Adaptation and mitigation strategies for impacts and efforts of climate change in Indonesia

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Abstract. Global warming has become an important issue at this time, where this phenomenon is caused by an increase in the concentration of Greenhouse Gases (GHGs). Climate change is believed to have a negative impact on various aspects of life and the development sector, especially the agricultural sector, and it is feared that it will bring new problems to the sustainability of agricultural production, especially food crops. Rice fields are one the main anthropogenic source of nitrous oxide (N$_2$O) gas, which contributes to global warming. Impact of climate change requires an active effort to anticipate it through mitigation and adaptation strategies. Therefore, the government of Indonesia has taken several steps to cope with anticipated greater losses, among others, through mitigation and adaptation programs. Mitigation measures in the agricultural sector is done through several activities, among others: the development of low-emission rice, ZA fertilizer use as nitrogen source, the development of rice cultivation technology without processing, the development of organic agriculture, green energy development and the development of intermittent irrigation technology. While adaptation measures in this program include: adjustment of time and cropping patterns, use of resistant varieties of drought, submergence, and salinity; rain harvesting technology development, and irrigation technology. This paper attempt to highlight the position agricultural sector in climate change, either as an emitter, sink or impact prone sectors climate change.

1. Introduction

Global warming has become an important issue at this time, where this phenomenon is caused by an increase in the concentration of Greenhouse Gases (GHGs), especially CO$_2$ in the atmosphere and has resulted in various adverse effects on humans. Various countries, including Indonesia, pay great attention to the effects of global warming. Internationally mitigation of global warming is contained in The Kyoto Protocol which regulates the obligation to reduce GHGs emissions for advanced industrial countries [1].

Global climate change issues cannot be rejected by people all over the world, including Indonesia, so that global climate change will be a challenge for Indonesia in achieving sustainable food security. Global climate change may cause changes in the factors important in the development of agriculture, such as changes in rainfall patterns, rising temperatures, changes in air humidity. The changes also impact on unfavorable events such as floods, droughts, which can lead to large losses. Various things have been done by The Government of Indonesia in ensuring the sustainability of food security, such as the development of agricultural technologies that are adaptive to global climate change, develop environmentally friendly farming technologies [2].

The agricultural sector in addition to receiving the impact of global climate change, is also one of the causes of global climate change is included in the category or anthropogenic factors. Increased concentrations of GHGs like CO$_2$, CH$_4$, N$_2$O, SF$_6$, HFCs and PFCs are the result of human activity, especially in the utilization of fossil fuels, industrial development, waste, agriculture and animal husbandry, conservation land that is less controlled. Indonesia has been blamed as the country of the world's third largest producer of GHGs, mainly due to changes in land use and deforestation. However, based on the results of GHGs inventories by the United Nations Framework Convention on
Climate Change (UNFCCC) turned Indonesia into the order of 16 emitters of GHGs from 20 countries. Agricultural sector GHGs emissions released in the form of CO$_2$, CH$_4$, N$_2$O into the atmosphere in significant quantities [36]. Emissions come from a variety of activities such as burning crop waste, soil organic matter, and decomposition of organic matter, ruminant digestive fermentation, livestock manure, and wetlands [37]. Therefore, the strategy of anticipating and preparing adaptation technology is a key aspect that must be a strategic plan of the Ministry of Agriculture in order to respond climate change and develop agriculture that resilience climate change [1].

2. Interaction between greenhouses gases (GHGs) and rice fields

Greenhouse Gases (GHGs) is a collective term for gases that have a greenhouse effect, such as chlorofluorocarbons (CFCs), carbon dioxide (CO$_2$), methane (CH$_4$), nitrogen oxides (NO$_x$), ozone (O$_3$) and water vapor (H$_2$O). Some of these gases have a greater greenhouse effect than other gases. For example, methane has a 20 – 30 times greater effect than CO$_2$, and CFCs are thought to have a greenhouse effect 1000 times stronger than CO$_2$ [3]. The GHGs: CO$_2$, CH$_4$, and N$_2$O are the main contributors to radiative forcing in the atmosphere [4, 5, 6]. Rice fields are one the main anthropogenic source of N$_2$O gas, which contributes to global warming [7]. N$_2$O concentrations in the atmosphere are reported to have increased at a rate of 0.25% every year [8], [9]. N$_2$O gas is naturally produced in the soil through microbiological processes, denitrification and nitrification. The process is affected by available organic matter, nitrate supply, oxygen availability, soil water content, soil reaction (pH), soil temperature and the presence of plants [8], [9]. N$_2$O gas is naturally produced in the soil through microbiological processes, denitrification and nitrification. The process is affected by available organic matter, nitrate supply, oxygen availability, soil water content, soil reaction (pH), soil temperature and the presence of plants [8], [9]. Nitrifying bacteria (Nitrosomonas and Nitrobacter) which are chemoautotrophic bacteria play a role in the nitrification process that is responsible for the loss of N from paddy fields [10]. In reductive soil conditions, facultative denitrifying anaerobic bacteria convert nitrate to nitrogen molecules (N$_2$O, N$_2$) [11]. According to [12], some soil microorganisms able to produce N$_2$O gas that is nitrifying bacteria, denitrification bacteria, non-nitrifying bacteria reducing nitrates, nitrate reducing fungi or other fungi.

Availability of nitrates in the soil is one of the factors determine the rate of denitrification. NO$_3^-$ is very unstable in stagnant soil conditions, which within a few days after flooding of nitrates will disappear as N$_2$O and N$_2$ through denitrification [13]. The denitrification process produces N$_2$O gas in an anaerobic atmosphere, but it is also reported that the process can take place in the presence of O$_2$. Some denitrification bacteria use O$_2$ and NO$_3^-$ simultaneously as an electron acceptor [12].

Provision of organic ingredients in cultivated plants it is suspected that it promotes increased activity of denitrifying microbes and N$_2$O emissions [14]. Natural N$_2$O emissions can increase due to various types of agricultural activities. The activity is directly increase the supply of N into the soil that can be converted to N$_2$O [15]. According to [16], an average of 1.25% N added to the soil as fertilizer or organic waste or biological fixation is transformed into N$_2$O.

N$_2$O gas emission rates depend on the amount and composition of fertilizer either fertilizer organic or mineral fertilizers [17] Increase in fertilizer dosage cages up to 7.5 t ha$^{-1}$ increase N$_2$O emissions range from 28.8-100.3% [18]. Input material organic which is easily degraded through immersion of the remaining plants the land will increase the amount denitrifier and denitrification rate, so provide favorable conditions for N$_2$O formation [19], [20]. Nutrient loss through nitrification denitrification causes efficiency Low N fertilizer [21]. N nutrients that are lost through denitrification in paddy fields can range from 30-40% [22], [23], which can affect the N balance in crop production systems [8].

3. Impact of climate change in the agriculture sector

Agriculture, especially the food crop subsector, is most vulnerable to climate change related to three main factors, namely biophysical, genetic, and management. This is because food crops are generally seasonal crops that are relatively sensitive to stress, especially excess and lack of water. Technically, vulnerability is closely related to land use systems and soil properties, cropping patterns, land, water
and crop management technologies, as well as crop varieties [24]. Three main factors related to global climate change, which have an impact on the agricultural sector are: 1) changes in rainfall patterns, 2) increased incidence of extreme climates (floods and droughts), and 3) increases in air temperature and sea level [25]. See Figure 1 and 2 in below.

Figure 1. The area of rice plantations that experienced drought (above) and flood (below) in Indonesia in the period 1989-2010 [27].
Figure 2. The Indonesia Drought Impact Index (IDKP) map that shows damage in the rice crops from drought period in the West Java and South Sulawesi [28].

At the International Panel on Climate Change reported that since 1850, there were 12 warmest years recorded based on global surface temperature data. Eleven of the 12 warmest years occurred in the last 12 years. Number of temperature increase from the year 1850-1899 to 2001-2005 peak in 0.76°C. Global average sea level has also increased by an average of 1.80 mm per year in the period 1961-2003 [30]. Rising sea levels also have a serious impact on the agricultural sector. The most significant impacts were the shrinking of agricultural land on the coast (Java, Bali, North Sumatra, Lampung, West Nusa Tenggara, and Kalimantan), damage to agricultural infrastructure, and increased salinity that damaged crops [26]. See Figure 3 below.

Figure 3. The trend of sea level rising based on altimeter data from January 1993 to December 2009 using spatial trend analysis [29].

4. Efforts to face climate change
International and national policy is an indicator that the problem of climate change is a serious problem that must be addressed to avoid a more severe impact, which is detrimental. In the agricultural sector, at least there are two approaches used in anticipation of global climate change,
among others, Mitigation and Adaptation. Mitigation is a series of active measures to prevent or slow down climate change / global warming and reduce the impacts of climate change or global warming (through efforts to reduce GHGs emissions, improve the absorption of GHGs. Adaptation to climate change is essential and must be done, given Indonesia's vulnerability to the impacts of climate change and low capacity to adapt [2].

4.1. Mitigation technology

4.1.1. Use of low emission rice varieties. Paddy rice is known as the main source of CH₄ gas emissions, which is between 20 – 100 Tg CH₄/year [7]. CH₄ gas emissions are determined by differences in the physiological and morphological characteristics of rice varieties. The ability of rice varieties to emit CH₄ depends on the aerhenal cavity, number of tillers, biomass, root patterns, and metabolic activity. [31] have compiled various rice varieties and their emission levels and recommended the use of several low emission varieties, including Maros with emissions of 74 kg CH₄/ha/season, Way Rarem 91.60 kg CH₄/ha/season, Limboto 99.20 kg CH₄/ha/season, and Cihera with emission of 114.80 kg CH₄/ha/season. The dominant rice variety planted by farmers is IR64. However, currently farmers are starting to replace IR64 with similar varieties, namely Cihera. Besides being more resistant to pests and diseases, Cihera variety also emits lower methane gas. Thus, the wider planting of Cihera varieties will reduce GHGs emissions from paddy fields. Low emission rice varieties in tidal land, especially on land sour sulfate, like the Punggur variety and Indragiri can be used as consideration in applying technology environmentally friendly tidal farming to support improvements national rice production.

4.1.2. Use of ZA fertilizer as a source of fertilizer Nitrogen. N fertilizer sources such as ZA can reduce CH₄ gas emissions 6% compared to urea if fertilizer is spread on the soil surface, and reduce CH₄ emissions by 62% if ZA fertilizer is immersed in the soil [32]. However, this method cannot be practiced in all locations, and should be applied to Sulfur-deficient soils or high pH. CH₄ gas emissions using ZA fertilizer reached 157 kg CH₄/ha/season [33], 12% lower than when using urea fertilizer emitting CH₄ 179 kg CH₄/ha/season [34].

4.1.3. Application of technology without tillage. Application technology without tillage. Processing of dry soil can suppress the emission of CH₄ from the soil compared to the processing of wet soil or siltation. This is due to the continuous improvement of the organic material is aerobically, so that C released in CO₂ form is lower than CH₄ on heating rates. However, wetting the soil when dry, can spur N₂O emissions. Minimum tillage or no treatment can reduce levels of methane gas emissions from about 31.50 to 63.40% compared with a perfect treatment. Minimum tillage can be done in-textured soil crumbs and a little weed [35]. Common practice in Indonesian farmers cultivate the land with perfect or nearly perfect, especially in the process of rice cultivation.

4.1.4. Intermittent irrigation technology. In addition to saving water, intermittent technology can reduce methane gas emissions from paddy fields. The saving of irrigation water can be done by means of intermittent irrigation (irrigating the land and drying the land periodically within a certain period of time), and the leb system (irrigating the land and then allowing the water to dry, then irrigating again). This method affects the physic-chemical properties of the soil (pH and Eh) which are more beneficial for plant growth because it removes toxic substances for plants, such as organic acids and H₂S, in addition to reducing methane gas emissions by 88% [36]. CH₄ gas emissions in IR64 rice varieties with continuous and intermittent irrigation were 254 kg and 136 kg CH₄/ha respectively, or could reduce emissions by 49% [37]. According [2] reported able to save irrigation water use by more than 30%.
4. 1. 5. Development of organic farming systems

Development of organic farming systems in Indonesia, now began to run very fast, along with increasingly aware of the importance of safe food (food safety). Through the development of organic agriculture is expected to be able to reduce greenhouse gas emissions. Specific CH\textsubscript{4} emission reductions may be greater in line with the utilization of livestock waste into bio-gas, green energy [2].

4. 1. 6. Development of Green Energy

Green energy development is in line with government programs to realize the Independent Energy Village. One of the government’s efforts to meet its own needs for the village, is the development of green energy, which is now starting a lot of discussion. One of the green energy that can be generated in the agricultural sector is the development of bio-gas is a gas CH\textsubscript{4}, which is flammable. Now the government will have to spend quite heavily in developing green energy in rural areas in order to satisfy themselves. CH\textsubscript{4} gas generated from bio-gas manufacturing process, is one sizeable gas emissions resulting from the agricultural sector. Through the utilization of livestock waste into CH\textsubscript{4} gas, will be able to reduce the amount of gas emissions into the air, which will eventually accumulate to avoid the occurrence of global climate change.

4.2. Adaptation technology

4.2.1. Time adjustment and cropping patterns. In farming systems in Indonesia, farmers generally use planting calendar, based on indicators such as the natural variety of stars, the development of several specific types of plants, which shows the condition of the season. So that the rice cultivation system is known in Indonesia as the term "Kerta-Masa" which informs whether the moon is a good time or not for rice cultivation. But with global climate change, then plant the way is the right time for certain crops like paddy need to be adjusted. Timing and cropping patterns are very strategic efforts to reduce or avoid the effects of climate change due to seasonal shifts and changes in rainfall patterns. The Ministry of Agriculture has published the Atlas Map of the Java Island Planting Calendar on a scale of 1: 1,000,000 and 1: 250,000. The map is prepared to describe the potential pattern and time of planting for food crops, especially rice, based on the potential and dynamics of climate and water resources [26]. To guide farmers in adjusting planting times and patterns, the Indonesian Agency For Agricultural Research and Development (IAARD), Indonesian Ministry of Agriculture, since 2007 has compiled information on rice planting calendars for every sub-district all over Indonesia in the form of an atlas. The Map of Food Cropping Calendar at a scale of 1: 250,000 has been made for the islands: Java [38, 39], Sumatera [40]. Planting calendar maps are arranged based on the condition of the current cropping pattern of farmers (existing), with three climate event scenarios, namely wet year (TB), normal year (TN), and dry year (TK). In its use, the planting calendar map is equipped with climate predictions to determine future climate events, so that the planting plan can be adapted to climate and water resource conditions [1].

4.2.2. Use of superior varieties resistant to drought, soaking and salinity. In anticipation of the dry climate, the Ministry of Agriculture has released several varieties / lines of plants that are tolerant to dry climates, namely paddy fields of Dodokan and Silugonggo varieties, and expectations of S3382 and BP23; Argomulyo and Burangrang soybean varieties and GH SHR / WIL-60 and GH 9837 / W-D-5-211 hope lines; peanuts varieties of Singa and Jerapah; mung bean Kutilang variety and GH 157D-KP-1 hope line; and Bima 3 Bantimurung, Lamuru, Sukmaraga and Anoman corn varieties. One of the impacts of rising sea levels is increasing salinity, especially in coastal areas. Salinity in rice is closely related to heavy metal poisoning, especially Fe and Al. Since 2000 a number of rice varieties that are resistant to salinity have been released, namely the Way Apo Buru, Margasari, and Lambur varieties, and obtained several GH TS-1 and GH TS-2 hope lines. Swampland has great potential and prospects for agricultural development, especially in supporting national food security. The land throughout the year or for a certain time it is always saturated or waterlogged with shallow water. In an effort to optimize the use of the land, some rice lines have been obtained that are tolerant of inundation, such as
4.2.3. **Rain harvesting technology.** This technology is one alternative water management technology with the principle of accommodating excess water during the rainy season and using it in the dry season to irrigate crops. The technology of rain harvesting that has been widely applied is ponds and trench dams [1]. Creating a pond with a larger scale which is used to irrigate the fields within a certain area, such as a pool (reservoir) Telaga Tunjung in Bali, which can irrigate the fields more than 500 ha. In addition to the effort of making small-scale ponds, generally used for the needs of human life and livestock, as many have built in critical areas, such as some areas of Karangasem Regency and Nusa Penida island in Bali Province [2].

4.2.4. **Irrigation technology.** Irrigation technology that has been developed to cope with water stress in plants both jointly and severally, capillary irrigation, drip irrigation, *macak-macak* irrigation (*macak-macak* irrigation means very little irrigation water, just wet paddy soil by water), rotating irrigation, and intermittent irrigation. The application of irrigation techniques that aim to meet the water needs of plants in conditions of very limited water availability and improve the usability of the water. In addition, please note that plants also need to be given water as needed. For example, rice is not a water plant, but plants that need water, so the provision of water to rice should be done in a timely manner, with the right amount of water. Excess or shortage of water will affect less favorable for the achievement of plant productivity [2].

5. **Conclusions**

The strategy of anticipating and preparing adaptation technology is a key aspect that must be a strategic plan of The Ministry of Agriculture in order to respond climate change and develop agriculture that resilience climate change. Impact of climate change requires an active effort to anticipate it through mitigation and adaptation strategies. Therefore, The Government of Indonesia has taken several steps to cope with anticipated greater losses, among others, through mitigation and adaptation programs. Mitigation measures in the agricultural sector is done through several activities, among others: the development of low-emission rice, ZA fertilizer use as N source, the development of rice cultivation technology without processing, the development of organic agriculture, green energy development and the development of intermittent irrigation technology. While adaptation measures in this program include: adjustment of time and cropping patterns, use of resistant varieties of drought, submergence, and salinity; rain harvesting technology development, and irrigation technology.

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