Strengthening Agricultural Resilience Against Climate Change through Climate Smart Agriculture

Book · July 2022

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Supplementary material for issues related to Agriculture

Agriculture Ministers Meeting (AMM)
Agriculture Deputies Meeting (ADM)
Meeting of Agricultural Chief Scientists (MACS)
MACS Workshop on Climate Change

STRENGTHENING AGRICULTURAL RESILIENCE AGAINST CLIMATE CHANGE *through* CLIMATE SMART AGRICULTURE

Edited by: Edi Husen, Setiari Marwanto, and Fahmuddin Agus

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT
MINISTRY OF AGRICULTURE

Strengthening Agricultural Resilience Against Climate Change through Climate Smart Agriculture

Printed in Indonesia
ISBN: 978-602-6916-594

Husen, E., Marwanto S., and Agus, F. (Eds) 2022 Strengthening Agricultural Resilience Against Climate Change through Climate Smart Agriculture. IAARD, Jakarta, Indonesia

Manuscript check/Assistant editor: Laelatul Qodaryani

Design and layout: Edh

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INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT

MINISTRY OF AGRICULTURE

Remarks from Minister of Agriculture

Today we are constantly alarmed by the speed and intensity of global warming. Global warming which is marked by an increase in the earth's surface temperature has an impact on other elements of climate and weather in all regions of the world and has a direct effect on the economy and food security. This global warming is triggered by an increase in greenhouse gas emissions from various sources. Therefore, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) have pledged a significant emission reduction as stipulated in the Paris Agreement at the 21st UNFCCC Conference of Parties (COP) meeting on 12 December 2015. As a member of the UNFCCC Indonesia has committed to reduce Greenhouse Gas (GHG) emissions by 29% with its own efforts and 41% with foreign collaboration by 2030 relative to the Business as Usual (BAU).

The agricultural sector is very vulnerable to the impacts of climate change. An increase in air temperature will reduce productivity and increase pest and disease attacks. Changes in rainfall distribution patterns will make it difficult to determine the planting time and create uncertainty of water availability. An increase in extreme climate events triggers floods, landslides and droughts. In addition, sea level rise expands the area affected by salinity and inundated areas, including agricultural areas. Therefore, adaptation efforts are a must to be able to maintain national food security.

Some examples of adaptation actions taken are: the use of varieties that are adaptive to temperature increases and resistant to pests and diseases, the application of an Integrated Cropping Calendar (KATAM), improvement of soil physical properties to increase infiltration and water holding capacity by applying organic matter, water conservation and water harvesting, developing plant varieties that are drought and flood resistant as well as salinity tolerant, maintaining nutrient balance and sufficiency, and improving livestock management.

In facing the challenge of global warming that can threaten national food security, there are numbers of national programs that can improve resilience of agriculture from the adverse effects of climate change and at the same time reduce GHG emissions significantly. The Ministry of Agriculture continues to encourage farmers and farming business to implement various climate smart agricultural, both based on the results of research and studies by research institutions and from local wisdom developed elsewhere.

I welcome this booklet as a supplementary material for G-20, 2022, on issues related to agriculture. I thank the authors who have allocated their precious time for writing. This booklet is intended for G20 member countries and beyond, on Indonesian agriculture, and the adaptation and mitigation strategieas and effort that have been done so far.

Syahrul Yasin Limpo
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Introduction

Fahmuddin Agus

Indonesian Soil Research Institute

Climate change is a reality that is happening and affecting all aspects of life and agriculture, being one of the most vulnerable sectors is severely affected and becoming the victim of climate change. Range of climate change phenomena, including increased air temperature, stormier but shorter rainy season resulting in floods, longer dry season causing agricultural land drought and hence crop failure, strong winds that cause crop damage are all affecting agriculture in a negative way. Being a victim, agriculture must improve its resilience through adaptation.

Prioritizing adaptation is in line with the agreement of the United Nations Conference of the Parties 26 (COP 26) on climate change held in November 2021 (*see FCCC/SB/2021/L.1; https://unfccc.int/sites/default/files/resource/sb2021_L01_E.pdf*). The Subsidiary Body for Scientific and Technological Advices (SBSTA) and the Subsidiary Body for Implementations (SBI) welcomed the Koronivia road map workshop on topic 2(d) (Improved nutrient use and manure management towards sustainable and resilient agricultural systems and the workshops on topic 2(e) (Improved livestock management systems, including agropastoral production systems and others) and 2(f) (Socioeconomic and food security dimensions of climate change in the agricultural sector).

Having considered the report on the workshop on topic 2(d) of the Koronivia road map, the SBSTA and the SBI recognized that soil and nutrient management practices and the optimal use of nutrients, including organic fertilizer and enhanced manure management, lie at the core of climate-resilient, sustainable food production systems and can contribute to global food security.

Having considered the report on the workshop on topic 2(e) of the Koronivia road map, the SBSTA and the SBI also recognized that livestock management systems are very vulnerable to the impacts of climate change, and that sustainably managed livestock systems have high adaptive capacity and resilience to climate change while playing broad roles in safeguarding food and nutrition security, livelihoods, sustainability, nutrient cycling and carbon management. They noted that improving sustainable production and animal health, aiming to reduce greenhouse gas emissions in the livestock sector while enhancing sinks on pasture and grazing lands, can contribute to achieving long-term climate objectives, taking into account different systems and national circumstances.

Having considered the report on the workshop on topic 2(f) of the Koronivia road map, the SBSTA and the SBI recognized that socioeconomic and food security dimensions are critical when dealing with climate change in agriculture and food systems. They also recognized the fundamental priority of safeguarding food security and ending hunger by designing sustainable and climate-resilient agricultural systems applying a systemic approach in line with the long-term global climate objectives, further recognizing the importance of long-term investments in agriculture focused on this objective.

The SBSTA and the SBI noted the importance of scaling up support to enhance action on safeguarding food and nutrition security and ending hunger, aiming for inclusive, sustainable and climate-resilient agricultural systems, taking into consideration the vulnerability of agriculture to the impacts of climate change. They recognized the need to improve the enabling environment for mobilizing resources to implement action at the local, national and international level.

The SBSTA and the SBI invited Parties to consider relevant policies, actions and measures, including national plans and strategies, that would help with implementing the activities referred to in previous paragraphs above.

The SBSTA and the SBI welcomed the participation in the workshops the observers and representatives of the operating entities of the Financial Mechanism; the Adaptation Fund; the Least Developed Countries Fund and the Special Climate Change Fund (both administered by the Global Environment Facility); and the constituted bodies under the Convention. They also welcomed the work already undertaken on issues related to agriculture by these entities. The SBSTA and the SBI encouraged the continued involvement of constituted bodies and financing entities in the Koronivia joint work on agriculture, highlighting the potential of creating interlinkages that lead to enhanced action and improvements in implementation.

Other topics that will also be considered by the SBSTA and SBI is the results of the intersessional workshop on the topics: sustainable land and water management and strategies and modalities to scale up implementation.

It's clear that all of the decisions on the topics of agriculture emphasize the importance of adaptation actions, considering the strategic importance of agriculture in producing food and ensuring sustainable food security. Mitigation is aimed while adapting to climate change, meaning that it's one of the co-benefits expected from adaptation.

In this book we showcase efforts that have been done by Indonesia in dealing with

Figure 1.1. Impacts of climate change on agriculture, flood and drought

climate change, in particular the adaptation actions. Chapter 2 elaborates the Causes of Climate Change and Climate Change Hazards. The causes bring global perspectives of climate change, while the threats emphasize the threats to Indonesian agriculture. Chapter 3 is a glance of Indonesian agriculture and the general policies on adaptation and mitigation. Chapter 4 is on the lowland (flooded) paddy system, how it is impacted by climate change, methane and nitrous oxide emissions from the system and adaptation strategies and co-benefits in terms of mitigation. There are two main systems of agriculture under upland (non-flooded system); annual crops and perennial crops, the former being more vulnerable than the latter. These subjects are explained in Chapters 5 and 6, respectively. Following the description of the annual and perennial agricultural systems, explanations continued with the impact of climate change on the crops, emissions (and sequestration) from each system and adaptation actions and adaptation co-benefits. Wetlands, including peatlands, are important land resources in Indonesian agriculture. In Chapter 7 we elaborate on the kinds of agriculture on wetlands, how the system is impacted by climate change, the emissions from wetlands, and adaptation strategies, as well as the co-benefits. Animal husbandry is dominated by smallholders and the system is not free from climate change impacts and it is a source of GHG emissions. There are opportunities to increase resilience and at the same time harvests the co-benefits. This subject is in Chapter 8. Land use and land use change could be the major source of emissions in the land based sectors. It could also be the major source of mitigation, depending on how high and how low the carbon stock of the displaced land and how high is the carbon stock of the agricultural crop. The government of Indonesia has enacted regulation to curb GHG emission from land use change and this aspect is explained in Chapter 9. Finally, none of the adaptation action could be done without full consideration of the socio-economic aspects of the actions and this is elaborated in Chapter 10.

Recover together
Recover stronger

2

Causes of Climate Change and its Impacts on Agriculture

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Agriculture both contribute to and affected by climate change. Farming in particular releases significant amounts of methane and nitrous oxide, two powerful greenhouse gases. Agricultural GHG emissions is responsible for 8% of total Indonesia emission by excluding forestry and other land uses and peat fire. Historical data shows that increasing temperatures and changes in rainfall patterns have occurred in Indonesia and are projected to occur in the future.

Indonesia has experienced a sea level rise up to 3.9±0.4 mm year^{-1}, that may contribute to a loss of arable land through inundation and increased soil salinity, affecting crop growth and yield. Increased temperature and changes in rainfall patterns have caused changes in planting time, decreased productivity, land degradation, crop and harvest failures, and changes in commodity suitability. Studies to date suggest that climate change has reduced growth in crop yields by 1–2% decade^{-1} over the past century, and adverse impacts are projected to increase in the future.

Sources of greenhouse gases from various sectors

Greenhouse gases trap heat and make the planet warmer. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years (IPCC, 2007). The Green House Gases (GHG) inventory includes emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3) in the following five sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Waste; and Land Use, Land-Use Change and Forestry (LULUCF).

In 2016, the total GHG emissions for the three main greenhouse gases (CO_2, CH_4 and N_2O) excluding forestry and other land uses (FOLU) and peat fire, amounted to 822 million tonnes CO_2-e. With the inclusion of FOLU and peat fires, the total GHG emissions from Indonesia become 1,457 million tonnes CO_2-e. The main contributing sectors were AFOLU including peat fires (51.59%) followed by energy (36.91%), waste (7.71%), and IPPU (3.79%) (Figure 2.1). The GHG emissions were distributed unevenly between the three gases at 82.46%, 13.29% and 4.26% for CO_2, CH_4 and N_2O respectively (Republic of Indonesia, 2017)

Agricultural greenhouse gas (GHG) emissions is responsible for 8% of total Indonesia emission by excluding forestry and other land uses (FOLU) and peat fire. The major GHGs associated with agricultural production are CH_4 and N_2O. CH_4 arising mainly from paddy rice cultivation, the anaerobic decomposition of organic matter during enteric fermentation and manure management. N_2O arising from the microbial transformation of N in soils and manures – during the application of manure and synthetic fertilizer to land and via urine and dung deposited by grazing animals (Figure 2.2).

Document from Ministry of Agriculture (2020) detailed that CH_4 emissions from rice cultivation and enteric fermentation and N2O emissions from soils are responsible for more than 80% of total agricultural GHG emissions. CH_4 from manure management is the fourth most important source of emissions, accounting for about 14%. The remaining sources such as urea fertilizer, biomass burning and liming make relatively small contributions, accounting for 6% of agricultural GHG emissions in total (Figure 2.3).

Between 2010 and 2020, the Indonesia's agricultural GHG emissions changed very little, and this trend is expected to continue (Figure 4). CH_4 emission need to decline by 10% by 2030 and 35% by 2050 (Rogelj *et al*. 2018). Indonesia needs to reduce its emissions within its 'fair-share' range compatible with global 1.5°C IPCC scenarios. A 1.5°C 'fair-share' pathway in agriculture requires animal dietary shifts and climate-smart farming practices.

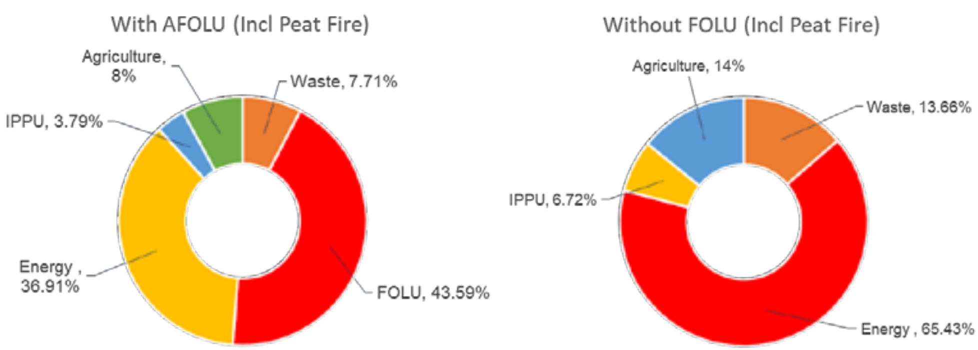

Figure 2.1. National GHG emission (CO_2, CH_4, N_2O) by sector in 2016 (Data source: Republic of Indonesia 2017)

Figure 2.2. Example of greenhouse gases emission from agriculture

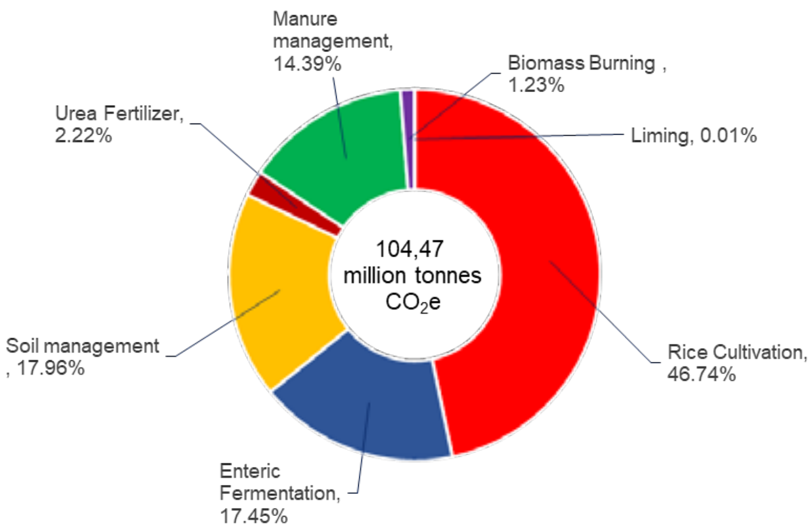

Figure 2.3. Source of emission from agriculture sector (MoA, 2020)

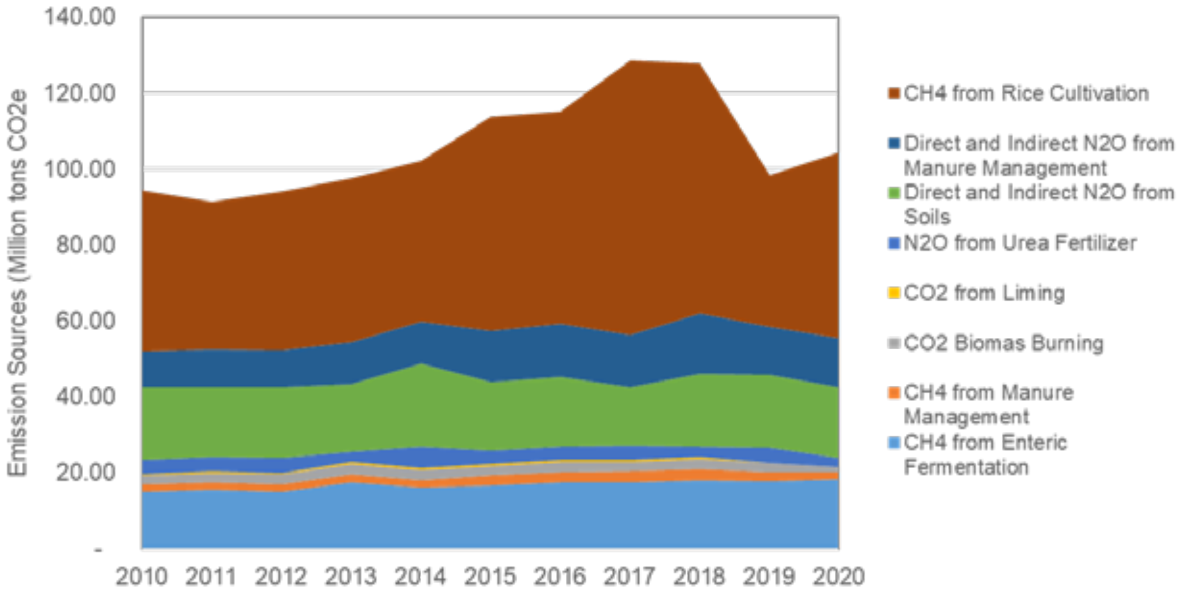

Figure 2.4. Indonesia's Agricultural GHG total emissions from 2010-2020 (MoA 2020)

Indonesia's commitment is strengthened through the first Nationally Determined Contribution (NDC) document in November 2016 with the stipulation of an unconditional target of 29% and a conditional target of up to 41% compared to the business as usual (BAU) scenario in 2030. The projected BAU emission of agriculture sector in 2030 is 120 million tons of CO_2-e, the projected emission for both unconditional/through national mitigation efforts (CM1) and conditional (Strengthened by mitigation efforts through international cooperation CM2) are estimated at 110 million tons CO_2-e and 116 million tonnes CO_2-e (MoEF 2021).

The signs of climate change

Increase of air temperature

An increase in air temperature is one indicator of climate change caused by an increase in GHG concentrations in the atmosphere. GHGs are gases in the atmosphere resulting from various human activities and natural processes such as volcanic eruptions and others. This gas has the ability to absorb solar radiation in the atmosphere to a certain extent, causing the temperature on the earth's surface to be warmer. However, if the concentration of GHG gases in the atmosphere exceeds the threshold, it will cause some of the solar radiation to be retained and cannot be transmitted to the atmosphere, causing the earth to heat up excessively, resulting in a GHG effect which in the long run will cause global warming and trigger climate change.

Human activities are estimated to have caused a global temperature increase of about 1.0°C compared to pre-industrial levels, with a range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at current rates (optimistic scenario). Even by 2100 the atmospheric temperature is estimated to be more than 2°C higher than the temperature of pre-industrial times. If that happens, it is feared that humans will not be able to adapt. Therefore, the temperature rise should be no more than 1.5°C. Net zero emissions are required by 2050 to limit the temperature increase so that it does not exceed 1.5°C by 2100 compared to temperatures in pre-industrial times (IPCC 2019) (Figure 2.5).

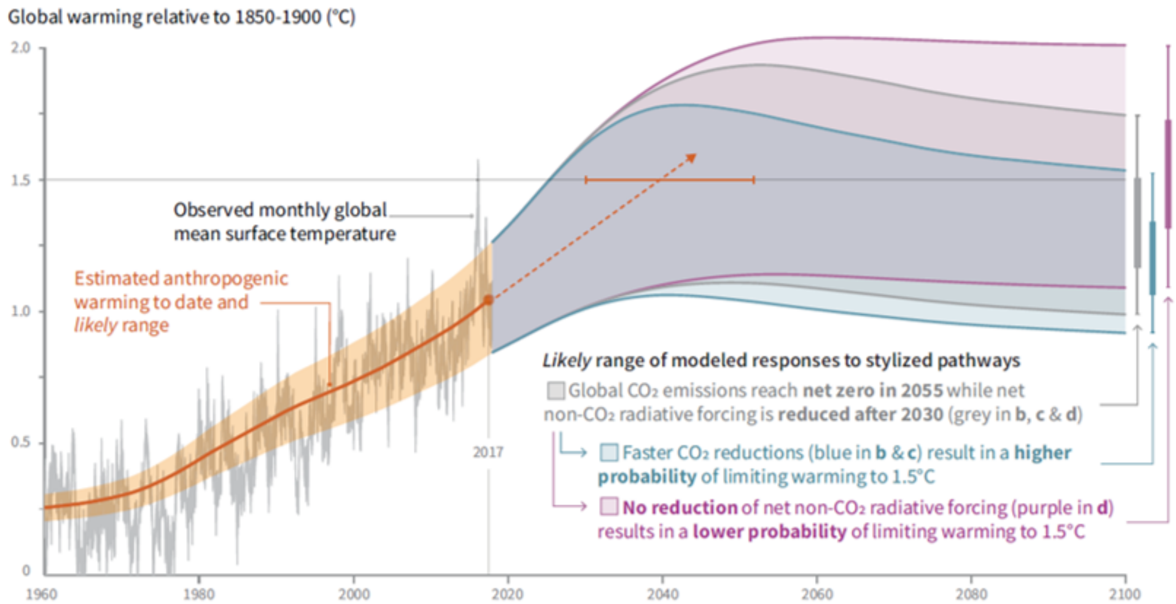

Figure 2.5. Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways (IPCC 2019)

Global temperature projection results using a combination of 24 models CMIP5 GCM (Coupled Model Intercomparison Project-General Circulation Models) RCP: Representative Concentration Pathways 2.6; 4.5; 6.0 and 8.5 indicate that Indonesia's average air temperature will increase by 2100 in all RCP scenarios but the increase will be lower than the increase in global temperature (MoEF 2019). The average temperature in Indonesia is influenced by decadal variability. Based on 30 years of data (1991-2020), various regions in Indonesia have experienced an increase in temperature. The rate of increase in temperature varies across locations, between 0.01°C and 0.06°C per year, with an average of 0.03°C per year, so that in 30 years, the temperature in the territory of Indonesia has increased by around 0.9°C (KLHK 2020). The results of the research by Siswanto *et al*. (2015) based on historical data from Jakarta for 130 years show that the daily mean air temperature increased by approximately 1°C until the middle of the 20th century and has increased by almost 2°C over the last 100 years (Figure 2.6). The increase in mean temperature, exceeding that of the global land temperature, is compatible with the effects of increased urbanization in the transient development of Jakarta in which the high-rise buildings trap radiant energy in their walls and radiate more thermal energy back to the surrounding.

Increase in air temperature has a significant impact on agriculture production. Peng *et al*. (2004) using a crop simulation model stated that the decrease in yield due to an increase in temperature of 1°C was 0.6 t ha^{-1} and every 1°C increase in minimum temperature will reduce rice yields by 10%. In addition, the emergence of pest and disease attacks can also be caused by temperature conditions and other climatic factors. A hot and humid environment is a very favorable condition for pathogenic microbes. The increase in temperature causes livestock to be susceptible to disease and even cause death. An increase in temperature also facilitates the development of pathogenic and parasitic microorganisms, making livestock more susceptible to disease.

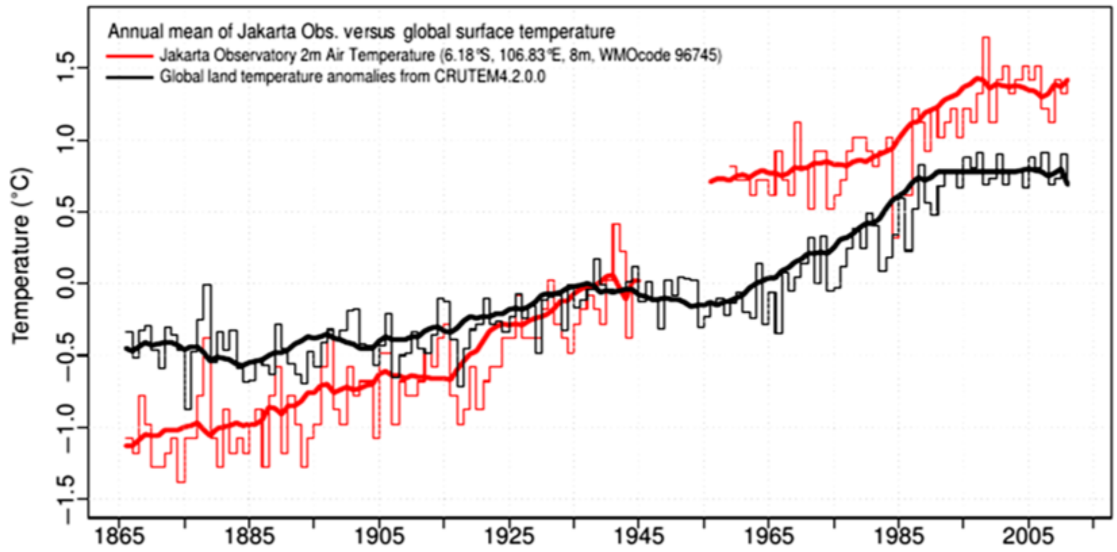

Figure 2.6. The anomaly of Jakarta Observatory (red) and global (black) mean surface air temperature (Siswanto et al. 2015)

The change of precipitation pattern & areas affected

The emergence of the phenomenon of climate change has caused changes in the pattern and intensity of rain. The results of the study on the impact of climate change in Indonesia show that the change in rainfall is projected up to 30% from baseline conditions (MoEF, 2019). To find out the distribution of rainfall in Indonesia, Supari *et al*. (2016) conducted an analysis of 162 rain stations. For rainfall analysis, stations are grouped into the three sub-regions i.e., A (monsoonal), B (semi-monsoonal) and C (anti-monsoonal) (Aldrian and Susanto 2003).

At regional scale, the trends of total annual rainfall indicated notable spatial variations throughout the country. Consistent with the country level, the estimated trends at the regional scale were not significant. In Region A, which is a monsoonal regime, the decreasing trends were spatially coherent in the southern part of the country although the trends were mostly not significant. In contrast, one station in the North Sulawesi (also part of region A) showed a significant increasing trend (Figure 7). Hence, a station that has similar annual cycle may have different characteristics of long-term changes. On the other hand, Region B (semi-monsoonal) and Region C (anti-monsoonal) showed a more coherent trends that have a tendency towards wetter conditions with rates of 52.09 and 107.34 mm decade^{-1}, respectively. However, some stations in Region B and Region C indicated significant increasing trends of annual rainfall. Despite the wetter tendency for Region B and C, the overall trend for the country level was decreasing. This is due to the fact that Region A covers a much wider area than Regions B and C.

Figure 2.7 also clearly depicts the influence of ENSO events in the inter-annual variability of precipitation (PRCPTOT) index. In Region C, the decreased in PRCPTOT was also observed in 1987, 1994 and 2002, indicating a consistent impact of El Niño events in this region. However, during 2010 La Niña event, the impact was only clearly depicted for country level and Region A. Historical data shows that increasing temperatures and changes in rainfall patterns have occurred in Indonesia and are projected to occur in the future.

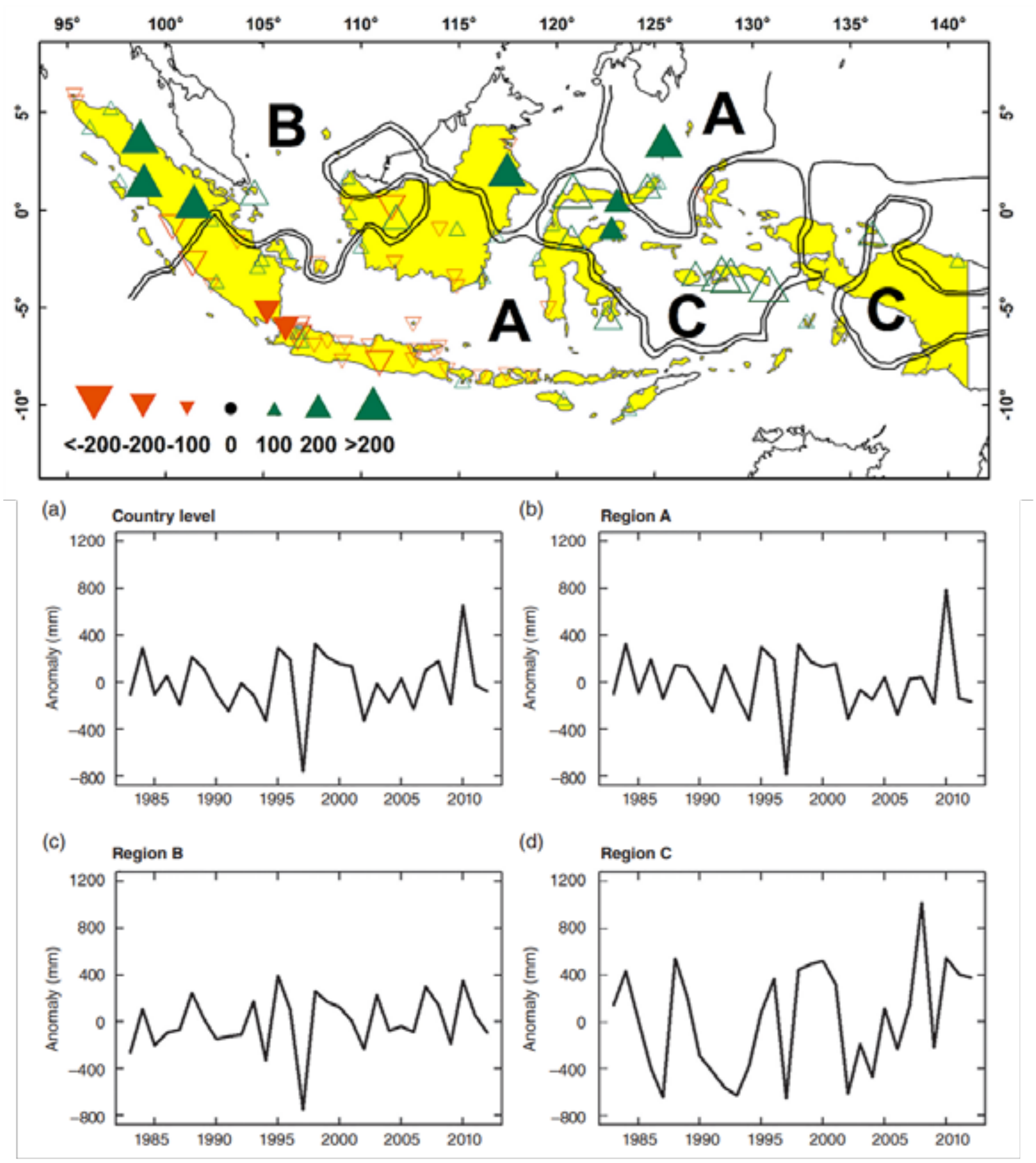

Figure 2.7. Changes in the annual total of rainfall. Filled (open) triangles denote significant (not significant) changes at 95%. Upward (downward) triangle means increasing (decreasing) trends. Unit is in mm per decade. Time series of anomaly of annual rainfall total for across the country (a), regime of monsoonal rainfall (b), regime of semi-monsoonal rainfall (c) and regime of anti-monsoonal rainfall (d) (Source: Siswanto et al. 2015)

Sea level rise

With thousands of small islands and tremendous coastlines, Indonesia is expected to encounter severe impacts from a sea level rise. In Indonesia, economic activity centers are mostly located in its coastal cities, making them very vulnerable to inundation. Sea level rises and land subsidence pose many risks to communities, ecosystems, and the economy. Sea level data in Indonesian waters varies with time from the 1990s to 2019, but generally has an increasing tendency. Therefore, continuous rate measurements and future projections are needed to find out how severe the sea level rise is in Indonesia (Triana and Wahyudi 2020). The major impact will be felt by about two million people live

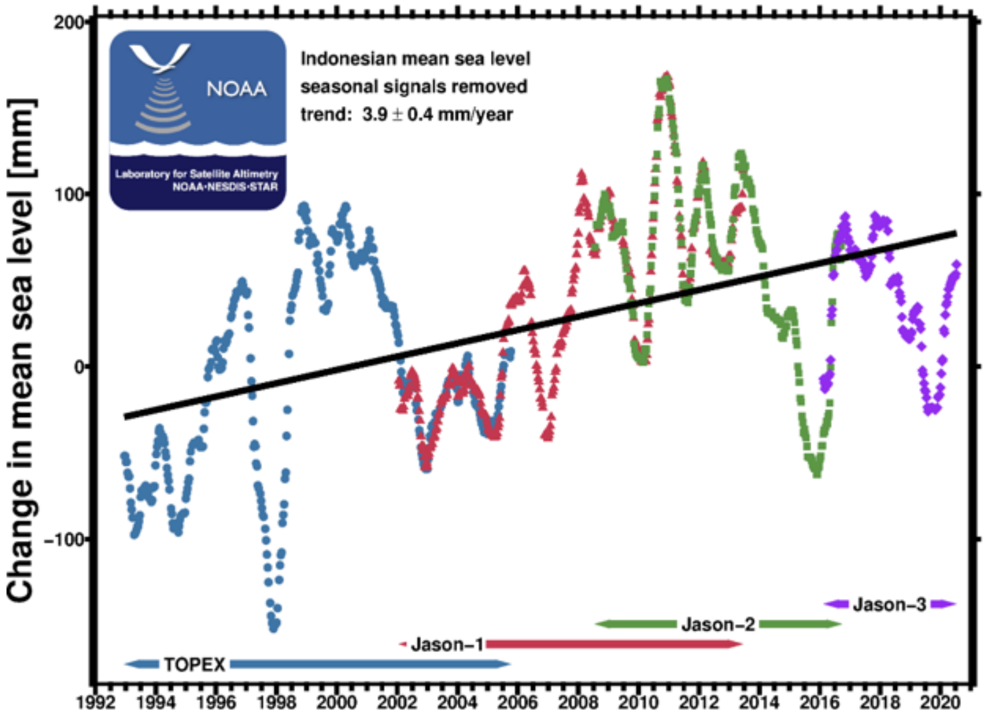

Figure 2.8. The trend of sea level rise in Indonesia in 1992–2020 is estimated to be 3.9 0.4 mm year-1, based on NOAA (2020)

in coastal areas with an elevation of between 0 m and 2 m above sea level (MoE 2007). A substantial proportion of these agricultural areas are within close proximity of the sea.

NOAA (2020), through data from TOPEX/POSEIDON and Jason 1–3 altimetry satellites, estimates that Indonesia experienced a sea level rise up to 3.9±0.4 mm/year between 1992 and 2020 (Figure 2.8). The highest sea level trend in Indonesia was detected in the Pacific Ocean in the north of Papua, which reached 10–12 mm year-1, while the lowest trend was detected in the south of Java, west of Sumatra, south of Nusa Tenggara, and the Karimata Strait, which only ranged 2–4 mm year-1 (Sofian *et al*. 2011; Sofian 2013; Sofian and Nahib 2010, Nababan *et al*. 2015).

The increased of sea level rise may contribute to a loss of arable land through inundation and increased soil salinity, affecting crop growth and yield, especially in the dry season when water irrigation is limited. Some rice areas in low lying areas adjacent to the coast are specifically vulnerable to inundation due to sea-level rise are as follows (a) North coast of Java, (b) East Coast of Sumatra. (c). South, east and west coast of Kalimantan. (d). West coast of Sulawesi. (e). Swamp areas in Papua, located on the west and south coasts (Förster *et al*. 2011).

The reduction of rice production in the Pantura region (the northern coast of Java Island), one of which is thought to be caused by a severe salinity in the rice fields. In the dry season, salt-affected land increases due to reduced irrigation water in the mainland, while seawater intrusion occurs through channels, streams, or swamps. Agricultural land that is affected by seawater intrusion, can reach as far as 20 km from the coastline (Erfandi and Rachman 2011). ACIAR (2018) delineated agricultural areas in Indonesia are within close proximity of the sea. On the island of Java, about 29% of rice-growing areas are within 10 km of the sea. The north coastline is a major rice-producing region for the country,

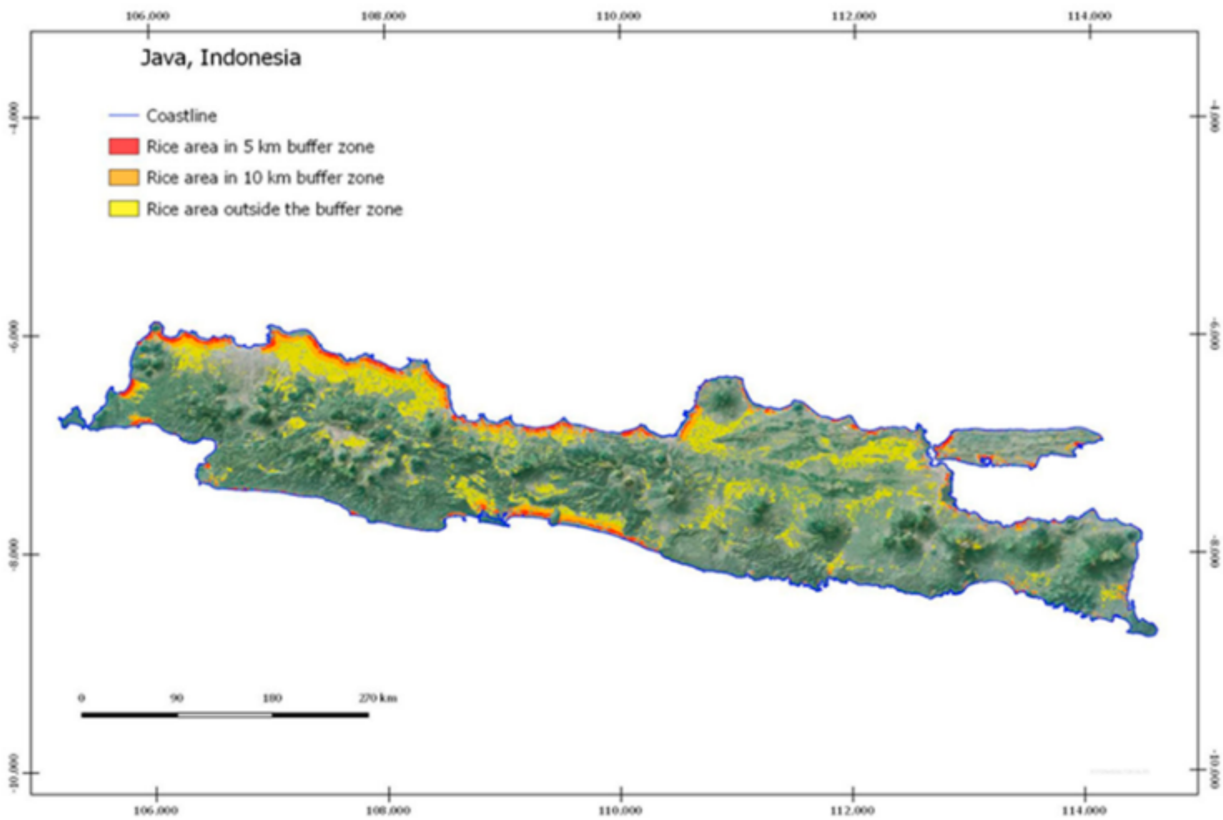

Figure 2.9. Rice growing areas in Java Island with buffer zone within 5 km and 10 km (ACIAR, 2018)

with a path length around 1316 km (Figure 2.9). Suroso *et al*. (2009), it is estimated that by 2050 the area of paddy rice fields could be reduced by 182,556 ha in Java and Bali, 78,701 ha in Sulawesi, 25,372 ha in Kalimantan, 3,170 ha in Sumatra, and 2,123 ha in Lombok. In South Kalimantan, tidal swamplands have been reclaimed for various agricultural activities and are now especially prone to risk due to sea-level rise (Saidy and Azis 2009).

Under elevated sea level, the sea water intrusion and water salinity will increase. The mixed freshwater with seawater cannot be consumed in a few months, and the farmers, could not have paddy harvesting. The length of salinity intrusion depends on the balance between the freshwater upstream flow and seawater levels (Trinugroho *et al*. 2020). In Indonesia, about 13.2 million ha of potential rice production areas in tidal swampland are affected by salinity (Suprianto *et al*. 2010).

Based on extensive literature survey covering 30 years, it was found that majority of crop plants fall within the sensitive end of the salt tolerance spectrum. According to Radanielson *et al*. (2018), the exceeding threshold per 1 dS m^{-1} will pose a rice yield reduction to 12%. The high salt content of seawater contaminates agricultural soils and groundwater, impose constraints on the growth and production of rice in Indonesia. Based on the year 2017 data from the rice basket area in Java, more than a half-million hectares of rice fields suffer salinity due to seawater intrusion, with the average rice yield during the dry season was 0.65 t ha^{-1} lower than the yield during the wet season (Sembiring *et al*. 2019).

Extreme climate events

One of the impacts of climate change is the increase in extreme climate events. BMKG (2019) defines extreme climate when air temperature is 3°C higher or lower than the average, strong winds with a speed of >45 km hour^{-1}, heavy rain with an intensity of 50 mm hour^{-1} or 100 mm day^{-1} and horizontal visibility is less than 1 kilometer. Extreme climate is climate event that occur unusual and can disrupt human lives and natural ecosystems caused by one or more climate indicators extremely changes. For example, air temperature and rainfall changes extremely. Extreme climate will also happen when a Day Without Rain (HTH) lasting more than 60 days. Extreme climate is statistically rare which showed by variable value of climate parameters are above or below the threshold value. The threshold value of climate parameters is obtained from observed data of a certain period of time (30 years). The climate parameters that are usually analyzed are rainfall, temperature, wind speed and humidity.

Extreme climatic events such as El Niño and La-Niña in several parts of Indonesia cause differences in rainfall from normal conditions. El Niño is dominated by a decrease in rainfall which causes drought disasters, whereas La Niña is associated with an increase in rainfall and floods. The results of the 2015 strong El Niño and 2016 weak La Niña analysis (Attoillah *et al*. 2017) shows the impact of El Niño began on dry season. That is decrease of rainfall below the normal around 50–300 mm month-1 occurs in August to October 2015, especially in southern Indonesia. The impact of La Niña was seen in September–December 2016, where there was an increase of rainfall above the normal around 50–400 mm month^{-1}.

The composite precipitation anomalies during El Niño events show that are most of the Indonesian region experienced a precipitation deficit during both the JJA (June-July-August) and SON (September-October-November) seasons (Lestari *et al*. 2018). Figure 10 shows the composite patterns of precipitation anomalies over the Indonesian region during the JJA and SON seasons for both El Niño and La Niña. (Figures 10(a) and 10(c). In contrast, during La Niña events almost the whole Indonesian region experienced a precipitation surplus in the JJA season, except over the northern part of Sumatra (Figure 10(b)). Meanwhile, during the SON season, La Niña events caused positive precipitation anomalies over the Kalimantan, Sulawesi and Papua (Figure 10).

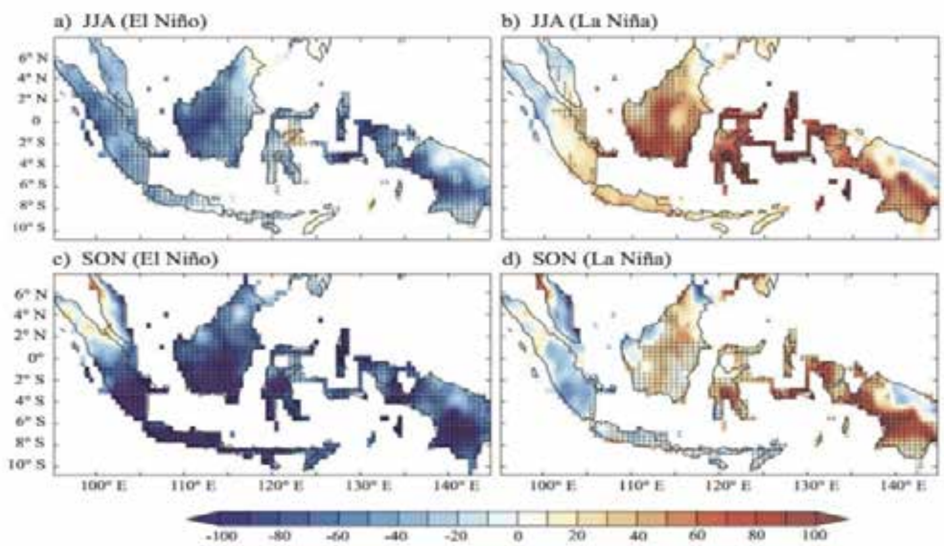

Figure 2.10. Rainfall anomaly during strong El Niño and Weak La Niña (Lestari et al. 2018)

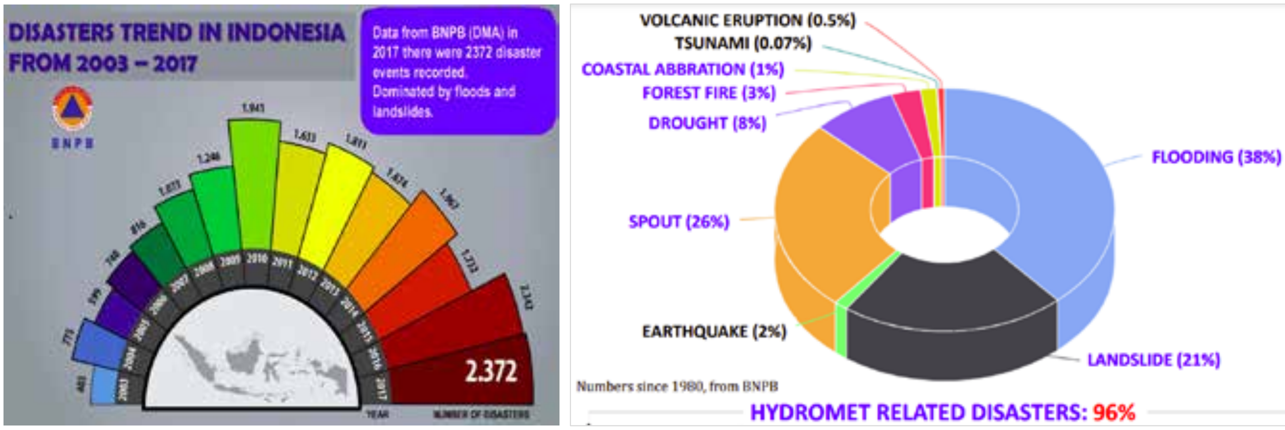

Figure 2.11. Disaster trend in Indonesia (2003-2017) and proportion of hydrometeorology disaster (source: BNPB)

The impact of extreme climate is becoming a serious problem for human lives all over the world. The damage caused by extreme climate has increased globally over the past few decades. In many areas of the world including Indonesia, extreme climate is becoming more extreme. The impacts of extreme climate include droughts, flood, landslide, erosion, hurricane, forest fires, disease outbreaks, and crop failures. The following is an illustration of the increase of disasters in Indonesia during a period of 2003-2017 (Figure 2.11.) and disasters happened during a period of 2018-2020 according to the record of BNPB namely: 3397, 3814, and 4650 and is dominated by floods and landslides.

According to Supari *et al*. (2016) there was a significant change in the temperature index in Indonesia during a period of 1983-2012. This is consistent with other studies conducted in various countries in Southeast Asia. The mean daily maximum (TXmean) and minimum temperature (TNmean) have increased significantly by 0.18 and 0.30°C respectively. On the other hand, extreme rainfall is generally insignificant change spatially. However, wet conditions were observed to have trend of change which is in agreement with the results on a global scale. The daily rainfall intensity (SDII) has increased significantly across the country by 0.21 mm day^{-1} decade-1. The wetting trend of a number of extreme rainfall indices is clearly illustrated in the period of December–January–February (DJF) and/or March–April–May (MAM), both at the country and regional levels. Meanwhile, for the southern part of Indonesia, drought was observed increase in JJA and SON.

IPCC (2012) has warned that climate change potentially to cause changes in the frequency, area, duration and timing of extreme climate events. Such extreme events can lead to unprecedented extreme climate events. Extreme climate events such as droughts and floods are projected to occur more frequently with higher duration and intensity in the future. According to Surmaini and Faqih (2016), the most influential extreme climate events for agricultural sector in Indonesia are El Niño and La Niña. The impact of these extreme climate events includes increased crop damage area, reduced harvested area as well as decreased crops productivity and yield. The Indonesian Ministry of Agriculture reported that the highest paddy damage area due to drought occurred in El Niño years, ranged between 350 and 870 thousand hectares. On the other hand, in La Nina years the paddy damage area due to flooding reached the highest area of 311 thousand hectares (Figure 2.12). To some extent, extreme climate events may create conducive climate conditions for certain agricultural commodities. For example, the prolonged rainy season due to La Niña has a positive impact on rice production due to the increase in planted area during the dry season planting.

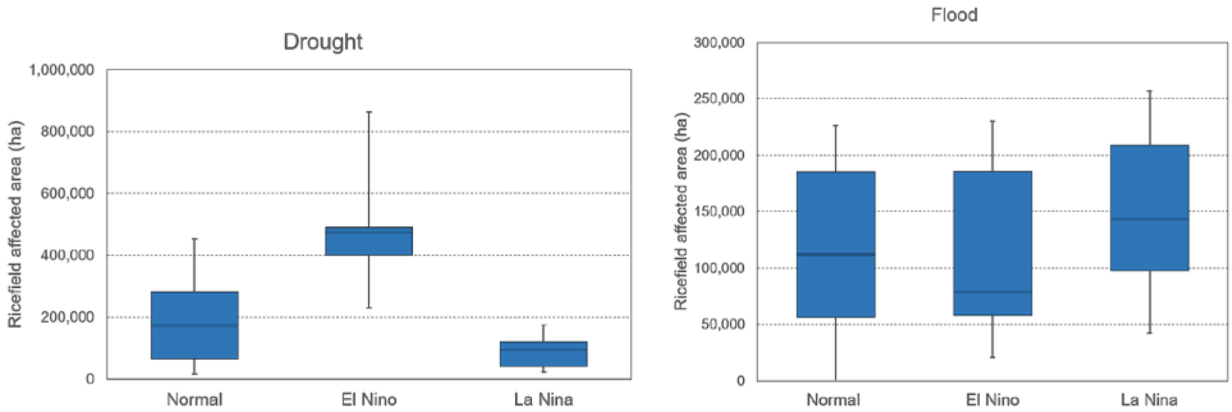

Figure 2.12. Paddy damage area due to drought (left) and flooding (right) (Data source: Directorate General of Food Crops, MoA)

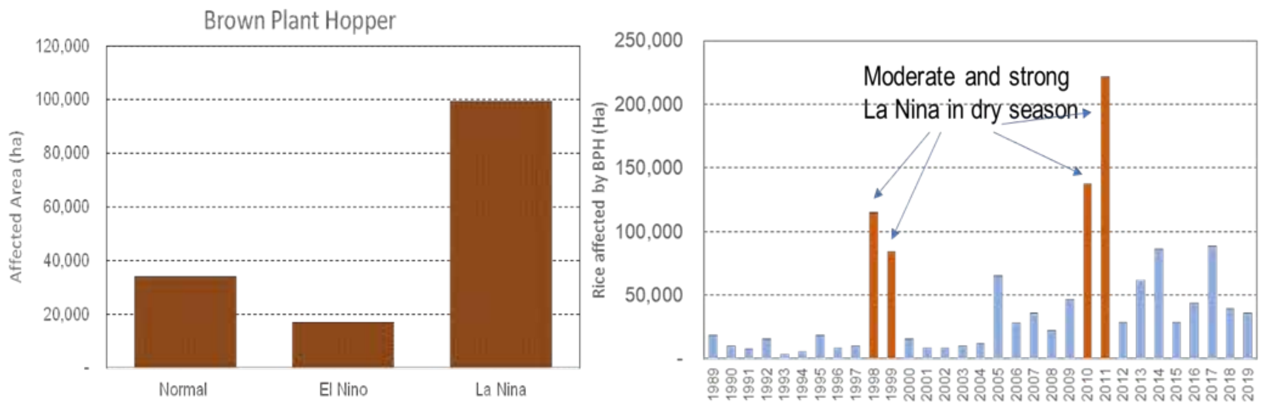

Figure 2.13. Affected rice field due to BPH in Normal, El Niño and La Niña years (left). Rice affected area in moderate and strong La Niña in dry season (right)

Changes in the amount, intensity, and frequency of precipitation are very important indicators of climate change. Insect species that overwinter in the soil are directly affected by overlapping rainfall. This event threatens insect survival and at least affects their diapause. Susanti *et al*. (2019) studied the effects of increased dry season rainfall cause rapid growth population of Brown Plant Hopper (BPH). Data affected area due to BPH period 1989-2019 indicated that increase of rainfall in La Nina years have caused increased in affected area of BPH attack three times from normal years (Figure 2.13).

The data described above shows that the impact of climate change experienced by the agricultural sector is greater than its contribution to GHG emissions. All indicators of climate change have a direct impact on crop production such as sea lever rise, temperature and rainfall. In addition to direct impacts, there are also indirect impacts, such as increased attacks of pests and plant diseases. Therefore, adaptation and mitigation efforts that have adaptation co-benefits are a priority for the agricultural sector.

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3

Overview of Indonesia's Agricultural Adaptation and Mitigation Policies

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The agricultural sector is very vulnerable and a victim of climate change. Therefore, adaptation should be the priority in order to maintain resilience to climate change and maintain food security. At the same time, as agriculture is a source of greenhouse gases, there is a need for this sector to also aim for mitigation, i.e. reducing the amount or else intensity of greenhouse gases. In general, mitigation is seen as the co-benefits of adaptation, especially among the smallholders.

There are policies on adaptation and mitigation at the global (United Nations Framework Convention on Climate Change, UNFCCC) level. Meanwhile, there are regulations imposed by importing countries with a focus on mitigation, and alongside those international policies there are national policies that may emphasize adaptation, mitigation, or a balance of both, depending on the country's circumstance.

This chapter starts with a general overview of Indonesia's agriculture and how vulnerable it is to climate change, and policies on adaptation and mitigation from the global to national levels. This chapter concludes with the challenges in addressing those policies.

Indonesia's agriculture and its vulnerability

From the total land area of 187.8 million ha (Mha), 62.3 Mha is used for agriculture, 92.7 Mha is for forests, and the rest is for various uses (FAOSTAT. *https://www.fao.org/countryprofiles/index/en/? iso3=IDN*). Indonesia's agriculture varies widely in terms of the crops being cultivated, the edaphic factors, the climate, and the socio-economic backgrounds of the farmers. As such the vulnerability to climate change also varies, not only determined by the biophysical, but also socio-economic circumstances of the farmers.

Lowland rice area is about 7.1 Mha (Decree of the Minister of ATR/Head of BPN-RI Number 339/2018). A more recent, but unpublished data mentioned that the lowland rice area is about 7.46 Mha, while the harvest area between 2019 to 2021 ranged from 10.4 to 10.7 Mha (*bps.go.id*), meaning that, on average, harvesting intensity is about 1.4 times per year. For other crops, the "standard" area is not easy to define since many of those crops share the same piece of land with lowland rice during the dry season Agus *et al.* (2019). For instance, maize could be planted in a rotation with rice in an irrigated or rainfed system. In the upland it is likely to be in rotation with other crops too, such as peanut, soybean, or vegetable crops (e.g. Santoso et al. 2021). The area tends to decrease due to conversion to non agricultural uses (Mulyani et al. 2016; Andrade et al. 2021). Updated data is not available, but the 2015 figures of harvest areas (Mha) is 3.75 for maize, 0.61 for soybean, 0.45 for peanut, 0.95 for cassava, and 0.14 for sweet potato (*bps.go.id*). The irrigated lowland rice areas, lowland rainfed areas, and the upland areas are vulnerable because of the annual crops short and frangible shoots and roots and hence easily affected by drought, floods, and strong winds (Surmaini and Agus 2020).

Besides the crop type – where annual crops are relatively more vulnerable, the geographical location determines vulnerability. With thousands of small islands and hence, very long coastlines, the coastal areas of Indonesia are expected to encounter severe impacts from a sea level rise. NOAA (2020) estimates that Indonesia experienced a sea level rise of 3.9±0.4 mm year^{-1} between 1992 and 2020. Rice fields which are dominant in its coastal areas are very vulnerable to inundation. This may contribute to a loss of arable land through inundation and increased soil salinity, affecting crop growth and yield. An increase in sea level of up to 1 m will cause coastal areas which currently have an altitude of 1 m above sea level to be inundated, impacting 134,509 ha of rice fields throughout Indonesia, of which 5% is located in the island of Java. This event will cause a loss of rice production potential of up to 976,688 tons in that year (Surmaini *et al.* 2022).

The high salt content of seawater contaminates agricultural soils and groundwater, imposing constraints on the growth and production of rice in Indonesia. Based on 2017 data from the rice basket area in Java, more than a half-million hectares of rice fields suffer salinity problem due to seawater intrusion, with the average rice yield during the dry season of 0.65 t ha^{-1} lower than the yield during the wet season (Sembiring *et al.* 2019). Surmaini *et al.* (2022) concluded that any increase in salinity will have an impact on reducing rice production following a logarithmic function. An increase in electric conductivity (EC) up to 4 dS m^{-1}, causes a loss of 1,835 tons of dry unhusked rice production per year where production in Java contributes 46.5%.

Like for many food crops, defining the areas for tree based horticultural crops (such as fruit trees) is not easy. Many trees are located at home gardens or in combination with various other crops in agroforestry systems (Abdoellah *et al*. 2020). Large scale and monoculture fruit trees are not common. These crops, being tree crops, are relatively more resilient to extreme weather events such as floods, droughts and strong winds. Except for its relatively small scale, in aggregate, these tree crops store a significant amount of carbon.

Like fruit tree crops, annual vegetable crops such as tomatoes, potatoes, carrots, broccoli, cabbage belong to horticultural crops. They are mostly planted on high elevation areas which are usually associated with steep slopes, high rainfall, and volcanic ash derived soils. The soil is deep and high in organic matter (Sukarman and Dariah 2015), but the steep landform and the high intensity and high amount of rainfall threaten soil conservation. Furthermore, the higher frequency of weather extremes, such as torrential rains (Surmaini and Faqih 2016) makes the steep slope agriculture more vulnerable to water erosion (Agus and Widianto 2004).

Plantation crops such as rubber, oil palm, and cacao, develop relatively rapidly, but the expansion is dominated by oil palm and to some extent, cacao (Figure 3.1). Oil palm plantation area increased from 4.2 Mha in 2000 to 14.9 Mha in 2020. Cacao has expanded from about 0.6 Mha in 2000 to about 1.5 Mha in 2020. Oil palm has a very high adaptability to produce well on acid soils, including very acidic peat soils. The main prerequisite is high annual rainfall of at least 1750 mm $year^{-1}$ with no distinct in dry months (Djainudin *et al*. 2003). Cacao requires less acidic soils with deeper solum (Aini *et al*. 2020).

Most plantation crops are tree crops with a long life cycle and high carbon stock, meaning that if they are planted on lands with previously low carbon stocks, such as grasslands or shrubs, the plantation crops sequestrate carbon from land use change and change the landscape carbon stock from low to moderate or high (Agus *et al*. 2013). Among the plantation crops, oil palm expands most rapidly, and cacao expands relatively slowly. Rubber and coffee plantation areas are almost unchanged (Figure 3.1). With regards to their resilience, in general the perennial plantation crops can withstand droughts and floods better than annual crops, due to their deep root distribution and tall stems such that they are not easily inundated, nor do they easily dry due to their long roots

Despite the more resilient and mitigating capacity, that does not mean that the tree crops can be developed limitlessly without maintaining the balance of the proportion of areas among different commodities with market demands and land suitability.

The urgency of adaptation and mitigation

Chapter 2 has explained the sources of greenhouse gases and the signs of climate change. Part 3.1. of this chapter has also highlighted Indonesian farming systems and their vulnerability to climate change. This section reviews literature on the urgency for adaptation and mitigation.

The IPCC Assessment Report 6 (IPCC AR6) published several books related to scientific basis of climate change, adaptation, mitigation, as well as an improved methodology of GHG inventories (*https://www.ipcc.ch/*). IPCC (2019a) demonstrates the trend of anthropogenic warming and the maximum increase that can be managed through adaptation and mitigation, beyond which adaptation will be too difficult and too costly to do. Should the world proceed with the Nationally Determined Contribution (NDC) scenarios, the 1.5°C temperature increase will be easily exceeded. Hence a series of "deep cut" carbon emissions must be conducted such that the global average atmospheric tempera-

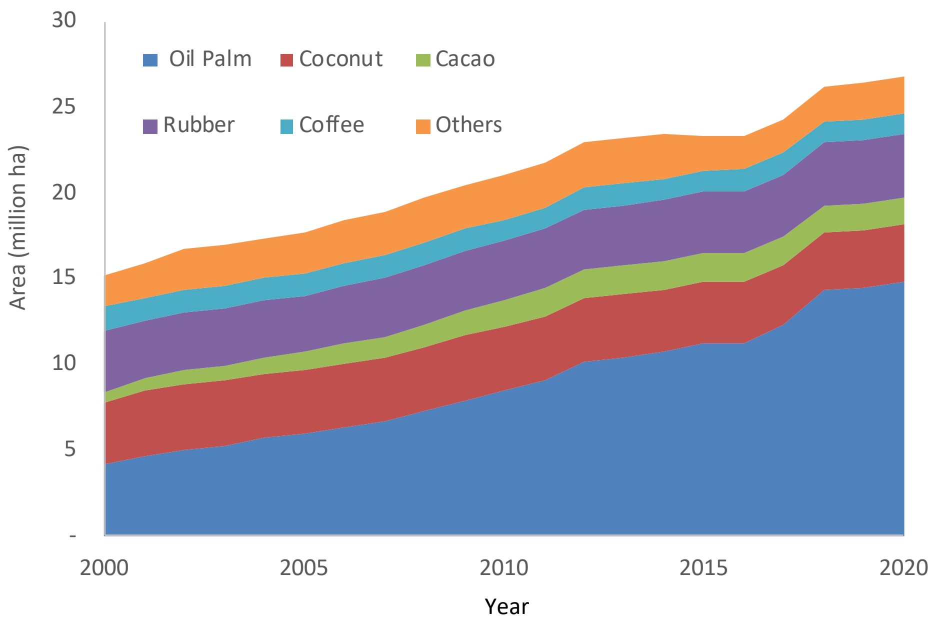

Figure 3.1. Areas of selected plantations from 2000 to 2020 (data processed from bps.go.id). Others include tea, kapok, cashew nut, nutmeg, cinnamon, candlenut, betel nut, pepper, vanilla, clove, sugar cane, tobacco, lemon grass, castor, and patchouli

ture will not exceed 1.5°C by 2100. IPCC (2019b) explains the relationship between climate change and land, i.e. how climate change affects lands, including the farming systems, and how improved land management could improve adaptation capacity among different farming systems, and at the same time can potentially mitigate climate change.

To be able to limit the temperature increase below 1.5°C, the net zero CO_2 emissions need to be achieved by 2050 (Figure 3.2). Reliance is high on the energy sector, especially through phasing out the use of non-renewable fossil fuels. In Glasgow United Nations Climate Change Conference (COP 26) there were intensive talks about phasing out of coal, which was responded differently among the producers and consumers countries. Economic consequences and countries' readiness to replace this source with non carbon-based fuels vary a great deal. "Global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050. This means that any remaining emissions would need to be balanced by removing CO_2 from the air" (IPCC 2019).

The pathways to limit global warming to 1.5°C with limited or no overshoot, bioenergy with carbon capture and storage (BECCS) deployment is projected to range from 0–1, 0–8, and 0–16 Gt CO_2 year^{-1} in 2030, 2050, and 2100, respectively, while agriculture, forestry and land uses (AFOLU) related carbon dioxide removal (CDR) measures are projected to remove 0–5, 1–11, and 1–5 Gt CO_2 year^{-1} in these years (medium confidence). The upper end of these deployment ranges by mid-century exceeds the BECCS potential of up to 5 Gt CO_2 year^{-1} and afforestation.

BECCS is not agreed by some demand-side countries and their measures rely on greater AFOLU-related CDR measures. However, the use of bioenergy can be as high or even higher when BECCS is excluded compared to when it is included due to its potential for replacing fossil fuels across sectors.

CDR is not an easy subject. The measures could have significant impacts on land, energy, water or nutrients if deployed at large scale. Af-

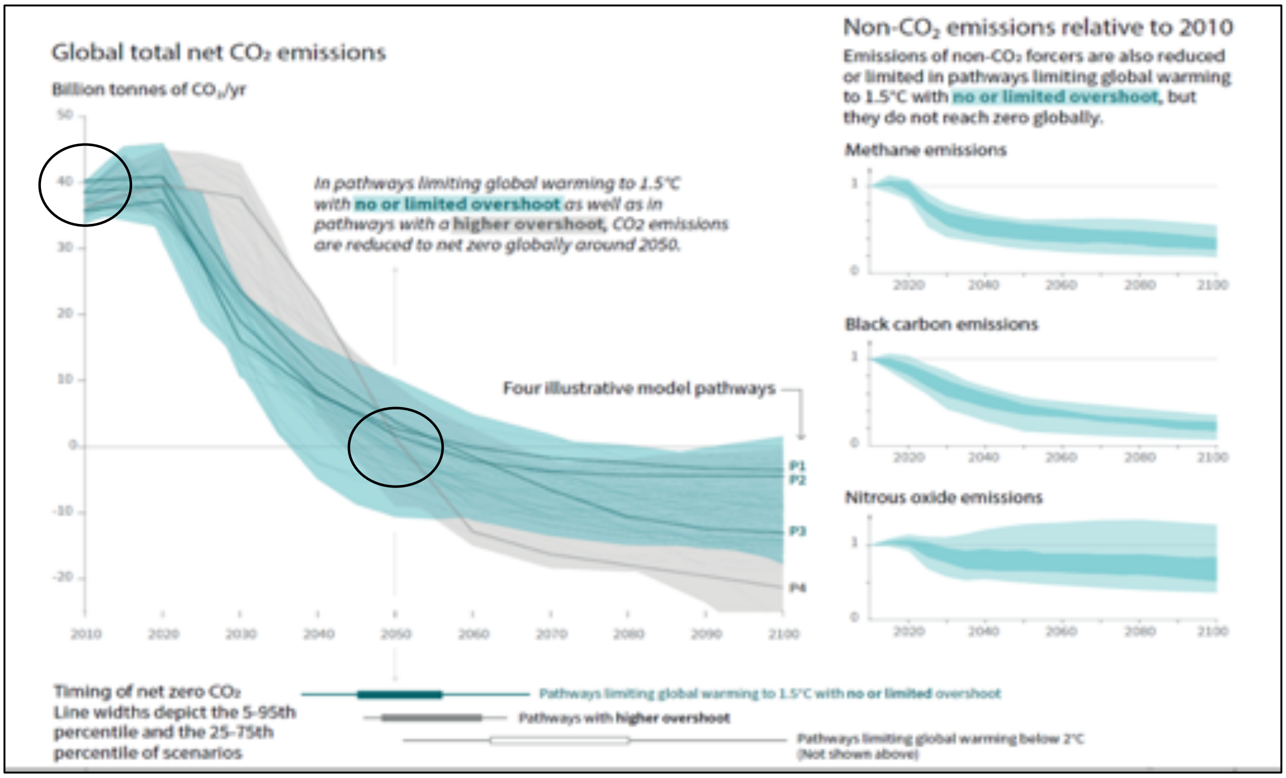

Figure 3.2. Global emission pathways for net zero emissions scenarios by 2050 for limiting the global warming below 1.5 °C (IPCC 2019)

forestation and bioenergy may compete with other land uses and may have significant impacts on agricultural and food systems, biodiversity, and other ecosystem functions and services. Some AFOLU-related CDR measures such as restoration of natural ecosystems and soil carbon sequestration could provide co-benefits such as improved biodiversity, soil quality, and local food security. If deployed at large scale, they would require governance systems enabling sustainable land management to conserve and protect land carbon stocks and other ecosystem functions and services.

Figure 3.2 shows the pathways for achieving net zero emissions by 2050. As shown on the right hand side panel, while net zero emissions is impossible for methane, black carbon, and nitrous oxide, much of which is related to agriculture, but at the global level these emissions can be reduced by various ways such as alternate wetting and drying (for CH_4 from flooded rice system), and balance fertilization to improve nitrogen use efficiency. However, in developing countries methane and nitrous oxide emissions may increase to address the deficit of meat consumption and to adjust fertilizations in accordance with crop needs, respectively.

The nationally determined contribution and the position of agriculture

Mitigation

Based on Indonesia's updated First Nationally Determined Contribution (1st NDC) the GHG emissions of Indonesian Agricultural Sector in 2010 were around 111 million tons (Mt) CO_2-e, the third highest after Forestry and Energy (Table 3.1). Under the business as usual (BAU) scenario, emissions from the agriculture sector in 2030 will moderately increase to 120 Mt CO_2-e. With counter measure 1 (CM1) that relies on the national efforts, the emissions in 2030 are estimated at 110 Mt CO_2-e (about 9 Mt CO_2-e lower than the BAU level). At the same time this value also approaches the historical 2010 emission.

Table 3.1. Historical and projected greenhouse gases emissions from different sectors based on Indonesia's first Nationally Determined Contributions

Sector	GHG emission level 2010* (Mt CO_2-e)	GHG Emission level 2030			GHG Emission reduction				% Annual average growth BaU (2010-2030)
		Mt CO_2-e			Mt CO_2-e		% of total BaU		
		BaU	CM1	CM2	CM1	CM2	CM1	CM2	
1. Energy*	453.2	1,669	1,355	1,223	314	446	11	15.5	6.7
2. Waste	88	296	285	256	11	40	0.38	1.4	6.3
3. IPPU	36	70	67	66	3	3.25	0.10	0.11	3.4
4. Agriculture**	111	120	110	116	9	4	0.32	0.13	0.4
5. Forestry and other Land Uses (FOLU)***	674	714	217	22	497	692	17.2	24.1	0.5
Total	1,334	2,890	2,034	1,683	834	1,185	29	41	3.9

Notes: BAU is the business as usual scenario, CM1 is the unconditional counter measure which is based on national efforts, CM2 is conditional counter measure, for which the scenario can be realized through international collaboration. GHG = greenhouse gases.
*) Including fugitive
**) Only include rice cultivation and livestock
***) Including emissions from estate crop plantations

Under CM2, i.e. strengthened by international cooperation (CM2), emissions in 2030 are estimated to be 116 Mt CO_2-e, which is about 4 Mt CO_2-e lower than BAU, but about 6 Mt CO_2-e higher than the CM1. This shows that increasing efforts to control climate change in agricultural sector are not necessarily effective in reducing GHG emissions, but are expected to improve agricultural resilience against climate change.

The main source of emission in agricultural sector included CH_4 from lowland rice, enteric fermentation from livestock, direct N_2O from soil and manure and indirect N_2O from soil (Figure 3.3). There are cross-sectoral sources of emissions, such as emissions from agriculture, forestry and land use (AFOLU), including emissions from peatlands. The AFOLU sector is inventoried by the Ministry of Environment and Forestry and this includes land use change to agriculture. We recognize potential emission reduction from improved water management in peatland by raising the water table, for instance by constructing canal blocks. Until present, this aspect has not been recorded as part of the regular mitigation achievement, but now temporarily inventoried by the Ministry of Agriculture.

During the early development of the 1st NDC, interventions in agricultural sector were limited to only livestock and paddy rice and with the volumes of intervention relatively very small (Table 3.2). We briefly discuss the interventions as shown in the 1st NDC (Table 3.2) and how relevant they are now.

1. The use of low emission crops.

   There are two or more simultaneous processes taking place along with this intervention. Besides the use of low CH_4 emission rice varieties, there is also the dynamics of planting/harvest intensity, which was assumed to increase from 2.11 to 2.5 in Java and from 1.7 up to 2.0 outside of Java islands. These are expected to result in an increased planting area, and hence the period of inundation

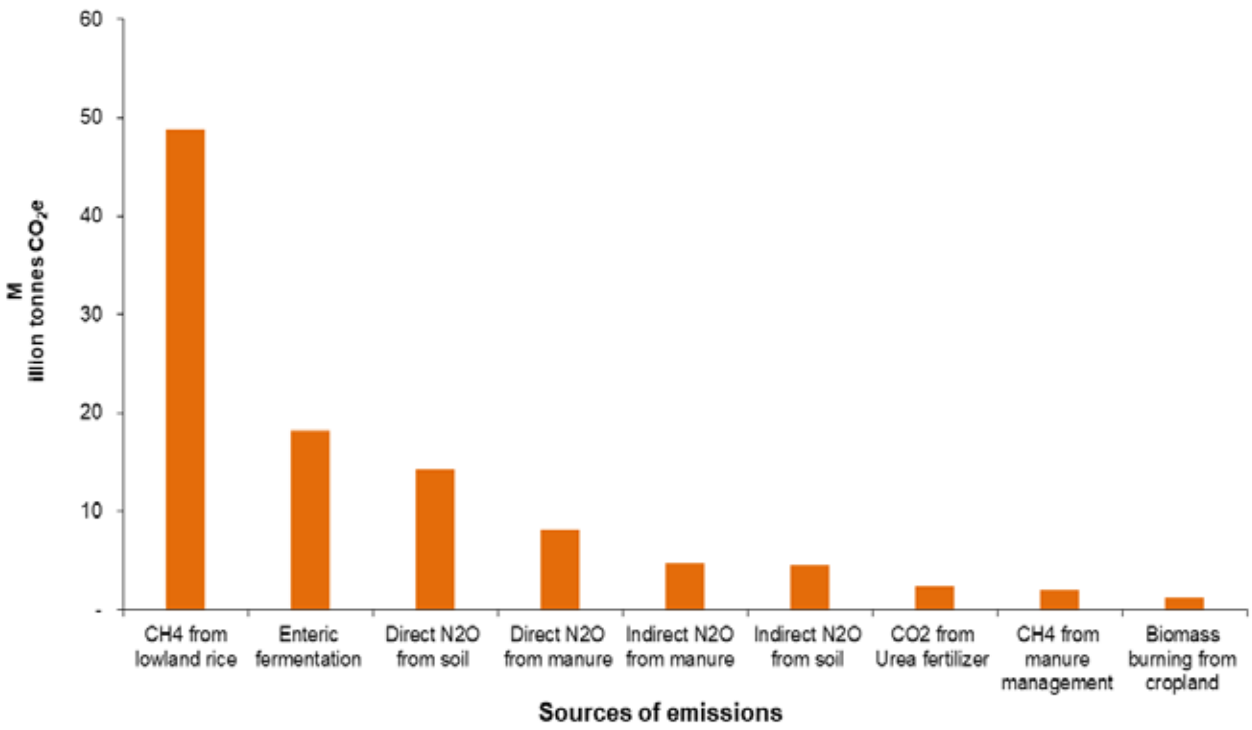

Figure 3.3. Emissions from various sources in agricultural sector in 2020. The total national emission from agriculture was 104 Mt CO_2-e, which is already below the business as usual level of 2030

and CH_4 emission. The actual data showed that the increase in cropping intensity did happen in 2015, 2016, and 2017, but it dropped again in 2018, 2019 and 2020 (unpublished data in Indonesian GHG inventory for agricultural sector). Another optimistic assumption which is not valid anymore, was that all paddy fields outside Java would have been improved to irrigated paddy systems by 2030. Until present, there is no strong indication of such development, and most of rainfed areas will likely be under rainfed management for some time in the future.

The use of low emission varieties potentially contributes to mitigation (Gutierrez *et al*. 2013) and this is related to different root exudates produced by the different varieties (Aulakh *et al*. 2001), as well as the different community structure of methane producing bacteria (Eller and Frenzel 2001). In Indonesia, IR36 varieties is a conventional variety with emission of one rice cycle of 202.3 kg CH_4 ha^{-1}. The more popular variety recently was Ciherang with CH_4 emission rate of 0.57 of the IR64. Hervani *et al*. (2019) provide a list of 40 varieties, the length of each variety crop cycle, average yield, and scaling factor for CH_4 emission calculation.

It's important to note that in practice, in the selection of rice varieties, the CH_4 emission factor is not taken into consideration neither by the government, nor by farmers. The main consideration is the yield and rice quality that the varieties can offer. While Ciherang meets all three criteria (low emissions, high yield, and good quality rice), low CH_4 emission varieties may not associate with high yield and high quality rice, depending on the future rice genetic development.

2. Efficient water management

This intervention is realized in the forms of intermittent irrigation, flooding during the vegetative growth and drying during the generative phase of rice, and the system of rice intensification (SRI) (Uphoff *et al*. 2015).

Table 3.2. Emission reduction strategies and assumptions used in the First Nationally Determined Contribution (Indonesia Updated NDC 2021, with modification for clarity). BAU is the business as usual scenario, CM1 is the unconditional counter measure which is based on national efforts, CM2 is conditional counter measure, for which the scenario can be realized through international collaboration

Mitigation measures in agricultural sectors	BAU	CM1	CM2
1. The use of low-emission lowland rice crops varieties.	No mitigation actions.	In total, the use of land for low emission crops is up to 926,000 hectares in 2030*.	In total, the use of land for low emission crops is up to 908,000 hectares in 2030*.
2. Implementation of efficient water management in lowland rice cultivation.	No mitigation actions.	Implementation of water efficiency is up to 820,000 hectares in 2030*.	Implementation of water efficiency is up to 820,000 hectares in 2030*.
3. Manure management for biogas	No mitigation actions.	Up to 0.06% of the total cattle in 2030**.	Up to 0.06% of the total cattle in 2030**.
4. Feed supplement for cattle.	No mitigation actions.	Up to 2.5% of the cattle population in 2030**.	Up to 2.5% of the cattle population in 2030**.

In doing so, not only the use of water becomes more efficient, but CH_4 emissions also decrease due to the reduced number of flooding days. Hidayati *et al*. (2016) claimed an impressive 24% yield increase under the system of rice intensification (SRI). Thakur *et al*. (2013) claimed yield increase of 48% under SRI, compared to the conventional flooding rice system. However, Glover (2011) argued that the claim of yield improvement under SRI has been controversial and this is mainly due to the lack of standardized description of SRI, such that testing of the method is challenging.

The adoption of SRI varied depending on the farmers' backgrounds. A case study in Timor Leste revealed that the more knowledgeable farmers about the system and the higher availability of labor likely increase the adoption since SRI is not very simple and it's a labor demanding technique (Noltze *et al*. 2012).

3. Manure management for biogas

The assumption of adoption of 0.06% in 2030 (Table 3.2) is very low and very conservative because it was based on a small-scale biogas program using small digestion tanks. This program could belong to the energy sector, but could be considered also as a rural development program. There is a potential for further development of this program, but it also depends on the price of conventional fuels. Maintenance and gas piping systems are not simple for farmers to manage, and hence continued supervisions for this initiative will be necessary to ensure maintenance.

4. Feed Supplement for Cattle

The most common feed supplement for livestock, including cattle, is mixing grass with high protein fodder, such as those of leguminous origin, as well as concentrate. These supplements not only improve feed quality, and hence livestock production, but also reduce CH_4 emission from enteric fermentation (Chapter 8 of this volume). Again, what is assumed in the NDC are small scale demonstration programs. The impact of the demonstration has not been taken into account. Voluntary adoption by farmers is not yet recorded because of difficulties in activity data collection.

However, in the annual reporting of GHG emission reduction, mitigation actions also included:

1. Intensified use of organic fertilizers. This intervention is expected to increase soil carbon stock.
2. Balance fertilization which is mostly associated with improving N use efficiency. This intervention is especially suitable for areas with overuse of the subsidized nitrogen fertilizers. However, there are also areas with underuse of N fertilizers where increasing fertiliser uses, not only N, but also P and K, should be prioritized. If this program is successful the aggregate national N_2O emission may increase.
3. Raising water table in farming on peatlands. Drained peatland is a major source of CO_2. An approach to reducing emission is by raising water table by canal blocking.

Adaptation

At the 23rd Conference of the Parties (COP) as a new process to advance discussions on agriculture in the United Nations Framework Convention on Climate Change (UNFCCC), the parties agreed on a roadmap called the Koronivia Joint Work on Agriculture (KJWA) roadmap. The KJWA addressed six topics related to improved soil management, nutrient use, water management, livestock management, methods for assessing adaptation, and the socio-economic and food security dimensions of climate change in the agricultural sectors (FAO 2018).

Following the completion of the series of KJWA Workshop, Indonesia emphasizes the importance of speeding up the implementation. The Indonesian government recognizes the importance of the availability of the land managers, and hence providing the means of implementation becomes as a prerequisite for adaptation. Due to its main role to ensure food security, and as has been outlined in the KJWA agreement, adaptation is the priority. Mitigation is regarded as a co-benefit of adaptation. With the same token, adaptation should be regarded the entry point, and as much as possible, measures that address adaptation, has positive impacts on mitigation.

The KJWA outlined that improving soil and nutrient management, including the use of organic fertilizers and manure, is important in increasing agricultural resilience to climate change, creating sustainable food production systems, and achieving global food security. It was stated that some of these actions and policies already exist in the Indonesian agricultural sector, but ambitions in the field of handling climate change in the agricultural sector need to be increased because it is very important to increase the resilience of the agricultural system and food security in Indonesia.

Indonesia's National Development Planning Agency (Bappenas) has recently launched a policy recommendation document entitled Climate Resilient Development Policy, issued on 1st April 2021. It will act as a guideline for handling climate change for local and regional governments, as well as related institutions to implement the Medium-Term National Development Plan (RPJMN) 2020-2024. In the 2020-2024 RPJMN, increasing climate resilience is targeted to reduce potential economic losses from the impacts of climate change by 1.15 percent of GDP by 2024. Climate resilient development policies are an implementation of the Sustainable Development Goals (SDGs), Low Carbon and Climate Resilience Strategy, Sendai Framework, and fulfilment of Paris Agreement targets.

Table 3.3. Adaptation activities by each cluster (adapted from BAPPENAS 2021)

Cluster	Activities
Infrastructure	1) Development of water storage (dams, ditches, long storage);
	2) Development of irrigation networks through: (a) construction of tertiary irrigation networks on agricultural lands, (b) new developments or modifications of irrigation systems into piped irrigation, drip irrigation, and sprinklers;
	3) Provision of flood protection buildings with restoration and construction of polders in paddy fields, and construction of river embankments around agricultural lands;
	4) Provision of adaptive farming facilities such as superior plant seeds with high productivity and resistance to climate stress and pests, provision of organic fertilizers, provision of pest control facilities, and provision of modern machinery to increase labour efficiency; and
	5) Expansion of agricultural land by building new paddy fields and other agricultural areas on unproductive land.
Technology	Implementing technologies:
	1) Tolerant varieties against drought, floods, salinity, and pests and diseases
	2) Agricultural machinery, for speeding up activities for tackling labor shortage.
	3) Intermittent irrigation system and low emission rice varieties with high productivity;
	4) Organic matter application,
	5) Improvement of manure management;
	6) Balanced fertilization
	7) Soil conservation techniques on mineral soils
	8) Improved water management systems on peatlands for reducing the risk of fires and GHG emissions.
	9) Reducing land extensification in areas with high C storage and planting crops with high C storage in areas with low C stock such as shrubs.
Capacity Building	1) Increasing awareness of policy makers on the danger of climate change
	2) Farmer's counselling and assistance, including technical guidance on climate-resilient and low-carbon agriculture.
Governance and funding	1) Climate insurance
	2) Access to credit, finance
	3) Labour intensive scheme
	4) Regulation

In carrying out climate-resilient development implementation actions, the government establishes programs and activities through the approach of Infrastructure Development, Utilization of Technology, Capacity Building, and Governance and Funding (Bappenas 2021). These programs and activities need to be elaborated by each ministry and institution. For the agricultural sector, the Ministry of Agriculture classifies adaptation activities as follows (1) Provision of agricultural infrastructure (2) Implementation of adaptation technology with mitigation co-benefits, (3) Research and development of adaptation and mitigation; (4) Capacity building; and (5) Governance and funding of climate change actions (Ministry of Agriculture 2022) as described in Table 3.3.

Figure 3.4. Examples of climate change adaptation, clockwise from top-left, artificial lake as a water retardation lake in East Nusa Tenggara Province; cover crop of Arachis pintoi at ex-tin mining area of Bangka Island as a measure to improve soil fertility and increase organic matter supply to the soil; Arachis pintoi cover crop for pepper (Pepper nigrum) farm in Lampung Province. In sloping areas this cover crop can function not only to improve soil fertility, but also reduce erosion by water; natural grass strips for filtering runoff water and reducing erosion (location was unidentified)

Increasing mitigation ambition above NDC

Along with the accord of United Nations climate summit in Glasgow, in November 2021, in which there is a pressing need to increase ambition of greenhouse gases mitigation, and that by 2050 several developed countries commit to achieve net zero emissions, Indonesia issued Presidential Decree (PERPRES 98/2021) emphasizing the importance of economically valuing carbon (NEK), which was then translated as carbon Cap-Trade-Tax. It's important to note that for agricultural sector that has been discussed under the Koronivia Joint Work on Agriculture (KJWA), mitigation is not the main target. The KJWA agreement emphasizes the importance of improving agricultural resilience by improving adaptation measures such that this sector can maintain its role to ensure food security. Mitigation is aimed at, along with adaptation.

Since this policy is intended to increase mitigation ambition above that of NDC, the measures under NDC are considered as part of the Cap (the new baseline). If a business sector can lower the emissions below the NDC Cap target, it can sell the carbon credit to other companies that are yet to increase their mitigation achievement. Likewise, if a company fails to achieve emission reduction target and its emission level is not lower than the cap, then it must pay Tax based on the difference between Cap and the achieved emission level. For the initial step Indonesia chose \$2 per tonne CO_2-e for the carbon Tax.

This carbon trading system may be very complicated for smallholder farmers due to very small scale farms (ranging from a fraction of hectare to a few hectares) and so variable farm practices, but it has a potential for large scale plantations. The challenge is setting up the standardized methodologies for life cycle analysis (LCA) of GHG emissions (Bessou *et al*. 2014). In addition, the government could also implement mitigation programs that are in synergy with adaptation.

Setting the priorities

Agricultural sector is very vulnerable and a victim of climate change, so adaptation is a priority in order to maintain resilience to climate change and maintain food security (see options in Table 3.3 and Figure 3.4). By adapting, it is hoped that there will also be a reduction in GHG emissions (mitigation) as a co-benefit from adaptation. This position of Indonesian Agricultural Sector is in line with the 26th COP26 Agreement, in 2021, in Glasgow.

There are opportunities for implementing climate smart agriculture. However, for the narrow definition of agricultural sector these have been part of NDC. Increasing NDC ambitions could be developed through multi-sectoral approach, especially between agriculture and forestry. Segregation between sectors would hinder the opportunities to implement climate smart agriculture. These programs could include sustainable intensification of agriculture among smallholders, and controlling land use change from high carbon stock areas.

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Recover together
Recover stronger

4

Lowland Rice as the Main Producer of Indonesian Staple Food Despite its Relatively High Methane (CH_4) Emission

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Rice is the staple food of more than half of the world's population including Indonesia and take account as a strategic agriculture commodity. The data from the OECD-FAO stated that the amount of rice consumption in Indonesia in 2022 up to 123.5 kilograms per capita (Statista Research Department 2022). Indonesia's people eat rice two or three times a day, which often uses almost all domestic production only for consumption. Indonesia only exported rice production for an average of 1,627 tonnes between 2013-2017 and imported from international markets annually with an average of 751,000 ton or about 1% from national rice production and 2.3% from national rice consumption (FAO 2020; Sleet and Phoebe 2018). This condition showed that the share of household expenditure on rice is the largest across the others. Meanwhile global rice consumption remains strong, driven by both population and economic growth.

Indonesia is the third largest producer of rice in the world after China and India (FAO 2020). Rice is Indonesia's primary production system and the most important staple crop. Rice area occupies 25% of total agriculture's harvested area, with yields averaging 5.2 ton ha^{-1} between 2015 and 2019 (FAO 2020). Marked it as the highest yields in Southeast Asia, after Vietnam, and exceeded the regional average of 3.8 ton ha^{-1} by 36% (FAO 2020). According to Statistic Indonesia, the total rice production in 2021 is up to 55.27 million ton (increased 1.14% from 2020) from 10.52 million ha of harvested and total rice consumption reached 31.69 million ton or increased up to 1.12% compared to 2020 due to successful implementation of government policies and action programs in rice intensification. Rice is critical to Indonesia's food security; nationally, 92% of households are net buyers of rice, including 87% of poor agricultural households who buy more rice than they sell (Sleet and Phoebe 2018). Along with this increasing, about 14% of Indonesia's GDP comes from the agriculture sector, which is predominantly run by smallholder farmers (93%). In terms of workforce, agricultural sector absorbed more labour during the pandemic due to the decline in the manufacturing sector and other business sectors that encourage more people to become farmers in rural areas.

Food security has become a central issue in various parts of the world i.e., climate change. Climate change may cause negative effect to rice production, a decline that could jeopardize food supply. On the other hand, rice cultivation has been identified as a source of greenhouse gas (GHG) emissions, namely methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). With the potential to be further developed for national food security and exports, the agricultural sector needs to improve productivity exponentially. However, some cultivation methods for increasing rice production are likely to impact negatively on the environment if sustainable systems are not developed to intensify rice cultivation. Hence, this chapter attempts to summarize the information on the impact of climate change, the emission, the strategies to do climate change adaptation and mitigation for improving rice productivity in lowland area, to meet the future food demands.

Description of Indonesia's lowland rice

Rice is cultivated in both lowland and upland throughout Indonesia. Lowland rice is rice grown on land that is flooded or irrigated. While, the upland crop typically being rainfed. Rice cultivation in Indonesia, generally cultivated in wetlands (Figure 4.1). According to the Indonesian Ministry of Public Works (MPW), approximately 60% of Indonesian harvested rice area is irrigated, while the remaining 40% is rainfed. Irrigated lowland rice yields on average are about 60% higher than rainfed because most of irrigated lowland rice fields are well-watered and heavily fertilized. Lowland rice cultivation is concentrated on Java (largest producer), but is also prevalent on Sumatra and Sulawesi. These three islands are contributing about 90% of total national rice production (FAO 2020). Though upland rainfed systems and lowland irrigated systems are both well represented, lowland systems tend to be heavily fertilized and can support three crops per year, and as a result account for 80% of Indonesia's rice growing area and 93% of total production, with 60% larger yields than upland areas (FAO 2020).

In Indonesia, there are typically three rice growing periods or seasons, a single wet season crop followed by two dry season crops. Approximately 45% of total production is usually from the wet season crop during October to April. Indonesia's main rice growing season for both rainfed and irrigated systems occurs at the onset of the rainy season around October and November, with harvesting taking place at the season's

Figure 4.1. Rice cultivation in Indonesia

close in April (FAO 2020). In tropical area such as Indonesia, temperature and solar radiation could not be limiting factors for cultivation, thus rice cropping season is planned by a schedule of irrigation or even by farmers arbitrary decision. The increase of rice production in Indonesia is achieved by implementing rice intensification programs. This program includes balanced fertilization, seed and varieties improvement, water management, pest and disease control as well as tools and machinery.

Climate change impact

Climate change has severely impacted all sectors of life, agricultural sector is no exception. Under the adverse impacts of climate change, producing more rice for the future is an advance challenge. Rainfall is the determining factor for irrigation water supply while temperature controls evapotranspiration and affects the length of crop growing season. The frequency of occurrence of extreme events (flood and drought) are increasing, which causes crop decline. Monsoon dominates Indonesia's climate (more than 50%) which gives a degree of homogeneity across the region. El Niño is considered as one of the causes of forest and land fire in the region. Outbreaks of crop pests and diseases are often connected with this phenomenon. Furthermore, Climate change has led to substantial changes in the dates of planting and harvesting, which has led to changes in the growing season due to variations and uncertainties in rainfall and temperature, thereby impacting food demand. Naylor *et al*. (2007) estimated that a 30-day delay in the onset of rainy season will diminish wet season rice production in West/Central Java and East Java/Bali by about 6.5 and 11.0 %, respectively.

Indonesia is particularly vulnerable to sea-level rise because thousands of small islands and tremendous coastlines, with the country ranked fifth highest in the world terms of the size of the population inhabiting lower elevation coastal zones. Encroaching seawater and increased salinity in groundwater tables is causing much of the water supply and soil to become too salty to grow crops. Myers *et al*. (2015) predicted that increasing CO_2 concentration over the next 40–60 years will lead to deficiencies of essential elements, including nitrogen (protein), zinc, and iron, in C3 grains.

Mitigating potential food security issues by projecting future rice production in Indonesia through a climate projection and crop simulation model is crucial to anticipate the impact of climate change on rice production. Changing rainfall patterns, rising temperature, and intensifying solar radiation underclimate change can reduce the rice yield in all three growing seasons. Under the Representative Concentration Pathway (RCP) 8.5 in the 2050s, the impact on rice yield in the second dry season may decrease

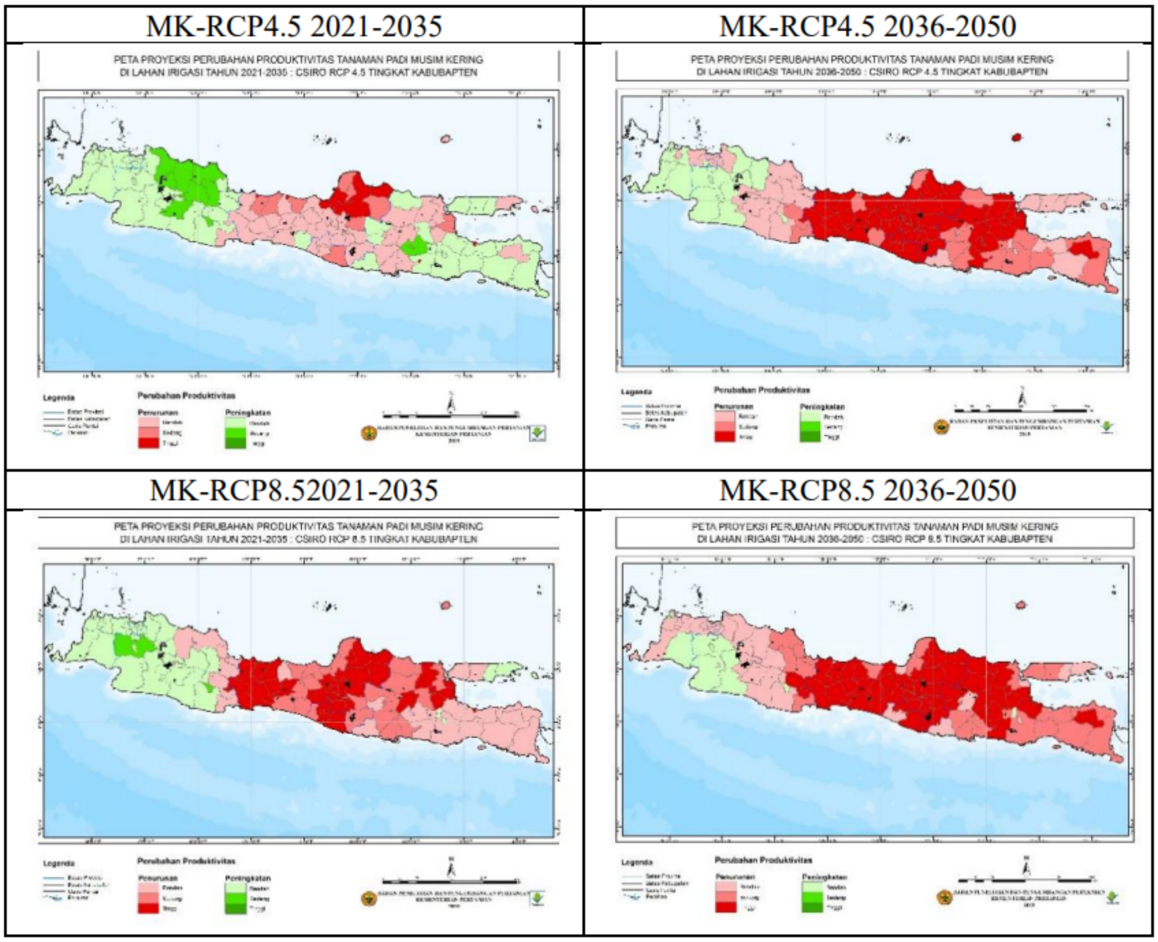

Figure 4.2. Projection of irrigated rice yield change in the dry season 2021-2035 and 2036- 2050 for the RCP4.5 and RCP8.5 scenarios using CSIROMK3.6 model (Susanti et al. 2021)

by up to 12 % in Central Java (Ansari *et al*. 2021). Susanti *et al*. (2021) integrated downscaled climate projections and crop simulation model to provide projection of on rice production anomaly in 2035 and 2050 in Jawa Island using the Representative Concentration Pathway (RCP) 4.5 (stabilization scenario, which means the radiative forcing level stabilizes at 4.5 W/m2 before 2100) and 8.5 scenarios (BAU) to provide projection of rice production in Jawa Island. They concluded that in the 2050, based on the RCP 4.5 scenario, it is projected that rice production in dry season planting will decrease by 20-30%, except in West Java, which is projected to increase by 10%, while in the RCP 8.5 scenario, most of Central Java and East Java will experience a decline in rice production of > 30% (Figure 4.2).

Impact of temperature increase

Temperature is considered one of the most important factors affecting the rate of development, growth and crop yields (Rehman *et al*. 2015). Rice yields are sensitive to the rising of minimum temperatures in the dry season; yields could decrease 10% for every 1°C increase in minimum temperature (Peng *et al*. 2004). Temperature extremely low and beyond optimum can have detrimental effects and negatively affects crop development, growth, and ultimately reduces the grain yield (Fahad *et al*. 2017). The impact of high temperature depends on intensity, duration, and timing of stress, however, there are more negative effects during reproductive stage (Tenorio *et al*. 2013). High temperature causes various morphological symptoms, such as leaf wilting, leaf curling and yellowing, and reduced tiller number and biomass (Xu *et al*. 2020). Average temperature elevation of 1°C during rice growing season reduced paddy yield by 6.2%, total milled rice yield by 7.1%–8.0%, head rice yield by 9.0%–13.8%, and total milling revenue by 8.1%–11.0% (Lyman *et al*. 2013). Grain-filling rate was increased and the total grain-filling duration was reduced by 21.3%–37.1% for different genotypes at the grain-filling stage due to exposure to high temperature (Shi *et al*. 2017). Another effects of temperature increase are water availability, the occurrence of strong winds, and the intensity and duration of sunlight. Moreover, temperature rise increases frequency of heat waves and the impacts on pests, weeds, and plant diseases.

Impact of elevated CO_2 concentration

Rice as a C3 species has lower respiration rates and higher photosynthetic and metabolic efficiencies at high CO_2 concentration levels. The C3 group of plants are more sensitive to an increase in atmospheric CO_2 concentration than C4 plants. Increased CO_2 concentration enables faster growth due to rapid carbon assimilation (Woodward 1990). The main effects of elevated CO_2 on plants are a reduction in transpiration and stomatal conductance, improved water and light-use efficiency, and thus an increase in photosynthetic rate. Elevated CO_2 increased grain length and width as well as grain chalkiness but decreased protein concentrations (Jing *et al*. 2016). However, according to Stigter and Winarto (2013) rice yield was estimated to increase by 0.5 ton ha^{-1} for every increase in CO2 concentration.

Impact of changeable precipitation pattern

Indonesia's climate consists simply of one wet season and one dry season each year. The distinguishing feature of the wet season is that at least 200 mm or more of rain falls per month, and in the dry season mean rainfall is less than that

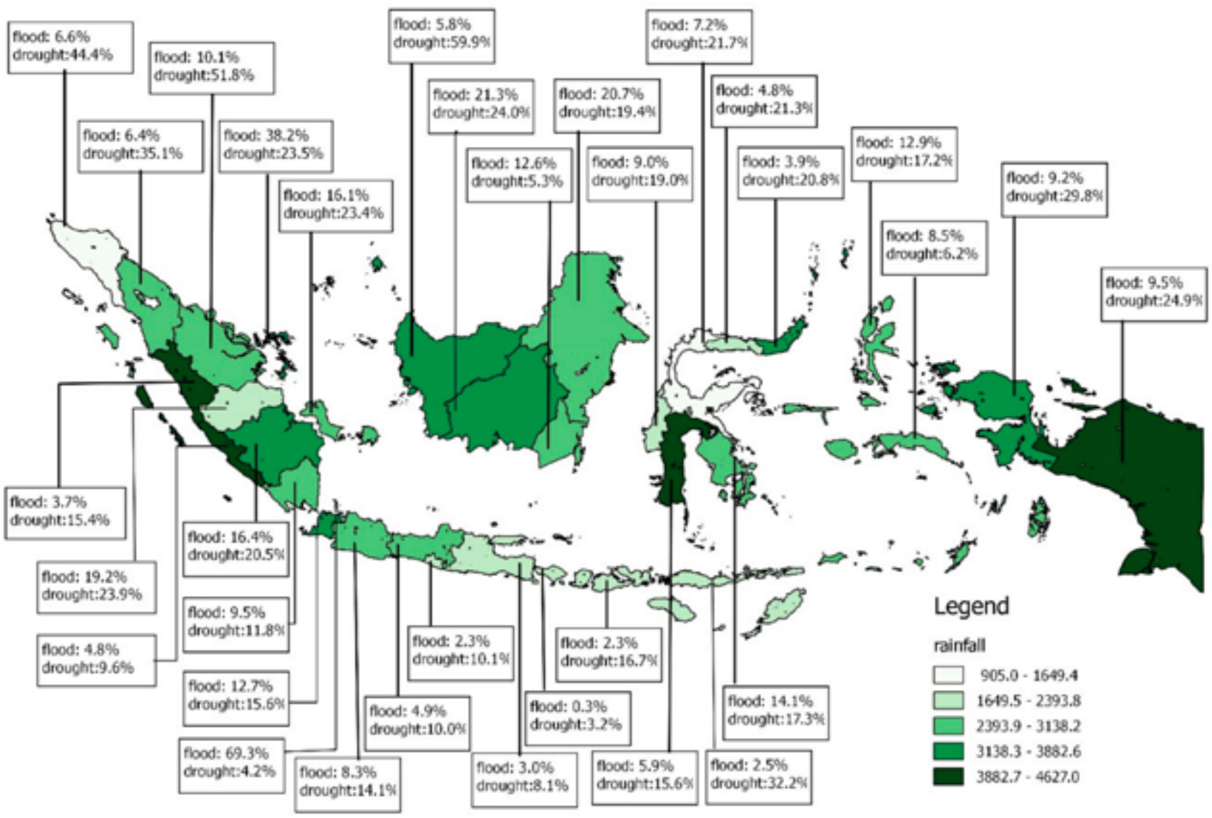

Figure 4.3. Distribution of farmers who have experienced flood and drought events in Indonesia (the rainfall intensity unit in the legend is mm/year) (Rondhi et al. 2019)

threshold. However, Indonesian rainfall exhibits substantial variability within the year across districts as well as within districts over time. There have been changes in precipitation and cycles of droughts and floods triggered by the Australasia monsoon and by the El Niño Southern Oscillation (ENSO) for the past three decades in Indonesia (Naylor R. L. 2007; Boer 2010). Thus, this has led to agricultural production damage, causing negative consequences for rural incomes, food prices, and food security in Indonesia. Rainfall variability in Indonesia is influenced by many large-scale climate phenomena, one of them is El Niño Southern Oscillation (ENSO). Figure 4.3 showed that more farmers have experienced droughts than floods and farmers outside Java are more vulnerable to climate change (Rondhi *et al*. 2019).

According to Surmaini *et al*. (2015), damages to rice crops due to droughts are mostly occurred during dry season planting. The Indonesian Ministry of Agriculture has reported that during the El Niño years, damages to crops due to droughts have ranged between 350 and 870 thousand hectares and have led to significant crop production lost. The damage mostly occurs during dry season within May through October as illustrated in Figure. 4.4.

El Niño has played a key role by often leading to droughts resulting in decreased crop yields that could further result in famine in some food insecure regions (Hansen *et al*. 2011; Iizumi *et al*. 2014), including Indonesia (Naylor *et al*. 2007; D'Arrigo and Wilson 2008; Surmaini *et al*. 2015; 2019). Given the strong teleconnection of ENSO and agricultural production, linking vari-

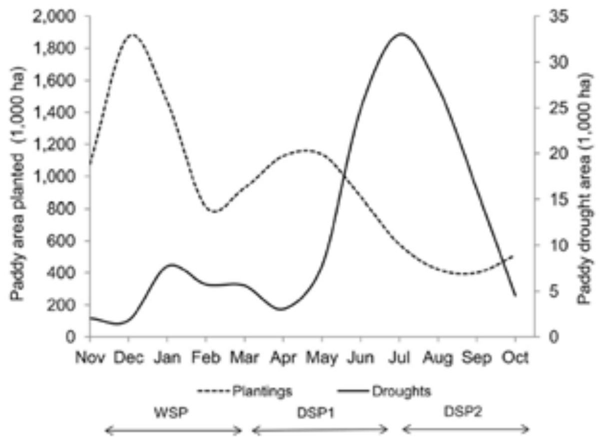

Figure 4.4. Plots of average paddy area planted (dashed line) and average paddy damaged area due to drought (solid line) in Indonesia against calendar year (Surmaini et al. 2015)

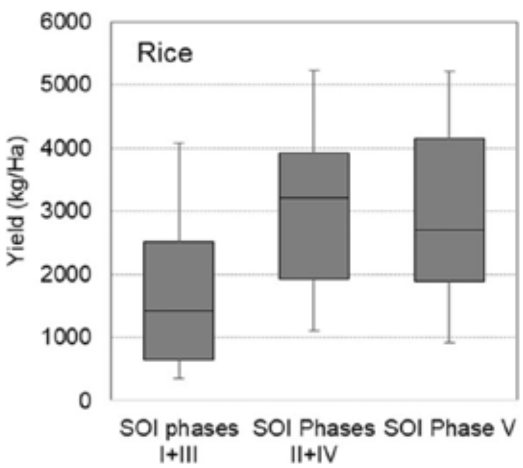

Figure 4.5. Distribution of simulated rice yields for crops planted on May 1 in Bojongsoang and Ciparay of Bandung District associated with the SOI phases I +III (El Niño), SOI phases II + IV (La Niña), and SOI phase V (Neutral) of March/April) (Boer and Surmaini, 2020)
SOI = Southern Oscillation Index

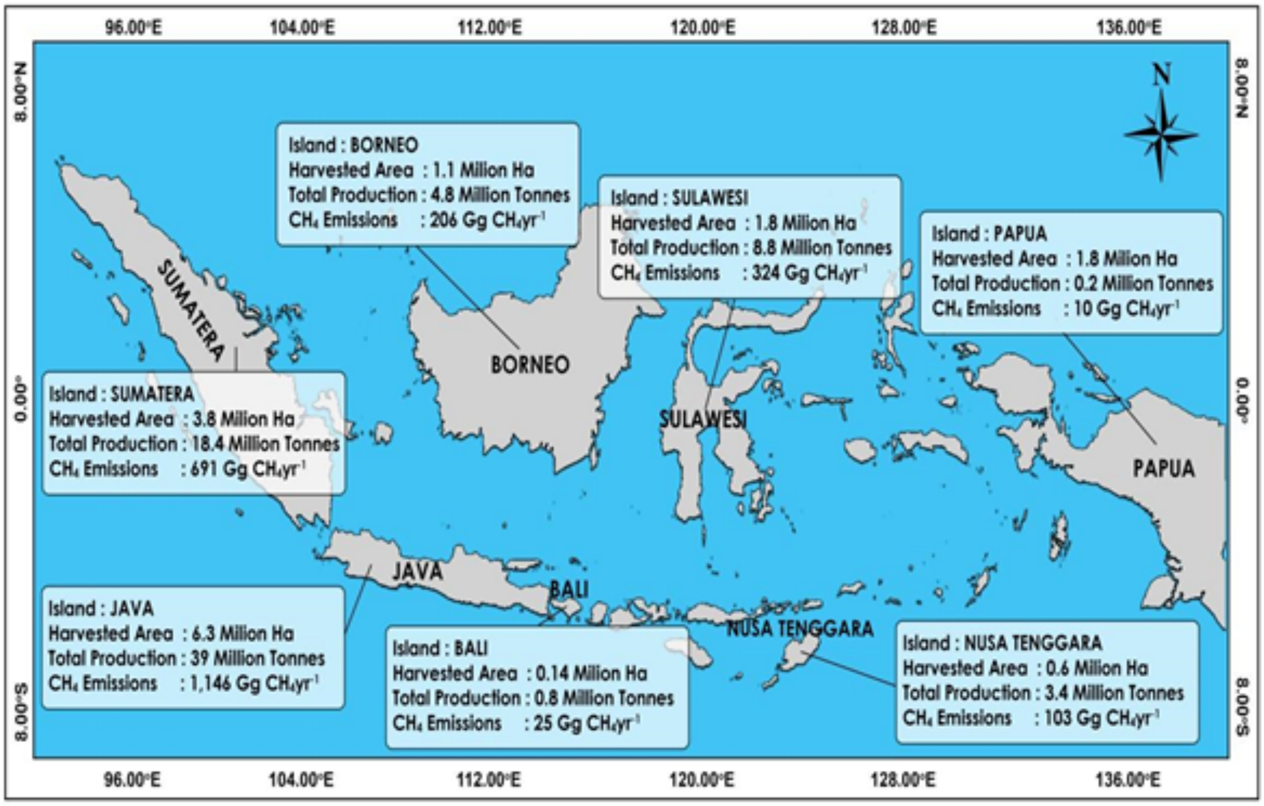

Figure 4.6. Rice-harvested areas, production, and GHG emissions in Indonesia (Ariani et al. 2021)

ations in crop yields with ENSO phases has the potential benefit for food monitoring and early warning systems. There are multiple metrics that can be use as ENSO indices; however, there is no consensus within the scientific community as to which index best defines ENSO years or the strength, timing, and duration of events (Hanley *et al*. 2003). Boer and Surmaini (2020) used Southern Oscillation Index (SOI) March/April phase in conjunction with crop simulation to determine the likely rice yield in different ENSO scenario in Bandung District. The result showed that the averaged rice planted on dry season have experienced the lowest simulated yields following the El Niño events (Figure 4.5).

Stronger ENSO climate oscillations are expected in the near future, as climate forecasts project more frequent extreme El Niño and La Niña conditions. In terms of future climate projection, Indonesia is predicted to experience temperature increases of approximately 0.8°C by 2030 and will be occurred at a rate highly variable across regions of 1.16°C to 1.58°C until 2070 (Susandi 2007). Increasing temperature causes pest's reproduction, survival, spread and population dynamics as well as the relationships between pests, the environment, and natural enemies (Skendži´c *et al*. 2021). It is reported that a reduction in crop yields will occur in some parts of Asia at a level of 2.5-10% until 2020 and 5-30% until 2050 (Tesfaye *et al*. 2017). Studies in Indonesia estimated that climate change will likely decrease rice yield by 4% per year and it is predicted that yield reduction will be at a level of 20.3- 27.1% until 2050 (Bappenas 2011 and World Bank 2007).

Emissions from lowland rice

Rice fields are important contributors of CH_4 and N_2O emissions. Recently, emission of CH_4 from paddy fields was estimated for about 5-19% of the total CH_4 emissions, while fertilized

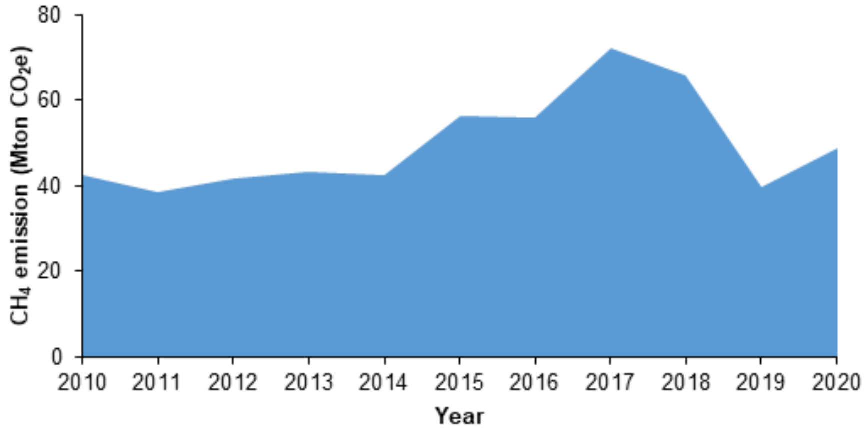

Figure 4.7. CH_4 emission from rice during 2000-2020

agricultural soils was estimated for about 13-24% of annual global N_2O emission (Mosier *et al*. 1998; Olivier *et al*. 1998; Kroeze *et al*. 1999, IPCC 2007a). CH_4 and N_2O have different global warming potentials (GWP) on a mass basis, which are 298 times higher for N_2O and 25 times higher for CH_4 than CO_2 on a 100-year time scale (IPCC 2007b). The CH_4 emission from rice field in Indonesia were shown in Figure 4.6.

The Indonesia National Greenhouse Gases Inventory including emission from rice cultivation (Figure 4.7) for the period 2000-2020 was estimated by methodologies that comply with IPCC Guideline (2006) for National GHG Inventories and IPCC GPG for LULUCF. Agriculture contributes about 6% to the national GHG inventory. Methane emission from rice cultivation is the highest contributor to the total GHG emission from agriculture sector through the years compare to other sub-sectors. In the year 2020, it contributes about 46%. There were reduction emissions during 2019 and 2020 due to different methods to calculate the harvested area. This emission was calculated from lowland and upland rice. Indonesia's lowland rice area is more than twice the size of upland rice area. Farmers in lowland rice area tend to manage their rice fields in continuous flooding condition for the whole rice growing season which leads to higher CH_4 emission. Rice cultivation is both an important sequester of carbon dioxide from the atmosphere and an important source of greenhouse gases (e.g. CH_4 and N_2O) emission. The island of Java as the main rice producer with approximately 6.3 M ha harvested area in 2016 marked also as the island's largest contributor to the GHG emissions from rice cultivation (Figure 4.6)

Adaptation strategies and mitigation co-benefits in lowland rice field

The Indonesian government submitted an updated national climate commitment to the United Nations. The plan includes new measures on adaptation and resilience and some new targets in specific sectors, but has the same top line emissions targets submitted in 2016: an unconditional target to reduce greenhouse gas (GHG) emissions 29% below business-as-usual by 2030, or a 41% reduction target contingent on sufficient international financial support. Indonesia also submitted its first long-term strategy to the UNFCCC, which indicated the country plans to peak GHG emissions in 2030 and could reach net-zero GHG emissions by 2060 or sooner. The agricultural sector has a strategic position because the actions must be in line with activities/programs to achieve food security. The agricultural sector also plays an important role in national economic and social resilience. Adaptation action is the main strategy and mitigation is a co-benefit.

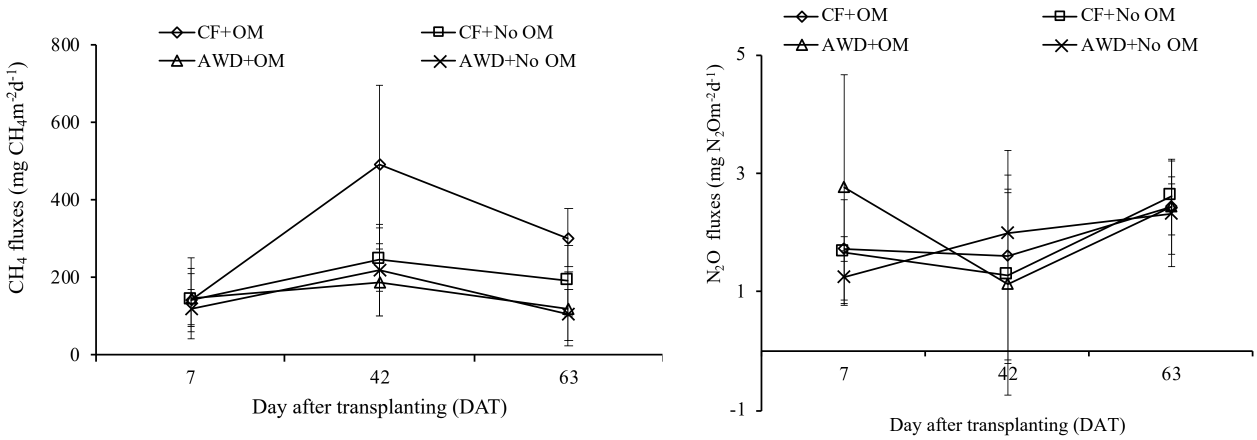

Figure 4.8. CH_4 and N_2O fluxes in water regulation treatment and organic matter application on Inceptisol Jakenan soil, 2019 Dry Season. (CF = continuous flooding, AWD = alternate wetting and drying, OM = organic matter, No OM = without organic matter)

Adaptation is an effort to develop resistance on the negative impacts of climate change (Ridwan & Chazanah 2013). Adaptation actions e.g., optimizing the management of land and water resources; adjusting the management of cropping patterns and timing, crop rotation and varieties; development and application of adaptive technology tools; the application of adaptive (production, crop protection, harvest, and post-harvest) and environmentally friendly technology (IAARD 2011). While, GHG mitigation opportunities in the agricultural sector e.g., water-saving technology; the use of rice varieties that emit low CH_4; fertilization and amelioration organic matter management, and planting methods.

Optimizing land management and water resources

Sustainable management of agricultural land and water is important to global food security, especially in the face of climate change and increasingly erratic weather. Marginal land such as dry land, swamp land, acid sulphate land which has relatively low productivity of agricultural crops. This marginal land can be used as a future agricultural land resource. Optimization of land and water resource management aims to increase production and productivity of agricultural crops (IAARD 2011). Land conservation is needed to provide an important aspect, especially for crop production, while maintaining stabilization and improvement of ecosystem functions. Optimizing land management can be done through crop rotation, fertilization and amelioration.

Adjustment of cropping patterns and timing is a strategic action to reduce the impact of climate change due to changes in rain patterns (Surmaini *et al*. 2011). Moreover, crop rotation is an effort to improve soil structure, improve drainage, reduce run-off and increase groundwater availability. Crop rotation can also control weeds and pest attacks so as to reduce the use of chemical pesticides (Christensen *et al*. 2012). Crop rotation between rice and secondary crops as well as horticulture is a wise alternative to maintain productivity and land fertility, and the economy of farmers. Rice crop rotation with secondary crops can improve the soil structure of paddy fields (Chen *et al*. 2021). Crop rotation can also improve the chemical, physical and biological properties of the soil (Suprihatin & Amirrullah 2018).

Nitrogen (N) fertilizers containing sulphate, ammonium sulphate and phosphorus gypsum reduces CH_4 emissions (Yagi *et al*. 2020). The use of urea in form of tablets slightly reduced CH_4 emissions and significantly reduced N_2O emissions. Malyan *et al*. (2019) showed that the use of

Figure 4.9. Water reservoir as water storage for harvesting precipitation

azolla was able to reduce the intensity of greenhouse gases (GHGI) without reducing rice yields. Biochar at a dose of 40 t ha^{-1} was able to reduce N2O emissions and increase rice yields. Zhang *et al*. (2020) further stated that the use of biochar significantly decreased the GWP and GHGI values by 23% and 41% by increasing crop yields by 21%, respectively. In general, biochar plays a role in the denitrification process, facilitating the reduction of N_2O to N2 (Rittl *et al*. 2021).

Mitigation options with organic matter can be done by using fine/mature organic fertilizer, straw residues from previous plantings or composting. The combination of straw management with water regulation is effective in reducing GHG emissions. The addition of organic matter to land with Alternate Wetting and Drying (AWD) irrigation resulted in lower daily CH_4 emissions than in the flooded system (Figure 4.8). Carbon levels in the soil are positively correlated with CH_4 emissions in flooded systems (Ariani *et al*. 2019).

Utilization of water resources should be aimed to increase water and food security by building many dams that act as water reservoirs during the rainy season so that they can provide water during the dry season. The availability of water in the dry season will increase the planting index from IP-100 or IP-200 to IP-300 (Sutrisno & Hamdani 2020). The advantages of dams and ditches for climate change anticipation include store run-off water during the rainy season, to support the development of agricultural systems in dry season, fisheries and livestock sub-sectors (Figure 4.9). Several irrigation technologies that can be used to optimized land management are joint wells (sumur renteng), capillary irrigation, drip irrigation, spray irrigation, ditch irrigation, saturated irrigation, intermittent irrigation and rotational irrigation and AWD (IAARD 2011; Setyanto *et al*. 2018).

Water regulation in addition to affecting rice yields also influencing the amount of CH_4 emissions and water efficiency. Several alternative practices of direct seed planting in dry conditions can also be done to combat the water crisis (Haque *et al*. 2021). Temporary land drainage in rice cultivation such as single drainage, multiple drainage, mid-season drainage, and AWD can

Table 4.1. CH4 emission under alternate wetting and drying (AWD) system for six rice growing seasons (Setyanto *et al*. 2018)

Season	CH4 emission (kg ha-1)							
	CF		AWD		AWDS		Average of season	
Wet season 2013	250	a	160	a	159	a	190	D
Dry season 2014	300	a	167	a	253	a	240	CD
Wet season 2014	597	a	323	ab	221	b	380	B
Dry season 2015	432	a	303	b	236	b	324	BC
Wet season 2015	699	a	539	a	553	a	597	A
Dry season 2016	425	a	260	b	244	b	340	BC
Average of treatment	450	A	292	B	278	B		
CH4 reduction (%)			34.5		37.6			

Means with different letters indicate significant difference at the 5% level
CF=Continuous Flooding; AWD = Alternate Wetting and Drying (water level 15 cm below soil during dried phase); AWDS = site specific AWD (water level 25 cm below soil during drying phase)

reduce CH_4 significantly (Wassmann et al. 2000; Sander *et al*. 2015; Setyanto *et al*. 2018). The study of AWD in Indonesia showed a reduction in GHG emissions of 34-37% (Table 4.1) and save water by 10-20% compared to flooding treatment. AWD is effective only in the dry season (Sander *et al*. 2017).

New high yielding rice varieties that tolerant in biotic and abiotic stresses

The Indonesian Agency for Agricultural Research and Development (IAARD) has developed high-yielding rice varieties as the main agricultural commodity with several high-yielding varieties that are tolerant to drought, i.e., Inpari 18, Inpari 19, Inpari 20, Inpago 4, Inpago 5, Inpago, 6, Inpago 8 and Inpago Lipigo 5. The submergence tolerant rice includes Inpari 29, Inpari 30, Inpara 4, Inpara 5. The salinity resistant rice varieties namely Inpari 34, Inpari 35 and Inpara 5. The rice varieties resistant to brown leafhoppers and leaf blight include Inpari 13, Inpari 18, Inpari 19, and Inpari 20. Another variety resistant to tungro disease is Inpari 9 Elo. Blast resistant varieties, namely Inpari 15 Parahiyangan and leaf blight resistant varieties is Inpari 28 Kerinci (BB Padi 2016). Rice varieties that resistance to bacterial leaf blight (HDB) pathotype III are HIPA 9, 10, 11, 12, 13, 14, and HIPA Jatim 2 (Jamil *et al*. 2016). Gagak Hitam and Pandan Wangi rice varieties were included in the resistant varieties of pathogen Cercospora oryzae which causes brown leaf spot disease. While, IR64, Inpari 4, Sunggal and Ciherang were included in the susceptible varieties (Lakshita *et al*. 2019).

Indonesian Agricultural Environment Research Institute (IAERI) has measured GHG emissions from several superior rice varieties. Inpari 13 and Mekongga rice varieties emitted GHGs with a low GWP of 10.3 ton CO2–e ha^{-1} and 12.8 ton CO2–e ha^{-1}, respectively, compared to 6 other varieties tested such as Ciherang, Inpari 18, Inpari 31, Inpari 32, inpari 33 and IPB3S (Kartikawati *et al*. 2019). Mekongga and Inpari 13 rice varieties produced more effective tillers up to the generative phase compared to other varieties that produced high CH_4 fluxes. Several varieties of low CH_4 emission include Ciherang, Unsrat 2, Inpari 23, Inpari 28 (Kartikawati *et al*. 2018). In paddy fields, CH_4 emission is end product of the organic matter degradation and the result of complex interactions between rice plants and soil microbes under anaerobic conditions (Cicerone and Oremland 1988; Neue and Sass 1994;

Conrad 1996; Conrad 2007). Under anaerobic condition, more than 90% transport CH_4 from rhizosphere into the atmosphere and the oxygen diffusion into roots is mediated by the aerenchyma and intercellular space system of rice plants and the rest is released by the bubbles up from the soil and/or diffuses slowly through the soil and overlying flood water.

Development & application of adaptive technology & preparation of various guidelines/tools

One of the efforts to reduce risk of yield loss due to climate variability, is adjusting the planting times and applying cultivation technologies that are in accordance with climatic conditions. The Ministry of Agriculture has developed the Integrated Cropping Calendar Information System (The ICCIS). The ICCIS can describe shifts in planting time and planted area under climate variability based on water balance calculations with input prediction of rainfall for the next six months conditions. This information is very useful for farmers to optimize planting in favourable climatic conditions, on the contrary reducing the risk of crop failure/harvest in conditions of insufficient rainfall for planting (Apriyana *et al*. 2021). The latest version of the ICCIS is available on the website with an interface as illustrated in Figure 4.10. The ICCIS contains recommendations on planting time, cropping pattern, planting area, varieties, fertilizers, agricultural machinery, potential livestock feed, and crop damage, due to extreme conditions for rice, maize, and soybean, for the upcoming planting season. The data displayed is from the national, provincial, district to sub-district levels. Determining the suitable planting pattern and time can support the sustainability of the agricultural system in the future. This technology can also help farmers get the accurate information and make the right decisions in the next season. The challenge of climate change will cause the use of cropping calendar to provide benefits in supporting increased crop production.

Integrated crop and livestock system

The integrated crop-livestock system (ICLS) not only increases farmers' income, but also reduces emissions of CH_4, N_2O, and CO_2 from paddy fields and livestock. The main feature of the ICLS is the mutually beneficial synergism between agricultural or plantation crops and livestock. Farmers use livestock manure as organic fertilizer for their plants, then use agricultural waste as animal feed (Hendrickson et al. 2008). Application of manure as organic fertilizer reduces the use of inorganic fertilizers, improves the structure and availability of soil nutrients so increase land productivity and create a sus-

Figure 4.10. The interface of Integrated Cropping Calendar Information System (ICCIS). https://katam.litbang.pertanian.go.id (accessed on 31 March 2021)

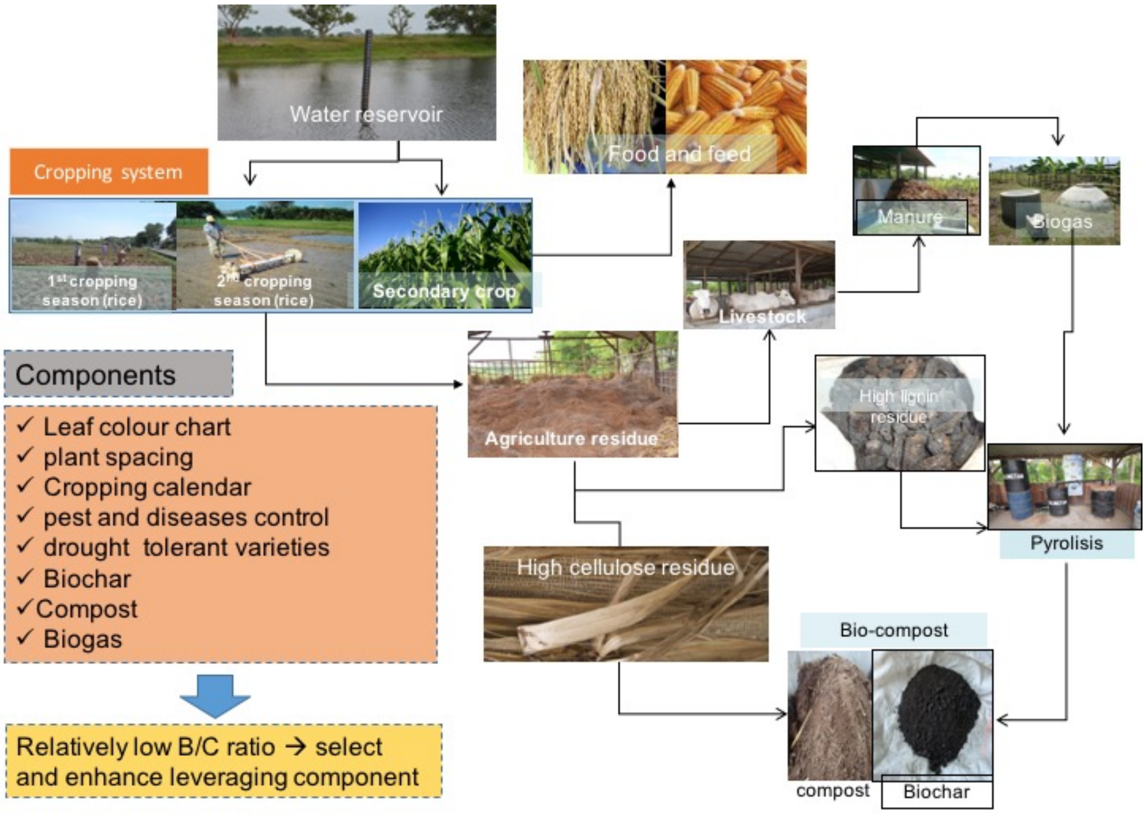

Figure 4.11. Integrated Crop-Livestock System (ICLS) is very suitable to support crop and livestock production

Table 4.2. Yield, GWP and emission index under direct seeding and transplanting methods during the rainy season (Susilawati *et al*. 2019)

Treatment	Yield (ton/ha)	GWP (t CO2-e/ha)	GHG Intensity
Direct seeding	4.9a	4.4b	00.09
Transplanting	5.2a	8.2a	01.06

Different letters in the same column showed significant differences at the 0.05 level on the Tukey's HSD test. GWP = Global Warming Potential, GHG Intensity = Greenhouse Gas Intensity (is calculated by dividing GWP by rice grain yield)

tainable agriculture. Integrated system of rice plants and cattle reduced GHG emissions from lowland rice about 23.2–32.0% and increase rice yields by about 2.2–27.7% compared to conventional method (Susilawati *et al*. 2021). Moreover, utilization of animal dung into anaerobic biodigester produce CH_4 for energy substitution as an alternative fuel. In addition, the application of ICLS increase the B/C ratio compare to conventional land management by farmers. The approaches of environmental friendly ICLS model that adaptive to climate change can be seen in Figure 4.11. In this closed system, carbon is less released into atmosphere and can be utilized efficiently as the concept of "zero waste".

Planting methods

Direct seeding significantly reduced CH_4 emissions compared to transplanting (Table 4.2). Aerobic rice and water-saturated land management (SRI cropping system) can reduce GHG emissions. Rotation of rice crops with maize or sorghum reduced CH_4 emissions (Yagi *et al*.

2020). Crop rotation is applied to optimize selected crops, especially to increase nitrogen fixation while increasing soil carbon stocks and reducing the need for inorganic fertilizers.

Closing

Rice is the world's most important staple food and pressure to grow more rice is increasing. However, flooded rice fields have been identified as a major source of atmospheric CH_4. Methane is released to the atmosphere through diffusion of dissolved methane, ebullition of gas bubbles, and via aerenchyma tissue of rice. The complex interactions among formation and oxidation of CH°C during rice growth and cultivation require an integrated, interdisciplinary research approach and farmers participation, to achieve feasible and effective mitigation technologies. By using a combination of feasible mitigation technologies, however, there is great potential to stabilize or even reduce CH4 emission from rice fields while increasing rice production. The technologies should combine climate change adaptation and mitigation strategies. Agriculture sector is vulnerable to climate change, so adaptation is a priority, but it promised to climate change mitigation. Adaptation options are prioritized on actions that provide mutual benefits (priority in line with global agreements). Low carbon technology innovation and environmentally friendly technology practices provide emissions reduction and able to support raising productivity.

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5

Annual Upland Agriculture as a Vulnerable System to Climate Change

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Upland is a stretch of land that has never been flooded or inundated most of the year (Soil Survey Staff 2014). It plays an essential role in the national food supply (Dariah and Heryani 2014). It is also referred to as the second food land after the paddy fields as it meets half of the national food, especially for rice (5%), corn (60%), and soybeans (40%) (Suryani *et al*. 2022). The position of upland as food land will be increasingly important in the future because of the further reduction of paddy fields due to land conversion that is difficult to control, also the leveling off and degradation of some intensive paddy fields. On the other hand, the population grows at 1.45% per year, impact on food demand continues to increase. Therefore, increasing the productivity of upland is a must.

Increasing productivity and production can be achieved by intensifying existing areas and increasing the planting area in new areas (extensification). BBSDLP (2015) states that the potential for upland available for additional planting is 24.9 million ha. These lands face various difficulties, including low soil fertility, limited water resources, insufficient farmer human capacity, etc., making it difficult to achieve production targets. Climate change is also another challenge that is a serious obstacle to the development of annual upland, because annual upland is very vulnerable to climate change, so it is essential to implement technologies that can improve climate change adaptation.

Apart from being a victim of climate change, agriculture also contributes to the release of greenhouse gas emissions. For this reason, agriculture is also committed to contributing to the mitigation of greenhouse gas emissions. Emission mitigation in the agricultural sector is carried out as long as production is not reduced. The option is to apply adaptation technology with mitigation co-benefits. Several adaptation technologies in the annual upland, such as applying soil and water conservation techniques, optimizing the use of organic matter, water harvesting technologies, and others, have the opportunity to achieve mitigation co-benefits. Some of these adaptation actions can also help reduce the rate of degradation of the upland, so agricultural productivity in the upland can be sustainable. This chapter describes Indonesia's annual upland, climate change impacts and emissions from annual upland agriculture, adaptation strategies, and mitigation co-benefits.

Description of Indonesia's annual upland agriculture

Indonesia has a land area of 191.1 million ha, most of which (75%) is upland (144.5 million ha), and the rest is wetlands, consisting of swamp and non-swamp land (BBSDLP 2015). Almost 70% of the upland area is potential for agriculture, or approximately 29.4, 1.1, 66.7, and 2.4 million ha are potential for food crops, horticulture, perenials crops, and cattle grazing (pasture), respectively. Considering forest areas within the framework of agricultural sustainability, the recommended upland area for agricultural cultivation or Other Areas of Use (APL) is around 40.7 million ha, with a further 59.9 million ha being forest areas. The potential and distribution of agricultural uplands are shown in Table 5.1.

In line with the population growth, the upland area used for agriculture is no longer sufficient to cover the food need. Therefore, the government makes forest land available for food reserves, particularly in the Conversion Production Forest (HPK) and Permanent Production Forest (HP) areas. HPK areas are designated as reserve areas for agricultural development in Law 41/2009, while HP areas are production forest areas that can still be converted if necessary. There is the replacement of forest areas in Other Areas of Use (APL). Based on the analysis results, there are 29.9 million ha of land in the two forest areas that have the potential for agricultural development.

Annual crops other than rice are mainly planted in the upland. The total annual area under cultivation in Indonesia, excluding paddy fields or what are referred to as secondary crops, is around 16.2 million ha (BPN 2021), divided between wet and dry climate zones. The annual crops commonly planted are food crops (such as corn, upland rice, and beans) and horticultural crops, especially vegetables. Food crops are predominantly planted in the lowlands (Figure 5.1), while vegetables are planted in the highlands (Figure 5.2). Annual crops are generally planted for two planting seasons per year in wet climate areas. In areas with dry climates, annual crops are generally only planted for one planting season per year unless there is support for supplemental irrigation. Short-lived vegetable crops are usually planted for more than two planting seasons per year (Figure 5.3).

Table 5.1. The potential and distribution of agriculture upland (BBSDLP 2015)

Island	Upland Potential (Ha)				Area (Ha)
	Food crops	Vegetable crops	Perennial crops	Pasture	
Sumatera	7,463,804	29,708	7,287,308	-	14,780,820
Jawa	1,710,159	646,071	4,172,000	-	6,528,230
Bali & NT	1,099,048	36,222	1,624,512	392,519	3,152,301
Kalimantan	3,966,867	-	6,647,383	57,413	10,671,663
Sulawesi	1,471,012	22,969	2,521,131	351,177	4,366,289
Maluku	276,094	1,766	380,044	29,382	687.286
Papua	342,466	-	154,748	9,048	506,262
Indonesia	16,329,450	736,736	22,787,126	839,539	40,692,851

Figure 5.1. Food crop in upland: planted in monoculture system (left) and intercropping (right)

Figure 5.2. Vegetable crops in highland

Figure 5.3. The conditions of annual crops that experience a water deficit

Upland management for annual crops faces biophysical, socioeconomic, and environmental problems. The main difficulty of upland management from a biophysical aspect is the scarcity of water to support agricultural production, even in upland with wet climate conditions, since water is only available during the rainy season. Also, most upland have relatively low soil fertility, especially on the acidic upland that dominates Indonesia's upland. The erosion potential of the upland is relatively high as more than 50% of the upland area lies on a gentle slope to a very steep slope (slope >8%) (Hidayat and Mulyani, 2005). Upland degradation rates are classified as high and represented by an average of low to very low organic matter content. The decrease in organic matter content is caused not only by erosion and surface runoff but also by the acceleration of the decomposition rate due to intensive land management. In the meantime, the return of organic matter to the field has not been carried out optimally. In general, carbon stock (C) decline has been associated with global issues such as CO_2 emission and local issues such as soil erosion, high nutrient leaching, and the low ability of the soil to store water.

Climate change impact

Climate change greatly affects productivity and production, as well as the quality of annual crop yields, especially those planted on upland. The impact of climate change on production and productivity is due to increasing of air temperature, pest and disease attacks, intensity and frequency of extreme climates, as well as seasonal uncertainty. Seasonal uncertainty results in rainfall patterns are one of the impacts from climate change that significantly affects the production and productivity of annual crops because water requirement depends on rainfall. Changes in the rainfall patterns make it difficult for farmers to manage planting schedules, resulting in un-optimizing planting time in the rainy season.

The increasing frequency and intensity of El-Niño and La-Niña extreme climate events (Subagyono and Surmaini 2007; Faqih and Boer 2013) significantly affected annual crop yields. El-Niño events can decrease rainfall, while La-Niña events can increase rainfall. These two climate anomalies have a greater impact on production of annual crops than perennial crop due to short live of annual crops. The average decrease in regular rainfall due to El-Niño is 80 mm month^{-1}, while the increase in regular rainfall to

La-Niña does not exceed 40 mm/month (Las *et al*. 1999). The impact of El Niño on the decline in crop yields was highest for corne, reaching 11.93%. Then, soybeans, sweet potatoes, and peanuts decreased by 5.10%, 4.74%, and 3.30%, respectively (Irawan 2013). Corn is very sensitive to water scarcity, while cassava is relatively drought tolerant.

In contrast to El Niño, La Niña tends to increase secondary crop yields, particularly in upland ones, as rainfall increases water availability. The secondary crops affected by La Niña had the highest yield increase in corn, at 3.92% (Irawan 2013; 2006). On the other hand, La Niña has a negative affect on vegetable crops which are more sensitive to pests and diseases. Rainfall and high humidity tend to increase the number of pests and diseases. During the 2010 La Niña, increased pest attacks resulted in a 20-25% drop in vegetable yields (Ditjen Hortikultura 2018).

The factors of high rainfall and prolonged rainy season also impact the decline in harvest quality because these factors hamper post-harvest activities, mainly because most farmers in upland do not yet have post-harvest management facilities. The drying process is usually done after harvest, so a long rainy season can disrupt the drying process, resulting in poor quality and interrupted crop yields.

Erosion is the leading cause of upland degradation. Exceptionally high rainfall conditions impact increasing the erosivity index (the ability of rainfall to erode the soil). Excessive rainfall can also cause inundation or flooding. In addition, prolonged rainfall is prone to landslides, as most annual highland farming activities are conducted on sloping land.

The subsequent impact of climate change on the annual crop increases the CO_2 concentration and air temperature. Increasing CO_2 concentration to a certain level can increase the rate of photosynthesis, especially in C3 plants. In addition, the increase in CO_2 can decrease the rate of transpiration due to reduced stomata openings, aiding support water use efficiency. However, higher temperatures offset yield increases due to increased CO_2 concentrations, leading to water stress, delayed harvest maturity due to increased aging, and shortened grain-filling periods. Increasing the air temperature at the optimal point can help the metabolic process to allow plants to grow well. However, after the temperature has passed the optimum point, the plant's growth will be restricted. The crop climate model shows an average decrease in 3-17% productivity with a temperature increase of 2°C (Lone *et al*. 2017). Rising temperatures also affect the quality of crop yields as they affect sugar content, organic acids, and antioxi-

Figure 5.4. Pest and disease attacks increase especially in horticultural crops when humidity is high at La-Niña year

dant levels, which affect storage and transportation processes (Moretti *et al*. 2010; Chandradewi, 2014). According to Essono *et al*. (2007), the influence of temperature on yield quality is more substantial in the wet tropics such as Indonesia.

Emissions from annual upland agriculture

Apart from being a victim of climate change, annual upland agriculture contributes to GHG emissions. Most of the annual crop farming applies inorganic fertilizers such as nitrogen fertilizer, which is one of the sources of N2O emissions. This gas has a GWP (Global Warming Potential) level of 273 times CO2 (IPCC 2021). However, fertilizer is not applied as much as in paddy fields in annual upland agriculture because annual upland farmers generally have relatively little capital. Based on fertilizer dosage recommendations, urea fertilizer dosage for corn is about 400 kg ha^{-1}. However, legumes use fewer N fertilizers 50 kg ha^{-1} because legumes can get N independently from atmospheric N2 in collaboration with symbiotic rhizobia. Severely degraded soils make it difficult to achieve optimal production without inorganic fertilizers. Currently, the practice of organic farming is used in annual upland farming on vegetable crop areas, and in limited fertile land conditions, high doses of organic fertilizers are also required for best results.

GHG emissions from nitrogen fertilizers in the agricultural sector are approximately 20.1 million t CO_2-e $year^{-1}$. They account for approximately 22% of total emissions from the agricultural sector (Susilawati *et al*. 2021), excluding emissions from land-use change and peatlands. Nitrogen fertilizer emissions include fertilizer applications in paddy fields and perennial crops (including plantation crops). There is no data on the proportion of nitrogen fertilizers for annual crops in the upland.

Other source of emissions from upland agriculture based on annual crop farming practices comes from burning biomass for land clearing. The ash from burning biomass obtained by farmers can be used as a source of nutrients and to increase soil pH. Emissions from burning biomass are approximately 123 t CO_2-e $year^{-1}$, which is less than 1,165 t CO_2-e $year^{-1}$ of biomass burning in rice fields.

Annual upland farming may also generate emissions due to the accelerated decomposition of organic matter stored in the soil due to the effects of intensive farming. The IPCC (2021) states that the emissions from intensive tillage of upland are 0.1 times higher than minimum tillage. Another source of emissions from upland is erosion. Erosion not only plays a role in the transfer of organic matter, but also contributes to greenhouse gas emissions. About 20-30% of the organic carbon carried by erosion or runoff is also emitted and releases greenhouse gases into the atmosphere (Lal 1995; Lal 2003; Jacinthe and Lal 2001) (Figure 5.5).

Figure 5.5. Sources of emission from upland agriculture: Urea application (left), and Biomass burning (right)

Adaptation strategies & mitigation co-benefits

Apart from being an agricultural sub-sector vulnerable to climate change, annual upland farmers' adaptability is relatively low, both from a technical and socio-economic aspect, compared to other agricultural sub-sectors. Therefore, specific adaptation strategies are required to ensure the sustainability of agriculture. Agricultural sector policies dealing with climate change are prioritized in adaptation strategies, particularly those capable of producing generating co-benefits of mitigation. In addition, the policy could support contributions from the agricultural sector to mitigate GHG emissions. Some adaptation strategies may not lead directly to mitigation co-benefits, but they should still be chosen to support the sustainability of annual upland crop productivity. Some of the tools to support the annual upland agricultural adaptation strategy are as follows:

Water management

Water management is an important to optimizing annual upland. According to Heryani *et al*. (2003), upland productivity can potentially be optimized provided that: (1) water availability problems should be minimized, (2) the natural and artificial water storage capacity of the watershed can be maximized, and (3) water use efficiency and the type of commodity cultivated can be optimized.

Implementing techniques such as rain water harvesting and runoff are options to reduce fluctuations in water availability in upland. Several water harvesting techniques have been implemented in upland, such as channel reservoirs in cascade, water reservoirs, micro-ponds, and long storage (Figure 5.6). The distribution of supplemental irrigation equipment should accompany water harvesting implementation techniques to compensate for crop water deficiencies (Figure 5.7).

Through water harvesting, runoff and supplemental irrigation techniques, the growing season for annual crops is no longer limited to the rainy season as it can be extended into the middle of the dry season. In addition, the risk of water shortages as a result of climate change can also be reduced. Several findings suggest that the effectiveness of water harvesting techniques in parallel with supplemental irrigation can improve cropping index, land area and crop productivity (Irianto *et al*. 2001, Pujilestari *et al*. 2002; Heryani *et al*. 2001, 2002a, 2002b, 2006; Dariah and Heryani 2014).

Besides optimizing storm water and runoff for land management, groundwater can also be used for annual crop agricultural management. Drilling wells and pumps can use groundwater to irrigate annual crops. The use of solar pumps employs a low-carbon technology as it reduces the use of fossil fuels (Fig. 5.8). However, the

Figure 5.6. Water harvesting: reservoirs (left) and channel reservoirs in cascade (right)

Figure 5.7. Irrigation in annual upland agriculture: big gun sprinkler (left), drip irrigation (middle) and furrow irrigation (right)

Figure 5.8. The use of solar pumps on vegetable fields in Central Java

technology requires expensive initial investment and capacity building for farmers to ensure the technology is sustainable.

Water Use Efficiency (WUE) is an essential aspect of water management that can support climate change adaptation, particularly in upland areas, where the main limiting factor is water availability. WUE describes the crop yield per unit of water, which is important for water resource management and climate change adaptation, especially in upland. Haryati (2011) mentions several techniques to improve WUE, such as land configuration (gulud and ditches, beds, border strips, terraces, surjan, water harvesting techniques), agronomic practices (how to cultivate the soil), alley cropping systems, weed control, intercropping systems, strip cropping/vegetative barriers, and mulch. Some of these practices are considered soil and water conservation measures, meaning that soil and water conservation is intended to prevent erosion and improve water use efficiency.

Soil conservation

The application of soil and water conservation in the era of climate change is becoming increasingly important. Soil conservation is not only a tool to prevent erosion and reduce land degradation but also a primary tool to improve adaptation, reduce carbon losses, and enhance carbon sequestration opportunities (Agus 2013, Agus *et al*. 1999a, 1999b; Agus 2000). Various conservation techniques have been developed in the annual upland farming area. Until the 1970s, physical soil conservation techniques, particularly bench terraces, were widely developed in annual highland agriculture, especially on Java Island (Figure 5.9).

Figure 5.9. Bench terraces in annual upland agriculture in Java Island

After the 1970s, vegetative conservation techniques were prioritized (Figure 5.10). These techniques were relatively inexpensive and suitable for shallow soils and acidic upland. Vegetative conservation techniques can also provide mitigation co-benefits, reducing C loss and offering the opportunity to increase carbon sequestration. Combining physical soil conservation techniques with vegetative conservation techniques is recommended to improve efficiency.

Some regions have indigenous knowledge classified as soil conservation techniques. For example, in several areas of Java, many stone terraces are found in areas with higher rock content. Farmers in East Nusa Tenggara practice tabatan watu, or rock arrangement cutting slopes. In addition, they practiced kebekolo, arranging branches along the contour direction or cutting slope (Fig. 5.11).

Conservation tillage (minimum or no-tillage) is also an adaptation technique that can result in mitigation co-benefits. The adaptation strategies of conservation tillage lead to efficient use of the growing season. Conservation tillage combined with mulch application can control water loss and maintain optimal soil temperatures for plant growth. The mitigation benefits of conservation tillage are to reduce the loss of soil carbon sequestration, and when combined with organic mulching, conservation tillage offers the opportunity to increase carbon sequestration.

Figure 5.10. Vegetative conservation techniques: Alley cropping (left), and Grass strip (right)

Figure 5.11. Indigenous knowledges of soil conservation: Stone terraces in Java island (left), "Tabatan watu" in East Nusa Tenggara (middle), and "Kebekolo" in East Nusa Tenggara (right)

Organic matter management

Optimizing the use of organic materials is one of the main tools for improving the adaptability of annual upland farming, which can also have mitigation co-benefits. The average upland organic matter content has declined, causing most of the soils in the uplands to suffer from soil degradation. This condition affects the decline in water-holding capacity, resulting in inefficient water use. The application of organic matter is very beneficial for improving soil properties (physical, chemical, and biological soils) while also increasing carbon storage (Dariah 2013).

Even though the potential sources of upland organic matter are available, the application of organic matter in annual upland farming has not been optimal. Table 5.1 shows the potential of organic matter as a fertilizer or organic soil amendment. Based on the harvested area of BPS data (Biro Pusat Statistik 2019) and assuming the proportion of the harvested area in the upland, the potential for dry biomass produced from upland rice, corn, soybeans, peanuts, green beans, and cassava in the upland is approximately 22.5 million t year^{-1}.

Assuming the amount of biomass returned to the soil and the carbon/biomass ratio listed in Table 5.2, the potential C returned to the soil is around 8 million t year^{-1}. Besides plant residue biomass, manure is another source of organic matter in annual upland farming. The nutrient content of manure is relatively high. In addition, manure production is relatively high, with BPS data (2019) showing that the number of cattle (beef and dairy) in Indonesia is around 17.5 million.

Table 5.2. Harvested area and biomass potential from food crops on average five years (2010-2015)

Commodity	Harvested area (ha) [1]	Estimation harvested area from upland (%)	Estimation harvested area from upland (ha)	Potential productivity of dry biomass [2] (t ha^{-1})	Total of potential dry biomass [3] (t year^{-1})
Upland rice	2,041,295	100	2,041,295	3.04	6,960,817
Corn	3,899,976	60	2,339,985	4.00	9,430,141
Soybeans	605,212	30	181,564	1.05	272,346
Peanuts	532,051	70	372,435	2.00	729,973
Green beans	236,674	50	118,337	1.01	130,171
Cassava	1,086,099	100	1,086,099	4.06	4,996,055
TOTAL	8,401,308.5		6,139,719.5		22,519,508

Note: [1]Biro Pusat Statistik (2019); [2] Nurida and Jubaedah (2015), [3] column 4 x column 5

Table 5.3. Carbon potential from biomass of food crop upland agriculture, national data

Commodity	Total of potential dry biomass (t year^{-1})	Assumed biomass returned to soil (%)	Biomass as a source of C (t year^{-1})	Ratio of carbon/ biomass	Total C potential (t year^{-1})
Upland rice	6,960,817	70	4,872,572	0.6	2,728,640
Corn	9,430,141	80	7,544,113	0.6	4,149,262
Soybeans	272,346	100	272,346	0.5	138,896
Peanuts	729,973	100	729,973	0.4	306,589
Green beans	130,171	100	130,171	0.5	59,879
Cassava	4,996,055	50	2,498,027	0.4	899,29
Total	22,519,508		16,047,201		8,282,556

Note: Column 4= column 2 x column 3; column 6= column 4 x column 5

The amount of carbon that may be sequestered in soil depends on its use. As compost, the total amount of C potentially stored is relatively low. However, mitigation opportunities may increase if compost reduces the use of inorganic fertilizers (particularly nitrogen fertilizers) (Dariah 2013). When applying plant biomass residues as mulch (Figure 5.12), both surface mulches and vertical mulching (mulch inserted into the hole) require a longer time to decompose than compost. Therefore, it takes a long time for organic matter to release carbon, followed by a low replacement capacity of organic fertilizer. The application of organic matter as biochar is a mitigation method since biochar can be stored in the soil for long periods, up to hundreds of years. Easily decomposable organic matter is used as raw materials for compost. On the other hand, organic materials that are difficult to decompose, such as rice husks, corn cobs, and cassava stems, are better suited for biochar. Organic materials such as straw or corn biomass can be used as mulch.

Manure is another source of organic matter that could play the role of fertilizers, organic soil amendment, and carbon sources other than plant residues or plant waste. According to BPS data ((Biro Pusat Statistik 2019), the number of beef cattle is > 17 million, and the number of dairy cattle is > 500,000. The manure production of adult cows is about 15 kg fresh weight head^{-1} day^{-1}, but after the composting process, 15 kg fresh weight manure becomes 3-4 kg compost. For cattle in the barn, it is assumed that around 50% of the manure is available, which results in 19-25 million t year^{-1} of manure. Compost can be significant when counting manure from buffalo, goats, sheep, and chickens.

Setting cropping patterns and utilizing other adaptive agricultural facilities

Setting planting patterns is an option to increase the adaptability of annual upland farming. Intercropping and relay cropping are cropping patterns that can optimize the use of rainy seasons, especially in areas with relatively short rainy seasons or extreme climatic conditions that have been common recently. Intercropping

Figure 5.12. Returning crop residues (mulch) as a source of organic matter to maintain soil moisture and increase soil carbon Vegetative conservation techniques: Alley cropping (left), and (b) Grass strip (right)

Figure 5.13. Composting process (left) and biochar production using the kontiki system by farmers (right)

is a cropping system in which two or more crops are grown simultaneously in a single growing area at the same time. Relay cropping is a cropping pattern in which crops are planted before the existing crops are harvested, usually when a crop in the intercropping system has a relatively short lifespan compared to other crops. Other adaptation methods include abiotic stress-resistant varieties (drought-resistant, disease-resistant, shorter lifespan), soil amendments (like hydrostock or hydrogels) for water storage or increased water retention, and mineral soil amendments (like zeolite).

Biofertilizers are also a means of adaptive agriculture and have the potential to provide mitigation co-benefits. For example, biofertilizers containing nitrogen-fixing microorganisms and exopolysaccharide-producing microorganisms can reduce nitrogen fertilizers and improve soil structure. Biofertilizers containing decomposing microorganisms are adaptive agricultural strategies due to their role in organic matters, mainly composting. Biological disease prevention is also one of the strategies of adaptive agriculture.

Closing

Upland plays an essential role in Indonesian food supply. It is referred to as the second food land after the paddy fields as it meets half of the national food, especially for corn and soybeans. However, upland agriculture especially for annual crops, is very vulnerable to climate change as its water needs are highly dependent on rainfall. The adaptation strategies that need to be applied in upland areas are water management techniques, conservation techniques, optimal use of organic matter, selection of cropping patterns, and other adaptive technologies. Most of these adaptation strategies are also capable of generating mitigation co-benefits.

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6

Developing Perennial Crop on Upland Agriculture amidst Climate Change

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Indonesia has numerous important commodities of the perennial crop for food, energy, and industries, needed by national and global markets. With the increasing number of human populations, the demand for certain perennial crop products, such as palm oil, cocoa, has increased, leading to expansion of agriculture lands both at small and large-scales. Perennial crops in Indonesia are cultivated in a wide range of management levels, from traditional, low input management to very intensive agro-industry systems. The management levels determine the yield and the efficiency of land and labor.

In general, perennial (tree) crops are more resilient to extreme weather and climate change relative to short rooted annual crops. However, it is not free from being negatively affected by climate change. The productivity of perennial crops is threatened by the global warming, extreme drought and floods, shortened rainy seasons and prolonged dry seasons. An important feature of perennial tree crops is that they have high carbon stocks. Unless its expansion is conducted on high carbon stock lands such as forests and peat lands, they contribute to enhancing terrestrial carbon stock.

This chapter provide the description of Indonesian perennial agriculture, climate change impacts on perennial agriculture, carbon stock and dynamics, and adaptation and adaptation co-benefits of perennial crop agriculture.

Description of Indonesia's perennial crop agriculture

Several perennial crop products from Indonesia dominate international market, which is supported by a large cultivation area. Based on current official statistic data from Directorate General of Estate Crops, Indonesia Ministry of Agriculture (2020), Indonesia was listed as the largest palm oil producer, with the largest plantation area in the world. In 2020, Indonesia had 14.8 million ha of oil palm plantations area, which means more than 200 times the land area of Singapore. The plantations are distributed mainly in the islands of Sumatra, Java, Kalimantan and Papua. Rubber is another important commodity from Indonesia which had second domination in the global rubber market. Rubber plantation area is 3.7 million ha distributed over Sumatra and Kalimantan Islands. Opposite from oil palm, the area of rubber plantations tends to decrease with time due to relatively low and declining price and high labor demand.

Pepper was one of the most famous commodities that had attracted European explorers to trade and colonize in the past. Pepper is cultivated in Indonesia on 0.2 million ha area and Indonesia is the second largest producer in the world based on 2020 data. Cacao production from Indonesia is the third largest at the global market, originating from 1.5 million ha area spread over Sumatra, Sulawesi, and Java islands. Meanwhile, coffee and clove are other important commodities and Indonesia is listed as the fourth largest world producer of both commodities. Plantation areas of coffee and clove are 1.2 and 0.6 million ha, respectively. Moreover, Indonesia is the seventh largest tea producer in the world, with land area of 0.1 million ha which is dominantly found in Java Island. There are many other important perennial crop commodities including coconut, cashew, sago, sugarcane, tobacco, patchouli, cotton, and candlenut, which all distributed over 4.6 million ha area in Indonesia.

The plantations area managed by smallholders, government estates, and private estates. For example, the area of oil palm plantations owned by the government, private companies, and smallholders is 4%, 55%, and 41%, respectively (Figure 6.1.). This shows that private estates and smallholders have a dominant contribution in driving the national palm oil industry. Meanwhile, the rubber estates area is dominantly owned by smallholder farmers (89%), while the rest is owned by the government and private estates.

Perennial crops contributed 26.5% to the Gross Domestic Products (GDP) of the agriculture-forestry-fishery sector (Directorate General Estate Crops 2020). The contribution almost unaffected by COVID-19. The perennial crop industry drives the rapid increase of rural development and also the welfare of people in rural areas (Sayer *et al*. 2012).

Most of the perennial crop estates in the upland area are located outside Java Island which is dominated by hilly to mountainous landforms. The crops grow on upland acid soils that are prone to erosion hazards, low organic matter, low macro and micronutrients, and high toxicity

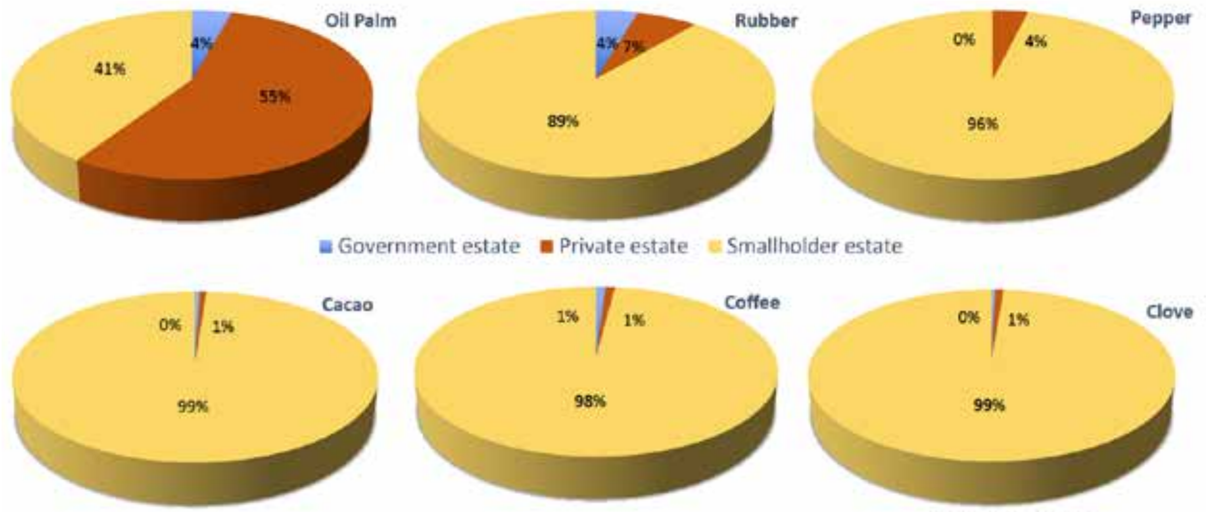

Figure 6.1. Plantation areas own and managed by the government, private companies, and smallholder

Figure 6.2. Oil palm grown on undulating to hilly landscape (left, from www.gimni.org); typical smallholder plantations (middle) and a soil profile of oil palm plantation in Rokan Hulu Disrict, Riau Province with the soil type Typic Hapludults (right)

of Al, Fe, and Mn (FAO 2005). Naturally, the Indonesian monsoon climate and tropics circumstances cause land degradation that takes place more quickly than in the sub-tropic region. This land degradation causes the productivity of perennial crops. Agriculture intensification program to increase crop productivity is one solution to reduce the rate of expansion of perennial crop areas. However, the agriculture intensification program poses a big challenge due to the lack of capacity and capital, especially among the smallholder farmers.

Burning practice for any purpose is strictly prohibited in Indonesia (Sofiyuddin *et al*. 2021). Land preparation for plantations crops is undertaken by cutting down the old crops or by clearing vegetations of other land uses such as shrublands. In the early growth period, perennial crops, especially those under smallholder plantations, were intercropped with food crops such as rice and corn. This intercropping system is beneficial for subsistence purposes. After the canopy of the perennial crop became denser then the intercropping is no more economical due to shading.

Climate change impact

Agriculture sectors including perennial crop plantations have a unique position amidst the climate change. It is one of the victims of climate change, but, depending how it is managed, it could mitigate significant amount of carbon if it replaces low carbon stock lands such as shrubs or grassland, but it could also cause a major source of CO_2 emissions if it replaces high carbon stock lands such as forests or peatlands. Other sources of GHG emissions associated with perennial crops, include soil respiration, biomass burning (a practice that is strictly banned nowadays), and fertilizer use, especially nitrogen fertilizers. Biomass C could be released into the atmosphere when it is subjected to burning, or with time it's decomposed. Fertilizer contains substantial elements to provide nutrients for plants; however, excessive use of fertilizers will promote the release of C (from urea) and N (from N fertilizers) into the atmosphere in the form of CO_2 and N_2O, respectively. The residue of fertilizer may also pollute the surrounding ecosystem. Furthermore, as the biggest industry of perennial crop in Indonesia, the Palm Oil Mill Effluent (POME) is also an important source of CH_4 emission, if the POME is managed in a conventional way. Other activities that may contribute to GHG emission from estate industry include transportation with carbon based fuels.

The growth and productivity of perennial crops are very vulnerable to climate change such as temperature increases and climate variability, while the impact scale depends on agroecological circumstances.

CO_2 increases

Climate change is associated with elevated CO_2 concentration in the atmosphere. On the other hand, CO_2 is an important element for photosynthesis (Way *et al*. 2015), meaning that glucose formation increases with the increase CO_2 concentration. In general, the raising CO_2 concentration led to preserve higher performance of carbon assimilation even in high temperature (Martins *et al*. 2014). However, the response of perennial crops to this elevating CO_2 varies, depending on species characteristics and other environmental factors such as water, nutrient, temperature, and humidity (Pirker *et al*. 2016; Corley & Tinker 2015; Rodrigues *et al*. 2016; Rahn *et al*. 2018). The increased atmospheric CO_2 level scenario over the 21st century could improve oil palm yield significantly by up to two third of the current figure (Corley and Tinker 2015). However, this elevated CO_2 concentration has no effect on growth of hardwood plantations (Wesolowski *et al*. 2020; Ellsworth *et al*. 2017; Battaglia and Bruce 2017). In these circumstances, no clear evidence of interaction between coffee yield and the raising CO_2 level; although the bean quality was found to be preserved well in higher CO_2 level (Ramalho *et al*. 2018).

The increased carbon dioxide levels is usually followed by the increased temperature which could offset the losses in crop yield due to the latter. However, the interaction effects between these are still not clear (Long *et al*. 2006).

Temperature increases

Climate change including the increased temperature that occurred around the world may affect the distribution of perennial crop cultivation areas (Golbon *et al*. 2018; Ray *et al*. 2016, Arshad *et al*. 2013). The expansion of perennial crop area was projected to the direction of higher elevation areas. In general, all perennial crop needs a suitable climate for them to optimize their growth and productivity but the increased air temperature cause a stress on plants and disrupt plant biochemical and physiological processes. Soil organic matter is substantial to improve water and nutrient availability for crops, but it is prone to accelerated decomposition under higher temperature. The drought causes water stress problems for crops in upland where soil becomes drier and this directly hamper the growth and productivity of crops. (Pirker *et al*. 2016; Corley and Tinker 2015; Paterson *et al*. 2015, Arshad *et al*. 2012). Moreover, crop biomass easily dry and flammable in high tempera-

Figure 6.3. Composting process of empty fruit bunch (left), pond of palm oil mill effluent (POME, middle), transporting fresh fruit bunch to manufacture by trucks (right). Pictures taken from www.infosawit.com

ture, increasing the risk of fire.

Climate variability

Rainfall variability in Indonesia is strongly connected to ENSO (Hendon 2003) and it would likely to increase until 2100 based on a modeling study by Cai *et al*. (2022). The effects of climate variability to perennial crops is questionable whether favorable or not. The warmer climate of El Niño is reported to reduce crop yield when the lack of water availability causes crop stress. In such a climate extreme, coffee production reduced around 10% (Syakir & Surmaini 2017) and so is with oil palm (Corley & Tinker 2015). On the other hand, the wetter climate of La Niña deteriorate coffee yield up to 80%, especially when it occurs in the flowering stage. The high intensity raindrops break the coffee flower, causing the failure in coffee production (Syakir & Surmaini 2017). The increased flood frequency during La Niña raises the risk of crop failure. Moreover, high-intensity rainfall on sloping land causes soil erosion and water runoff that removes topsoil, the most favored layer for the plant, from the upper to the lower slope areas. This soil erosion causes land degradation and reduces crop yield significantly.

Fortunately, the spatiotemporal distribution of rainfall generally is advantageous in some areas where the water availability increases in the previously drier areas. Arshad *et al*. (2012; 2013) reported the future climate variability increases suitable areas for oil palm, and rubber. In other places when rainfall becomes less, the productivity of perennial crop reduced significantly and no longer profitable.

The extreme rainfall season may also affect pests and diseases infestation of perennial crops although this effect is still unclear and vary by location (Paterson *et al*. 2013, 2015). Differing environmental conditions may be less suitable for pests and diseases, which would allow yield to improve. However, there is particular uncertainty regarding pests and diseases in possible new locations for oil palm. When conditions are sub-optimal for oil palm, such as when temperatures are high or there is limited water availability, palms may be less able to resist pests and diseases, and hence causing yield decrease.

Carbon dynamics related to perennial tree crops

When perennial tree plantation is established, it's likely started with clearing the land. During and shortly after the clearing, the amount of stored carbon in the biomass that is emitted depends on the initial land cover. Forests store high amount of carbon and hence will lose high amount of C during land clearing. Shrub and grassland store low amount of carbon (mostly lower than the carbon stocks of most perennial tree crops), and hence their clearing will release less CO_2.

When it is cut for plantation preparation, most of the biomass rots and eventually emits as CO_2. Some of the wood may be processed as timber, and in turn, form furniture. In this case,

Figure 6.4. Preparation for replanting by felling and chopping of old palms (left), oil palm seedling in the nursery (middle), young palms (right). Pictures taken from www.kaltim.tribunnews.com (left), www.infosawit.com (middle), www.pkt-group.com (right)

the stored carbon is conserved for a longer period of time (10-20 years). Otherwise, the left over biomass in the field may be decomposed within about a year or else be burned – a process of rapid CO_2 formation.

When the seedlings of the perennial trees are planted, it started with near zero carbon stock. Gradually carbon accumulates in the biomass and reach the peak level at maturity. When the next replanting takes place, similar process occurs, where the biomass of the old palm decomposed after felling and gradually the transplanted palm accumulate carbon until maturity. IPCC (2019) assumes the mean biomass C stock of a cycle system such as plantation, as carbon stock at maturity divided by 2. For example, the default Tier 1 mean biomass C stock of the oil palm plantation is 30.0 t C ha^{-1} ± 41%, while for rubber plantation is 40.1 t C ha^{-1} ± 15%, and tea plantation are 18.3 t C ha^{-1} ± 25% (IPCC 2019).

These carbon stock data are used in the national GHG inventories, as well as in assessing GHG emission reduction from perennial estates towards sustainable agriculture. While Tier 1 provides generic carbon stock (emission factors), using Tier 2 or Tier 3 based on country-specific data is encouraged by the IPCC, as the higher tier associate with a higher certainties.

Adaptation strategies & mitigation co-benefits

Adaptation strategies

One of the adaptation strategies is the use of environmental stresses-tolerant plant species. Plant breeding and biotechnology become important tools to produce high productivity crops in a high-pressure environment. Adaptation action is also carried out by planting of taller shading trees than the main tree crops, and intercropping of annual crops, forming a multi-strata system. This system is well suited to sloping areas that pose soil degradation and promises to ease pressure from the adjacent forest by providing firewood, timber, and other product from the shading tree component. The various wood trees grown in plantation areas increases C sequestration. Example of these include coffee agroforestry, silvo pasture systems, and traditional home garden. Establishing multistrata system usually done gradually under smallholder farmers. Another adaptation action is practicing intercropping system between perennial and food crops. This intercropping system can be carried out for 1-2 years until the canopy of the perennial crop grows and becomes dense.

The use of environmental-friendly technology in perennial crops cultivation, such as biopesticides, bio-fertilizers, and compost, has increased over time. This smart adaptation action reduces the risk of environmental degradation and human health, and increases crop productivity. The waste of the perennial crop industry can be used to produce compost and animal feed. Thus, the livestock population can be increased in the estate through a national program of crop-livestock integration. In this case perennial crop contribute to both animal fat and protein supply.

To achieve a decent economic level from the farm, farmers prefer to enlarge the plantation areas than implement an intensification program. Currently, the Indonesian productivity of the estate crop is below its potential level. Crop productivity is the key to increasing yields as well as farmer's income. The intensification program through implementing best management practices to cultivate the crops is believed to solve many problems from farmers' income, land use efficiency, and avoidance of deforestation. Crop intensification programs and other adaptation strategies will be more successful if they are supported by suitable partners. For this reason, it is necessary to conduct capacity building and empowerment programs for smallholders including women, local and indigenous communities. More knowledgeable and skillful farmers are much easier to survive and adapt to climate change.

Mitigation strategies

One of the mitigation actions in the perennial upland farming in Indonesia is performed by issuing official regulations to prohibit deforestation and biomass burning in land clearing. The implementation of this regulation began with socialization, education, and finally law enforcement in the field. Preventive and educative approaches by respecting local culture are prioritized over repressive approaches. On the other hand, people need to access the innovation of no-burning technology as compensation for the official fire restriction.

The Ministry of Agriculture of Indonesia organized and trained local community groups including farmers to be able to manage and control fire. This trained group called the Brigade of Land and Estate Fire fighter (Brigade Pengendalian Kebakaran Lahan dan Kebun), exists in all provinces that are prone to fire. To increase the awareness of people to practice sustainable agriculture including land fire prevention, dissemination, and capacity building are scheduled simultaneously.

The utilization of waste becomes very important to reduce environmental damage including GHGs emissions. Methane emissions from POME have great potential as a source of biogas. Methane utilization technology from POME continues to be developed and disseminated. GHGs emissions from the perennial crop industry can also be suppressed by storing C in terrestrial for a long period of time. This can be done by planting trees with long crop cycle. In the conventional ways, the old and unproductive crop were removed and gradually decomposed, yielding CO_2 into the atmosphere. Recent innovation converts those biomass waste to high-quality furniture, and hence increasing the economic value, and maintain carbon in the furniture for 10-20 years period. Thus, the plantation sector can reduce emissions significantly and contribute to the achievement of sustainable development goals.

Figure 6.5. Rubber-pineapple intercropping under rubber (left), coffee-based multistrata (middle), oil palm-cattle integration (right). Pictures taken from www.balingtan.litbang.pertanian.go.id (left), www.prcfindonesia.org (middle), and www.infosawit.com (right)

Figure 6.6. The unit of Brigade of Land and Estate Firefighter (left), methane capture from palm oil mill effluent (middle), the use of oil palm trunk as furniture (right). Pictures taken from www.borneo24.com (left), www.bppt.org (middle), and www.kompasiana.com (right)

Closing

Perennial tree farming is relatively more adaptable to climate change. However, under extreme climate conditions the perennial tree growth and production is also affected. In the tropics, the land suitable for perennial tree crops may extend to a higher elevation. This pose a threat to the environment as higher elevation areas are likely to be more sloping. Perennial tree crops store high carbon, at least higher than those of shrublands and grassland. Hence limiting perennial crops expansion to the low carbon stock areas can contribute to mitigation. Nevertheless, sustainable intensification is preferable than land expansion, as this can increase the efficiency of land and minimize the pressure for expansion.

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Recover together
Recover stronger

7

Agriculture on Wetlands: A Fragile System Requiring Wise Management Systems

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Wetland is generally defined as areas that are strongly influenced by the water regime, tidal movements of rivers or seas, inundation due to rainfall or shipping flooding, flat to basin topography, poor drainage, waterlogged, and problem soils such as acid sulfate soil, saline soil, and peat soil. Wetland is a unique ecosystem which highly dependent on surface water existence. According to the Ramsar Convention, signed in 1970, wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters. Wetlands, especially peatlands and mangroves, play an important role in climate change because of their ability to regulate the concentration of greenhouse gases (GHG) in the atmosphere (IPCC 2007).

The area of wetland in Indonesia is about 43 million ha or 23% of the total land area of Indonesia i.e ± 191.09 million ha, spread over major islands, Kalimantan, Sumatra, and Papua, a small part of Sulawesi, Java, Nusa Tenggara and Bali (BBSDLP 2015). Indonesia's wetlands are an essential ecosystem on earth, supporting ecological and hydrological services as well as basic necessities for humans and wildlife. Indonesia's tropical peatlands and mangroves are among the largest terrestrial carbon pools on Earth (Murdiyarso *et al*. 2010). These tropical wetlands are of great interest because of the numerous ecosystem services at risk and the extensive greenhouse gas emissions that arise since land-use conversion, especially for agriculture, often raises environmental issues at the national and global levels.

A few decades ago before the 1920s Indonesia's coastal wetlands such as tidal swampland, mangroves, freshwater swampland, and peatlands in Sumatera and Kalimantan were spontaneously opened and settled by surrounding communities Bugis people from South Sulawesi, Banjar people from South Kalimantan, and Malay people from Riau and West Kalimantan to cultivate annual crops (rice, secondary crops, horticulture), perennial crops (coconut, rubber, citrus, coffee, oil palm) and fish ponds. (Tejoyuwono 1998; Suwardi *et al*. 2005), The community has divided land use zone into residential zones, shrubs, former fields (jurungan), fields (pahumaan), plantations, and sacred zones (Suwardi *et al*. 2005). They selected the better land on the low broad natural levees of big estuaries, avoiding carefully the too deep back swamp peat soil. Since 1950, the government has built swamp irrigation networks in Kalimantan, Sumatra, Papua, and Sulawesi with various reclamation systems, including the canal system in South Kalimantan and Central Kalimantan. The increasing population over time with their activities affects the increased pressure on wetlands (Ward 2022; Wittmann *et al*. 2022). Climate change deteriorates the scale of wetland pressures with regard to the diversity of wetland types and their characteristics (Li *et al*. 2021).

The current global climate change is a problem and a challenge for the agricultural sector, especially in the process of crop cultivation systems. Agricultural sectors are extremely vulnerable to climate change. At the same time, the agricultural sector is one of the sources of greenhouse gas emitters, such as those from land clearing, fertilization, agriculture practices on peatlands, livestock activities, and so on. Indonesia's agriculture sectors contribute to around 8 % of the total national emission (MoEF 2018). Hence synergizing mitigation and adaptation strategies and measures in tropical wetlands is a key approach. Co-benefits between adaptation and mitigation may be derived from the conservation of standing natural forests, such as biodiversity, aesthetics, ecotourism, non-timber forest products, and restoration of degradation areas are additional potential financial incentives.

Description of Indonesian wetland

According to the Government of Indonesia Regulation (PP 73/2013), the swamp is a container of water along with the water and water strength contained therein, inundated continuously or seasonally, naturally formed on relatively flat land or basins with mineral deposits or peat and overgrown with vegetation, which is an ecosystem. Therefore, the swamp is a wetland, but a wetland is not just a swamp. According to BBSDLP (2014), the wetland is land that inundated with water, either continuously or seasonally, has soft characteristics, and overgrown with aquatic plant vegetation. Swampland is the most extensive wetland owned by Indonesia.

Wetland is divided into three main groups, namely (1) coastal and marine wetlands; (2) mainland wetland, and (3) artificial wetland. Artificial

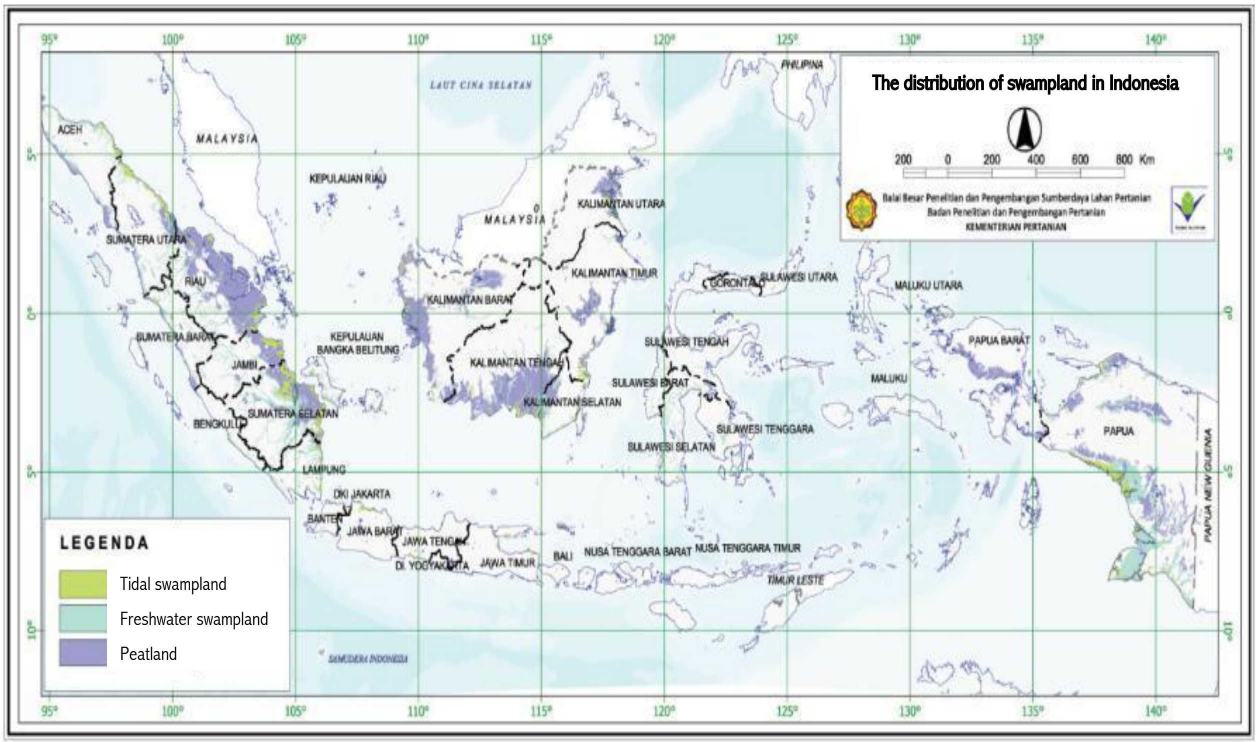

Figure 7.1. The distribution of swampland in Indonesia (BBSDLP 2014)

wetland is a group that considered a dilemma because its development is absolutely necessary to fulfill the life of the population such as food and other agricultural products, but its development is the cause of the reduced function and natural value of wetland. Therefore, its development requires good and proper management (Puspita *et al*. 2005). In the context of land resource development, divides wetland as (1) swamp wetland and (2) non-swamp wetland (BBSDLP 2014). Non swampland wetlands is generally closely related to their use as rice fields.

It is estimated that around 34.91 million ha of swampland are spread over 22 of 34 provinces, of which 14-19 million ha of swampland are suitable for food production (BBSDLP 2014), 13.4 million ha of which are peatlands (Histosols) (Anda *et al*. 2021). The largest swampland area is in Sumatra island (12.93 million hectares), followed by Kalimantan island (10.02 million ha), Papua island (9.87 million ha), and Sulawesi island (1.05 million ha) (BBSDLP 2015).

Land suitability and utilization

Euroconsult (1984), reported that 17.77 million ha of 23.75 million ha swampland was suitable for agriculture. According to BBSDLP (2015) there were 14 million ha suitable for agriculture from 34.12 million ha of swampland. Meanwhile, 3.0-3.5 million ha have been opened by the government or private-owned enterprises, consisting of 0.5-1.0 million ha for rice field or food crop and 2.0-2.5 million ha for plantation. In addition, there were 3.0 million ha which have been opened by the community independently for rice field and plantation. Therefore, there is still a huge area of swampland available for agriculture development. Table 7.1 shows the area of tidal swampland with mineral soil as 11.38 million ha that potential for rice field while the area of peatland is very little or almost non-existent. The area of oil palm plantations at the end of 1997 was 2.9 million ha, increased in 2007 to 6.6 million ha and in 2009 reached 7.2 million ha with an increased rate of 10% per year. According to a Wetlands International report, 20% of oil palm plantations in the Southeast Asia Region

Table 7.1. Potential area of swampland for rice field

Island	Swampland typology (million hectares)				Total
	Tidal swampland		Freshwater swampland		
	Mineral	Peat	Mineral	Peat	
Kalimantan	0.567	0	2.684	0.176	3.427
Sumatera	1.656	0.173	3.620	1.402	6.851
Sulawesi	0.010	0	0,671	0	0,681
Papua	0.286	0.032	1.819	1.082	3.219
Maluku	0.011	0	0.087	0	0,098
Total	2.530	0.205	8.881	2.660	14.276

Source: BBSDLP (2015)

(Malaysia and Indonesia) are on peatlands (Noor 2016).

Landscape

The advantage of peatland for agriculture includes: 1) easier tillage due to the physical nature of the porous soil compared to mineral soil, 2) absorbs and/or stores high levels of water, 3) as long as it is not dry/unburned, the soil chemical properties are quite good, 4) rarely experiences iron or aluminum toxicity as generally swamp mineral soils, 5) high carbon reserves, thereby reducing greenhouse gases emissions if managed properly, 6) the availability of land that has not been cleared and suitable for agriculture is still wide. Of the 14 million ha, only 2.5 million ha have been used, and 7) the availability of land that was abandoned due to technical and social factors so that it became a large bare land (4 million ha)

Soil type

Some of the soils in swampland are influenced by wet conditions and the main constituent materials so that, some types of soil are specific. For example, the aquic properties, which is the inherent nature of the soil formed in the swamp ecosystem. Based on the national soil classification, the soil in swampland is mostly gleisols, alluvial, and organosols (Subardja *et al.* 2016). Gleisol is swamp soil that has begun to show cross-sectional development, characterized by the formation of rust on its cross-section. Meanwhile, alluvial soil is swamp soil that has not shown the development of cross-section and the presence of material stratification. While Organosol or often also called peat soil is swamp soil formed from organic matter. In the Soil Taxonomy, the swamp is classified into the order histosols, entisols and inceptisols categories (Soil Survey Staff 2014). Types of soils in swampland are presented in Table 7.2. Soil types/land typologies in swampland include 4.32 million ha entisols, 2.37 million ha inceptisols, and 14.90 million ha of histosols, while on freshwater swampland is entisols and incetisols with 13.26 million ha.

Land use & management of swampland

The utilization of swampland or agricultural cultivation, especially food crops (rice) has been carried out for a long time. With the increasing need for swampland products and the development of management technology, swampland has also developed for several commodities such as annual food, horticulture crops, plantation crops, as well as fisheries, and livestock. The management of swampland for annual crops, perennial horticultural, and plantation crops will be discussed further.

Table 7.2. Soil types on swampland

No	Ordo	Sub order/great group	Land typology	Area (hectares)	Proportion (%)
1	Entisol	Sulfaquent/Typic Sulfaquent	Acid sulphate Potential	1,132,750	3.39
		Sulfaquent/Histic Sulfaquent	Potential acid sulphate associated with peat	66,000	0.20
		Sulfaquent/Haplic Sulfaquent	Potential acid sulphate associated with silty saline	997,430	2.99
		Sulfaquent/Hydraquent/Haplic Sulfaquent	Potential acid sulphate associated with saline	2,127,800	6.37
2	Inceptisol	Sulfaquept/Haplic Sulfaquept	Actual acid sulphate associated with saline	2,374,000	7.11
3	Histosol**)	Saprist	Shallow peat	5,241,437	35.16
		Saprist- Hemist	Mediun peat	3.915.291	26.27
		Hemist-Fibrist	Deep peat	2,763,475	18.54
		Fibrist	Very deep peat	2,985,371	20.03
	Total***)			21,603,554	100.00

Source: processed from *) Nugroho *et al*. 1992 and **) BBSDLP (2011); ***) not including the mineral soil in freshwater swamp 13.28 million ha.

Swampland management for rice

The management of tidal swampland for rice is still mostly done traditionally based on local knowledge and local wisdom. Generally, farmers grow local rice varieties with a long life cycle of about 9-10 months, so that only one crop cycle can be cultivated annually. With the Green Revolution which was started in the late 1960s in Indonesia, new high-yielding varieties were introduced. Recently Inpara 2, Inpara 3, Mekongga, and Ciherang have been introduced on acid-sulfate tidal swampland (Simatupang *et al*. 2017). Several other varieties have also been reported (Mamat and Sukarman 2020). However, local varieties are still maintained by the communities. The slender shape and tender taste of rice, high adaptability, relatively high resistance to pests and diseases, and the higher selling price compared to high yielding varieties have caused local farmers to still cultivate them, despite the relatively low yield of 3-4 tonnes ha^{-1}(REF).

Peatland is a type of soil that has long been used by the community to produce food crops. Shallow peat (< 100 cm thickness) can be utilized for annual crops including rice (Noor *et al*. 2017). Water and soil fertility management are critical for the success of peatland farming (Nusyamsi *et al*. 2020; Noor and Sosiawan 2020).

Swampland management for other annual crops

In the program to increase the production of national food crops, corn and soybeans are food crops that are cultivated in swampland other than rice. According to, Maize and soybeans can be cultivated on tidal swampland both on mineral and peat soil, on types C and D swamplands towards the end of the rainy season and during the dry season (Simatupang *et al*. 2017). Planting in the dry season requires water management by applying a block system called dam overflow (locally called tabat) to maintain the groundwater level. In type B, maize and soybean can still be planted with the raised-bed (surjan) system after the rice harvest in the dry season.

Various vegetable crops (spinach, celery, long beans, cucumbers, chilies, and tomatoes) and fruits (oranges, papaya, bananas, and rambutan) are commonly grown on swamplands. Horticultural crops generally require a growth medium that is fertile, loose, contains lots of humus, has a pH of 5.5-7.0, and is not flooded. Meanwhile, swampland is very different from the conditions required by the requirements for growing horticultural crops. Therefore, the cultivation of horticultural crops in swampland requires technological innovations in the form of land preparation and arrangement, water management, adaptive types and varieties, amelioration, fertilization, and post-harvest.

The land arrangement is carried out by applying a raised-bed or gradual surjan (locally called tukungan) system. This system also functions as water management, coupled with an increase in water quality by adding lime or dolomite to the water which functions to increase pH, increase Ca and Mg concentrations, and reduce Fe concentrations, while increasing plant productivity (Raihana and Koesrini 2017). Application of Ca and Mg through dolomite (Ca-$MgCO_3$) can actually improve the quality of citrus fruits, including taste because it increases sugar and acid levels, and vitamin C (Antarlina and Noor 2011).

The application of rice husk biochar enriched with agricultural waste compost in swampland increased soil pH, reduce Fe toxicity, reduce methane (CH_4) emissions, and increased grain yield by 28%. As a soil amendment, biochar can act as an atmospheric carbon sink due to the conversion of bio-degradable carbon (biomass) into less degraded aromatic carbon (biochar) (Annisa *et al*. 2021).

Swampland management for annual crops

Swampland with mineral soil and deep peat soil (2-3 m thick peat) can be utilized for perennial crops. Annual crops that are cultivated and are in great demand in swampland are oil palm and rubber. Both of these plants are reported to grow well on peat with medium thickness (1-2 m), while coffee and cocoa can grow on shallow peat (0.5-1 m). According to Sabiham and Sukarman (2012) oil palm is a commodity that is able to adapt well to peatland. By applying appropriate water management technology, along with increasing the stability of peat material and CO_2 absorption by plants in oil palm development areas, the utilization of peatland will provide great benefits, not only for the present but also for the future.

Currently, the utilization of swampland for annual crops such as oil palm is mostly directed at degraded peatland. Technology to increase productivity is needed through water management, amelioration, fertilization, the use of decomposers, and cropping systems to increase the productivity of annual crops on peatland.

Figure 7.2. Raised-bed system for growing chili on medium freshwater swampland at Banjarbaru Experimental Station, September 2019

Water management in oil palm cultivation on degraded peatland is more problematic than on mineral soil because if it experiences drought it is irreversible, so its ability to hold water is reduced (Sosiawan *et al*. 2021). Water management must be able to create favorable conditions for various chemical reactions in the soil, wash out toxic elements, and slow down the process of peat subsidence. Therefore, water management is the key to increasing oil palm productivity. The best growth and productivity are obtained if the water level can be maintained at 60-80 cm from the soil surface.

The low productivity of oil palm on degraded peatland is due to low soil fertility and soil biological properties that are unfavorable for plant growth. Therefore, soil amelioration is needed to improve the chemical and biological properties, so that it can increase oil palm productivity by 0.34-0.61 tons ha^{-1} $month^{-1}$ (Masganti *et al*. 2019). Now, oil palm plantations in Indonesia reached 9.7 million ha, of which 2.0-2.5 million ha are in swampland. The average productivity of oil palm in swampland is low, but with technological innovation, it can be obtained 20 – 24 tons of FFB ha^{-1} $year^{-1}$ (10 years old). Oil palm productivity on peatlands was 19-25 tons FFB ha^{-1} $year^{-1}$ (Noor 2001; Noor 2004).

Swampland management for livestock

Livestock can be carried out on swampland, both tidal swampland, and freshwater swampland, and need to be matched to its land characteristics. Poultry can be cultivated in swampland, especially ducks and chickens, as well as for ruminants, namely cattle and buffalo. Taking care can be done either extensively or intensively depending on the scale of business, water depth, and type of livestock. An important aspect that needs to be considered is the adequacy and quality of feed. In tidal swampland, drinking water for livestock should be provided from well water instead of from drains to reduce sour taste and improve quality.

Cattle rearing on both tidal and freshwater swampland is carried out intensively due to natural conditions that do not allow them to be released into the wild. However, if there is open land where the soil is dense enough, livestock can be released for several hours to train their muscles and get enough sunlight (Rohaeni *et al*. 2017). Management integration between plantation crops and livestock has long been recommended, such as between oil palm and cattle to be more efficient and more profitable (Noor 2016).

Climate change impacts

Climate variability

The climate variability of ENSO (El Niño Southern Oscillation) which is caused by the changes in the sea surface temperature (SST) mainly affects rainfall patterns in Indonesia. By using the plausible IPCC model, ENSO is predicted to increase in the future due to global warming. This ENSO prediction is based on a scenario in which the increase of atmospheric greenhouse gas (GHGs) emissions cannot be cut as planned (Cai *et al*. 2022).

El Niño mode is driven by SST interannual variability. El Niño drought increases evaporation and then reduces water levels in wetlands (Stirling *et al*. 2020). The lowering water table exposes soil to aerobic conditions that accelerate organic matter decomposition rate, releasing GHGs into the atmosphere (Salimi *et al*. 2021). In peatland, El Niño causes groundwater to drop drastically and makes peat dry quickly, turning it into massive fuel for land fires. Peat fires during the 2015 El Niño were reported to cause massive damage both on land and in the atmosphere (Field *et al*. 2016; Parker *et al*. 2016). The fire was difficult to control and destructed wildlife habitats. Meanwhile, the haze was spread out to larger areas including neighboring countries, disrupting human health and human activities for weeks. This haze calamity affected economic loss on a local and regional scale (Voiland 2015). Moreover, the high temperature and the lack of rainwater supply during El Niño stresses the plant through the disruption of plant physiological tissues (Feng *et al.* 2021).

In general, agriculture production decreases during El Niño (Irawan 2013). However, the decreased level of inundated water in wetlands during El Niño drought creates ideal conditions for rice cultivation, especially in mineral soils with fluvio-marine and alluvial physiography (Ritung *et al.* 2020). Rice cultivation area increased significantly during the El Niño period in Indonesia's wetland areas (unpublished). However, the interaction between crops growth during El Niño and the high air temperature is not clear. The increase in heat intensity and duration during the El Niño event generally may disrupt plant tissue metabolism which has an impact on plant growth and productivity.

La Niña events increase the risk of flooding in the wetlands, which threatens to damage crops, property, and lives of people (Irawan 2013). The inundation phase in the wetlands during the La Nina event is longer than normal years. The higher level of water submersion compare to normal year inhibits crop cultivation. This water submersion creates an anaerobic circumstance, where the decomposition rate of the organic matter becomes slower. It means that GHG emissions, especially CO_2 gas, can be suppressed, while CH_4 emissions increase (Debanshi and Pal 2022; Mitsch and Mander 2018). In general, the exceeded rainfall during La Nina can preserve the carbon in the wetland (Salimi *et al.* 2021). The increase in humidity generally triggers pest and disease outbreaks in wetlands.

Seawater Level Rise

Global warming causes the melting of glaciers in the polar regions, thereby increasing the volume of ocean water in significant quantities and then raising the global sea level. The climate model using RCP (Representative Concentration Pathways) model scenarios predicts an average sea level rise of 26-98 cm (minimal emission scenario) to 93-243 cm (high emission scenario) in the year 2100 (Kopp *et al.* 2017). This seawater level rise threatens low-lying areas including coastal wetlands and small islands in Indonesia to be in danger of sinking.

Coastal wetland areas that have been used as residential and crop cultivation areas are vulnerable areas that are prone to sinking and are no longer able to be inhabited and produce agricultural products. With the vast area of agricultural coastal wetland in Indonesia (Ritung *et al.* 2020), the loss of them affects the problem of food security. Moreover, seawater level rise threatens hydrological functions, wildlife habitats, and human civilization in wetlands (Kopp *et al.* 2017; Martinez-Megías and Rico 2022; Adyasari *et al.* 2021).

When the sea level rises gradually towards the predicted level, it will be accompanied by an increase in salinity, both by increasing salt concentrations in groundwater and soils and the salinity penetration to the mainland (Forster *et al.* 2011; Wassmann *et al.* 2009). Crops will experience stress due to increased salinity and further interfere the crop growth and yields.

Temperature Increases

The increase in air temperature due to global warming has an impact on increasing the risk of drought in wetlands. The existence of wetlands depends on the availability of water, considers very vulnerable to the risk of drought. It was detected that a third of the global wetland area had been lost in 2009, with mostly happened in Asia (Hu *et al.* 2017). The loss of wetland is caused by hydrological drought due to water abstraction and drainage for agricultural use (Li *et al.* 2021). Aerobic conditions in the soil surface layer are very important to favor the growth of crop roots. Global wetland shrinkage occurs at a rate of 1% per year (Davidson and Finlayson 2018) and possibly gets worse due to meteorological drought of climate change (Dai 2013).

Water loss from soil causes oxygen penetration into the wetland and subsequently accelerates organic matter decomposition and increases acidity. Decomposition of organic matter releases GHGs which is dominated by CO_2, causing an increase in GHG concentrations in the atmosphere. In general, drought in wetlands causes environmental damage (Stirling et al. 2020).

In wetlands with marine physiography, this drought accelerates the water evaporation and exposes the iron sulfide of pyrite in the soil layer to oxygen, and drops the acidity down to < 3 pH (Anda et al. 2009). The roots of crops are mostly failed to survive in such low pH. The extreme acid solution possibly contaminates the lower areas and deteriorates the damage to the ecosystem (Stirling *et al*. 2020).

Emissions from wetland

Potential emissions from wetlands mainly come from the release of above and below-ground C-stocks. Emissions from aboveground carbon stocks occur when land uses with high carbon stocks, such as primary forests, are converted to land use types with relatively low carbon stocks. Agriculture does not always cause the release of carbon stock, as some agricultural areas are developed on lands with a relatively low carbon stock If shrubs are converted to plantations, this conversion likely results in net carbon sequestration (Susanti dan Dariah 2014; Agus 2013). Carbon stocks depend not only on plant type but also on soil fertility and climatic factors. National Development Planning Agency/Bappenas (2021) publishes default carbon stock values for 23 land-use types, some of which apply to wetlands (Table 7.3).

Agriculture on peatlands in Indonesia is dominated by plantations, mainly oil palm and rubber. Horticultural crops such as pineapples and vegetables are also grown on peatlands but scattered in small areas. Drainage is often practiced when peatlands are used for agricultural activity, as aerobic soil conditions are required for growing commodities. Drainage triggers the accelerated decomposition of organic matter and produces GHG emissions, mainly in the form of CO2. In addition to accelerated decomposition, peat fires are the leading cause of wetland emissions from drained peatlands. The fire risk on drained peatlands increases during a long dry season, or when there is extremely dry weather like El Nino.

The use of mangrove forests for agriculture is not as extensive as the use of peatland. The main plant grown on mangrove land is sago, which does not require a drainage process as this plant is resistant to puddles. Sago plants also grow in several peatland areas, such as in Papua and the Riau Islands. The lowlands generally used for

Table 7.3. Above ground C-stock of wetland types (National Development Planning Agency /Bappenas 2021)

Landuse	Aboveground C-Stock (t ha-1)						
	Sumatra	Java	Bali-Nusa Tenggara	Kalimatan	Sulawesi	Maluku	Papua
Primary Mangrove Forest	124.15						
Secondary Mangrove Forest	94,9						
Primary swamp forest	103.67	90.69	90.69	129.27	100.86	90.69	84.15
Secondary swamp forest	71.22	74.94	74.94	80.21	60.36	74.94	68.54
Plantation forest	75.7	87.26	87.26	85.27	85.27	117.2	72.84
Shrub swamp	30						
Plantation	63						
Paddy field (Sawah)	2						

Figure 7.3. Various agricultural systems on peatland: oil palm plantation (left), rubber plantation (middle), intercropping of rubber and pineapple (right)

Figure 7.4. Sago (left) and rice (right) on tidal swamp area; both do not require intensive drainage

rice cultivation (especially tidal swampland and freshwater swamp) will be mostly flooded, so the potential for emissions is much lower than peatland and mangrove. Carbon in peatlands and mangroves is primarily stored as belowground carbon pools and is unstable, which means it can quickly decompose if its natural conditions change, i.e., under aerobic conditions (Rieley *et al*. 2008; Agus *et al*. 2013; Husen *et al*. 2014; Maswar & Dariah 2014). Emissions from the release of belowground carbon pools from wetlands are discussed below.

Emission from organic soil decomposition

Research on GHG emissions from swamplands in Indonesia is mostly carried out on peatlands. A part to the relatively larger use of peatlands is because the potential emissions from peatlands are much higher than other swamplands due to the higher (below ground) carbon stock of peatlands. According to Agus and Subiksa (2008), carbon stocks in peatlands range from 300-6,000 t C ha^{-1}, while mineral soils are only 30-300 t C ha^{-1}. Various studies on Indonesian peatlands have resulted in widely varying emissions data. This is partly due to different measurement methods. Previously, the value of GHG emissions from drained peatlands was based on subsidence measurements, as has been done by Couwenberg *et al*. (2010), Couwenberg & Hooijer (2013) and Aich *et al*. (2013). The use of subsidence data to estimate emission levels has several drawbacks, i.e. there are other factors such as shrinkage and compaction that have not been carefully considered. However, the phenomenon of bouncing back (Anwar *et al*. 2020) is also an obstacle in estimating emissions based on subsidence.

Recently, observations of CO_2 fluxes from peatlands have been mostly carried out using the closed chamber method. CO_2 fluxes from peatlands under oil palm plantations range from 20-66 Mg CO_2 ha^{-1} year-1 (Melling *et al*. 2005, 2007; Wicke *et al*. 2008; Jauhianien *et al*. 2008; PPKS 2009; Fargione *et al*. 2010; Sabiham *et al*. 2014; Dariah *et al*. 2014; Marwanto and Agus 2014; and Husnain *et al*. 2014). The varying numbers are caused by differences in the relative contribution of root respiration. Several studies have shown that the relative contribution of root respiration to measured CO_2 fluxes in peatland oil palm plantations ranged from 14 to 74% (Melling *et al*. 2007, Murdiyarso *et al*. 2010; Hergoualc'h and Verchot 2011; Agus *et al*. 2010; Dariah *et al*. 2013; Husnain *et al*. 2014; Sabiham 2014). The relative contribution of root respiration depends not only on plant type, but also on plant age, other plant populations, understory cover crops (UCCs), and environmental conditions that affect root respiration rates.

The variation of peatland emissions is also due to quite complex processes of decomposition depending on various parameters such as temperature, moisture, aeration, plant composition, and the microbe community, which are interconnected with each other and would change with time and depth. Understanding changes in heterotrophic fluxes in ecosystems is critical for determining their contribution to soil respiration (Nurzakiah *et al*. 2021). Of the various parameters that affect peat decomposition, Itoh *et al*. (2017) pointed out that temperature and water availability play a crucial role in peat decomposition among all these variables. However, some findings suggest that the relationship between heterotrophic fluxes, soil temperature, and soil water content is not always consistent (Nurzakiah *et al*. 2021; Taneva and Gonzalez-Meler 2011). Some researchers have interpreted CO_2 loss from peatlands as a function of groundwater levels, with most reporting positive correlations, one of them as shown in Figure 7.6. However, the relationship is not always linear. Several other studies have shown that groundwater levels are not associated with increased CO_2 emissions (Melling *et al*. 2013; Sumawinata *et al*. 2014; Järveoja *et al*. 2016). The inconsistent relationship between groundwater levels and CO_2 emissions may be due to widely varying soil properties and environmental conditions.

Based on the CO_2 fluxes from many related references, most of which resulted from research conducted on peatlands on the islands of Sumatra and Kalimantan, IPCC (2013) provides the default CO_2 emission factors of drained peat soils (organic soils) in the tropics, as shown in Table 7.4. The average emission from peat decomposition from oil palm plantations is 40 Mg CO_2-e ha^{-1} $year^{-1}$. Plantations with shallow drainage of less than 0.3 m, typically used for sago palm have a much lower CO_2 flux of around 5.5 CO_2-e Mg ha^{-1} $year^{-1}$. Under paddy field, the CO_2 flux from cropland was also relatively low, at about 34.5 CO_2-e ha^{-1} $year^{-1}$. Flux values for croplands

Figure 7.5. Measurement of emissions on peatlands using chamber (left and middle) and measuring subsidence with subsidence rod (right)

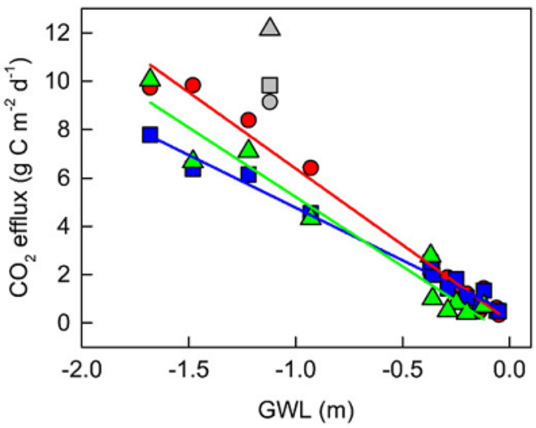

Figure 7.6. Relationship between peat decomposition (PD) and groundwater level (GWL) in trenching plot 1 (circles), 2 (squares) an 3 (triangles). A grey symbol denotes total soil respiration (SR) or CO_2 fluxes from outside of the trenching plots. A line is fitted without the grey symbol for each trenching (p b 0.001):
1) y=0.07 - 6.31x (r^2= 0.98)
2) y=0.41 - 4.35 x (r^2 = 0.98)
3) y= -0.53 - 5.47 x (r^2 = 0.94)
(Wakhid et al. 2017).

are higher than for sago because the drying period is close to harvest time.

Most of the research results in IPCC (2013) use the chamber method. Anwar *et al*. (2020) analyzed the CO_2 flux from the peat surface based on the measurements using an automatic chamber with an interval of every 30 minutes. They enhanced their research by measuring carbon dioxide fluxes above the tree canopy using the Eddy Covariance technique. In obtaining the net CO_2 flux values, several flux determination methods were performed simultaneously, i.e., subsidence method, conventional and automatic chamber methods, eddy covariance method, trenching method, and peat decomposition analysis method. This study found that CO_2 flux from heterotrophic respiration (peat decomposition) was 28.8 Mg ha^{-1} $year^{-1}$. This study also demonstrated that the amount of CO2 absorbed by plants was relatively higher than the amount of CO_2 released through root respiration. This fact suggests that part of CO_2 uptake by oil palm and UCC comes from the decomposition of peat used for the growth of these plants (Anwar *et al*. 2020).

Dinitrous oxide (N_2O) emissions are also considered important GHG to control in wetlands. Like CH_4, the amount of N_2O emissions is lower than CO_2 but has a much higher GWP value reaching 296 times CO_2. N_2O emissions are closely related to nitrification and denitrification processes, which are influenced by land-use patterns and agricultural farming management such as fertilization. According to Takakai *et al*. (2006), N_2O emissions in peatland for horticulture, grassland, natural peat forest, and burned forest was 21-131 kg N ha^{-1} $year^{-1}$, 7.1 kg N ha^{-1} $year^{-1}$, 0.62 kg N ha^{-1} $year^{-1}$, and 0.4 kg N ha^{-1} $year^{-1}$, respectively. According to Hadi *et al*. (2007), N_2O emissions in tidal swamplands are influenced by overflow types A<B<C/D, with the magnitude for A, B, and C/D types are 0.07 kg C m^{-2} season-1, 0.10 kg C m^{-2} $season^{-1}$, and 0.19 kg C m^{-2} $season^{-1}$, respectively. According to Melling *et al*. (2007), the factors that influence the emission of N_2O are soil moisture, temperature, water-filled pore space, N content, and redox potential (Eh). According to Nykanen (2003), N_2O emissions from natural peatlands are low (< 4 mg N_2O m^{-2} $year^{-1}$). Inubushi *et al*. (2003) indicated that N_2O emissions from peatlands used for agriculture ranged from 0.5 to 3.7 g m^{-2} $year^{-1}$.

Emissions from land fires

In addition to decomposition processes, greenhouse gas emissions from wetland especially peatlands also come from fires. According to Hatano *et al*. (2004), a peatland fire at a depth of 15 cm, with an average carbon content of 50 kg m^{-2} (range 30-60 kg m^{-2}), will produce emissions of 275 t CO_2-e ha^{-1}. Fire risk occurred during the dry season or during extreme climatic events such as El-Nino in 1997 and 2015 (Faqih and Boer 2013; Yananto and Dewi 2016). There are three types of land and forest fires, namely: (i) ground fires, which are fires burning humus and deep peat; (ii) surface fires that spread on the forest floor; and (iii) canopy fires that spread to higher plants among dry canopy (Barani *et al*. 2021). The first type of fire, ground fire, is the riskiest fire event and is difficult to control.

Table 7.4. Emission factor for drained organic soils in some land-use categories at tropical region (IPCC 2013)

Land Use category	Emission Factor (Mg CO2eq ha-1 yr-1)	95% Confidence interval		No. of sites
Plantation, drained, unknown or long rotation	55.1	36.7	77.1	na
Plantation, drained, short rotation, i.e. Acacia	73.4	58.7	47.7	13
Plantation, drained, oil palm	40.4	20.6	62.4	10
Plantation, shallow-drained (typically less than 0.3 m), typically used for agriculture, e.g. sago palm	5.5	-8.4	19.8	5
Cropland and fallow, drained	51.4	24.2	95.4	10
Cropland, drained, paddy rice	34.5	-0.7	73.4	6

Figure 7.7. Fire incident on peatland

Ground fire happens when the water content in the peat soil is relatively low.

Research results from Maswar (2015) showed that the water content of the peat surface <117% (w w^{-1}), has led to heavy fires; whereas at the water content on the surface >291% (w w^{-1}), peatlands experienced light fires (fires only burned litter and vegetation on the surface of the peatlands). Other studies suggest that the critical moisture content of peat soils is at risk of burning, i.e. 117-213% (w w^{-1}) (Winarna 2016; Rein *et al*. 2008; Putra 2003). At a certain water content, peat has irreversible drying, in which the peat is at a very high risk of being burned.

As one of the efforts to prevent peat fires, the Government of Indonesia has issued a regulation, i.e., Government Regulation No. 57 of 2016, which stipulates that the groundwater table depth on peatlands must be <0.4 meters below the peat surface. The groundwater table depth <0.4 m on drained peat is difficult to achieve throughout the year, especially during the dry season. The results of observations on peatlands under oil palm in Riau Province show that the depth of the groundwater table ranges from -28 cm to 100 cm from the soil surface and the water content of the peat in the surface layer (0-10 cm depth) ranges from 227.6-367.4% (w w^{-1}).

A long-term study by Adhi *et al*. (2020) showed that the groundwater table in oil palm plantations ranged from -18 cm to -96 cm in depth throughout the year, and the water content of the 10 cm layer ranged from 332 to 486% (w w^{-1}).

Adaptation strategies and mitigation co-benefits

Based on Indonesia's First Biennial Update Report (BUR) submitted to UNFCCC in January 2016, national greenhouse gas (GHG) emissions were 1.453 Gt CO_2-e in 2012 which represent an increase of 0.452 Gt CO_2-e from 2000 emissions. The main contributing sectors were came from land-use change and forestry (LUCF) including peat fires (47.8%) and energy (34.9%). The 2nd BUR reported a slight increase in emission level to 1.457 Gg CO_2-e in 2016, which was also dominated by emissions from LUCF including peat decomposition and fires (43.59%) and energy (36.91%), respectively (MoEF 2021). It can be seen that peatlands are one of Indonesia's biggest GHG emitters.

In 2015 the Government of Indonesia pledged to reduce emissions from 2020 to 2030 by 29% (unconditional) up to 41% (conditional) against the 2030 business as usual scenario, an increased unconditional commitment compared to the 2010 pledge of 26% (MoEF 2021). These core missions are consistent with the national commitment toward low carbon and climate-resilient development path, in which climate change adaptation and mitigation constitute an integrated and cross-cutting priority of the National Medium-Term Development Plan (RPJMN). In order for Indonesia to achieve this ambitious national emission reduction target, the potential to significantly reduce emissions is from peatlands. However, without consideration of adaptation, initiatives for greenhouse gas emission (GHG) reductions from cultivation areas of peatland could underperform due to direct climate hazards (e.g. increasing the length of the dry season), as well as increase the vulnerability and reduce the plant's ability to adapt to climate changing.

The role of Indonesia's peatland in climate change

Peatlands are a type of wetland ecosystem in which waterlogged conditions prevent plant material from fully decomposing, so peatlands are a potential carbon reservoir. Indonesia's tropical peatlands are among the largest terrestrial carbon pools on the Earth with estimates of 55 Pg C (Murdiyarso *et al*. 2010), these are one-third of the carbon stocks in tropical peat soils (Gumbricht *et al*. 2017). This is because the natural condition of peatlands absorbs carbon dioxide out of the atmosphere and stores it in their peat soil material, they could severely impact climate change if not managed well.

The map of peatland use shows the four main land-use classes found in peatland areas in the Indonesia such as forest (47.50%), uncultivated/shrubs (20.26%), (oil palm, rubber, and pulp) plantations (16,41%), agricultural land (4,85%) (BBSDLP 2017). This indicates that more than 50 percent of Indonesia's natural peatland areas are currently deforested and converted for several land use and mostly drained (BBSDLP 2017). Indonesia's tropical peatlands are of great interest because of the numerous ecosystem services at risk and the extensive greenhouse gas emissions that arise from these land conversions. Intense natural forest logging and draining of the peatlands are causing severe ecological and environmental impacts. Drainage of peatland for example increases vulnerability to fire; this is one of the most significant causes of peat degradation and GHG emissions. When the natural peatlands are drained causes an increase in the oxygen levels in the soil, and they release a significant amount of CO_2, a greenhouse gas, which exacerbates global warming and climate change of irrevocable damage and further accelerates degradation. Most reports highlighted that increased carbon emissions in Indonesia came from peat decomposition and large-scale fires. Emissions from peat decomposition and burning significantly contributed to Indonesia's total GHG emissions (DNPI 2014; MoEF 2021). Besides, some areas of peatland drained had to

Table 7.5. Land cover of Indonesian peatlands

Land use	Area (hectares)	%
Forest	6,287,941	47.5
Plantation	1,637,295	12.37
Pulp Plantation	534,832	4.04
Shrubs/bush	2,682,214	20.26
Agriculture land	642,149	4.85
Ex. Mining Concession	8,763	0.07
Paddy field	195,765	1.48
Others	1,252,906	9.22
Total	13,269,705	100.00

Source: BBSDLP (2015)

Figure 7.8. Snap shot land cover of peatlands: Natural peatlands (top left), Shurbs/uncultivated (top right), Oil palm plantation (bottom left), and Agriculture practices (bottom right)

be abandoned as soil surface subsidence as a consequence of these activities.

The expansion of agriculture and/or plantation in to peatland areas in Indonesia is unavoidable due to limited availability of mineral soil that can be utilized. Utilization of peatlands for agriculture practices in Indonesia has a long historical foundation. Traditionally. indigenous people use peatlands to produce traditionally food crops, fruits, and spices, such as the sonor system in South Sumatera. Starting from the 1980s. they have been growing into large plantations managed modernly to get a better income like oil palm plantations. Besides, other areas have been opened for timber logging and

Figure 7.9. Peat subsidence with rate 69 cm from 2001 to 2012 (11 years) at Lubug Ogong village, Sei Sekijang sub-district, Pelalawan Regencyc, Riau Province (left), and fire impact on peat loss (subsidence rate around 30 cm during 7 day fire i.e. 2-8 October 2014) at Jabiren village, Jabiren Raya sub-district, Pulang Pisau Regency, Central Kalimantan Province (right)

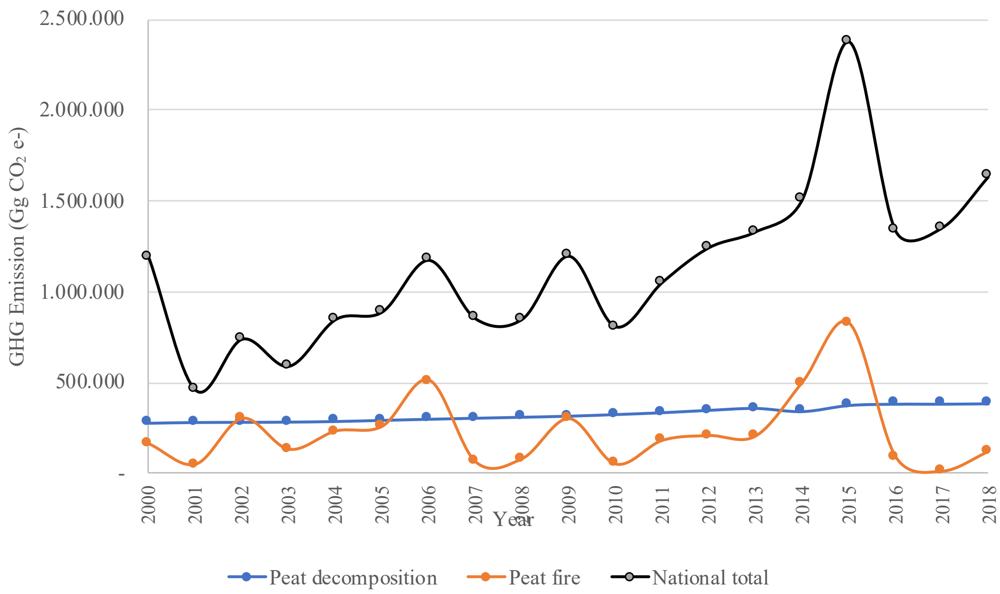

Figure 7.10. Indonesia's GHG emission trend from peat decomposition and fire compared to national total in year 2000 until 2018 (MoEF 2019)

land claiming but were then abandoned. However, it is required to be sustainable for which grown water level, wildfire, and biodiversity must be managed appropriately.

Synergies between adaptation and mitigation of peatland management

The impact of climate change and global warming is one of the biggest problems facing of agricultural practices on wetlands today. Failure to prevent both global warming and climate change can have a very bad impact on agriculture practices on wetlands. In this regard, various efforts and strategies for adaptation and mitigation, both short and long-term anticipation, have been carried out in certain aspects. This is very important because delaying adaptation and mitigation efforts to climate change will cause greater losses in the future.

The agricultural sector of the wetland is expected to be able to contribute to dealing with climate change, especially in efforts to reduce greenhouse gas emissions. In this regard, adaptation must be used as an entry point for mitigation because farmers do not understand and/or are not concerned with mitigation actions. Many emission reduction treatments are beneficial for farmers, and conversely, various adaptation treatments are also able to reduce emissions (mitigation as a co-benefits of adaptation). However, adaptation action can influence mitigation positively or negatively or vice versa.

The government of Indonesian (GOI) considers climate adaptation and mitigation efforts of agricultural sectors, such as:

- In anticipating climate change, agricultural policies should prioritize the principle of adaptation without neglecting mitigation actions. so that every action to reduce GHG emissions in the agricultural sector must also ensure that it supports efforts to increase production and productivity.
- Climate change adaptation and mitigation actions must provide benefits in improving the welfare of farmers. so the selected action must be adapted to the system and people's agricultural businesses. Adaptation and mitigation actions are operationally described in each echelon I as well as at the regional level. Thus, the agricultural sector contributes to the national target for reducing GHG emissions.
- Climate change adaptation and mitigation activities are location-specific by taking into account the geographical conditions of each region. so the technology to be applied must be appropriate and location-specific by adopting as much local wisdom as possible.

Several actions of agriculture and plantation activities have synergized between adaptation and mitigation action on peatland such as:

- Improved water management by canal blocking in peatlands is a fundamental step to supporting the sustainable management of peatlands.
- A sustainable alternative for utilizing peatland with minimum drainage is Aero hydro culture, which basically involves growing crops in peatland under conditions of the lower water table. Maintaining a high water table in aero hydro culture potentially reduces soil subsidence, fire risk and CO_2 emissions.
- The protection of remaining peatlands is one of the most important and cost-effective management strategies for minimising GHG emissions. Currently. the Indonesian government has put a ban or moratorium on the conversion of peatland area. These moratorium could contribute greatly to future fire prevention and significantly contribution to reduce Indonesia's green house gas emissions.
- Improving physical, chemical, and biological characteristics of peat soil used for agriculture practices by amelioration. Ameliorant use can be organic or inorganic materials. Theoretically, the ideal material used for im-

proving peat soil characteristics is that has high base saturation, can increase peat pH, and contains complete nutrients, so it can also work as a fertilizer and has the ability to improve the structure of peat soils. The type of ameliorant that has been widely used for agriculture practices are volcanic ash, lime, and mineral soils. wood/litter ash, biochar, and animal manure. The characteristics of ameliorant materials for peatlands and their function in adaptation and mitigation to GHG emissions that are commonly used are:

- Lime/dolomite function: to reduces organic acids' toxicity, increases soil pH and base saturation, and mitigates GHG emissions.
- Animal manure function: to increase nutrient availability and soil stability, and mitigation GHG emission
- Biochar function: toreduces soil acidity and mitigation GHG emission
- Mineral soil function: to reduce toxicity of organic acids and mitigation GHG emission
- Pugam (peat fertilizer) function: to reduce toxicity of organic acids, increase nutrient availability and mitigation GHG emission

Conclutions

1. Wetlands, especially peatlands and mangroves, play an important role in climate change because of their ability to regulate the concentration of greenhouse gases (GHG) in the atmosphere. The potential emissions from peatlands are much higher than other swamplands due to peatland's higher below-ground carbon stock.

Figure 7.11. Water table control by canal blocking (left and middle), Aero hydro culture treatment on oil palm plantation in peatlands (right)

Figure 7.12. Ameliorant application by farmer for agriculture practices in peatland

Table 7.6. Several synergies between adaptation and mitigation action of agriculture practices in peatland

Activity	Adaptation	Mitigation
Reduce water table depth on peatlands (canal blocking)	• Reduce fire risk • Extended life service of peatlands	Reduce: CO2 emission, fire risk, subsidence
Balanced fertilization	• Reduce the cost • Yield increase • Reduce plant pest organisms.	Reduce emission (especially N2O)
Amelioration	• Increase nutrient availability • Reduce toxicity of organic acids • Reduce soil acidity	Reduce GHG especially CO2 emission
Aero Hydro culture	• Reduce fire risk • Extended life service of peatlands • Increase nutrient and oxygen adsorption by plant	Reduce GHG especially CO2 emission, fire risk, and subsidence rate

2. Swampland has potential as agricultural land by implementing a management and cultivation system based on the characteristics and capabilities of the soil and its environment.
3. Various mitigation actions are beneficial for adaptation, but other options risk increasing costs and decreasing yields.
4. Adaptation efforts need to be prioritized over mitigation because they are closely related to farmers' livelihoods, food security, and agricultural sustainability.

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INDONESIA
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8

No Regret Interventions for Climate Change Adaptation and Mitigation in Animal Husbandry

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The rise of national population leads to increased consumption of animal products. It is also become the primary drivers of the growth of demands for agricultural products. In Indonesia, there has always been a gap between supply and demand of beef meat. The government increased the livestock population through intensive program of livestock production involving artificial insemination, animal fattening, and community-based livestock breeding. However, the increasing livestock population caused an increase of enteric fermentation and manure production as sources of greenhouse gases (GHG) emissions from the livestock sector. To support the improvement of the GHG inventory and systems for measurement, reporting and verification (MRV) of emission reductions, this report summarizes the situation, gaps and needs related to the livestock GHG inventory, mitigation and adaptation co-benefit actions and MRV systems for the livestock subsector.

Description of Indonesia's animal husbandry

Livestock and national economy

The agriculture contributes 9.4% to Indonesia's national GDP 2019-2020. It consisted from food crops (2.95%), horticulture (1.45%), estate crops (3.14%), livestock (1.67%) and other agriculture services (0.19%) based on prices prevailing at the time of production (Indonesian Statistics-BPS 2020). The contribution of agriculture to national GDP has continued to increase over time. The GDP growth from livestock (7.84%) in 2019 is the highest among other subsector in agriculture. This shows the critical contribution of the livestock subsector to Indonesian agriculture.

The livestock subsector plays an important role in Indonesian economy, absorbing 12.22% of 31.86% the labour involved in agriculture. In 2020, consumption of protein derived from beef, poultry, milk, and eggs in Indonesia was relatively low, averaging 21.9 kg per capita per annum (Ministry of Agriculture 2021). This figure still needs to be increased because it is still far from the annual average per capita consumption of such products in the Southeast Asian region. Therefore, many national programs aim to support an increase in livestock populations and production.

Indonesia has the fourth largest population in the world and is growing at a rate of 1.2% per annum. By 2021, Indonesia has a total population of 272.7 million (Indonesian Statistics-BPS 2022). Rising the standard consumption of protein adequacy has helped beef consumption to grow.

Livestock and greenhouse gases

As a consequence of increasing livestock population every year, the livestock sector also emits GHG. Livestock is one of agriculture sectors under consideration for its contribution to climate change. Livestock sector is a major contributor to climate change from the emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). This contribution is directly from enteric fermentation and manure management and also from other indirect sources.

Beef cattle are the highest contributors to CH_4 emission due to the highest population and its body size. Calculated using Tier 2, in 2014 CH_4 emission from beef cattle was 9,850 ton CO_2-e year^{-1} (Widiawati 2016). Beef population continuously increases, and the increase is expected to be higher than the previous years due to a special program of government to increase beef cattle population in order to achieve domestic beef self-sufficiency. The increase of beef cattle population will have consequences in increasing GHG emission.

Livestock structure and trends

Population of livestock in Indonesia increased year by year following the government national program to fulfil the demand on animal's protein needs (Figure 8.1). In the period 2016 to 2020, the population of ruminants (beef and dairy cattle, buffalo, sheep and goats) increased by 13.06%. Swine increased by 14.75% and the largest increase was in poultry (22.19%). The population of each type of livestock is expected to increase by 9.66% in the period 2020 to 2030.

Government programs on livestock development aim to increase the population of livestock, in particular large and small ruminants. The program is focused on development of livestock outside Java island, such as Sumatra, Kalimantan, Sulawesi and Papua. The most suitable systems for raising livestock in these islands are extensive or semi-intensive. Following an increase in palm oil plantation area (almost 14.6 million hectares in 2019) spread across 26 provinces in Indonesia, oil plantations provide areas for raising cattle or goats under oil plantations in both extensive and semi-intensive systems. The extensive system means that the animals are raised under the palm oil area all the time. While semi-intensive means that the animals are grazed under the palm oil area during the day and are kept in a barn close to the farmer's house during night time (Mathius *et al*. 2017). The inte-

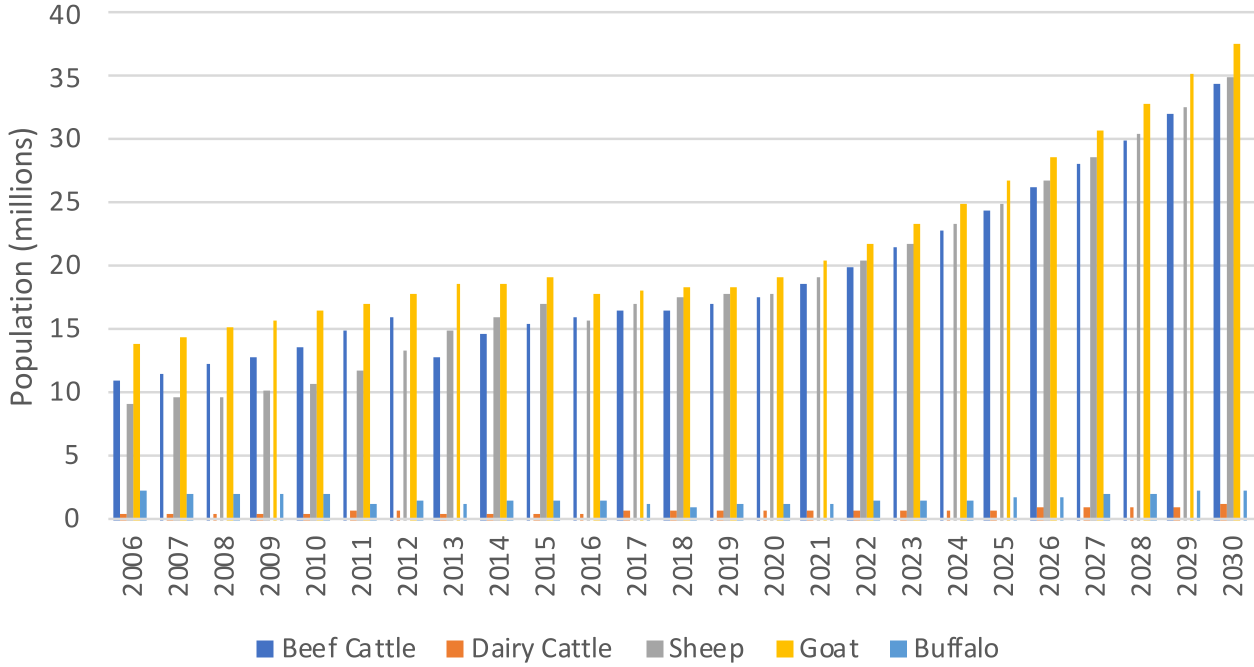

Figure 8.1. Trend on population of ruminant animals with the estimated increasing population up to year 2030 (calculated and developed from BPS-Statistics Indonesia)

gration between cattle and palm oil plantation has become the priority program for increasing beef cattle production (Mathius *et al*. 2017).

Climate change impact

The increase of the global surface temperature has potential impacts on livestock production due to feed supply fluctuation caused by changing in production and quality of forage (Chapman *et al*. 2012); water availability (Henry *et al*. 2012); animal growth and milk production (Nardone *et al*. 2010); diseases (Thornton *et al*. 2009); reproduction (Nardone *et al*. 2010); and biodiversity (Reynolds *et al*. 2010). These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide (CO_2) concentration, precipitation variation, and a combination of these factors (Aydinalp and Cresser 2008; IFAD 2010; Polley *et al*. 2013). Among the factors, temperature is a critical factor which affects water availability, animal production, reproduction and health. While forage quantity and quality are affected by a combination of increase in temperature, CO_2 concentration, and precipitation variations.

Climate change has direct and indirect effects on livestock. The direct impact of climate change on livestock production is through water availability, that in turn affects animal production, reproduction and health. Indirect impact of climate change is through availability of feed both in terms of quality and quantity. Agriculture sector is vulnerable to climate change and thus it becomes a victim of climate change. Since livestock depends on agricultural by-products as their sources of feed, climate change also has an impact on the availability of feed sources for livestock.

Livestock productivity is influenced by genetic and environmental factors, where superior breeds will not provide optimal productivity if they are not maintained in a comfortable environment (comfort zone). Environmental factors consist of biotic and abiotic elements (temperature, humidity, rainfall and wind speed) affect livestock productivity both directly and indirectly. The threat of climate change is in the form of climate uncertainty, especially an increase in the frequency of extreme weather, an increase in temperature and seawater intrusion.

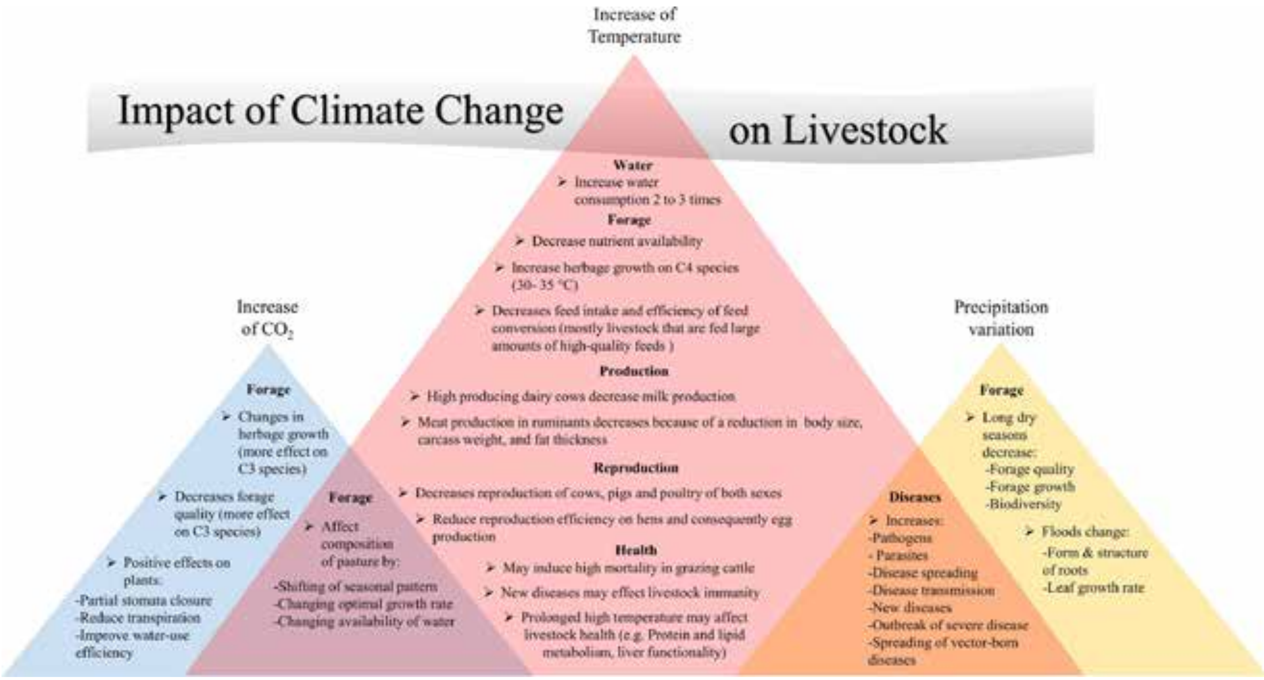

Figure 8.2. Impact of Climate change on Livestock (Compiled & Edited by-Dr Rajesh Kumar Singh, Jamshedpur from Chapman et al. 2012; Henry et al. 2012; Nardone et al. 2010; Thornton et al. 2009; Nardone et al. 2010; Reynolds et al. 2010; Aydinalp and Cresser, 2008; IFAD, 2010; Polley et al. 2013)

Impact on feed supply

Increased carbon dioxide levels may result in less nutritious feed and forage, even if the yield is higher (FAO 2015). Growers are likely required to utilize feed additives in order to observe the projected growth improvements in cattle and avoid diseases. This additional expense to the grower would result in higher food prices for consumers. If there isn't enough water and nutrients in stressed soils to keep up with plant development, therefore feed availability may decline (FAO 2015).

Climate change causes an increase in temperature and changes in the rainy season. This has an impact on cropping patterns and seasons for food crops and plantations (FAO 2015). Therefore, the availability of agricultural by-product, which is the main source of animal feed, will fluctuate both in quality and quantity. Furthermore, the global climate change has an impact on moving the area of adaptation in most fodder crops. According to Harmini and Fanindi (2020), actions that can be taken in anticipating these impacts include the use of drought tolerant crop varieties, crop diversification, changes in cropping patterns, and soil and water conservation. An increasing in CO_2 atmosphere will increase the competition between plants and microorganisms for nitrogen (N) in the soil. Therefore, there will be an increasing in photosynthesis of high temperature adaptive crops, as well as an increasing in nitrogen fixation, resulting in leaching of N in the soil. Thus, providing adequate nitrogen and other minerals to the soil is required. Furthermore, the intercropping system gives higher yields of alfalfa under conditions of increased CO_2, but distance between plants must be considered due to increased competition for water and N.

Impact on production

An increase in temperature can lead to heat stress which has an impact on animal behavior, health and reproduction problems, and decreased livestock productivity (Bernabucci 2019). Heat stress in dairy decrease feed consumption, production and quality of milk, thus causing low production efficiency (Dahl *et al.* 2016). Several studies have been conducted in Indonesia to investigate the impact of climate change on the productivity of various types of livestock. Those studies were conducted in difference microclimate, temperature and humidity, Temperature Humidity Index (THI) and elevation (lowlands and highlands). The results of the studies were summarized in Table 8.1.

Climate change increases ambient temperature and humidity and influences the milk production of dairy cows, in a negative manner. In several areas of Indonesia, daily temperature can reach up to 27°C for more than 6 hours, and this will influence the performance of dairy cattle (Suherman *et al*. 2013). Therefore, it is important to overcome the dairy cattle production due to the changing climate such as improving the management practices in low elevation areas through manipulating optimal ambient temperature and humidity (HTI < 72), breeding of dairy cattle adaptive to low land and/or higher ambient temperature, manipulating the reproduction rate as well as the availability of feed supply.

The average skin temperature, rectal temperature and respiratory rate of Bali cattle housed in lowland areas was higher (P <0.05) compared to middle and highland areas. The study showed that the micro climatic conditions of the barn and physiological responses of Bali cattle housed in the middle and highland areas was higher than the barn and lowland (Nuriyasa *et al*. 2019). Saiya (2014) reported those parame-

Table 8.1. Impact of climate change (temperature and humidity) on livestock's physiology and productivity in several locations in Indonesia

No.	Type	Location	Impact on Physiology and Productivity	Sources
1.	Dairy cattle (lactating)	West Java	• Feed intake reduction	Suherman *et al*. (2013)
		Central Java	• Milk production decrease (5.37%)	Prihantini *et al*. (2017)
2.	Beef cattle (local breed)	Bali	• Skin and rectal temperature increase	Nuriyasa *et al*. (2019)
			• Respiration rate increase	
		Merauke	• Skin and rectal temperature increase	Saiya (2014)
			• Respiration rate increase	
		Merauke	• No impact of climate change on puberty age of local cattle (male and female)	Nurcholish and Salamony (2019)
3.	Goat	Lampung	• Feed intake reduction	Qisthon and Hartono (2019)
			• Less susceptible to heat stress than other ruminant	
4.	Chicken (broiler)	Aceh	• Weight gain decrease	Sugito *et al*. (2007)
			• Jejenum villi height decrease	
			• Feed Conversion Ratio increase	
		East Java	• Feed intake decrease (starter period)	Ximenes *et al*. (2018)
			• Weight gain decrease (starter period)	
			• Feed Conversion Ratio increase (starter period)	
		Central Java	• Reduce the quality of meat	Rini *et al*. (2019)
		South Sulawesi	• Feed consumption decrease	Qurniawan *et al*. (2016)
			• Body weight decrease	
			• Feed Conversion Ratio increase	
5.	Chicken (layer)	West Java	• Performance and quality of egg decrease	Setiawati *et al*. (2016)

ters will influence their production performance such as feed intake, body weight and reproduction rate. The study showed that Bali cattle were able to maintain the physiological responses during monsoon changed. Nurcholish and Salamony (2019) reported there was no significant influence of the performance for cows from different sites, as well as the influence of high ambient temperature to the reproduction performance.

Goats are less susceptible to heat stress than other ruminants. However, their voluntary feed intake declines when the ambient temperature is more than 10°C above their thermal comfort zone. Qisthon and Hartono (2019) reported that the goat breed has no effect on all physiological responses. Thus, modification of the microclimate by misting effectively maintains body temperature under normal conditions and increases the adaptability of goats to hot environments.

Modern chicken (broiler and layer) is very sensitive to the effect of heat exposure. The addition of local feed additives, such as Salix tetrasperma Roxb (jaloh) (Sugito *et al*. 2007) and Nigella sativa (Zulkifli *et al*. 2018) can reduce the heat stress caused by temperature increment. Ximenes *et al*. (2018) reported that heat stress exposure has negative effect to the broiler chicken performance at starter period. Qurniawan *et al*. (2016) reported that final body weight of broiler was significantly ($P<0.05$) influenced by different elevation altitude (low <300, medium 300-600 and high >700 Meter Above Mean Sea Level. Moreover, broiler raised at high temperatures have lower physical quality, such as meat quality, than broiler which are kept at a comfortable temperature (Rini *et al*. 2019). While, Setiawati *et al*. (2016) reported that the layer chicken has better performance and egg quality when kept in neutral temperature (18°C). Abnormalities, egg shell thickness, and egg shell weight, egg shell thickness were not influenced by air temperature, but more to the genetic potential of the layer.

The direct effect of climate change on livestock can be seen from the development of pathogenic microorganisms which are closely related to livestock health and ultimately affect livestock productivity. A hot and humid environment is a very favourable condition for pathogenic microbes. In addition, the direct influence of the environment is seen in the heat balance in the body of livestock, where livestock that cannot balance heat will experience stress. However, if the livestock can balance their heat production, they will be in a comfortable condition and their productions in terms of meat, eggs, and milk will not significantly be affected.

The interaction between animal production and climate change is complex and multidirectional since animal production contributes to climate change; but to the reverse and worse condition, climate change highly affects animal production. Climate change, animal production systems and animal diseases are strongly linked to each other. But what is worse is that both change in climate and the production systems of animals highly affect the occurrence, distribution, emergence and re-emergence of animal diseases.

Impact on livestock disease

Climate change affects livestock health through several pathways involving both direct and indirect effects. The direct effects are most likely pronounced for diseases that are vector-borne, soil associated, water or flood associated, rodent associated, air temperature or humidity associated and sensitive to climate. Furthermore, the indirect effects of climate change influence the emergence and proliferation of disease hosts or vectors and pathogens and their breeding, development and disease transmission.

The negative effects of climate change on animal health and welfare will be the consequence of combined changes of air temperature, precipitation, frequency, and intensity of extreme weather events and may be both direct and indirect. The direct effects of climate change may be due primarily to increased temperatures and frequency and intensity of heat waves. Depending on its intensity and duration, heat stress may affect livestock health by causing metabolic disruptions, oxidative stress, and immune suppression causing infections and death. The indirect effects of climate change are primarily those linked to quantity and quality of feedstuffs and drinking water and survival and distribution of pathogens and/or their vectors. Development and application of methods linking climate data with disease occurrence should be implemented to prevent and/or manage climate-associated diseases.

Climate change also has an impact on animal health through four ways: a) disease and stress related to high temperature, b) disease related to extreme climate, c) adaptation of animal production system to new environment; d) new disease or existing disease that spread as a result of climate change. Higher temperature as well as humidity will cause emergence and re-emergence of animal diseases (Forman *et al*. 2008). It is reported that since 2010 to 2011, there was an increasing in poultry diseases in Indonesia, such as Newcastle Disease (ND), Chronic Respiratory Disease (CRD), Infectious Bronchitis (IB), Infectious Bursal Disease (IBD), Infectious Laryngotraechitis (ILT), Avian Influenza (AI). While in ruminant animals, increasing disease outbreak occurred for Pasteurellosis, Anthrax, Black Leg and West Nile (Bahri and Syafriati 2011).

Climate change affects distributions and host–parasite relationships and its assemblages to new areas. Climate factors also influence habitat suitability, distribution, and abundance; intensity and temporal pattern of vector activity. Pathogens and parasites that are sensitive to moist or dry conditions may be affected by changes to precipitation and soil moisture. Higher temperatures resulting from climate change may increase the rate of development of certain pathogens or parasites that have one or more life cycle stages outside their animal host. This may shorten generation times and, possibly, increase the total number of generations per year, leading to higher parasite population.

Zoonoses natural ecosystems and allows disease-causing pathogens to move into new areas where they may harm wildlife and domestic species, as well as humans. Climate change affects diseases and pest distributions, range prevalence, incidence and seasonality but the degree of change remains highly uncertain. The occurrence and distribution of vector borne diseases in Indonesia are closely associated with weather patterns and long-term climatic factors, and strongly influence the incidence of outbreaks.

Emissions from livestock

Emission factors

The GHG emission from Livestock in Indonesia is contributed from GHG generated from enteric fermentation (CH_4) and manure management (CH_4 and N_2O). Estimated GHG emission from livestock was generated by using Tier-2 approach both using local emission factor (enteric fermentation) (Agus *et al*. 2019) and default emission factor published in IPCC (2006) for manure management.

Livestock emission prediction

The GHG emissions calculated from livestock are come from beef and dairy cattle, goat, sheep, chicken, swine and horse. National statistic is used as the main data sources for livestock population. A series of calculation for GHG emission from livestock has been conducted. The calculation was started from year 2006 up to 2021 according to population data available in national statistics. Based on the population growth rate value reported on national statistics, the increasing in population can be predicted up to year 2030. Thus, the GHG emission from livestock can also be predicted up to year 2030. The calculation was based on the source of emission, namely CH_4 from enteric fermentation and manure management; and also, N_2O from direct and indirect of manure management. Figure 8.3 presents contribution of each GHG emission of four different sources. The figure indicates that the livestock GHG trend is increasing year by year following an increase in the livestock population.

In year 2021, it was reported that among the four gases, CH_4 from enteric is the highest contributor (Figure 8.4) (Widiawati et al. 2021). Therefore, the CH_4 from enteric fermentation become the key contributors of GHG emission from livestock.

The contribution of GHG emission from each type of livestock in 2021 is presented in Figure 8.5. Based on the type of livestock, the highest GHG emission was come from beef cattle (63% of total emission from livestock), Then followed by buffalo and sheep; goat and chicken; and dairy cattle; horse; and swine.

Since beef cattle is the most contributor for GHG emission and CH_4 enteric fermentation is the key GHG category, therefore enteric fermentation from beef cattle become key category for GHG emission from livestock in Indonesia.

Adaptation strategies & mitigation co-benefits

In dealing with and anticipating climate change, mitigation and adaptation activities in livestock cannot be separated. Many mitigation

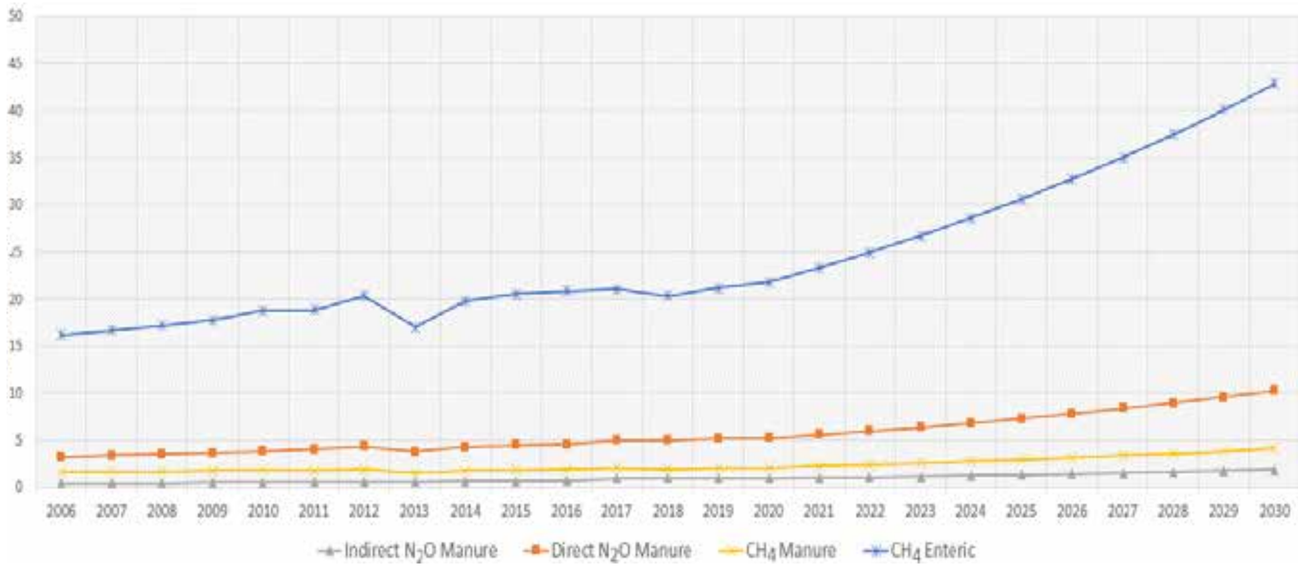

Figure 8.3. Annual emissions million tonnes (CO_2-e year[-1]) from livestock showing continuous increase with time (Widiawati et al. 2021)

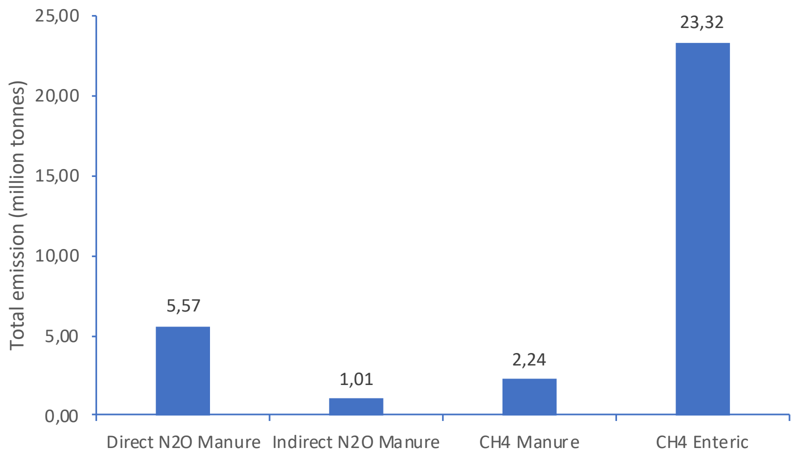

Figure 8.4. Contribution of each gas to total emission from livestock (ton CO_2-e year-1 x 1.000.000) in year 2021 (Widiawati et al. 2021)

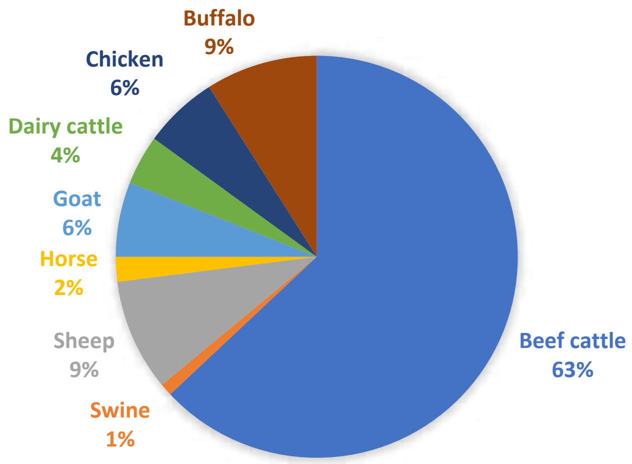

Figure 8.5. Gas emission from Livestock in Indonesia (2021) Using Tier-2 IPCC (Widiawati et al. 2021)

activities have been in synergy with adaptation, and vice versa. National policies for GHG emission have been regulated since 2011 with the issuance of the Presidential Decree No. 61 about National Action Plan on Greenhouse Gas Emission stipulating the country's commitment in handling the climate change problems. Activities on GHG emission reduction from livestock sub-sector are part of the agriculture sector action plan stated on the Guidelines on Implementation of Greenhouse Gas Reduction Action Plan (*Pedoman Pelaksanaan Rencana Aksi Penurunan Emisi Gas Rumah Kaca*) (NDPA 2011).

Current activity for adaptation & mitigation co-benefits

Some mitigation technologies and adaptation approaches have been applied through feeding strategies and livestock management improvement. The aim of these program was to increase the quality of feed, as well as to provide better sources of feed for ruminant animals. The program consisted of many activities including using concentrate; feeding with leguminous shrubs such as *Gliricidia sepium* (Figure 8.6 and Figure 8.7), *Calliandra callothyrus, Leucaena leucocephala*, and *Indigofera zollingeriana*; improving forage quality on pastures (Figure 8.8); and feed processing (Figure 8.9 and Figure 8.10). Improving the quality of feed consumed by livestock ruminants can reduce the production of methane from enteric fermentation.

Improvement of feed quality can be done through supplementation techniques by providing forage in the form of legume leaves and concentrate as a feed supplement for basal feed. Leguminous and cassava leaves can be used as supplements, while the concentrate ingredients are rice bran, cassava tuber, pollard, palm kernel cake, corn. These supplementation techniques reduced enteric methane emissions by approximately 8-20% (Widiawati and Thalib 2006). Improvement of feed quality has been implemented as a national program. The calculation on emission reduction of the program implementation has been conducted in five sub-districts at Subang regency, West Java by involving about 1,785 heads of a total of 2,336 head cattle. The results showed that when the supplementation techniques were applied on 59.07% of total beef cattle population in the regency, there was a reduction on enteric methane emissions from beef cattle by 0.0545 tons CO_2-e year^{-1} (Nurhayati and Widiawati 2019). If it is assumed that about 59.07% (10 million head) of national beef population (17 million head) applied the supplementation strategy, there will a reduction on enteric methane emission for about 305.6 tonnes CO_2-e year^{-1}.

Figure 8.6. Shrub legume Gliricidia sepium fed to Onggole crossbred beef cattle as feed supplement to native grass basal diet. These supplementations increased nutrient content of low quality of basal diet

Figure 8.7. Shrub legumes Gliricidia sepium used as a living fence in a pasture, as well as used as source of high protein diets supplemented to low quality basal diet

Figure 8.8. improving natural pasture (left) by high quality grass and legume (right) in Lar Badi, Sumbawa, West Nusa Tenggara

Figure 8.9. The process of making maize straw silage mixed with rice bran. Maize straw is chopped then mixed with rice bran. The mixture then is stored in plastic bags and subjected to anaerobic conditions for at least 21 days before used. The process increases the nutrient content as well as preserve the forage quality to be kept in a longer time

Figure 8.10. Low quality rice straw is processing by adding urea called by "ammonization" to increase nitrogen content of rice straw as well as to increase its digestibility. Ammoni-zation can be applied to low quality and high fibre content of feedstuff

Since the livestock population increase year by year, the GHG emission will also increase. Based on the GHG inventory calculation by Indonesian Center for Animal Research and Development (ICARD), the GHG emission from livestock was predicted to increase by 9.67% per year or become 59,100 tonnes CO_2-e year^{-1} in 2030, if without mitigation action. The GHG from beef cattle is projected to increase from 18,900 ton CO_2-e year^{-1} in 2020 to become 36,960 tonnes CO_2-e year^{-1} in 2030 (Widiawati *et al*. 2021). Thus, application of mitigation strategies is predicted to reduce the livestock GHG up to 15%.

Future strategies for adaptation & mitigation

In addition to feed improvement as government's national programs, there are several mitigation and adaptation activities that have been widely applied by farmers communities. However, these activities have not been recorded as national mitigation and adaptation actions from livestock sub-sector. Therefore in the future some promoting and potential activities related to mitigation and adaptation are:

1. Feeding management: other activities regarding feeding management are balanced diets and feed additives for rumen manipulation system (Wina *et al*. 2018; Krisnawan *et al*. 2015; Widiawati and Hikmawan 2021).
2. Integration between livestock and crops, including between palm oil plantation with beef cattle (Figure 8.11); paddy rice or maize with beef or dairy cattle; goat and sheep integrated with cocoa or coffee plantation (Bambang and Widjaja 2012; Mathius *et al*. 2017).
3. Creating new new breed of livestock and development of animal's breed which are adapted to the impact of climate changes, such as low methane production, heat stress, disease and low quality feed. Several studies were created new well adapted breeds and tolerant to diseases. Indonesian Agency for Agricultural Research and Development (IAARD) has released several new breeds that well-adapted to hot humid climates. Some of them are Pogasi Agrinak beef cattle (Figure 8.12), Boerka Galaksi Agrinak goat (Figure 8.13), Compass Agrinak sheep, Bahtera Agrinak sheep, IAARD's superior native chickens (KUB), etc. (Yulistiani *et al*. 2021; Balai Penelitian Ternak 2014; 2017; Loka Penelitian Kambing Potong 2020). The development of new breeds for the rural farmers is very important to support the food system of the country.

Many of those activities have been carried out at the level of smallholder farms and private

Figure 8.11. National program on Palm oil-cattle integration system become one of many strategies for livestock industry in facing problem on lack of forage availability due to climate change

Figure 8.12. Pogasi Agrinak is a new beef cattle breed released by IAARD that has good adaptability on low quality diet and heat stress

Figure 8.13. Boerka Agrinak goat (left) and Compass Agrinak sheep (right) are new breeds released by IAARD. They have good adaptability on low quality diet and high resistance to disease, heat stress, as well as better carcass percentage

companies, but have not been considered yet as a national mitigation and adaptation program. Therefore, the national program for mitigation and adaptation needs to be improved with the above activities. Socialization and training, as well as continuous supervising, need to be carried out through local governments and extension workers. Support from local and central governments can be done through the establishment of policies for the implementation of these activities.

The success of implementing GHG mitigation programs and adaptation to climate change on the national basis is highly dependent on awareness of livestock business actors. In fact, in the field, many livestock business actors do not understand the importance of mitigation and adaptation activities in relation to the sustainability of their business. Therefore, an improvement of farmer's knowledge and willingness to adopt strategies on mitigation of GHG and adaptation to climate change become an important issue.

Implementing national program of mitigation and adaptation could be synergized with other national program launched by the government, such as the National Medium Term Development Plan (RJPMN 2020-2024) and the Cattle and Buffalo Improvement Program (Sikomandan). The goals of these two programs are to increase cattle population and meat production in order to meet the meat consumption of 9.7 kg^{-1} $capita^{-1}$ $year^{-1}$ in year 2024. The main target for these programs is small to medium scales farmers.

Currently, the emission reduction calculation has not been included mitigation action conducted by medium-large scale enterprises. On the other hand, many of them have already implemented high quality feed in their management system. Therefore, the regulations are required to allow the emission reduction calculation from those enterprises.

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Land Use and Land Use Change Strategies

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Many tropical countries are experiencing massive land-use change with profound environmental and socioeconomic implications (Chrisendo *et al*. 2020). Land use change development in Indonesia during the last three or four decades has brought major changes, not only to the socio-economic life of the community, but also to changes in land use. Conversion of forest land into other land uses is a long-standing phenomenon and has a direct impact on reduced diversity, air pollution, and global warming (Sandin 2009; Hu *et al*. 2008). So that the change in land use does not have a bad impact, it is necessary to approach it through the Concept of Environmentally Friendly Development. Based on Law Number 23 of 1997 concerning Environmental Management, that environmentally sound development is a conscious and planned effort in order to use and manage resources wisely in sustainable development to improve the quality of life. Various regulations need to be drawn up to address the problem of environmental change due to this land cover change. Presidential Regulation

No. 61 of 2011, concerning the National Action Plan for Reducing Greenhouse Gas Emissions is one of the efforts to overcome this problem. This effort has been followed up by compiling a technical guidebook that describes the scientific basis for calculating greenhouse gas emissions in the business as usual (BAU) scenario and several emission reduction scenarios.

One of the consequences of land cover changes can cause green house gas emissions. The emission factor for land cover change is the difference in the amount of carbon stock when land with one cover class changes to another cover. To obtain these emission factors, it is necessary to have reference data (default) for carbon stocks from all types of land cover. For each type of land cover, a representative reference figure is built from the results of research or national inventories in various locations which are then averaged. Depending on the availability of data, for land cover at the national level the reference carbon stock data comes from various locations representing dry and wet climates and from fertile and infertile lands. Accordingly, if data is available for the provincial level, representative data is used from various locations within the province (Agus *et al*. 2013).

Land suitability

Indonesia has a land area of 191.09 million ha, consisting of 511 regencies/cities (BPS 2013), has a variety of land resource characteristics due to the diversity of climate, topography, parent material/lithology, and other environmental bio-physical conditions. Therefore, for the development of agricultural commodities, an instrument that can be scientifically justified is needed. One of the instruments used is the land suitability approach, which is an assessment that provides information on potential and or land use as well as production expectations that may be obtained as well as environmentally friendly land uses (Sukarman *et al*. 2018). Land suitability is the suitability of a plot of land for a particular use (Ritung *et al*. 2011). Specifically, land suitability is the suitability of the physical characteristics of the environment, namely climate, soil, topography, hydrology and or drainage for farming or certain commodities that are productive, environmentally friendly and take into account the impacts of climate change. Some of the new agricultural lands in Indonesia have applied the results of their land suitability assessment, but there are still many lands that have been used for a long time that have not used the principle of land suitability, especially in mountainous areas with steep slopes.

Land suitability evaluation in Indonesia is currently evolving from land evaluation based on the framework of FAO (1976). Furthermore, this method was developed by the Center for Soil Research / Indonesian Center for of Agricultural Land Resources Research and Development adapted to the characteristics of the land and the growing requirements of various commodities in Indonesia to select the types of commodities that can be developed in an area. The commodity groups in question include wet land food crops (paddy rice), dry land food crops, lowland horticultural crops, highland horticultural crops, lowland plantation crops, highland plantation crops, and forestry plants. In the last land suitability assessment mentioned above, the inhibiting factors due to climate change have been considered. Thus, in the recommendations for land use, efforts to adapt to climate change can be made.

The land evaluation system that has developed so far uses various approaches, including the parameter multiplication system, addition and matching system or matching between land quality/characteristics with plant growth requirements (Ritung *et al*. 2011). Several land evaluation systems that have been used and

Figure 9.1. Examples of land use change from forest to agricultural land

Figure 9.2. Agricultural land that applies soil and water conservation principles and agricultural land that does not apply soil and water conservation principles

have been developed in Indonesia include:

According to Ritung and Sukarman (2014) in land suitability assessment there are three main factors that must be considered, namely: crop requirements, management requirements and conservation requirements. The three main factors are reflected in the quality and characteristics of the land.

Data source

Semi detailed soil map

In determining the suitability of land for agricultural commodities, it is necessary to have basic data containing data on land/soil characteristics. The basic data are in the form of digital data and tabular data of land/soil resources resulting from land mapping. The most recent and

Figure 9.3. Soil observation in wet and dry land

large-scale data is the result of semi-detailed soil mapping (scale 1: 50,000). The semi-detailed soil maps are presented in the form of Atlas of Semi-Detailed Soil Maps at a scale of 1:50,000 per district/city throughout Indonesia (Figure 9.3) and in the form of a data base (big data). Currently the Map Atlas is available in 511 districts/cities throughout Indonesia. This map was created and correlated from 2016 to 2019, based on the existing data base at BBSDLP and additional observations were made.

This land resource data is used to assess land suitability classes and sub-classes as well as recommendations for their use. Thus, the characteristics of the soil and its environment are used as the basis for determining the recommendations for land use, so that when there is a change in land use, it will not cause environmental damage, nor the possibility of carbon emissions due to changes in land use.

Peatland map of Indonesia

Peatlands are part of swamp land, namely land that occupies a transitional position between land and water systems. This land throughout the year or for long periods of the year is always waterlogged or inundated (BBSDLP 2019). According to Government Regulation No. 27 of 1991, swamp land is land that is naturally inundated with water that occurs continuously or seasonally due to obstructed natural drainage and has special physical, chemical and biological characteristics. Swamp land is divided into: (a) tidal swamp/coastal swamp, and (b) non-tidal swamp/inland swamp (Minister of Public Works Decree No. 64/PRT/1993).

Based on the Soil Taxonomy system (USDA, 2014), peat soils are called Histosols (histos = tissue), while in the National Soil Classification system (Dudal and Soepraptohardjo 1961) peat soils are called Organosols (soil composed of organic matter). In the National Soil Classification (Subardja *et al*. 2016), peat soil or Organosol is soil that has an H horizon > 50 cm thick (if the organic matter consists of spaghnum or moss > 60 cm or has a bulk density of < 0.1 gr cm^{-3}) from the soil surface, or cumulatively 50 cm within 80 cm of the top layer; The thickness of the H horizon may decrease if there are rock layers or rock fragments filled with organic matter in between.

The Indonesian Center for of Agricultural Land Resources Research and Development (ICALRRD) as the guardian of peatland maps has carried out mapping of peatlands at a scale of 1:50,000 based on districts/cities since 2013. Until 2019, mapping of peatlands at a scale of 1:50,000 has been carried out in 130 districts / cities identified as having peat, covering the islands of Sumatra, Kalimantan, Sulawesi and Papua.

The peatland map that has been produced has been used as a reference in determining the use of the land, so that any change in peatland cover must pay attention to the characteristics of the land. It is hoped that by referring to the characteristics of the peat, if there is a change in land use it will not cause environmental problems, especially the emission of greenhouse gases from peat.

Peatlands in Indonesia are used as forests, shrubs, plantations (oil palm, coconut, rubber), and food agriculture. Shrubs on peatlands are unproductive land, in addition to increasing greenhouse gas emissions, it will also increase the risk of land fires, reduce biodiversity and reduce watershed stability. The economic and social benefits of bushland are very low, even negative because of the high threat of fire hazard.

Based on the results of spatial calculations from updating the peat map using data from the latest research results, the total area of peat land on a 1:50,000 scale map in 4 main islands, namely Sumatra, Kalimantan, Sulawesi and Papua is 13,430,517 ha, consisting of Sumatra Island covering an area of 5,850,561 ha, Kalimantan with an area of 4,543,362 ha, Sulawesi with an area of 24,783 ha and Papua covering an area of 3,011,811 ha (Table 1). The results of this peat mapping have been published in the Q1 global indexed International Journal, Geoderma in 2021 (Anda *et al*. 2021).

Figure 9.4. Peatland Map of Indonesia Scale 1: 50.000

Figure 9.5. Profile of peat soil and oil palm plantations on peat soils

Land suitability map

The 1:50,000 scale land suitability map is generated from the 1:50,000 scale soil map through land evaluation activities. Land evaluation is done by matching (matching) between land quality/characteristics (Land quality/characteristics) with land use requirements. The result of this activity is information on the level of land suitability for a particular use as indicated by the land suitability class and limiting factors, as well as its area and distribution in an area. Furthermore, based on the limiting factors found, recommendations for land management are drawn up to increase the productivity of strategic agricultural commodities.

With the results of this land suitability assessment, it is hoped that every new land clearing for agricultural commodities follows the recommendations for land use based on the results of the land suitability assessment. By following these recommendations, it is hoped that changes in land use will not result in excessive carbon emissions. Even for lands that were originally in the form of shrubs which were converted into agricultural land (annual plants) which have high CO_2 absorption capabilities, so as to reduce carbon emissions from the land.

The 1:50,000 scale land suitability map contains information with a fairly high accuracy, so it can be used to support agricultural development planning at the district/city level. Until 2019, an Atlas of land suitability maps and directions for agricultural commodities was produced, as well as recommendations for land management in 511 regencies/cities throughout Indonesia. An example of an Atlas of Land Suitability Maps and Commodity Directions in two districts of DI Yogyakarta Province is presented in Figure 9.6.

Land suitability maps at a scale of 1: 50,000 should be used as a guide when taking land use changes, for example when opening new agricultural land. With the guidelines, the impact of changes in land use will have very little effect on environmental changes related to the possibility of greenhouse gas emissions. Based on the reality in the field, it is not always in accordance with the recommendations for land use, so it is very possible that any change in this use will affect changes in plant biomass that cause greenhouse gas emissions.

Table 9.1. Peatland area and distribution by depth in each province in Sumatra, Kalimantan, Sulawesi and Papua

Island	Peat depth						Area	
	D1	D2	D3	D4	D5	D6	ha	%
Sumatera	660,011	1,352,069	1,016,955	1,494,099	782,59	544,838	5,850,561	43.56
Kalimantan	672,525	1,332,268	1,199,923	789,175	507,398	42,072	4,543,362	33.83
Sulawesi	2,606	11,885	8,506	1,687	99	-	24,783	0.18
Papua	1,831,405	740,69	395,74	39,312	4,664	-	3,011,811	22.43
Total	3,166,546	3,436,912	2,621,124	2,324,274	1,294,751	586,911	13,430,517	100.00

D1 = shallow peat (50 - <100 cm), D2 = medium peat (100 - <200 cm), D3 = deep peat (200 - <300 cm), D4 = very deep peat (300 - < 500 cm), D5 = very-very deep peat (500 - < 700 cm), D6 = extrem deep peat (> 700 cm).
Source : BBSDLP (2019)

Figure 9.6. Atlas of Land Suitability Map and Commodity Direction in Sleman scale 1: 50,000 and Land Suitability Map for Rice field in Subang, West Java Provinsi

Land use change

Many tropical countries, including Indonesia, have experienced massive land use changes which have implications for environmental and socio-economic changes for the wider community. The increase in population has actually had the effect of increasing pressure on land and water resources which has shown a number of serious negative impacts such as uncontrolled land use changes in the form of forest encroachment and illegal logging to the upstream areas, loss of forest land cover into other types of land use which are proven to have more limited environmental carrying capacity, so that floods and droughts are becoming more frequent, accompanied by associated disasters, such as landslides, loss of life, displacement of the population, health problems, to starvation, and children dropping out of school.

In this regard, the Ministry of Environment and Forestry (2021) has carried out periodic calculations of Indonesia's deforestation rate, using information since 1990. The development of Indonesia's deforestation (Million ha) from 1990 to 2020 is presented in Figure 7. From the figure, it can be seen that the highest deforestation oc-

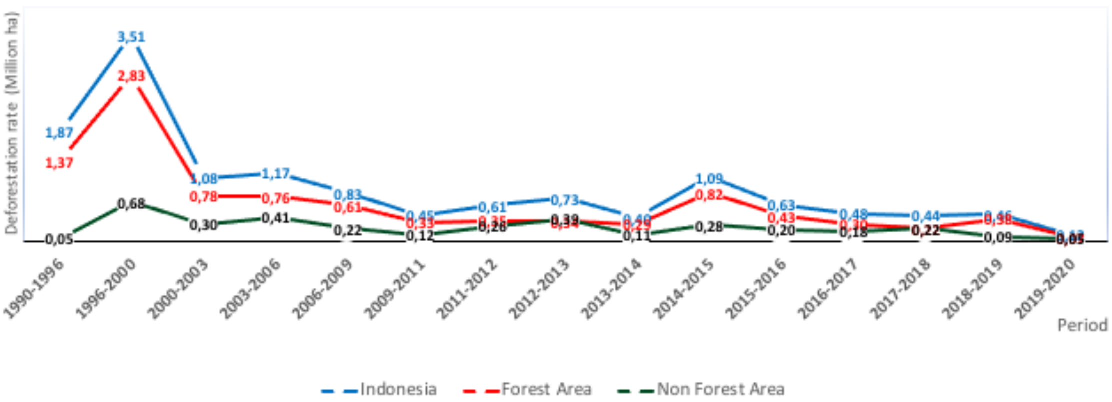

Figure 9.7. Diagram of Indonesia's deforestation progress (Million ha) 1990-2020 (KLHK 2021)

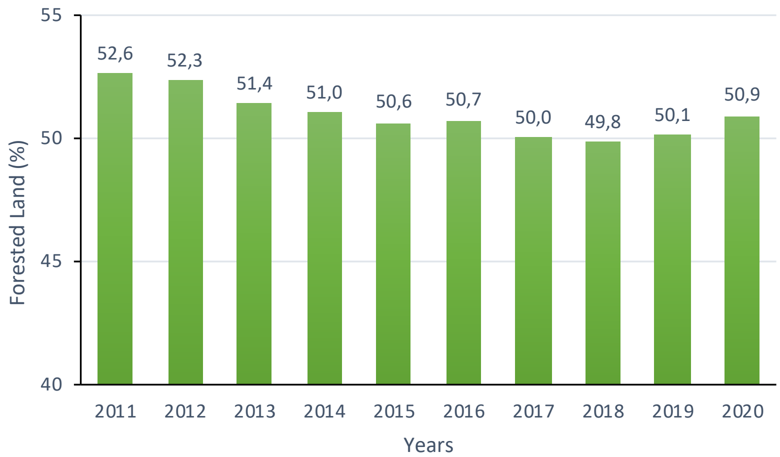

Figure 9.8. Percentage of forested land to Indonesia's land area (KLHK 2021)

curred in the 1996-2000 period, then decreased and in the 2019-2020 period, only 0.12 million hectares of deforestation occurred. Deforestation generally occurs in forest areas compared to non-forest areas.

In line with the deforestation rate that occurs, the results of Indonesia's Land Cover Recalculation from year to year also show a decrease in the percentage of forested land to Indonesia's land area. The complete data is presented in Figure 8.

Overall, the conclusions from the calculation of forest cover in Indonesia until 2020 are as follows:

1. The total land area of Indonesia is 187.8 million ha consisting of 95.6 million ha (50.9%) of forested land and 92.2 million ha (49.1%) of non-forested land.
2. The land forest area is 120.3 million ha consisting of 88.4 million ha (73.5%) of forested land and 31.9 million ha (26.5%) of non-forested land.
3. The area for other uses is 67.5 million ha consisting of 7.2 million ha (10.6%) of forested land and 60.3 million ha (89.4%) of non-forested land.

According to the Ministry of Environment and Forestry (2021) the decline in forest area and land damage has caused negative impacts on people's lives, including floods, landslides, erosion and sedimentation, to the loss of biodiversity and decreased state income from wood

Figure 9.9. Land that has changed land use in mountainous and plains area

products. Various factors can influence land cover change in Indonesia. However, in general, activities that cause a reduction in forest area in Indonesia include the conversion of forest areas for development purposes in other sectors, namely for plantations, agriculture, settlements/ transmigration; illegal timber trading (illegal trading), or illegal logging (illegal logging); forest utilization activities and forest area uses that do not apply the principle of sustainability, legal changes to the designation of forest areas and non-forest areas (Other Use Areas/APL), land encroachment and occupation, forest fires, natural disasters and others.

From the data in Figure 9.2, it can be seen that from 2011 to 2020 there was a decline in forested land to Indonesia's land area, from 52.6% to 50.9% of Indonesia's land area in 2020. One of these changes has a bad impact on increasing greenhouse gas emissions. One that is often blamed is the development of oil palm plantations. Between 2005 and 2015, the area of oil palm in Indonesia more than doubled from about 5 million ha to more than 11 million ha (Indonesian Ministry of Agriculture 2016). The rapid expansion of oil palm has been criticized for environmental reasons, as it is linked to deforestation, loss of biodiversity, greenhouse gas emissions, and other environmental problems (Susanti and Maryudi 2016).

According to Chrisendo (2020), in Indonesia, oil palm is not only cultivated in the plantations of large companies; around 40% of palm oil is produced by smallholder farmers. These farmers benefit economically because oil palm is more profitable than food crop production and less labor than traditional cash crops such as rubber. Beyond profits and income, the effects of oil palm cultivation on other social dimensions of household well-being – such as nutrition – have hardly been analyzed until now. Oil palm has the potential to threaten food security if it is replaced by local food crop cultivation and thus reduces local food availability. On the other hand, palm oil can also improve food security and nutrition through increased income and thus better economic access to nutritious food.

The results of the study of the collaboration between the Indonesian Oil Palm Farmers Association and the Faculty of Forestry and Environment, Bogor University (2022), obtained the following results:

1. With an area of no less than 16.8 million ha (56% are privately owned and BUMN, 44% are smallholder oil palm plantations), oil palm plantations have provided various positive impacts including generating state foreign exchange reaching Rp 200 trillion year^{-1} to overcome the problem of poverty in rural areas, to create jobs so that it absorbs a workforce of around 21.49 million people, as well as various other positive effects. Even in 2017-2018, it managed to make a real contribution as the largest foreign exchange

contributor with a value of 22.97 billion US dollars (GAPKI 2018).

2. Oil palm plantations do not dry out well water, rivers and because the absorption of water from the soil by oil palm plants is not possible to exceed the depth of the soil solum in the root zone.
3. Oil palm plantations can be a habitat for various wildlife taxa (mammals, birds, amphibians and reptiles). Changes in cover in the form of secondary forest to oil palm plantations generally reduce the diversity of mammal species, while for other taxa there is an increase. Changes in non-forest cover to oil palm plantations tend to increase the species diversity of almost all taxa.
4. Oil palm plants have the ability to absorb high CO_2 and are the most efficient in the utilization of solar radiation compared to other forestry commodity crops.
5. Based on the results of studies/analyses on various aspects: origin history, bio-ecology, land suitability and hydrology, biodiversity conservation, micro-climate/GHG absorption and emissions, financial economic performance and its impact on social and culture and society

One of the things that happens in land cover changes in Indonesia is the conversion of agricultural land into non-agricultural land. One example is the conversion of rice fields to non-agricultural land. The results of research by Mulyani *et al*. (2016) estimate the national rice field conversion rate of 96,512 ha year^{-1}. If you focus specifically on this problem, then the change from paddy fields to non-agricultural land will even reduce emissions. Intensive rice cultivation in paddy fields with Green Revolution technology is accused of being less environmentally friendly due to the use of high doses of fertilizers and excessive use of pesticides. In addition, lowland rice cultivation is seen as a source of GHG emissions, especially methane (CH_4), which has the potential to cause global warming. However, changes in land use from agricultural (non rice fields) to non-agricultural land such as settlements, roads, will cause carbon emissions, because changes in plant biomass will cause greenhouse gas emissions.

Closing

The need for land for agriculture, settlement, industry, and other uses has forced land that was previously forest to be converted to non-forest. Greenhouse gas emissions from land use changes occur when the area of forest and land cover does not change during the analysis period. Plant biomass (living plant tissue above the soil surface and plant roots) is one of the most important carbon (C) pools. In addition to biomass, carbon is also stored in dead plant tissue called necromass and in the soil as soil organic carbon.

The development of Indonesia's deforestation from 1990 to 2020 shows that the highest deforestation occurred in the 1996-2000 period, then decreased and in the 2019-2020 period, only 0.12 million ha of deforestation occurred. Deforestation generally occurs in forest areas compared to non-forest areas.

To prevent changes in land use from having a negative effect on the environment, these changes must be guided by the recommendations for the land suitability class. Soil resource data and environmental data are very helpful in assessing land suitability for new land uses.

Oil palm plantations are one of the fastest growing plantations in Indonesia. Most of the new oil palm land comes from abandoned land in the form of shrubs, both on dry land and swamp land. Compared to shrubs, oil palm plants have a high CO_2 absorption capability and are the most efficient in the utilization of solar radiation. Oil palm plantations can be a habitat for various wildlife taxa (mammals, birds, amphibians and reptiles). Around 40% of oil palm plantations in Indonesia are owned by smallholder farmers. These farmers benefit economically because oil palm is more profitable than being used for food crops and less labor than traditional cash crops such as rubber.

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Accelerating Climate Change Adaptation and Mitigation Implementations in Indonesia's Agricultural Sector

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There are direct and indirect impacts of climate change on agriculture, i.e., biophysical and socio-economic ones (IPCC 2001). Biophysical impacts consist of: (i) physiological effects on crops and livestock/fish, (ii) changes in land and water resources, (iii) increased crop pests and diseases, and (iv) increased salinity and sea level, etc. Social-economic impacts are: (i) lower levels of people's and farmers' health, (ii) decreased yield and production, (iii) unstable food commodity price, (iii) increased food insecurity.

Climate change due to global warming is a long-term process of human behavior (anthropogenic). However, it is likely irreversible within a human life period. In the measurable period, technical and socio-economic measures is strengthening adaptation and mitigation capabilities on climate change carried out synergistically (IPCC 2001; 2007).

There is interrelations of synergies and trade-offs between climate change and sustainable development (Beg *et al*. 2002, Karimi *et al*. 2021). Therefore, one of the determinants of sustainable development embeds in global climate change adaptation and mitigation actions. Based on the theoretical views and the lessons learned from empirical phenomena, many complementary points of adaptation and mitigation actions need to be developed interactively (Klein *et al*. 2007).

The biggest contributing factor to global warming resulted in climate change is carbon emission produced by fossil fuel uses since the industrial revolution era. Timely efforts to encourage clean and renewable energy and carry out energy conservation measures will lessen the expense of achieving further emissions reductions in the long term. Slowing down the actions would lead to infrastructure developments that lock in emissions-intensive channels that may be expensive or impossible to change in time to limit warming (Wijaya *et al*. 2017).

There are two regional parts spatially very strategic. First, mountains areas essentially play important role in mitigation actions related with deforestation phenomenon. Second, coastal areas are affected by sea level rise and the coastal land areas shrink. On the other hand, resources sustainability in which most population's livelihood in the coastal areas depend on is affected by mangrove condition. Moreover, mangroves are also essential to climate change mitigation and adaptation (Murdiyarso and Kauffman 2011)

In adapting and mitigating climate change, the role of the agricultural sector is very strategic. In line with population growth, it is necessary to increase food production for feeding the world. However, agriculture is inherently sensitive to climate conditions and the most vulnerable sector affected by global climate change [Parry and Carter 1989, Reilly 1995, Parker *et al*. 2019). Therefore, climate change will negatively affect crop production in major part of the world (Abbasi *et al*. 2020; Praveen and Sharma 2019). In Southeast Asia, while cereal production could increase, rainfed crop production will decline (Chambwera 2011). In the region, the yields of the most important crops required for food security are depressed by climate change. In addition, changing climate have adverse effects not only on food production but also food distribution, infrastructure, land availability for agriculture, and livelihood assets and opportunities. At the same time, agriculture also makes a significant contribution (14%) to greenhouse gas emissions (FAO 2009).

In developing countries, including Indonesia, agriculture is important not only for providing food but it is also a primary source of livelihoods, especially in rural areas. With the main elements of food security, i.e., food availability, accessibility, utilization, and food system stability, adaptation should also target production and non-production aspects of agriculture. In other words, adapting food systems to improve food security for the poor and to avoid future negative impacts of climate change require attention to more than just agricultural production. Food security can only be confirmed and augmented through a range of interventions across different agricultural systems and along the associated value chains, from production to distribution and allocation.

Indonesia's long-term strategy on low carbon and climate resilience (LTS-LCCR) consist of three scenarios. Three scenarios were exercised during the development of Indonesia's LTS-LCCR to provide understanding in a transparent manner on the impacts of each alternative related with emission reduction and economic impacts, prerequisites both domestically and internationally for successful implementation of the determined scenario. The three defined pathway scenarios are as follow: (i) enhanced unconditional commitment of NDC/current policy scenario (named as CPOS), (ii) transition scenario (named as TRNS), and (iii) low carbon scenario compatible with the Paris Agreement target (named as LCCP) (Government of Indonesia 2021).

Historically, autonomous adaptation has been carried out by farmers since centuries ago in accordance with their science and technology. Climate pattern knowledge has been developed indigenously long time ago. However, in the climate change era the rainfall pattern is irregular and unpredictable. Extreme climates take place more frequently. It implies that autonomous adaptation is not sufficient to deal with the farmers' issues. It is not about unavoidable decreased yield and lower harvest quality, but harvest failure probability is bigger.

Adaptation is an equally important objective as mitigation in a world that cannot evade climate change anymore because of already clear evidence of climate change affecting agriculture. A complete response of agriculture to climate change should therefore pursue both agricultural mitigation and adaptation. In order to plan for adaptation effectively, policy makers need reliable information on the nature of both adaptation and mitigation, its costs and how these are related to ongoing efforts to develop the agriculture sector and food systems. For this reason, it is essential to scale up adaptation and mitigation in a synergistic manner.

Adaptation and mitigation principles have been explained extensively by the IPCC experts. To implement them at farm level, however, it needs comprehensive farmers' characteristics and their environment understanding. In general, adaptation and mitigation capacities of smallholders are lower than those of large-scale farmers.

Effectiveness of adaptation and mitigation is not determined by the applied technology, but the key factor is the stakeholders' participation. Using middle technology with very high participation rate of stakeholders will have higher effects than that of high-level technology with low participation. Thus, systematic and consistent collective actions are urgent. Climate change adaptation and mitigation are long journeys impossible to implement sporadically or even in one-shot action.

This paper aims at discussing the strategic loops useful for accelerating climate change adaptation and mitigation actions at farm level. Based on empirical field conditions, the substances are focused on adaption aspects. The first part of the paper describes general Indonesian farmers' characteristics, farmers' food insecurity due to climate change, and some adaptation and mitigation cases applied. The next part depicts general principles of cost and benefit of adaptation and mitigation. Third part deals with enabling climate change actions. The last part is the concluding remark.

Indonesian Farmers & Current Climate Actions

Based on the official data (BPS 2018), total number of Indonesian farm households is more than 27.6 million. The number of farm households by sector is depicted in Fig. 10.1. Classified by spatial distribution, more than 50% of the farm households are found in Java Island. The second and third ranks are Sumatera Island (25%) and Sulawesi Island (8.6%).

Around 64% of farmers are 45 years old or more. Out of 64%, as many as 22% is between 55-64 years old and 13% is 65 years old or more. However, the farmers below 35 years old are less than 12%. Low percentage of young farmers affect information technology adoption rate. Farmers using internet for their farm business are around 13% only.

Most of the farm households are smallholders

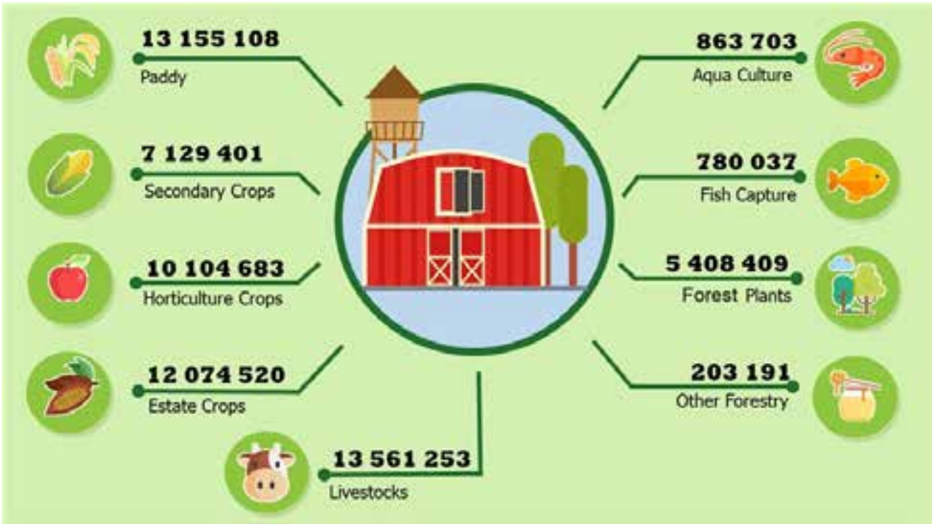

Figure 10.1. Number of farm household by sector in Indonesia BPS (2018)

with less than 0.5 ha of land holding. In aggregate, the smallholders are 59%. Only 25% of the farm households have 1 ha or more of farmland. In Java Island where half of the farm household live, the smallholders are around 80% and only 7% of the farm households have 1 hectare or more of farm land.

To maximize income and to minimize risks, some of the farm households diversify production through growing some commodities outside the main crops. Diversification reasons are: (i) improving farm households' income, (ii) minimizing farm business risk, and (iii) combination of (i) and (ii). In addition, income from small farm land holding is not sufficient to meet the farm households' expenditure. Some farmers also work at non-farm activities for additional income. Percentage of farm households focusing on one subsector only (e.g., on rice farm only, estate crop only, or animal farming only), is 37% and those participate in two, three, and four subsectors are each of 31, 18, and 9.6% (BPS 2018). Agricultural sector's role as the main source of income is indicated by the percentage of farm households depending their main income on agriculture sector. Around 64% of the farm households relay their main income on agriculture, while the remaining 36% depend their income on non-agriculture. In Java Island, only 58% of the farm households rely on agriculture for their income.

Related with low farmland holding of the Indonesian farm households, most farmers in the country deal with food insecurity due to climate change. About 36.5% of farm households cope with food security with the probability of food insecurity of 0.79 (Sumaryanto *et al*. 2018).

At national level, the farm households' adaptation capacity to climate change is well known and it is estimated most of them are classified into relatively low to medium. A study conducted by Sumaryanto (2013) in four regencies, i.e., Central Lampung, Cilacap, Blora, and Sumbawa, revealed rice farmers' adaptation to environment stress were high (13.9%), medium (69.6%), and low (16.5%). Another study also showed that rice farmers' adaption capacity in Pasuruan Regency (East Java) was also relatively low (Salampessy *et al*. 2018).

The empirical studies (Boer *et al*. 2009, Sejati 2011, Sumaryanto *et al*. 2012) concluded that critical loops in enhancing rice farmers' adaptation capacity depended on the following aspects:

1. Improving supply and reliability of irrigation water.
2. Cropping pattern arrangement.

3. Upgrading farmers' access to accurate information on climate forecast.
4. Enhancing farm road quality.
5. Increasing knowledge and skill on adaptation methods.
6. Strengthening Farmers Group Federation's role for implementing cropping pattern on the same expanse.

Based on synergistic adaptation and mitigation, the Indonesia's strategies are as follow. To maintain national food security, climate action priority on food subsector is adaptation while that on estate crop is mitigation (Badan Penelitian dan Pengembangan Pertanian 2011). It is in accordance with COP 26 in Glasgow that agricultural sector is the main victim of climate change. Using the right measures, co-benefit of adaptation action in these subsectors also contribute to green-house gas emission reduction.

There are some adaptation methods to take according to condition and available resources. Those are land and water conservation, water-saving technology for farming, cropping calendar, salinity, drought, and puddle tolerant variety, integrated pest management, balanced fertilizer, and soil conditioner. Those measure include water container construction (pond, ditch, supplement irrigation), grass terracing, cover crop (legume), intercropping, alley cropping.

Some mitigation measures are synergistic with adaptation, such as enhancing organic fertilizer application, low-emission rice variety, peatland water level management, sustainable oil palm farming management, land preparation without burning, etc.

Cost-benefit analysis of adaptation & mitigation

The Cost Benefit Analysis (CBA) focuses on the quantitative evaluation of climate change impacts on (crops). It allows for estimation of the net benefits of different adaptation and mitigation options and is used to assess the options when efficiency is the only decision-making criteria. This involves calculating and comparing all the costs and benefits expressed in monetary terms. This approach identifies the most economic adaptation and/or mitigation strategy and allows ranking all the proposed strategies based on economic efficiency.

In the CBA, the sum of all costs and benefits that will materialize in the future must be brought to present value by applying a discount rate. This rate measures the opportunity cost of investing in a certain measure and not allocating the funds to other activities that could be more profitable. Net present values (NPV) are preferred because they discount the future benefits to present values, whilst internal rate of returns are used to evaluate the most economical strategy. This can be done by: (i) identifying the options employed in the communities, and (ii) for each option, the total costs incurred when using that strategy and benefits were identified and to compute the net benefit for that particular option. The approach for quantifying the measures that do not have direct costs and benefits is shadow price or opportunity cost.

The adaptation or mitigation strategy with a positive and highest NPV is the most economical and efficient. Of course, sensitivity analysis using some scenarios of discount rate should be taken into account. Besides NPV, the other important criteria are internal rate of return (IRR). IRR is the discount rate at which NPV is zero. Usually, the strategy with the highest IRR is preferred.

Costs and benefits of adaptation

This part discusses understanding on critical aspects of costing adaptation – not on how it is estimated. It is based on various implementation level, and magnitudes of cost and benefit depending on technology and institution applied. To some extent, those factors are location specific.

In line with civilization, truly farmers have a long record of adapting to climate variability. At the farm level, measures will be implemented spontaneously by farmers through short term production decisions including adjustments in planting dates, intercropping, or in the intensity of input use. Especially since modern agricultural systems, the decisions will take into account the influence of economic environment including market conditions and public policies, particularly those stimulating research and development, diffusing information, providing institutional support and promoting efficient use of resources.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) defines adaptation as any adjustment in natural or human system in response to actual or expected climatic stimuli or their effects which moderates harm or exploits beneficial opportunities (IPCC 2007). The adaptation consists of deliberate actions undertaken to reduce the adverse consequences, as well as to harness any beneficial opportunities. A wide range of adaptation measures can be implemented in response to both observed and anticipated climate change. The measures are undertaken both by public and private actors through policies, investments in infrastructure and technologies, and behavior change. How much adaptation might cost, and how large its benefits might be, are issues that are increasingly relevant.

The process of adapting to climate and climate change is both complex and multifaceted. As such it is very difficult to do adaptation analytical justice, and a number of typologies have been developed to classify adaptation activities. For example, adaptation measures have been classified according to timing (anticipatory vs. reactive); scope (local vs. regional, short-term vs. long-term); purposefulness (autonomous vs. planned); and adapting agent (natural systems vs. humans, individuals vs. collective, private vs. public).

There are so many measures of adaptation in agriculture among others: (i) altering farming practices and crop varieties, (ii) building new water reservoirs, (iii) enhancing water use efficiency, (iv) farm diversifications, (v) cultivating saline tolerance varieties, (vi) adjusting planting date, etc.

The IPCC AR4 defines adaptation costs as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs," and defines benefits as "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures". The CBA of climate change adaptation measures must be a social CBA. This means that merely financial profitability cannot be the determining factor when assessing whether or not to implement an adaptation measure. In other words, many should be implemented even if their economic costs seem to exceed their benefits. The following two operational difficulties result from this: (i) how to quantify in monetary terms all the benefits associated with an adaptation measure since most of them are intangible and therefore have no market price, (ii) how to select an appropriate discount rate to determine the present value of costs and benefits that will take place in different moments in time.

The Cost – Benefit Analysis (CBA) establishes a framework to evaluate whether the cost of implementing a measure of adaptation is greater or less than the benefits that would be derived from it. The CBA can be either financial or social. The objective of a financial CBA is to obtain a monetary return, while the objective of a social CBA is emphasized to increase the well-being of a community.

There are biophysical, economic, and social economic limits with regard to the level and rate of climate change that the different systems can adapt to (Klein *et al*. 2007). The gross benefit of adaptation is the difference between the climate damages with and without adaptation. Adaptation, however, will also entail costs. It implies that these costs need to be deducted from the gross benefits to arrive at the net benefits of adaptation. So, while adaptation can reduce negative impacts of climate change, there will nevertheless be residual damages.

Table 10.1. A hypothetical classification of adaptation costs and benefits (Agrawala and Fankhauser 2008)

	Current climate	Changed climate
Current adaptation	Adaptation cost: 90	Adaptation cost: 90
	Ordinary climate damage: 50	Ordinary climate damage: 50
	Climate change damage: 0	Climate change damage: 200
Extended adaptation	Adaptation cost: 150	Adaptation cost: 150
	Ordinary climate damage: 20	Ordinary climate damage: 20
	Climate change damage: 0	Climate change damage: 120
Net benefit of extended adaptation	Incremental adaptation cost: 60	Incremental adaptation cost: 60
	Incremental adaptation benefit: 30+0	Incremental adaptation benefit: 30+80
	Net benefit: - 30	Net benefit: +50

To get better understanding, there was an interesting illustration of the issue (Agrawala and Fankhauser 2008) as follows (Table 10.1).

The starting point is the society adapted to the current climate through measures ranging from farmland irrigation to flood protection infrastructure. The top left of Table 10.1 represented the current state. In the top middle column of the table: the society is spending an amount of 90 units on adaptive measures. Included in these costs are both monetary components (e.g., capital costs) and nonmonetary components (e.g., the impact on the environment). This level of adaptation is sufficient to prevent most adverse climate effects, but not all. There is a residual damage of 50 units, for example due to occasional extreme flooding.

Current adaptation is preferred over extended adaptation because the additional cost of more comprehensive protection (150-90=60) is higher than the additional benefits of reduced flood damages at the margin (50-20=30). The calculus changes with climate change (associated, for example, with a higher frequency of storms and floods). Under a changed climate, the extra costs of adaptation (150-90=60) are more than offset by the reduced costs of climate change (200-120=80). In this particular example, the climate change benefits alone are sufficient to justify adaptive action, but the extra reduction in ordinary climate impacts (50-20=30) is an important ancillary benefit. The ancillary benefits occur because the extended protection system will reduce the impact of both climate change-induced and ordinary floods.

Obviously, the example of Table 1 is simplistic and ignores important complications, such as uncertainty and continuous change. However, it helps to flesh out two important issues: the costs of adaptation have to be measured against current adaptive measures; and many adaptive measures may have climate change as well as non-climate-change-related benefits, although distinguishing between the two will not be possible in practice.

At the theoretical level, costing adaptation is a simple way in the sense of involving the identification of the likely impacts of climate change and their required responses followed by constructing the budget required to undertake these responses and aggregating them across different scales. However, there are numerous complexities that need to be addressed in the implementation ranging from the nature of developing local to national agriculture to the methodological difficulties of employing costing techniques to an emerging and vaguely-defined field such as adaptation.

There are some studies related to the impacts of climate change and the benefits of adaptation in the agricultural sector in various regions (Adams *et al*. 1995, Seo and Mendelsohn 2008, Wang *et al*. 2009). At the global level, Reilly *et al*. (1994) and Darwin *et al*. (1995) examined the climate change and adaptation impacts on world agriculture and economy. Global assessment of Rosenzweig and Parry (1994) reported the impacts and adaptation benefits in terms of increased cereal production and food security. The adaptation benefits also assessed by Tan and Shibasaki (2003) using a GIS-based crop model. A general finding from those studies is that relatively modest adaptation measures can significantly offset declines in expected yields as a result of climate change. However, based on the review of 69 studies on the impacts of climate change on crop yields conducted by IPCC (IPCC 2007) there is a key message that while farm level adjustments yield significant benefits, such benefits do not occur equally in all regions. As tropical developing countries are, in many cases, expected to benefit less from low-cost adaptations, benefits may be larger in developed countries than in developing ones.

Costs and benefits of mitigation

Different with adaptation, the boundaries of mitigation measures are more clearly defined. There is a clear metric (reduction in greenhouse gas-GHG emissions) for assessing the effectiveness of such measures and it implies that pricing GHG emissions according to the polluter-pays-principle is the most economically efficient approach to limiting global warming. However, despite their efficiency, the economic burden that such carbon pricing policies could place on some agricultural producers and consumers can make them politically difficult to introduce. Much of the mitigation from an emissions tax would be driven by the reallocation of production away from more towards less emission intensive sectors and regions. While this lowers the overall emission intensity of agricultural production, it could cause a large decline in ruminant production – especially in developing countries, raising concerns about food security among poor producers and consumers (OECD 2019). Based on national and regional budgets (APBN and APBD) the GHG reduction measures are carried out as follow: (a) According to sustainable development principles; (b) Usefulness of cost utilization for integrated GHG emission reduction based on the lowest cost principle; (c) Easy implementation by taking into account the political, social and cultural aspects; (d) In accordance with the national and the regional development priorities in the activity location; (e) Using the principle of mutual benefits by prioritizing development/activity programs that contributed to the GHG emission reduction or Co-Benefit (Thamrin 2011).

In the agricultural sector, GHG emissions could be minimized by using different techniques such as biofuel, conservation tillage, cover crops, drained wetland management, lime amendments, residue management, etc. The emissions from rice-based cropping systems could be minimized by water and residue management, organic amendments, ratoon cropping, fallow management, use of nitrification and urease inhibitors and different fertilizer placement methods and sulfur products. In animal production, GHGs emission is mainly due to enteric fermentation, and manure management. It means that emissions from enteric fermentation and housing could be modified by using different methods. It includes management in the feed and use of different microorganism products. In case of manure management techniques like anaerobic digestion, liquid manure storage and treatment practices could be used to minimize or modify GHG emissions.

IPCC Special Report on Global Warming of 1.5ºC confirms there is an important role for land use sectors in stabilizing global temperatures (IPCC 2018). Options could be implemented in the agriculture sector to mitigate GHG emissions are: (i) introducing farm practices that reduce agricultural non-carbon dioxide (non-CO_2) emissions; including methane (CH_4) and nitrous oxide (N_2O), and (ii) introducing practices to remove CO_2 from the atmosphere and accumulate as carbon in vegetation and soils, or that reduce emissions from the degradation and removal of these carbon stocks.

Recent GHG mitigation research in the agriculture and allied sectors has explored a range of options that can significantly reduce GHG emissions from the global food systems. Livestock accounts for up to half of the technical mitigation potential of the agriculture, forestry, and land use sectors (Herrero *et al*. 2016). Mitigation options in the livestock sector include improved feed and manure management, grazing optimization, development of silvo-pasture systems. Advances in agronomy (tillage, nutrient, water, weeds, and energy management) and improved breeding have a large potential to reduce GHG emissions from crop fields (Beach *et al*. 2016, McKinsey 2020).

Enabling climate actions in agriculture

The agricultural sector has a crucial role in meeting development goals around the world. Not only is the sector responsible for meeting demand for food, it also has a major influence on essential ecosystem services and provides a livelihood for more than half of rural household especially in the developing countries. Additionally, growth in the agriculture sector is vital in inducing wider economic development.

The changing climate will have adverse effects on food production, food distribution, infrastructure, land availability for agriculture, and livelihood assets and opportunities in rural and urban areas. Adapting food systems to both enhance food security for the poor and to prevent the future negative impacts of climate change will require attention to more than just agricultural production. Food security can only be ensured and enhanced through a range of interventions across different agricultural systems and along the associated value chains, from production to distribution and allocation.

The current efforts to get agriculture into the global climate policy framework after the expiry of the Kyoto Protocol emphasizes mitigation. Adaptation is an equally important objective in a world that cannot avoid climate change anymore due to accumulated greenhouse gases. In developing countries, adaptation is the primary concern due to their vulnerability to climate change and high dependence on weather-dependent agricultural systems. A complete response to climate change that integrates agriculture should therefore pursue both agricultural mitigation and adaptation. To plan adaptation effectively, policymakers need reliable information from developing countries on the nature of adaptation, its costs, and how these are related to ongoing efforts to develop the agriculture sector and food systems of developing countries. Ignoring the linkages between adaptation and agricultural development could lead to duplication and inefficient use of scarce resources or even to interventions in one area conflicting with the other's goals. For example, a focus on maximizing food production could promote mono-crops that foreclose the ability of farmers to diversify their food sources. Given that developing country agriculture is already being affected by climate variability and other development constraints, the greatest promise that a new global climate change policy framework offered is the potential to enable these countries to move from a focus on negotiations to actions through effective planning tools and resources for implementing their plans.

Implementation of synergistic adaptation and mitigation to climate change in agricultural sector is equally problematic. One thing that is clear is that time is running out. Agriculture is already suffering adverse impacts from climate change. There is a limited window for action to ensure a robust agricultural system that can withstand the more serious consequences projected for the future. But different stakeholders see adaptation in different ways. So, while the International Food Policy Research Institute (IFPRI) advocates more research, the UN Conference on Trade and Development highlights issues in global trade; and most development agencies concentrate on boosting sustainable development, poverty reduction and social protection.

Agricultural systems are also complex, with links across scales and sectors. This means that the impacts of climatic events have multiple dimensions. For instance, the impact of a drought can be seen in the lack of rainfall that reduces yields on a dryland plot, the failure to deliver water to marginal farmers in a small irrigation scheme, and adjustments to national food availability and prices mediated by the political economy. Differentiating climate change impacts and adaptation from this dynamic complexity over the next few decades is impossible in most situations.

Adaptation options in agriculture are shaped by a combination of climate, development and environmental considerations and there is no single planning approach that suits every community or country. But thinking of adaptation as a 'pathway' of social, economic and institutional change can help actors to adjust to known climatic and developmental stresses while learning how to adapt to future climates as better information becomes available.

The shape of adaptation pathways over time is influenced by several factors. In many cases, today's decisions can shape tomorrow's options. The decision to gather new information or train new actors now could significantly expand choices later. For example, establishing a network of weather stations now opens up the future option of weather insurance, which requires at least ten years' of data to establish baseline risk. Conversely, investing in major water reservoirs now precludes other adaptive options later.

A range of actions that could help lay the ground for adapting agriculture to climate change consist of:

1. The need to assign institutional responsibility for coordinating adaptation. Adapting agriculture to climate change cannot be done by any single organization alone. Integrating local and district 'agents of change' into national processes and plans will help ensure effective action on the ground. Such inclusive planning can also help ensure the necessary funding for agricultural development and adaptation at all scales.
2. The need to integrate adaptation into agricultural institutions. The emergence of climate change units in agricultural research institutes is a promising start for building capacity. But institutional change at national level is also required. Operational ministries should mobilize effective coordination, access to funding and knowledge-led capacity.
3. The need to enable continuous assessment along the adaptation pathway, which is essential to apply lessons learnt, scale up successes, develop innovative technical, financial and institutional instruments and prepare to adapt to the more challenging scenarios of climate change beyond 2030.

Agriculture is a part of the whole economic sectors. Climate change affects all economic sectors. It implies that adaptation and mitigation to climate change in agriculture sectors is also a part of the whole sectors adaptation and mitigation.

In Indonesia a large part of the problem is the diversity of variables, states and processes that exist in the country; and the different ways in which these interact with regional and global conditions. This makes it very difficult to predict how agriculture will develop and be affected by climate change in terms that provide robust targets for adaptation. For example, while climate models generally predict a warming in almost all areas, they vary significantly in predictions for agro-ecological zones particularly with regards to rainfall. Additional uncertainty about the future of environmental services, especially soil quality, adds to the difficulty in making predictions that can inform adaptation planning for specific adaptation actions now.

Adaptation and mitigation are two inextricable actions in responding to global climate change (Government of Indonesia 2021). Integrating mitigation and adaptation measures can increase local people's acceptance and interest

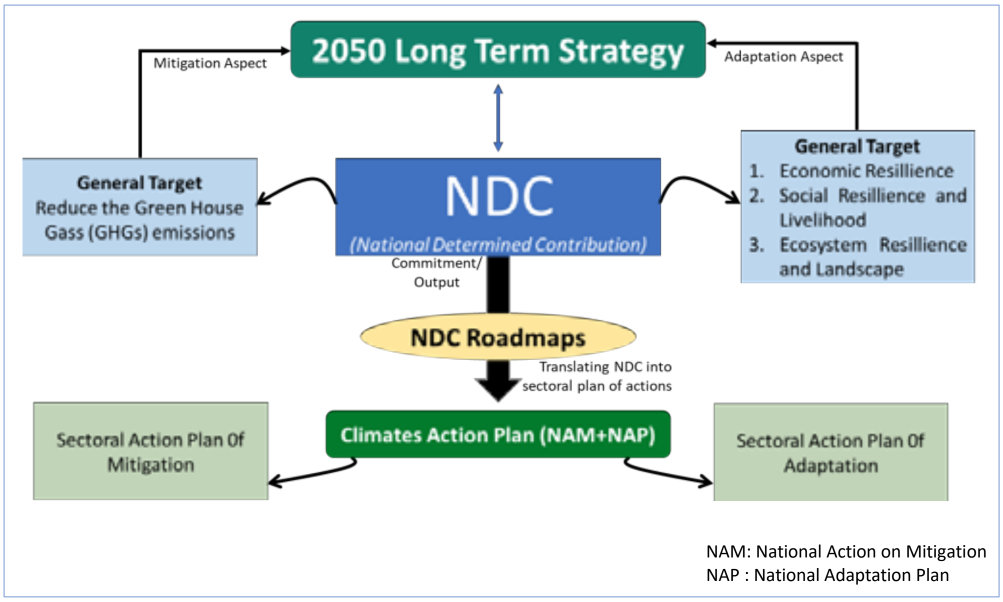

Figure 10.2. Connectivity between mitigation and adaptation in long term strategy (Government of Indonesia 2021)

in mainstreaming climate change actions. This is because adaptation emphasizes the urgent needs of local communities, while mitigation has more long-term global benefits. Therefore, the greater the mitigation effort, the less adjusted impacts, and the less risk involved. Conversely, the greater the degree of adaptation preparedness, the less impact associated with a particular level of climate change.

Climate change mitigation and adaptation cannot be seen as alternatives to each other, because they are not independent activities, but have a complementary role in responding to climate change which is carried out at different spatial, temporal, and institutional scales (Fig. 10.2). If mitigation is successful in reducing greenhouse gas emissions substantially, the effects of climate change will continue because the lag time remains between the reduction in greenhouse gas concentrations and the reduction in the rate of warming. This means that adaptation is very important, regardless of the impact of mitigation. However, very few communities at the grassroots level are aware of their vulnerabilities and risks. Therefore, the objectives of Indonesia's climate change adaptation strategy are directed at reducing risks, increasing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change in all development sectors by 2030 through increasing climate literacy, strengthening local capacity, improving knowledge management, policies convergence on climate change adaptation and disaster risk reduction, and the application of adaptive technology.

General target of mitigation aspect is GHGs emissions reduction prioritized for agriculture, forestry, energy, waste, IPPU (Industrial Processes and Product Use). While general targets of mitigation economic resilience, social resilience and livelihood, and ecosystem resilience and landscape.

Referring to NDC roadmaps, implementation of climate action plans (NAM) is prioritized for: (i) forestry and land use, (ii) agriculture, (iii) energy including transportation, (iv) industry, and (v) waste. Adaptation priorities area: (i) food (agriculture, food product, technology), (ii) energy, (iii) health, (iv) livelihood, (v) infrastructure, (vi) ecosystem and biodiversity, (vii) cities, and (vii) coastal and small islands.

Financing strategy for climate mitigation and adaptation in Indonesia [50] is currently at the preliminary stage of development. The concept is built with the assumption that the finance needs for climate actions should be addressed by optimizing climate finance system, starting from finance sources, finance institutions and their mechanisms as well as institutions receiving finance to carry out programs/activities to achieve the set target. Therefore, the current efforts as part of the financing strategy for climate mitigation and adaptation includes increasing diversification of sources of finance, strengthening capacity of finance institutions, and strengthening capacity of stakeholders in accessing finance.

The Government of Indonesia has taken a number of policies that open opportunity to increase diversification of finance sources from both national and international – public and private sources. At the national level, the opportunities to optimize state budget are explored (e.g., using instruments of green sukuk or green bonds and draft of PERPRES NEK on Carbon Pricing Instruments such as fees and carbon levy; instruments of intergovernmental fiscal transfer; instruments of PAD or regional income and other sources of income). Furthermore, Indonesia continues to mobilize international financial sources through bilateral, regional, and multilateral channels, including result-based payment for REDD+ under the Paris Agreement, grant, and other potential sources and mechanisms.

Adaptation to climate change and lower emission intensities per output will contribute both to achieve food security and agricultural development as a whole. The transformation must be accomplished without depletion of the natural resource base. FAO introduced Climate-Smart Agriculture (CSA) to contribute transformation. CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. The approach is designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges (FAO 2013). It is composed of three main pillars:

1. Sustainably increasing agricultural productivity and incomes;
2. Adapting and building resilience to climate change;
3. Reducing and/or removing greenhouse gases emissions, where possible.

The scaling up of CSA practices will require appropriate institutional and governance mechanisms to disseminate information, ensure broad participation and harmonize policies. It may not be possible to achieve all the CSA objectives at once. Context-specific priorities need to be determined, and benefits and tradeoffs evaluated.

Climate change is already having an impact on agriculture and food security as a result of increased prevalence of extreme events and increased unpredictability of weather patterns. This can lead to reductions in production and lower incomes in vulnerable areas.

Enhancing food security while contributing to mitigate climate change and preserving the natural resource base and vital ecosystem services requires the transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs, and are more resilient to risks, shocks and long-term climate variability. More productive and more resilient agriculture land, water, soil nutrients and genetic resources management to ensure that these resources are used more efficiently. Making this shift requires considerable changes in national and local governance, legislation, policies and financial mechanisms. This transformation will also involve improving producers' access to markets. By reducing greenhouse gas emissions per unit of land and/or agricultural product and increasing carbon sinks, these changes will contribute significantly to the mitigation of climate change. Innovative financing mechanisms linking and blending climate and agricultural finance from public and private sectors are a key means for implementation, as are the integration and coordination of relevant policy instruments and institutional arrangements.

Conclusions

Dealing with climate change adaption and mitigation, the agricultural plays a very critical role. This sector bears more obligation as it should meet the increased food demand along with population growth. On the other hand, agriculture itself is quite sensitive to climate change risks.

Many elements involved in the agricultural system including other sectors and each element is inter-dependent. Multi-dimension effect is quite possible as the impacts of climate change on agricultural sector.

Sustainable development should take account climate change adaptation and mitigation as it is one of the determining factors. Climate change adaptation and mitigation are inseparable actions. Thus, these actions should be carried out together such that the benefit results will be surpass the cost spent.

Climate change has taken place and feasible actions are adaptation and mitigation. It needs to accelerate the actions because delay will worsen the impacts. Adaptation and mitigation should be carried out synergistically and the main key determinant is participation.

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ISBN 978-602-6916-59-4
9 786026 916594