Sumatra

Climate change projections on Sumatra and habitat change for Sumatran species

Cover photo: Kampar peat swamp in the middle of Kampar Peninsula in Riau, Sumatra.
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1. CONTENTS

1 INTRODUCTION

These paragraphs are a combined copy from two reports on climate change and its effect on Sumatra[1,2]

Sumatra Island is covering an area of approximately 481,000 km2. It is also the 3rd largest island in Indonesia (after Borneo and Papua New Guinea). The island is also home to 11 national parks, including 3 listed as the Tropical Rainforest Heritage of Sumatra (TRHS) - Gunung Leuser National Park, Kerinci National Park and Bukit Barisan Selatan National Park. Berbak National Park is one of three national parks in Indonesia listed as a wetland of international importance under the Ramsar Convention.

In 2014, 10.8 million hectare (ha), or 25% of the total area of Sumatra, remains forested. In 1990, the forested area on Sumatra was still 21.3 million ha (48.2% of the total area of the island). That means, in the last 22 years, 10 million ha of the tropical rain forest on Sumatra has been converted at an average rate of 507.000 ha per year, equivalent to a deforestation rate of 2.1% per year. 81% or 10.1 million hectares of the total deforestation in Sumatra occurred in non-peat and peat areas below an altitude of 150 meters (data from 1985 - 2008/2009).

Within that same period four important flagship species experienced a drastic decline in the population such that they were listed in the IUCN Redlist as Critically Endangered (IUCN). The Sumatran Tiger population dwindled from more than 1,000 individuals in 1978 to number less than 400 throughout Sumatra. Whereby the Sumatran elephants ranged between 2800-4800 individuals spread across 44 locations in Sumatra in 1978; in 2007 they numbered 2400-2800 (Department of Forestry 2007). Meanwhile, the Sumatran orangutan that was recorded by Ian Singleton et al. (2004) as 7,501 individuals, in 2008 the estimated population was 6,624 individuals (Serge Wich et al. 2008). The most recent Population and Habitat Viability Assessment (PHVA) by the specialist group estimated the number of orangutans at 14,495 individuals (Sri Suci Utami Atmoko et al., 2016). The increase in observed orangutan individuals is most likely due to extensive monitoring as compared to previous observations. As for the Sumatran rhino, which was recorded to number between 250-390 in 1993, their current population is estimated to stand between 135-185 in the Sumatra natural wilderness.

Current threats include Indonesia's increasing human population and rapid development resulting in large-scale deforestation and wildfires, land conversion and habitat destruction, over-exploitation of marine resources, and a multitude of environmental problems associated with rapid urbanization and economic development in addition to global climate change. Climate change threatens not only to exacerbate the aforementioned issues, but also create new ones, some of which are already taking place.

Impacts of observed changes in climate are already evident in Indonesia and will likely worsen due to further human-induced climate change. Rising concentrations of greenhouse gases will continue to raise the atmospheric and ocean temperatures, change precipitation patterns, increase sea levels, and cause various other impacts from more frequent and intense drought events resulting in forest fires, to increased human health risks (World Bank, 2012; IPCC, 2013). Climate change will also continue to affect "natural" climate variability, such as El Niño, and may lead to more frequent and more extreme weather events.

[1] Suhandri, N. A. (n.d.). *WWF Indonesia Sumatra Strategic Plan 2014-2018.* WWF Indonesia.

[2] Michael Case, F. A. (2007). *Climate Change in Indonesia, Implications for Humans and Nature.* WWF.

This document describes recent studies on the impacts of climate change for Sumatra by two scientific organizations; Naturalis Biodiversity Center and Deltares.

Naturalis Biodiversity Center:

Three studies were conducted by Naturalis Biodiversity Center and focusses on future climate conditions and its possible consequences for Sumatra. These two scientific studies by Naturalis (Raes, 2017) consists of three components;

1. Relative Future Climate Change
2. Quantitative Future Climate Change
3. Predicted Species Response to Climate Change

This document describes the first two components in short and illustrates more extensive the possible consequences of climate change for five species occurring on Sumatra; Sumatran Orangutan, Sumatran rhinoceros, Sumatran elephant, Sumatran tiger, and Oil palm under component number three.

Deltares:

The climate impact study by Deltares (Sperna Weiland, Perwitasari, Hermawan, Gebremedhin, & Gao, 2018) focusses on the changes in flood extremes and extents which can have both positive and negative environmental impacts on fresh water resources availability and the possible reduction and alterations of environmental flows. The results are available for use in further studies and stakeholder assessments, but the flood maps should be interpreted with care and we do not recommend their use for management purposes outside this project since there are large uncertainties in the flood models on which the flood maps are based due to a lack of local data. The maps provide an indication of where interventions are needed, an indication where investments are still worthwhile, but it remains hard to reliably conclude where future floods will occur and to what extent.

The structure of this document follows the components of Naturalis study. Where applicable, the results of the Deltares study has been integrated. A separate chapter is dedicated to the consequences of climate change on flooding in Sumatra by the study of Deltares.

RELATIVE FUTURE CLIMATE CHANGE

1 NATURALIS - RELATIVE FUTURE CLIMATE CHANGE

The study by Naturalis merges the values of 19 bioclimatic variables (annex) on temperature and precipitation for two development scenarios into one dataset: The two scenarios **[BOX 1]** cover the entire range of future greenhouse gas concentrations in the atmosphere.

- RCP2.6 - optimistic climate change scenario resulting in a global mean temperature increment of 2°C by 2100 (figure 1 - left column). This scenario needs radical reduction of greenhouse gasses on a global scale to stay within 2°C.
- RCP8.5 - worst-case scenario, a 4°C warmer world by 2100 (figure 1: - right column). This scenario is a Business As Usual (BAU) scenario.

The predictions for the years 2030/2050/2070 for these two future scenarios were compared to the present situation (as baseline and noted as zero change) and expressed as a relative measure of climate change in 19 bioclimatic dimensions that ranges between no future change and maximum future climate change. (Figure 1). No change is indicated by white colors and maximum change is indicated by red colors. Overall predicted future change in 19 bioclimatic dimensions on Sumatra is dominated by changes in two bioclimatic factors knowingly:

1: 'Maximum temperature of the warmest month' (Annex Bio05 & Figure 2)
2: 'Precipitation of the driest quarter' (Annex Bio17 & Figure 3)

We illustrate the direction and quantitative change predicted for these bioclimatic variables for the future for both RCPs.

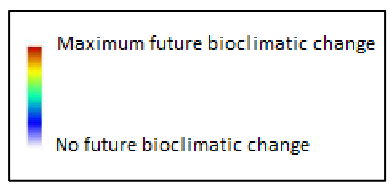
[BOX 1] Climate scenarios and global mean temperature changes
In this report we refer to two climate change scenarios, also known as the Representative Concentration Pathways (RCPs) 2.6 (optimistic climate change scenario) and 8.5 (Business as usual). The RCPs (2.6 & 8.5) are expressed as *global mean* temperature rise of 2°C and 4°C, respectively, following the Wold Bank terminology. It is important to mention that global mean temperature increases of 2°C and 4°C represent a world average increment. Thus, some regions will experience higher temperatures (e.g. the poles) than the global mean temperature, whereas other regions will experience lower temperatures.

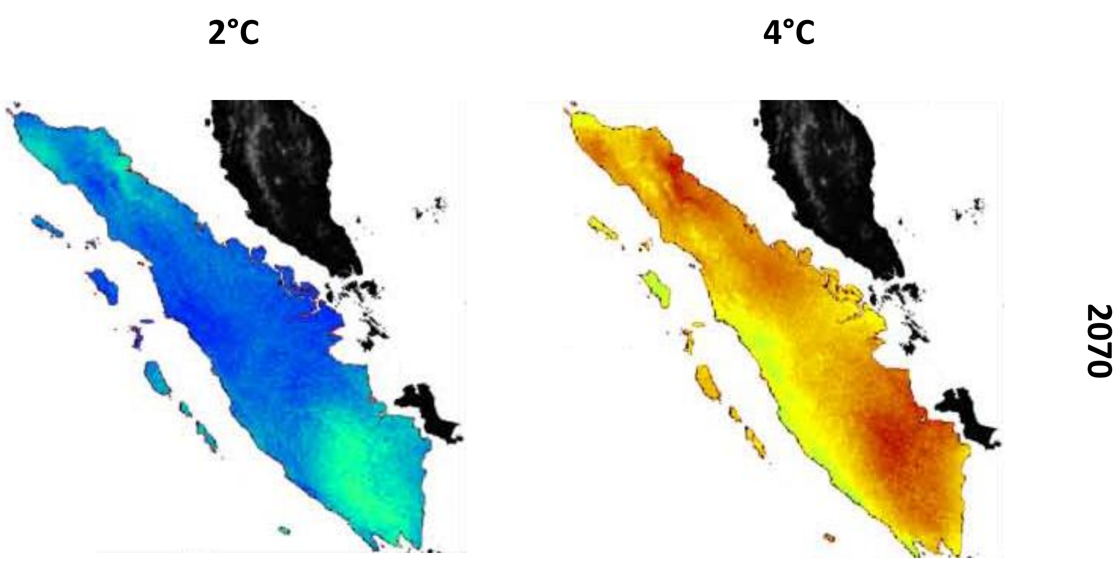
1.1 RELATIVE FUTURE CLIMATE CHANGE – RESULTS

Here, we only show the results for 2070 as the effects of predicted future climate change are most profound for this time period. The patterns of change for 2030 and 2050 were largely the same, however, just not as severe. Plotting the predicted future changes for the 2°C (RCP2.6) and 4°C (RCP8.5) scenarios on the map of Sumatra results in the predicted patterns of future change as shown in figure 1. The patterns of predicted change between the two scenarios are comparable but as expected about twice as severe for RCP8.5 and for RCP2.6. The most severe impacts are predicted for southern Sumatra, as well as for north eastern and north-western Sumatra. All areas on Sumatra will face impacts of climate change as nowhere a value of zero change is predicted. Furthermore, the lowland regions are more affected than the montane regions. The climate change studies calculated the relative future climate change, which means that the studies express the future change in climate (e.g. 2070) against current climatic conditions. It is important to note that the 2030 climate study and the 2050-2070 study are two independently performed studies. Both studies (2030 and 2050/2070) reflect where the highest and lowest future climatic changes occur in Sumatra, but both studies compare against the reference (current) conditions relative to their future projection years. In this report (figure 1) we illustrate the future climatic changes for the year 2070.

When considering the above statement, we can still observe where spatially Sumatra would receive the highest climatic changes. All the future projections, for both scenarios, show similar spatial patterns where climatic conditions have the highest change against current conditions. These are the south central Sumatran lowlands, and the northern coastal zones of Sumatra. Overall, the whole of Sumatra will face large scale climatic changes. The next section will illustrate which two bio-climatic variables had the most influence on predicting the future climate change as spatially visualized in figure 1.

Figure 1: Here we illustrate the two climate scenario's, the optimistic scenario (2°C) and the BAU scenario (4°C), for the year 2070. The maps indicate the level of modelled climate change against the current climate conditions in Sumatra, ranging from high (red), to minimal (green/blue) to no climate





1.2 QUANTITATIVE FUTURE CLIMATE CHANGE

Maximum temperature of the warmest month

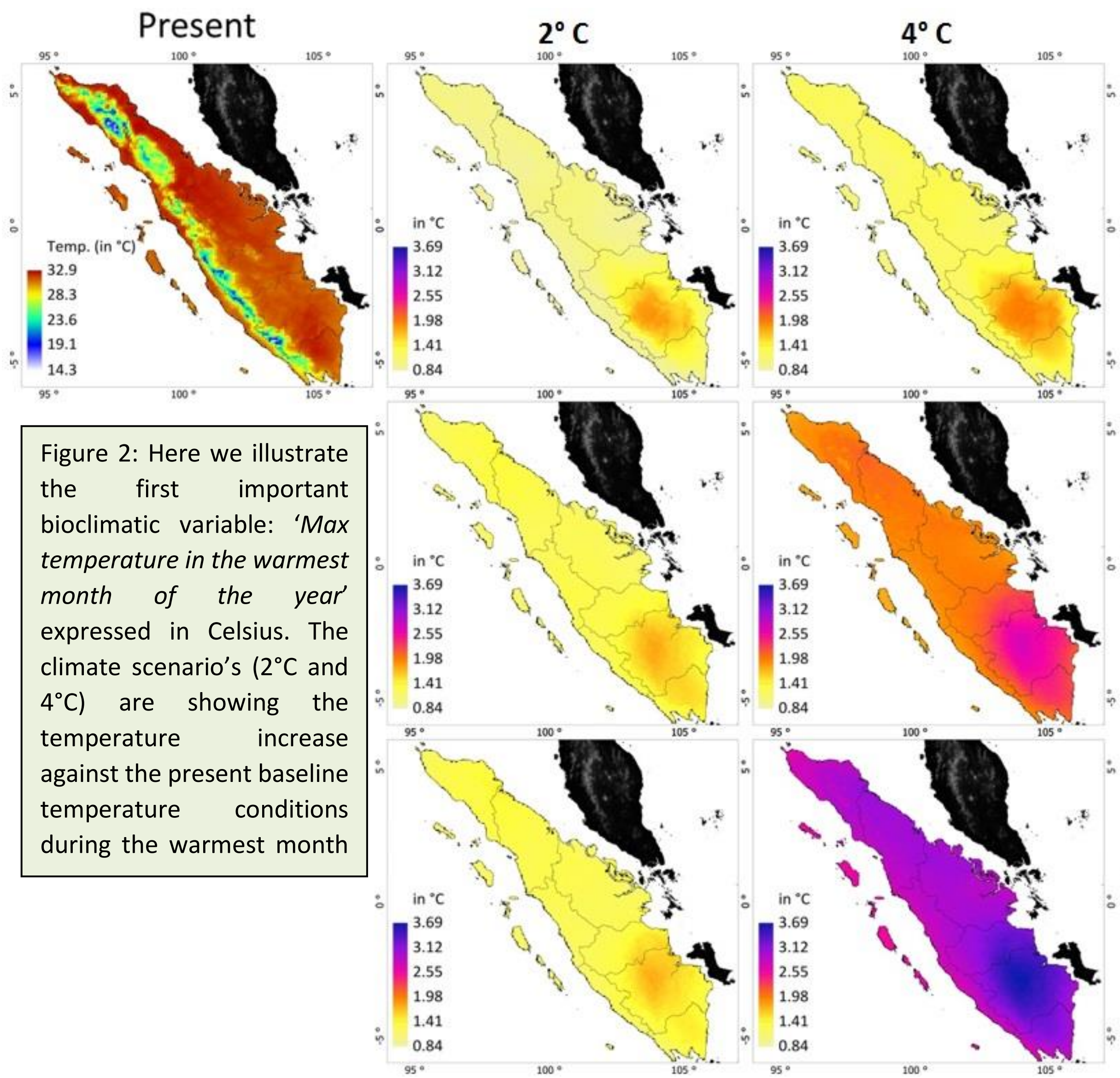


Figure 2: Here we illustrate the first important bioclimatic variable: '*Max temperature in the warmest month of the year*' expressed in Celsius. The climate scenario's (2°C and 4°C) are showing the temperature increase against the present baseline temperature conditions during the warmest month

The bioclimatic variable that explained most of the overall future climate change on Sumatra (Fig. 1) is '*maximum temperature of the warmest month*'. Thus, future predicted climate change is mostly influenced by increased maximum temperatures in the warmest month of the year. When expressed in absolute values, this means that Sumatra will face increased maximum temperatures in the warmest month by up to 1.9 degrees (south-central Sumatra) under the 2°C scenario for 2030. For the 4°C scenario, this increase in maximum temperature can reach up to 3.7 degrees during the warmest month by 2070, especially in the south-central lowlands of Sumatra (Figure 2). Thus, by 2070 under the 4°C scenario, the future maximum temperatures are predicted to reach over 37 degrees during the warmest month. By 2050, the maximum temperature is already predicted to increase by 2 degrees throughout Sumatra. Increasing maximum temperatures during the warmest month of the year increases the risk of forest fires due to more severe droughts, especially in combination with El Niño events.

Precipitation of the driest quarter

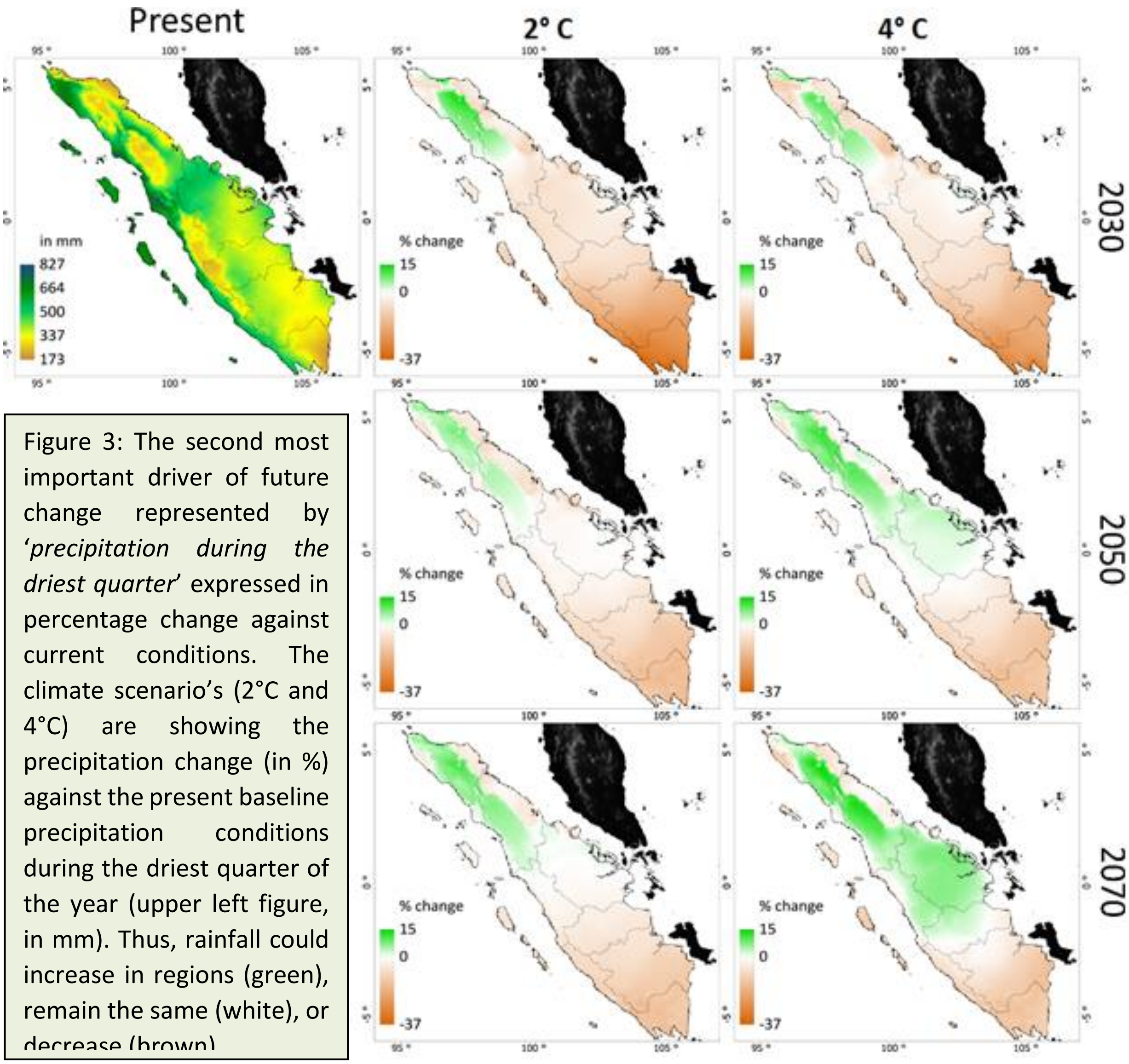


Figure 3: The second most important driver of future change represented by '*precipitation during the driest quarter*' expressed in percentage change against current conditions. The climate scenario's (2°C and 4°C) are showing the precipitation change (in %) against the present baseline precipitation conditions during the driest quarter of the year (upper left figure, in mm). Thus, rainfall could increase in regions (green), remain the same (white), or decrease (brown)

The second most important driver of future climate change on Sumatra is represented by *'precipitation during the driest quarter'.* Unlike the 'maximum temperature in the warmest month' which only showed increased future values, 'precipitation in the driest quarter' is predicted to increase, mostly in northern Sumatra, and decrease in other areas of the island. For Northern-central Sumatra, there is an increased predicted rainfall during the driest quarter, up to 15% more in addition to the current rainfall. However, there is a decline in rainfall (up to 37% less) during the driest quarter for the coastal zones, and south-central Sumatra (Figure 3). This could have severe consequences in attribution to water availability, crop irrigation, droughts and related threats such as forest fires.

1.3 FINDINGS ON CLIMATE CHANGE PROJECTIONS

Based on the two studies by Naturalis over the time periods of 2030, and 2050-2070, the following findings can be summarized;

- The 2°C scenario indicates that climate change will occur all over Sumatra with the impacts ranging from relatively low to medium levels. Not a single place will stay unaffected. The 4°C increment scenario shows stronger levels of climate change all over Sumatra.
- At the landscape level, relatively large changes are predicted for south-eastern Sumatra and the northern coastal/lowland zones under both scenarios of 2°C and 4°C.
- Under the 2°C scenario, climate change stabilizes after 2050, with no predicted further change (according the definition of the scenario). Similar to the 2°C scenario, the 4°C scenario indicates high relative climate change as early as 2030, most likely due to reduced rainfall during the dry quarters of the year and increased temperatures during the warmest months. The entire island will face increased temperatures in the warmest months/quarter (dry season) with the largest increase in the south-eastern lowland areas of Sumatra. This could have severe consequences for vegetation (plant phenology), agriculture and increase the frequency and intensity of forest fires.
- The south of Sumatra will face a both an increase in maximum temperatures and a decrease in rainfall during the driest quarter, which could have consequences for certain crop rotations, extent dry periods, and consequently increase forest fires.

2 DELTARES – FUTURE RAINFALL CONDITIONS

The study by Deltares focuses on changes in future hydrological conditions and flood hazard. The results of the study are presented and illustrated in 6 important river basins in Sumatra. Three river basins are located in Aceh province to the north of Sumatra and are part of the PJT landscape, namely**: Peusangan, Jambo Aye** and **Tamiang**. Three more river basins have been selected in middle and south Sumatra because they are located next to three large rivers and have cities of significant size; **Rengat, Jambi and Palembang** (Figure 4). The main difference between the selected rivers located in Aceh and these basins located more in the Southern part of Sumatra is the projected decrease in rainfall during the wet season. To model those future hydrological conditions in these river basins, Deltares required the future rainfall projections as input to model the future changes in hydrology, as also used in the Naturalis study. This data was derived from the WorldClim data portal (www.worldclim.org).

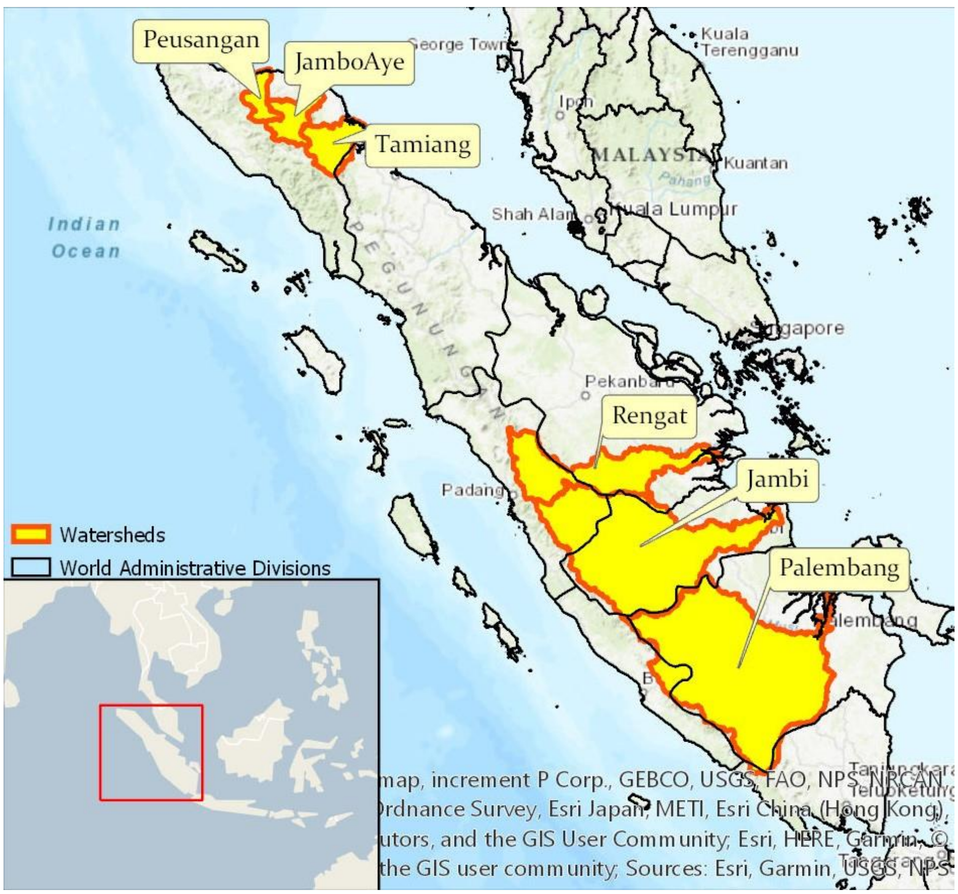


Figure 4: The six selected watersheds for river flows simulated for Sumatra (Rengat, Jambi, Palembang) with focus on Aceh (Peusangan, JamboAye, Tamiang)

Similar to the Naturalis study, Global Circulation Models (GCMs) were used to model the future changes. However, instead of using all the available GCMs, Deltares used 5 GCMs that represent the monsoon in Sumatra well. Meaning that using a subset of the available GCMs in the hydrological modelling would improve the performance of the models and thus the quality of the results. In the figures below, we illustrate the annual average historical precipitation as derived from the WorldClim data portal for the period 1970-2000 (Figure 5). The subset of GCMs used were averaged to improve the illustration of future changes in precipitation against historical rainfall. The historical monthly rainfall amounts are displayed in orange and the future projected rainfall are represented in black. The numbers 1 to 12 refer to the months January to December.

For all river basins in Aceh there is a likely increase in rainfall for the months July to October with the largest increases for the months September and October. These results give an indication of an earlier onset of the heavy rain during the Monsoon months and an increase in Monsoon rainfall overall that may reduce the length of the dry season and possibly the severity of the dry conditions. Raes (2017) concluded similarly that the conditions will likely become wetter in the wettest quarter of the year.

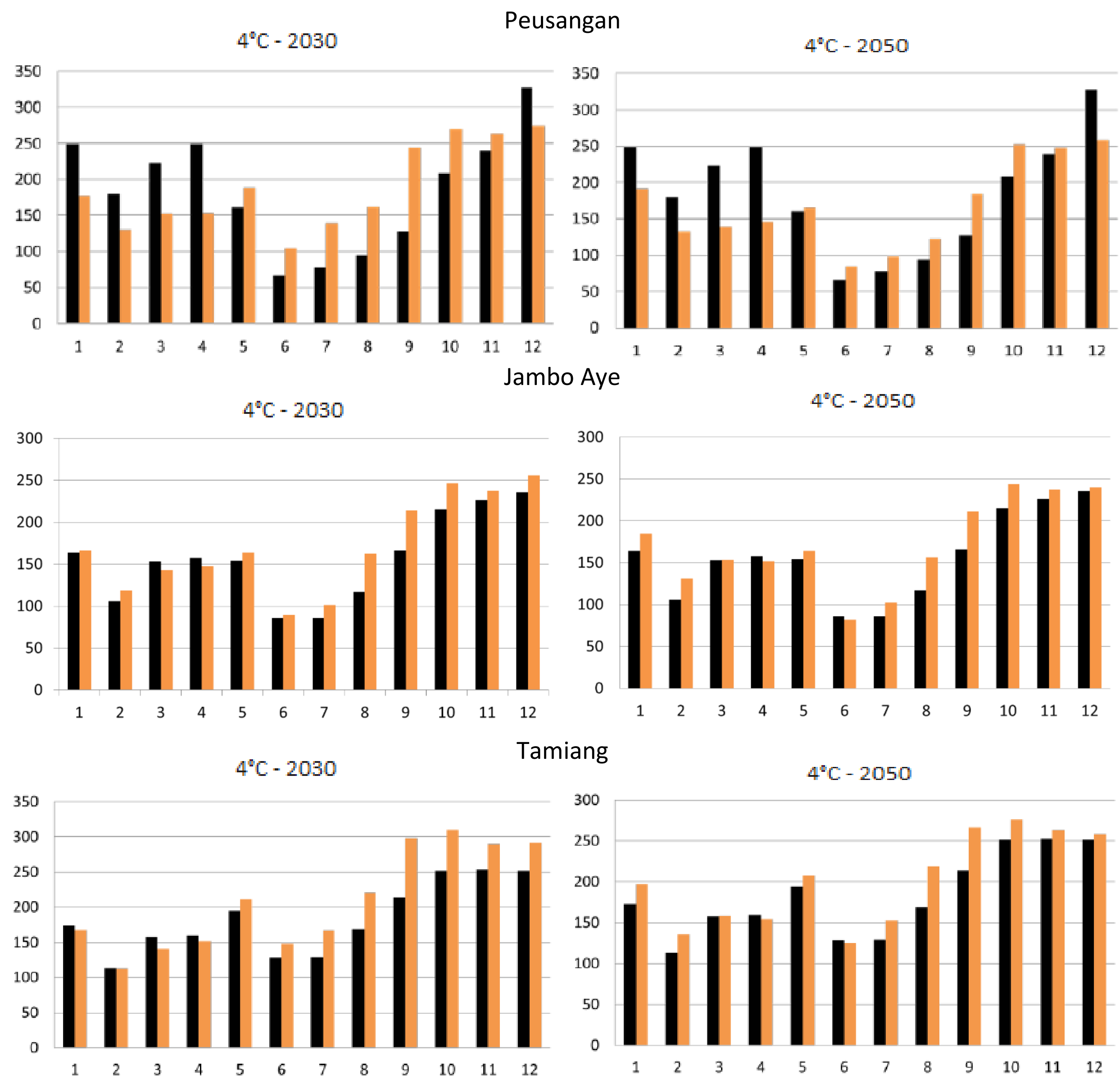


Figure 5: Historical (black) and future monthly average WorldClim rainfall (orange; mm/month) for the river basin in Aceh province for the 4°C scenario by 2030 (left) and 2050 (right). The numbers 1 to 12 refer to the months January to December.

For the southern part of Sumatra there is a projected decrease in rainfall during the wet season. in the months September to December all scenarios agree upon decreases for all three rivers (Figure 6). For the dry season some decreases are projected, mainly for the Palembang. These results are in line with the Naturals projections and allow to determine the consequences of climate change for these important watersheds in more detail. Specifically, in the months September to December (especially for Palembang), consequences previously mentioned, such as droughts, forest fires and crop failures will be more common.

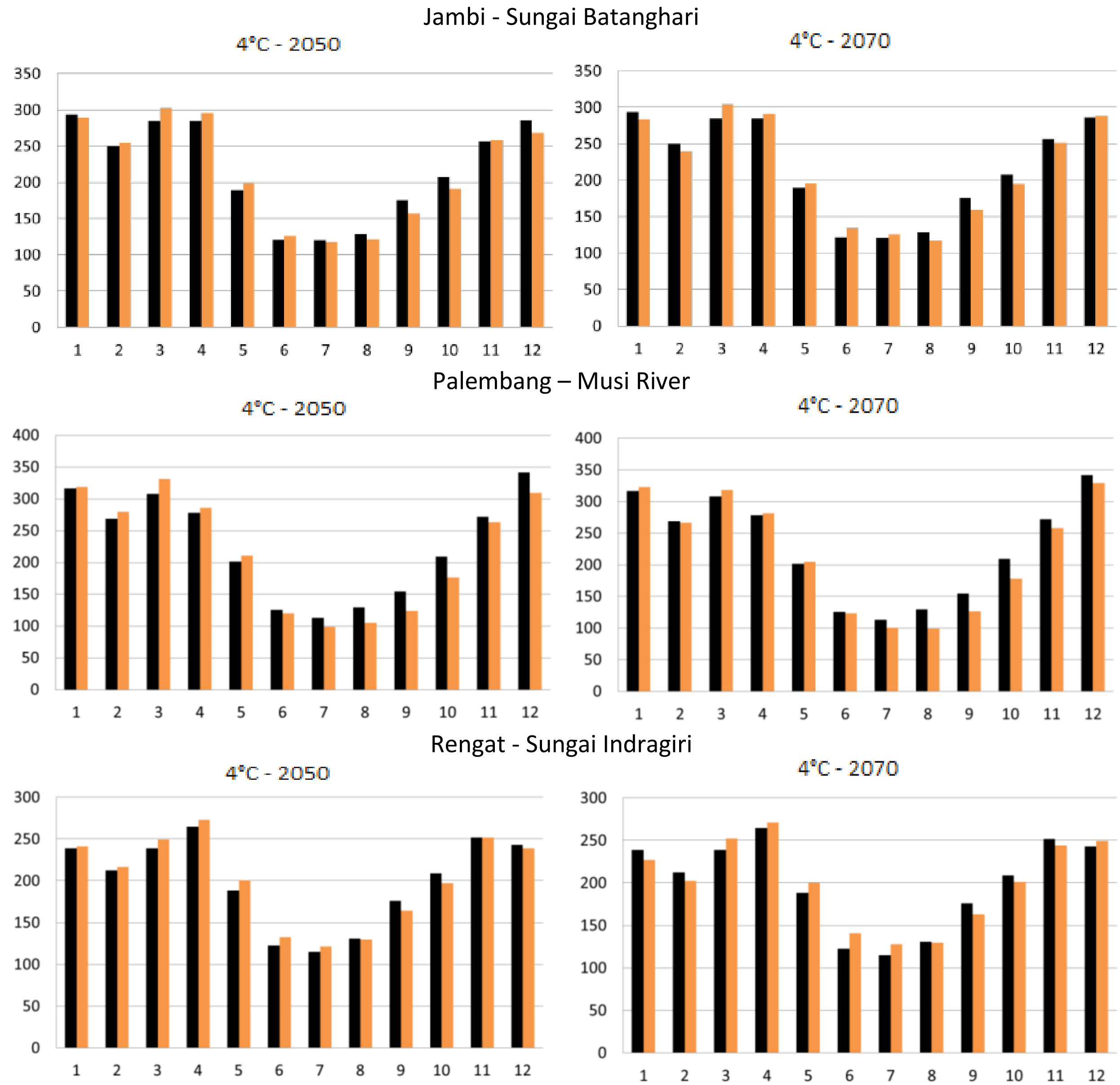


Figure 6: Historical (black) and future monthly average WorldClim rainfall (orange; mm/month) for the river basin in middle and south Sumatra for the 4°C scenario by 2050 (left) and 2070 (right). The numbers 1 to 12 refer to the months January to December.

3 NATURALIS - SPECIES RESPONSE TO CLIMATE CHANGE

Climate change is expected to have a lot of consequences on species. In the study by Naturalis five species were modelled, namely;

- Sumatran Orangutan (Pongo abelii)
- Sumatran rhinoceros (Dicerorhinus sumatrensis)
- Sumatran elephant (Elephas maximus ssp. sumatrensis)
- Sumatran tiger (Panthera tigris)
- Oil palm (Elaeis guineensis)

As such, the analysis of species response to future climate change should only be seen as an illustration of its potential impacts. It should be noted that the results were allowed to extrapolate to non-analogue or novel future climatic conditions, thus assuming that species can adapt to novel climatic conditions. However, there is no certainty that species can actually adapt for we lack knowledge on how they will react to changing circumstances.

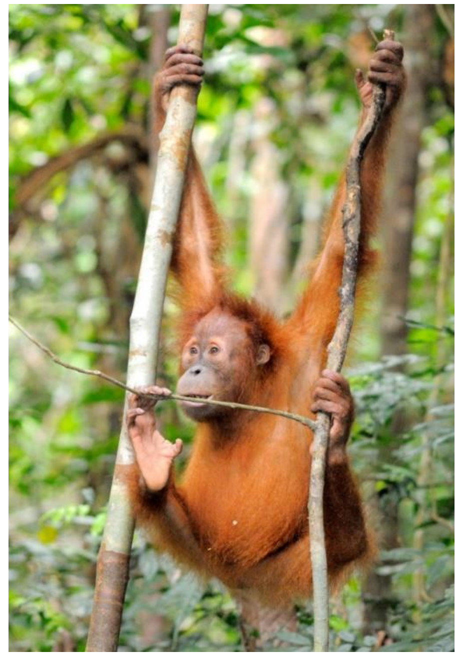
Furthermore, the models are limited to show responses to climatic changes only; it does not account for other external influences – such as interactions with other (prey) species, the availability of food, or the accessibility of suitable habitats due to habitat loss as result of deforestation and land use change. Current and future land uses were also not considered. Corrections for these external influences and non-climatic conditions, can be made after the identification of areas with suitable future climatic conditions for a species to survive.

The distribution of species (climatic) habitat is displayed using three colours:

- White = White areas represent suitable areas at present and in the future (2030,2050,2070)
- Red = Areas that are presently suitable but that will become unsuitable under future climate change conditions.
- Green = Areas that are presently unsuitable but that will become suitable under future climate change conditions. *Note; there might be other reasons why the species does not yet occur in 'green' areas, such as lack of food, unable to reach, or/and anthropogenic influences*.

Gain Stable Loss

3.1 SUMATRAN ORANGUTAN (*PONGO ABELII*)



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The current distribution of the Sumatran Orangutan (Pongo abelii) is confined to the northern and central-northern lowland and lower montane regions of Sumatra, where an estimated 6600 individuals survive today (Fig. 7-a – shaded area; Nater et al. 2013).

The present distribution of the Sumatran Orangutans is characterized by areas with intermediate seasonal changes in temperature. Furthermore, the Sumatra orangutan occurs in areas with intermediate minimum and maximum temperatures, so not in the cold highlands and not in the hot lowlands.

The north of Sumatra is climatically suitable and will remain climatically suitable under future climate change projections. The mountain range of Sumatra is predicted to become suitable habitat in terms of climatic requirements (Figure 7c-d) as a result of increased predicted temperatures. Under the BAU scenario (4°C) even parts of the southern lowlands are predicted to become suitable habitat (Figure 7c-d). It is very important to realize that the habitat suitability projections are only based on rainfall and temperature. Although Orangutans do appear to occur at higher altitudes than previous expected (Wich, Buij, & Schaik, 2004), the mountain ranges that are predicted to become suitable habitats are covered by forest types in which the availability of food plants for orangutans is much more restricted than in the lowlands. The natural montane vegetation cannot rapidly change, and become suitable for orangutans, between now and the near future. The absence of orangutans in the southern part of Sumatra is also caused by factors (land use, fragmented landscape) that are not related to climate or food plant species. The phenology of fruit trees, the primary food source of Orangutan, will be affected by increasing temperatures and changing rainfall and seasonality patterns (Michael Case, 2007). Prolonged and more extreme drought events will reduce the abundance of fruits, especially considering El Niño events.

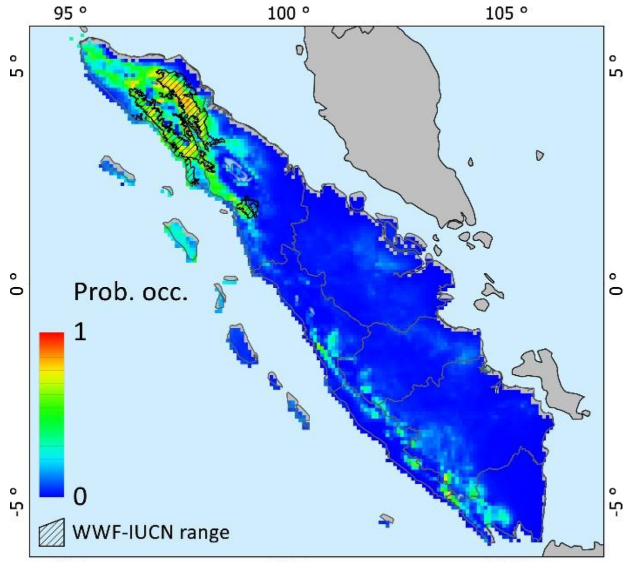


FIGURE 7-a: SUITABLE CLIMATE HABITAT MAP OF THE SUMATRAN ORANGUTAN. GRIDDED LINES REPRESENT CURRENT HABITAT OF TH SUMATRAN ORANGUTAN. RED/GREEN AREAS ARE HIGHLY SUITABLE BLUE AREAS ARE CLIMATICALLY UNSUITABLE.

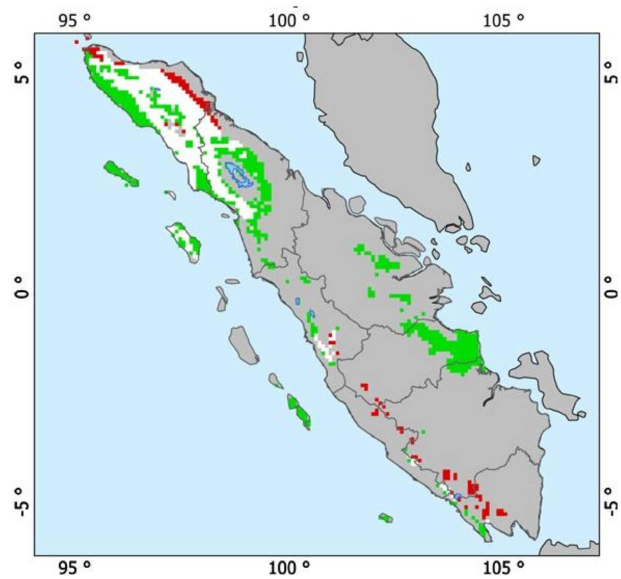


FIGURE 7-b: SUMATRAN ORANGUTAN WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2030

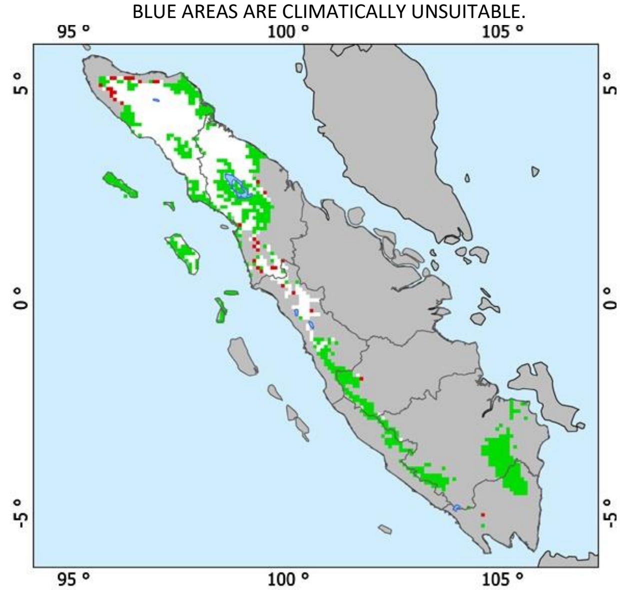


FIGURE 7-c: SUMATRAN ORANGUTAN WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2050

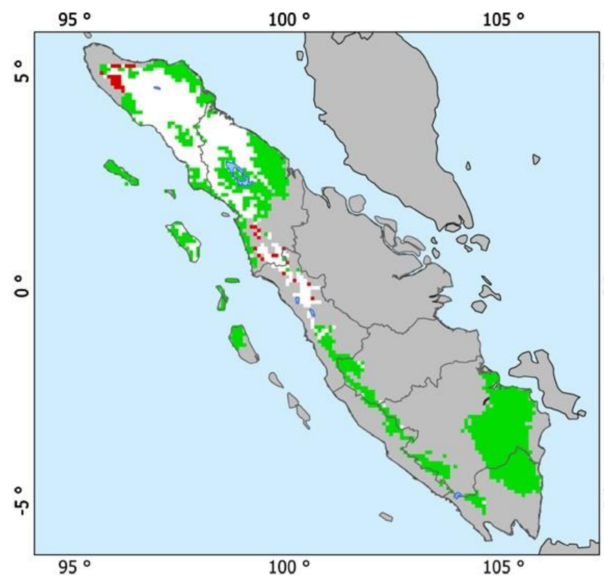


FIGURE 7-d: SUMATRAN ORANGUTAN WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2070

3.2 SUMATRAN RHINOCEROS (DICERORHINUS SUMATRENSIS)

© naturepl.com / Mark Carwardine / WWF

The present population distribution (Figure 8a) is restricted to 3 pockets on Sumatra; in Gunung Leuser, Way Kambas, and Bukit Barisan Seletan National Parks (Miller, 2015). Earlier estimates on the Sumatran Rhino were less than 400 individuals surviving (Foose and van Strien 1997). More recent estimates however put the number at less than a 100, making the Sumatran species the most critically endangered of all rhinoceros.

The distribution of the Sumatran Rhino is predicted to be influenced mostly by the 'maximum temperature of the warmest month'. For the Rhino this means that the probability of presence drops with increasing temperatures in the warmest month. The present predicted suitable habitat for the Sumatran Rhinoceros is mainly confined to the montane areas on Sumatra that have lower temperatures (Figure 8b-d).

Overall, the Sumatran Rhino do not indicate serious losses of potential suitable habitat, provided that they can survive under the warmer future climatic conditions. Additionally, lower montane and montane areas will get warmer which makes them less suitable as habitat. Food plants for rhinos are sufficiently available in montane habitats. These areas serve as refuges for species adapted to lowland and upland climatic conditions. Because no serious losses and gains in climate suitable habitat for the Rhino are predicted the focus should be on conserving the current habitat range of the Sumatran Rhino. Additionally, under the 4°C scenario, the south-east of Sumatra is predicted to become climatically suitable habitat for the Rhino. However, a far more worrying factor for survival towards the future is land use change. Furthermore, extremely small population sizes, reduce reproduction due to lack of breeding.

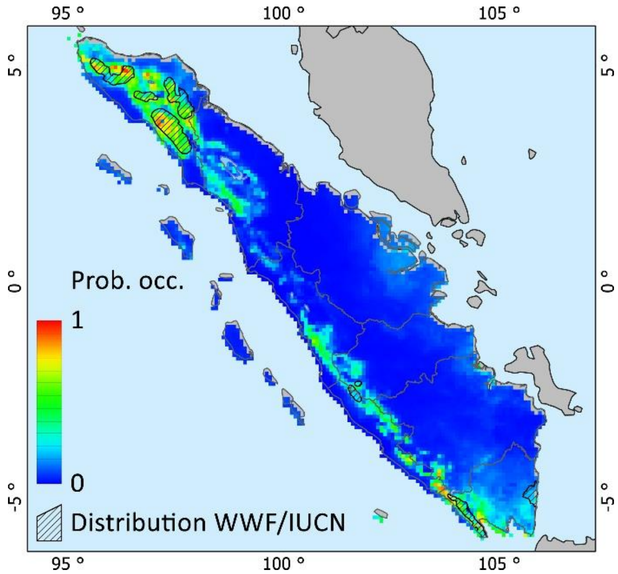


FIGURE 8-a: SUITABLE CLIMATE HABITAT MAP OF THE SUMATRAN RHINO. GRIDDED LINES REPRESENT CURRENT HABITAT OF THE SUMATRAN RHINO. RED/GREEN AREAS ARE HIGHLY SUITABLE. BLUE AREAS ARE CLIMATICALLY UNSUITABLE.

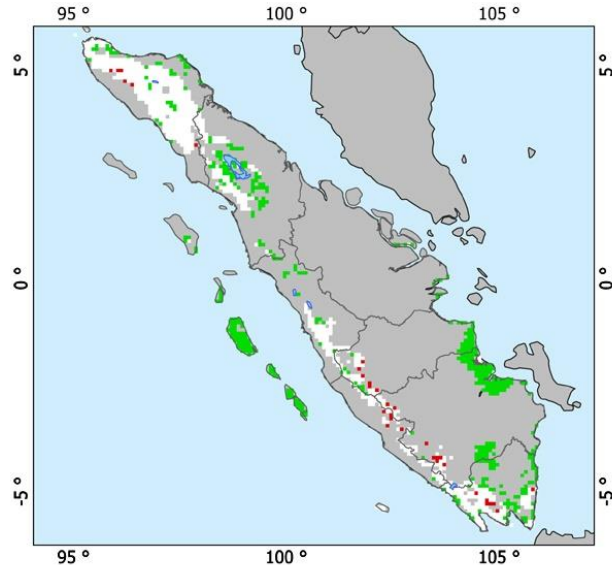


FIGURE 8-b: SUMATRAN RHINO WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2030

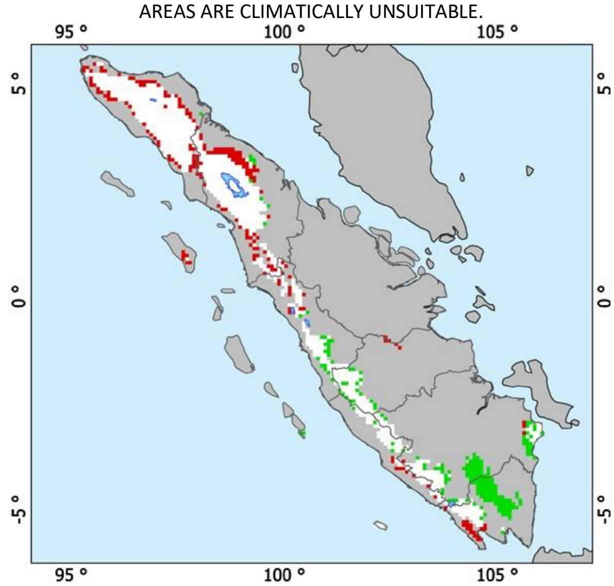


FIGURE 8-c: SUMATRAN RHINO WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2050

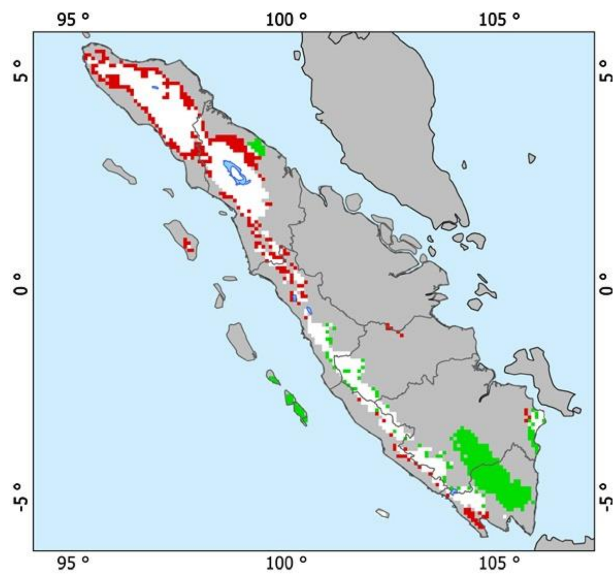


FIGURE 8-d: SUMATRAN RHINO WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2070

Gain Stable Loss

It is important to realize that raising temperatures, especially higher mean temperatures during the warmest months, will exacerbate the duration of droughts. The intensity and increasing number of forest fires due to extended dry periods potentially leads to more habitat loss for the Rhino. Consequently, smaller areas with suitable habitat makes it easier to predict the Rhino's whereabouts for poachers. Similar poaching situations due to increased Intensity and severity of floods, further strengthened by climate change, are happening in Assam State, India. Here the monsoon floods cause wildlife to escape to higher grounds, where poachers are stalking the Rhino's (see Photo below).

Increased forest fires (due to climate change and land use conversion), habitat loss, poaching, extremely small population sizes, and isolation threaten the Sumatran Rhinos survival and ability to breed.

Source: BIJU BORO / AGENCE FRANCE-PRESSE — GETTY IMAGES

3.3 SUMATRAN ELEPHANT (ELEPHAS MAXIMUS SUMATRENSIS)

According to the WWF distribution ranges the Sumatran elephant is still surviving in a reasonable number of pockets in the remaining forested lowland areas of Sumatra, and a number of higher elevation pockets in northern Sumatra.

The predicted suitable habitat was mostly influenced by seasonal temperatures. The models showed that the Sumatran elephant endures a wide range of temperatures throughout the year and is not very selective. This results in a predicted potential distribution throughout most lowland areas of Sumatra. Additionally, using improved Worldclim 2.0 data in the 2030 study, the *minimum temperature of the coldest month* also showed importance in the definition of suitable habitat. This means predicted absence of Elephants in the cooler montane areas under present bioclimatic conditions. Elephants fourage on a high variety of food plants which are widely available in open (disturbed) forest and shrublands of the lowlands and uplands. Also, due to predicted future increase in precipitation during the coldest quarter in the montane areas, the habitat of the Sumatran elephant expands to these montane areas. However, elephants generally avoid higher areas with steep slopes (Wulffraat, 2007) for reasons probably not related to food availability.

Overall, given the wide range of bioclimatic conditions under which the Sumatran Elephant occurs, most of the current habitat (Figure 9a) will remain climatically suitable in the future. Additional habitat is predicted to become climatically suitable: the montane (along west Sumatra) areas and floodplains (central-North Sumatra). the next step should be to identify the presence of other elephant habitat requirements and threats (human pressure, forested areas, food sources, water availability, etc.) within these new climatically suitable habitats. Establishing or conserving corridors for Elephant migration to these areas should be considered within strategies. This consideration is supported by the current main threats to elephant populations, in particular lowland habitat loss due to human settlements, agriculture, and Oil palm and wood-fibre plantations (Yoganand & Payne, 2016). Similar to the rhino, and other mammalian species in Sumatra, the increased duration and intensity of droughts could contribute to more frequent and severe forest fires. Habitat loss, fragmentation (leading to increased Human-Elephant Conflict (HEC)) and elephant isolation are threats aggravated by climate change. Less (and fragmented) habitat allows for easy access to poachers, resulting in more wildlife crime. Since the Elephants are strongly dependent on water, the pollution of freshwater sources by mining and other industrial effluents has been an overlooked threat (Yoganand & Payne, 2016). Increasing temperatures, especially in the warmer months, could have additional effects on Elephant freshwater sources, as well in quantity as in quality.

Predicted areas with suitable bioclimatic conditions for the Sumatran Elephant cover most of Sumatra for the 2°C scenario. For the 4°C scenario, more habitat becomes climatically suitable, with in particular the floodplains to the east and the montane regions along west Sumatra (Figure 9b-d). However, since elephants generally avoid higher areas with steep slopes, these climatically suitable montane areas might not be accessible for elephants. Therefore, conservation strategies should focus on the current climatically stable (white) suitable habitat of the elephants.Priorities for climate-informed Asian elephant conservation should include securing fresh water; maintaining and increasing suitable, connected habitat; controlling the spread of invasive plant species; and increasing monitoring for disease and other causes of mortality. It is also essential to create improved conditions in which people can adapt to current and future changes in climate and continue to focus on reducing threats such as human-elephant conflict.

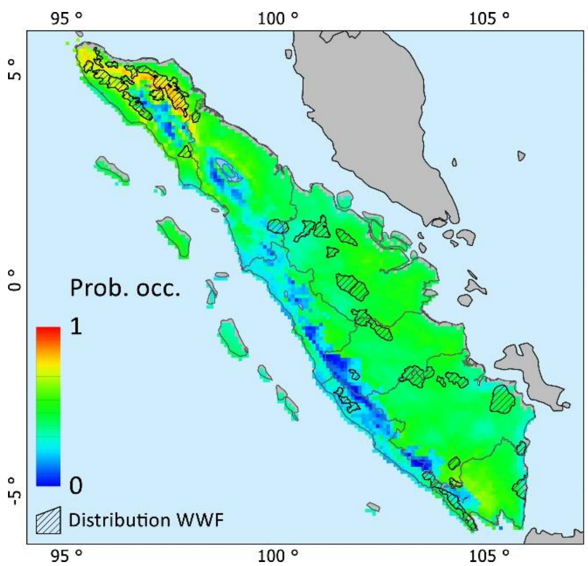


FIGURE 9-a: SUITABLE CLIMATE HABITAT MAP OF THE SUMATRAN ELEPHANT. GRIDDED LINES REPRESENT CURRENT HABITAT OF THE SUMATRAN ELEPHANT. RED/GREEN AREAS ARE HIGHLY SUITABLE. BLUE AREAS ARE CLIMATICALLY UNSUITABLE.

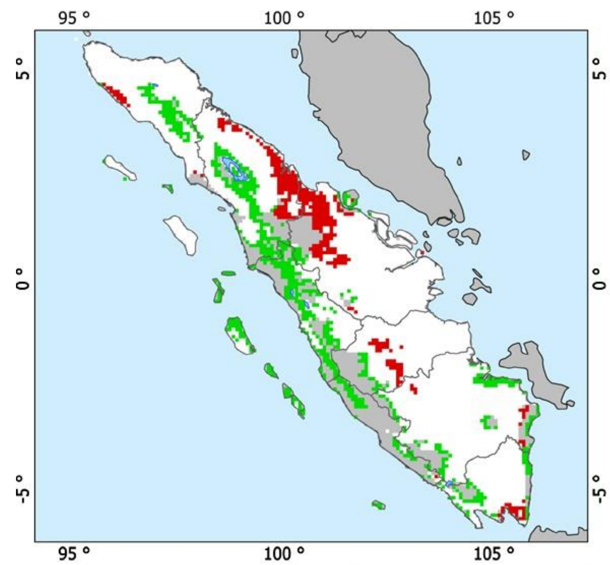


FIGURE 9-b: SUMATRAN ELEPHANT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2030

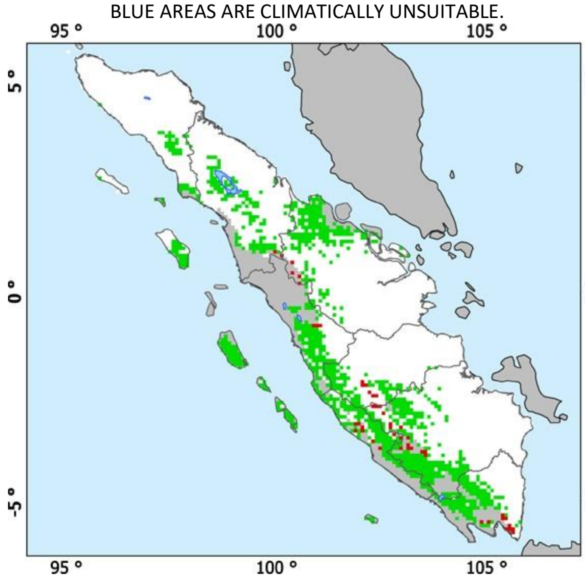


FIGURE 9-c: SUMATRAN ELEPHANT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2050

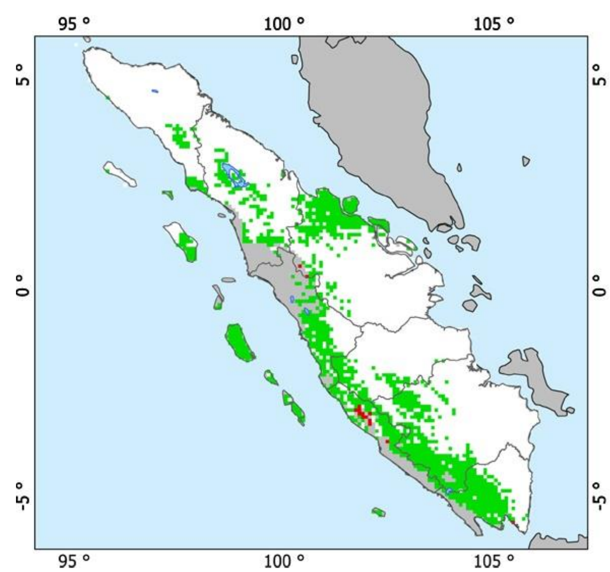
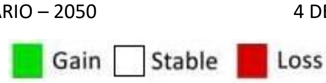


FIGURE 9-d: SUMATRAN ELEPHANT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2070



3.4 SUMATRAN TIGER (PANTHERA TIGRIS SONDAICA)

© David Lawson / WWF-UK

The predicted distribution shows that the montane backbone of Sumatra and the central eastern coastal areas represent the best bioclimatic conditions for the Sumatran tiger (Figure 10-a). The highest bioclimatic suitability for the Sumatran tiger is found in areas with;

- the lowest precipitation in the coldest quarter, and
- The lowest temperatures in the warmest quarter

It could be that the prey of the Sumatran tiger is influenced by human pressure or favours vegetation in lower temperature during the warmest quarters and lower rainfall during the coldest quarters. This might explain why these bioclimatic variables are important in explaining habitat due to climate change. Further case studies and monitoring results could support these assumptions.

Current habitat and tiger conservation landscapes (Figure 10a) are relatively spread throughout Sumatra, but mainly located at montane areas. The mountain chain and the central eastern lowland areas still remain forested (Figure 10-b).

Whether the Sumatran tiger is capable of adapting to novel future bioclimatic conditions remains to be seen. According to the historic distribution of the Sumatran tiger, they inhabited the entire island of Sumatra (Kitchener and Dugmore 2000), assuming that the Sumatran tiger can adapt to, or cope with different bioclimatic conditions does not seem unrealistic. The present and future distribution of the Sumatran tiger depends to a larger extent on remaining habitat and the availability of prey, together with law enforcement against poaching. Remaining fragments with suitable habitat need to be large enough to sustain a viable population of tigers, which is estimated to be 12 individuals (6 females and 6 males) (Sanderson et al. 2006). This results in minimum patch sizes of suitable habitat of 1000 km2, when some overlap in home ranges (150 km2) between males and females is allowed. Furthermore, these patches should be connected by corridors; tigers can disperse, up to a distance of 4 km through landscapes with unsuitable conditions (Sanderson et al. 2006).

However, looking at climate change, the predicted model shows that large areas with bioclimatic conditions where the Sumatran tiger presently occurs will be negatively affected by climate change, mainly due to increased maximum temperatures. Climate suitable habitat will be reduced in the lower montane regions, forcing the tigers to remain in the higher montane regions (Figure 10). The decrease in suitable habitat could create opportunities for poachers.

It is important to note that this study did not include the availability of prey species (due to data scarcity), which is considered an important indicator for suitable tiger habitat. More research and studies are required to look at prey availability and freshwater resources for the Sumatran tiger.

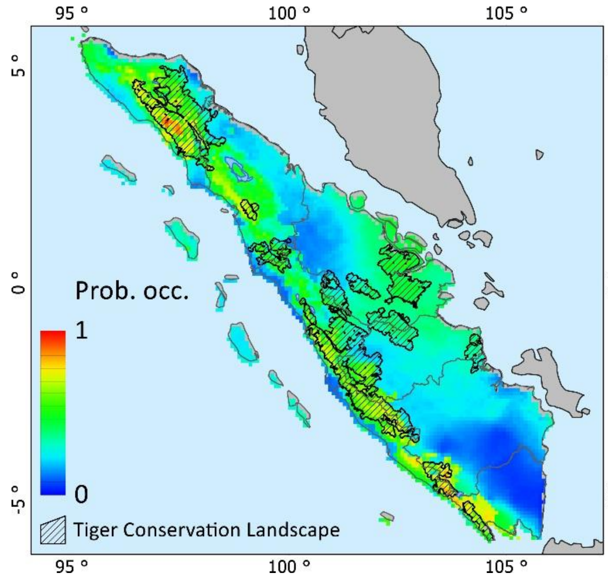


FIGURE 10-a: SUITABLE CLIMATE HABITAT MAP OF THE SUMATRAN TIGER. GRIDDED LINES REPRESENT CURRENT HABITAT OF THE SUMATRAN TIGER. RED/GREEN AREAS ARE HIGHLY SUITABLE. BLUE AREAS ARE CLIMATICALLY UNSUITABLE.

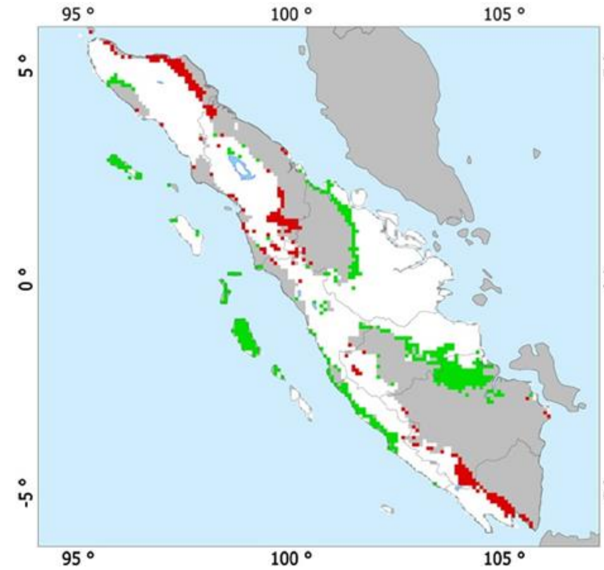


FIGURE 10-b: SUMATRAN TIGER WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2030

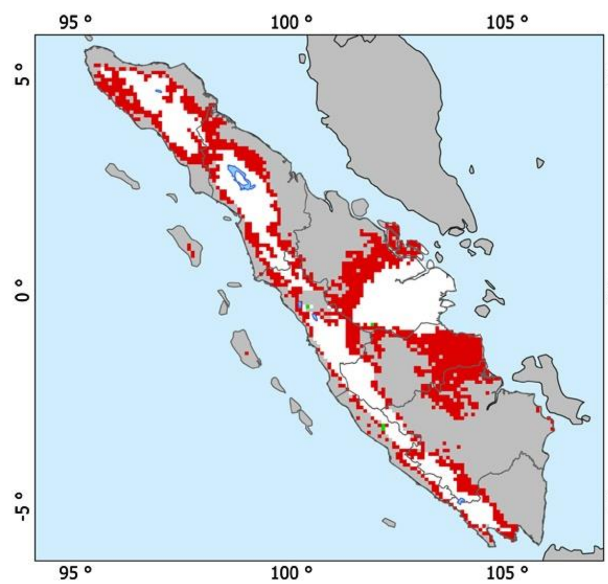


FIGURE 10-c: SUMATRAN TIGER WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2050

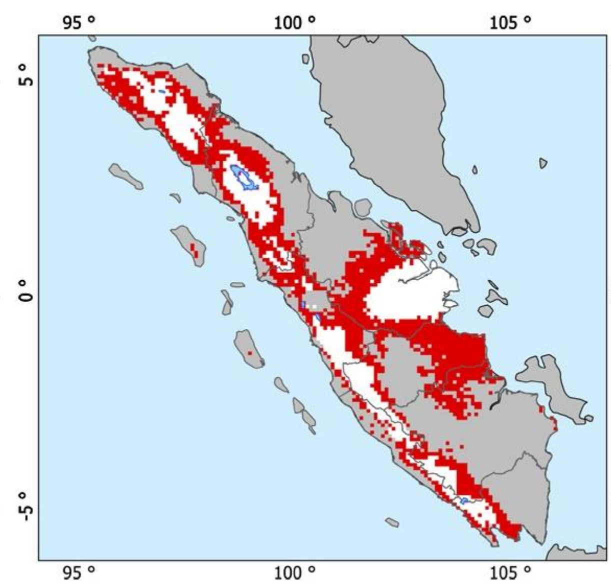


FIGURE 10-d: SUMATRAN TIGER WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2070

3.5 OIL PALM (ELAEIS GUINEENSIS)

At present, Oil palm plantations are widely distributed throughout the lowland areas of Sumatra.

All future climate change projections under the 2°C scenario predict little area loss for Oil palm due to climate change.
The most important predictor for the successful cultivation of Oil palm is the 'maximum temperature in the warmest month'. Once the temperature during the warmest months exceeds 20°C, the presence of predicted suitable habitat for Oil palm increases significantly. Since higher elevated areas are usually colder, that means with increasing temperatures during the warmer months of the year, the higher elevated areas are predicted to become suitable for Oil palm. Under the 4°C scenario, the suitable areas for Oil palm are expanding into the lower montane regions along West Sumatra (Figure 11b-d). This means that more (climatic) suitable habitat will become available for the cultivation of Oil palm in 2030, 2050 and 2070.

The predicted results are worrying, because the mammalian species considered in this study (Tiger, Rhino, Orangutan, Elephant) show that their habitat will become more suitable in montane regions or remain stable at higher elevations (tiger). A direct conflict could arise in land use planning and conservation, since both Oil palm and the mammal species favor the same future montane habitat. The increase in suitable Oil palm cultivation land could also lead to the disruption of corridors, corridors that are needed to connect the lowland regions to the montane areas for species migration. Species migrations are already happening worldwide, as land-based species are moving poleward by an average of 17km per decade (Carrington, 2017) (mainly for the temperate regions) in search for suitable temperature- and rainfall patterns. In the tropics, species tend to migrate to higher elevations. Since Sumatra is an island, species migration routes are limited to higher elevations. This stresses the importance of a continuity of corridors from lower montane regions to climate suitable refugia at cooler and higher elevations.

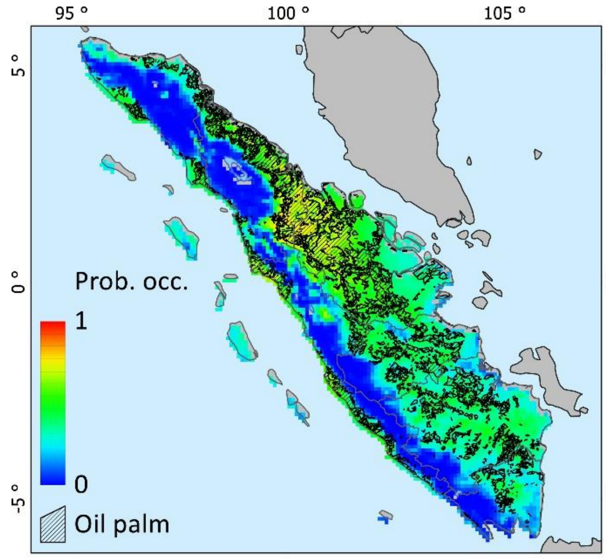


FIGURE 11-a: SUITABLE CLIMATE HABITAT MAP OF THE OIL PALM. GRIDDED LINES REPRESENT CURRENT LAND COVERED BY OIL PALM. RED/GREEN AREAS ARE HIGHLY SUITABLE. BLUE AREAS ARE CLIMATICALLY UNSUITABLE.

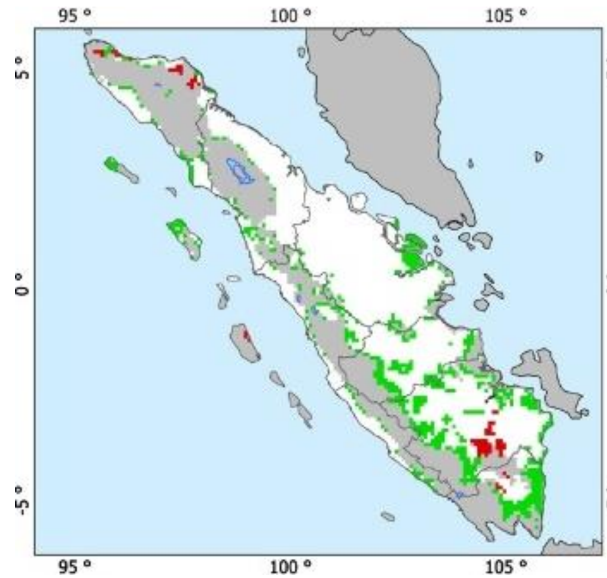


FIGURE 11-b: OIL PALM HABITAT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2030

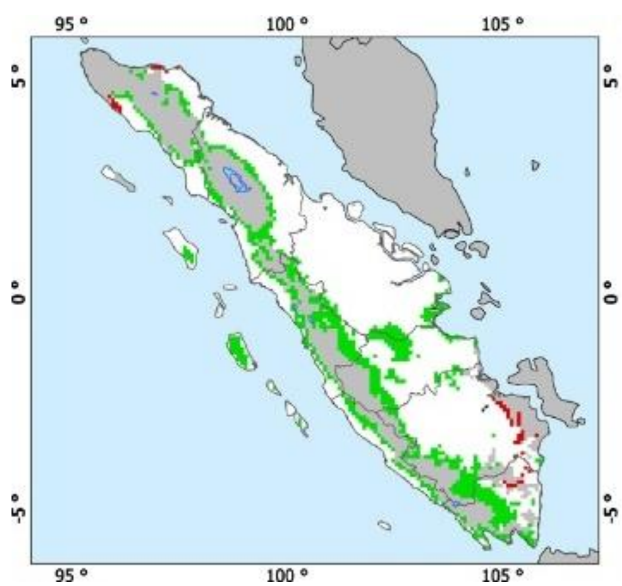


FIGURE 11-c: OIL PALM HABITAT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2050

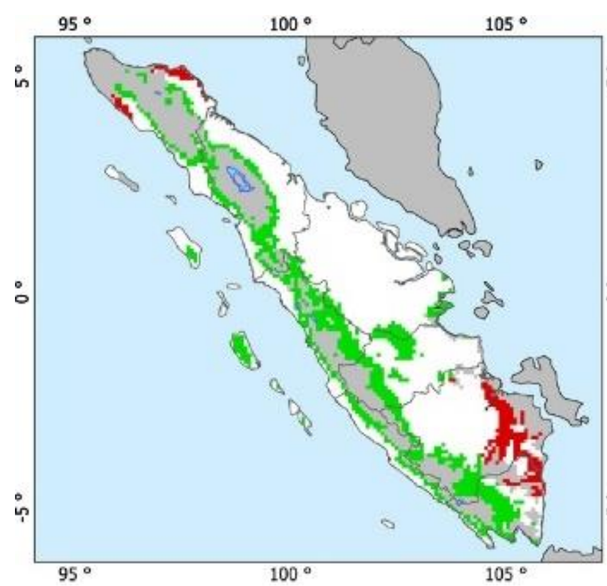


FIGURE 11-d: OIL PALM HABITAT WITH THE 4 DEGREES TEMPERATURE RISE SCENARIO – 2070

4 DELTARES - FLOODING AND HYDROLOGICAL CLIMATE ANALYSIS FOR SUMATRA

The Deltares hydrological study focuses on changes in future hydrological conditions and flood hazard caused by climate change. We selected three watersheds in the central-south of Sumatra where the Naturalis study predicted less rain during the driest quarter of the year. We were also interested to observe the results of this study in three watersheds in Aceh in the PJT landscape. The main difference between the selected rivers located in Aceh the basins more in the Southern part of Sumatra are the projected decrease in rainfall during the wet season. We will illustrate two watersheds (Peusangan & Jambo Aye) for Aceh and one (Palembang) for central-south Sumatra and how the river flow will be affected by climate change.

Future river flows have been simulated with the hydrological Wflow model, an open source Wflow hydrological modelling package developed by Deltares. Future reservoirs were included for four future scenarios, for the short-term future horizon 2030, the mid-term future horizon 2050 and the long-term future time horizon 2070. To remain consistent with the Naturalis studies, both 2°C and 4°C scenarios have been considered. River flows were simulated for the historic period 1979-2012 and future changes have been projected on this historical precipitation data.

4.1 PEUSANGAN RIVER BASIN – ACEH

Summarizing the results in the rainfall graphs for the Peusangan river basin, it is likely that precipitation in the months February, March and April and possibly January will decrease possibly resulting in earlier dry conditions in the basin, with the largest reductions being 50% (Figure 5). This is in line with the conclusions of Raes (2017) that the Northern coastal areas will become drier. Whereas precipitation increases are very likely from July to October with the largest increases for the month September. This is an indication of an earlier onset of the heavy rain occurring during the Monsoon (less than a month).

Annually, the maximum discharges of the Peusangan river will likely increase with approximately 10% in the future. This is a result of the annual increase in rainfall which is largest during the wet season. Consequently, the frequency of flooding and the flood extents will likely increase as well. River discharge will increase for November with a range up to 25% for 2070 for the most extreme scenario (4°C). The 2°C scenario projects small decreases of up to -5% throughout the year for both 2030 and 2050 (Figure 12).

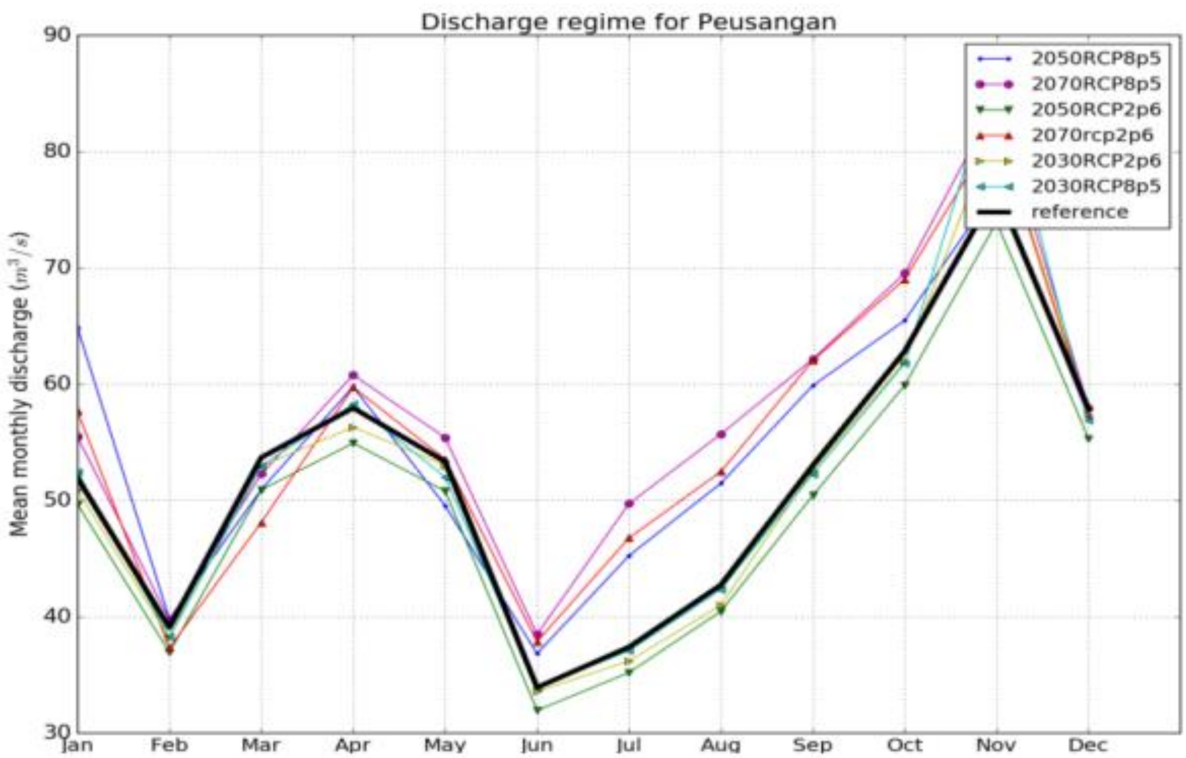


Figure 12: Average monthly simulated discharge regime for Peusangan for the four future scenarios together with the historical reference situation (black).

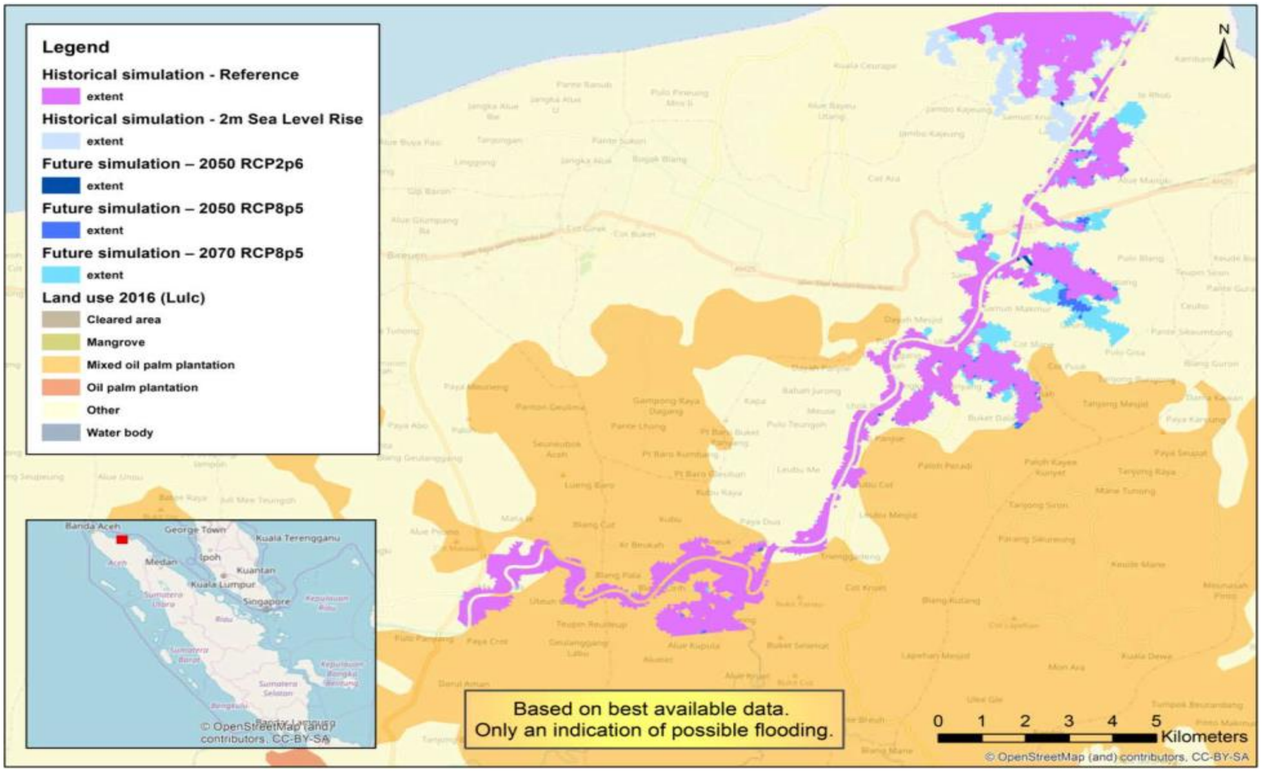


Figure 13: Simulated flood extents for the different scenarios (blue) and historic conditions (pink) for the Peusangan for a wet year - with in the background the different land use classes (LULC – WebGIS).

During the historical 'wettest years', flooding occurs on many locations along the path of the Peusangan river (Figure 13). A future increase in sea level of 2 meters would increase the flood extent and depth from the river in the North close to the coast. Flood extents will change very little by 2050 for the 2°C scenario. Increases for 2050 are also small for the 4 degrees scenario. Yet, by 2070 increased flood extents are simulated for the 4°C scenario.

4.2 JAMBO AYE RIVER BASIN – ACEH

To assess the impact of the construction of the new reservoirs in Jambo Aye, Deltares has simulated river discharge with the hydrological model including and excluding the reservoirs. The Jambo Aye was selected for the assessment because it has the largest planned reservoir. For a year with average rainfall conditions, the influence of the newly planned reservoir is negligible. However, for a typical wet year (as for example in 1997 for Sumatra) the difference between the situation with and without the reservoir is more pronounced. That means that the reservoir reduces the highest flows in the river, because water is stored and released over time, mainly during the low river flow periods. This also means that the lower flow during certain times of the year are increased as well (Figure 14, blue line), as water is released from the reservoir (depending on reservoir management).

We expect that the region could benefit from the construction of the reservoir. The higher flood (or higher river discharge/flow) peaks can be reduced herewith reducing the flood risk and impacts. Yet, depending on the species and their reliance on wet / flooded conditions reduction of flood extents and occurrence may be less favorable. It would be important to research what ecosystem functions and species rely on the variability of water flow throughout the year. Since the reservoir will be able to release water when river discharge is low, the river discharge during e.g. the dry season can increase. Yet, all will depend on the reservoir management that will likely serve other purposes such as electricity generation. Additionally, the design and locations of dams should ensure that critical habitat should be protected when planning a dam.

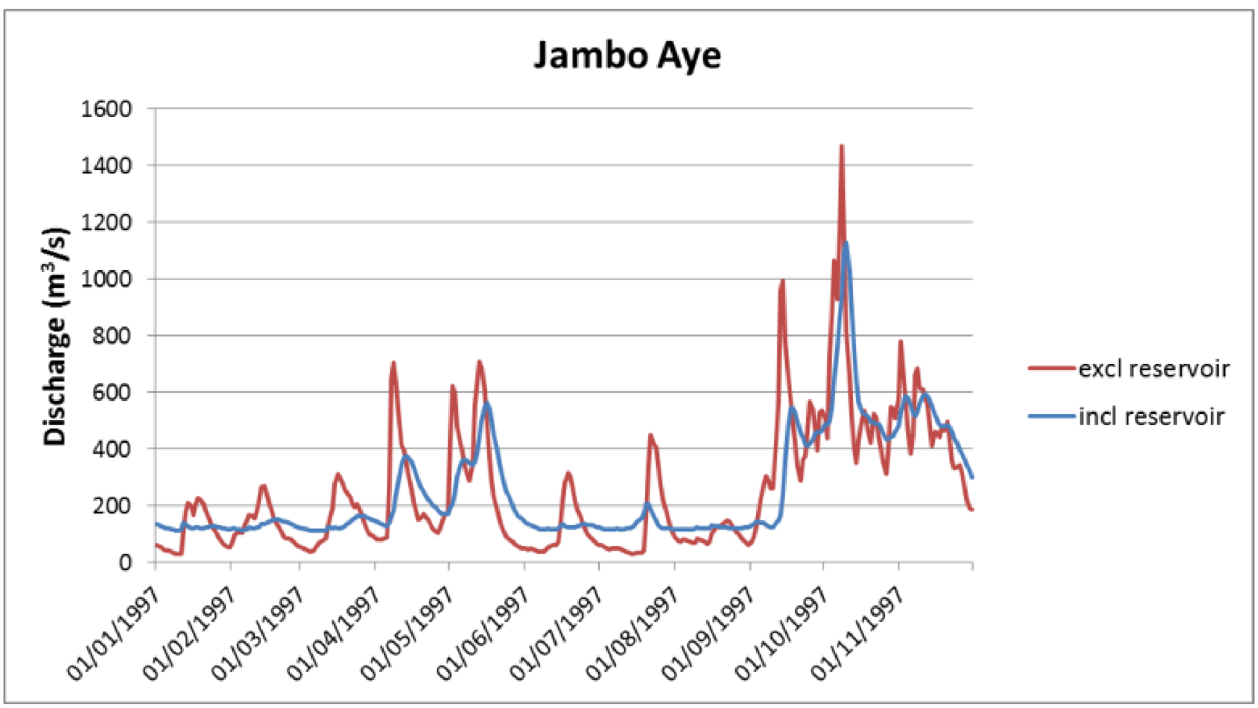


Figure 14: Simulated river discharge for the Jambo Aye river in 1997 without the reservoir under construction (red) together with the river discharge simulated with the hydrological model that includes the reservoir (blue).

On an annual basis, the river discharge will increase in the Jambo Aye river basin for almost all climate scenarios and time horizons. Especially between June and September there is a significant increase in discharge (Figure 15). River discharge is expected to increase most by 2070 for both the 2°C as the 4°C scenario. Proper reservoir management would be crucial to avoid the consequences of increased river flows, such as flooding's.

Jambo Aye is one of the river basins where flooding is likely to increase significantly in the future, with most flooding occurring at the 4°C scenario by 2050 and 2070 (Figure 16). Flood extents are especially large for the river south of *Paya Deumam Lhee*. Models show an increase of over 300% in flood extent against the baseline of historical modelled wet conditions in 1997. Keep in mind that the projected flood maps should be interpreted with care as their quality relies on limited data for river dimensioning and a course and biased digital elevation model which were used. The flood extent will likely be even larger for the 4°C scenario because of the 2D flood model used. In summary, there is a very likely indication of increased flood extents in the future for the wet season.

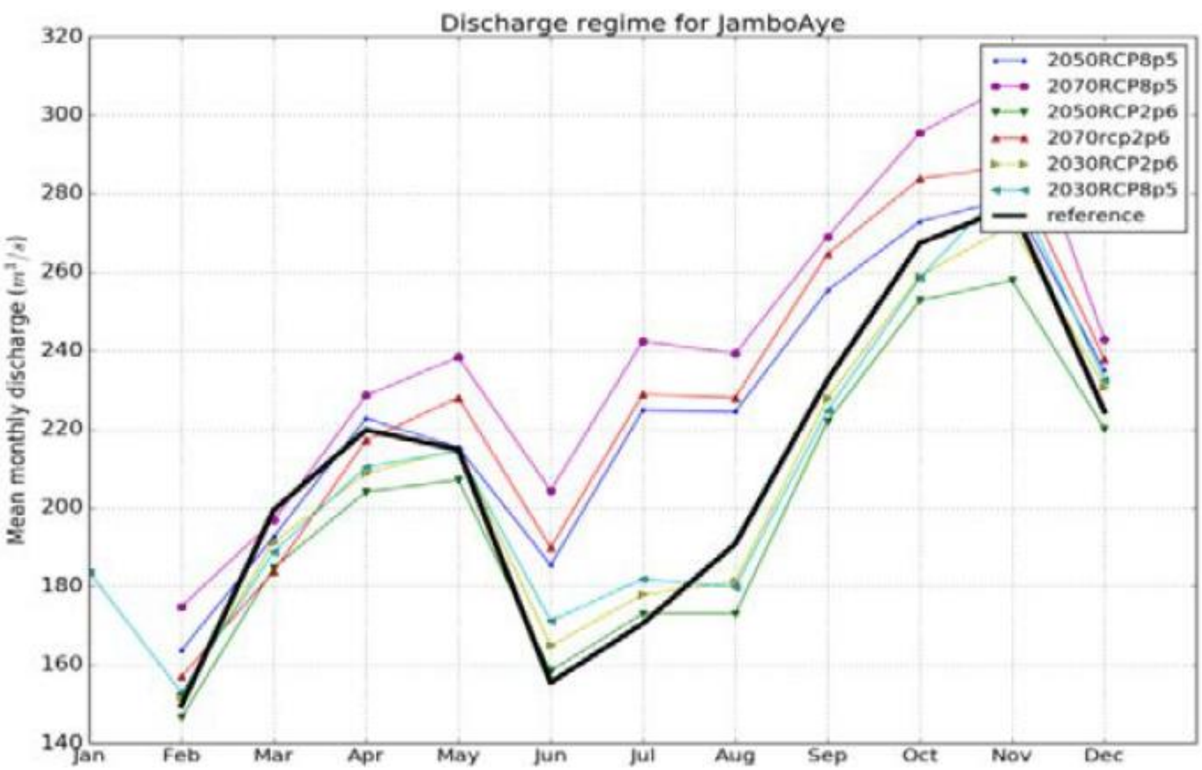


Figure 15: Average monthly simulated discharge regime for Jambo Aye for the four future scenarios together with the historical reference situation (black).

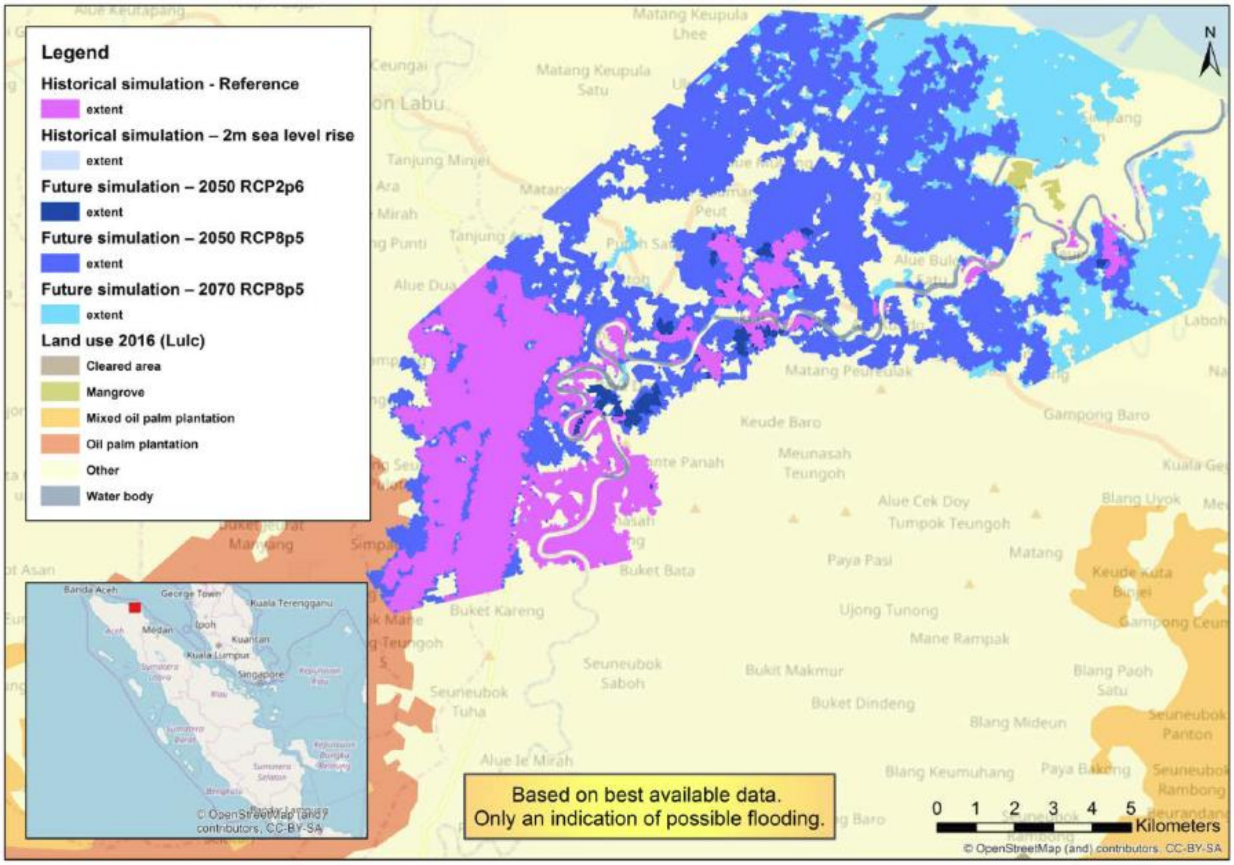


Figure 16: Simulated flood extents for the different scenarios (blue) and historic conditions (pink) for the JamboAye for a relatively dry year - with in the background the different land use classes (LULC – WebGIS).

4.3 TAMIANG RIVER BASIN – ACEH

For river flow of the Tamiang increases for the wet season months are ranging up to 10 % by 2050 and increases of nearly 20% are projected for 2070. For 2030 the changes are very small, only an increase in river flow for November can be distinguished (Figure 17). Flood extents during a relatively wet year will not increase much, but flood extents during a moderate wet year will increase (with approximately 40%) leading to annually reoccurring large floods.

For the Tamiang the flood model has been optimized but the model still seems to overestimate observed floods, the resulting historical and future flood maps should be interpreted with care. During a relatively wet year flooding will likely occur all along the reach of the Tamiang that was included in the flood model (Figure 18). A possible future sea level rise of 2 meters will result in increased flood extents in the most downstream part in the North-East reaching approximately 5 kilometers land inward. For 2°C the flood extent may slightly decrease by 2050. For the 4°C scenario nearly any changes in flood extent are projected, most likely because the historic flood extent was very large.

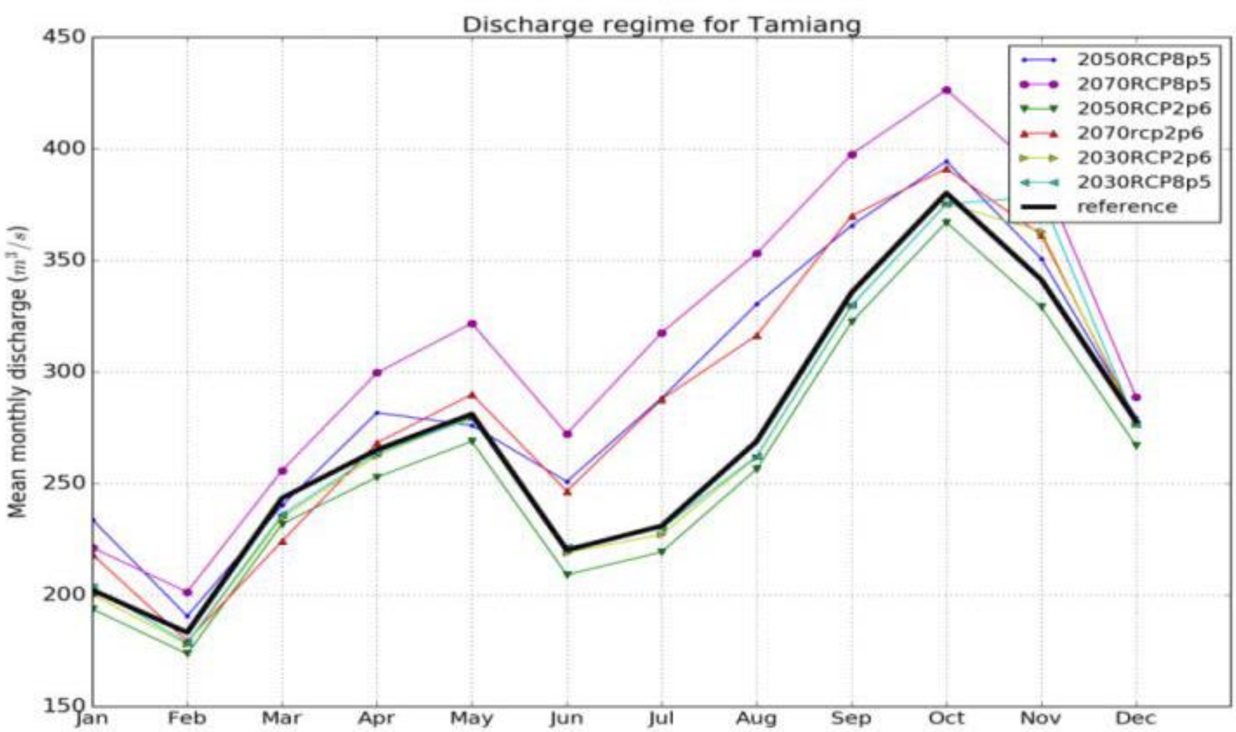


Figure 17: Average monthly simulated discharge regime for Tamiang for the four future scenarios together with the historical reference situation (black).

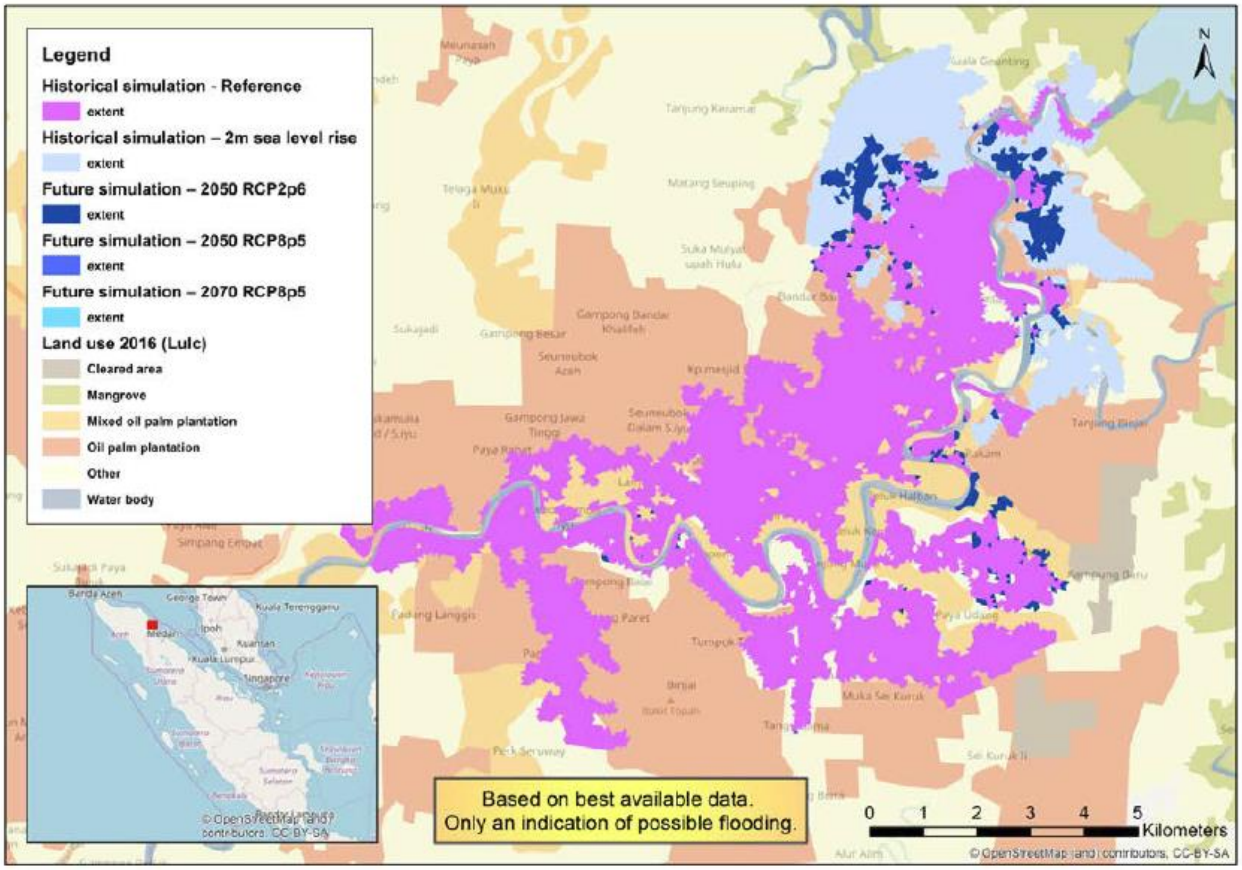


Figure 18: Simulated flood extents for the different scenarios (blue) and historic conditions (pink) for the Tamiang for a relatively wet year - with in the background the different land use classes (LULC – WebGIS).

4.4 PALEMBANG RIVER BASIN – SOUTH SUMATRA

For the Palembang river basin decreases in monthly average flows are projected. The decreases are largest for 2050, especially for the 2 degrees scenario (Figure 18, green line). For the 4°C scenario decreases are smaller, and the 4°C scenario projects the largest precipitation increases during the wet season and this results in an increase of the annual precipitation. Looking at the figures from Raes (2017) for 2050 (Figure x), the 2°C scenario projects increases of ~20 mm for the most Southern part whereas the 4 degrees scenario projects increases up to ~100 mm. This is in line with the precipitation projections of Raes (2017). Yet, little change in precipitation is projected for the south of Sumatra for the wettest quarter and decreases, up to 100 mm in some locations in the very south, are projected for the driest quarter. This in combination with temperature rise and resulting evaporation increases, will decrease river discharges (Figure x), with the largest decreases are projected for July with 15%. This requires the water abstraction sectors (agriculture, businesses) to consider less available water for e.g. irrigation during certain months of the year.

South and middle Sumatra river basins:

Overall, the results of river discharge amongst the river basins in middle and south Sumatra show similar trends (Figure 19). All rivers were projected to decrease in monthly average flow. The decreases are largest for 2050, especially for the 4°C scenario.

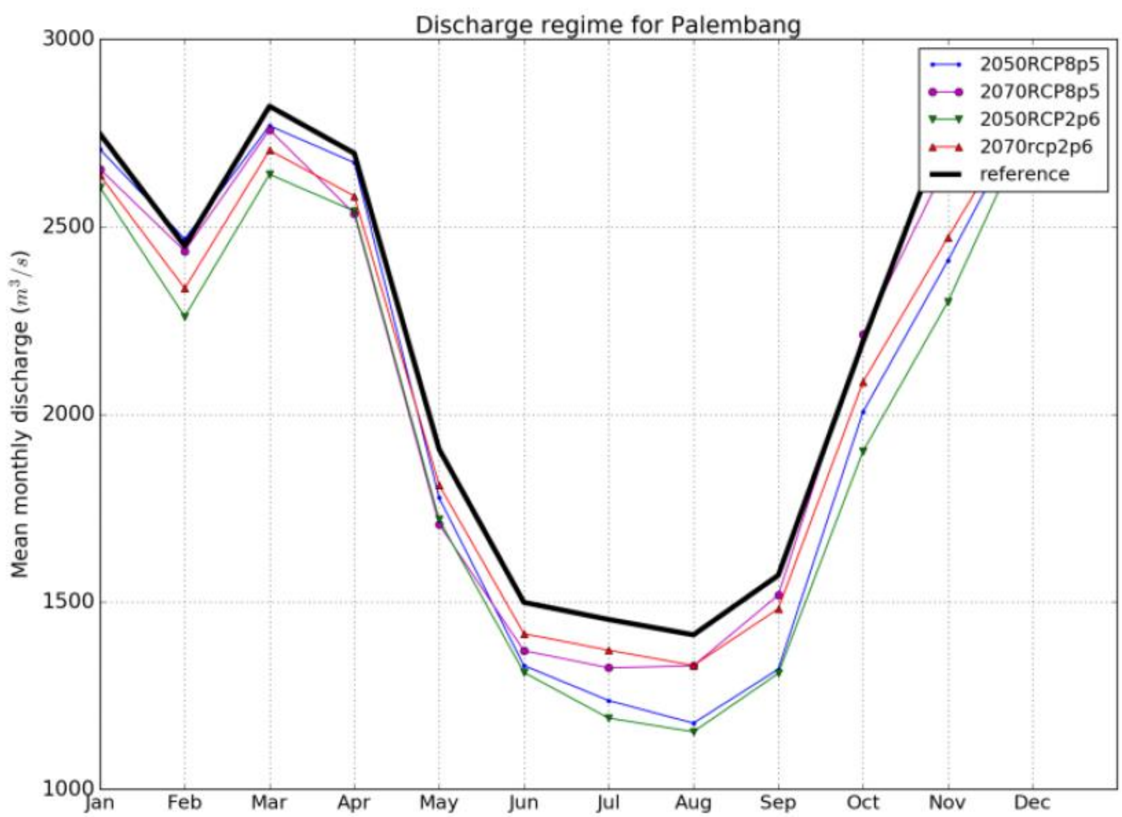


Figure 19: Average monthly simulated discharge regime for Palembang for the four future scenarios together with the historical reference situation (black).

4.5 FINDINGS DELTARES FOR RIVER BASINS IN ACEH

Annual rainfall for the Jambo Aye, Peusangan and Tamiang river basins (in Aceh) will likely increase. This results in an indication of an earlier onset of the heavy rain months of the Monsoon and an increase in Monsoon rainfall overall. Raes (2017) concluded similarly that the conditions will likely become wetter in the wettest quarter of the year. Rain may slightly decrease for the drier months, February and March.

River flow

- The 2°C scenario shows small decreases in flow for 2050, especially for the wet season. The other scenarios project increases in monthly flows for both 2050 and 2070, for 2070 projected increases are largest. For 2030 projected changes are small.
- When considering climate impacts only, annual average and annual maximum river discharges will likely increase with approximately 10%.
- Not only climate change will affect the river flow, the reservoirs that are under construction will also moderate flow. According to the simulations (on Jambo Aye) they can have a positive effect; however, this depends on the actual management. Mean annual maximum flows may decrease and 7-day minimum flows will increase. An increase in 7-day minimum flows suggest that there will be longer periods of low flow, thus lower water availability during the dry season. The effect during extreme floods will be minimal as the reservoir will likely be fully filled before the flood is over and thus flood risk will likely increase.
- Other human influences have not been considered, yet deforestation and oil tree plantations have severely degraded the land and hydrological conditions. The population and wildlife, especially in the upstream areas, could benefit from the projected future hydrological conditions that indicate increases in rainfall, but only when integrated watershed management is improved and becomes more sustainable.
- The simulations indicate that in the middle and south of Sumatra monthly and annual average river flows will more likely decrease and changes in maximum flows are very small or negligible.

Floods

- For the Peusangan floods occur along the course of the downstream part of the river during a wet year, yet only nearby the river. During dry years there is very little flooding. A 2-meter sea level rise would increase the flood extent and depth in the north reaching more than 5 km land inward. 4°C scenario projections show an increase in flood extent, especially for 2070.
- Flood extent during moderate years will remain much smaller than flood extents obtained for historical wet years.
- For the Jambo Aye in the historical wet situation flooding mainly occurs in the western downstream part. For 2050 2°C scenario projects very little change, yet the 4°C scenario projects large increases for both 2050 and 2070. In a moderate wet season there is nearly any flooding. The projected flood maps should be interpreted with care, the flood extent will likely be larger than displayed on the current flood maps as the extents are now limited to the boundaries of the 2D flood model but the quality of the DEM and dimensioning of the river system influences the results. Still there is a very likely indication of increased flood extents in the future for the wet season for both extreme and moderate high flows. In addition, small floods are likely to occur yearly in the future.

- During a relatively wet year flooding will likely occur all along the reach of the Tamiang that was included in the flood model. For a moderate flood season the flood extents are much smaller. A possible future sea level rise of 2 meters will result in increased flood extents in the most downstream part in the North-East reaching approximately 5 km land inward. For the 2°C scenario the flood extent may slightly decrease by 2050. For the 4°C scenario nearly any changes in flood extent are projected for wet conditions and slight increases for a moderate wet season.

Overall:

Flood extents and depths are likely to increase in the future, especially according to the 4°C scenario. A sea level rise of 2 meters will result in an increased flood extent reaching approximately 5 km land inward.

5 CLIMATE MODELLING IN CONSERVATION – SPATIAL OVERLAYS

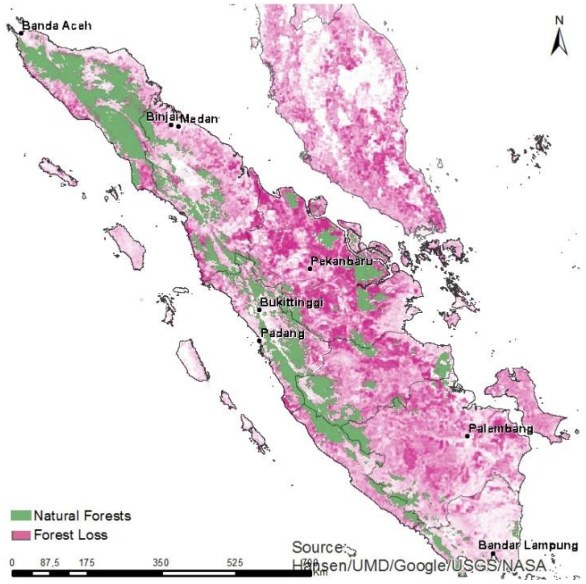


Figure 20-a: Forest cover loss (between 2000-2012), Source: Global Forest Watch

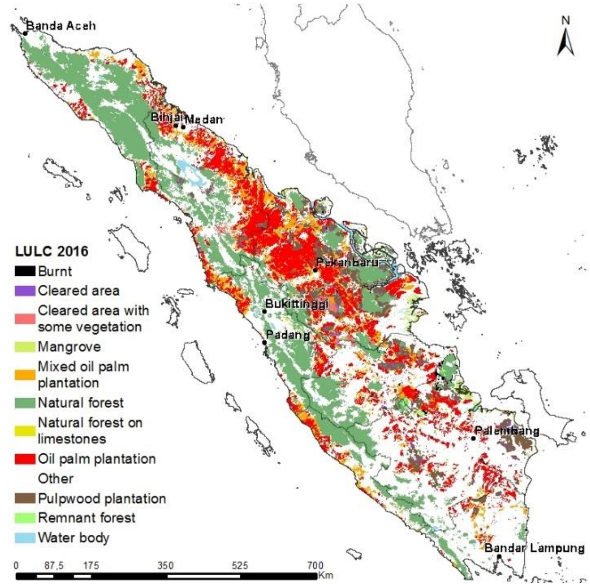


Figure 20-b: Land cover map 2016, Source: WWF Indonesia

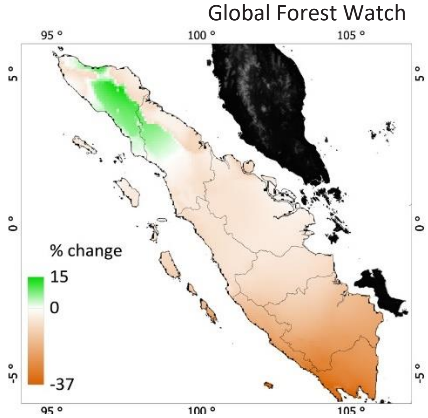


Figure 20-c – Change in precipitation driest quarter (in %) - 2030

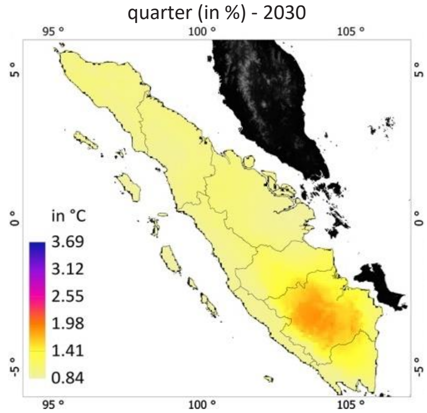


Figure 20-d – Increase in max. temperature warmest month - 2030

Sumatra has experienced intensive forest cover loss in between 2000-2012 (Figure 20a), which has resulted in a fragmented landscape for the remaining natural forests. These remaining forests are key for the conservation of priority species. The current spatial distribution of Sumatra shows that agricultural practices *(class 'other': rubber, rice, coffee)* are widespread, but appear most in the south-central region. If precipitation during the driest quarter is expressed in percentage change against current conditions, South central Sumatra will receive significantly less rain during the driest quarter of the year (up to 37% less rain) by 2030 (Figure 20c & Figure 3). This could have severe consequences for the production in the agricultural sector (Figure 20b), due to water shortage, drought proneness, and altering fire regimes. These threats are strengthened by increasing maximum temperatures in the warmest month of the year, which for south central Sumatra can increase with up to 2 degrees by 2030 (Figure 20d & Figure 2).

What now?

- Determine if current crops used in agriculture can continue to produce/grow in reduced projected rainfall (up to 37%) during the driest quarter.
- The increase in maximum temperature during the warmest month, especially in south central Sumatra, will increase vulnerability to droughts for agricultural practices. Develop and introduce adaption techniques (irrigation techniques etc.) in agricultural practices.

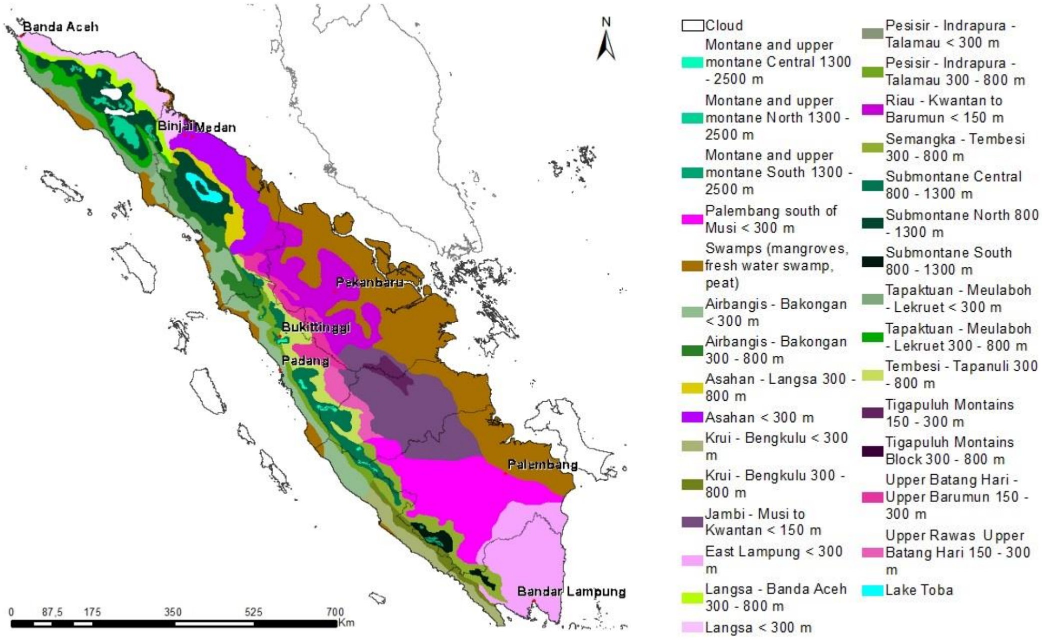


Figure 21-a: Eco-floristic sectors (EFS) by (Laumonier, et al., 2010)

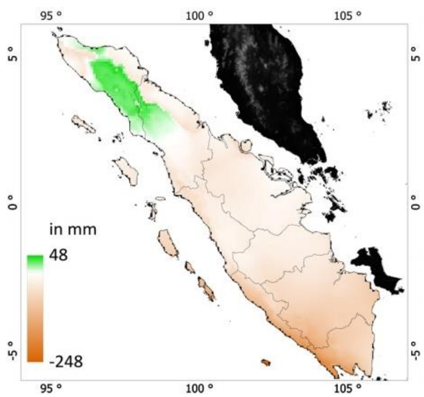


Figure 21-b – Change in Precipitation driest quarter (in mm) - 2030

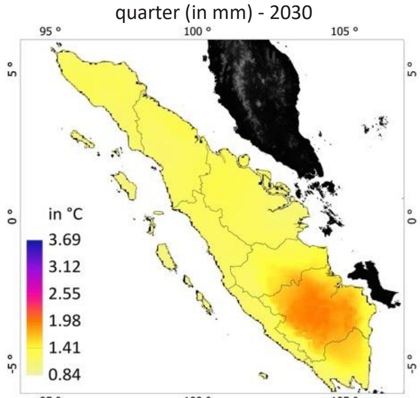


Figure 21-c – Max temperature warmest month - 2030

For Sumatra, Eco-floristic sectors (EFS) have been identified (Figure 21a), which represent the possible forest types in the absence of human activity (Laumonier, et al., 2010). Most forest types have been converted to other land uses over the last decades, resulting in fragmented and isolated forest types. Increasing temperatures and changing rainfall patterns could alter the composition of species that make up these forest types. The EFS '*East Lampung*' and '*Palembang South of Musi'*, located in south central Sumatra, will receive less rainfall during the driest quarter and higher extreme temperatures by 2030 (Figure 21b). This could alter the reproduction timings of species and the phenology of plants within those EFS. Additionally, the ecosystem services provided by these forest types would be influenced or even lost. The current threats to peat swamps (drainage) combined with predicted reduced rainfall (Figure 21b) and increasing max temperatures in the driest quarter (Figure 21c) of the year will make peat highly flammable, and a substantial source of greenhouse gas emissions.

What now?

- Climate adaptive management for tropical peatlands.
- Identify ecosystem services provided by climate vulnerable forest types and plan adaptation techniques.
- Study the effects of increasing temperatures and reduced rainfall on important plant food sources for species.

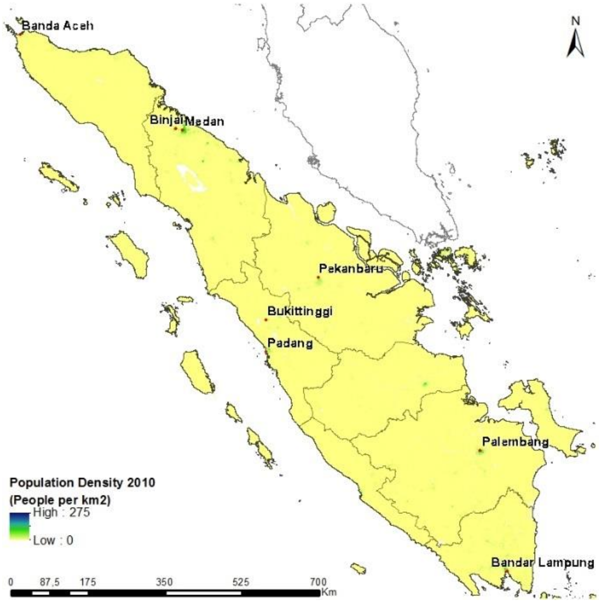


Figure 22-a: Population Density 2010, source: WorldPop (www.worldpop.org)

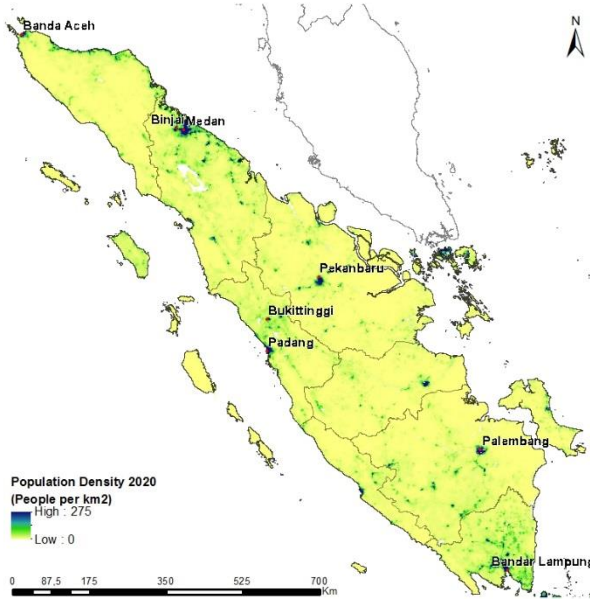


Figure 22-b: Population Density 2020, source: WorldPop (www.worldpop.org)

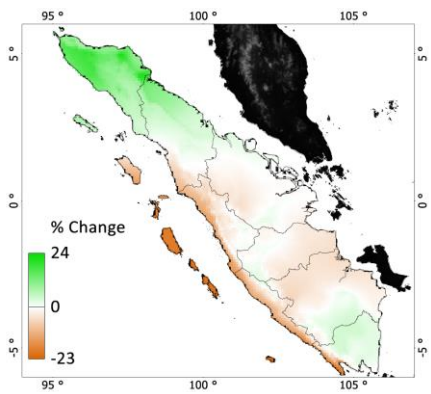


Figure 22-c: – Change in Precipitation of the wettest quarter - 2030

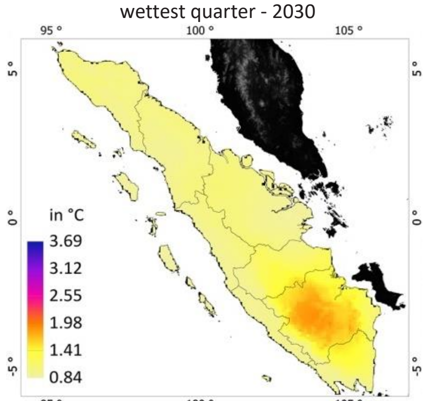


Figure 22-d: – Change in Max temperature warmest month - 2030

Human population density estimates for 2020 show a significant increase in density compared to 2010 (WorldPop data) (Figure 22a-b). The projections show that major cities are expected to expand in urban population densities, such as Medan and Palembang. Furthermore, the increase in population density is concentrated along the coastal zones. Coastal protection by mangroves is one measure that will provide the coastal communities with protection against rising sea levels and extreme weather events, such as floods and storms. Additionally, northern Sumatra will receive significantly more rainfall during the wettest quarter of the year (up to 24%, Figure 22-c) compared to current conditions. This high rainfall overlaps with regions that experience exponential population growth in the coming years. Rivers will increase in discharge of water flow, flooding inland areas and coastal zones. River and forest banks require protection against the increasing water flow to prevent erosion and mud slides.

What now?

- Erosion control interventions in (especially) North Sumatra through e.g. agroforestry.
- Flood prevention or control techniques to protect inland and coastal communities.
- Mangrove protection or rehabilitation to protect coastal communities, which are expected to increase in population density.

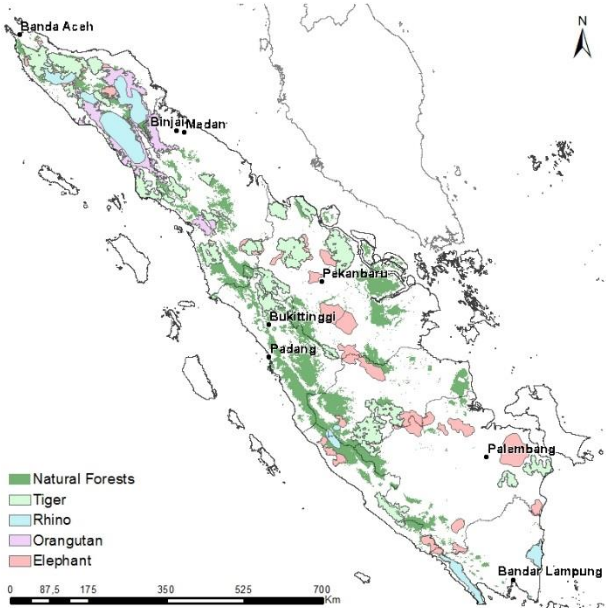


Figure 23a: Species habitat, source: WWF Indonesia

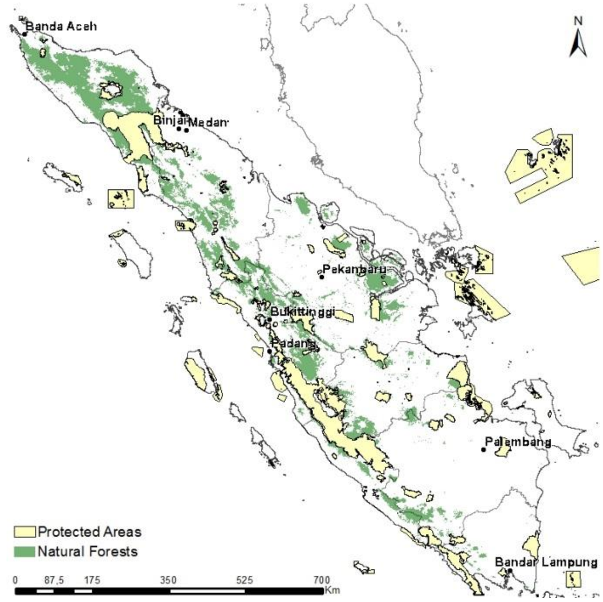


Figure 23b: Protected Areas, source: IUCN's World Commission on Protected Areas (WCPA)

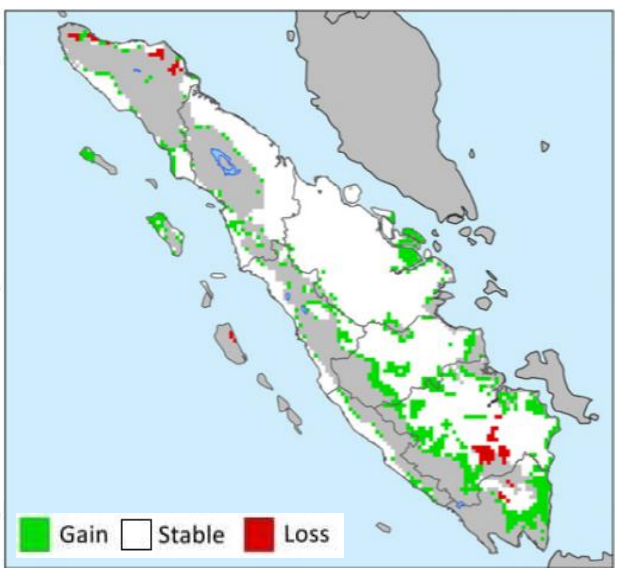


Figure 23c: Oil palm – 4 degrees – 2030

As temperatures at higher elevations increase, suitable climate habitat for Oil palm will increase (Figure 23c). Climate suitable Oil palm habitat will encrouch to current protected areas and species (e.g. tiger) habitat (Figure 23a-b), mainly in south-western Sumatra and lower montane areas. Future conflicts between forested areas and oil palm plantations could arise. Quite some uncertainty exists on how oil palm yields will be affected by climate change. The increasing frequency of droughts have, for example, declined oil palm yields with 10-30% for South-East Asia (Russell, Paterson, Kumar, Taylor, & Lima, 2015). This requires current oil palm plantations to adapt to droughts, or could force oil palm plantionas to shift to more climate suitable habitat.

What now?

- Spatial planning strategies to avoid conversion of natural forest to Oil palm plantations
- Identify high value and climate resilient corridors and protect these from conversion to Oil palm
- Identify biodiversity corridors that are vulnerable to climate change and plan climate adaptation interventions

6 OVERAL FINDINGS

It's important to realize that climate change is already happening and is an exacerbation to many current environmental and biodiversity threats on Sumatra, such as; severe droughts, increased forest fires, quality and quantity of freshwater supplies, increased habitat fragmentation due land use change, and poaching. Current observations show that precipitation patterns have changed; rainy seasons are shifting. There has been an increase in (per media reports) floods, mainly due to increased precipitation, deforestation and water retention loss. Water quality and quantity in rivers is decreasing during the drier seasons, impacting livelihoods, but also biodiversity (e.g. Elephants).

Other reported observations made during a climate workshop (August, 2017) in Aceh, Sumatra, are changes in fish community composition in rivers, fishponds and rice fields. There are already more mosquitos at higher altitudes. These observed climate related findings are early indicators of climate change, and the impact on livelihoods and biodiversity.

It is valuable to start monitoring and collecting 'stories' on the consequences of climate change as they are experienced through communities and local people in the field. This can validate the scientific climate change models, but can also bring the consequences of climate change more into context. Monitoring climate change through e.g. communities and citizens will also raise the awareness of vulnerable groups, and start building climate adaptation interventions.

Another study (Jeff Price, 2016) on the climate effects on priority regions of WWF using different modelling techniques predicted similar results. Here the predicted results for species richness on mammals in general on Sumatra show that the highland areas remain the most suitable, for both the 2°C as for 4°C scenario. The benefit of both the Naturalis study and WWF UK study is the spatial visualization of (changing) suitable habitat for species. This allows for considering, and integrating, climate change threats in spatial planning.

7 RECOMMENDATIONS

The global community must strive to ensure that global warming remains below a 2°C rise to mitigate its impacts on Sumatra. However, we must start to adapt to expected changes in climate that are projected occur beyond the 2°C rise scenario.

Recommendations by stakeholder based on the Naturalis study:

NGO's & CSO's:

- Start monitoring of (local) climate change observations to validate climate projection models and to raise awareness. This data collection should happen in both vulnerable climate change regions, but also less vulnerable regions.
- Explore and include citizen science in the monitoring of local climate change observations, such as new observed species, lost species, floods, fish stocks, droughts, crop harvests, rainfall and temperature variation where data is lacking.
- Raise awareness for farmers on climate change and start discussing possible adaptation management, for example use climate resilient crops and adapt their farming practices to current/future climate conditions.
- NGOs should stimulate the government to collect and share climate data by the government so NGOs and CSOs are informed and can advise on the integration of climate change adaptation in development plans.

Government (Local & Central government):

- Climate change analysis should be used and considered in development planning processes, and short and long-term environmental risk assessment (floods, erosion) and management.
    - Increase the status of the current forest area and don't allow palm oil to move up to higher elevations.
- Landscape connectivity and contiguous forest corridors should be maintained or developed to link existing species habitats; for example, a high priority is the connectivity of habitats at lower elevations to final species refugia at higher (cooler) elevations.
- Identify climate refugia for (wildlife) species through climate change analysis.
- Forest fires should be prevented at high risk forest (fire) areas through strict law enforcement and awareness campaigns to avoid the burning of natural vegetation for land clearing.
- Initiate collaboration with CSO's/NGO's and data gathering institutes to collect climate data to validate the climate change projection models.
- The government should have an accessible and open (free) data policy on climate change data and weather (forecasting) data in order to validate and inform climate change projections.

Private sector:

- Private sector concession holders, such as palm oil, should ensure that high value conservation areas are protected and maintain connected.

Recommendations by stakeholder based on the Deltares study:

NGO's & CSO's:

- Using the results of the Deltares study (Sperna Weiland, Perwitasari, Hermawan, Gebremedhin, & Gao, 2018), NGO's and CSO's can recommend the government to consider these changes in flood hazard in national / provincial spatial plans. For local infrastructure plans it is recommended to do additional modelling.
- Advocacy is needed of the likely increases in flood hazard for the private sector in order to show them the joint interests of the private sector related to investment risks. The government and NGO's & CSO's can work together with the private sector to improve a sustainable and a climate resilient future.
- Raise awareness for the private sector on the risks of climate change on the hydrological system and encourage them to take their own responsibility to ensure the provision of ecosystem services in the landscape.
- Ensure that the results of this study can inform the National Adaptation Plan and Integrated River Basin Plans.
- NGO's & CSO's could actively start to collect on the ground data for validation of the hydrological assessment and specifically the simulated flood extents and frequency of occurrence. Data should be collected during the wet seasons and especially during and after flood events.

Government (Local & Central government):

- Ensure that flood risks (and other climate related projections) are integrated in any Strategic environmental assessment (SEA) and Environmental Impact Assessment (EIA). For interpretation and use of flood maps Deltares[3] and WWF do the joint recommendation that more detailed modelling is required for the areas indicated as being flooded in the current and / or future situation.
- The government should include the consequences of flooding into their green infrastructure guidelines and enforce implementation. If the current guidelines are found insufficient, these require to be updated. For inland rivers with a high flood risk, green infrastructure development should be included, such as strengthening river embankments through green infrastructure (vegetation).
- The government should initiate follow up studies or more detailed studies on the hydrological system and consequences of climate change, to which the private sector should contribute, as it might affect their businesses.
- Mangrove rehabilitation activities are crucial in order to reduce the impacts of coastal flooding through sea level rise. Furthermore, mangrove rehabilitation should consider use of mangrove species that can coop with rising sea levels and changing (sea) salt levels.

[3] Due to the current limited availability of local data the results are uncertain and may be biased. The flood maps give an indication of likely flooded areas and changes therein. There is a high certainty on the projected trend and direction of change and these can be used and presented in further discussions and advocacy activities. On the absolute flood extents there are however more doubts and as discussed with WWF we propose the maps are presented with the disclaimer that these are based on best available data and should be interpreted with care.

Recommendations for further research:

Universities & scientific organizations:

- Further research should address the impact of changes in flood occurrence and extent as well as changes in fresh water availability for businesses and agriculture, as well as for biodiversity (e.g. elephant corridors).
- The main improvement for the Deltares study on hydrology and flooding risk can be obtained by improving the elevation maps in the flood models which would require a LIDAR DEM of the river basins.
- The increased coastal flooding risk (sea level rise) will result in increased salt intrusion. Further research is needed to identify agricultural practices, surface water and aquifers that are sensitive to salt intrusion.
- Governments and NGO's & CSO's should make (climate) data available for universities to enrich research and validate climate change models used e.g. in prediction modelling.
- Study the impacts of climate change on other commodities: Coffee, Cocoa, Rice, Aquaculture, Resin (Damar).
- Study the impact of climate change: Human elephant conflict and behavior, key species migration, connectivity, habitat quality.
- Study the consequences of climate change for peatland areas in Sumatra

8 ANNEX

TABLE 1: BIOCLIMATIC VARIABLES DERIVED FROM MONTHLY MINIMUM AND MAXIMUM TEMPERATURES AND MONTHLY PRECIPITATION

	Description
bio01	Annual Mean Temperature
bio02	Mean Diurnal Range (Mean of monthly (max temp - min temp))
bio03	Isothermality (BIO2/BIO7) (*100)
bio04	Temperature Seasonality (standard deviation *100)
bio05	Max Temperature of Warmest Month
bio06	Min Temperature of Coldest Month
bio07	Temperature Annual Range (BIO5-BIO6)
bio08	Mean Temperature of Wettest Quarter
bio09	Mean Temperature of Driest Quarter
bio10	Mean Temperature of Warmest Quarter
bio11	Mean Temperature of Coldest Quarter
bio12	Annual Precipitation
bio13	Precipitation of Wettest Month
bio14	Precipitation of Driest Month
bio15	Precipitation Seasonality (Coefficient of Variation)
bio16	Precipitation of Wettest Quarter
bio17	Precipitation of Driest Quarter
bio18	Precipitation of Warmest Quarter
bio19	Precipitation of Coldest Quarter

ENDNOTES

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