Chapter 6
Vulnerability Assessment on Agriculture in East Nusa Tenggara

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Abstract Despite the region's vulnerability, climate change adaptation strategies in poor contexts such as Asia are limited. A vulnerability assessment was conducted in one of the poor areas of Indonesia, East Nusa Tenggara (NTT) Province. The study demonstrates the future of the NTT agricultural sector, focusing on estate crops, particularly coffee. The assessment applied a three-domain function of exposure, sensitivity, and adaptive capacity based on (1) climate data and land suitability; (2) the commodity production data; and (3) socioeconomic, policy, and institutional context, respectively. This study utilises climate data from as the exposure and the land suitability projection (the sensitivity) was obtained from modelling by Matlab and ArcGIS. As a semi-arid region, the viability of NTT's agricultural lands is projected to decline due to increasingly prominent climate-change impacts. The result showed divergent temperature rises and precipitation patterns across the islands. Consequently, the suitable land would gradually decline for all estate crops in the region; hence, bringing these farmers out of vulnerability requires multi-prolonged climate-resilient agricultural practices. In addressing climate change, this study gives a holistic recommendation to increase the adaptive capacity by strengthening extension support, crops diversification, institutional change, added-value-chain, and the co-finance should be considered in the poor context like NTT province.

Introduction

Climate change impacts have become more severe across Indonesia, particularly in rural areas' economic activities and environmental changes. Because the area is an archipelago, the Indonesian population mostly lives along the coastlines, including Sumatra, Java, and Nusa Tenggara Islands. the coastal communities are at high

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risk of suffering from negative effects and natural disasters, where flood, landslide, tornado, and drought were the top four disasters (Kuswanto et al. 2019). The shift in weather patterns is the main cause of worsening droughts and wildfires in the last two decades, negatively impacting the agricultural sectors and food security (Mayer et al. 2011). Climate change has exacerbated the vulnerability of East Nusa Tenggara at an alarming rate because it is island province and one of the major crop producers in Indonesia.

East Nusa Tenggara, or *Nusa Tenggara Timur* (NTT), is located within the lesser Sunda Island in the south-eastern part of Indonesia (see Fig. 6.1). This province includes more than 1,100 islands, with the largest islands being Flores, Sumba, Timor, and Alor. With over 5.3 million people, the province is divided into 21 districts (*kab.)* and one autonomous city (BPS NTT 2021). Climatically, NTT is categorised as a semi-arid region that experiences four months of wet season (January–March and December) and eight months of dry season with moderate rainfall (BPS 2018). This climate shift significantly impacts the livelihood of the NTT population, particularly farmers. In 2020, the labour force reached more than 2.8 million people, around 51% of whom was absorbed by the agriculture, forestry, and fishery sector and contributed 28.51% to the province's gross regional domestic product (GRDP) (BPS NTT 2021). However, recent data places NTT as the third poorest province nationally after Papua and West Papua, with 21% living under the poverty threshold (BPS NTT 2021). Although agriculture is the highest contributor to industrial, trade and service sectors, agriculture's GRDP has decreased slightly since 2016. With rising concern about NTT's agriculture, this paper entails vulnerability assessment focusing on coffee crop combined with a sustainable livelihood framework to assess the projected impact and adaptive capacity required for NTT.

Fig. 6.1 Map of East Nusa Tenggara

Materials and Method

Vulnerability Concepts

Climate change adaptation has two concepts of vulnerability, encompassing outcome vulnerability and contextual vulnerability (IPCC 2007; O'Brien 2011; Takama et al. 2016). The perspective of outcome vulnerability is the overall effect of climate change, its impacts, and adaptive capacity. Meanwhile, contextual vulnerability assumes the main influence of potential characteristics of issues, context, purpose, and system. This study is based on the outcome vulnerability framework defined by the IPCC's Fourth Assessment Report (AR4), which has been re-interpreted in the Fifth Assessment Report of the IPCC (AR5) with an alternative approach and terminology. However, since the updated framework tends to approach the disaster risk concept, this study opted for the AR4 definition.

Vulnerability, according to AR4, is "…the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC 2007: 6). Based on this definition, vulnerability is further defined as a function of three domains, comprising exposure, sensitivity, and adaptive capacity.

$$\text{Vulnerability} = \text{f}(\text{exposure},\ \text{sensitivity},\ \text{adaptive capacity})$$

As the natures and the measures of these domains differ, each shall be assessed separately. For instance, exposure must be explored by considering the climatic analysis, including the current, historical, and projected climate change and variability and locations of the potential climate variations. Meanwhile, sensitivity can be investigated through the susceptibility level of the condition in an interference, such as agricultural productivity, cropping pattern input use, income inequality, or even employment migration (IPCC 2007). In terms of adaptive capacity, this domain is defined as the ability of humans or communities to adjust or cope with climate change variability.

Framework of Adaptive Capacity

There are different frameworks to assess adaptive capacity: the sustainable livelihood framework based on assets (DfID 1999), paired with institutions and political contexts that influence their availability and mobility (Smit and Wandel 2006). This framework is chosen as it encompasses both a bottom-up (livelihood of the farmers) and top-down (support from the government is considered from policy and institutional context) perspective (Nelson et al. 2009) to assess adaptive capacity. The livelihood assets comprise:

- Human capital encompasses skills, knowledge, and support labour activities to achieve livelihood objectives, such as health and education, as these two factors contribute to poverty.
- Natural capital comprises the natural resources that are beneficial and essential to achieving the livelihood objective, such as the atmospheric environment and biodiversity.
- Physical capital is the basic infrastructure and producer goods that can help achieve the livelihood objective. Infrastructure is the modification of the existing environment to help support the welfare; meanwhile, the producer goods include the equipment or tool that people use to support their functionality.
- Financial capital is the financial resources to reach the aim of livelihood and contribute to consumption and production, with two main sources: (a) available stocks, such as bank deposits, livestock, and jewellery and (b) regular inflows of money, such as salary and pension.

Vulnerability Assessment

Exposure is defined as changes in temperature and precipitation between current conditions and the future projection. Climate data and facts as part of exposure were collected from literature and modelling activities. The modelling was conducted with a downscaled WRF model and post-processed Matlab and ArcGIS. At its core, climate data includes the average value of the maximum and minimum temperature and precipitation. The climate data utilises the gridded data from Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG). The results for each sample point are then processed using categorised symbols into unique values and grouped into five ranges (very low, low, moderate, high, and very high). The reference period used in ArcGIS modelling is 1979–2004.

The model has three scenarios: the baseline scenario, RCP 4.5 and RCP 8.5. The baseline scenario ranges between 1970 and 2004, where the activities flow in line with the business as usual. The RCP 4.5 and RCP 8.5 scenarios present the projection of three different time ranges, encompassing near future (2010–2039), mid-future (2040–2069), and far-end (2070–2099), as explained in (Table 6.1).

The second component, sensitivity, is translated through literature review and land suitability maps of the crop to climate variables derived from the FAO (1981) framework, presented in baseline condition and at the projected time frame. The suitability will be divided into four categories: S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable). In addition to four livelihood assets, the adaptive capacity of the farmers will also explore policy context and existing institutional support from local, national, and international aspects. These dimensions of adaptive capacity will be scoured through literature reviews and national data statistics.

Table 6.1 Characteristics of RCP 4.5 and RCP 8.5 scenarios (Riahi et al. 2011; Thomson et al. 2011)

	RCP 4.5	RCP 8.5
Scenario type	Stabilisation scenario	Failed mitigation scenario
Simulation	Stabilisation to 4.5 W/m^2 at stabilisation after 2100	Rising radiative forcing pathway up to 8.5 W/m^2 in 2100
Assumptions	Existence of effective climate policies	Rapid population growth, low-income rate, inadequate technological shift and energy development, long-term energy demand, increasing GHG emissions

Table 6.2 Comparison of productivity of key crops in NTT to national level

Commodity	Production area (ha)	Productivity in NTT (ton/ha)	National average productivity (ton/ha)	Average production growth per year in NTT (%)
Coffee	73,251[a]	0.325[c]	0.608[d]	6.62[b]

Source [a] (BPS NTT 2019a), [b] (BPS NTT 2020), [c] (BPS NTT 2019b) [d] (BPS 2020)

Context: Current Conditions of Agriculture Sector in NTT

Agriculture has a big role in driving economic activity of NTT. The top five economic contributor of 2020 are staples crops production (7.75% to the province GRDP), livestock services and production (9.89%), fishery (5.75%), horticulture crops (2.2%), and estate crops production (2.34%) (BPS NTT 2021). Ninety-nine percent of staple crops and 82.5% of horticulture crops produced were consumed locally. On the contrary, estate crops such as coffee, cacao, cashew, and coconuts account for almost 70% of exported commodities of the combined agriculture, forestry, and fishery industries. Estate crops are one of leading subsectors that absorbs the majority of the smallholder farmers in NTT. However, East Nusa Tenggara lags far behind the estate crops' average productivity compared to other productive provinces in Indonesia, as shown in (Table 6.2). Therefore, coffee was selected to be investigated in the region in correlation with the climate change impacts.

Coffee

Coffee is one of Indonesia's major plantation commodities. It grows on almost all islands in Indonesia and involves smallholder farmers. As one of the main coffee crop regions, NTT holds 57% of the national coffee production area with more than fifty-one thousand coffee farmers (DFAT 2016). From 2016 to 2019, the coffee production in NTT increased up to 6.62% per year and continued to grow every year (BPS NTT 2021). There are two types of coffee grown, (1) Robusta that is mainly grown at low altitudes and (2) Arabica that is grown at high altitudes and mountainous areas. Among other regions, Flores Island, particularly East Manggarai, and Ngada regency are the biggest Arabica coffee producing areas, with more than 84% of the province coffee production. Thus, it is internationally known as *kopi flores,* traditionally managed without artificial agrochemicals (BPS NTT 2021). However, due to lack of knowledge and limited access to technology for Good Agricultural Practices (GAP) and post-harvest handling, the coffee productivity in NTT is lower than the national level, as shown in Table 6.1 (DFAT 2016). Therefore, coffee farmers there are still dependent on traditional cultivation methods resulting in low quality and yields are highly vulnerable. The climate also potentially jeopardises the production quality and quantity, causing many coffee-growing regions to become unsuitable for coffee plantations.

Result and Discussions

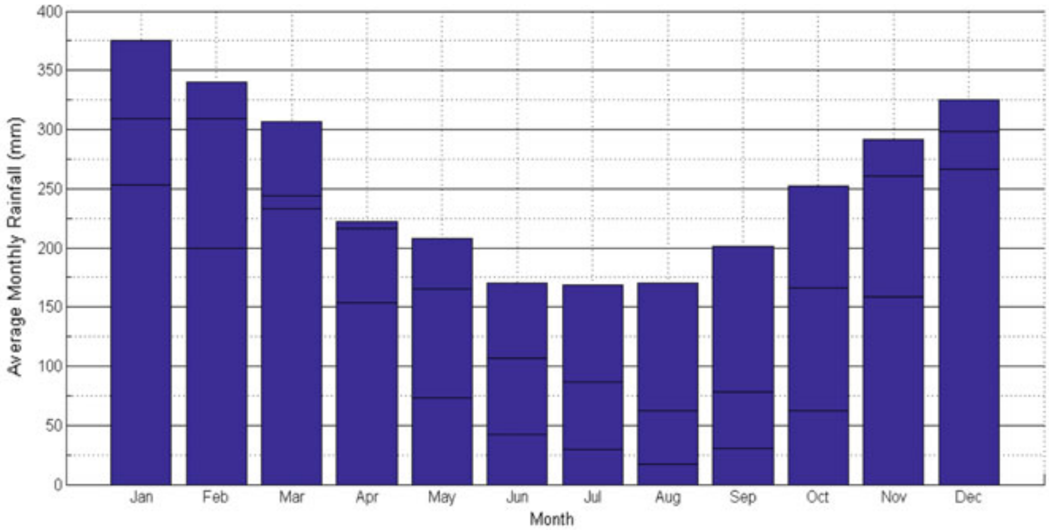
Exposure

Observed Climate in NTT

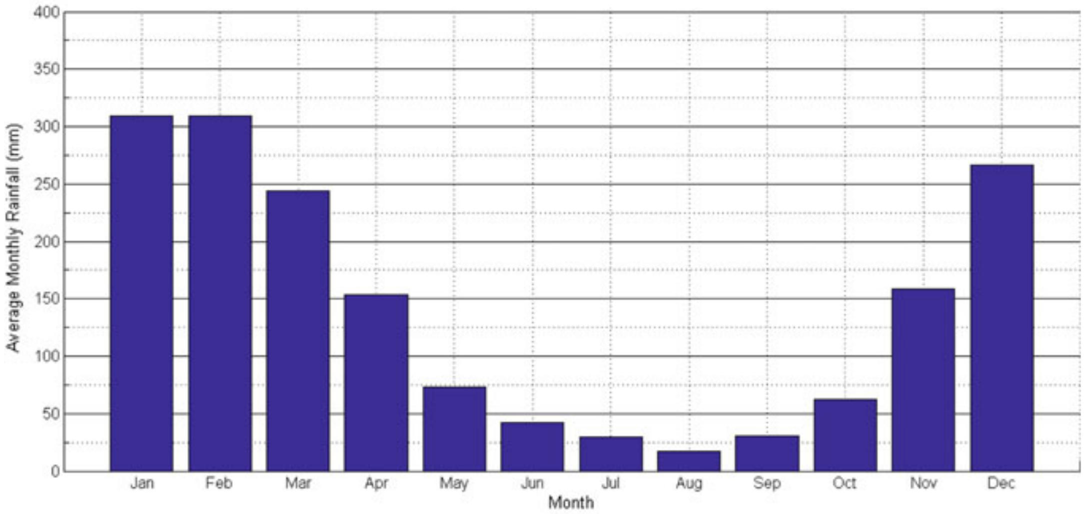
Indonesia has a balanced number of months for both wet and dry seasons, but the southern regions like NTT have a longer dry season. Based on 1981 and 2010 historical data from Global Precipitation Climatology Centre (Schneider et al. 2011), NTT annual average precipitation is approximately 1,696 mm, 36% lower than the national average rainfall (Fig. 6.2). Meanwhile, Vijendra K. Boken et al. (2005) previously estimated that Sumba and Eastern Flores have relatively longer dry seasons, lasting 25 dekads (one dekad equals 10 days).

While the area experiences a longer dry season, the precipitation varies across the region during the wet and dry season (see Fig. 6.3). Higher precipitation during the wet season is mostly identified at the western part of Flores Island, the northern part of West Timor, the northern area and some eastern parts of Sumba Island.

The temperature also varies across the islands. The maximum temperature of NTT areas, such as Sumba Island, Ende, and some parts of West Timor, has reached more than 35.3 °C (see Fig. 6.4. Climate in NTT 1970–2004 (3) average maximum temperature (left); (4) average minimum temperature (right).). The maximum and minimum temperature maps also show that the southern coasts of each island, the smaller islands, and narrower lands experience relatively lower temperature variability, which is from 26.3 to 31.5 °C. The opposite occurs on the midlands and northern coasts, where the temperature range is larger, around 15.7° difference. Sikka and East Flores district have the lowest precipitation and temperature variability during all seasons (see Table 6.3. Climate in NTT 1970–2004 Precipitation and Average Temperature level according to District). Due to longer dry season and



(a)



(b)

Fig. 6.2 Indonesia **a** and NTT **b** monthly average rainfall in 30 years between 1981 and 2010

low precipitation, NTT could lead to severe drought; difficulties in access to clean water and agriculture leading to crop failure, reduced income, food shortage, and potentially malnutrition and other diseases.

Projected Climate in NTT Province

Echoing the ArcGIS findings above, most areas in NTT will reach even higher maximum temperatures if RCP 4.5 and 8.5 scenarios occur, as demonstrated in Fig. 6.5. In the observed climate, the moderate temperature is around 32–34.2 °C; whereas through the projected climate, most areas may experience 35 °C in both

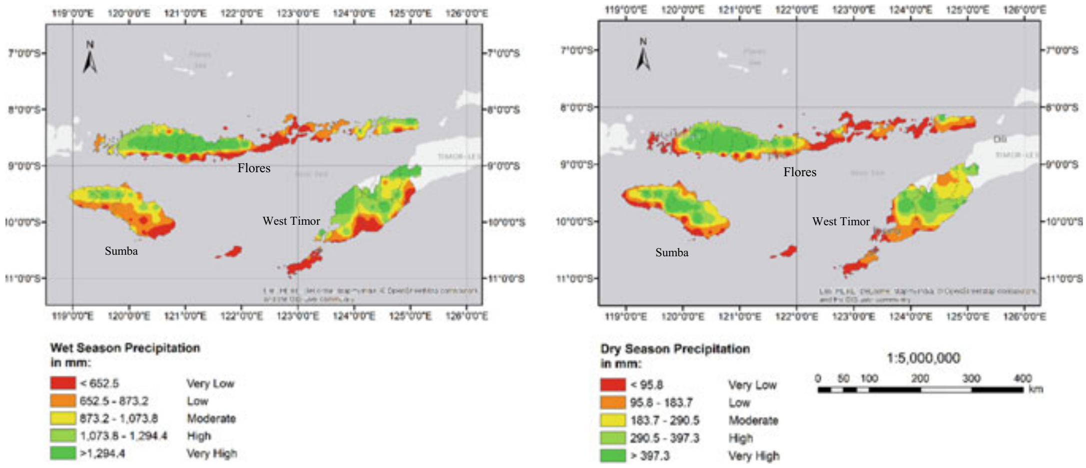


Fig. 6.3 Climate in NTT 1970–2004: (1) wet season precipitation (left); (2) dry season precipitation (right)

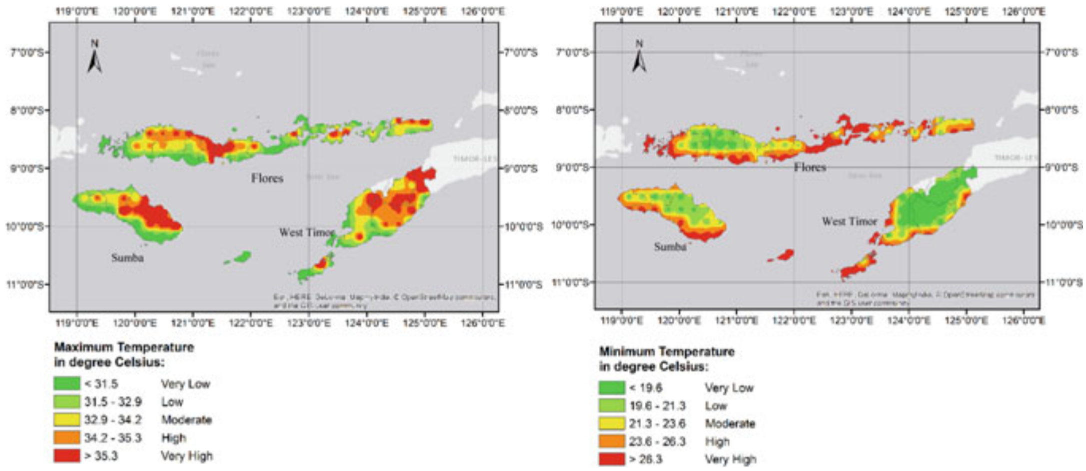


Fig. 6.4 Climate in NTT 1970–2004 (3) average maximum temperature (left); (4) average minimum temperature (right)

scenarios for 2040–2069, with Belu overshooting the 40 °C mark. As shown in Fig. 6.5. Projection of maximum temperature in NTT (2040–2069) the maximum temperature is even higher if RCP 8.5 occurs, except Southwest Sumba.

The same ArcGIS modelling study also claims that a divergent rainfall pattern may occur in NTT. It is shown in Fig. 6.6. Projection of precipitation trends in NTT that rainfall projections vary depending on districts. Overall, the result implies that the rainfall is projected to be much lower in scenario RCP 8.5 than RCP 4.5. Therefore, based on the highest maximum temperature and lower precipitation projection, some districts, such as South Timor and East Sumba, are highly susceptible to drought. An increase in rainfall is likely to happen in Manggarai, East Manggarai, and Sikka, hence, floods and landslides are likely to occur in those areas.

The projection shows the declining precipitation in NTT in both wet (December–January–February, Fig. 6.7) and dry (June–July–August, Fig. 6.8) seasons. Note that

Table 6.3 Climate in NTT 1970–2004 precipitation and average temperature level according to district

Category	Wet season precipitation	Dry season precipitation
Very low	Sikka, Flores Timur, Rote Ndao, TTS	Sikka, Flores Timur, Rote Ndao, TTS
Low	Lembata, Sumba Timur	Lembata, Alor, Kupang
Moderate	Alor, Sumba Barat, TTU	Sumba Barat, Timur Tengah Utara (TTU)
High	Manggarai Barat	Manggarai Barat, Sumba Timur
Very high	Manggarai, Ngada, Ende, Kupang	Manggarai, Ngada, Ende
Category	**Max temperature**	**Min temperature**
Very low	Flores Timur	Kupang, TTU, TTS
Low	Ngada, Sikka, Alor, Rote Ndao	Manggarai Barat, Manggarai, Ngada, Sumba Timur
Moderate	Manggarai Barat, Sumba Barat, Kupang	Ende, Alor, Sumba Barat
High	Manggarai, TTS	Lembata
Very high	Ende, Lembata, Sumba Timur, TTU	Sikka, Flores Timur, Rote Ndao

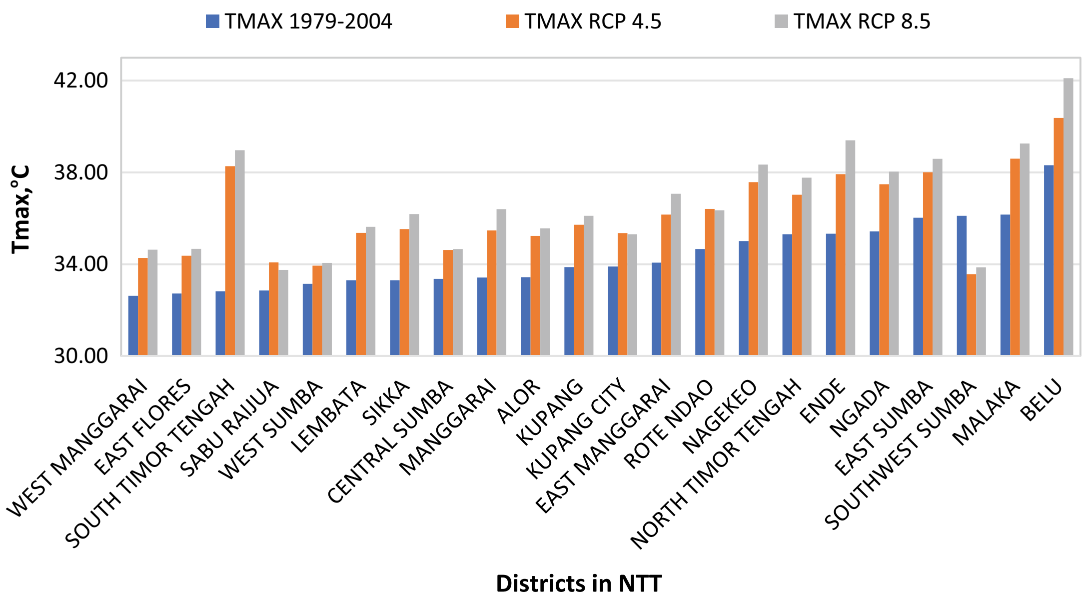


Fig. 6.5 Projection of maximum temperature in NTT (2040–2069)

the predominant pattern of wet season precipitation decrease begins from the southern coast of Sumba, Flores, and West Timor Island before approaching the midlands. The island region of Kupang, Rote Ndao, East Flores, and Lembata is already considered drier than other parts of NTT due to the geographical locations. If the decline in precipitation continues, the amount of arable land left will also diminish. In Fig. 6.7a, by 2039, only the northern part of Flores and West Timor will be left in the midland of Sumba as the regions with higher precipitation. Fig. 6.7c shows that by 2069,

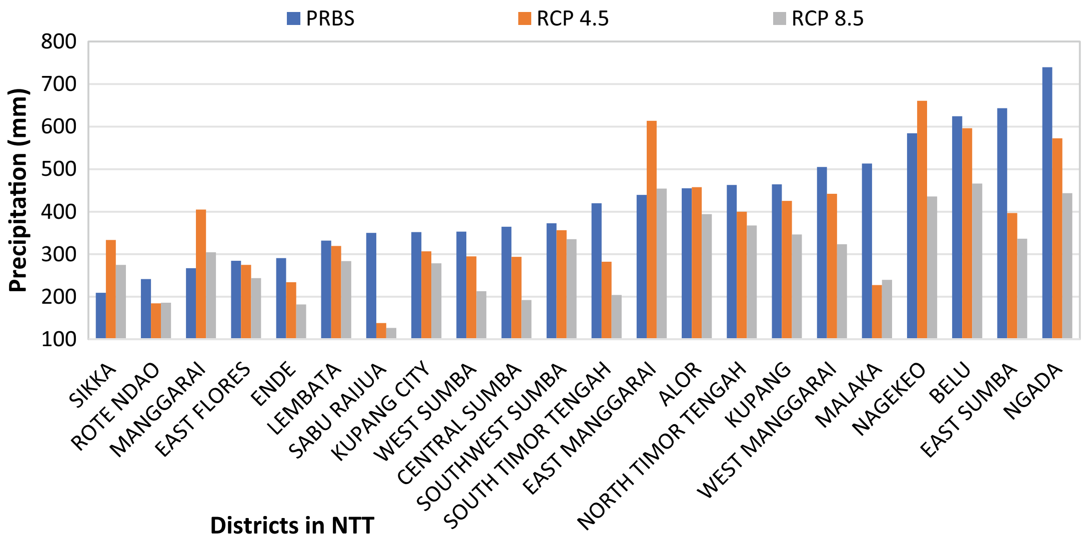


Fig. 6.6 Projection of precipitation trends in NTT

only the northern part of Flores Island and lesser West Timor northern coasts and a small area in Sumba Island will experience moderate to high precipitation. Finally, Fig. 6.7e indicates that by 2099, the lesser north coasts and midlands of Flores Island and a narrow region of midland West Timor will be the only regions that experience average precipitation during wet seasons. Both scenarios show similar coverage areas but the RCP 8.5 scenario shows lower range of precipitation (Table 6.4).

A similar case occurs during the projected dry seasons, where the lower precipitation pattern approaches the coasts to the midlands (Fig. 6.8; Table 6.5). Although some areas will continue to receive very high precipitation due to higher elevation, such as Flores, this condition will create limited options for agriculture. It is also critical as El Niño will further decrease and disturb the rainfall in NTT. By the end of 2099, NTT's decent precipitation level will be in the "moderate" level under both scenarios, ranging 183.7 and 290.5 mm. The dry month threshold is around 60 mm, and 180 mm will be the threshold cumulation over three dry months.

The spatial pattern of maximum temperature contradicts the precipitation pattern, with the highest number occurring at the midlands and/or the higher elevation levels. Two patterns of maximum temperature and minimum temperature are shown. The maximum temperature tends to be the lowest at the outer parts of the provinces, reaching 31.5 °C or less, particularly the southern coasts and narrower lands. Interestingly, the maximum temperature in the midlands can be very high, up to 35.3 °C or more. The increasing propagation will start from the midlands and radiate to the coastal zones (Table 6.6). However, heat transfers between sea and land and the coasts will remain the areas with lower maximum temperatures than other NTT areas (Fig. 6.9).

While the minimum temperature spatial figure shows the opposite pattern, it is coherent with the precipitation pattern (Fig. 6.10. Minimum temperature projection in various time ranges under RCP 4.5 [left] and RCP 8.5 [right] scenarios). The temperature range between the coasts and midlands and/or the mountainous regions

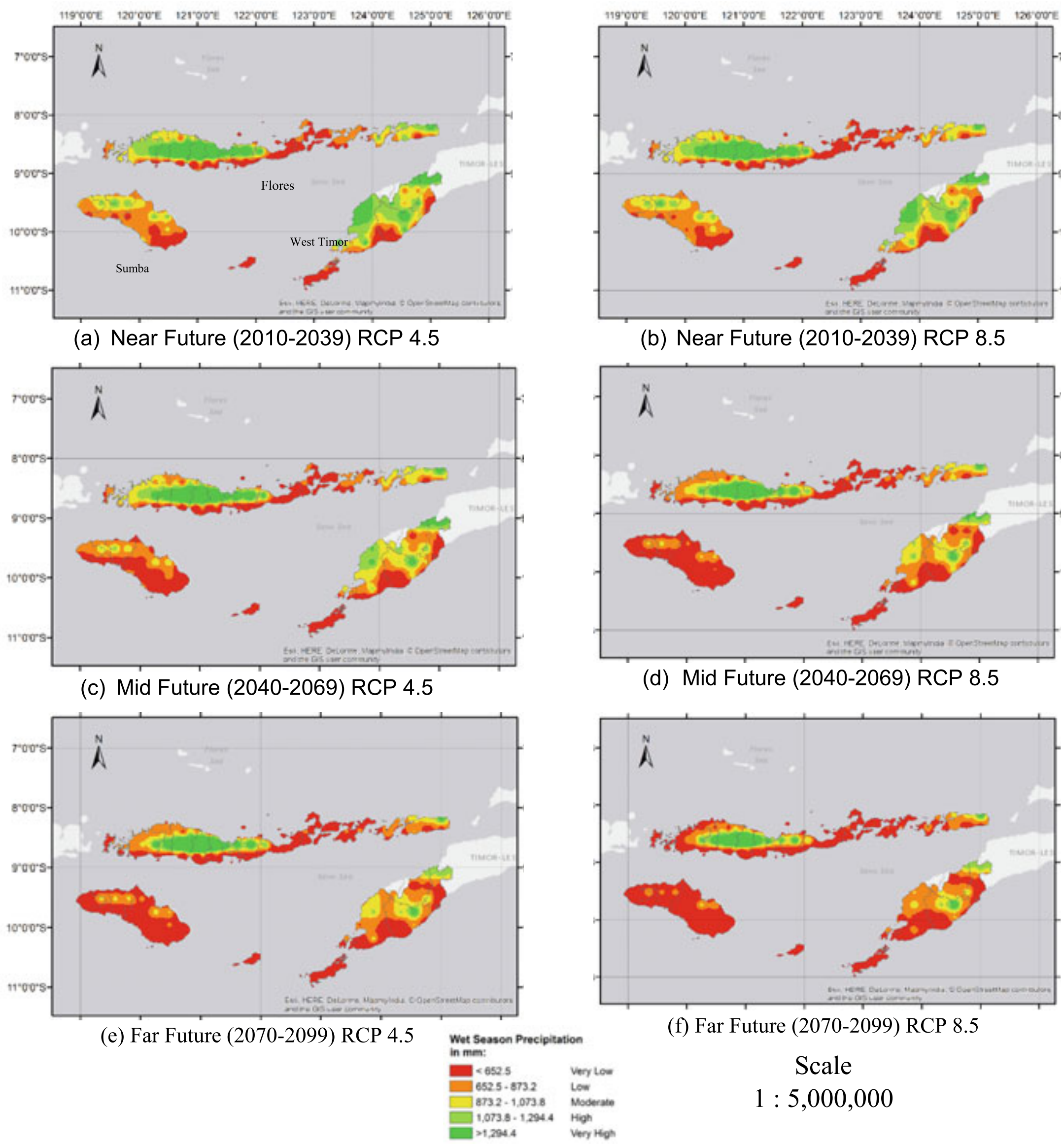


Fig. 6.7 Wet season rainfall projection in various time ranges under RCP 4.5 (left column) and RCP 8.5 scenarios (right column)

are different due to different heat transfer processes. Lower temperature range can be found at the coastal regions, particularly at the southern coasts (Table 6.7). Therefore, the mean temperature will follow the increasing trend as the projection suggests due to increasing maximum and minimum temperatures. This information can help the agriculture sector to determine suitable crops.

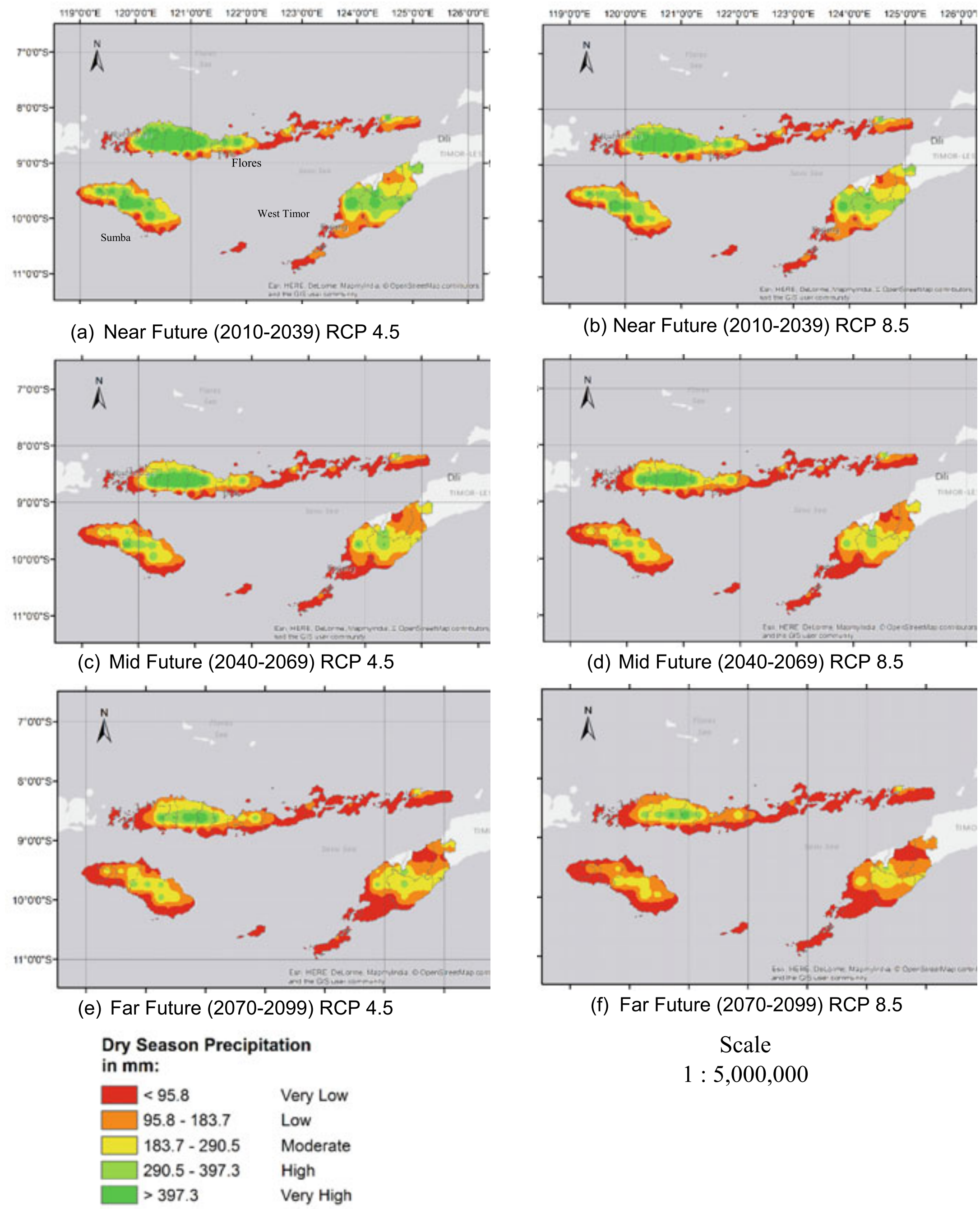


Fig. 6.8 Dry season rainfall projection in various time ranges under RCP 4.5 (left column) and RCP 8.5 (right column) scenarios

Table 6.4 Descriptive wet season rainfall projection in various time ranges under RCP 4.5 and RCP 8.5 scenarios

Precipitation (wet season)	RCP 4.5	RCP 8.5
Near Future (2010–2039)	*Low precipitation*: southern Sumba, south eastern and northern Timor, eastern and southern part of Flores, small islands in the south *High precipitation*: northern Sumba, Northern Flores	The wet and dry regions are relatively similar to those shown under the RCP 4.5 scenario, with expanded areas: *Low precipitation*: north-western part of Flores and the western part of Sumba *Moderate precipitation*: middle part of West Timor following the topography relief of the lowlands
Mid Future (2040–2069)	*Low precipitation*: a few areas of the northern part of Flores, larger Sumba, lowlands Timor, eastern part of Flores *High precipitation*: midland Flores and Highland Timor	Western coasts of Flores start experiencing drier conditions than the RCP 4.5 scenario projects Almost the whole Sumba will receive very low rainfall, meanwhile the lowland areas that receive low rainfall will expand
Far Future (2070–2099)	The projection shows similar condition to Mid Future projection under the RCP 8.5 scenario	The north-western coast of Flores will receive what is categorised as very low rainfall and the northern coast of West Timor will become drier. The only wet areas remaining are the highlands

Table 6.5 Descriptive dry season rainfall projection in various time ranges under RCP 4.5 and RCP 8.5 scenarios

Precipitation (dry season)	RCP 4.5	RCP 8.5
Near Future (2010–2039)	*Very low precipitation*: the west and east coast of Sumba, as well as the southern coast of Flores and West Timor Narrow lands and small islands will remain the areas with very low precipitation	Similar to RCP 4.5 scenario, with more emphasised and extended dry areas. Some areas with very high precipitation under the RCP 4.5 scenario will receive moderate rainfall
Mid Future (2040–2069)	Low precipitation areas will expand. The contrast of precipitation level in each island will be higher lower than the Near Future time frame	Similar to RCP 4.5 scenario, but with larger dry areas. Topographic influence is more prominent in this time frame
Far Future (2070–2099)	Only small areas are receiving a very high amount of rainfall and the midlands will mainly remain the wetter areas	Mountainous areas at Flores Island will become the only areas receiving the highest amount of rainfall during the dry season; meanwhile the midlands of Sumba and West Timor will receive moderate rainfall

Table 6.6 Descriptive maximum temperature projection in various time ranges under RCP 4.5 and RCP 8.5 scenarios

Maximum temperature	RCP 4.5	RCP 8.5
Near Future (2010–2039)	The lowest maximum temperature will occur at the coasts (in Flores at the southern coasts), small islands, and narrow lands	Similar to RCP 4.5 scenario, with a small expansion of very high maximum temperature
Mid Future (2040–2069)	Very high maximum temperature will start propagating toward the lowlands. Southern and coasts will experience the lowest and moderate maximum temperature	Similar to RCP 4.5 scenario, with a slight difference at the eastern part of Flores. The maximum temperature will increase to the moderate level, while remaining very low under the RCP 4.5 scenario. Overall spatial change will occur towards the coasts
Far Future (2070–2099)	The areas near the coasts will start experiencing very high maximum temperature	This projection shows the most notable change of maximum temperature. The region will experience very high maximum temperature, except the small islands, narrow islands, some parts of western Sumba, and a small area at the southern Flores

Sensitivity

Coffee

In NTT, the Robusta coffee is more suitable in the Sumba Island and West Timor than in Flores Island (Fig. 6.10). While Arabica coffee has higher market value, the crop is more sensitive to temperature rise than Robusta coffee. Hence, this study selected Robusta for further suitability analysis, as it is more widely practised in NTT and its climate change impact indicates the severity for Arabica coffee. Based on the projected climate data, divergent rainfall and temperature variability promote damage conditions to coffee crops in NTT. Robusta coffee requires 3–4 months of dry months to grow at the worst case (marginally suitable; S3) and 1–2 months of dry months to grow at the optimum level. Too little rainfall interferes with plant growth and fruiting, while too heavy rainfall causes coffee defects such as mould growth, disease, and excessive fermentation (Kath et al. 2021). Continuous temperature rise will also accelerate the ripening of fruit development, which eventually will degrade the coffee bean quality (Davis et al. 2012). In 2099, these islands will no longer be suitable due to decreased water availability in NTT and the number of dry months (Fig. 6.11).

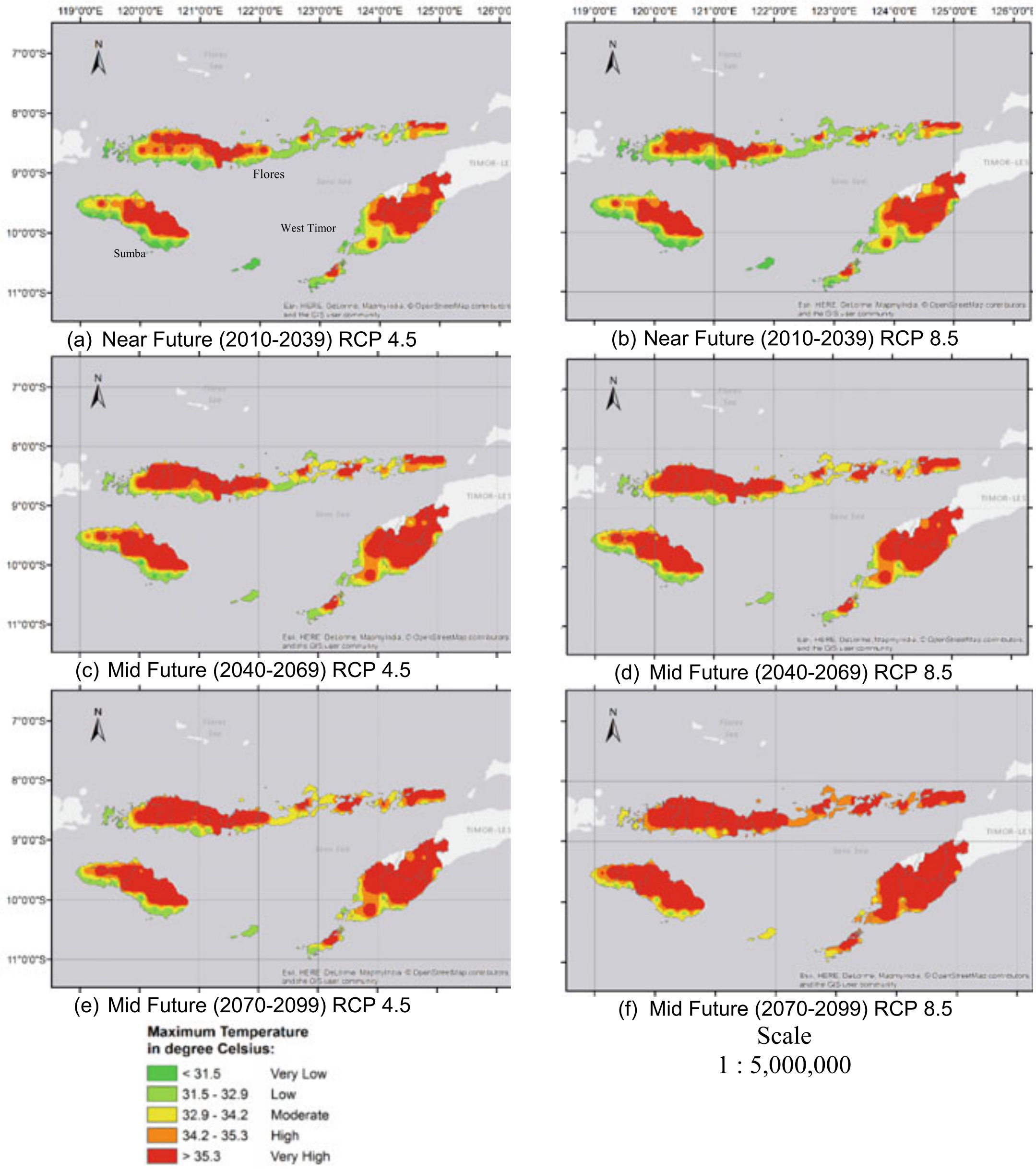


Fig. 6.9 Maximum temperature projection in various time ranges under RCP 4.5 (left) and RCP 8.5 (right) scenarios

Adaptive Capacity

Human Capital

Farmers in Indonesia tend to manage the crop planting by themselves based on their traditional knowledge and practices (Sarjana 2010). However, as climate change has become harder to predict, agricultural workers meet many constraints. The farmers' lack of understanding about climate information from the national meteorological

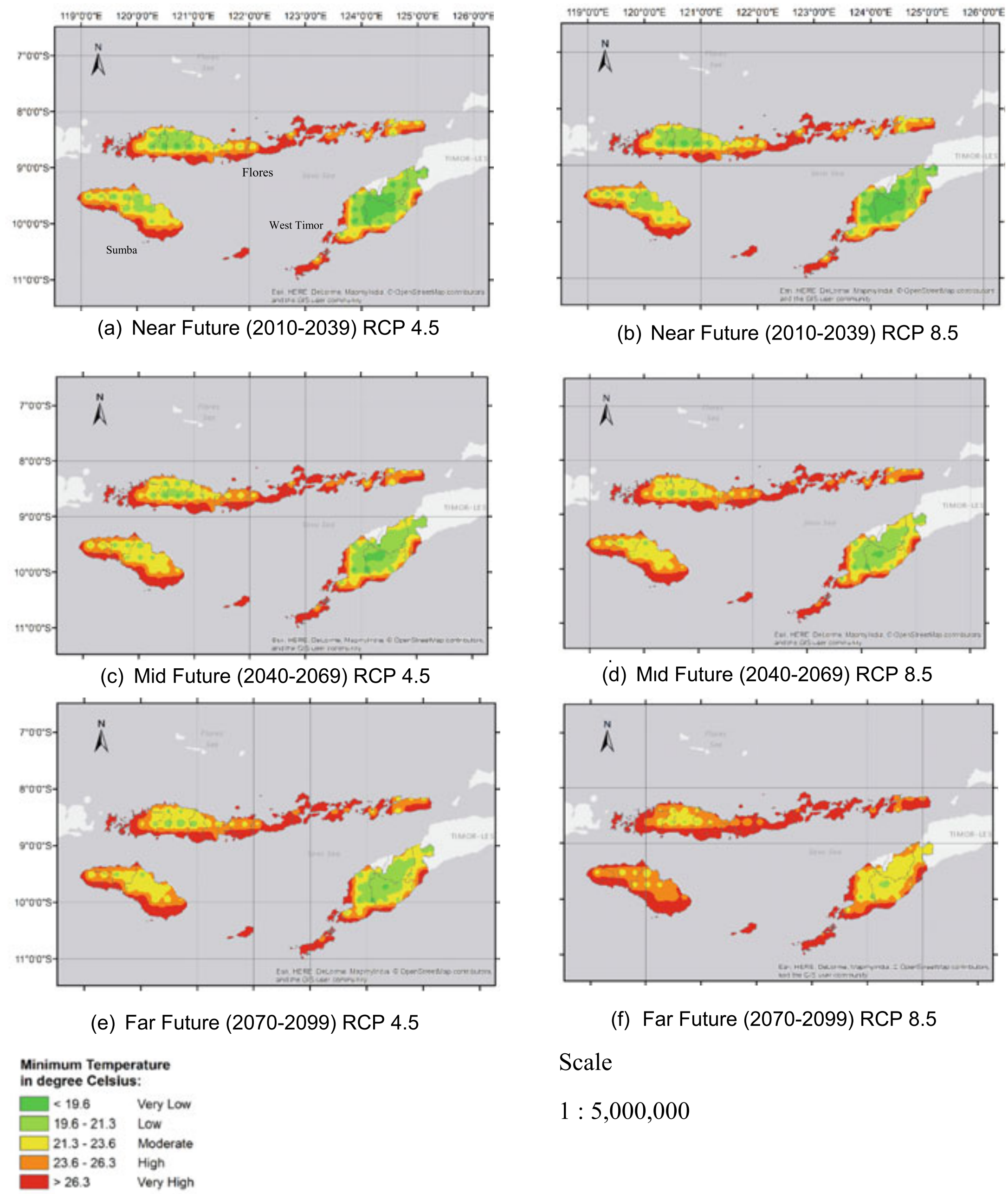


Fig. 6.10 Minimum temperature projection in various time ranges under RCP 4.5 (left) and RCP 8.5 (right) scenarios

agency, climate-smart farming practices, and financial aspects have become underlying challenges of building adaptive capacity in NTT (Sarjana 2010, DFAT 2016). These challenges relate to the fact that most households' heads are primary school-level graduates. Although 70% of households in NTT have access to weather update through public television or radio, the public did not utilise the forecast due to low accuracy and lack of adaptive capacity building to change agricultural practices from the government (Kuswanto et al. 2019).

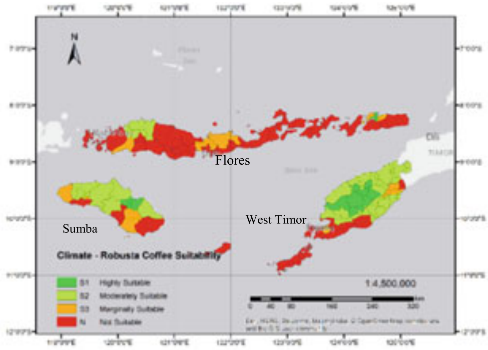
Table 6.7 Descriptive minimum temperature projection in various time ranges under RCP 4.5 and RCP 8.5 scenarios

Minimum temperature	RCP 4.5	RCP 8.5
Near Future (2010–2039)	The lowest minimum temperature occurs in the midlands and mountainous regions	A slight expansion area with very low temperature at the Sumba midlands
Mid Future (2040–2069)	Most areas will shift to the moderate level. Large areas at Flores and West Timor's midlands will still experience very low minimum temperature	Wider expansion of increasing minimum temperature toward the midlands
Far Future (2070–2099)	Similar spatial pattern to the Mid Future RCP 8.5 projection; however, only a few regions on the Flores midlands will experience very low minimum temperature. The very low minimum temperature will remain occurring at West Timor	The minimum temperature in West Timor will increase significantly (will become at the moderate level) and in the midlands of Flores

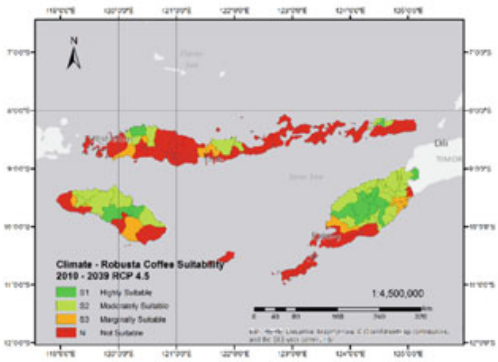
In terms of health, malnutrition poses serious concerns to numbers children under the age of five aged who suffered malnutrition in El Niño in 2002 and 2005, which are three times higher than in a non-El Niño year (UNDP, UN ESCAP, RIMES, APCC, OCHA 2017) to become: In places affected by El Nio / La Nia-related phenomena—most notably in South-Eastern Asia and South Asia—there have been recent decreases in food availability and increases in food costs. For example, in Village Bene, the food shortages occurred during the recent El Niño in 2016 because the water shortage halted the growth of nutritious plants, and it might continue until before the next harvest season (Vaessen 2016). There are potentially around 15,000 people living in 5 villages in South Timor Tengah experiencing severe crop failure. Other regencies, such as East Flores, East Sumba, Central Sumba, and West Sumba also had similar conditions with South Timor Tengah (Bonasir 2015; Saptohutomo 2015).

Social Capital

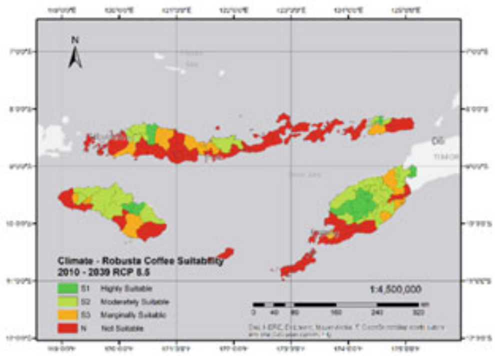
As the main source of NTT livelihood, various social resources have been formed to pursue agricultural practices. The information was gathered through field visits and interviews in 2016 at resources across Flores Island.



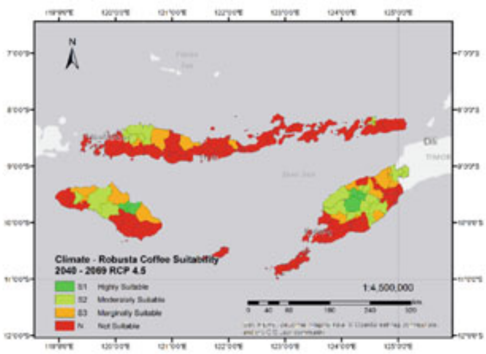
(a) Baseline level



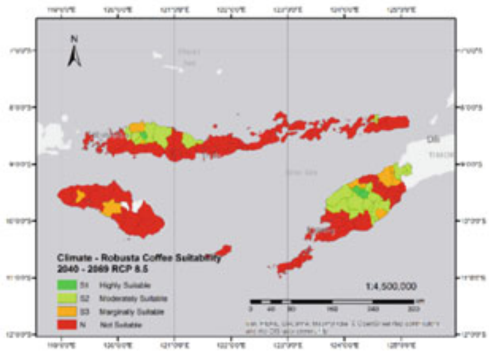
(b) Near Future (2010-2039) RCP 4.5



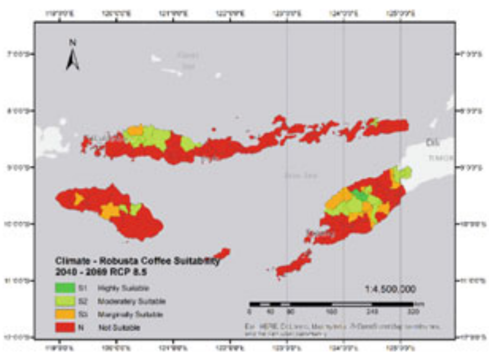
(c) Near Future (2010-2039) RCP 8.5



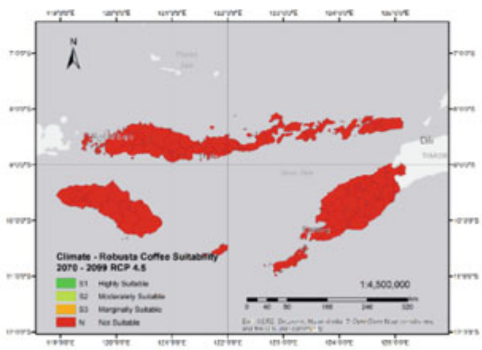
(d) Mid Future (2040-2069) RCP 4.5



(e) Mid Future (2040-2069) RCP 8.5



(f) Far Future (2070-2099) RCP 4.5



(g) Far Future (2070-2099) RCP 8.5

Fig. 6.11 Land suitability of Robusta coffee to the climate variables, top depicts the baseline level, left (right) column represents suitability projection under RCP 4.5 (RCP 8.5) scenario

Ethnic and Religious Groups

Basic values in each ethnic group include family relations, tolerance, and togetherness inherited by their ancestors. The group takes authority in their community's behavioural pattern to prevent conflict, enhance partnership, and maintain peace. The social capital is used as the communities' tool to address their problems if the government does not intervene too deeply. In some regions, a Religion Leader Communication Forum has major roles in reducing the conflicts among religious groups, enhancing relationships, and facilitating communication.

Farmers Groups

Historically, the farmer group is based on top-down government initiative through the Department of Estate Crops and Horticulture under the Ministry of Agriculture. In Manggarai regency alone, government has established 81 farmers groups. However, farmers groups do not have a significant role in the chain due to the nature of liberalised market system that enabled farmers to access the marketing channel independently. The association mainly provides training and technical assistance in coffee cultivation and contributes to the government's machinery or financial grant. In June 2014, there were 20,112 farmers divided into 2,321 farmers' groups (gapoktan) and dominated by beginner class (83.74%).

Savings and Loan Cooperatives

In NTT, there are many saving and loan cooperatives in which farmers depend on this cooperative to support their livelihood. The saving and loan cooperative started from the small one with around 20 members until the big one such as the primary cooperative of saving and loan Pintu Air in Sikka. Pintu Air Cooperative is a primary cooperative for savings and loans. This cooperative was established in 2004 with 80,637 members, consisting of 39,479 male members and 41,158 female members. Other saving and loan cooperatives need to be further checked during the field visit.

Commodity Cooperatives

Only a few cooperatives work for commodity, while others usually start from saving and loan cooperatives or multipurpose cooperative. The list below is of cooperatives that work on commodity or has a business unit that deals with commodity. There are potential cooperatives in NTT that play a significant role in the agriculture sector in NTT.

a. ASNIKOM (cooperative)

Asnikom merges the concept of association and cooperatives with 1,062 members. It connects marketing agreements with coffee exporters, in which each member pays fees and receives a profit share. Asnikom carries out three marketing channels after receiving coffee beans from the members: (1) Direct selling to exporter, (2) Selling through auction, (3) Selling to the individual buyer (café e.g., Anomali coffee, individual exporter). Non-member farmers can sell the coffee beans with a selling price similar to the open market price and not receive profit shares at the end of the year. The cooperative gains a slight margin from purchasing and selling price to maintain the operational cost.

b. Kopsi

Formed in 2015, Kopsi is a cooperative focused on coffee production and sales with around 150 members. Previously nurtured by VECO under PRISMA fund and with the help of Tananua, a local NGO, Kopsi connects with 30 coffee producing villages in Ende. Both Arabica and Robusta farmers under Kopsi produced almost 4 tonnes of coffee in 2016. Most of the arabica is processed in a full-washed method while the robusta is treated traditionally. The farmers' plantation is mostly under an intercropping system with candlenuts and cloves. Kopsi had almost 10 farmers who are well trained in post-harvesting and sorting, with their buying the coffee cherries from other farmers. With no funds available, Kopsi's activities are halted and only continued with consignment with farmers to sell the coffee to a reputable market. With only household scale fermentation drums for each farmer, the lack of proper storage and drying facility caused production delay, leaving Kopsi unable to fulfil buyers' quality level and quantity demand. Kopsi had its own incentivised system for each value-adding activity done by the members or farmers' group that could potentially be improved for all coffee-producing villages in Ende. However, its unreliable management requires improved facilities and business models to advance the value-adding process by producing roasted coffee.

Natural Capital

Water availability, hilly topography, and low soil organic matter content are the main challenges for agriculture development in NTT (Suriadi et al. 2021). On top of being highly vulnerable to erosion, the slash-and-burn method as a common agricultural practice is accused of causing land damage; particularly the forest loss and declining soil productivity (Hidayatullah 2008). There was no evidence of any smallholder agroforestry resulting in forest loss unless supported by any governmental programmes (Fisher 2010). As a semi-arid region, NTT is also often exposed to drought and water shortage. During the dry season in 2003, NTT's water availability balance was a deficit. The increasing drought severity due to El Niño, declining trend, and erratic rainfall worsened access to water availability, clean water, and sanitation, leading to harvest failure, food shortage, and income reduction. This situation will exacerbate poverty due to the reduced productivity of the livelihood, environment, and nature, which even caused death to many villagers (Vaessen 2016). To anticipate the seasonal El-Niño issue, the communities in NTT have access to a reservoir called "embung," which provides water for household consumption, irrigation, and cattle needs (Widiyono 2010). However, due to the limited technical capacity of the "embungs," many of them are predicted to become dry (Bere 2017).

Physical Capital

Improvement in cultivation and processing technology was also on the line of adapting to climate change (Takama et al. 2016). Although farmers have been encouraged to use new technologies, they hardly accept innovations due to their high dependence on their knowledge. Among many reasons, findings identify scepticism and pride in their method (Thrupp 1989). This means no matter how much aid is provided to them, the reduced vulnerability will not be achieved due to capital discrepancy (agricultural aid as physical capital, scientists as social capital, and knowledge as human capital) (Jacobs et al. 2015). On the other hand, the provision of knowledge by the scientists did not guarantee to reduce the vulnerability since the farmers did not own financial capital to apply and operate the technology. Thus, farmers' engagement is crucial in physical capital development as their traditional practices follow modest physical capital.

The needs and capability of the farmers in operating the solution are critical. For instance, a government-built initiative to address water scarcity, "embung" fulfils the communities' water intake and irrigational needs during the dry season (Pusat Analisis Sosial Ekonomi dan Kebijakan Pertanian 2010). However, due to the poor construction and operation, the reservoirs built by the government become dry during the dry terms (Bere 2017). The identified issues of "embung" in Oemasi, Kupang, such as water delivery and efficiency issue from the storage to the utilisation regions may occur in the whole province (Widiyono 2010).

Financial Capital

NTT receives funding allocation from the Ministry of Agriculture to finance district agricultural services implementation (MOF 2015). However, the farming practice did not continue after procuring agricultural equipment. The farmers group believes that the local agency lacked in the fund disbursement monitoring and farmer selection, particularly in choosing committed and hard-working farmers instead of new farmers who are only in for the money (Sura 2020). Especially since NTT is considered too risky for profit-oriented private sector entities, private commodity buyers are likely to continue to support farmers only in locations with profit-generation prospects. The government and donors are likely to continue to offer piecemeal support without a multiple-barrier-removal approach in mind. The increasing vulnerability of the farmers also includes the secretive money lenders, with the loan-sharking system, which is one of the most common microfinance practices in Indonesia. The loan sharks mostly operate at the markets and have face-to-face interactions with the farmers in the villa. This loan is an accessible way to obtain an immediate loan without collateral. However, the issue lies in the very high interest offered by the loan sharks, resulting in financial insecurity among the farmers, which is usually occurs in poor and developing economies (Hull and James 2012).

Farmers' income depends highly on the seasonal pattern (Khandker and Mahmud 2012). The farmers in NTT, who are mostly subsistence farmers, gain their income by selling their cash crops annually, constrained by steep slopes, unpredictable rainfall, and drought (Smits and Mthembu 2012). Most villagers' major cash income source is from the agricultural production system, mostly maise and livestock production that family labour can only handle with traditional practices (UNDP 2015). However, this situation is not sufficient to fulfil the need of the households across the season due to frequent post-harvest losses (van de Fliert et al. 2008). When farmers receive reduced income due to crop failure, farmers respond by reducing their food expenditure (Kuswanto et al. 2019).

Institutional and Policy Context

In the updated Nationally Determined Contribution (NDC) in 2020, sustainable agriculture and plantations were included as station programmes for economic resilience (UNFCCC 2021). In the RAN API or National Action Plan on Climate Change Adaptation, issues were categorised into five domains: (1) economic resilience, which also encompassed energy and food security; (2) life system resilience, which consisted of some sub-sectors, like health and infrastructure; (3) ecosystem resilience; (4) special regional resilience, including the coastal areas and small islands; and (5) supporting systems that could directly or indirectly assist other mentioned domains. Based on Minister Decree SK Menteri PPN/Kepala Bappenas No Kep.38/M.PPN/HK/03/2012, RAN API works under the Climate Change Action (CCA) Coordination Team. Related to the proposal, the climate change adaptation program considers economic resilience very important, especially on food security. NTT, which has serious issues on food security, has become the priority for the national adaptation strategy. Under Ministry of Agriculture Decree No. 64.1/KPTS/RC.110/J/12/2017, Indonesia has adopted technical instructions to diversify staple food beyond rice and wheat. However, the production side has not changed, with rice fields expanding (CIFOR 2021). With the updated NDC finalised in 2021, more revisions and enactment of adaptation-related national and sub-national level provisions will follow.

Ministry of Environment and Forestry, Ministry of Agriculture, and Ministry of National Planning and Development Agency (BAPPENAS) have actively, with local government and stakeholders, resulted in Presidential Regulation 59/2017 that initiates sustainable food production system to ensure food access for all (Arif 2020). As a commitment to end hunger, address malnutrition, and increase agricultural activity in sustainable ways (SDG 2), combined with SDG no. 13.1 on strengthening resilience and capacity, it has also translated climate smart agriculture training into

NTT local mid-term development 2018–2023 (RPJMD). As a result, NTT integrated an adaptation curriculum for local universities and trained 587 agriculture workers and 17,092 farmers through farmers field school programs conducted in collaboration with BMKG (BAPPENAS 2019).

With regard to SDG and national targets, international development agencies have been actively involved in climate change adaptation efforts. A UNDP-led project called (Strategic Planning and Action to strengthen Climate Resilience in NTT (SPARC) has developed 120 community action plans and 21 pilot projects based on RAN API, in which Bank NTT played a crucial role in channelling and leveraging financing to vulnerable communities (UNDP 2016). As a result, SPARC becomes a major reference for the NTT Medium-term plan (RPJMP) 2013–2018 (MOF 2015). During the same years, the Australian-Indonesia Partnership for Rural Economic Development, in collaboration with the Ministry of National Development and Planning, also initiates to boost farmers income by addressing market constraints and policy advocacy to increase competitiveness in Eastern Indonesia (DFAT 2016). Those organisations are key actors in promoting climate change adaptation in top-down approach.

Discussion and Conclusions

Based on the vulnerability assessment and the adaptive capacity, NTT farmers are highly vulnerable to climate change. The current farming system and overall capital are sensitive to climate change because of the limited adoption of climate-resilient production for the highly potential estate crops. Moreover, a substantial proportion in NTT derives their revenue from rain-fed, extremely small-scale farming, putting their livelihoods at risk from climate change. Through precipitation and temperature analysis, coffee crop suitability maps indicate that most arable land will be reduced drastically in both scenarios, RCP 4.5 (stabilisation) and RCP 8.5 (failed mitigation). Without climate-smart extension support, farmers are highly risk-averse to adopting new approaches due to the low baseline development of the province, high prevalence of poverty, and limited social safety nets. Given the cross-sectoral barriers, this study encouraged adaptation strategies should be a combination of incremental, system, and transformative adaptation are an effective way to achieve the objective as proposed by Rickards and Howden (2012). However, addressing adverse climate change impacts requires a transformative adaptation.

Given the complex barriers, a dominant social capital that embodies a wide existing network of agricultural cooperatives and farmers groups could be an asset for an extensive transformative adaptation by utilising the farmers network in strengthening their knowledge and learning capacity with support from other actors such as government, development agencies, and non-governmental agencies. Currently, the climate information still emphasised rice production and neglected high-value estate crop production like coffee. Ultimately, funding allocation to local NTT development plan is crucial to achieve sustainable and resilient coffee production. The limited institutional, policy, physical, and financial capital that are not intact to adapt to the projected condition may exacerbate farmers' livelihood insecurity during one external shock like a prolonged dry season. Thus, further research is necessary to explore the management and funding support for NTT financial literacy and marketing knowledge capacity building for coffee farmers. The capacity of private and non-government entity networks will be strengthened as a critical agent that works with both farmers and the government, especially in farmer climate-smart agriculture training in production and post-production. The project's changes in climate risk transfer are expected to transform how climate risks are shared between vulnerable farmers and a third-party entity. Since the forecast is perceived as inaccurate and requires high literacy, integrating this vulnerability assessment into the climate smart agriculture training will be one strategy to engage and prioritise NTT farmers in pursuit of local adaptation measures and updated policies. Although this study emphasized that climate information should be extensively communicated among farmers, additional empirical research is still required to determine whether this intervention could trigger transformative adaptation.

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