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KlimRess – Impacts of climate change on mining, related environmental risks and raw material supply

Case study on tin mining in Indonesia

For our Environment

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KlimRess – Impacts of climate change on mining, related environmental risks and raw material supply

Case study on tin mining in Indonesia

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Abstract

The following case study is one of five country case studies carried out as part of the project 'Impacts of climate change on the environmental criticality of Germany's raw material demand' (KlimRess), commissioned by the German Federal Environment Agency (Umweltbundesamt, UBA). The project team comprised adelphi, ifeu Heidelberg and the Sustainable Minerals Institute of the University of Queensland. The aim of the project was to assess how climate change potentially affects the environmental risks of mining and raw material supply chains.

This case study analyses on- and offshore tin mining operations in Indonesia's Bangka Belitung province, where both large-scale industrial companies (in particular PT Timah) and artisanal and small-scale miners (ASM) operate. It is not always possible to distinguish whether environmental impacts are caused by large- or small-scale operations, or indeed both. Onshore tin mining has a large land footprint, marked by changes to topsoil and vegetation cover. This leads to watershed degradation, sedimentation and flooding, while overburden and tailings lead to a decrease in soil quality. Meanwhile, offshore tin mining can affect the marine ecosystem by destroying the seabed or spilling toxic fuel and oil into the water. Whereas PT Timah has monitoring measures in place and engages in marine rehabilitation, ASM offshore operations are largely uncontrolled.

Banka Belitung province has a tropical climate, which is expected to experience different climate change impacts. Rainfall and flooding events are expected to increase during wet seasons, while mining-related landscape changes increase the susceptibility for flooding. Although flooding can impact the water quality through erosion and sedimentation, it remains unclear if the washed out radioactive heavy minerals stored at the smelter could contribute to pollution. Flooding can also increase the transmission of malaria and dengue fever by making breeding conditions for mosquitoes more favourable. Finally, extreme weather events and other climate impacts could potentially interrupting the mining operations affecting the tin supply from Bangka Belitung.

Kurzbeschreibung

Die vorliegende Fallstudie ist eine von fünf Länderfallstudien des im Auftrag des Umweltbundesamtes (UBA) durchgeführten Projekts „Auswirkungen des Klimawandels auf die ökologische Kritikalität des deutschen Rohstoffbedarfs“ (KlimRess). adelphi, das ifeu (Institut für Energie- und Umweltforschung Heidelberg) und das Sustainable Minerals Institute der University of Queensland untersuchten dabei die möglichen Auswirkungen des Klimawandels auf mit dem Bergbau einhergehende Umweltrisiken und Rohstofflieferketten.

Diese Fallstudie analysiert die Zinngewinnung in der indonesischen Provinz Bangka Belitung, der sowohl durch große Bergbauunternehmen (insbesondere PT Timah) als auch im Kleinbergbau erfolgt, wobei eine eindeutige Zuordnung der Umweltauswirkungen nicht immer möglich ist. Der Zinnabbau an Land (onshore) hat einen großen Landverbrauch mit gravierenden Auswirkungen auf den Oberboden und die Vegetation. In Küstengewässern (offshore) kann der Zinnabbau marine Ökosysteme durch die Beeinträchtigung des Meeresbodens oder giftige Emissionen beschädigen. Während PT Timah Kontrollmaßnahmen und Rekultivierung betreibt, ist der Kleinbergbau weitgehend unkontrolliert.

Die Provinz Banka Belitung hat ein tropisches Klima, welches sich im Kontext des Klimawandels verändern wird. Die Landschaftsveränderungen durch den Zinnabbau erhöhen die Anfälligkeit für Hochwasser. Gleichzeitig dürften Niederschläge und damit auch die Überschwemmungsgefahr in der Regenzeit zunehmen. Überschwemmungen können die Wasserqualität durch Erosion und Sedimentation beeinträchtigen und die Übertragung von Malaria und Dengue-Fieber erleichtern (durch verbesserte Brutbedingungen für Moskitos). Ob das Auswaschen der radioaktiven Schwermetalle, die bei der Ver-

hüttung entstehen, zu Verschmutzung führen könnte, ist unklar. Zusätzlich können extreme Wetterereignisse den Zinnabbau in Bangka Belitung unterbrechen und damit die Versorgung mit Zinn beeinträchtigen.

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List of Abbreviations

Af	Tropical rainforest climate (Köppen-Geiger classification)
AR4	Fourth Assessment Report of the Intergovernmental Panel on Climate Change
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
ASEAN	Association of Southeast Asian Nations
ASM	Artisanal and small-scale mining
Aw	Tropic winter dry (Köppen-Geiger classification)
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
BNPB	Badan Nasional Penanggulangan Bencana (National Disaster Management Agency)
ENSO	El Niño-Southern Oscillation
ILO	International Labour Organization
RAN-API	Rencana Aksi Nasional Adaptasi Perubahan Iklim (National Action Plan for Climate Change Adaptation)
TOE	Tonne Oil Equivalent
UBA	Umweltbundesamt (German Federal Environment Agency)
VRLA	Valve-regulated lead acid

1 Introduction

1.1 Project background

The following case study is one of five country case studies of the project 'Impacts of climate change on the environmental criticality of Germany's raw material demand' (KlimRess), commissioned by the German Federal Environment Agency (*Umweltbundesamt*, UBA). The project team comprised adelphi, ifeu Heidelberg and the Sustainable Minerals Institute of the University of Queensland. The aim of the project was to assess how climate change can potentially impact the environmental risks of mining and affect raw material supply chains.

Based on a systematic assessment of the case study results, the project team identified the most significant climate impacts across case studies. The project team also explored the links between climate change and a newly developed method to evaluate environmental hazard potentials as part of an environmental criticality assessment (OekoRess method) in order to inform the discussion of environmental criticality. Lastly, the project team combined data on current production and expected future production of nine raw materials with data on countries' vulnerability to climate change in order to identify patterns of particularly vulnerable raw materials and producing countries. The results are published in the final report of the project (see Rüttinger et al., 2020).

Based on these results, the project team developed recommendations on how to best adapt the mining sector, how to incentivise climate change adaptation measures in mining and how to foster effective mechanisms for the exchange of knowledge and expertise on the topic globally. These policy recommendations were published separately in the form of a recommendation paper (see van Ackern et al., 2020).

1.2 Selection of case studies

The case studies conducted as part of the project covered five different (climatic) regions:

1. Arid regions with water stress
2. Humid tropical regions
3. Polar or subpolar regions
4. Temperate regions
5. Coastal regions

In addition, the case studies covered nine raw materials that were identified and selected based on the following criteria:

- The importance of minerals and metals for future and environmental technologies
- Base metals, alloys and auxiliary materials important for the German economy

Other criteria that informed the case study selection were the climate change vulnerability of countries, their governance contexts and the prevalence of conflicts related to mining. The aim was to select a set of most different cases. Further selection criteria were the political relevance for Germany, the research institutions' partner networks and the availability of data.

The selected metals and minerals were: bauxite, coking coal, copper, iron ore, lithium, nickel, PGMs, tin and tungsten.

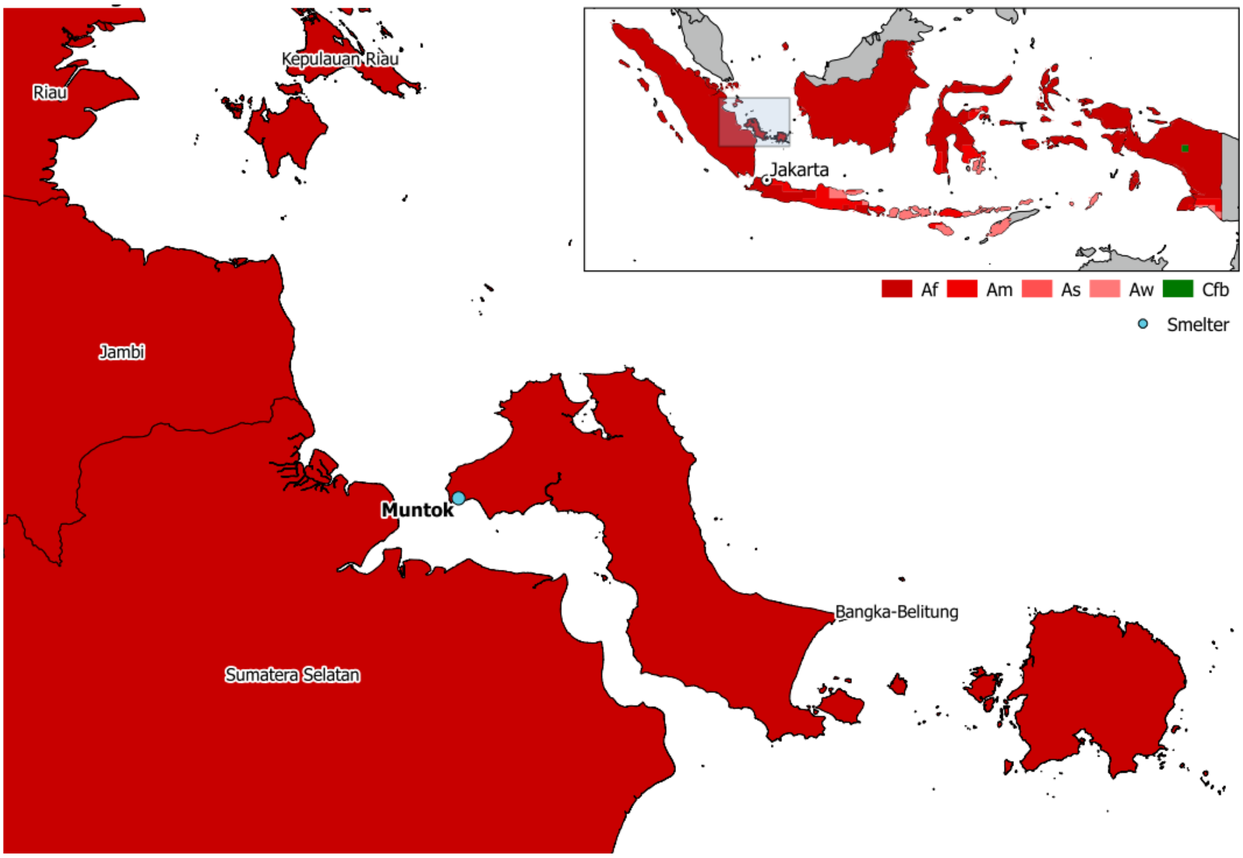
Each case study analysed a chosen mine site and the processing steps (to the extent these take place in the relevant country). The project team evaluated the environmental and supply risks potentially caused by climate stimuli and/or direct climate impacts for each of the mining and processing sites.

1.3 Content and structure of case studies

This study on Indonesia focuses on the following resource and mining sites (see Figure 1):

- PT Timah mining operations:[1] Onshore and offshore tin mining (tropical climate)

Figure 1: Map of Bangka Belitung Province and Indonesia (box) indicating Köppen-Geiger climate classification and smelter location



Source: Maps prepared by adelphi using QGIS Geographic Information System (http://qgis.osgeo.org); climatic regions based on Rubel and Kottek, 2010.

The case studies are based on extensive secondary research, including the scientific literature, as well as reports and statements published by national government agencies, civil society organisations, mining and processing companies and the media.

First, the case studies provide a brief overview of the climatic conditions and projected climatic changes (in the case of this case study, for tropical and coastal regions and for Indonesia as a whole). The studies then present an overview of the country's mining sector and its economic relevance as well as a summary of the country's mining governance (including disaster risk management, climate change adaptation, the environment, indigenous people and mining-related conflicts).

Second, we analyse the resources separately, covering the following topics:

- The global value chain of the respective resource

[1] As the boundaries between PT Timah industrial operations and other artisanal and/or small-scale mining operations in the region are blurred, we take both forms of mining into account.

- Site-specific overview of the mine site
- Extraction and processing technologies
- Current environmental impacts and mitigation measures
- Current climate impacts and risks
- Climate change impact assessment:

The climate impact assessments are based on the *Guidelines for Climate Impact and Vulnerability Assessment*, published by the UBA (Buth et al., 2017). The Guidelines propose a combination of concepts outlined in the *Fourth Assessment Report* (AR4) (IPCC, 2007) and *Fifth Assessment Report* (AR5) (IPCC, 2014) of the Intergovernmental Panel on Climate Change. We use the terminology proposed by the Guidelines. To increase the compatibility across the Guidelines and the new AR5 approaches, we also indicate in the right margin the AR5 terminology in the climate impact chain diagrams (i.e. hazards, exposure and risks).

Finally, we summarise and discuss main findings of the case study.

2 Overview of climatic conditions and projected changes

The Indonesian Bangka and Belitung Province, where the tin mining operations analysed in the case study are located, are characterised by a tropical climate and an insular nature with long coastlines.

2.1 Tropical regions

The climate classification outlined by Köppen-Geiger defines the tropics as a region where the mean temperature of the coolest month is 18°C or higher (Peel et al., 2007). This climatic zone has three subtypes, defined by precipitation criteria: wet equatorial climate or tropical rainforest climate[2]; tropical monsoon and trade-wind littoral climate[3]; and tropical wet-dry climate or tropical savannah climate[4] (Arnfield, 2016; Peel et al., 2007). The tropics cover 19 per cent of the global land area (Peel et al., 2007).

Tropical regions are characterised by a warm climate, with mean annual temperatures exceeding 20°C and in many parts even 25°C. The temperature varies little during the year. The annual temperature ranges are usually very small; near the equator, the mean temperature of the hottest months is only marginally higher than the mean temperature of the coolest months. Day-to-day temperature fluctuations are also minimal. In contrast to the relatively constant temperature, precipitation regimes differ considerably throughout the tropics, ranging from the driest places on earth (e.g. in the South American Atacama desert with less than 1 mm mean annual rainfall) to the wettest (e.g. some locations in Hawaii with more than 10,000 mm mean annual rainfall) (Trewin, 2014). In regions with wet equatorial or tropical rainforest climates, rain falls regularly throughout the year. Tropical monsoon and trade-wind littoral climate zones can be characterised by a well-defined, but brief dry season, while zones with tropical wet-dry/tropical savannah climate usually have a longer dry season. At locations on islands or near the coast, temperature and precipitation vary slightly.

The El Niño-Southern Oscillation (ENSO) causes high natural climatic variability in the tropics, which makes it harder to detect the impacts of anthropogenic climate change. Other human impacts, such as deforestation and urbanisation, also have impacts on the region's climate (Corlett, 2014). A lack of climatic data, especially for continental Africa, the Amazon and the tropical Pacific, constrains projections (Trewin, 2014). Nevertheless, there has been an observable warming by 0.7 to 0.8 °C over the last century. This has led to some visible impacts on land and in the sea: high-mountain flora and fauna have moved upslope, glaciers in the Andes and East Africa have shrunk and extreme mass coral bleaching periods have occurred in the oceans (Corlett, 2014).

Rainfall trends for the tropics are less clear, since the amount of rainfall fluctuates from year to year, partly due to ENSO. However, the last 30 years have shown a general increase in precipitation, with some parts of the tropics experiencing a decrease (e.g. in parts of Brazil and the central equatorial Pacific) (Trewin, 2014).

Tropical cyclones are important tropical atmospheric phenomena. They can unleash particularly destructive forces, as they combine extreme winds, extreme rainfall (can cause freshwater flooding and landslides) and storm surges (can cause elevated sea levels and flooding). Storm surges caused by cyclones have led to many fatalities in the past, especially along low-lying coastal areas with large populations. The number of tropical cyclones per year has stayed notably constant from year to year, at between 75 and 100 cyclones per year. In terms of intensity, there are no clear trends in cyclone activities (Trewin, 2014).

[2] Precipitation in the driest month is at least 60 mm.

[3] Precipitation in the driest month is less than 60 mm but equal to or greater than 100-average annual precipitation total mm/25.

[4] Precipitation in the driest month is less than 60 mm but less than 100-average annual precipitation total mm/25.

Climate projections show a further temperature increase of 1°C by 2050 and a 1-2°C increase by 2100 under the lowest-emission scenario, whereas high-emission scenarios project increases of 1-2°C (by 2050) and 3-4°C (by 2100). This is slightly less warming than in other climatic regions. For rainfall projections, there is generally low confidence and therefore high uncertainty. Rainfall might increase, seasons with rainfall might intensify (with wetter and longer wet seasons and drier dry seasons) and extreme rainfall events might occur more often. Projections show that the number of cyclones will either decrease or stay more or less the same, but that there will be a larger share of intense cyclones (Trewin, 2014). Heatwaves are likely to increase in frequency and severity. These changes can have severe impacts on many less-developed tropical countries due to their high vulnerability to extreme weather events – especially poor people in urban informal settlements and rural areas with less access to supporting infrastructure and public services (Trewin, 2014; Corlett, 2014).

2.2 Coastal regions

Coastal regions are geographical areas that lie in all climatic zones. Coastal systems and low-lying areas are defined as areas close to the mean sea level (Wong et al., 2014).

According to AR5, the global sea level is very likely to rise. There is high confidence that coasts will be impacted by submergence, flooding, coastal erosion and salt water intrusion caused by relative sea level rise which can vary substantially from the projected global mean sea level rise based on location. General sea level rise will also mean an increase in extreme sea levels[5] (Wong et al., 2014).

Coastal ecosystems will suffer from increasing ocean acidification and warming (Wong et al., 2014). In terms of extreme weather events, tropical cyclone frequency is likely to decrease or not to change, while the intensity of tropical cyclones is likely to increase (Wong et al., 2014). The intensified impacts of cyclones (e.g. storm surges, storm waves, coastal flooding, erosion and the potential damage to coastal infrastructures) would be felt most strongly in coastal regions (Corlett, 2014). Projections for increased winds and waves generally have low confidence (Wong et al., 2014).

Population growth, economic development and increasing urbanisation in coastal areas will put additional pressure on natural and human coastal systems. Coastal populations, especially in tropical countries, are most vulnerable to sea level rise (Wong et al., 2014; Trewin, 2014). AR5 states with high confidence: "Without adaptation, hundreds of millions of people will be affected by coastal flooding and will be displaced due to land loss by year 2100; the majority of those affected are from East, Southeast, and South Asia" (Wong et al., 2014: 364).

2.3 Indonesia

With around 17,000 islands, Indonesia is the largest archipelagic country in the world (Wingqquist and Dahlberg, 2008) and shows a great variety in topography and geography. In terms of climate, the country lies in the tropics. Further climatic differentiations vary mainly due to the differing levels of rainfall, which range from 1,800 to 3,200 mm in the lowlands up to 6,000 mm in the higher mountain areas (USAID, 2017). Average annual temperatures range between 23 and 28 degrees Celsius, with lower temperatures in the mountain areas, and higher temperatures in coastal plains (GERICS, 2016). Indonesia has two main seasons: the north monsoon (November to May) and the south monsoon (May to September). During the north monsoon north-facing coasts and northern islands experience wetter weather, while during the south monsoon south-facing coasts and southern islands are wetter (GERICS 2016). The interannual climate variability is affected by ENSO (USAID, 2017), whereas monsoon and ENSO can interact (Supari and Setiawan, 2013).

[5] Description of extreme sea levels: 'Extreme sea levels are those that arise from combinations of factors including astronomical tides, storm surges, wind waves and swell, and interannual variability in sea levels. Storm surges are caused by the falling atmospheric pressures and surface wind stress associated with storms such as tropical and ETCs [extratropical cyclones] and therefore may change if storms are affected by climate change' (Wong et al. 2014: 370).

According to the Köppen-Geiger climate classification, Indonesia is mainly characterized by tropical rainforest climate (Af), with constant high temperatures and constant rainfalls. To the east of the country, this characteristic climate gradually shifts to a drier tropic climate (Aw – tropic winter dry). The mining facilities analysed in this case study (PT Timah tin mining and processing sites and small-scale mining areas) are located in Indonesia's central western Bangka Belitung Province, situated between Malaysia in the north and the bigger Indonesian islands Kalimantan (east), Sumatra (west) and Java (south). The Bangka-Belitung region is characterized by tropical rainforest climate (Af) with consistent rainfall (Rubel and Kottek, 2010).

Indonesia's National Action Plan for Climate Change Adaptation (RAN-API), published by the Indonesian Ministry of National Development Planning, the Ministry of the Environment, the National Council on Climate Change and the Meteorological, Climatological and Geophysical Agency (Republic of Indonesia, 2013) and other reports give an overview of observed current changes in Indonesia's climate and projections for future developments. The report states that mean temperatures did increase around 1 degree Celsius during the 20th century. However, the report also states that due to inconsistent historic data, an accurate estimate is difficult. Changes in annual rainfall (comparison of the periods 1961-1990 and 1980-2010) vary. Rainfall slightly increased over most regions. However, there are also areas with decreasing trends in average rainfall. The frequency of daily extreme rainfall events increased over most parts of Indonesia. Droughts are reported to occur more frequently (every 4 years before 1960, now every 3 years) (NCEA, 2016). Sea-level rise was assessed based on Simple Ocean Data Assimilation and around 0.8 mm/year from 1860 on, changing to 1.6 mm/year in 1960 and sharply increasing to values around 7 mm/year after 1993 (Republic of Indonesia, 2013).

Based on AR4 models and three different scenarios (B1, A1B and A2), the RAN-API 2013 outlines the projected increase in average surface temperature between 0.8 and 1°C throughout Indonesia for the period of 2020-2050. Looking further into the future, results for the different scenarios diverge, showing temperature increases from 0.8 to above 3°C by 2085 (GERICS, 2016). AR5 projections indicate the same magnitude of increase (GERICS, 2016). As natural variability is characteristic for rainfall, it is not projected to change significantly for the period of 2020-2050 (Republic of Indonesia, 2013). Projections for 2080 for all scenarios show increasing precipitation over most of Indonesia, with the exception of some southern parts, where a decrease in precipitation is projected (Case et al., 2007). The RAN-API 2013 states that comprehensive projections for extreme weather events are still limited. Projections indicate that the frequency and the intensity of heavy rain fall events might increase (USAID, 2017). The Netherlands Commission for Environmental Assessment (NCEA, 2016) reports that droughts (particularly during El Niño events) are projected to increase, while floods are projected to become more intense during the rainy season in the south of Indonesia. Some studies suggest that the frequency of tropical cyclones decreases, but the intensity could increase (Met Office, 2011). Future trajectories of ENSO remain difficult to project, as it is expected to have a non-linear response to global warming (Power et al., 2013). Sea surface temperature[6] is projected to increase by 0.65°C until 2030 and 1.1°C until 2050 under the A1B scenario (Republic of Indonesia, 2010). The sea level is projected to rise by 22.5 cm ± 1.5cm by 2030 and by 35 cm to 40 cm by 2050, also under the A1B scenario (Republic of Indonesia, 2010).

[6] Sea surface and sea level rise projections are relative to 2000.

3 Overview of the mining sector

The mining sector is an important, yet relatively small sector of the Indonesian economy. In 2016, it contributed 13 per cent of the total Indonesian exports and 4.34 per cent of the national GDP (PWC, 2017) as well as a much more significant share in some regional economies in particularly resource-rich provinces, e.g. Bangka Belitung, West Papua, East Kalimantan or West Nusa Tenggara (Devi and Prayogo, 2013). Indonesia has rich resources of coal, copper, gold, tin, nickel and bauxite (PWC, 2017; VDMA, 2012).

The country is an important raw material supplier to the international market. Its main export in 2016 was palm oil – followed by coal, natural gas, petroleum oils, copper, natural rubber and other agricultural products (Kementerian Perdagangan, 2017). The country is one of the largest exporters of thermal coal worldwide (PWC, 2017). Having coal deposits of a similar size to that of the US, Indonesian coal makes up for 9 per cent of global exports and 95 per cent of coal exports from ASEAN (SES Professionals, 2017).

Although Indonesia is by far the second largest tin producing country worldwide (after China), the mineral has little significance to the whole Indonesian economy. The resource's share of total exports of the country was only 0.78 per cent in 2016 with a total value of 1.1345 bn USD (in comparison: sports footwear contributed 0.82 per cent) (Kementarian Perdagangan, 2017a). This amounted to 0.12 per cent of the GDP in 2016 (Trading Economics, 2017). While low, this value is higher than in previous years, probably owing to the increased global tin price. Indonesian tin mining is mainly concentrated on the two islands of Bangka and Belitung, where about 90 per cent of the country's tin is sourced (Carlin, 2003). Tin mining contributed 13.51 per cent to Bangka Belitung's regional GDP in 2014, less than in earlier years: in 2010, tin mining contributed over 17 per cent to the regional GDP (BPS-Statistics of Kepulauan Bangka Belitung Province, 2015). In some of Bangka Belitung's regencies (the province's administrative subunits), however, tin mining has a more important share of the local GDP; e.g. in the regency Bangka and Selatan it was 22.96 per cent in 2016 and 34.29 per cent in 2010 (BPS-Statistics of Bangka Selatan Regency, 2017).

Both domestic and international companies engage in large-scale industrial tin mining. The national market is dominated, however, by PT Timah – the world's largest integrated tin mining company (Devi and Prayogo, 2013) and third largest producer of refined tin (ITRI, 2017c). The state-owned company is the largest operator in Bangka Belitung, followed by PT Koba Tin in which PT Timah has a 25 per cent share and the Malaysian Smelting Corporation a 75 per cent share (Devi and Prayogo, 2013). Historically, tin mining has always drawn investments from abroad, notably featuring 'new' mining players from China, India, Russia and South Korea (Devi and Prayogo, 2013). However, corruption, collusion, nepotism, lacking coordination between central, provincial and regional governments, unpredictable changes in governmental policies, as well as conflicting mining and forestry regulations, have all contributed to a generally low investor confidence in Indonesia (PWC, 2017; Devi and Prayogo, 2013).

Artisanal and small-scale mining (ASM) plays a large role in the Indonesian tin mining sector. Most of ASM in the tin sector is informal and does not provide social protection and environmental safeguards are lacking (Devi and Prayogo, 2013; Friends of the Earth, 2012). A multitude of different regulations and small-scale miners operating partially with permits from larger mining companies or private land owners make it difficult to assess whether their operations are legal or illegal (Pöyhönen, 2009). ASM activities are intertwined with the formal mining sector, as big mining companies often lease land to ASM operators and/or purchase tin mined in ASM operations (Pöyhönen, 2009; ILO, 2015).

According to estimates from the International Labour Organization (ILO), there are over 154,700 adults employed in tin mining in Bangka Belitung. Tin mining has a 27 per cent share of total employment in the province. However, the majority of employment in the tin mining sector is in informal tin mining (78 per cent). It is a male-dominated sector: about 90 per cent of workers are men. In addition, some 6,500 children work in tin mining in Bangka Belitung, representing 2 per cent of the total child population. Almost all of the child labour in tin mining is informal (97 per cent) and predominantly carried out by boys (90 per cent) (ILO, 2015).

4 Overview of mining sector governance

4.1 Disaster risk management and climate change adaptation

Indonesia has a high exposure to various geophysical hazards (such as earthquakes, tsunamis and volcanic eruptions) as well as meteorological hazards (see section 2.3. on Indonesia's climate) (CFE-DM, 2015).

The catastrophic 2004 Indian Ocean Tsunami pushed the transformation of disaster risk management in Indonesia as it overwhelmed the disaster response structures in place at that time. As a consequence, in 2007, the government established the first comprehensive disaster management law (Law 24/2007) and created a new National Disaster Management Agency (BNPB) as well as counterparts at the provincial and district level (CFE-DM, 2015). However, Bangka Belitung has no local disaster management office. Therefore, BNPB is in charge of local disaster management in Bangka Belitung (ASEAN AHA Centre, 2017). In 2012, the Government of Indonesia launched the National Disaster Management Plan 2010-2014 which entails policies, strategies, program priorities for disaster management and disaster risk reduction (CFE-DM, 2015).

The new law enhanced the disaster management approach from reactive disaster response to a broader, more proactive approach that covers all disaster phases (before, during, post) (CFE-DM, 2015). The government's capacity and capability for disaster management was rated in the Indonesia National Progress Report on the Implementation of the Hyogo Framework for Action. Limited financial resources and/or operational capacities were identified as shortcomings (CFE-DM, 2015). In addition, the coordination between stakeholders and the mainstreaming of disaster risk reduction on the local level has to be improved (CFE-DM, 2015).

In 2008, Indonesia formed the National Council for Climate Change, which supervises several working groups (e.g. adaptation, mitigation, technology transfer, funding, forestry and land use) (Djalante and Thomalla 2012). Overall, climate change action in Indonesia is mostly directed at mitigation activities (Djalante and Thomalla 2012). However, in 2014, the Indonesian government launched the first national adaptation plan (RAN-API), with the aim of reducing the negative impacts of climate change on people and ecosystems (Ministry of Finance, 2015). The RAN-API had no legal status until January 2015. Nevertheless, it formed part of the government planning process as proposed policy measures were integrated into Indonesia's National Medium Term Development Plan for the period 2015-2019 (Ministry of Finance, 2015). The RAN-API designates five areas with specific targets, strategies and clusters of action plans: economic resilience (agricultural production and energy security), livelihood resilience (public health, settlements and infrastructure), ecosystem resilience, special area resilience (urban and coastal/small island areas) and supporting systems (e.g. capacity building, information systems, planning and budgeting) (Republic of Indonesia, 2013). The mining sector is not mentioned in the RAN-API. The RAN-API serves as benchmark for the development of provincial adaptation plans and indicates 15 sub-national pilot governments (Republic of Indonesia, 2013). On this basis, these 15 governments have prepared sub-national adaptation strategies (Ministry of Finance, 2015). Bangka Belitung was not part of the list of pilot governments and has not yet developed a sub-national adaptation strategy. In general, there is little awareness about climate change in Bangka Belitung, as the Province's development plans do not refer to climate change mitigation or adaptation actions (Ministry of Finance, 2015). However, development plans give priority to the environment and an increased awareness of the environmental damage associated with onshore and offshore tin mining (Ministry of Finance, 2015).

The tin mining company PT Timah has no public statements on climate change adaptation in relation to their operations in Bangka Belitung. Nevertheless, the Ministry of Finance's review of Bangka Belitung's Climate Public Expenditure and Institutions identifies PT Timah as a potentially important private sector institution in manging climate change in Bangka Belitung (Ministry of Finance, 2015).

4.2 Environmental governance

Indonesia's environmental governance is enshrined in various laws and regulations, notably the most recent 'Environmental Law' (Law No. 32/2009). Together with the 'Mining Law', it requires companies to conduct an assessment of their environmental impact as well as to plan and monitor accordingly to ensure sustainability in the mining sector. Contrary to countries such as the Philippines, public consultation is not required for environmental impact assessments for mining developments in Indonesia (Miranda et al., 2003). Breaching the Environmental Law may lead to 3-15 years of imprisonment and/or a fine of the equivalent of 7,400-55,000 USD (Law No. 32/2009; PWC, 2017).

As 60 per cent of Indonesia's land area is forest (Nurmansyah and Marseille, 2017), Law No. 18/2013 against forest destruction and the regulation 24/2010 (as amended by 61/2012 and 105/2015) are to be considered as well. While mining is officially forbidden in areas designated as 'conservation forests', it is, however, allowed in 'protected forest' (as underground mining) and 'production forest' areas – provided a 'borrow-and-use' permit has been granted by the Minister of Forestry, or rarely (in areas of strategic value) by the parliament (PWC, 2017). If conflicting, Indonesia's legislation grants mining operations precedence over forestry operations (Singer, 2009). Exceptions for mining companies from laws for water quality control also exist (Rüttinger et al., 2013).

While environmental regulations do exist, they are not always complied with. Often, near-term economic interests take priority.

The large extent of illegal mining plays an important role in Indonesia. While it is debatable to what extent ASM activities are illegal or not, it is clear that they are uncontrolled and do not follow environmental regulations (Friends of the Earth, 2012). Normally, post-mining restoration of the land is an obligation under Law No. 32/2009 (Law No. 32/2009). However, the informal sector does not comply but rather hinders reclamation by re-opening pits previously closed by PT Timah or PT Koba; the latter companies do not always fully comply either (Pöyhönen, 2009). Nevertheless, no sanctions have been imposed and reclamation funds, in which mining companies are obliged to deposit money for the post-mining reclamation, have not proven successful in its current structure (Friends of the Earth and WALHI, 2014).

The provincial government of Bangka Belitung has declared a moratorium on the issuance or renewal of mining permits in August 2017 to avoid further environmental degradation (Al Azhari, 2017).

4.3 Indigenous people

There is no common definition of 'indigenous people' in Indonesia, nor is there one concurrent name. It is common, however, to refer to them as 'adat' – meaning custom or tradition (Safitri and Bosko, 2002).

Formally, the adat have been guaranteed various rights in many laws and regulations since the 1960s (Safitri and Bosko, 2002) and in 2013, the Constitutional Court has reaffirmed their constitutional rights to their land and territories, including their collective rights over customary forests (Broch et al., 2017). However, especially in rural areas, land rights are often only informally or traditionally recognised by the local community. Moreover, the constitutional rights to indigenous lands are only recognised for as long as their use does not clash with national interests (Resosudarmo et al., 2009). Consequently, especially during the rule of Haji Suharto (1966-98), when the government reverted to the principle that all land, water and natural resources contained therein shall be controlled by the State, companies were given mining rights against the will of the local inhabitants, regardless of the land's economic, cultural and spiritual importance to the adat communities (Resosudarmo et al., 2009; Devi and Prayogo, 2013). With regards to the relationship between tin mining and indigenous groups in Bangka Belitung, no qualified information was available.

4.4 Mining-related conflicts

Conflicts around mining go back to colonial times in Indonesia. Under both British and Dutch rule, local communities in Bangka Belitung were forcibly relocated, to give way for tin mining and to gain control over the local populations that were increasingly marginalised (Erman, 2007). Access to and control over tin resources has been a major driver of conflict between various actors in Bangka Belitung. Conflicts evolved between the colonial rulers, the local elites and communities. After independence, authorities on national and subnational levels as well as local communities had conflicting interests over who is allowed to engage in tin mining. It was contested whether the state had the mining monopoly or other miners were also allowed engage legally in tin mining. This conflict escalated regularly in protests, riots and state violence occurred. For example, after the closure of various informal mines and private smelters, 2,000 affected people took the streets in Bangka in 2006 (Erman, 2007).

During colonial times, Bangka Belitung's labour force was mainly recruited from China. From 1900 to 1930, between around 38 to 47 per cent of Bangka Belitung's population were of Chinese origin (Somers Heidhues, 2007). To this say, many miners come from other regions, creating social tensions between locals and migrants (Devi and Prayogo, 2013; Nurtjahya et al., 2017). Other conflicts revolve around social problems such as crime, gambling, alcoholism and prostitution in the vicinity of the mining sites (Devi and Prayogo, 2013).

Offshore mining is particularly contentious nowadays. By impacting marine ecosystems with dredging and suction ships, offshore tin mining harms the livelihoods of local fishermen (Erman, 2007); in some areas, the fishermen's incomes decreased by up to 80 per cent (Ten Kate, 2009). The local environmental NGO WALHI has recorded over a dozen conflicts between fishermen and marine mining companies on Bangka Belitung between 2006 and 2011 and lists numerous accounts of specific incidents between certain ships and communities (Friends of the Earth and WALHI, 2014). This has led to demonstrations and protests of the local civil society (Erman, 2007; Rüttinger et al., 2014).

5 Case study: tin mining

5.1 The global value chain of tin

Tin (Sn) has a combination of a low melting point, malleability, resistance to corrosion and fatigue; it is non-toxic and easy to recycle. The largest single application for tin and its alloys is in solders (48 per cent), particularly in the electronics industry, followed by chemicals (17 per cent), manufacturing of tinplate, or steel coated with tin which is widely used for food packaging (14 per cent), lead-acid batteries (8 per cent) and copper alloys (5 per cent) (ITRI, 2017a).

The most important tin ore is cassiterite (SnO_2); small amounts of tin are also recovered from sulphide minerals such as stannite (Cu_2FeSnS_4). Primary deposits of tin are typically associated with granite intrusive rocks. Cassiterite is chemically resistant, heavy and readily forms residual concentrations. Through weathering and erosion, these concentrations may develop over a primary deposit (eluvial) and on slopes below the deposit (colluvial). When the cassiterite reaches a drainage system, it may be transported to a river channel and concentrated into an alluvial placer deposit. Deposits in oceanic submerged river channels are important sources of tin. More than half of the world's tin production is from deposits such as these, mainly in Indonesia, Malaysia and Thailand (Geoscience Australia, 2015).

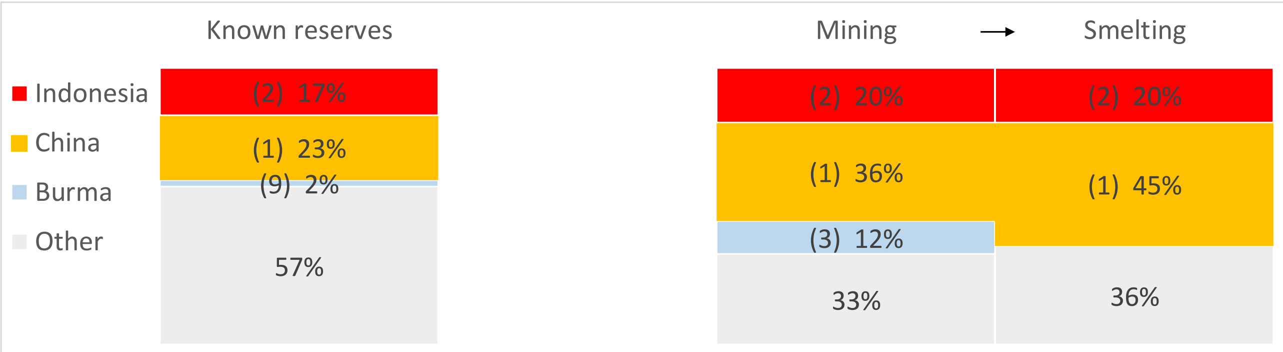
The world economic reserves of tin are estimated at 4700 kt (2016), with annual primary production stabilised at 250-280 kt per year since early 2000s (USGS, 2017). China and Indonesia have dominated the tin market over the last two decades, and currently account for about 40 per cent of known reserves, 55 per cent of tin mining and 65 per cent of tin (primary) smelting. Other important tin miners and producers are Burma (Myanmar), Brazil, Bolivia, Peru, Malaysia, and Thailand. Tin was designated as a conflict mineral[7] through the introduction of the Dodd-Frank Act in 2010 in the United States. The law requires companies listed at the US stock exchange to carry out specific due diligence measures on tin or other conflict minerals sourced from the Democratic Republic of Congo or neighbouring countries[8] (Rüttinger and Griestop, 2015). In 2017, a new EU Conflict Minerals Regulation came into force. The regulation sets down supply chain due diligence obligations for companies that import tin into the EU from any country with a (post-)conflict or fragile governance context – so-called 'conflict-affected and high-risk areas' (European Commission, 2017). It is the first binding law that applies to producer countries worldwide. The EU Commission plans to publish a regularly updated list of all conflict-affected and high risk areas in 2019. To date it is not clear which countries will be included.

Indonesia is the second largest tin producing country in the world, with an estimated 54 kt of tin mined in 2016 (USGS, 2017). The tin production in Indonesia is concentrated in the Bangka Belitung Province (~90 per cent), and roughly half is produced by the large scale state run company PT Timah while the remaining portion comes from small scale and artisanal mining and independent smelters. The global tin industry has a relatively high proportion of artisanal mining, representing challenges in assessing and managing the supply chain (ITRI, 2017a). A significant part of tin in Indonesia comes from the offshore operations, mainly due to the depletion of inland deposits. PT Timah reports about 70 per cent of its output from the offshore operations, while more than 80 per cent of company's current reserves are situated offshore (ITRI, 2017a).

7 Gold, tantalum and tungsten are also designated as conflict minerals.

8 These countries are Angola, Burundi, the Central African Republic, the Republic of Congo, Rwanda, South Sudan, Tanzania, Uganda and Zambia.

Figure 2: Tin global value chain and ranking for selected countries (2016)



Note: figures in brackets show the country's global ranking. Data sources: (USGS, 2017, ITRI, 2017a).

Globally, tin's primary use is in electronic solders. Trends such as the miniaturization of consumer electronics and improvements in production techniques contribute to reducing the use of solders, however these have partially been offset by the substitution of tin-lead solders by lead-free, high-tin alternatives, which as of 2016 accounted for as much as 77 per cent of worldwide solder consumption (Roskill, 2017). Among potential future growth in the use of tin is automotive battery application, including improved lead acid batteries (valve-regulated lead acid, VRLA) and the expected employment of tin alloys in anodes for better performing lithium-ion batteries (Roskill, 2017).

5.2 Site-specific overview – Bangka Belitung Province, Indonesia

The Bangka Belitung Province consists of two main islands – Bangka and Belitung – and several smaller islands and is situated off the eastern coast of Sumatra. Bangka Belitung has a history of producing tin for more than 150 years, and currently delivers about 90 per cent of Indonesia's tin. The state-owned company PT Timah (Persero) Tbk, based in Bangka Belitung, is one of the world largest tin suppliers. It produces tin ore at offshore and inland mines, operates tin smelters on Bangka Island and Riau Islands (north of Bangka Belitung Islands), as well as produces downstream products such as solder and tin chemicals (PT Timah, 2017a).

The alluvial tin ore, found in Bangka Belitung, can be processed at very low cost using basic washing and gravity separation methods, including via small scale and artisanal mining. Due to the long history of mining on the islands, the inland tin reserves have been significantly depleted while the ore grades have declined leading to higher costs and falling production. At the same time, offshore deposits around the islands of Bangka and Belitung have been discovered and are increasingly mined. The dredging method of mining has been very successful in the shallow waters over the last two decades. However, a significant part of offshore deposits of tin is located further (and deeper) offshore, which requires the development of new economically viable technologies to access them (ITRI, 2017a).

For the last two decades, a significant part of tin mined on and around Bangka Belitung islands comes from small scale operations, including illegal mining. This has led to a large number of mining sites being managed irresponsibly, as well as cases of previously rehabilitated sites being re-mined (ITRI, 2017a). ASM on land peaked in mid-2000s but started to decline quickly at the end of 2008 due to lower prices for tin and depletion of onshore resources (Rosyida et al., 2017, Pöyhönen, 2009). Today, 78 per cent of employment in tin mining in Bangka Belitung is in the informal sector (ILO, 2015). The environmental impacts on landscape, soil quality and vegetation have been significant, and sea mining operations have severely affected the reefs, seagrass and fish communities, as well as mangrove swamps along the coastline (IDH, 2013). It is not always possible to distinguish the origin of environmental impact – whether it comes from the official large-scale mining or informal ASM operations, and/or it is a cumulative result from both activities. The picture is further complicated, as the boundary between both types of mining is often blurry. PT Timah and other smelters are known to occasionally buy tin from informal miners (ILO, 2015; Pöyhönen, 2009).

Only relatively recently, PT Timah has started to officially engage with artisanal miners. Under the company's partnership scheme, these are issued with mining permits within the company's mining lease, and are obliged to follow good mining practices, including occupational health and safety (PT Timah, 2017a).

5.2.1 Overview of transportation systems and routes

All tin ore derived from offshore and inland mining operations is transported (mainly by sea barges) to the smelting facilities located on the coast at Mentok, Bangka Island. The produced tin metal is shipped to customers overseas, or transferred to downstream operations of PT Timah located in other parts of the country, namely Kundur, Archipelago of Riau Province (solder production), and Cilegon, Banten Province (tin chemicals).

5.3 Extraction and processing technologies

5.3.1 Extraction and processing technologies at PT Timah

Onshore mining

The main method of mining large placer tin deposits is bucket-line dredging. In general, this is considered to be one of the most devastating mining methods for the environment. However, the removal of top soil (often mixed with other overburden) and some vegetation prior to a major mining stage – to be stored and used in mined land rehabilitation later – can help offset the damage. Smaller deposits, as well as those unsuitable for dredging, are excavated by gravel pumping where alluvium is broken down by high pressure jet of water.

The dredgeline is typically comprised of a series of large metal scoops designed to go in a continuous loop and fitted with a boom to extend the digging radius, which enables the digging of large amounts of material in a short period of time. The alluvium containing the tin is washed and pre-concentrated at the interior of the dredge. The impure tin (cassiterite) concentrate is then transported via land or sea to the washing plant where it is upgraded by gravity methods that separate the heavy cassiterite from the lighter minerals such as quartz (ITRI, 2012).

Offshore mining

Offshore dredging of tin placer deposits is currently the largest marine metal mining operation in the world, mainly concentrated in Indonesia where it is cost-competitive and increasingly dominant due to depletion of onshore tin resources (Baker et al., 2016). PT Timah's operates bucket line dredges and cutter suction dredges with a digging capability of about 15 to 50 meters below sea level. These can recover more than 3.5 million cubic meters of material per month. More than 70 per cent of the company's tin output is currently originating from these operations (PT Timah, 2017a). In order to access deeper parts of the offshore deposits, the company is also developing bucket wheel dredges, which can reach up to 70 meters below sea level.

In the sea dredging operations, firstly the feed (submarine sediments) is sucked up from the sea floor, then it is transferred to the rotary screen for separation from the rocks and large sized materials, followed by primary and secondary jigs for washing and pre-concentration. The separated rocks and washed tailings are dumped back into the sea, while the ore is delivered by barges to the port near the smelter (Hutahaean and Yudoko, 2013; Albar et al., 2002).

The tin ores from offshore and onshore mining contain about 20 to 30 per cent tin, which is further concentrated in the washing plant (located at the smelter in Mentok) up to 72 to 74 per cent of tin content as required by the smelting process (PT Timah, 2017b).

Smelting and refining

Cassiterite is reduced to tin by heating with a carbon-reducing agent (limestone and silica fluxes) at 1200-1300°C in reverberatory furnaces. The molten tin is cast into slabs or pigs for refining, and the slag, which contains 10 to 25 per cent tin, is crushed and re-smelted (Geoscience Australia, 2015). PT Timah operates 12 furnaces, of which 11 furnaces are in Mentok, Bangka Island, and one in Kundur[9], Riau Islands.

The metallic impurities in tin produced by smelting are removed in the refining process. The most widely used method is heat treatment, which is based on the difference in melting temperature of tin (which is relatively low) and other metals. Extremely high-purity tin can be produced via the electrolytic method, which is more costly and rarely used. The final products from tin smelters – tin bars – can have different sizes and shapes according to international standards and customer specifications (PT Timah, 2017b).

5.4 Environmental impacts and mitigation measures

5.4.1 Bangka Belitung Islands onshore mining area

Land use

Onshore tin mining has a large land footprint. PT Timah has onshore mining licences for 331,580 ha on Bangka, Belitung and Kundur[10] (PT Timah, 2018).

The process of onshore tin mining results in the destruction of topsoil and vegetation. Tin mining operations contributed to deforestation in Bangka Belitung, and only 28 per cent of the forest area is still in good condition (Friends of the Earth and WALHI, 2014). Changes in topsoil and vegetation increase the risk of land and watershed degradation and sedimentation (Agus et al., 2017). Flooding is reported to be caused by onshore tin mining (Nurtjahya et al., 2017).

A significant part of mined material is left in the form of tailings – with significantly increased sand fraction, a decreased clay content and a close to zero organic matter, leading to lower nutrient content, soil moisture levels and lower pH-values (NCEA, 2015).

This poses challenges in establishing vegetation, and requires post-mine land rehabilitation. In addition, small scale miners have reopened old industrial mining sites (Friends of the Earth, 2012). A report from 2009 claims that approximately 10 per cent of the Bangka Island land area is covered by abandoned mines (Pöyhönen, 2009).

Water use

The total water use of PT Timah's tin operations in Bangka Belitung in 2016 was 385 ML, down from 427 ML in 2015 due to a decrease in production (PT Timah, 2017a).

In the process of tin mining, water is used for several activities, including ore mining by gravel pumping method, ore washing, and dust prevention on roads. The main source of water is the river dams at the mine sites. Older mine pits water runoff can also be utilised for mining operations in the vicinity. To minimize fresh water withdrawal and prevent the release of sediment sewage into the river system,

[9] The smelter in Kundur is not part of this study.

[10] Mining operations in Kundur are neither part of this study.

a water recirculation and recycling has been established via the system of water reservoirs and safety dams, pumping and filtration (PT Timah, 2017a). However, this would not be the case for ASM operations, which may affect the water streams. Particularly, this is the case when there are water users located downstream, e.g. for community purposes; a higher level of suspended solids in water caused by mining operations would require additional water treatment (Friends of the Earth and WALHI, 2014).

No waste water release from PT Timah mining operations is reported.

Energy use[11]

The main energy use in tin production is associated with fuel to power machinery (mainly diesel) at the mining operations, and electricity use at the washing plant and smelter. For the period of 2016, PT Timah's energy consumption totalled 49,819 TOE (Tonne Oil Equivalent) (PT Timah, 2017a).

Mine waste

There are two principal waste streams resulting from tin operations: relatively benign (e.g. non-acid generating) tailings from tin ore mining and washing operations, and concentrated heavy minerals from washing operations, such as ilmenite and zircon, as well as radioactive monazite and xenotime. The tailings from mining are reused in mined land rehabilitation, tailings from washing operations – much smaller in volume – are likely dumped (this is not reported), while heavy minerals could be potential valuable by-products. To date, the latter (radioactive) materials are stored at the smelter in accordance with regulated procedures and monitoring, with more than 80 kt of accumulated waste to date (PT Timah, 2010). The opportunities to reuse these materials (e.g. for rare earths elements and thorium extraction) are being explored (PT Timah, 2017a). The topography and morphology of land is changed due to the disposal of overburden and tailings.

Emissions

Major emissions from tin mining and processing come from the use of diesel to power mining equipment and diesel-fuelled power plants. To date, PT Timah does not report the GHG emissions associated with tin production, however the company continues to improve the energy efficiency of its operations (PT Timah, 2017a).

Biodiversity

In the area of its concessions, PT Timah conducts mapping of the ecosystem before the beginning of mining operations. Any identified protected species of flora and fauna are relocated to protected forests or to other areas outside mining operations. This is claimed to be measure to maintain biodiversity, however the detailed mapping of endangered species habitat and the development of appropriate conservation measures may still be required (IDH, 2013). A more recent publication indicated that onshore mining activities reduce biodiversity (Nurtjahya et al., 2017).

Rehabilitation

According to Indonesian regulations, mining companies are required to provide assurance for mine reclamation and closure in the form of a time deposit, bank guarantee, insurance, or accounting reserve that term to meet the scheduled reclamation. PT Timah's reclamation plan has been submitted to the Ministry of Energy and Mineral Resources, and is currently under review (PT Timah, 2017a).

[11] It was not possible to separate energy use according to the different stages of mining and processing.

PT Timah has an ongoing land rehabilitation (or reclamation) program which is conducted in four stages. The first stage includes placing tailings into ditches or disused mine shafts, covering with overburden, flattening of land, fertiliser addition, the placement of topsoil, and the establishment of a drainage system to prevent erosion. This is followed by revegetation, new vegetation support for several years, and finally monitoring of vegetation growth, soil quality and groundwater to ensure the successful restoration of an ecosystem (PT Timah, 2017a). In some cases, this process also involves local communities to define the type of productive plants that can be planted and cultivated on the former mining sites. The plan for land reclamation activities over 2015-2019 covers 2,027 ha (PT Timah, 2017a). This is relatively small compared to total disturbed by mining activities area to date, including historic abandoned mine sites, which likely accounts for more than 100,000 hectares.

Studies on similar reclaimed tin mines, namely at PT Koba Tin, show that the post-mining area 20 years after reclamation is still of a poorer soil quality (e.g. lower soil fertility) than non-mined areas (NCEA, 2015). This underlines that land reclamation can be very lengthy and difficult.

In the case of artisanal and small-scale mining, including illegal operations, no rehabilitation activities have been reported. Natural revegetation of abandoned mine sites seems to be a very lengthy process, mainly due to poor soil characteristics of sandy tailings (Nurtjahya et al., 2017).

Health

Mining operations may have significant health impact on workers and members of the local community. Onshore tin mining in Indonesia results in an increase in cleared areas and shafts that may be filled with water during the rainy season. These may become breeding sites for malaria and dengue fever bearing mosquitoes, quickly spreading the disease. Unlike ASM where there have been multiple accidents and life losses in the past, no health related issues for official large scale mining operations have been reported to date (PT Timah, 2017a).

5.4.2 Bangka Belitung Islands offshore mining area

Offshore (sea) area use

Offshore tin mining operations are also spread over large areas. PT Timah holds 108,753 ha of mining licences offshore from Bangka Island (24 per cent of total offshore Bangka licencing area) and 30,075 ha offshore Belitung Island (approximately 40 per cent of total offshore Belitung licencing area) (Elsner, 2014). The company has a fleet of 52 dredgers (Baker et al., 2016). In addition, hundreds of makeshift pontoons and rafts of informal small-scale miners operate offshore Bangka and Belitung (Baker et al., 2016; Friends of the Earth, 2012).

Water use

No fresh water is used in the process of offshore tin mining. The ore is delivered by sea barges to the washing plant near the smelter, where it undergoes the same beneficiation processes as the ore from onshore mining.

Energy use

The major energy use is associated with fuel to power the dredge fleet, as well as barges for ore transportation. It may vary significantly depending on the depth of sea dredging operations and ore grade.

Waste

In the sea dredging operations, the ore is usually washed and pre-concentrated on the dredger before shipping to the smelter. The separated larger rocks and some washed tailings are dumped back into the sea (Hutahaean and Yudoko, 2013; Albar et al., 2002). Most of the dumped sea waste materials cover the dredged sea floor in the mined area, however a small amount can escape as a result of ocean currents. The sea dredging operations increase the total suspended solids in seawater. The offshore operations may also result in toxic waste release in the form of spillages of fuel and oil from the dredge fleet. The coastline has been altered by dumped tailings (Baker et al., 2016).

Emissions

No significant emissions are associated with sea dredging operations.

Rehabilitation

The measures that the company conducts as a part of the marine environment rehabilitation include planting of mangroves and coastal plants along the Bangka Island coast, placement of fish shelters in West Bangka Regency, establishment of artificial reef for fish in West Bangka, and coral reef transplantation in Bangka and West Bangka Districts (PT Timah, 2017a).

Biodiversity

The sea dredging operations may result in direct destruction of marine ecosystem at the sea bed (primary impact), and affect the quality of water over the larger area by increasing the total suspended solids, which also results in lower levels of light penetration (secondary impacts) (Nurtjahya et al., 2017).

The important factors in minimizing these environmental impacts include the use of different types of dredges with a number of varying capacities appropriate to the deposit location and depth, accounting for the sea currents and physical characteristics of the sediment at the seabed (e.g. mud, dust, or sand composition), keeping distance from coral reefs and other rich in biodiversity parts of the seabed, regularly monitoring the water quality and marine ecosystem health in the area (PT Timah, 2017a, Baker et al., 2016). The monitoring of the seawater quality includes sampling at points 500 m to the left and the right of the location of the dredge ship, and 250 m and 500 m behind the ship (PT Timah, 2017a).

PT Timah operates a number of different types of dredges to extract resources from the sea, and conducted an Environmental Impact Assessment (EIA) before opening offshore mining operations. The sea areas covered by coral reefs as well as areas close to tourist attractions are excluded from mining operations (PT Timah, 2017a).

To date, a number of endangered species are found in the areas of PT Timah's operations, including coral reef (T.floreana/R. Wellingtoni P. isabela), oyster/scallop shell (Amusium spp.), sea worm (M. sanguena), white shrimp (Penaeus merguinensis), tiger shrimp (Penaeus monodon), and black crab (Scyla serrata) (PT Timah, 2017a). As mentioned above, the Bangka Belitung Province has a number of conservation and protected areas where mining is not allowed, this is claimed to be a measure to maintain biodiversity, however the detailed mapping of endangered species habitat and the development of appropriate conservation measures may still be required (IDH, 2013).

Offshore ASM operations are mostly uncontrolled and have no monitoring or mitigation measures in place. These operations are reported to damage the marine environment (Pöyhönen, 2009).

Fishermen's livelihoods have been negatively impacted by offshore tin mining as fish catches have diminished (Friends of the Earth and WALHI, 2012; Nurtjahya et al., 2017).

Health

Offshore mining can be severely affected by weather conditions; in particular, high waves at the sea may threaten the safety of dredge ships and the health of the workers, leading to suspended mining operations (PT Timah, 2017a).

5.4.3 Smelter operations on Bangka Island

Land use

The tin smelter is located on the coast at Mentok, Bangka Island. The occupied area is relatively small compared to mining.

Water use

In tin smelting, water is not directly involved in the processes, and is mainly used for cooling electrical generators and machinery, as well as domestic purposes.

Energy use

Tin smelting and refining are energy consuming operations, mainly in the form of electricity use. No detailed information on energy consumption at the smelter is disclosed.

Waste

The major waste material in smelting operations is slag, which contains 10-25 per cent of remaining tin and therefore is valuable for reprocessing. The slag is recycled along with other tin contained waste, such as dust, dross, hardheads and iron tin. The total amount of recycled materials at PT Timah's tin smelters in 2016 was 13,542 tons or 65 per cent of the total input materials for smelting (PT Timah, 2017a). With current operations, most of radioactive minerals are taken out before smelting.

Emissions

Major emissions from tin mining and processing come from tin smelting operations. To date, PT Timah has not reported the GHG emissions associated with tin production – however ,the company continues to improve the energy efficiency of its operations (PT Timah, 2017a).

The emissions of nitrogen (NO_x) and sulfur oxides (SO_x) and particulate matter from tin ore smelting operations are treated through flue gas desulphurization technology. The NO_x emissions are also controlled by selective non-catalytic reduction technology to reduce the remaining content in the exhaust gases. This enables compliance with the regulatory requirements and the maintenance of the air quality in the area where the smelting facility is located. The total reported emissions in 2016 include 2,279 tonnes of SO_x, 352 tonnes of NO_x and 369 tonnes of particle matter (PT Timah, 2017a).

Rehabilitation

No rehabilitation plans for the smelter have been disclosed to date. The major concern would be with the closing and long-term monitoring of the radioactive materials storage, located at the smelter.

Biodiversity

No information available.

Health

No information available.

5.5 Current climate impacts and risks

5.5.1 Current climate

The geography of the islands of Bangka and Belitung consists of plains, valleys and some small mountains and hills. Bangka Belitung's natural forest (mainly secondary forests) covers about 50 per cent of land area and consists of dry forest (heath forest) and bush (Ministry of Finance, 2015; Marisa and Setiawan 2012). The climate is tropical, hot and wet, and classified as Af by the Köppen-Geiger system. The average temperature in Bangka Belitung is 27.5°C, with an average annual rainfall of about 3,200 mm. Wet season starts at the end of October and lasts until May, while the dry season ranges from early June until mid of October (Supari and Setiawan, 2013). Bangka Belitung experiences typhoons (Ministry of Finance, 2015).

Table 1: Bangka Belitung - monthly mean rainfall (Climate-Data, 2017)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	265	209	250	288	276	221	195	186	284	324	405	315

5.5.2 Past weather extremes

Indonesia Disaster Information and Data has recorded several floods (2007, 2008, 2013 and 2014), typhoons (2007, 2008, 2011, 2013 and 2014) and one landslide (2013) on Bangka and Belitung between 2007 and 2014 (Ministry of Finance, 2015). Local people perceive that the frequency of weather extremes has increased over the past years (Ministry of Finance, 2015).

In February 2016, flooding on Bangka Island led to limited access to smelters and mining sites as well as electricity cuts. PT Timah shut one mining site during the flooding (ITRI, 2016). The company saw a historically low tin production in the first quarter of 2016, due to "extreme monsoon weather conditions" as well as delays in the granting of export licences (ITRI, 2017b). One person was killed on Bangka Belitung during the flood (UN OCHA, 2016).

Bangka Belitung experienced two serious floods in 2017. In January, a combination of heavy rain and high tides caused a flooding in western Bangka which affected 2,000 people and damaged three bridges (Davies, 2017). In July 2017, parts of Belitung were flooded after several days of heavy rain. Over 3,700 people were affected and several bridges and main roads were damaged (ASEAN AHA Centre, 2017).

5.6 Climate change impact assessment

To date, there is no comprehensive report on regional climate change projections for Bangka Belitung. If available, we refer to downscaled climate models for the region. Where unavailable, we derive information from global climate models and projections for Indonesia as a whole.

As Figure 3 shows, downscaled models for Indonesia indicate that temperature change will be relatively uniform across the whole country. For Bangka Belitung, the mean annual temperature is projected to increase between 0.9°C (B1-low scenario) and 2.4°C (A2-high scenario) by 2050, based on the respective scenario (see also Figure 3). Further in the future, by 2080, the projected temperature increases are higher: the mean annual temperature might increase between 1.1°C (B1-low) and 3.7°C (A2-high) on Bangka Belitung, depending on the underlying scenario (see Figure 3).

Precipitation projections are not as uniform, as there are significant variations between different climate models, regions and seasons of the year (Case et al., 2007; see Figure 4). Projections for Bangka Belitung are only available for the 2080 and distinguish between wet and dry season. Under the different AR4 scenarios, precipitation over Bangka Belitung is projected to increase during the wet season (December to February) by 9 to 35 per cent (see Figure 4). The current risk of flooding could therefore be exacerbated during the wet season. No precipitation changes are projected for the dry period (June to August) (see Figure 4). Projections for drought on Bangka Belitung are not available. However, RAN-API estimates that the drought risk for Sumatra is high to very high. As Bangka Belitung lie close to the south-eastern coast of Sumatra, the drought risk for Bangka Belitung might also increase.

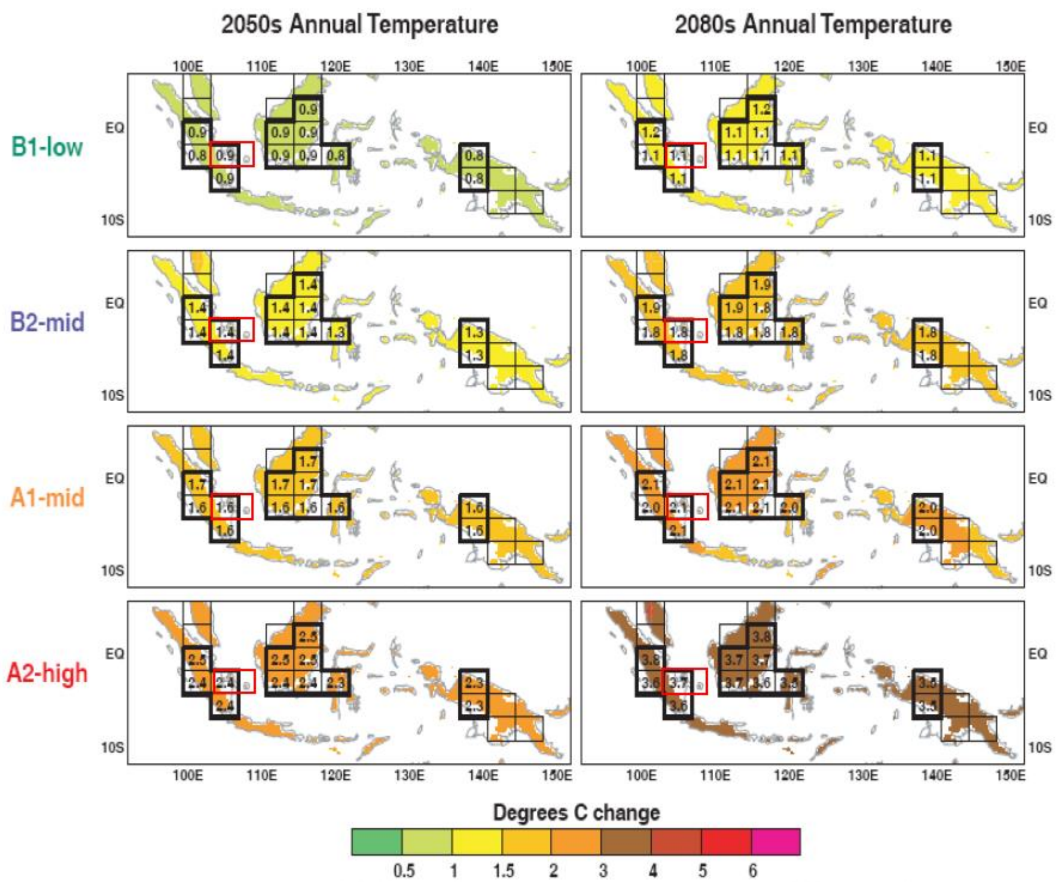
However, precipitation and therefore also drought is strongly influenced by ENSO events whose future trajectories are difficult to project (see Chapter 2.3) (Power et al., 2013). In contrast, some studies find that ENSO events will be more frequent in the future (Tsonis et al., 2005; Cai et al., 2015).

There are no downscaled projections for typhoons, wind or heatwaves. However, global climate models project that Indonesia will experience more than three heat waves between 2020 and 2052 under a high emission scenario (RCP8.5). In the period 2068 to 2100, projections show that at least once every two years an extreme heat wave will occur in Indonesia (Russo et al., 2014).

With regards to regional sea level change, projections under RCP 8.5 for the Indonesian archipelago region estimate an increase of between 0.6 and 0.8 m by the end of the century (Oppenheimer et al., 2019). These projections take into account contributions from Antarctica and Greenland, as well as glaciers and land water storage.

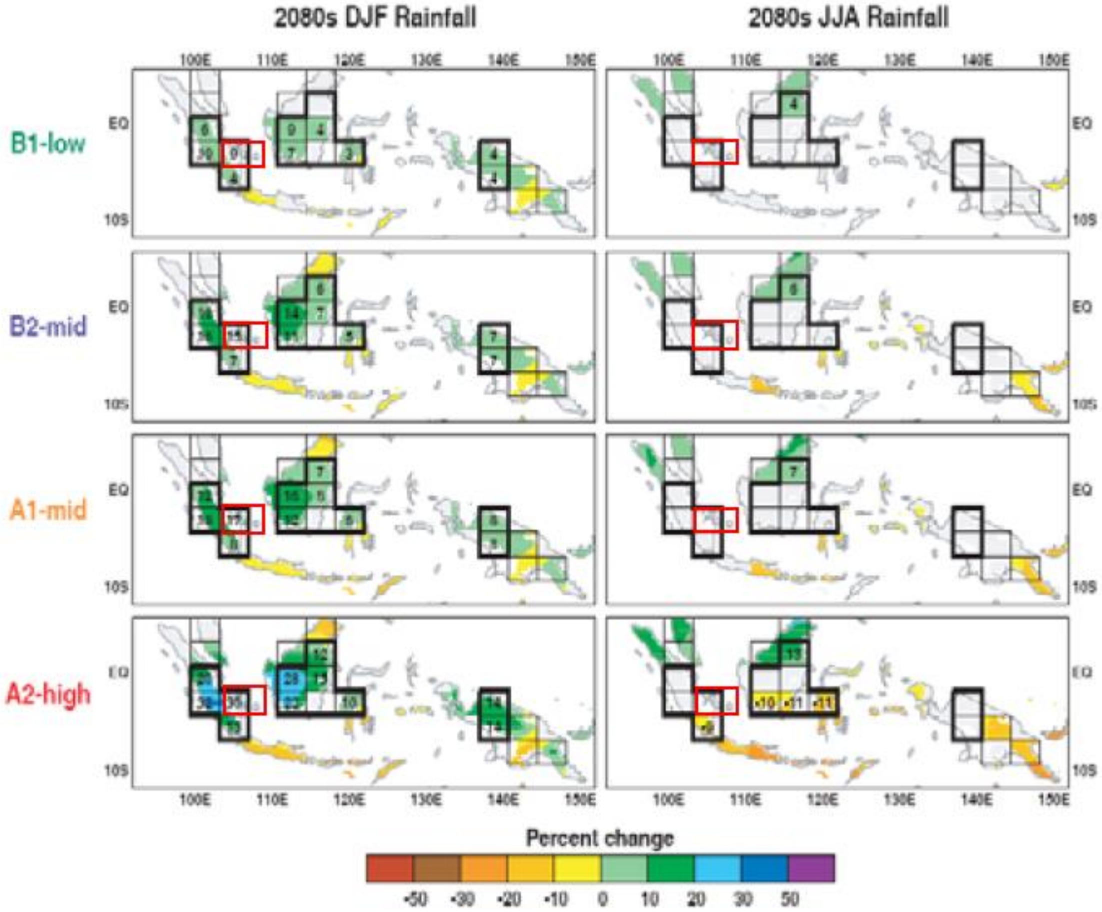
Likewise, sea surface temperatures for the tropical Pacific Ocean in general are expected to rise under RCP 8.5 by the end of the century (Bindoff et al., 2019).

Figure 3: Change in mean annual temperature (in °C from the average 1961-1990)



Source: Case et al., 2007: 4 (adapted from Hulme and Sheard, 1999). The red boxes highlight Bangka Belitung.

Figure 4: Change in December-February and June-August rainfall (percentage change from the average 1961-1990 climate)



Source: Case et al., 2007: 4 (adapted from Hulme and Sheard, 1999). The red boxes highlight Bangka Belitung.

5.6.1 Potential climate impacts on onshore mining

Onshore tin mining operations are expected to face several climate change-related impacts now and in the future.

Although there are no or no exact projections for heavy rainfall, typhoons or heavy waves, these events occur frequently and could become even more prevalent in the future. Flooding events caused by heavy rainfall or in connection with typhoons or heavy waves could exacerbate land and watershed degradation and sedimentation caused by onshore tin mining operations. Reports state that flooding events can be more extreme due to mining-related landscape changes (Ministry of Finance, 2015; Nurtjahya et al., 2017). Flooding can swamp drainage systems and wash pollutants into water systems which could adversely impact the water availability for communities in the area (Ministry of Finance, 2015; USAID, 2017). It is difficult to evaluate, if and to what extend washed out mining waste (i.e. tailings) could negatively affect soil and water quality. Increased mean rainfall, flooding events and increased mean temperatures could elevate the transmission of malaria and dengue fever (USAID, 2017), as mosquitoes have better conditions for breeding in mining holes that have not been closed. In addition, flooding and extreme weather events could also lead to a decreased or interrupted tin production through preventive closure or damages at the mining site. In the long term, sea level rise will exacerbate the risk of coastal flooding and the potential impacts of extreme events.

As tin mining and processing require inputs of water, drought conditions can lead to water shortage, either in terms of physical availably or due to officially imposed water restrictions. This could lead to competition over freshwater with other users. Already today, Bangka Belitung residents experience limited availability of drinking water in the dry season (PT DIM, 2012). During times of drought, the mining operations could face a reduced water supply which could potentially decrease its productivity onshore. Additionally, less water might be available for dust suppression on roads which could harm workers as well as communities.

The challenging rehabilitation of former mining sites could be further hampered by changing climatic conditions and extreme weather events. Changes in mean temperature could make germination more difficult and extreme weather events and their direct impacts (heat waves, droughts, heavy rain, flooding, landslides, typhoons, heavy wind) could impede rehabilitation efforts. These climate stimuli and direct climate impacts could damage the local flora and fauna, which has already reduced due to the impacts of mining. Extreme weather events, particularly heat waves, floods and landslides, could put the workers' health at risk. This is especially true for workers in ASM, as their working conditions are often precarious and dangerous.

5.6.2 Potential climate impacts on offshore mining

Offshore mining is expected to face some particular climate-change related impacts.

Operations on sea could be negatively impacted by bad and extreme weather conditions such as heavy waves, heavy wind and typhoons. This puts workers at risk as well as decreases the productivity of the mining operations. Similar to their counterparts onshore, workers engaged in offshore ASM operate under unsafe conditions and are therefore at a higher risk. In addition, heat waves could endanger workers.

Increasing sea surface temperatures are harmful for marine ecosystems and could reduce fishery productivity. In combination with the impacts of offshore tin mining – which already reduce the resilience of marine ecosystems – the destruction of marine ecosystems could intensify and severely affect and livelihoods of local fishers. Further, sea warming could hamper rehabilitation efforts. Similar to rehabilitation on land, coastal rehabilitation could be impeded by an increased mean temperature and by extreme weather events.

5.6.3 Potential climate impacts on smelter operations

The smelter operations in Mentok could be mainly impacted by wet weather extremes and heavy wind.

Typhoons or heavy rain and heavy wind as well as flooding could damage the smelter. It is difficult to evaluate whether these damages could lead to an uncontrolled release of partly radioactive materials stored at the smelter (heavy minerals), other waste materials or SO_x and NO_x emissions and what the environmental impact of such an incident would be. In any case, when disturbed by a climate-related event, the smelter's productivity could decrease. The smelter operations do not require much water, therefore are not expected to be impacted by drought conditions.

Workers' health could be negatively affected by extreme weather events, in particularly heat waves, floods and landslides.

5.6.4 Potential climate impacts on transport routes

Transport routes which connect the mining site to Mentok where the smelter and port is located are expected to be mainly impacted by flooding and landslides. Past events showed that flooding in particular has impacted roads and bridges in Bangka Belitung.

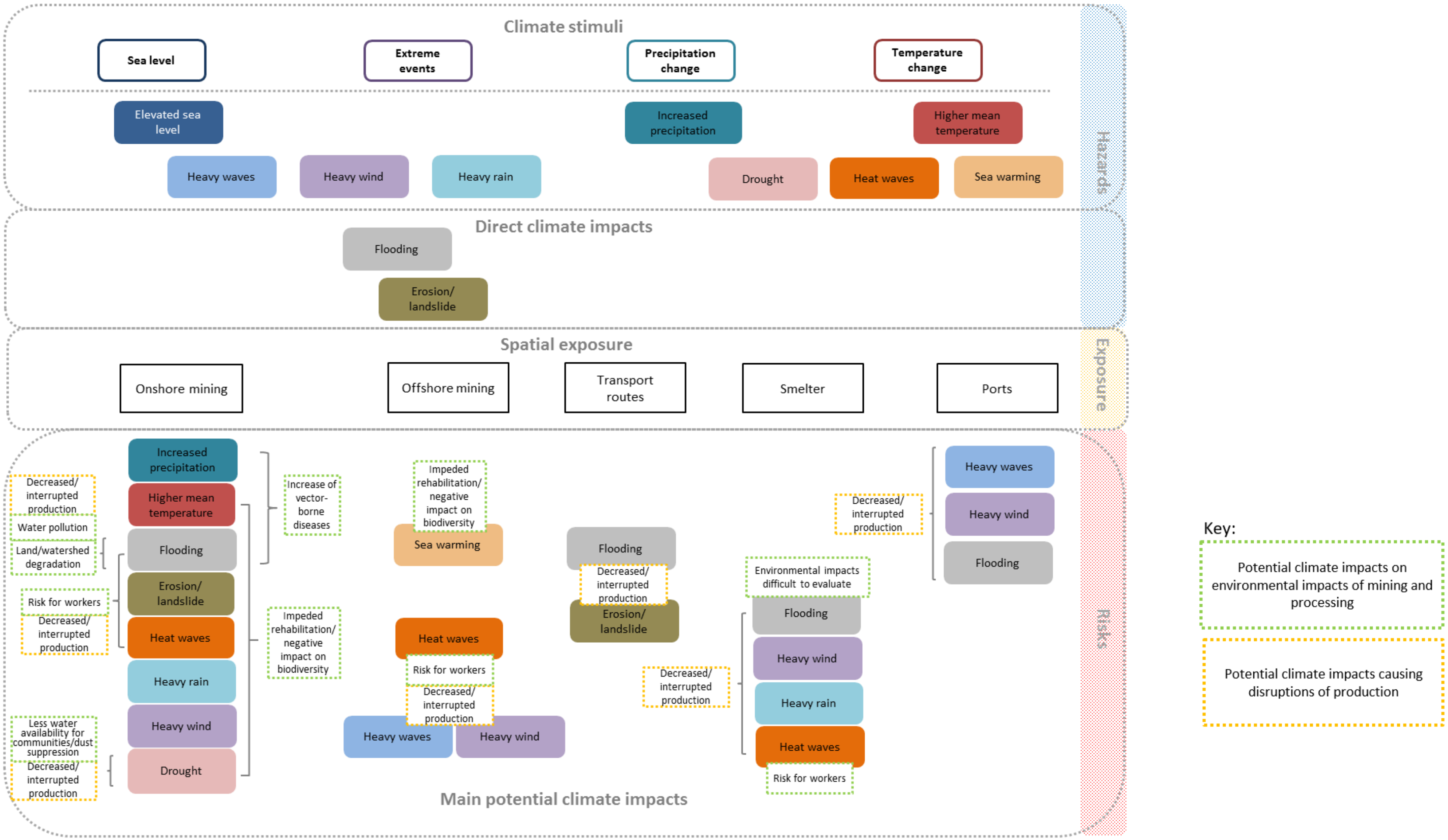
5.6.5 Potential climate impacts on the port

The main potential climate impacts for the port of Mentok could be caused by more intense extreme weather events, in particular typhoons or heavy wind, which can cause heavy waves, leading to the flooding of coastal areas. However, no projections are available for these extreme events.

Extreme weather events could damage the port, which might result in decreased or interrupted tin exports. As precautionary measure, the port can be instructed by the port or maritime authorities to halt operations when there is warning for bad weather or extreme weather events. This minimises the risk of damage but leads to an interruption of exports. A potential spill of tin bars into the sea is not expected to be harmful to the environment.

Based on the sea level projections for 2100 under a high emission scenario, substantial sea level rise by almost 2 meters could harm the ports operations, unless adaptive measures are taken.

Figure 5: Climate impact chain for tin



The diagram illustrates the specific climate stimuli, the spatial exposure, the direct climate impacts and the potential climate impacts. In order to visualise the links between these components of the climate impact chain, the colours of the frames of the potential climate impacts are used accordant to the corresponding climate stimuli and direct climate impacts.

6 Summary and conclusions

The islands of Bangka and Belitung are characterized by a hot, tropical climate with high rainfall during the wet season. The islands frequently experience severe floods as well as typhoons. In 2016, PT Timah had to close one mining site during a flood, which reduced its tin production in the first quarter of 2016. Floods in January and July 2017 affected approximately 5,700 people and damaged main roads and bridges.

Climate projections for Bangka Belitung have limited accuracy because no comprehensive report is available for the province. However, based on reports covering climate projections for Indonesia and some downscaled projections for Bangka Belitung, several key climate change impacts can be identified. Projections show that the mean temperature will rise in the future. Precipitation is projected to increase during the wet season, while no changes are projected for the dry season. Bangka Belitung might experience more floods as well as droughts. However, reliable projections for ENSO, which strongly influences precipitation patterns, are difficult to make. At the time of the case study no downscaled projections for typhoons, wind and heatwaves were available.

Environmental impacts of mining and processing

Tin is mined onshore and offshore in Bangka Belitung both by large-scale industrial companies (in particular PT Timah) and ASM operators. It is not always possible to distinguish whether environmental impacts are caused by large-scale or small-scale operations or are cumulative impacts from both. In addition, both sectors are intertwined as large-scale industrial companies occasionally buy tin originating from ASM operations.

Onshore tin mining in Bangka Belitung uses large land areas and changes topsoil and vegetation cover, leading to watershed degradation, sedimentation and flooding. Overburden and tailings alter the topography and morphology of the area and have poorer soil quality than non-mined areas. There are two main types of tin mining waste: non-acid generating tailings from tin ore mining and washing operations and concentrated radioactive heavy minerals from washing operations which are stored at the smelter in Mentok. Although PT Timah has rehabilitation schemes in place, rehabilitation can be challenging, as soil conditions are poor and ASM operators often reopen closed industrial mining sites. Furthermore, the area targeted for rehabilitation by PT Timah is relatively small compared to the total area disturbed by mining activities. Onshore tin mining is reported to have reduced biodiversity in Bangka Belitung. Further, when filled with water, open mining holes are breeding sites for mosquitoes and therefore increase the transmission of vector-borne diseases such as malaria and dengue fever. While PT Timah workers enjoy generally good working conditions, ASM operators mostly work under very dangerous conditions.

Offshore tin mining is also spread over large areas. Sea dredging operations affect the marine ecosystem by destroying the sea bed and increasing the total suspended solids in the sea water. In addition, toxic fuel and oil spills can occur. Consequently, fisheries are negatively impacted by mining operations. Whereas PT Timah has several monitoring measures in place, ASM offshore operations are mostly uncontrolled. Most of the overburden and tailings is dumped back into the sea. PT Timah engages in coastal and marine rehabilitation, e.g. by mangrove planting and placement of fish shelters.

The main environmental impacts from smelter operations on Bangka Island are the generation of potentially radioactive slag and emissions of NO_x, SO_x and particulate matter. However, most slag is recycled and emissions are filtered.

Climatic changes potentially exacerbate environmental impacts of mining and curb supply

Although it is difficult to assess some impacts of climatic changes, various environmental impacts of tin mining are expected to be exacerbated by climate change, in particular by extreme weather events.

As rainfall is projected to increase during the wet season, flooding events might increase as well. On the one hand, flooding events can aggravate land and watershed degradation and sedimentation caused by mining operations. On the other hand, mining-related landscape changes increase the susceptibility for flooding in the first place. Therefore, mining-related landscape changes and climatic changes both potentially intensify the risk for flooding. While flooding can potentially impact the water quality through erosion and sedimentation, it is not clear to what extent washed out radioactive heavy minerals, stored at the smelter, can contribute to pollution.

In addition to flooding, drought risk could increase in Bangka Belitung. Water availability could be affected by drought, potentially leading to competition with other water users such as communities in the mining area, farmers or tourism.

Climate change will also have an impact on health issues. Fresh water flooding increased mean rainfall and mean temperature could increase the transmission of malaria and dengue fever, as breeding conditions for mosquitoes become more favourable. The workers' wellbeing is affected by extreme weather events, particularly heat waves, floods and landslides. Offshore, heavy wind and waves are risks for workers on dredgers. Both onshore and offshore ASM workers are at higher risk, as they work in unsafe conditions.

Rehabilitation measures and biodiversity are also expected to be impacted by climate changes in the future. A higher mean temperature, changed precipitation patterns, extreme weather events and their direct possible impacts (e.g. heat waves, droughts, heavy rain, flooding, landslides, typhoons, and heavy wind) could negatively affect rehabilitation efforts and local biodiversity. Sea warming harms ecosystems, which are already damaged by offshore mining, and therefore potentially reduce fisheries further. Adverse weather conditions also negatively impact rehabilitation efforts offshore and at the coast.

The smelter operations could be damaged during extreme weather events; however, the potential environmental impact of such damage is unclear.

In addition, tin supply from Bangka Belitung could be affected by weather events that interrupt the mining operations. Flooding and drought could disturb onshore mining, bad and extreme weather conditions adversely impact offshore mining operation and ports. Damaged smelters could also be less productive.

Challenges could be addressed by better governance and monitoring

Complex, dynamic and often dysfunctional mining and environmental governance structures are characteristic for Bangka Belitung, especially as national and subnational authorities have conflicting interests over mining issues. Mining is generally prioritized over environmental concerns and the enforcement of existing environmental regulations is weak. Although it is difficult to attribute environmental impacts to PT Timah operations or ASM operations, it is clear that regulatory action is required to mitigate uncontrolled environmental damage, ensure rehabilitation measures and to improve working conditions in the ASM sector. Nonetheless, the large-scale industrial sector's rehabilitation measures could also be more ambitious. Already prevalent risks of flooding and the transmission of vector-bone diseases could be reduced by comprehensive rehabilitation measures. In the light of a changing climate, these measures become even more urgent. Further, already contentious offshore mining should be closely monitored in the future, as PT Timah plans to expand its operations to deeper grounds and sea warming is already putting additional pressure on marine ecosystems.

While the awareness for environmental concerns linked to mining operation increases, climate change is not recognized as an issue for Bangka Belitung by local government and authorities. To date, a subnational adaptation strategy does not exist. The involvement of different stakeholders with conflicting interests would be crucial for the development of an adaptation strategy for Bangka Belitung.

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