Climate Change and Food Security: Indonesian Experience

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Abstract

Food security is very important for Indonesia with a large population. Agricultural sector as a contributor about 5-7 percent to CO_2 emissions, is a victim of climate change as this sector is very sensitive to the change of climate such as rise of temperature, drought, El Nino and La Nina and rise sea level. The decline in production due to climate change and extreme climate is very risky for Indonesia's food security. Various studies have been conducted to evaluate the impact of climate change. However, Since 2009, voluntary commitment of Indonesian Government to reduce 26 percent of CO_2 emissions set up the strong effort in many sectors to adapt with climate change. In agriculture, improving soil quality is key in maintaining food production. Soil conservation using vegetative or engineering technique is one of the most important technology. Nutrient management by applying balance fertilization, the use of organic material and ameliorant such as biochar, zeolite and other natural mineral are beneficial for plant production. All these ameliorants will be very useful in maintain soil organic matter (SOM) and soil carbon which very important in increasing water holding capacity. Water harvesting is one option to capture high precipitation and important to irrigate agricultural area. Besides, the use of cropping calendars, high yielding varieties which adapt to biophysical stress will be very useful. Other effort is also needed to control the peat fire, peat drainage and deforestation.

Keyword: *climate change, CO_2 emissions, El Nino, La Nina, extreme climate events*

Introduction

Food security in Indonesia could be threatened by climate change. Climate change is well known as a result from emission of greenhouse gases (e.g. CO_2, CH_4, & N_2O, etc.) that cause atmospheric warming (IPCC, 2007). According to Baumert et al. (2005) Indonesia rank on 16th GHG emitter in the world. Source of CO_2 emission in Indonesia are mostly from forest due to land use change and forest fires. Agricultural sector emit CO_2 and also a victim of the CO_2 emissions. Many studies has been conducted to evaluate the CO_2 emission on agricultural farming systems (Wihardjaka, 2015; Mulyadi et al., 2001 ab; Mulyadi et al., 2002), and under different land uses on agroecosystems including peatland (Husnain et al., 2014; Dariah et al., 2014; Marwanto &Agus, 2013). Some studies are related to the adaptation and mitigation plan for reducing CO_2 emissions and action plan into provincial, district and regency level. Current and future predicted pattern of global climate change are a major concern in many areas including socio-economic activities, such as agriculture, forestry, and very crucial for biodiversity and ecosystem functions (Lepetz et al., 2009).

The main issue that every country must face is how to adapt this current and future climate change. Agriculture is one of the sectors, which are very sensitive to climate change through, increasing atmospheric temperature, precipitation, soil moisture, sea level and humidity which all contributes to the climate change. Greenhouse gases especially CO_2 has been claim as the dominant factor caused global warming and thus climate change. This climate change also resulted extreme climate events as like El Nino and La Nina. The Pacific Oceans are the dominant oceanic source of CO_2 emission to the atmospheric counted about 72% (IPCC, 1994; Tans et al., 1990 and Takahashi et al., 1997). Some studies also reported the effect of El Nino are significantly contributed to the CO_2 emission (Feely et al.,1995; Wanninkhof et al., 1996; Inoue and Sugimura, 1992), however, the effect has not been quantified. According to the NOAA, the role of El Nino maximum about 20% in increasing CO_2 emissions. At recent, extreme climate events, especially those related to El Nino and La Nina, increase in intensity and frequency.

The agricultural sector, particularly food subsector, is the most sensitive in dealing with this extreme climate. Floods and droughts that follow the two phenomena above greatly affect productivity, planting area and harvested area of food crops (Amedie, 2013; Morison & Lawlor, 1999; Lukac et al., 2010; Gunderson, 2012; Chen, 1996). The ability to achieve and maintain food security is a must for Indonesia with a population of around 265 million people (the fourth largest in the world) with a growth rate of 1.33% per year (World Bank, 2018). Various extreme climate events, both globally and nationally, have provided various experiences and learning related to the risks and impacts they have caused as well as learning in anticipating, facing and mitigating them. Serious negative impacts from extreme climates can occur in food security which leads to social and economic aspects and even politics. All experience and learning must be used as a reference in preparing strategies and approaches in dealing with global warming and extreme climate events.

In Indonesia and Asia region, extreme climates are closely related to the phenomenon of ENSO (El Nino southern oscillation) in the form of El Nino and La Nina that occurred very often (Kovats et al., 1999). The negative impact of El Nino and La Nina significantly affect plant yields according to the intensity and period of their appearance.

To adapt with this climate change its required actions and supporting policy to support the program which can be implemented. Several program has been launched and applied since 2007. Government Policy related to the actions plans to cope with climate change are many as follows: National Action Plan by the Ministry of Environment in 2007, Law Number 6 Year 1994 concerning Ratification of the United Nations Framework Convention on Climate Change; 2. Law Number 17 of 2004 concerning the Ratification of the Kyoto Protocol; 3. Law Number 32 of 2009 concerning Environmental Protection and Management; 4. Minister of Forestry Regulation No. P14 of 2004 concerning Guidelines for Preparing Afforestation or Reforestation Projects in the framework of Clean Development Mechanism (CDM); 5. Presidential Regulation Number 46 of 2008 concerning National Council on Climate Change (DNPI); 6. Minister of Forestry Regulation No. P.68 of 2008 concerning Implementation Demonstration Activities Reduction Carbon Emissions from Deforestation & Forest Degradation (REDD); 7. Minister of Forestry Decree No. P.30 of 2009 concerning Procedures for Reducing Emissions from Deforestation & Forest Degradation (REDD); and 8. Minister of

Forestry Regulation No P.36 of 2009 concerning Business Licensing Procedures for Utilizing Carbon Absorption and/or Storage in Production Forests and Protected Forests.

In line with policy support, practical implementation in the field by researchers and practitioners focus on to disseminate the adaptation and mitigation program mainly through application of climate smart technology such as the use of Integrated Planting Calendar Information System, soil and water conservation, water harvesting, cropping pattern, use of high yielding varieties, balanced fertilization, controlling of pest and disease of plant (IAARD, 2011). Reported in IAARD (2011) since 2015 El Niño incident, Indonesia addressed the improvement of the irrigation system and the construction of water infrastructure. Besides the spread of drought-resistant seeds, application of soil and water conservation techniques and through cross-sectoral activities in the form of controlling forest and land fires. Agricultural insurance is also one strategy in anticipating extreme climates that directly affect farmers has been introduced since 2015-2018 coordinating by Directorate General of Infrastructure and Facilities (Directorate General of Infrastructure and Facility, 2017).

In this review paper, we discuss the global warming, extreme climates events, especially on food production and how to deal with those situation. Indonesian experience may bring information sharing for the country experiencing the same climate.

Climate Change and Food Production

Effect of greenhouse gas emissions (CO_2)

Indonesian GHG emissions were 1.8 billion tons carbon dioxide equivalents (Gt CO_2eq) in 2005, ~65% of which were derived from the agriculture, forestry and other land use (AFOLU) sectors (Ministry of Environment, 2010). PEACE (2007) reported total emission 3,014 M tonnes, while USAID (2007) reported Indonesia's total GHG emissions in 2013 were 2,161 million metric tons of carbon dioxide equivalent (Mt CO_2e), totaling 4.47 percent of global GHG emissions. Different data of total GHG emissions probably due to different prediction or measurement. Based on data of Ministry of Environment (2010), Indonesia's 2013 GHG emissions (65.5%) were from land-use change and forestry (LUCF), followed by emissions from energy (22.6%), agriculture (7.4%), waste (3%) and industrial processes (1.4%).

Although agriculture's source emission was small, but this sector is the most sensitive to the effect of climate change. Thus the largest concern for Indonesia with regard to the impacts of climate change is the risk of decreased food security. Climate change will alter precipitation, evaporation run-off water and soil moisture; hence will have effects on agriculture and thus food security. The drought caused by the 1997 El Nino events affected 426,000 hectares of rice. Other important crop as like coffee, cocoa and rubber are also affected (FAO, 1996). Projected changes in crop yields in Asia could vary between -22 percent to +28 percent by the end of the century in the event of a doubling of CO_2 gas concentration (Reilly, 1996). Fischer et al., (1996) using models of the Goddard Institute of Space Studies (GISS) and Geophysical Fluid Dynamics Laboratory (GFDL) climate change scenarios produced yield changes ranging from +30 to -30%. Effects under the GISS scenario are, in general, more adverse than under the GFDL scenario to crop yields in parts of Asia and South America, while effects under the GFDL scenario result in more negative yields in the United States and Africa and less positive results in former USSR. The UKMO (United Kingdom Meteorological Office) climate change scenario, which has the greatest warming 5.2°C global surface air temperature increase, causes average national crop yields to decline almost everywhere. This result shows a decrease of crop harvest in West and East Java. Climate change will likely reduce soil fertility by 2 percent to 8 percent, resulting in projected decrease of rice yield by 4 percent per year, soybean by 10 percent and maize by 50 percent (Amin, 2004 and Parry and Nih, 1992). In Figure 1, using models with representatives data, showing the response of yield change due to the increasing temperature. Wheat production decrease sharply compared than maize and rice. The less effect likely found on rice probably as effect of submerged condition.

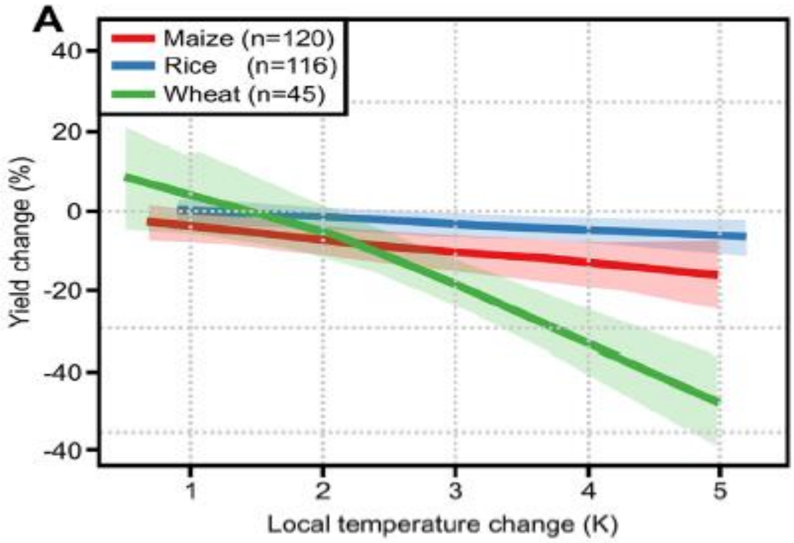
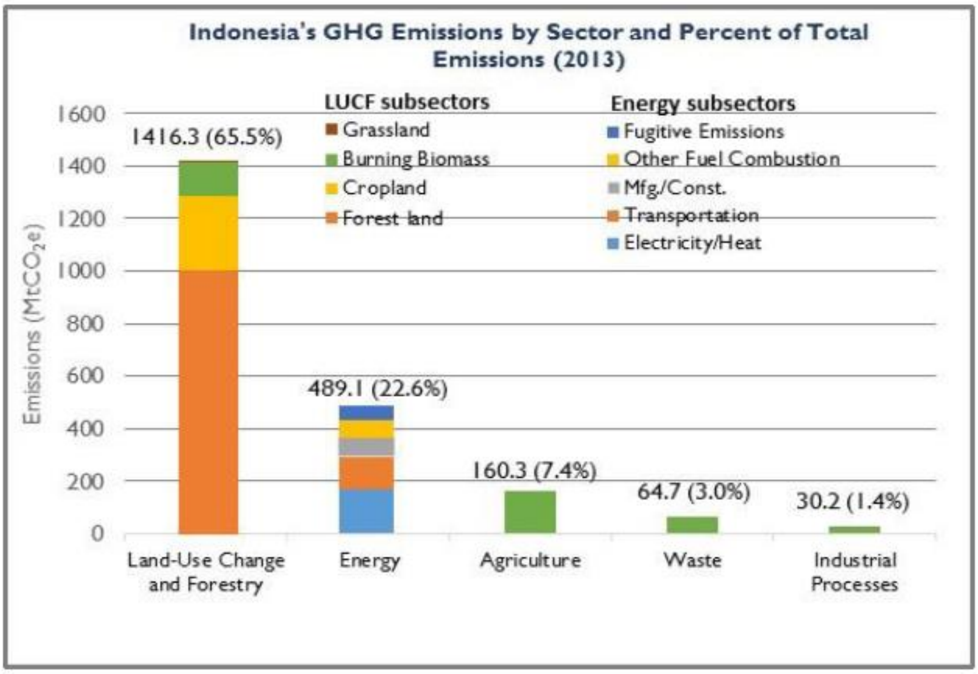


Figure. 1. Impacts of climate change on the productivity of tropical cereal. Adapted from Porter et al., (2014) in Campbell (2016) who develop yield response curves from a meta-analysis of published crop simulations.



Sources: WRI CAIT 2.0, 2017, FAOSTAT, 2017 in USAID (2007)

Figure 2. Indonesia GHG emissions by sector and Percent of Total Emissions (2013)

Effect of El Nino/La Nina

Perhaps the most important natural fluctuation in the Earth's climate is the El Nino process. Indonesia's climate diversity is also influenced by various atmospheric circulation and the most stronger influence by El Nino Southern Oscillation (ENSO). The warm phase of ENSO is known as El Nino which occurs because of the increase in sea surface temperature in the Middle and East Pacific and associated with drought whereas otherwise La Nina cooler sea surface temperatures occur in the Central and Eastern Pacific causing the mass of water vapor to move to Indonesia so that rainfall increases (Australian Bureau of Meteorology, 2010). Phase and intensity of ENSO expressed in an index by several prediction models such as Ocean Nino Index (ONI), Multivariate ENSO Index (Wolter and Timlin, 1993), Modoki ENSO Index (Ashok, 2007). According to Barnston et al, (1997) ONI describe ENSO much better.

According to Hidayat et al. (2018) Nino 3.4 index is highly correlated with Indonesian rainfall (r = -0.95). Positive rainfall anomalies up to 200 mm/month occurred mostly in Indonesian region during La Niña events, but in December, July and February in several areas of Sumatera, Kalimantan and eastern Indonesia tend to have negative rainfall. Data from Golden Gate Weather Service (2018) shows that in the last 68 years (period 1950-2017) occurred 18 times El Nino, of which three events where El Nino were very strong, four events each El Nino was strong and moderate and seven events El Nino were weak The number of cases of La Nina was lower, 15 times in that period, namely the incidence of La Nina was strong, five events of La Nina were moderate and six events of La Nina were weak. El Nino drought due to the wider area of impact due to drought is slow onset, takes place over a long time and in a wider area. On the other hand the characteristic flooding occurs suddenly in a short period of time with the affected area much smaller

According to Boer et al. (2014), the increase in 1°C anomaly in sea surface temperature in the region affected by El Nino has the potential to cause a decrease in monthly rainfall in the Indonesian region ranging from 0-50 mm. The increasing temperature due to CO_2 emission, extreme climate events are direct and indirectly affected plant growth and thus production.

Table 1. Impacts of drought on agriculture productivity in some recorded year (Sutardi, 2006)

Year	Decrease in productivity (Ha)	Harvest Failure (Ha)
1994	489,178	150,319
1995	18,462	3,385
1996	48,490	11,458
2001	145,545	11,344
2001	298,678	20,694
2003	430,258	82,690

Table 2. Impact of El Nino and La Nina on the productivity, harvested are and production of rice, corn and soybean during period 1970-2010 in Indonesia (Irawan, 2013 in Sulaiman et al, 2018).

Parameters	Climate events	Rice	Corn	Soybean
Productivity (%)	El Nino	-0.50	-0.82	-0.19
	La Nina	-0.65	-0.41	-0.78
Harvested area (%)	El Nino	-3.58	-4.85	-4.66
	La Nina	2.43	3.55	5.07
Production (%)	El Nino	-4.08	-5.67	-4.85
	La Nina	1.78	3.14	4.29

According to data in Table 2, El Nino during period of 1970-2011 caused decreasing of 0.50 percent rice productivity in average. Other studies reported about 0.15-0.47 percent (Sumaryanto et al., 2011) and Tawang (2003) found in Malaysia its about 1.15 percent. The effect of El Nino on rice production was relatively small. The reason is rice is cultivated under irrigation or during rain season. The effect of La Nina on the rice production are also decreasing by -0.65 percent, -0.41 percent and -0.78 percent for rice, corn and soybean respectively. Decreasing of harvest area are relatively higher than productivity, -3.58 to -4.85 percent. This phenomenon due to less water available during plant growth. Decreasing productivity and harvested area thus will affected production.

In contrary, La Nina showed positive impact on the harvested area of rice, corn and soybean. This due to long period of rain season, this will benefit upland especially for corn and soybean. According to Sulaiman et al, (2018), El Nino affect negatively production while positive impact during La Nina. While for vegetable crops and horticulture, both El Nino and La Nina caused negative effect by decreasing production of shallot, chilly pepper, and potatoes.

Positive impact of extreme climate events are occurred under swampland where under normal condition are always submerged for long time, during El Nino it became dry and could be cultivated. ICALRD (2017) in Las et al (2018) reported about 509.000 Ha of increasing harvested area under tidal swampland. In Table 3, about 42% of increasing tidal swampland during El Nino events. This phenomenon are an advantage to compensate the region which non cultivated due to drought.

Table 3. Potency of tidal swampland for agriculture under extreme climate events (Las et al., 2018 in Sulaiman et al., 2018)

Province	**Potency of cultivated tidal swampland (Ha)**		**Increasing**
	Normal	El Nino	
South Sumatra	200.400	368.700	+83.98%
Riau	131.800	113.600	-13.81%
Lampung	79.000	137.900	+74.56%
South Kalimantan	153.000	181.900	+18.69%
Total	564.200	801.900	+42.13%

Effect of rise sea level

Climate change will also increase the average sea level due to increased volume of the sea water and the melting of polar ice caps. The average depth of inundated area varies between 0.28 and 4.17 meters in 2050 (Meliana, 2005). In rural district such as Karawang and Subang, 95 percent reduction in local rice supply (down 300,000 ton) is estimated as a result of inundation of the Coastal zone. In the same district, Corn production would be reduced by 10,000 tons, abut half of this due to inundation. In the lower Citarum basin, sea level rise could result in the inundation of about 26,000 ha of ponds and 10,000 ha of crop land. This could result in the loss about 940,000 tons of rice production (Sulaiman et al., 2018).

The impact of El Nino is stronger in most of Kalimantan, Sulawesi and most of Java and Papua Islands. In the strong El Nino in 1982/83 and 1997/1998 the decrease in rainfall in the region was 50-100 mm from the average rainfall of 150-250 mm per month, while in other islands the decrease was less than 50 m from 200-250 mm per month (Ministry of Environment, 2010)

Programs and strategy to cope with climate change

Effect of climate change on food production are initially by affecting soil quality and plant growth. Verchot et al, (2010) found that CO_2 emissions of plantation under peat soil are three fold higher than that on mineral soil while the grass land are showing no emissions. It means soil is the most important factor need to take into account for the adaptation and mitigation strategy.

Table 4. Results of the modelled carbon dynamic for 3 scenarios over a 50 year horizon (Verchot, *et al.* 2010)

Scenario	Emissions/removals tCO_2 ha^{-1}	Total emissions/removals Million tonnes CO_2
Plantation on mineral soil	830	4130
Plantation on peat soil	2420	12080
Plantation on degraded grassland	-86	-435

Positive values represent emissions to the atmosphere; negative values represents removals. Emisssion and removals are calculated per ha and represent the total cumulative emissions over a 50 year period. Total emissions/removal are calculated assuming that all 5 million ha are successfully planted.

Table 5. Climate change variables, the effects on soil and adaptation approaches (Agus et al., 2015)

Climate change variables	Effect on soil	Adaptation approaches
Temperature rise	Increased microbial activities that potentially lead to increased carbon emissions and soil aggregate breakdown	Mulching with plant residues and regular cycling of organic matter to maintain high soil organic matter content
Unpredictable weather	Uncertainty in the amount and timing of soil water availability and hence uncertainty of planting date	Water prediction e.g. using cropping calendar
Extremely high rainfalls	Increased runoff, high erosion by water, high rate of soil nutrient leaching	Improvement of infiltration capacity, reduction of slope steepness and slope length, reduction of rain drop kinetic energy using cover crop and mulch. Increasing soil organic matter content, improvement or drainage systems and construction of water retardation system
Low rainfall and long dry season	Soil dryness, cracks and surface sealing because of high evapotranspiration	Water harvesting, mulching, organic matter application, irrigation, increasing water holding capacity
Sea level rise	Salty water intrusion and inundation causing salinization and dispersion of soil aggregate	Salt leaching, improving drainage, reducing evaporation (e.g. by mulching), applying chemical treatment, and a combination of these methods.

Agus et al, (2015) summaries the adaptation approaches in term of the negative effect of climate change on to the soil (Table 5). Best management practices (BMP) are the proper approach to cope the effect of climate change and all the method are well studied and practices in the field at farmer level. Several BMP includes: conservation tillage (vegetative and engineering conservation), soil nutrient management by practicing balance fertilization including maintaining soil organic content, the use of organic and biofertilizers.

Soil Conservation

Conservation tillage is a key for agricultural sustainable and has been proven adaptive to water shortage. Several model of conservation tillage such vegetative soil conservation measures, including agroforestry, vegetative grass strips, cover crop and cropping pattern (Agus and Widianto 2004) resulted maintaining soil organic and carbon, minimizes water evaporation due to the presence of crop residues on the soil surface. Several studies reported that this vegetative soil conservation increase soil organic carbon by reducing soil organic matter decomposition by soil microbes (Rachman et al. 2004; Zhang and Nearing 2005; Ugalde et al. 2007; Lal et al. 2011). Beside vegetative conservation technique, engineering conservation is also need to be consider. Engineering techniques in soil conservation is very effective but costly with labor intensive. According Agus (2001), bench terrace is one of the most popular engineering soil conservation techniques in Indonesia and elsewhere in Southeast Asia.

Nutrient management and organic matter

Broader and Volenec (2008) clearly explain on how temperature affecting root zone. By increasing the temperature, it will accelerate adsorption/desorption reactions and changes in soil moisture thus it would change the reactions by altering the ionic strength of the soil solution favoring nutrient availability in the root zone. In this condition, positive effect of increasing temperature reported. A long series of crop modeling study proved that climate change impacts on nutrient will be primarily affected through direct impacts on root surface area (Claassen and Barber 1976; Barber and Cushman 1981; Itoh and Barber 1983).

Balanced fertilizer application refers to the application of plant nutrients in optimum quantities in the right proportion through appropriate methods at the time suited for a specific crop and agro-climatic condition. In extreme weather condition such as high rainfall or even drought, improved management of fertilization and organic matter are very important. For example, one should avoid broadcast fertilizer in the rainy season to reduce nutrient loss. Instead, fertilizer incorporation in the surface layer is more recommendable. Also, to reduce the loss of organic compost, it can be applied in the plant hole at the time of planting.

Soil ameliorants such as organic matter, biochar, zeolite, and other minerals can also improve soil structure and protect soils from structural degradation. Soil ameliorants increase soil resilience to various stresses, including those related to climate change. According to Hillel (1998) soil structure could be improved by applying soil ameliorants with the main function in increasing water holding capacity, binding soil aggregate, thus provide proper rhizosphere condition for biological activity and biodiversity and thus improve crop yield.

Water Harvesting

Water management such as water harvesting is one best approach to anticipate water shortage. The principle of water harvesting is to collect excess water in the rainy season in such a way that it contributes to reducing the risk of floods and redistribute it in the dry season to minimize drought stress. Water retardation pond (WRP) is an example of water harvesting. Build irrigation facility such as an outlet from main river for the agricultural irrigation should be consider. Appropriate design of WRP determines its optimal use. The efficient use of water irrigation would be result of the proper management of irrigation system.

Cropping Calendar

We had use Integrated Cropping Calendar to provide easier access for planting time, fertilizer recommendation, pest and disease threatened region. This model are worked well as long as extension services and local government support in the district level. The use of high yielding variety which adjust to the biophysical stress are recommended. Overall, strong support from government and effort of all stake holder will be very beneficial to achieved the goal to maintain food security.

Several programs were implemented to anticipate climate change and extreme climate events as explained above. An integrated model in measuring the reduce in CO_2 emission in agriculture were reported. By using integrated framework of the national Asia-Pacific Integrated Model/Computable General Equilibrium (AIM/CGE) and a bottom-up technology model (i.e., the AFOLU model) built agriculture, forestry and other land use (AFOLU) (Hasegawa et al, 2016). Figure 3 shows the reduced emission in the agriculture and livestock management by 2030 with a share of countermeasures. Total reduced CH_4 and N_2O emissions reached 47 $MtCO_2$/year in 2030, which was a much smaller than that in the land use sector. High-efficiency fertilizer application (i.e., split fertilization) on cropland soils, water management in rice paddies and livestock' manure management contributed substantially to reducing emissions in the sectors. Increased crop and livestock production made more opportunities to implement these additional effective mitigation measures.

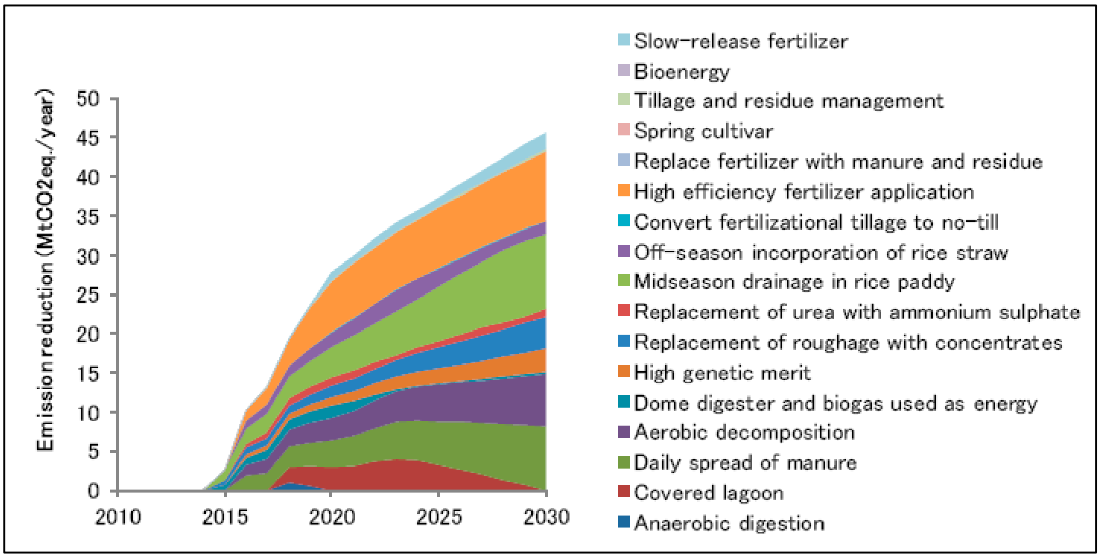


Figure 3. Reduced emission in the agriculture and livestock managements with a share of technical mitigation measures calculated using the AFOLU bottom-up model (Hasegawa et al., 2016)

As in 2009, the Indonesian government pledged to reduce carbon emissions by 26% through its own efforts and by up to 41% through international support compared with the business-as-usual (BaU) scenario by 2020. The LULUCF options for achieving reduction targets of CO_2 emissions are urgently required. Verchot (2010) listed some important actions to be taken such as controlling peat fires, peat drainage and deforestation/LUCF emissions.

Conclusion

Climate change will affect food security including food availability and accessibility. Agriculture and forestry will not only be affected by climate change, but also contribute to it through emitting greenhouse gases. They also contribute to climate change mitigation through reducing greenhouse gas emissions by changing agricultural practices. In the food and agriculture sector, adaptation and mitigation often go hand to hand, so adopting an integrated strategic approach represents the best way forward. Decreasing of food productivity, harvesting area and production due to climate change were reported for several main crops. Increasing temperature, drought, flood, El Nino and La Nina and rise sea level were significantly affected food production. The decreasing of food production will automatically high risk for maintaining food security. The best management practices was a key actions to deal with climate change. Several programs including conservation technique, nutrient management and water harvesting are the best practices which exist at some extent in Indonesia. Controlling fire, peat drainage and deforestation are very important in order to reduce GHG emissions. Those approaches of agricultural practices offer possible synergies among sustainable development and climate change mitigation, and should be prioritized in the national programs in reducing emissions.

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