps to overcoming those barriers.

The agriculture sector in Argentina plays a key role in the country's economy and its development trajectory. Argentina makes up 2.2% of total global arable land (Alston et al., 2010) and is a top international producer and exporter of certain agricultural commodities, including soybean and soy derivatives, bovine meat, cereals, and dairy products. Despite the large extent of land dedicated to agriculture, the country's high use of mechanization means a low share of agricultural employment in relation to total workforce; it amounted to 2% in 2019. Although the agricultural landscape continues to be dominated by small-scale producers in terms of the sheer number of farmers, many family-farming practices have been replaced with large-scale production systems. Currently, 1% of companies own approx. 40% of Argentina's agricultural land (Hiba, 2021a).

In 2019, Argentina's agricultural sector produced an estimated 149 mega tonnes of CO_2 equivalent ($MtCO_2e$) of GHG emissions, representing approx. 42% of total national emissions (excl. Land Use, Land-Use Change and Forestry (LULUCF)). As livestock production plays a critical and growing role in Argentina's agricultural economy, as it does for the sector's GHG emissions. Emissions from livestock make up the majority of Argentina's agricultural GHG emissions (~80%). Furthermore, indirect livestock emissions related to feed grain production and fossil fuel demand have increased over the last years due to intensified production and higher shares of feedlot operations (FAO and NZAGRC, 2017). Argentina has significantly expanded the extent of land used for agricultural purposes. Between 2001 and 2014, Argentina lost 12% of its forest area (World Bank Group, 2016), corresponding to very high LULUCF emissions in the same time frame – close to 100 $MtCO_2e$ annually. Deforestation in Argentina has been primarily driven by industrial-scale agricultural land expansion for soy used as livestock feed, biofuels, or exports, while cattle production played a secondary role (World Bank Group, 2016).

Three mitigation options were identified for detailed analysis based on the contribution of different emission sources, the potential for socio-economic and environmental co-benefits, the country-specific context of the agricultural sector (see Section 1), and the general feasibility for implementation.

For Argentina, we selected the following three mitigation measures:

- Implementing silvopastoral systems on native forest
- Livestock emissions intensity reduction – reproductive disease prevention
- Livestock emissions intensity reduction – feed optimisation.

According to our calculations, the implementation of these prioritised mitigation options could contribute to a reduction in livestock emissions of 16 $MtCO_2e$ compared to 2019 levels (assuming constant levels of production) and silvopastoral systems could result in 25 $MtCO_2e$ in

avoided emissions from deforestation compared to a 2030 baseline. Argentina's beef production, however, is predicted to increase in line with development and economic objectives. If production levels were to increase following historical trends, Argentina would see a significant increase in beef cattle enteric fermentation emissions that would entirely offset any emission reductions from improved livestock management and lead to an absolute emissions increase.

There are critical barriers that hinder the implementation of measures to achieve the outlined mitigation potentials and impair other activities to reduce GHG emissions in the agricultural sector. Current national policies encourage practices such as monocropping that are aligned with economic rather than climate objectives. This puts pressure on farmers to increase cattle herd size and subsequently leads to deforestation to expand the livestock frontier or to grow more feed. Argentina has a significant share of smallholder production systems, which presents challenges to disseminating knowledge and investing in new technologies, and many mitigation measures do not provide sufficient direct economic returns if implemented on a small-scale. The traditional and cultural values revolving around beef production and consumption can also pose a challenge towards shifting livestock production practices or exploring alternative proteins.

To accelerate the uptake and implementation of the measures described in this report, it is key to 1) more clearly translate national mitigation priorities to the agricultural sector and in turn ensure that all agricultural policies are aligned with mitigation objectives, 2) improve the regulatory framework on existing laws and policies, and 3) implement sectoral policies to comprehensively address the areas in which most mitigation is possible. These mitigation policies and incentives should also foster co-benefits between adaptation and mitigation in the agricultural sector. More specifically, Argentina could include a sectoral target for agriculture and LULUCF in its Nationally Determined Contributions (in Paris Agreement) (NDC) and Long-Term Strategy (LTS) that explicitly reflects mitigation requirements, improve the enforcement of the Native Forest Law, facilitate further capacity building and access to funds for smallholders, and consider policies that shift livestock production towards a low-carbon model and thereby avoid economic transition risks.

Zusammenfassung

Ziel dieses Berichts ist es, mögliche Optionen zur Emissionsminderung im Agrarsektor Argentiniens zu identifizieren, die Hindernisse bei der Umsetzung dieser Optionen aufzuzeigen und einige Empfehlungen zur Überwindung dieser Hindernisse zu geben. Der Bericht beginnt mit einer Beschreibung der aktuellen Situation der argentinischen Landwirtschaft im Hinblick auf die von ihr verursachten Treibhausgasemissionen und den klimapolitischen sozioökonomischen Kontext, der den Sektor prägt. Anschließend werden drei wichtige Optionen zur Verringerung der landwirtschaftlichen Emissionen aufgezeigt und ihr Minderungspotenzial abgeschätzt. Schließlich werden Hindernisse auf betrieblicher, nationaler, internationaler und Verbraucherebene sowie mögliche Schritte zur Überwindung dieser Hindernisse aufgezeigt.

Der argentinische Agrarsektor spielt eine Schlüsselrolle für die Wirtschaft des Landes und seinen Entwicklungspfad. Argentinien beansprucht 2,2 % der gesamten weltweiten Ackerfläche (Alston et al., 2010) und ist ein international führender Produzent und Exporteur bestimmter landwirtschaftlicher Erzeugnisse, darunter Sojabohnen und anderer Sojaprodukte, Rindfleisch, Getreide und Milchprodukte. Trotz der großen landwirtschaftlichen Nutzfläche ist der Anteil der Beschäftigten in der Landwirtschaft an der Gesamtzahl der Erwerbstätigen mit 2 % im Jahr 2019 gering, da die Landwirtschaft stark mechanisiert ist (Abbildung 3). Obwohl die Landschaft in Bezug auf die schiere Anzahl der Landwirte und Landwirtinnen weiterhin von Subsistenzwirtschaft dominiert wird, sind viele Familienbetriebe durch groß angelegte Produktionssysteme ersetzt worden. Derzeit besitzen 1 % der Unternehmen rund 40 % der landwirtschaftlichen Nutzfläche Argentiniens (Hiba, 2021a).

Im Jahr 2019 verursachte der argentinische Agrarsektor schätzungsweise 149 $MtCO_2e$ an THG-Emissionen, was etwa 42 % der gesamten nationalen Emissionen (ohne LULUCF) entspricht. Da die Viehzucht eine entscheidende und wachsende Rolle in der argentinischen Agrarwirtschaft spielt, ist sie auch für einen Großteil der THG-Emissionen des Sektors verantwortlich: Die Emissionen aus der Viehhaltung machen ungefähr 80 % der argentinischen landwirtschaftlichen THG-Emissionen aus. Darüber hinaus sind die indirekten Emissionen aus der Viehhaltung im Zusammenhang mit der Produktion von Futtergetreide und der Nachfrage nach fossilen Brennstoffen in den letzten Jahren gestiegen, weil sich die Produktion intensiviert hat und die Anzahl der Mastbetriebe gestiegen ist (FAO and NZAGRC, 2017). Argentinien hat die landwirtschaftlich genutzte Fläche erheblich ausgeweitet. Zwischen 2001 und 2014 hat Argentinien 12 % seiner Waldfläche verloren (World Bank Group, 2016), was im gleichen Zeitraum zu sehr hohen LULUCF-Emissionen führte - fast 100 $MtCO_2e$ jährlich. Die Entwaldung in Argentinien wurde in erster Linie durch die Ausweitung der landwirtschaftlichen Nutzflächen im industriellen Maßstab für Soja als Viehfutter, Biokraftstoffe oder Exporte vorangetrieben, während die Rinderproduktion selbst eine untergeordnete Rolle spielte (World Bank Group, 2016).

Auf der Grundlage des Beitrags verschiedener Emissionsquellen, des Potenzials für sozioökonomische und ökologische Zusatznutzen, des länderspezifischen Kontexts des Agrarsektors (siehe Abschnitt 1) und der allgemeinen Durchführbarkeit wurden drei Minderungsoptionen für eine detaillierte Analyse ausgewählt.

Für Argentinien haben wir die folgenden drei Minderungsmaßnahmen ausgewählt:

- Einführung von silvopastoralen Systemen in heimischen Wäldern
- Verringerung der Emissionsintensität in der Viehzucht - Prävention von Fortpflanzungserkrankungen

- Verringerung der Emissionsintensität in der Viehhaltung - Optimierung der Fütterung.

Unseren Berechnungen zufolge könnte die Umsetzung dieser Minderungsoptionen zu einer Verringerung der Emissionen aus der Viehwirtschaft um 16 $MtCO_2e$ im Vergleich zu 2019 beitragen (unter der Annahme eines konstanten Produktionsniveaus), und silvopastorale Systeme könnten zu 25 $MtCO_2e$ an vermiedenen Emissionen aus der Entwaldung im Vergleich zu einem Vergleichsszenario bis 2030 führen. Prognosen sagen jedoch voraus, dass die argentinische Rindfleischproduktion im Einklang mit den Entwicklungs- und Wirtschaftszielen steigen wird. Sollte das Produktionsniveau entsprechend den historischen Trends ansteigen, würde in Argentinien ein erheblicher Anstieg der Emissionen aus der enterischen Fermentation von Rindern zu verzeichnen sein, der jegliche Emissionsreduzierung durch eine verbesserte Viehhaltung vollständig ausgleichen und zu einem absoluten Emissionsanstieg führen würde.

Es gibt kritische Hindernisse, die die Umsetzung von Maßnahmen zur Erreichung der beschriebenen Minderungspotenziale behindern und andere Aktivitäten beeinträchtigen, die die Treibhausgasemissionen im Agrarsektor verringern könnten. Die derzeitige nationale Politik fördern Praktiken wie den Monokulturanbau, die eher auf wirtschaftliche als auf klimatische Ziele ausgerichtet sind. Dies setzt die Landwirte unter Druck, ihre Viehherden zu vergrößern, was wiederum zur Abholzung führt, um die Viehzucht auszuweiten oder mehr Futtermittel anzubauen. In Argentinien gibt es einen hohen Anteil an kleinbäuerlichen Produktionssystemen, was die Verbreitung von Wissen und Investitionen in neue Technologien erschwert, und viele Klimaschutzmaßnahmen bieten keine ausreichenden direkten wirtschaftlichen Erträge, wenn sie in kleinem Maßstab umgesetzt werden. Die traditionellen und kulturellen Werte, die mit der Rindfleischproduktion und dem Rindfleischkonsum verbunden sind, können ebenfalls ein Hindernis für eine Umstellung der Viehzucht oder die Erforschung alternativer Proteine darstellen.

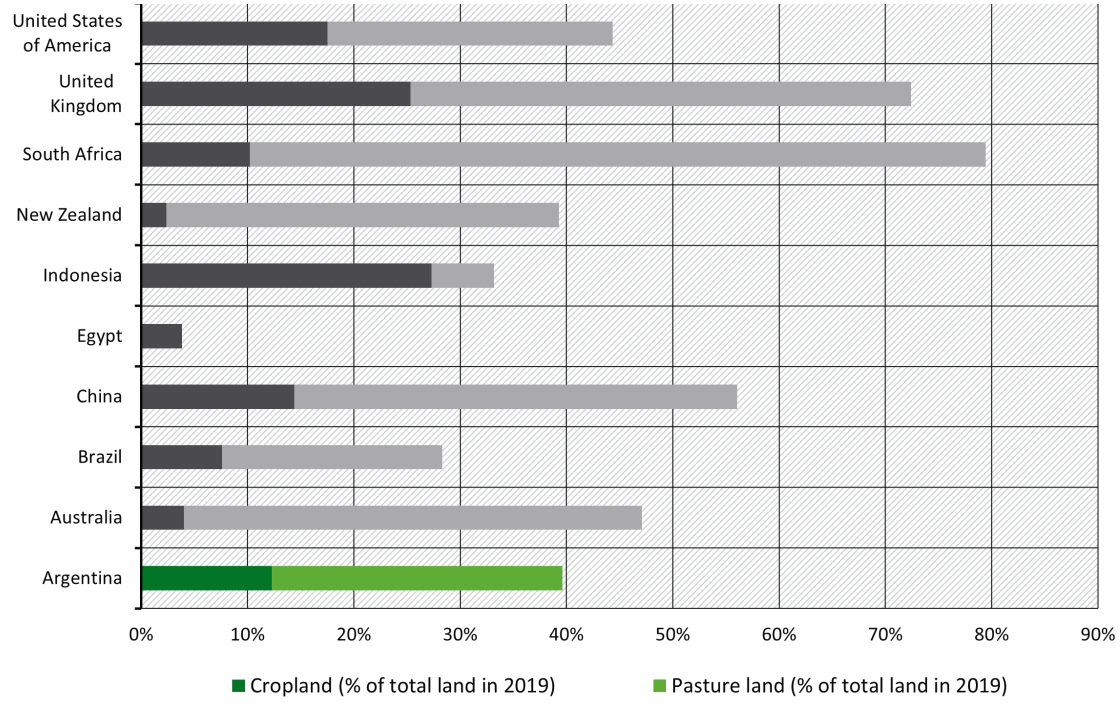
Um die Übernahme und Umsetzung der in diesem Bericht beschriebenen Maßnahmen zu beschleunigen, ist es wichtig, 1) die nationalen Klimaschutzprioritäten klarer auf den Landwirtschaftssektor zu übertragen, um sicherzustellen, dass alle agrarpolitischen Maßnahmen mit den Klimaschutzzielen in Einklang gebracht werden, 2) den Rechtsrahmen für bestehende Gesetze und politische Maßnahmen zu verbessern und 3) sektorale politische Maßnahmen umzusetzen, um die Bereiche, in denen die meisten Klimaschutzmaßnahmen möglich sind, umfassend zu berücksichtigen. Diese Minderungsmaßnahmen und -anreize sollten auch den gemeinsamen Nutzen von Anpassung und Minderung im Agrarsektor fördern. Konkret könnte Argentinien ein sektorales Ziel für Landwirtschaft und LULUCF in sein NDC und LTS aufnehmen, das die Minderungsanforderungen widerspiegelt. Außerdem könnte es die Durchsetzung des Gesetzes über die einheimischen Wälder verbessern, den weiteren Aufbau von Kapazitäten und den Zugang zu Finanzmitteln für Kleinbauern und Kleinbäuerinnen erleichtern und politische Maßnahmen in Erwägung ziehen, die die Viehzucht auf ein kohlenstoffarmes Modell umstellen und dadurch wirtschaftliche Übergangsrisiken vermeiden.

1 General characteristics of the agriculture sector and policy landscape

1.1 Characteristics of the agricultural sector in Argentina

The agriculture sector in Argentina plays a key role in the country's economy and its development trajectory. Arable land represents just under 40% of total land area, of which 12% is dedicated cropland and 27% pasture and range land (Figure 1). Recent trends indicate an overall increase in cropland, while pastureland has been declining (ibid). The sown area increased from approx. 32 million hectares in the 2006/2007 season to 39 million hectares in the 2015/2016 season.

Figure 1: Agricultural land as a share of total country area (2019)

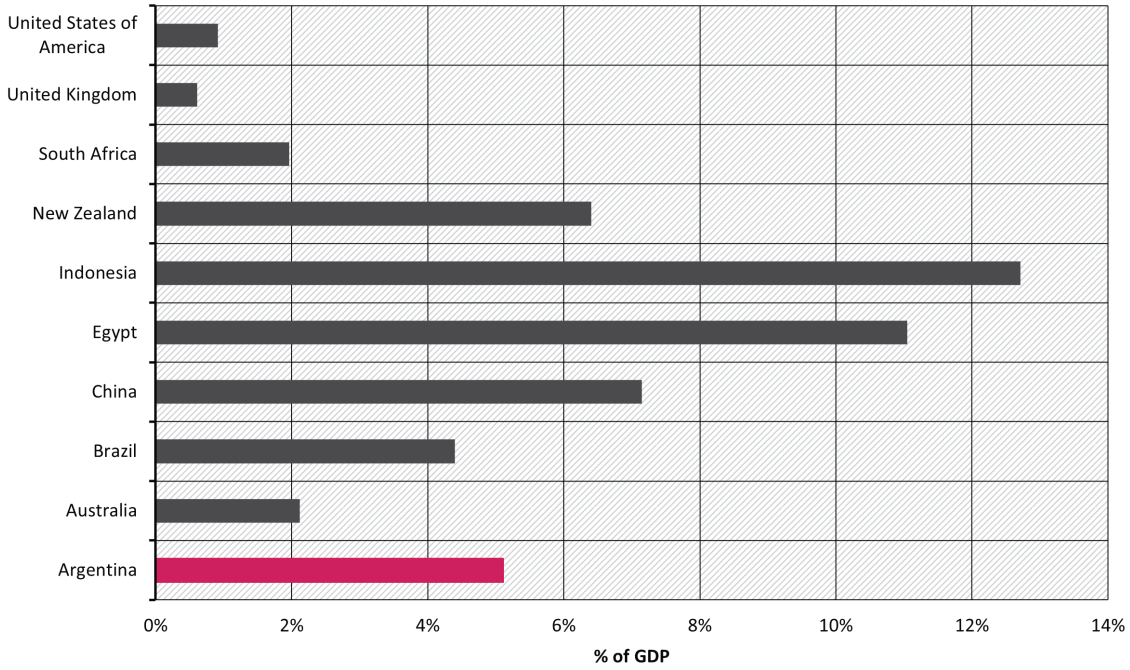


Source: **FAO (2022b)** data for all countries. Data includes "Cropland" and "Land under permanent meadows and pastures"

The expansion of the agricultural frontier was driven by the rise in agricultural commodity prices in the early 2000s and by favourable geographical and climatic conditions that allow for agricultural production over large areas (Government of Argentina, 2019a). On a global scale, Argentina makes up 2.2% of total global arable land (Alston *et al.*, 2010) and is a top international producer and exporter of certain agricultural commodities, including soybean and soy derivatives (e.g. meal, oil), bovine meat, cereals, and dairy products.

The agricultural sector contributed to 5.1% of the Argentina's gross domestic product (GDP) in 2019 (Figure 2), which is above the global average of 3.5% (OECD, 2021). Unsurprisingly, the agri-food sector is also a crucial source of foreign earnings for Argentina and accounts for more than 60% of total exports (OECD, 2019a). The Pampas region, including the main economic provinces of Buenos Aires, Córdoba, and Santa Fe, is one of the most important agricultural zones and produces the majority of Argentina's extensive export crops (Muñoz et al., 2021).

Figure 2: Agriculture, fisheries, and forestry's contribution to GDP (2019)



Source: World Bank (2022) data for all countries except New Zealand due to lack of data. Value for New Zealand was taken from OECD (2021)

Argentina is the world's third-largest exporter of soy, which made up 26% of its total exports across all sectors in 2019 and almost 50% of agricultural exports (INDEC, 2019; OECD, 2019a). Furthermore, Argentina exports around a quarter of its domestic beef production, which makes it the fifth-largest beef exporter (Wyatt, 2021). The beef sector generates 22% of agricultural GDP and 6% of total manufacturing GDP (FAO and NZAGRC, 2017).

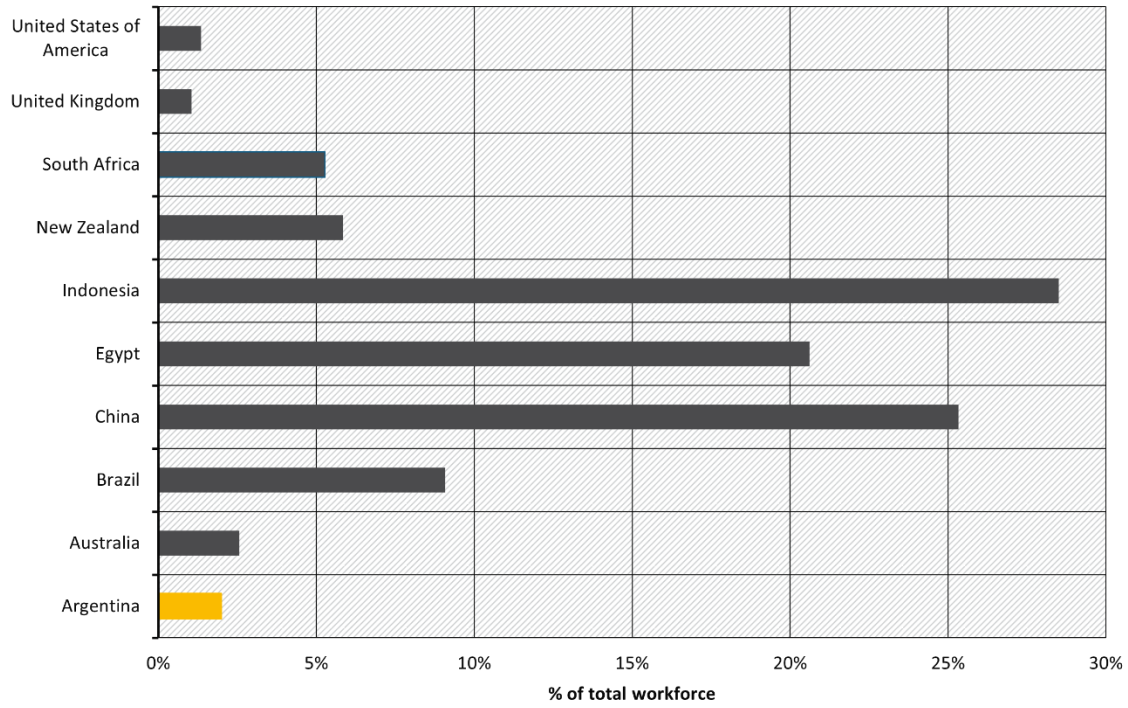
Agro-food imports, in contrast, only make up 7% of total imports (OECD, 2020). High-value imports include unprocessed soybeans, bananas, cocoa, pork, and coffee (World Bank *et al.*, 2015). Despite being a significant soybean exporter, low bean prices and drought conditions affecting domestic production have resulted in soybeans also being imported to meet high demand for biofuel production and livestock feed (ibid; Bronstein and Plume, 2018). While Argentina has sufficient production to ensure domestic food provisions, the country struggles with ensuring food access to its entire population (Feeney and MacClay, 2016).

1.2 Socio-economic dimensions

Despite the large extent of land dedicated to agriculture, the country's high use of mechanization means a low share of agricultural employment in relation to total workforce, which was at 2% in 2019 (Figure 3). The agri-food system in its entirety is responsible for 22% of total employment in the country (Muñoz et al., 2021).

While land area dedicated to agriculture has dramatically increased since the mid-1980s, around 40% of small- and medium-scale producers have disappeared (Government of Argentina, 2015b). To date, approx. 75% of Argentina's farms are considered family farms, but they account for only 18% of agricultural land and 27% of total production output (World Bank, 2021a). Currently, 1% of companies own approx. 40% of Argentina's agricultural land (Hiba, 2021a).

Figure 3: Agricultural employment as a share of total workforce (2019)



Source: **World Bank (2021)** data for all countries except Argentina due to data discrepancy. Value for Argentina was taken from **OIT (2021)**

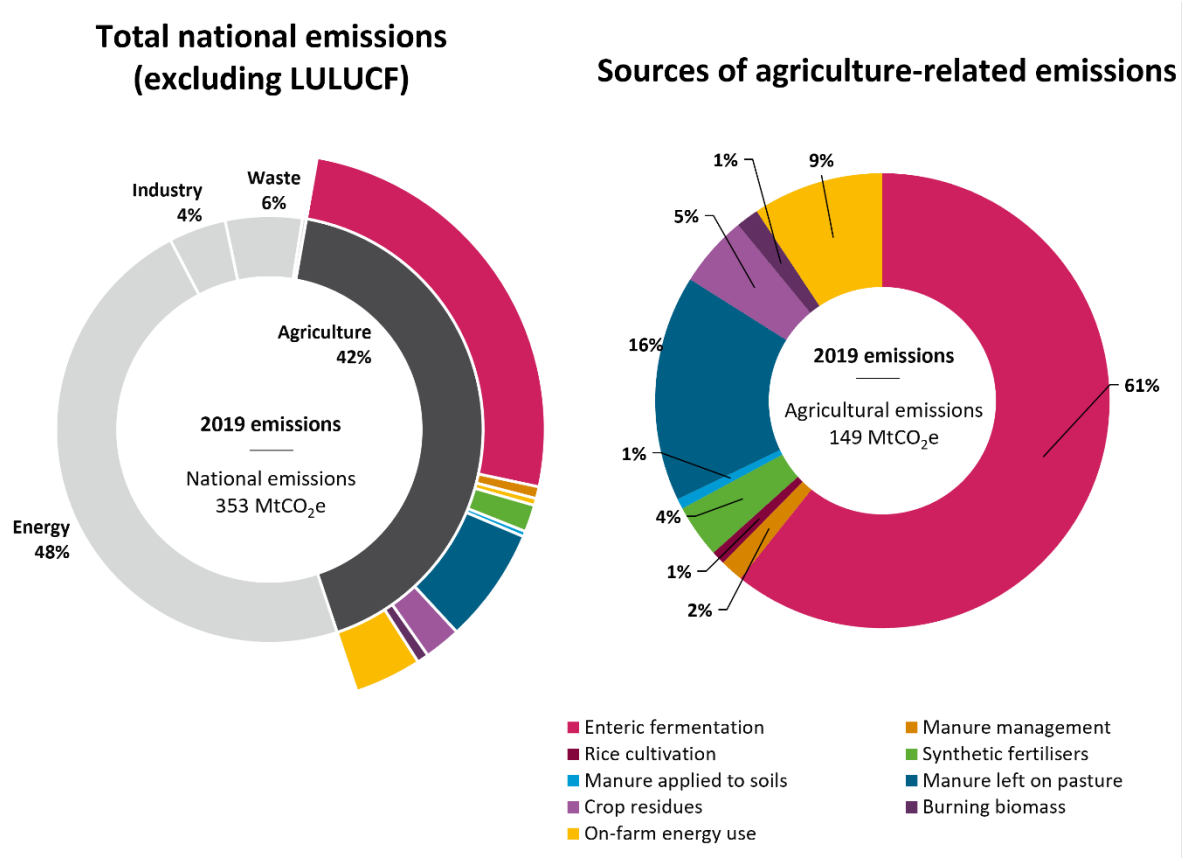
Although the agricultural landscape continues to be dominated by small-scale producers in terms of the sheer number of farmers, many family-farming practices have been replaced with large-scale production systems. An increasing number of farms are being rented out, which reduces incentives to ensure the long-term health of the land. This has implications for soil quality and ecosystem services that threaten traditional family farmer values (Government of Argentina, 2015b).

Argentina's extensive agricultural practices have important implications on water balance and quality (OECD, 2019b). In semi-arid and arid regions, inefficient irrigation systems have caused 23.5% of irrigated land in Argentina to be subject to some degree of salinization, which poses long-term threats to sustainability and productivity (ibid). Water scarcity and degradation can have significant social implications considering that, in 2015, approx. 87% of the urban population and only 55% of the rural population had access to drinking water supply.

1.3 Greenhouse gas emissions from agriculture, forestry and other land use (AFOLU) and the main drivers

In 2019, Argentina's agricultural sector produced an estimated 149 $MtCO_2e$ of GHG emissions, representing approx. 42% of total national emissions (excl. LULUCF) (Figure 4). The largest emissions sources are enteric fermentation (61%) and manure left on pasture (21%), most of which can be attributed to Argentina's role as a global beef producer and exporter.

Figure 4: Argentina's GHG emissions profile, 2019



Source: **Gütschow et al. (2021)** for energy (excl. on-farm energy use), industry, waste, and other sectors. **FAO (2022a)** for agriculture and agriculture-related emissions.[1,2]

As livestock production plays a critical and growing role in Argentina's agricultural economy, so does it for the sector's GHG emissions. Emissions from livestock make up the majority of Argentina's agricultural emissions. Furthermore, indirect livestock emissions related to feed grain production and fossil fuel demand have increased over the last years due to intensified production and higher shares of feedlot operations (FAO and NZAGRC, 2017). Forage quality and herd management practices, including adequate nutrition and reproductive efficiency, continue to influence emissions intensity and can represent opportunities to reduce emissions (ibid).

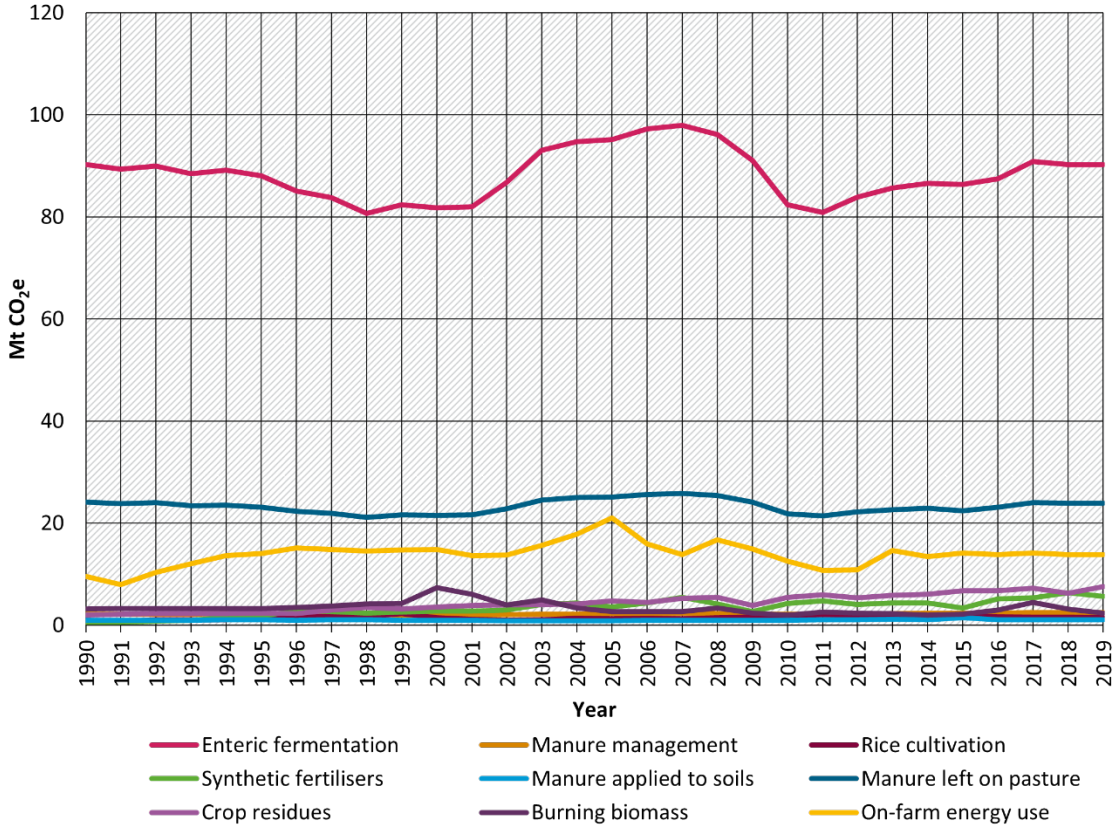
Cropland activities (crop residues, burning biomass, use of fertiliser, etc.) play a smaller role in Argentina's GHG emissions profile. Agrochemical use has increased by 1000% in the past 20 years, a significant extent of which was glyphosate herbicide use on genetically modified soy (World Bank Group, 2016). Fertiliser use per hectare of cultivated land increased by 408% between 1991 and 2014. Compared to neighbouring countries, however, Argentina's synthetic fertiliser use is still quite low. In 2018, Argentina applied approx. 28 kg/ha of nitrogen fertiliser,

[1] The PRIMAP-hist dataset used for all non-agriculture-related emissions combines multiple datasets but prioritises country-reported data (Gütschow *et al.*, 2016, 2021). FAO data may differ from nationally reported agricultural emissions under the UNFCCC, and thus agricultural emissions reported under PRIMAP-hist, as a result of data uncertainties and differing methodological approaches to reporting emissions in this sector. We use FAO for these graphs for non-Annex I countries since it includes a complete time series from 1990 to 2019, has a higher level of detail for non-Annex 1 countries (e.g. enteric fermentation emissions per category of animal), and to maintain consistency across the assessed countries.

[2] While on-farm energy use is generally reported under the energy sector emissions for both PRIMAP-hist (Gütschow *et al.*, 2021) and national data, we include it as an agriculture-related emissions source in this study because it is part of agricultural production (fuel use in harvesters, stable heating, grain drying etc.) and its relevance in several countries in terms of magnitude and mitigation potential. We refer to 2019 instead of 2020 data, which was the latest data available at the time of writing, due to COVID-related economic dynamics that affected national emissions in 2020.

compared to Brazil's rate of 81 kg/ha (FAO, 2020). Fertiliser is actually underapplied in many regions due to the prevalence of short-term land tenures, which is affecting soil fertility and quality from a lack of nutrients (Tan, 2018).

Figure 5: Agriculture-related emissions in Argentina (1990–2019)

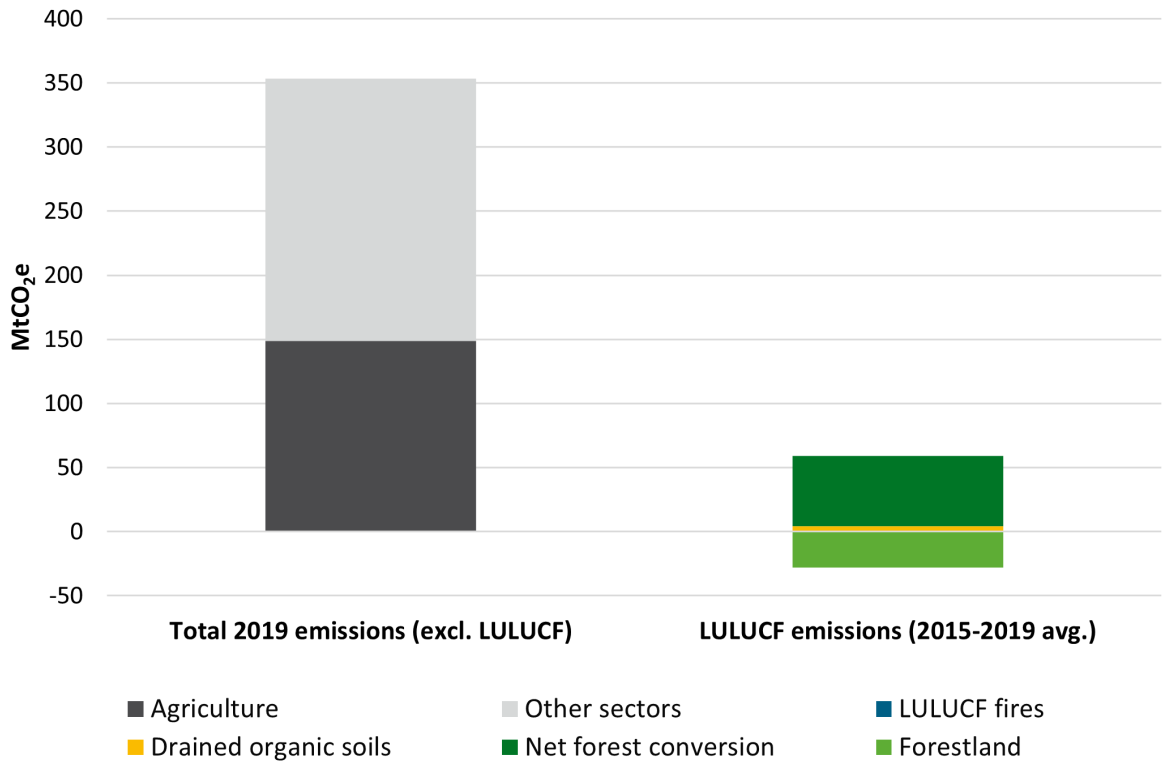


Source: **FAO (2022a)**

Land use change emissions (including emissions sinks from forests) accounted for 20% of AFOLU emissions in 2019 (Figure 6). Argentina has significantly expanded the extent of land used for agricultural purposes. Between 2001 and 2014, Argentina lost 12% of its forest area (World Bank Group, 2016), corresponding to very high LULUCF emissions in the same time frame (Figure 7). Deforestation in Argentina has been primarily driven by industrial-scale agricultural land expansion for soy used as livestock feed, biofuels, or exports, while cattle production played a secondary role (World Bank Group, 2016). Often, crops like soybean or maize replace existing pastureland, pushing cattle into forestland (ibid). Over the past 30 years, land dedicated to soybean production has dramatically increased from 2 million to 20 million hectares (OECD 2018). During the same period, land dedicated to maize has more than doubled from 3.3 to 8.4 million hectares (ibid).

Organic matter in the Pampeana region, Argentina's most productive agricultural zone, has decreased between 30-40% compared to pristine soils in the region, which increases the risk of erosion and decreases nutrient availability (INTA, 2019). Applying agroecological practices like crop rotation and cover crops can improve nutrient balance and facilitate greater soil carbon sequestration (ibid).

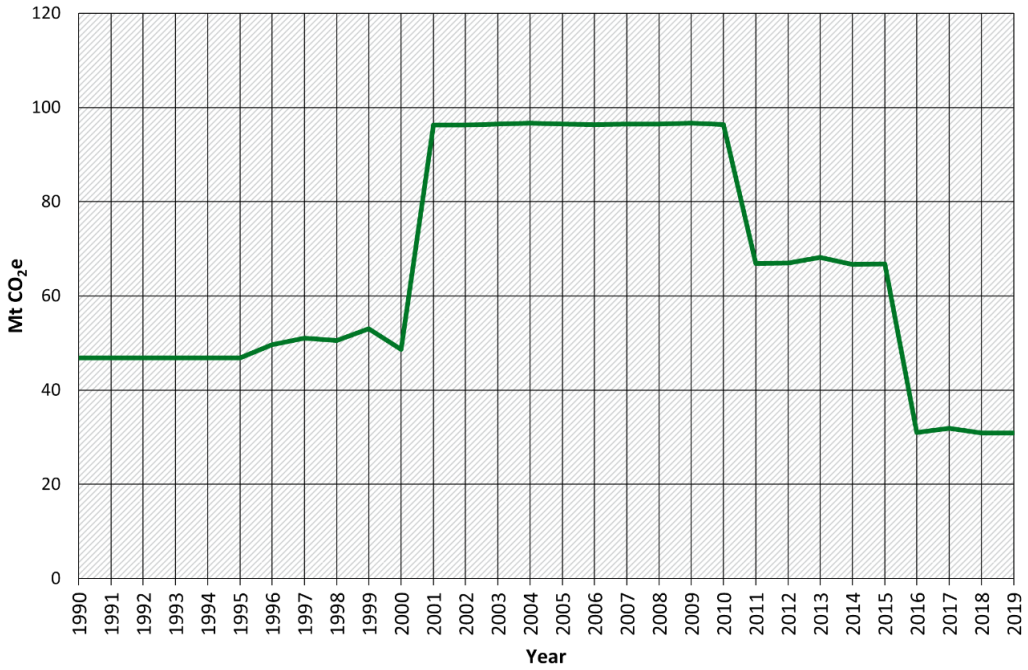
Figure 6: Argentina's land use, land use change and forestry (LULUCF) emissions (average over the period 2015–2019) relative to total national emissions in 2019 (excl. LULUCF)



Source: **Gütschow et al. (2021)** for emissions from 'Other sectors' (energy excl. on-farm energy use, industry, waste, and other emissions). **FAO (2022b)** for agriculture-related and LULUCF emissions. LULUCF fires includes the FAO categories "Forest fires," "Fires in humid tropical forests," and "Savanna fires"[3].

[3] In some countries, "Savanna fires" (which includes the prescribed burning of grassland) is accounted for in agricultural emissions under the burning biomass category instead of in the LULUCF sector. In this case, we followed national accounting standards based on UNFCCC reports to allocate the "Savanna fires" category under agriculture or LULUCF emissions. Savanna fires are reported under LULUCF for Australia, Brazil, New Zealand, and the United States, while they are reported under burning biomass for China and Indonesia. South Africa and Argentina report CO_2 emissions from savanna fires under LULUCF, but CH_4 and N_2O emissions under burning biomass. Since all emissions from savanna fires in both countries are non-CO_2 gases, they are accounted for under burning biomass.

Figure 7: LULUCF emissions in Argentina (1990–2019)



Source: **FAO (2022a)**. Includes FAO categories "Forestland," "Net forest conversion," "Forest fires," "Fires in humid tropical forests," "Forest fires," "Savanna fires,"[3] and "Drained organic soils". Note that FAO data differs from national data and uses forest activity data in 5-year intervals, meaning data is averaged over the 5-year periods and can highly fluctuate between those intervals.

1.4 Government structures and agricultural policy framework

In 2016, Argentina established its National Climate Change Cabinet (GNCC) to facilitate the adoption of climate change policies and the achievement of its commitments under the Paris Agreement. This cabinet was institutionalised by the Climate Change Law and substantially contributed to Argentina's second NDC submission (MAyDS, 2022b).

Following a ministerial reorganization in 2018, the agriculture, agribusiness, and bioeconomy secretariats were placed under the Ministry of Production and Labour. However, in 2019, due to the importance of the agricultural sector in Argentina's economy, the three secretariats were consolidated into the Ministry of Agriculture, Livestock and Fisheries (MAGyP) (Climate Action Tracker, 2019). The MAGyP implements programmes and policies relating to agricultural production, commercialization, technologies, and health. While Argentina's Ministry of Environment and Sustainable Development (MAyDS) is responsible for the country's forestry sector, GHG inventory, and the development of climate change sectoral plans, the execution of the agricultural sector plan is primarily overseen by the MAGyP and their corresponding Climate Change Commission (MAyDS, 2022b).

Argentina's second NDC, submitted in December 2020, sets the absolute, economy-wide and unconditional goal of limiting GHG emissions to 359 Mt CO_2e by 2030[4] (Government of Argentina, 2020). In November 2021, Argentina submitted an official update to this second NDC, limiting emissions to no more than 349 MtCO_2e by 2030 (Government of Argentina, 2021).

The second NDC also includes a vision for each sector by 2030. Argentina expects the agricultural sector to sustain its contribution to GDP through an increase in yields and

[4] Using global warming potentials from IPCC's second assessment report (SAR)

productivity via genetic improvements and good practices rather than using additional land or livestock population growth. Furthermore, the NDC states that Argentina will reduce deforestation through sustainable forest management and the implementation of the National Forest Management Plan with Integrated Livestock (MBGI) (Government of Argentina, 2020).

The objective of the MBGI is to contribute to the sustainable use of native forests as an alternative to land-use change. This plan aims at integrating livestock activities that take place in native forests into the production matrix taking into account ecological, economic and social criteria (Government of Argentina, 2015a).

In November 2022, Argentina submitted its Long-Term Strategy (LTS) to the United Nations Framework Convention on Climate Change (UNFCCC), which includes a target to reach GHG neutrality by 2050 (Government of Argentina, 2022). While there are no quantitative targets outlined in the plan, the transformation of food and forestry systems is mentioned as an important facet of the strategy. The strategy prioritises food security and sovereignty, as well as reducing sectoral vulnerability to climate change impacts rather than emission reductions (ibid).

Argentina's National Plan for Agriculture and Climate Change includes several adaptation measures and three mitigation measures that are to be implemented by 2030. The mitigation measures are: i) increased afforestation (reduction of ~18 $MtCO_2e$); ii) improved crop rotation (reduction of ~4.3 $MtCO_2e$); and iii) the use of biomass for energy generation (reduction of ~3.4 $MtCO_2e$). The cumulative 25.7 $MtCO_2e$ of potential emission reductions from these measures represent an additional reduction by 2030 (MAGyP, 2019); however, this only represents around a fifth of total AFOLU GHG emissions from 2018 (MAyDS, 2022a).

The Forest Law was instituted in 2007 and requires provinces to identify forests that can be cleared for agriculture, forest that cannot be cleared but managed, and forests dedicated to conservation purposes (Volante *et al.*, 2016). Although deforestation rates have recently declined, this may be partially attributed to drops in commodity prices (World Bank Group 2016). Favourable agricultural expansion conditions currently outweigh the regulatory power of the Forest Law due to a lack of enforcement and insufficient funding (Volante *et al.*, 2016). In 2018, 40% of deforestation occurred in forests seemingly protected by the Forest Law (Greenpeace, 2019).

1.5 Current developments and trends

Intensive cattle farming systems have been expanding in Argentina. Around half of slaughtered cattle come from feedlots, where they are fattened up in cramped conditions during the last months of their lives (Hartmann and Fritz, 2018). Although feedlot cattle can potentially produce less methane from enteric fermentation than grass-fed cattle, feedlots account for additional greenhouse gas emissions from feed production, feed transportation and manure management (AWA, 2013).

Silvopastoral systems, on the other hand, integrate livestock production with forestry and lead to above- and below-ground carbon sequestration and help reduce nitrogen application (World Bank *et al.*, 2015). They also improve the resilience of cattle production systems and make livestock less susceptible to heat stress (ibid). In Northern Argentina, approx. 3.7 million hectares – which represents about 30% of the plantation area in the region– are currently implementing silvopastoral livestock production systems (Peri *et al.*, 2016).

Regarding cropland, soy monocultures dominated Argentina's agricultural landscape for many years. In 2009, the area planted with soybean made up 59% of Argentina's total arable land (Catacora-Vargas *et al.*, 2012). Nearly 100% of soybean acreage in Argentina is genetically

modified, which requires significant glyphosate application (Hartmann and Fritz, 2018). In recent years, due to reduced profit margins from levied taxes, farmers have shifted towards cultivating wheat and maize in place of soy or including wheat and maize in soy crop rotations. Crop rotations are more beneficial for the environment than soy monocropping, since they improve soil quality, generate biodiversity, and lower risks from climate change impacts (Hiba, 2021b).

No-till farming became the dominant soil management practice in Argentina since its introduction 30 years ago, and it is currently applied on just over 90% of croplands (Brihet *et al.*, 2021). No-till practices must be combined with crop residue mulch, cover crop rotations, and little to no use of agrochemicals to have a positive impact on soil health (Domínguez *et al.*, 2010).

Globally, Argentina has the second largest extent of land area dedicated to organic production at 4.4 million hectares in 2021 (Bichos de Campo, 2021). The majority of organic land is dedicated to livestock production, although most of the exported products are crops such as oilseeds, fruits and vegetables (SENASA, 2016). Around 1 in 50 rural farms carry out work according to agroecological and organic principles (Koop, 2020). There has been significant progress in adopting such practices, but public policies favouring conventional agriculture, low domestic organic product consumption and limited access to land and technical advice continue to slowdown efforts (SENASA, 2016; Le Coq *et al.*, 2020).

1.5.1 Diets and food waste

Argentina has the second-highest global beef consumption per capita, which indicates a substantial dietary ecological footprint (Arrieta and Gonzales, 2018). In Argentina, average per capita meat consumption is 88 kg per capita, of which 38 kg per capita is beef and 38 kg per capita poultry (OECD, 2023). Meat consumption in Argentina is thereby significantly above the recommendation of 15.7 kg per capita from the planetary health diet.[5]

Beef consumption is currently subsidized since the value added taxes (VAT) on beef is half that of other meats, allowing its population to afford to buy beef at comparatively low prices (ibid). Still, beef consumption has declined over the past 20 years in favour of poultry and pig meat (Pavan *et al.*, 2017). In 2021, the government established export bans for certain beef cuts which will last until the end of 2023. The ban responded to a surge in beef prices that would make beef unaffordable for poorer families. But the ban, coupled with price controls, has failed in its main goal, as beef prices increased 48% in the province of Buenos Aires (Bloomberg, 2022). The Argentinian government has recognised the need to reduce meat consumption and launched the "Green Mondays" campaign to encourage residents to go meatless once per week, but this was met with strong opposition from both farmers and consumers (Lonas, 2021).

Argentina wastes approximately 16 million tonnes of food per year; losses are largest in the production, processing, and distribution stages of the food supply chain (Telam, 2017). At the same time, more than 11% of the population experiences severe food insecurity and, at the beginning of 2020, the government declared a "National Food Emergency" in response to rising hunger and economic instability. Two major policy developments in this context included the establishment of the National Plan for the Reduction of Food Loss and Waste and the Food Donation Law (Harvard Law School Food Law and Policy Clinic and The Global FoodBanking Network, 2020).

[5] https://eatforum.org/eat-lancet-commission/the-planetary-health-diet-and-you/.

1.5.2 Recent developments in national context

Argentina's fiscal policies have significantly influenced the agricultural sector's developments over the years. Unlike most countries, Argentina's government support for producers is negative due to distortionary taxes on several important export products, which means producers face a heavy price burden (Muñoz et al., 2021). As a result, producers struggle with limited access to financial services that impede investments in environmentally-friendly technologies and climate change risk mitigation (OECD, 2019a).

The agricultural sector has also been subject to high levels of government intervention. In order to raise revenues and avoiding defaulting on sovereign debt, the government raised export taxes on key agricultural commodities including beef, soy, wheat, and corn, despite strong opposition from farmers (Heath and Bronstein, 2019). In June 2021, the government instated a month-long ban on beef exports in order to stabilise domestic supply and reduce price inflation (Wyatt, 2021). A similar ban was placed on corn in early 2021 to ensure there were sufficient raw materials to use as livestock feed (Heath, 2020).

In general, the country and its agri-food value chain are facing an uncertain macroeconomic environment. By early 2020, the Argentine peso had lost two-thirds of its value since 2018, inflation is at a staggering 30% and the economy has contracted by 4% since 2015 (Muñoz et al., 2021). The situation was further exacerbated by the COVID-19 pandemic, contributing to high levels of inflation in basic consumer goods (Jourdan, 2021).

1.6 Vulnerability and adaptation

Argentina's agriculture sector is considered high-risk to climate variability and extreme events, especially since rainfed-agriculture is responsible for 87% of the sector's value (World Bank, 2021a). Past changes in precipitation patterns have promoted the expansion of the agricultural frontier in Argentina beyond traditional areas, which is an adaptive method that can further aggravate environmental damages from unsustainable practices (Magrin *et al.*, 2014). Climate change is expected to exacerbate water challenges. Changing precipitation patterns and intensified extreme water-related disasters will affect the inter-annual variability of crops and cause further environmental degradation (OECD, 2019b).

Threats to livestock production are expected to multiply due to climate change and variability, resulting in natural capital and revenue losses. In 2008/09, severe droughts in central North Argentina caused 700,000 livestock mortalities, a 70% decrease in beef exports and a 15% decrease in consumption (FAO and NZAGRC, 2017). Livestock productivity is generally expected to decrease in the northern and central regions due to reduced foraging opportunities, with displacement from the east highly likely due to increased temperatures (World Bank, 2021a).

In 2019, Argentina published their National Adaptation Plan to coordinate climate change adaptation measures on all relevant scales in the medium and long term (Government of Argentina, 2019b). The agricultural section includes ten adaptation measures, primarily focused on small producers and their vulnerabilities, and grouped under i) prevention and reduction of risks, ii) transferring risks, iii) managing emergencies, and iv) knowledge management (ibid).

Organic farming systems can enhance adaptive capacity by utilizing traditional knowledge and skills, improving soil fertility, and incorporating a high degree of diversity on farmlands (Magrin *et al.*, 2014). Other adaptation strategies for Argentina can include aligning planting with changing rainfall patterns, shifting crop varieties, and establishing irrigation systems to supplement water supplies during dry periods (World Bank, 2021a). These strategies can be facilitated by improved financing for technology transfer, and increased investment, insurance,

and credit options for climate impact assessments and adaptation measures, especially for smallholders (ibid). Currently, most small- and medium-scale farmers cannot afford agricultural insurance, thus increasing their risk to extreme climate events (Muñoz et al., 2021).

2 Key areas with high mitigation potential

2.1 Introduction

In this section, we quantify the potential of three mitigation options and explore the co-benefits and barriers to their implementation in a country-specific context. In selecting which three mitigation options to quantify, the contribution of different emission sources was considered, along with the potential for socio-economic and environmental co-benefits, the country-specific context of the agricultural sector (see Section 1), as well as the general feasibility for implementation.

2.1.1 Selection of priority mitigation actions

As seen in Figure 4, the largest source of agricultural sector emissions is enteric fermentation from livestock followed by emissions from manure left on pasture, both linked to Argentina's expansive meat production industry. Deforestation is another significant emissions source (see Figure 6), which is interlinked with the expansion of pastures for cattle farming.

For Argentina, we therefore selected the following measures:

- Implementing silvopastoral systems
- Livestock emissions intensity reduction through reproductive disease prevention
- Livestock emissions intensity reduction through feed optimisation.

The establishment of **silvopastoral systems**, which is at the core of the National Forest Management Plan with Integrated Livestock (MBGI), could reduce land use change linked to the displacement of the livestock frontier into forest regions. Measures to **improve reproductive health in livestock** can decrease the rate of disease and output loss, reducing emission intensity from milk and meat production, which is aligned with national goals of increasing meat production primarily based on higher productivity. Finally, **livestock feed optimisation** has been widely researched in the country. Changes in livestock diets to increase efficiency in milk and meat production are under consideration by government and technical institutions since they would also increase output per unit.

2.1.2 Overall mitigation potential

According to our calculations[6], improvements in cattle emissions intensity under constant levels of production could contribute to a reduction in livestock emissions of 16 $MtCO_2e$/year compared to 2019 levels, corresponding to an 11% reduction in total agriculture-related emissions. However, when beef and dairy production levels follow the 10-year historical trend, our calculations indicate that any emission reductions would be offset by future increases in herd size and overall production and would result in an absolute increase in GHG emissions. Other studies have also concluded that measures to improve livestock emissions intensity and productivity would likely result in an absolute emissions increase if beef production continues to increases (Gonzalez Fischer and Bilenca, 2020; Gonzales-Zuñiga *et al.*, 2022).

Silvopastoral systems could result in an additional reduction of 25 $MtCO_2e$/year in 2030 from avoided emissions from deforestation, compared to a baseline scenario (Gonzales-Zuñiga *et al.*, 2022). This additional reduction is comparable to the current net sink in existing forest land in

[6] See section 2.3.1. Further methodological details can be found in the final report for this project, available at https://www.umweltbundesamt.de/publikationen/ambitious-ghg-mitigation-opportunities-challenges.

Argentina, but the magnitude is around half that of the current emissions from deforestation (FAO, 2022a).

Overall, Gonzales-Zuñiga *et al.* (2022) found a mitigation potential of 28 $MtCO_2e$/year relative to a baseline scenario of 212 $MtCO_2e$ in AFOLU GHG emissions in 2030. The majority of the mitigation potential is derived from avoided emissions from deforestation from establishing silvopastoral systems (24.5 $MtCO_2$/year), the value also used in our analysis above. That same study also examined additional on-farm mitigation measures, including nutrient management, cover crops, crop rotations, extended grain-finishing times, and the efficient nitrogen use on dairy cattle, but estimated rather small mitigation potential for the combined measures (3.5 $MtCO_2e$/year) compared to the reference scenario (Gonzales-Zuñiga *et al.*, 2022). The study also concluded that any emission reductions from improvements in livestock health monitoring and feed optimisation would likely be offset by future increases in herd size and production increases. The reference scenario overall comprises an increase of 35 $MtCO_2e$, or 23% above 2019 levels, primarily due to the emission increase from further expansion of the cattle herd (ibid). Thus, further measures to prevent expansion of the cattle herd (and the corresponding beef production) would likely need to be combined with livestock management options to result in effective emission reductions.

Another study that explores deep decarbonisation pathways to 2050 estimates that Argentina can reduce its agriculture non-energy emissions between 17.6–26.4 $MtCO_2e$/year relative to an NDC scenario (where agricultural emissions follow business-as-usual) in 2050. The lower end of the range assumes a 30% reduction in emissions per head of livestock and a 20% reduction in crop production emissions, while the higher potential assumes a 40% and 30% reduction, respectively. Among the measures considered for livestock emission reductions are feed additives (nitrates, tannins)[7] and pasture management, while emission reductions from crop production are based on crop rotation, efficient nitrogen use, and incorporating crop residues into the soil. The study concludes that Argentina should place a greater focus on mitigation measures in the agricultural sector in order to reach deep decarbonisation (Lallana *et al.*, 2021). The study also considers afforestation as a means to increase Argentina's carbon sink, and assumes the possibility to plant 2 to 5 million hectares of forest, resulting in up to 92 $MtCO_2e$/year in 2050 in avoided emissions compared to the NDC scenario (ibid).

2.2 Prioritised mitigation options

2.2.1 Implementing silvopastoral systems on native forest

Measure

Silvopastoral farming refers to livestock production systems involving multi-purpose trees and shrubs, in combination with grasses and legumes and livestock species (Pezo *et al.*, 2018). It can be implemented either by planting trees on grazing land or by rearing cattle in pre-existing native or managed forest. These systems have become an attractive economical, ecological and productive alternative in some regions of South America, including the subtropical and temperate zones in Argentina, as they allow for diversification of farm income. This can either be through improving conditions for livestock (leading to increased survival and body weight of the animals) or through the sale of timber and other wood products (Peri *et al.*, 2016). By combining tree species with

[7] Feed additives in particular carry not just health, environmental, and animal welfare risks, but also have highly uncertain efficacy and the potentially more effective options are far from commercially viable.

farming activities, such systems reduce pressure on existing forest land and avoid emissions from deforestation attributed to the expansion of the livestock frontier.

In this analysis, we estimate the mitigation potential from introducing cattle into existing forest plantation area in subtropical systems. Combining existing plantations with cattle rearing allows for an increase in national cattle population but avoids expansion of rangeland into forestland, thereby avoiding deforestation emissions. The establishment of silvopastoral systems would not negatively impact forest biomass when they are established on low-carbon stock forests.

Status

In Argentina, about 34 million hectares are currently under silvopastoral systems, spread throughout different regions in the country (e.g. the Misiones, Corrientes, Delta, Chaco and Patagonian regions) with both native and cultivated forests, applied in different intensities and with different purposes in each region (Perez, 2016). This is also aligned with the country's National Plan for Forest Management with Integrated Livestock Production (MBGI) (Government of Argentina, 2015a).

Potential

Expanding silvopastoralism systems with beef cattle livestock from 30% to 60% of the plantation area (from 6 Mha to 15 Mha of silvopastoral area) in subtropical systems could result in avoided emissions of approx. 25 $MtCO_2e$ in 2030 compared to a baseline scenario (Gonzales-Zuñiga *et al.*, 2022). The avoided emissions stem from a reduction in deforestation attributed to the expansion of the livestock frontier.

Co-benefits

Depending on the types of trees planted, silvopastoral systems allow for the diversification of products such as timber, seeds, or food, with trees contributing longer-term income and cattle to shorter-term income. This can alleviate poverty and improve the livelihoods of both cattle and timber producers (FAO and ITPS, 2021). This can be compounded by further improvements in cattle productivity.

Silvopastoralism has positive implications for animal welfare and climate adaptation since trees provide a source of shade and can help mitigate the impacts of high temperatures on livestock (ibid). Introducing livestock into forestry systems can also help control weed expansion and fires, increase soil and biomass carbon, and conserve water and biodiversity resources (Ibrahim *et al.*, 2010).

Barriers

Economical barriers: Silvopastoral systems are more costly than standard pastures. There are usually high upfront costs from seedling and fencing requirements, and the return on investment is slow to show results and can be uncertain (FAO and ITPS, 2021).

Technical barriers: Silvopastoral systems are by nature complex and dynamic systems, this increases farmers' need for technical assistance, especially when compared to monocultures as more traditional farmers are often not familiar with these alternative systems (Braun *et al.*, 2016; Peri *et al.*, 2016).

Biophysical/environmental barriers: In silvopastoral systems where farmers need to plant trees on grazing land, a major challenge is to achieve successful establishment and growth of seedlings, due to browsing herbivores (rabbits, hare and livestock itself) and competition with other plants for light (Peri *et al.*, 2016).

Cultural barriers: There is a current lack of awareness and appreciation for the role of trees in farming systems (commercial, environmental, animal welfare,

landscape) and vice-versa, of the potential value added of including livestock in forestry production systems (Peri *et al.*, 2016). The longevity and cultural value of traditional livestock rearing practices can also limit the willingness to change from standard pasture systems (Andeweg and Reisinger, no date).

Policy/legal barriers: Argentina's land tenure laws permit short term leases of two years on farms, which encourages quick returns without consideration for long-term environmental consequences and decreases the incentive for farmers to change their practices (Hiba, 2021a).

2.2.2 Livestock emissions intensity reduction – reproductive disease prevention

Measure

Improving animal health and welfare, increasing reproductive efficiency and breeding for higher productivity all contribute to reducing the emissions intensity of livestock farming (Andeweg and Reisinger, no date). Strategies that increase productivity are very promising ways to reduce the livestock carbon footprint, but are sometimes achieved at the cost of animal welfare, due to shifts towards feedlot systems. Improving animal health is one measure where emissions can be reduced whilst simultaneously improving animal welfare (Llonch *et al.*, 2017).

This can be achieved, in part, through strategic feed supplementation (see section 2.2.3) to combat nutritional deficiencies and improve reproductive status and further controlling and monitoring of cattle health (FAO and NZAGRC, 2017). With healthier animals, fewer animals are needed to produce the same amount of meat and milk, thereby resulting in smaller herds and lower emissions for the same overall productivity. Improving cattle health also increases productivity through higher fertility rates and higher weaning (calving) rates, requiring less animals to produce the same number of offspring quicker, and allows cattle to gain weight faster by improving performance (ibid).

We assumed that these measures would be applied to existing production systems, and do not involve a shift towards a higher share of intensive livestock farming (e.g. feedlot systems).

Status

In Argentina, the weaning rate in the temperate zone, where over 50% of the national herd is, is relatively low at 68%, meaning 32% of cows do not produce a weaned calf. Controlling reproductive diseases can increase productivity by reducing losses of calves during gestation and increasing the number of calves produced and weaned (FAO and NZAGRC, 2017). Similarly, the fertility rate in the temperate zone (currently at 80%) could be improved by 5–10% by addressing seasonal nutrient deficiencies and supplementation during periods of low nutrient uptake, allowing cows to rebreed more readily (ibid; Gerber *et al.*, 2013).

Potential

Based on our own calculations[8] and FAO emissions data, if Argentinian livestock systems applied both good practices in health management and feed optimisation (see section 2.2.3 below), it would result in emission reductions of 16 $MtCO_2e$/year in 2030 compared to 2019 levels if beef production remained constant at 2019 levels. We assumed enteric fermentations emissions intensity would be reduced by 40%, which is in line with estimates by FAO and NZAGRC

[8] Further methodological details can be found in the final report for this project, available at https://www.umweltbundesamt.de/publikationen/ambitious-ghg-mitigation-opportunities-challenges.

(2017), who estimate a 39% improvement in the emissions intensity of beef cattle production from the controlling of reproductive diseases, feed supplementation of breeding cows, and the strategic feed supplementation of steers weighted across the population of livestock in different climatic zones (arid, subtropical, temperate).

These estimates comprise a maximum emission reduction potential based on decreasing the emissions intensity per tonne of beef or milk produced. There is a risk that further grain supplementation to achieve higher yields of milk and meat and lower emissions intensities would result in increased indirect emissions from feed production (i.e. synthetic fertiliser application to feed crops) and associated land use change. Intensive livestock production also contributes to significant environmental pollution and rising manure management emissions.

Furthermore, Argentina's beef production is predicted to increase in line with development and economic objectives. If production levels were to increase following the 10-year historical trend, at a high rate of around 4%/year, Argentina would see a significant increase in beef cattle enteric fermentation emissions that would entirely offset any emission reductions from improved health management and feed optimisation and could lead to an absolute emissions increase. Thus, implementing measures to improve individual animal performance are generally associated with higher absolute emissions levels when herd sizes do not accordingly decrease (ibid).

Co-benefits

Improved livestock health and disease monitoring generally improves animal welfare and well-being, which will have positive impacts on food safety and biodiversity conservation (Llonch *et al.*, 2017). The improved productivity of beef cattle and reduced mortality will result in positive economic returns for livestock farmers, while also enhancing food security and rural livelihoods (OIE, 2017).

Barriers

Economical barriers: Argentinian farmers may lack the financial resources needed to access the technology and labour needed to improve their health monitoring. Farmers also cite uncertainty with yield benefits as a primary barrier to adopting health interventions (Özkan *et al.*, 2022). This is especially the case for small-scale subsistence farmers, who will only see minor, if any, economic returns (Gerber *et al.*, 2013).

Technical barriers: Improving animal husbandry and herd health has been identified as a low-cost opportunity in all production systems in Argentina, but their uptake may be slowed down by farmers' need for further training and capacity building. Current monitoring, reporting and verification (MRV) approaches do not sufficiently reflect animal health conditions and data on disease statistics is limited, making it difficult to measure emission reductions from health improvements (Andeweg and Reisinger, no date; Özkan *et al.*, 2022).

2.2.3 Livestock emissions intensity reduction – feed optimisation

Measure

The composition of livestock feed can be optimised to reduce enteric fermentation. A lot of research has been carried out on this field throughout the years in Argentina, but feed optimisation is a longer-term process since determining the optimal feedstock for a specific region requires an iterative learning process on how local breeds of cattle respond to different locally available vegetation and grains. This measure also consists of maintaining cattle's

nutritional levels by supplementing with feed and/or nutrients during periods when pasture resources are low (e.g. winter) to combat energy or protein deficiencies (FAO and NZAGRC, 2017). Optimised nutritional levels can result in lower enteric fermentation emissions per head of cattle (or tonne of product), but also result in higher overall herd health and therefore require fewer cows to produce the same amount of beef. It can also mean shorter finishing periods and higher slaughter weights, resulting in less enteric methane per kilo of live-weight.

We assumed that these measures would be applied to existing production systems, and do not involve a shift towards a higher share of intensive livestock farming (e.g. feedlot systems).

Status

The relatively low calving percentages in Argentina's pasture systems is attributed to seasonal nutrient deficiencies, and the lack of supplementation during those periods of poor nutrient intake. Inadequate forage supplies from poorly-managed pastures has also resulted in low growth rates in rearing and fattening systems, meaning cattle has to be kept longer to reach its target weight (FAO and NZAGRC, 2017).

Potential

Based on our own calculations[7] and FAO emissions data, if Argentinian livestock systems applied both good practices in health management (see section 2.2.2 above) and feed optimisation, it would result in emission reductions of 16 $MtCO_2e$/year in 2030 compared to 2019 levels if meat production remained constant at 2019 levels. We assumed enteric fermentations emissions intensity would be reduced by 40%, which is in line with estimates with FAO and NZAGRC (2017), who estimate a 39% improvement in the emissions intensity of beef cattle production from the controlling of reproductive diseases, feed supplementation of breeding cows, and the strategic feed supplementation of steers weighted across the population of livestock in different climatic zones (arid, subtropical, temperate).

The estimates outlined above represent a maximum emission reduction potential based on decreasing the emissions intensity per tonne of beef or milk produced. There is a risk that further grain supplementation to achieve higher yields and lower emissions intensities would result in increased indirect emissions from feed production and associated land use change. Intensive livestock production also contributes to significant environmental pollution and rising manure management emissions.

Additionally, Argentina's beef production is predicted to increase in line with development and economic objectives. If production levels were to increase following the 10-year historical trend, at a high rate of 4%/year, Argentina would see a significant increase in beef cattle enteric fermentation emissions that would entirely offset any emission reductions from improved health management and feed optimisation and could lead to an absolute emissions increase. Thus, implementing measures to improve individual animal performance are generally associated with higher absolute emissions levels when herd sizes do not accordingly decrease (ibid).

Co-benefits

Improved nutritional quality from optimised feeding can increase livestock productivity, which will result in positive economic benefits for farmers. Supplementing feed can also be a low-cost method of pasture conservation since it allows time for the land to recover and replenish forage nutrient stores.

Barriers

Technical barriers: In extensive pasture systems where cattle move around freely, there is a practical barrier for optimising cattle's diets, as farmers cannot control or ensure uptake of preferred feed (Kipling *et al.*, 2019). Optimising feed is a highly knowledge- and labour-intensive process and Argentinian livestock farmers currently lack the capacity and resources to properly implement this action (FAO and NZAGRC, 2017).

Economic barriers: Poor functioning input markets can limit farmer's access to the supplementary feed needed to optimise their cattle's diet. Techniques such as forage conservation also require high up-front investments costs, which limit their adoption (FAO and NZAGRC, 2017). Reducing herd sizes by increasing productivity seems unlikely as it conflicts with smallholder's interest in large herds for non-commercial functions (e.g. subsistence, or as a form of insurance) and risk mitigation. Thus, the implementation of this measure might result in higher absolute emissions, as production rises while herd size is either sustained or increased.

Biophysical/environmental barriers: Potential increases in cattle grain consumption from optimised feeding interventions risks further expansion of cropland for grain feed production, which would result in increased synthetic fertiliser and land use emissions (from deforestation).

3 Barriers to implementing mitigation potential

In this section, we examine the main barriers identified for the country, in the context of the prioritised mitigation options, building on the findings of a report on general barriers prepared under this research project[9] and the country-specific circumstances described in Section 1 of this report. The analysis of barriers below follows the clustering proposed in the report on barriers, according to the relevant governance level for taking action, while taking into account the classification from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land within each of the governance levels.

3.1 Farm level

Most Argentinian farmers, especially smallholders, lack the capacity, resources, and financial assistance needed to adopt new technologies or sustainable practices (FAO and NZAGRC, 2017). There are usually significant upfront costs to adopting new technologies, and farmers may lack the knowledge on potential gains from sustainable practices or new technologies (ibid). Farmers may also lack awareness of the links between sustainable practices and climate change, or the potential environmental co-benefits of implementing emissions mitigation strategies. Many mitigation measures could be considered more knowledge- and labour-intensive, posing a considerable barrier to their implementation.

The livestock sector represents cultural and traditional values which often translate into resistance to explore changes to the sector's common practices and objectives, particularly if linked to changing diets and reducing meat consumption (Lonas, 2021).

In addition, short-term land tenure is becoming more common, which disincentivises farmers to invest in practices or technologies that contribute to long-term soil quality (Government of Argentina, 2015b).

3.2 National level

While Argentina's agricultural policies in the past mostly focused on stabilising domestic food prices and increasing government revenues, current national policies are more focused on increasing yields and productivity to integrate into world markets, sustain the sector's contribution to the country's economy, and increase food security (FAO and NZAGRC, 2017; OECD, 2019a). In the livestock sector, an increase in productivity [in kg meat/animal] can lead to higher absolute emissions, as overall production rises while herd size is either sustained or increased. Existing policies mostly promote these increases in productivity through slight improvements to current practices, rather than proposing more substantial systems changes, due to the perceived economic risks of transitioning to a different and more sustainable agriculture sector.

Government interventions that encourage the production of certain commodities over others can drive farmers to engage in monocropping practices rather than trying out combined systems such as agroforestry or silvopastoralism. Unlike in most countries, policies in Argentina have generally imposed export taxes for agricultural products (with taxes ranging from ~10% up to ~35%, depending on the commodity). This is considered "negative protection" for farmers as it generally increases their costs and reduces their revenues. In the past, changes in these taxes have determined whether farmers focus production on one crop over another (OECD, 2019a).

[9] See Siemons *et al.* (2023).

These interventions, along with the uncertain macroeconomic environment in Argentina, pose considerable risks to farmers and disincentivises the uptake of new practices.

Argentina has a considerable agribusiness lobby, in line with the government's objectives to strengthen the agro-export model. While the upcoming Law on Agroindustrial Development includes a component on sustainable production, it mostly refers to the sustainable use of nutrient and seed inputs and is overshadowed by the tax incentives and economic benefits to further increase production (Buenos Aires Times, 2021). The economic interests of large agribusinesses, which is significant since 1% of companies own 40% of Argentina's agricultural land, likely further prevents the uptake of mitigation measures.

At the institutional level, the limited coordination between government offices and their objectives (e.g. between the Ministry of Environment aiming to reduce emissions and the Ministry of Agriculture supporting increased production) creates a mismatch in incentives to farmers to change their current management practices, slowing down progress in designing and implementing a coherent and ambitious climate policy that includes specific targets for the agricultural sector. Furthermore, policy and regulatory incentives for agricultural expansion have historically outweighed the enforcement of regulations aimed at avoiding deforestation, such as Argentina's Native Forest Law, which defines forest areas that can be dedicated to agriculture, forest management or forest conservation (Volante *et al.*, 2016).

Regarding data monitoring and reporting systems, there is limited guidance for estimating soil carbon stocks, especially on a small scale (Peri *et al.*, 2018); this is of particular relevance for Argentina's grasslands, which cover about 25% of the country's land area. Thus, mitigation actions related to sustainable grassland and pasture management might not be captured in emissions inventories, reducing the recognition that governments can gain from implementing such policies.

3.3 International level

While there is considerable guidance from the scientific community for achieving healthy and sustainable diets globally, there are no clear targets defined on a country or regional level, and there is no international pressure to help support a shift to more sustainable global food systems. Investors in the agricultural sector have pointed out that there are considerable risks (e.g. environmental, productivity, political) impeding agricultural financing and investments in the sector's transition (Apampa *et al.*, 2021).

3.4 Consumer level

While the mitigation options explored in this study focus on improvements in agricultural production, Argentina has the second highest beef consumption rate in the world (Arrieta and Gonzales, 2018). Meat consumption in Argentina is usually linked to family gatherings and social events. This can represent an important obstacle to reducing meat consumption or to the implementation of practices that effectively increase meat quality and value. Sustainably produced beef may be priced higher, which is an unattractive option for consumers and may not gain traction in the market.

Additionally, in the Argentinian context, meat production and consumption are perceived as part of the population's identity and embedded in national traditions. While the Argentinian government launched the "Green Mondays" campaign to encourage going meatless once a week, it was met with backlash from farmers and the rural population, with beef cited as "a badge of national identity that represents us in the world like no other" (Lonas, 2021). This mindset makes it unlikely for alternative products to be able to compete.

4 Recommendations

In a world compatible with the Paris Agreement, the agricultural sector will need to meet the growing food demand of people and animals, while contributing to other equally relevant climate and development objectives and adapt to a changing climate. Argentina is one of the world's largest agricultural producers, and the sector is critical to the economy and foreign export earnings. Climate change mitigation is essential to Argentinian agriculture as the sector is threatened by more frequent droughts and impaired livestock production. Climate action from key importers pose additional economic risks to Argentina. This study identified and quantified three mitigation actions in Argentina's agricultural sector that would improve productivity and provide environmental and economic co-benefits: implementing silvopastoral systems, livestock health monitoring, and livestock feed optimisation.

To maximise emission reductions in the agricultural sector, Argentina would need to take a multi-faceted approach. According to our calculations, while improving beef cattle emissions intensity through health monitoring and feed optimisation could mitigate emissions of 16 $MtCO_2e$/year, or 11% of 2019 emissions, at current production levels, increasing beef production in line with historical growth trends would offset any emission reductions and result in an absolute increase in livestock emissions. Although many crop-related mitigation measures have relatively little mitigation potential, they provide important co-benefits and increase the resilience of the sector to climate change impacts (Gonzales-Zuñiga *et al.*, 2022).

The highest mitigation potential in Argentina's agricultural sector is derived from the implementation of silvopastoral systems and can result in avoided emissions of 25 $MtCO_2e$/year in 2030 compared to a baseline scenario from avoided deforestation emissions attributed to the expansion of the livestock frontier. Integrating livestock systems onto existing native forest has been growing in popularity amongst farmers, especially in the subtropical region. Considering the significant mitigation potential of land use interventions, the Argentinian government should continue to promote their implementation through existing frameworks such as the National Forest Management Plan with Integrated Livestock (MBGI).

However, the successful implementation of agricultural mitigation measures is hampered by numerous barriers on the farm-, national-, international-, and consumer-level. For instance, current national policies encourage practices such as monocropping and are aligned with economic rather than climate objectives. This puts pressure on farmers to increase cattle herd size and subsequently leads to deforestation to expand the livestock frontier or to grow more feed. Argentina has a significant share of smallholder production systems, which presents challenges to disseminating knowledge and investing in new technologies, and many mitigation measures do not provide sufficient direct economic returns if implemented on a small-scale. The traditional and cultural values revolving around beef production and consumption can also pose a challenge towards shifting livestock production practices or exploring alternative proteins.

To accelerate the uptake and implementation of the measures described in this report, it is key to enhance the national mitigation framework in the agricultural sector and reconcile agricultural and development goals and mitigation options, while strengthening the international competitiveness of the sector and protecting it from environmental and economic risks. Some concrete options are outlined in the following paragraphs:

1. *Enhance the national climate mitigation framework in agriculture and align development objectives with mitigation objectives*

While Argentina has a National Action Plan for Agriculture and Climate Change, its outlined mitigation measures only cover around a fifth of its current AFOLU GHG emissions, none of

which address the livestock sector. Considering the livestock sector's significant contribution to Argentina's agricultural GHG emissions and the minimum reduction potentials estimated from crop-related measures, Argentina's current planned mitigation measures will not be sufficient for it to meet its commitments under the Paris Agreement (Climate Action Tracker, 2022).

Argentina could include a sectoral target for agriculture and LULUCF in its NDC and LTS that explicitly reflects mitigation requirements and the planned measures to achieve the target along with their mitigation potentials. It is highly likely that emissions from the livestock sector will have to be addressed in order for Argentina to achieve a 1.5°C-compatible pathway.

While continued growth in meat production is planned in line with Argentina's development goals, Argentina faces significant transition risks if it does not adapt its livestock sector towards a low-carbon model (Marquardt, Gonzales-Zuñiga, *et al.*, 2022). For instance, the European Union (EU) ban of imported products linked to deforestation, changing consumer preferences, or an imposed Carbon Border Adjustment Mechanism (CBAM) on agricultural products can affect the economic prospects of the agricultural sector. For Argentina to meet its development objectives, it will have to maintain its competitive advantage as an export-oriented producer in a carbon-constrained market, which will require fundamental changes in the livestock industry.

2. *Improve regulatory framework on existing laws and policies*

Despite the existence of Argentina's National Forest Law, which designates forest areas for conservation purposes, more than 40% of deforestation has occurred in protected areas (Greenpeace, 2019). The favourable economic conditions for agricultural expansion currently outweigh the regulatory power of the Forest Law, attributed to a lack of enforcement and insufficient funding. While the law offers monetary incentives, its current budget is lower than that established by law (World Bank Group, 2022). Considering Argentina's sizable emissions from deforestation, it is critical to ensure that policies are aligned in their message to farmers and more resources are put in place to successfully enforce the established policies. This can primarily be improved by strengthening local government capacities and offering higher financial incentives for protecting forest area.

3. *Further ideas for strengthening mitigation in prioritised areas*

Building on existing policy structures and initiatives, the Argentinian government can foster mitigation in the agricultural sector. Possible activities span promoting and incentivising improved agricultural practices and strengthening the governance framework around existing laws. Some more concrete, non-exhaustive ideas are:

- **Facilitate further capacity building and knowledge transfer**, particularly for livestock management and smallholder farmers. This can be done by establishing regional support facilities and technology diffusion programmes. Argentina's farmers have historically been open to adapting current practices and technologies to new contexts (e.g. adoption of no-till), given the changing country circumstances (Peiretti and Dumanski, 2014).
- **Improve financial support mechanisms and access to funds for smallholder farmers.** Argentina's high levels of government intervention has resulted in lower revenues for farmers, and most of the agricultural budget has been allocated to general services (e.g. agricultural research institutions, road infrastructure, etc.) rather than producers (OECD, 2019a). Argentina could offer more fiscal incentives for farmers to adopt sustainable practices, especially to reduce farmer's risk aversion towards their adoption.

- **Explore alternative protein production scenarios.** There are significant investment opportunities in the plant-based and cultivated protein market, which Argentina is well-placed to take advantage of. In addition to reducing the pressure of agricultural expansion on native forests and the environmental impacts of the meat industry, new business models can reduce the transition risks for stakeholders in emissions-intensive industries and drive domestic employment, while ensuring the continued economic sustainability of the Argentinian agricultural sector (Marquardt, Woollands, *et al.*, 2022).
- **Increase the resilience of agricultural production to climate change impacts.** Argentina's extensive livestock industry and rain-fed agricultural production systems are at high risk to climate variability and extreme events (World Bank, 2021a). Implementing mitigation measures can have considerable adaptation co-benefits by reducing the risks of livestock heat stress and mortality as well as drought impacts, and will decrease the volatility of domestic food supply and natural capital losses.

While this report focuses on improvements on the production of agricultural products, it is essential to highlight that Argentina's meat consumption habits are far above the recommendations from the Planetary Health Diet.[10] Discussing alternative narratives next to the current agricultural expansion plans could help understand the implications of a shift to largely plant-based diets and potentially avoid disruptions in the sector in the medium to long term. International research reports that demand-side measures, such as shifting to less meat intensive diets and reducing food waste, have a high mitigation potential while contributing to other co-benefits at relatively lower costs (Roe *et al.*, 2021).

[10] https://eatforum.org/eat-lancet-commission/the-planetary-health-diet-and-you/

5 List of references

Alston, J., Babcock, B., and Pardey, P. (2010): The Shifting Patterns of Agricultural Production and Productivity Worldwide. Iowa, USA

Andeweg, K. and Reisinger, A. (no date): 'Reducing greenhouse gas emissions from livestock: Best practice and emerging options.' Global Research Alliance. Available at: https://globalresearchalliance.org/wp-content/uploads/2014/12/LRG-SAI-Livestock-Mitigation_web2.pdf

Apampa, A., Clubb, C., Cosgrove, B.E., Gambarelli, G., Loth, H., Newman, R., Rodriguez Osuna, V., Oudelaar, J., and Tasse, A. (2021): Scaling up critical finance for sustainable food systems through blended finance. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/115123/Scaling up critical finance for sustainable food systems through blended finance.pdf

Arrieta, E.M. and Gonzales, A.D. (2018): 'impact of current, National Dietary Guidelines and alternative diets on greenhouse gas emissions in Argentina', Food Policy, 79, pp. 58–66. Available at: https://doi.org/10.1016/j.foodpol.2018.05.003

AWA (2013): 'A Breath of Fresh Air'. Animal Welfare Approved. Available at: https://sites.evergreen.edu/grazing/wp-content/uploads/sites/66/2015/03/A-Breath-of-Fresh-Air-v1.pdf

Bichos de Campo (2021): La superficie argentina bajo produccion organica alcanzo un record historico de 4,4 millones de hectareas. Available at: https://bichosdecampo.com/la-superficie-argentina-bajo-produccion-organica-alcanzo-un-record-historico-de-44-millones-de-hectareas/ (last accessed on 3 May 2022)

Bloomberg (2022): 'Argentina Extends Export Ban on Popular Beef Cuts to Tame Local Prices', European Edition. Available at: https://www.bloomberg.com/news/articles/2022-01-03/export-ban-on-popular-argentine-beef-cuts-extended-for-two-years#xj4y7vzkg

Braun, A., Van Dijk, S., Grulke, M., and UNIQUE forestry and land use GmbH (2016): Upscaling Silvopastoral systems in South America. Washington D.C, USA.

Brihet, J., Gayo, S., and Regeiro, D. (2021): 'Prácticas ambientales en la producción agrícola Argentina - Informe mensual N° 41'. Bolsa de Cereales. Available at: https://www.bolsadecereales.com/imagenes/retaa/2021-02/219-retaamensualn°41-practicasambientales.pdf

Bronstein, H. and Plume, K. (2018): Spoils of trade war: Argentina loads up on cheap U.S. soybeans, Reuters. Available at: https://www.reuters.com/article/us-g20-argentina-grains-insight-idUSKCN1NZ0HC

Buenos Aires Times (2021): Argentina's agribusiness plan casts doubt on climate goals, Buenos Aires Times. Available at: https://batimes.com.ar/news/economy/argentinas-agribusiness-plan-casts-doubt-on-climate-goals.phtml (last accessed on 7 Feb 2023)

Catacora-Vargas, G., Galeano, P., Agapito-Tenfen, S.Z., Aranda, D., Palau, T., and Onofre Nodari, R. (2012): 'Soybean Production in the Southern Cone of the Americas: Update on Land and Pesticide Use', p. 43. Available at: http://genok.no/wp-content/uploads/2013/03/Soybean-Production-in-the-Southern-Cone-of-the-Americas-Update-on-Land-and-Pesticide-Use.pdf

Climate Action Tracker (2019): Climate Governance: Argentina. Available at: https://climateactiontracker.org/documents/543/2019-09-30_CAT_ClimateGovernance_Argentina.pdf

Climate Action Tracker (2022): Argentina | November 2022 update. Available at: https://climateactiontracker.org/countries/argentina/ (last accessed on 27 Jan 2023)

Le Coq, J.-F., Sabourin, E., Bonin, M., Fréguin-Gresh, S., Marzin, J., Niederle, P., Patrouilleau, M.M., and Vásquez, L. (2020): 'Public policy support for agroecology in Latin America: Lessons and perspectives', Global Journal of Ecology, 5(1), pp. 129–138.

Domínguez, A., Bedano, J.C., and Becker, A.R. (2010): 'Negative effects of no-till on soil macrofauna and litter decomposition in Argentina as compared with natural grasslands', Soil and Tillage Research, 110(1), pp. 51–59. doi:10.1016/j.still.2010.06.008

FAO (2020): 'Fertilizers indicators'. Food and Agriculture Organization of the United Nations (FAO). Available at: http://www.fao.org/faostat/en/#data/EF/metadata

FAO (2022a): Emissions Totals [Dataset], FAOSTAT. Available at: https://www.fao.org/faostat/en/#data/GT (last accessed on 20 Jan 2022)

FAO (2022b): Land Use [Dataset], FAOSTAT. Available at: https://www.fao.org/faostat/en/#data/RL (last accessed on 20 Jan 2022)

FAO and ITPS (2021): Recarbonizing global soils – A technical manual of recommended management practices. Volume 3: Cropland, Grassland, Integrated systems and farming approaches – Practices overview. Available at: https://www.fao.org/3/cb6595en/cb6595en.pdf

FAO and NZAGRC (2017): 'Low emissions development of the beef cattle sector in Argentina'. Food and Agricultural Organization of the United Nations (FAO) & New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), p. 39. Available at: http://www.fao.org/3/i7671e/i7671e.pdf

Feeney, R. and MacClay, P. (2016): 'Food Security in Argentina: A Production or Distribution Problem?', International Food and Agribusiness Management Review, 19(2)

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., and Tempio, G. (2013): Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome: Food and Agriculture Organization of the United Nations (FAO).

Gonzales-Zuñiga, S., Pelekh, N., Röser, F., and Marquardt, M. (2022): 'Mitigation options for Argentina's agriculture sector'. NewClimate Insitute

Gonzalez Fischer, C. and Bilenca, D. (2020): 'Can we produce more beef without increasing its environmental impact? Argentina as a case study', Perspectives in Ecology and Conservation, 18(1), pp. 1–11. doi:10.1016/j.pecon.2019.12.002

Government of Argentina (2015a): Manejo de Bosques con Ganadería Integrada

Government of Argentina (2015b): Republic of Argentina Intended Nationally Determined Contribution (INDC), United Nations Framework Convention on Climate Change (UNFCCC). Available at: http://www4.unfccc.int/submissions/INDC/Published Documents/Mexico/1/MEXICO INDC 03.30.2015.pdf

Government of Argentina (2019a): Argentina's Third Biennial Update Report (BUR) to the UNFCCC [Tercer Informe Bienal De Actualización De La República Argentina A La Convención Marco De Las Naciones Unidas Sobre El Cambio Climático]. Available at: https://unfccc.int/sites/default/files/resource/3er Informe Bienal de la Republica Argentina.pdf

Government of Argentina (2019b): National Plan for Climate Change Adaptation and Mitigation - Version 1 [Plan Nacional de Adaptación y Mitigación al Cambio Climático - Versión 1]. Available at: http://argentinambiental.com/legislacion/nacional/resolucion-447-19-plan-nacional-de-adaptacion-y-mitigacion-al-cambio-climatico/

Government of Argentina (2020): Argentina's Second Nationally Determined Contribution [Segunda Contribución Determinada a Nivel Nacional de la República Argentina]. Ministry of Environment and Sustainable Development (MAyDS). Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Argentina Second/Argentina_Segunda Contribución Nacional.pdf (last accessed on 11 May 2021)

Government of Argentina (2021): Actualización de la meta de emisiones netas de Argentina al 2030 - Octubre 2021. Available at: https://unfccc.int/sites/default/files/NDC/2022-05/Actualización meta de emisiones 2030.pdf

Government of Argentina (2022): Estrategia de desarrollo resiliente con bajas emissions a largo plazo a 2050. Available at: https://unfccc.int/sites/default/files/resource/Estrategia de desarrollo resiliente con bajas emisiones a largo plazo a 2050.pdf

Greenpeace (2019): Greenpeace: "Durante 2018, se deforestó ilegalmente el equivalente a dos veces Buenos Aires". Available at: https://www.greenpeace.org/argentina/story/issues/bosques/greenpeace-durante-2018-se-deforesto-ilegalmente-el-equivalente-a-dos-veces-buenos-aires/ (last accessed on 12 Oct 2021)

Gütschow, J., Jeffery, M.L., Gieseke, R., Gebel, R., Stevens, D., Krapp, M., and Rocha, M. (2016): 'The PRIMAP-hist national historical emissions time series', Earth System Science Data, 8(2), pp. 571–603. doi:10.5194/essd-8-571-2016

Gütschow, J., Günther, A., and Pflüger, M. (2021): 'The PRIMAP-hist national historical emissions time series v2.3 (1750-2019)'. doi:10.5281/zenodo.5175154

Hartmann, A. and Fritz, T. (2018): 'Trade at any cost?' foodwatch. Available at: https://www.foodwatch.org/fileadmin/foodwatch_international/campaigns/TTIP/2018-02_Trade-at-any-cost_report-foodwatch-powershift_EN.pdf

Harvard Law School Food Law and Policy Clinic and The Global FoodBanking Network (2020): The Global Food Donation Policy Atlas: Argentina Executive Summary. Available at: https://www.foodbanking.org/wp-content/uploads/2023/01/Argentina-Executive-Summary-05.29.20.pdf

Heath, M. (2020): UPDATE 5-Argentina suspends corn exports to ensure domestic food supplies, Reuters. Available at: https://www.reuters.com/article/argentina-corn-idINL1N2JA1MN

Heath, M. and Bronstein, H. (2019): Argentina's new government hikes export taxes on disgruntled farmers, Reuters. Reuters. Available at: https://www.reuters.com/article/us-argentina-grains-idUSKBN1YI0II

Hiba, J. (2021a): 'Argentina's land laws stifle sustainable agriculture'. China Dialogue. Available at: https://chinadialogue.net/en/food/argentinas-land-laws-stifle-sustainable-agriculture/

Hiba, J. (2021b): 'Is Argentina's soy boom over?', Dialogo Chino, July. Available at: https://dialogochino.net/en/agriculture/44411-is-argentinas-soy-boom-over/

Ibrahim, M., Guerra, L., Casasola, F., and Neely, C. (2010): Importance of silvopastoral systems for mitigation of climate change and harnessing of environmental benefits, Grassland Carbon Sequestration: Management, Policy and Economics. Available at: http://www.fao.org/docrep/013/i1880e/i1880e09.pdf

INDEC (2019): Comercio exterior - Complejos exportadores en Argentina

INTA (2019): 'El mapa de necesidades nutricionales de los suelos pampeanos'. Available at: https://inta.gob.ar/noticias/el-mapa-de-necesidades-nutricionales-de-los-suelos-pampeanos

Jourdan, A. (2021): 'Argentina inflation spikes to 18-month high with meat prices in focus'. Reuters. Available at: https://www.reuters.com/world/americas/argentina-inflation-speeds-48-march-fastest-pace-since-2019-2021-04-15/

Kipling, R.P., Taft, H.E., Chadwick, D.R., Styles, D., and Moorby, J. (2019): 'Challenges to implementing greenhouse gas mitigation measures in livestock agriculture: A conceptual framework for policymakers', Environmental Science and Policy, 92, pp. 107–115. doi:10.1016/j.envsci.2018.11.013

Koop, F. (2020): 'Depleted soils drive Argentina to sustinable farming', Dialogo Chino. Available at: https://dialogochino.net/en/agriculture/35279-depleted-soils-drive-argentina-to-agroecology/

Lallana, F., Bravo, G., Le Treut, G., Lefèvre, J., Nadal, G., and Di Sbroiavacca, N. (2021): 'Exploring deep decarbonization pathways for Argentina', Energy Strategy Reviews, 36. doi:10.1016/j.esr.2021.100670

Llonch, P., Haskell, M.J., Turner, R.J., and Dewhurst, S.P. (2017): 'Review: current available strategies to mitigate greenhouse gas emissions in livestock systems: an animal welfare perspective', Animal, 11(2), pp. 274–284. doi:10.1017/S1751731116001440

Lonas, L. (2021): Argentina launches 'Green Mondays' campaign to cut greenhouse gases, The Hill. Available at: https://thehill.com/policy/energy-environment/552058-argentina-launches-green-mondays-campaign-to-cut-greenhouse-gases/ (last accessed on 27 Jan 2023)

Magrin, G.O., Marengo, J.A., Boulanger, J.-P., Buckeridge, M.S., Castellanos, E., Poveda, G., Scarano, F.R., and Vicuña, S. (2014): Central and South America. In: 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., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1499-1566.

MAGyP (2019): Plan de acción nacional de agro y cambio climático. Ministry of Agriculture, Livestock and Fisheries (MAGyP). Available at: https://www.magyp.gob.ar/sitio/_pdf/plan_sectorial_cc.pdf

Marquardt, M., Woollands, S., Gonzales-Zuñiga, S., Pelekh, N., and Röser, F. (2022): 'The global protein transition: An opportunity for Argentina'. NewClimate Institute. Available at: https://ambitiontoaction.net/wp-content/uploads/2022/04/AmbitionToAction_WP3-Report-GlobalOpportunity-ENG_Mar22.pdf

Marquardt, M., Gonzales-Zuñiga, S., Röser, F., Cabrini, S.M., Gastaldi, L.B., Amaro, I.B., and Pace Guerrero, I.R. (2022): 'Transition risks for Argentina's agriculture sector'. NewClimate Insitute, INTA. Available at: https://ambitiontoaction.net/wp-content/uploads/2022/04/AmbitionToAction_WP1-Report-ENG-TransitionRisks_Mar22.pdf

MAyDS (2022a): Argentina's national GHG emissions inventory [Inventario nacional de gases de efecto invernadero de Argentina]. Ministry of Environment and Sustainable Development [Ministerio Ambiente y Desarrollo Sustentable]. Available at: https://inventariogei.ambiente.gob.ar/resultados (last accessed on 10 Dec 2022)

MAyDS (2022b): Informe Nacional de Inventario del Cuarto Informe Bienal de Actualización de la República Argentina a la Convención Marco de las Naciones Unidas para el Cambio Climático (CMNUCC). Available at: https://unfccc.int/sites/default/files/resource/Informe Nacional de Inventario del IBA 4_0.pdf

Muñoz, L.A. Gómez, M.C., Jiménez, D., Hasiner, E., Schroeder, K., Treguer, D., Juergenliemk, A., Horst, A., Jarvis, A., and Kropff, W. (2021): Digital Agriculture Profile - Argentina. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/a7eaf9ef-37d8-4e35-b89a-b02f1491b8da/content

OECD (2019a): Agricultural Policies in Argentina. Organisation for Economic Co-operation and Development (OECD). Available at: https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/CA(2018)9/FINAL&docLanguage=En

OECD (2019b): Water Governance in Argentina. Paris, France: OECD. doi:10.1787/bc9ccbf6-en

OECD (2020): Agricultural Policy Monitoring and Evaluation 2020 - Argentina. Available at: https://www.oecd-ilibrary.org/sites/891d50ae-en/index.html?itemId=/content/component/891d50ae-en

OECD (2021): Agricultural Policy Monitoring and Evaluation 2021: Addressing the challenges facing food systems. doi:10.1787/22217371

OECD (2023): Meat consumption (indicator), OECD. Available at: https://data.oecd.org/agroutput/meat-consumption.htm (last accessed on 19 Jul 2023)

OIE (2017): 'Animal welfare: an asset for livestock production'. World Organisation for Animal Health (OIE). Available at: https://www.oie.int/app/uploads/2021/03/bull-2017-1-eng.pdf

OIT (2021): 'Empleo informal en la economía rural de América Latina 2012-2019'. International Labour Organization (OIT). Available at: https://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/documents/publication/wcms_795313.pdf

Özkan, Ş., Teillard, F., Lindsay, B., Montgomery, H., Rota, A., Gerber P., Dhingra M., and Mottet, A. (2022): The role of animal health in national climate commitments. doi:10.4060/cc0431en

Pavan, E., Grigioni, G., Aguirre, P., and Leal, M. (2017): 'What is meat in Argentina?', Animal Frontiers, 7(4), pp. 44–47. Available at: https://doi.org/10.2527/af.2017.0434

Peiretti, R. and Dumanski, J. (2014): 'The transformation of agriculture in Argentina through soil conservation', International Soil and Water Conservation Research, 2(1), pp. 14–20. doi:10.1016/S2095-6339(15)30010-1

Perez, L. (2016): 'Silvopastoril, un sistema en expasion en la Argentina', RIA, 42(2), pp. 20–124

Peri, P.L., Rosas, Y.M., Ladd, B., Toledo, S., Lasagno, R.G., and Martínez Pastur, G. (2018): 'Modelling soil carbon content in South Patagonia and evaluating changes according to climate, vegetation, desertification and grazing', Sustainability (Switzerland), 10(2). doi:10.3390/su10020438

Peri, P.L., Dube, F., and Varella, A. (2016): Silvopastoral Systems in Southern South America. London: Springer

Pezo, D., Rios, N., Ibrahim, M., and Gomez, M. (2018): Silvopastoral Systems for Intensifying Cattle Production and Enhancing Forest Cover: The Case of Costa Rica. Washington D.C

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A., Doelman, J., Emmet-Booth, J., Engelmann, J., Fricko, O., Frischmann, C., Funk, J., Grassi, G., Griscom, B., Havlik, P., Hanssen, S., Humpenöder, F., Landholm, D., Lomax, G., Lehmann, J., Mesnildrey, L., Nabuurs, G-J., Popp, A., Rivard, Sanderman, J., Sohngen, B., Smith, P., Stehfest, E., Woolf, D., and Lawrence, D. (2021): 'Land-based measures to mitigate climate change: Potential and feasibility by country', Global Change Biology, 27(23), pp. 6025–6058. doi:10.1111/gcb.15873

SENASA (2016): Situation of Organic Production in Argentina during 2016. Buenos Aires, Argentina

Siemons, A., Urrutia, C., Gonzales-Zuñiga, S., Pelekh, N., and Jeffery, L. (2023): Barriers to mitigating emissions from agriculture: Analysis of mitigation options, related barriers and recommendations for action. German Environment Agency. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/cc_05-2023_barriers_to_mitigating_emissions_from_agriculture.pdf

Tan, L. (2018): Fertilizer: Argentina Might be the Next Big Market, AgFax. Available at: https://agfax.com/2018/01/26/fertilizer-argentina-might-be-the-next-big-fertilizer-market-dtn/

Telam (2017): 'El desperdicio de alimentos en Argentina llega a 16 millones de toneladas anuales'. Available at: https://www.telam.com.ar/notas/201706/191327-nestor-roulet-desperdicio-alimentos.html

Volante, J.N., Mosciaro, M.J., Gavier-Pizarro, G.I., and Paruelo, J.M. (2016): 'Agricultural expansion in the Semiarid Chaco: Poorly selective contagious advance', Land Use Policy, 55, pp. 154–165. doi:10.1016/j.landusepol.2016.03.025

World Bank (2021a): Climate risk country profile - Argentina. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15850-WB_Argentina Country Profile-WEB %281%29.pdf

World Bank (2021b): Employment in agriculture (% of total employment) (modeled ILO estimate), World Bank Open Data. Available at: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS (last accessed on 20 Jan 2022)

World Bank (2022): Agriculture, forestry, and fishing, value added (% of GDP) [Dataset], World Development Indicators. Available at: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?view=chart (last accessed on 2 May 2022)

World Bank, CIAT, and CATIE (2015): Climate-Smart Agriculture in Argentina. Washington D.C. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA-in-Argentina.pdf

World Bank Group (2016): Argentina Country Environmental Analysis. doi:10.1596/25775

World Bank Group (2022): Country Climate and Development Report: Argentina. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/38252/ARG_CCDR_ExecutiveSummary.pdfhttps://openknowledge.worldbank.org/bitstream/handle/10986/38252/ARG_CCDR_ExecutiveSummary.pdf

Wyatt, D. (2021): Argentina's beef export ban, Agriculture and Horticulture Development Board. Available at: https://ahdb.org.uk/news/argentina-s-beef-export-ban