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Makalah REVIEW

Environmentally Friendly Agricultural Development

Pembangunan Pertanian Ramah Lingkungan

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Abstract. Environmentally friendly agriculture is an agricultural system that manages all resources and inputs of the agricultural system to achieve optimal productivity and economic benefits, but has a low risk of resource and environmental sustainability, as well as global warming/climate change. Environmentally friendly implementation strategies lead to synergy and integration between technologies, optimization of resources and production inputs which are carried out through three approaches, namely: (1) Anticipation, adaptation, and mitigation approaches in the context of global warming and climate change, (2) Mitigation approach, countermeasures, and remediation in the context of edhapik and biological environments, and (3) Land remediation approach in the context of degradation and pollution of land, air and ecosystem resources due to excessive use of agrochemicals. Support for research activities and development of adaptation, mitigation and remediation strategies for the restoration of polluted land is expected to increase the economy while producing healthy agricultural products and environment. Various regulations and policies for implementing a sustainable agricultural environment, socialization and implementation in the field must be supported by an agricultural environment information system that is easily accessed by users.

Key words: environment friendly agriculture, strategy of implementation, technology component

Abstrak. *Pertanian ramah lingkungan merupakan sistem pertanian yang mengelola seluruh sumberdaya pertanian dan masukan sistem usaha tani secara bijak untuk mencapai produktivitas dan keuntungan ekonomi yang optimum, namun berisiko rendah terhadap kelestarian sumberdaya pertanian dan lingkungan, serta pemanasan global/perubahan iklim. Strategi penerapan pertanian ramah lingkungan mengarah pada sinergitas dan keterpaduan antar-teknologi, optimalisasi sumberdaya dan input produksi yang dilakukan melalui tiga pendekatan, yaitu: (2) Pendekatan antisipasi, adaptasi, dan mitigasi dalam konteks pemanasan global dan perubahan iklim, (2) Pendekatan mitigasi, penanggulangan, dan remediasi dalam konteks lingkungan edhapik dan biologi, dan (3) Pendekatan remediasi lahan dalam konteks degradasi dan pencemaran sumberdaya lahan, air dan ekosistem akibat penggunaan bahan agrokimia yang berlebihan. Dukungan terhadap kegiatan penelitian dan pengembangan strategi adaptasi, mitigasi dan remediasi pemulihan lahan tercemar diharapkan dapat meningkatkan ekonomi sekaligus menghasilkan produk dan lingkungan pertanian yang sehat. Berbagai regulasi dan kebijakan terhadap pelaksanaan pertanian berkelanjutan berwawasan lingkungan, sosialisasi dan implementasinya di lapangan harus diperkuat dengan dukungan sistem informasi lingkungan pertanian yang mudah diakses pengguna.*

Kata kunci: pertanian ramah lingkungan, strategi penerapan, komponen technologi

INTRODUCTION

Agricultural development in realizing food sovereignty face various challenges, including climate change, damage to the environment and natural resources, land use change, and population growth. The increase in human activities in the agricultural sector has led to environmental problems, such as climate change and the accumulation of hazardous toxic materials. Climate change occurs as a result of global warming due to increased concentrations of greenhouse gases in the earth's atmosphere. The global CO2 concentration in the atmosphere in April 2020 was 416.18 ppm, while the concentration in 1990 was 350 ppm (http://CO2.earth) (Figure 1). The uncontrolled use of agrochemicals and industrial activities in agricultural areas contributes significantly to the decline in soil quality, pollution of soil, water, and agricultural products, which can endanger human health.

Climate change is an environmental issue that has received serious attention from regional, national, and international communities that can threaten life in the future. Climate change can have a negative impact on the agricultural sector, such as the crisis of food availability, decreased productivity, and declining production of agricultural crops, as well as the degradation of land and water resources which can reduce the level of land fertility and cause pollution. Climate diversity causes floods and droughts, and the conversion of productive lands. As proof of the Government's seriousness in dealing with climate change, the Government issued Presidential Regulation (Perpres) No. 61/ 2011 concerning the National Action Plan for GHG Emission Reduction and Presidential Regulation No. 71/ 2011 concerning the Implementation of the National GHG Inventory. As in the attachment of Presidential Regulation No. 61/2011, the agricultural sector must reduce its emission level by 8 Gg CO2e. Various plans at the national level have been carried out to achieve these targets. Policies undertaken to support RAN-GRK include strengthening national food security and increasing agricultural production with low GHG emissions. As a follow-up to President Joko Widodo's statement of commitment at COP-21, the ratification of the Paris Agreement through Law no. 16 of 2016. At almost the same time, Indonesia submitted the Nationally Determined Contribution (NDC) document to the UNFCCC Secretariat, which is a further elaboration and replaces the Intended Nationally Determined Contribution (INDC) document submitted by Indonesia before COP-21 Paris. As part of its pre-2020 commitment, Indonesia has made efforts to reduce GHG emissions voluntarily since 2011 by setting a GHG emission reduction target of 26% from BaU in 2020, and up to 41% if there is international support. Learning from the implementation of these commitments becomes one of the considerations in determining targets up to 2030. In the NDC it is explained that the agricultural sector contributes 0.32% in efforts to reduce GHG emissions by 29% from BAU 2030 (Ditjen Pengendalian Perubahan Iklim 2017).

The agricultural sector is mostly affected by climate change which threatens food security. Apart from being a victim of climate change, the agricultural sector is both significant source and sink of greenhouse gases (GHG), which nationally contributes 6-13% of the greenhouse effect (Word Research Institute 2017). GHG emissions from the agricultural sector are sourced from lowland rice cultivation, agricultural land, animal husbandry, management of animal manure/waste, and biomass burning. The agricultural sector produces three main GHGs, namely carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), each of which has a global warming potential index of 1, 23, and 296 (Ministry of Environment and Forestry 2017). However, the plantation sub-sector has a superior ecological function in absorbing carbon dioxide. The plantation sub-sector plays an important role in mitigating the impacts of climate change (Balitbangtan 2011).

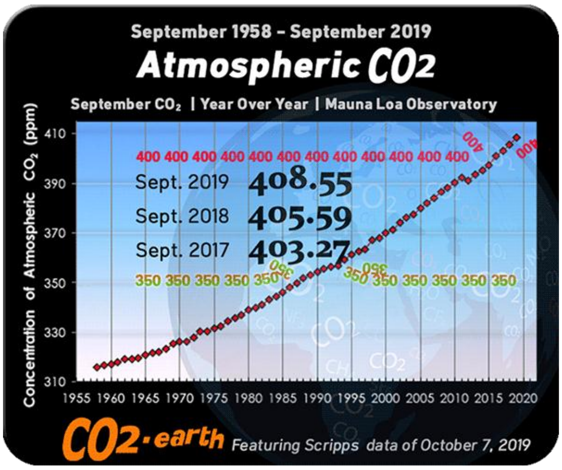

Figure 1. The tendency to increase the global CO_2 concentration in the atmosphere (Source: http://CO_2. earth/NOAA/NCEI Global analysis accessed May 19, 2020)

Gambar 1. Kecenderungan peningkatan konsentrasi CO_2 global di atmosfer (Sumber: http:// CO_2.earth/NOAA/NCEI global analysis accessed May 19, 2020)

The use of agrochemicals is intensive and tends to be uncontrolled leaving residues in the soil that are partially transported in products through the food chain. The tendency of farmers to use agrochemicals is based on the perception that agrochemicals, such as pesticides, are more effective than other control systems and that the use of certain inorganic fertilizers provides more nutrient requirements for plant growth. In addition, agrochemicals, especially pesticide formulations are always increasing from year to year, even in the field there are still various pesticide formulations that have been banned from circulation. The number of pesticide formulations circulating in the market is shown in Figure 2.

Over time, soil productivity has decreased due to increased environmental stress and plant susceptibility to plant pests and diseases *(OPT)*, so it is necessary to encourage more environmentally friendly agricultural systems or models that pay attention to environmental aspects and are sustainable. New alternative agricultural technologies that are environmentally friendly have not been fully adopted by farmers or replace old agricultural technologies. The application of environmentally friendly agricultural technology is carried out based on a good agricultural system approach (Good Agricultural Practices), for example the practice of cultivating lowland rice with the *jajar legowo super* system which includes components of new high-yielding varieties, giving biodecomposers before tillage, biological fertilizers used as seed treatment and balanced fertilization based on paddy soil test kit *(PUTS)*, pest control with vegetable pesticides or chemical pesticides based on control threshold, and the use of agricultural machinery *(alsintan)*.

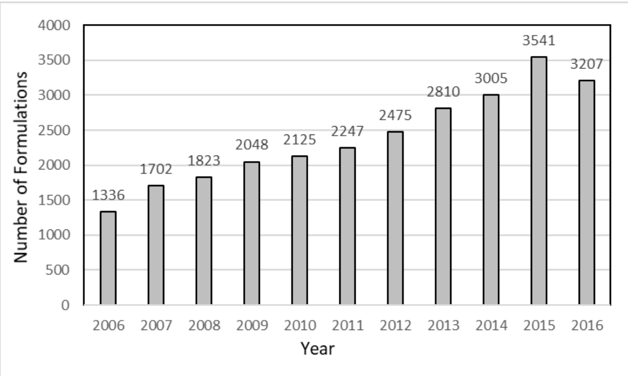

Figure 2. The formulation of pesticides circulating in the market period 2006-2016 (Source: Direktur Pupuk dan Pestisida 2016; Harsanti *et al*. 2018)

Gambar 2. Formulasi pestisida yang beredar di pasaran periode 2006-2016 (Sumber: Direktur Pupuk dan Pestisida 2016; Harsanti et al. 2018)

Existing regulations are the basis for implementing environmentally friendly agricultural systems, for example Law No. 22 of 2019 concerning sustainable agricultural cultivation systems, Regulations of Minister of Agriculture No. 107/SR.140/9/2014 concerning Pesticide Control, Law No. 16 of 2016 regarding the Paris agreement, Presidential Regulation No. 61 of 2011 concerning the reduction of national GHG emissions, and Presidential Regulation no. 71 of 2011 on GHG inventory. This paper aims to provide an overview of environmentally friendly agriculture and the technology components available to be implemented in order to build environmentally friendly agriculture.

ENVIRONMENTALLY FRIENDLY AGRICULTURE

The general strategy and policy for mitigating the impacts of climate change is to position adaptation action programs in the food crop sub-sector so that increased production and food security can be maintained. Furthermore, mitigation programs in the plantation, food crops, horticulture and livestock sub-sectors through the development of environmentally friendly agricultural technology. Environmentally friendly agriculture is an agricultural system that manages all agricultural resources and inputs of farming systems wisely to achieve optimum productivity and economic benefits, but has low risk to the sustainability of agricultural resources and the environment. In principle, there are four things currently focusing on environmentally friendly agriculture, namely ensuring land and crop productivity and profits for farmers; reducing environmental risks; ensuring the quantity and quality of agricultural products in a sustainable manner, as well as reducing GHG emissions.

Environmentally friendly agriculture involves three main aspects, namely biophysical, biotic, and socio-economic aspects with the main components including edaphic (soil), hydrology (water), atmosphere (air), and biology (plants-humans, livestock, etc.). In particular, Sumarno (2006) mentions that the paradigm of environmentally friendly agriculture includes several components, including (1) Biodiversity and the maintained ecological balance of biota, (2) The quality of natural resources physically, chemically and biologically is maintained, (3) The agricultural environment is protected from pollution, contaminants/pollutants, (4) increased land productivity, (5) controlled pests and diseases, and (6) safe agricultural products (food and feed).

As shown in Figure 3, environmentally friendly agriculture in acid dry land *(LKM)* was developed through a conservation agriculture approach model by applying no tillage or minimum tillage which is, in practice, integrated with several technological components, for example planting *serai wangi (Cympogon nardus)* for terrace strengthening, alley cropping system, intercropping system, integrated pest control, and crop-livestock integration system *(SITT)* by utilizing local resources in the cultivation. Food crop biomass, terrace strengthening plants or alley cropping

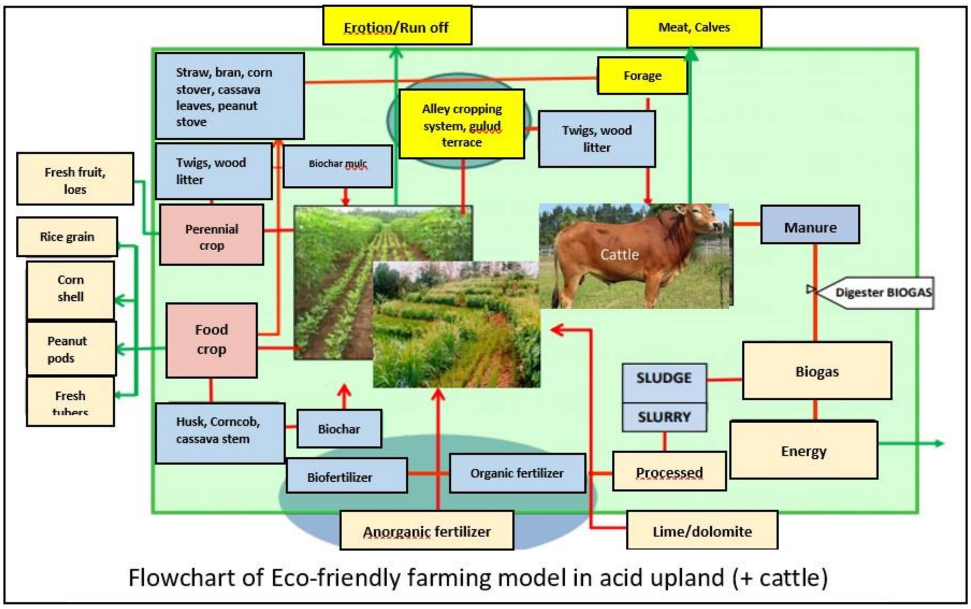

Figure. 3. Eco-friendly farming (Source: Balingtan 2018)

Gambar 3. Pertanian ramah lingkungan (Sumber: Balingtan 2018)

Table 1. Components of environmentally friendly technology in the integration system of paddy-livestock

Tabel 1. Komponen teknologi ramah lingkungan dalam sistem integrasi tanaman padi-ternak di lahan sawah.

No	Description	Paddy field	Livestock
1	Applied technologies	Intermittent irrigation; Balanced fertilization: Paddy Soil Test Kit *(PUTS)*, Leaf Color Chart *(BWD)*, organic matter/sludge, biochar; Low emission rice varieties; Vegetable pesticides; Cropping calendar	Rice straw and bran as feed; Silage Biodigester; Low emission feed management (high protein, low fiber)
2	Adaptation PI	Intermittent irrigation saves water; Balanced fertilization to increase rice yields; Cropping calendars reduce crop failures; Integrated pest control	Rice straw and bran are used for feed; Urine as a vegetable pesticide
3	Mitigation PI	Intermittent irrigation reduces CH_4 emissions; Balanced fertilization reduces N_2O emissions, increases carbon sequestration; Low emission rice varieties having high yield and reducing CH_4 . emissions	Animal dung in the biodigester reduces CH_4 emissions, renewable energy; Low emission feed management and reducing CH_4. emissions
4	Benefits	Rice yields may increase; saving water and organic fertilizers purchase; reducing GHG emissions and increasing carbon sequestration	Increase in cattle body weight, supplying energy for households, reducing CH_4 emissions from cattle dung

Source: Laporan Tahunan Balingtan 2018; 2019; Wihardjaka *et al.* 2020

forage plants can be used as animal feed and can be returned to the soil as compost which can increase acid dry land *(LKM)* productivity.

The technological components in an environmentally friendly crop-livestock integration system and adapting to climate change developed in paddy fields are shown in Table 1. The components of environmentally friendly agriculture include vegetable pesticides, product quality improvement, remediation of polluted land, use of low emission varieties, preservation of soil fertility and environment, adapting to climate change, soil conservation, and water management.

In general, environmentally friendly agricultural strategies lead to synergy and integration among technologies, optimization of resources and production inputs which are carried out through three approaches, namely: (1) Anticipation, adaptation and mitigation approaches in the context of global warming and climate change, (2) Mitigation approach , overcoming, and remediation in the context of the edaphic and biological environment, (3) Remediation approach in the context of degradation of land, water and ecosystem resources due to excessive use of agrochemicals. In implementing environmentally friendly agriculture, several criteria are emphasized, namely technical (increased yields, easy/simple application, proven performance); economical (cheap, profitable, and having added value); social (according to the needs of society and culture); the environment (its application does not damage the environment); and institutional (getting adequate support from relevant institutions).

CLIMATE CHANGE ADAPTATION

Climate change can be a serious threat in maintaining the achievement of food self-sufficiency in Indonesia. The impact of climate change is feared to be a problem in the sustainability of agricultural production, especially food crops, such as droughts, floods, and the explosion of plant pests and diseases *(OPT)*. Climate change can significantly reduce global food production. Climate change in the period of 2000-2050 is estimated to be able to reduce rice production by 12.7%; wheat, 25.3%; corn, 0.1%; millet, 7.7%; and sorghum, 2.5% (Simatupang 2017).

Indonesia has ratified the Paris Agreement through Law no. 6/2016 in which Indonesia is committed to reducing greenhouse gas emissions by 29% with its own efforts and 41% with international assistance by 2030. The operational policy for handling climate change impacts in the agricultural sector is to prioritize the adaptation principle by synergizing climate change mitigation actions in the agricultural sector and taking into account local wisdom (location-specific) and the realization of food sovereignty and improvement of farmers' welfare.

Adaptation actions in the agricultural sector are as follows:

a. Use of improved varieties that are adapting to climate change (flood or drought resistance or low emissions). Wihardjaka *et al*. (2020) reported that there are superior varieties that have high production potential, are tolerant of certain pests and diseases, or are resistant to drought, inundation, and salinity and others. Several early maturing varieties (eg Ciherang, Silugonggo, Inpari 38, 39, 40 and 41) and short *(Dodokan)* can increase cropping index. Amphibian rice varieties can be planted in rainfed rice field as an effort to adapt to climate change. Amphibian varieties are rice varieties that tolerant to drought and resistant to waterlogged soil conditions, some of these varieties are Inpago 4, 5, 6, 7, 8, and 9, Inpari 10 Laeya, Situ Bagendit, Situ Patenggang, Towuti, Batutegi, and Limboto.

   Differences in rice varieties determine the amount of methane (CH_4) emissions. Varieties have a very important role in the release of CH_4 emissions from paddy fields. According to Gutierrez *et al.* (2013), each variety has a different morphology and anatomy in forming aerenchyma and root oxidation processes. Both of these properties will affect the microbial activity involved in the dynamics of CH_4 in lowland rice. The influencing factors were plant age, number of tillers, root exudates and root oxidation capacity. In general, plants with short lifespans, few tillers, little root exudates and high root oxidation capacity will emit less CH_4. 70% of CH_4 gas is released through the aerenchyma tissue of rice plants. During the reproductive phase more than 90% of emissions are released through the rice plant (Cicerone and Shetter 1981; Schütz *et al.* 1989).

b. The application of an integrated cropping calendar *(KATAM)* is to determine planting time and area, recommendations of rice varieties and the need for seeds/seedlings and fertilizers and others. Technological system of integrated cropping calendar information is dynamic.

c. Improvement of irrigation and drainage networks, implementation of water harvesting movements (retention basin/ *embung* and dams), and water pumping. With the same availability of water, the planting area will be larger.

d. Encouraging environmentally friendly agricultural cultivation.

In sustainable agriculture, production enhancement technology must consider environmental aspects, so that production remains high but emits low GHGs. Efforts to reduce the release of CH_4 gas from paddy fields can be reduced by regulating water, using mature organic matter, rice varieties that emit low CH_4 gas, balanced fertilization based on soil nutrient status and leaf color chart (BWD). Environmentally friendly rice cultivation treatments can increase rice yields up to 21% and reduce CH4 emissions up to 5% compared to that of farmers' conventional methods. Based on Law no. 22 of 2019, sustainable cultivation of environmentally friendly agriculture is directed at achieving food sovereignty by taking into account the carrying capacity of ecosystems, mitigation and adaptation to climate change to realize an advanced, efficient, resilient, and sustainable agricultural system.

e. Improvement of soil physical properties to increase infiltration and water holding capacity with the application of organic matter.

The application of organic matter to rainfed land can increase the level of soil fertility. The addition of organic matter to paddy fields is very good when done in conjunction with the second tillage, so that organic matter will be mixed in the soil. The addition of organic matter into the soil will improve the physical, chemical and biological properties of paddy fields soils.

CLIMATE CHANGE MITIGATION

Based on the results of the USEPA Study (2006), the mitigation strategy of rice cultivation has the highest economic potential for reducing emissions in developing countries. Smith *et al.* (2007) reported that soil carbon sequestration offers the highest economic potential with the best prospects in developing countries. GHG mitigation technology is a technology that can reduce GHG emitted from an emission source. Indonesia's commitment to reduce GHG emissions from the agricultural sector by 0.008 Gt CO_2-e (independently) or 0.011 Gt CO_2-e (through international cooperation) in 2020 has been stated in Presidential Regulation no. 61 of 2011. The targets for reducing GHG emissions in the agricultural sector that support sustainable agricultural development are (1) plantation and peatland sub-sectors which are directed at area development/expansion, increasing sink/growth capacity, amelioration and drainage system, and utilization of organic waste; (2) food crops sub-sector, especially paddy fields through land, fertilizer and water management, use of varieties, etc., (3) livestock sub-sector through utilization of waste for biogas and feed formulation.

Water Management

Efforts to reduce the amount of CH_4 gas emissions from irrigation systems, in addition to reducing CH_4 gas emissions it can save excessive water use as well. The results of Setyanto and Abubakar (2006) showed that continuous inundation emitted methane of 254 kg CH_4 ha^{-1} $season^{-1}$, while intermittent irrigation emitted methane of 136 kg CH_4 ha^{-1} $season^{-1}$. Intermittent irrigation allows CH_4 oxidation by methanotrophic bacteria (Methylobacter luteus, Methylosinus trichosporium, Methylococcus capsulatus) in the rhizosphere of rice plants (Ferrando and Tarlera 2009). Methanotrophic bacteria require CH_4 as a source of energy and carbon for their metabolism. In rainfed rice field ecosystems, intermittent irrigation in non-*PTT* (Integrated Plant Management) can reduce CH_4 emissions by 57% of rice field in dry season and by 63% of upland rice *(gogorancah)* in rainy season. In the *PTT* treatment, in the *walik jerami* season, it can reduce CH_4 emissions by 13%, while in the *gogorancah* season it can reduce by 52%. Intermittent irrigation also increased rice yield by 5-9% compared to that of the flooded treatment (Pramono *et al*. 2015). Intermittent/wet-dry irrigation supports plant growth by supplying oxygen to the roots, prevents sulfate toxicity, improves root development and increases productivity (Kanno et al. 1997; Pramono *et al*. 2021).

Rice Plant Management

The GHG emissions released by rice plants are mainly CH4. About 80-90% of CH4 gas is released through the aerenchyma vessels of plants (Pandey *et al*. 2014). However, the ability to release CH4 gas varies depending on the characteristics of rice varieties such as nature, age and root activity. Rice that has more tillers will increase the amount of aerenchyma so that the emission of CH4 gas released is also greater. Meanwhile, the long-aged varieties produced higher CH4 gas emissions than the short-aged varieties. This is related to the life cycle of the rice plant. Rice plants play a role in supplying organic C through root exudation as a source of energy and substrate for methanogens or Archaeal microbes (Pandey *et al*. 2014). The rice cropping system affects crop yields and GHG emissions released from paddy fields. Rice grown using the transplanting system *(tapin)* releases higher methane gas and produces lower grain yields than the direct seeding system *(tabela)* (Wihardjaka 2011b). The *tabela* system in rainfed rice field, Ciherang rice grain yielded an average of 76% higher than that of the *tapin* system, and reduced methane emissions by 21.6%.

Land Management

Tillage has a positive effect on plant growth and development, especially root development and penetration in absorbing nutrients and water, as well as the release of gases from the soil into the atmosphere through deep root tissue. The results of the research by Setyanto and Hidayat (2001) showed that the perfect tillage system emitted 190 g N_2O ha^{-1} $season^{-1}$, while without tillage it emitted 171 g ha^{-1} $season^{-1}$. Perfect tillage with puddling is beneficial for organic matter decomposition and changes in soil structure (Wihardjaka and Abdulrachman 2007), so that organic C becomes more available to methanogenic microbes for methane formation.

The implementation of field school of the integrated rice crop management *(SL-PTT)* generally results in lower GHG emissions than that of rice fields without *SL-PTT* (Figure 4). CH_4 emissions from lowland rice cultivation in Indonesia in 2000 and 2016 were 38,587 CO_2-e and 42,263CO_2-e, respectively. The increase in emissions that occurred in 2016 can be attributed to the increase in the area of rice fields in the context of food self-sufficiency which is a priority program of the Ministry of Agriculture.

Amelioration is the provision of ameliorant material that aims to increase soil fertility through improving physical and chemical conditions and reducing GHG emissions. Amelioration can be done using dolomite, *kaptan* (agricultural lime), zeolite, manure, husk ash, and others. In addition, ameliorant materials can also be obtained from the environment around us by utilizing household waste materials (tea, coffee waste), turmeric rhizomes, and weeds. Some of these ameliorants can also be used as nitrification inhibitors.

Some plant materials can function as nitrification inhibitors, including *babandotan* (Ageratum conyzoides), turmeric (*Curcuma domestica* Val.), *randu* leaves (*Ceiba pentandra* Gaertn.), mangroves (*Rhizophora conjugata* Linn.), neem (*Azadirachta indica*), and

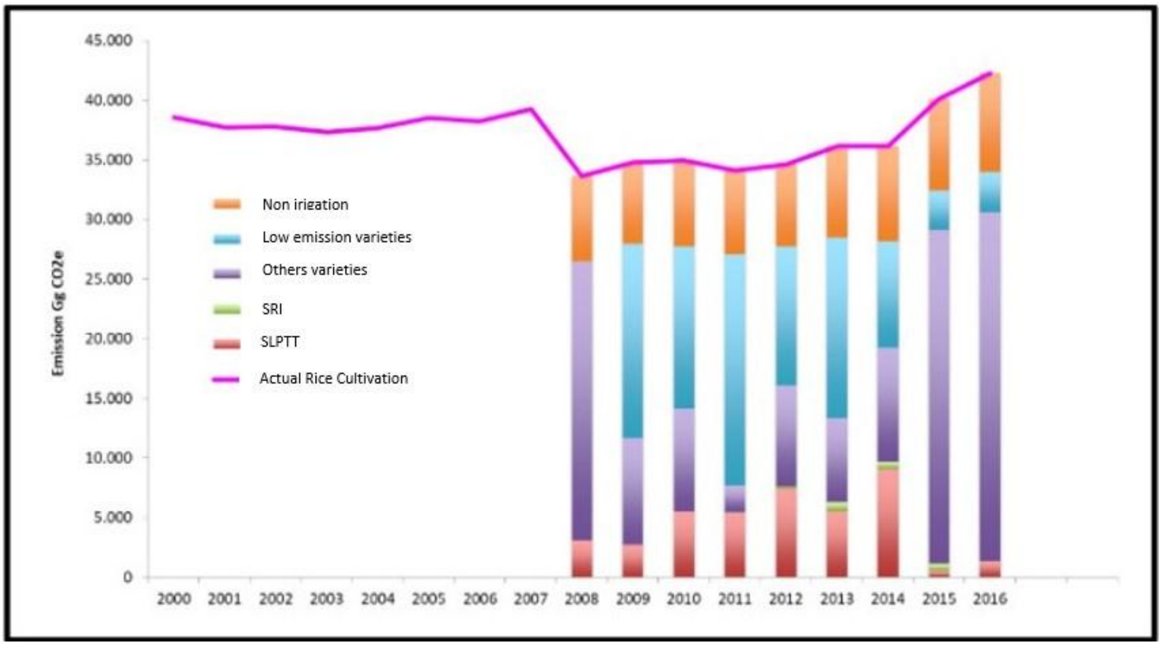

Figure 4. Methane emissions from rice cultivation in 2000-2016 (Source: Kementerian Lingkungan Hidup dan Kehutanan 2017)

Gambar 4. Emisi metana dari budidaya padi tahun 2000-2016 (Sumber: Kementerian Lingkungan Hidup dan Kehutanan 2017).

belimbing wuluh (*Averrhoa bilimbi* L). The use of neem seeds (20 kg ha^{-1}) can reduce the N2O flux by 48.9% in rainfed rice fields. Neem seeds contain polyphenolic compounds (0.13% tannin). Polyphenol compounds can inhibit the activity of nitrifying and denitrifying bacteria in the soil. The results of the research by *Balingtan* in *MK* 2011 showed that the use of *babandotan* weed (Ageratum conycoides) combined with NPK fertilizer (100% NPK) could reduce N_2O emissions by 12% compared to that in control and was able to reduce N_2O emissions by 18% when compared to that of 100 % NPK (Pramono *et al.* 2015).

Rice cultivation is inseparable from the use of inorganic fertilizers. The application of N fertilizer (usually in the form of urea) in paddy fields is a must to increase rice production. Fertilizer application has the potential to contribute to GHG, especially N_2O if it is not properly managed. Managing appropriate fertilizer can be an effort of GHG mitigation, among others by replacing prilled urea with tablet urea or slow release fertilizer, applying fertilizer in stages, applying fertilizer by immersing rather than spreading it, monitoring the need for N fertilizer with leaf color chart *(BWD)*, and using sulfur-containing N fertilizer. N fertilizer containing S can cause competition between methanogenic bacteria and sulfate reducing bacteria in obtaining hydrogen, thereby inhibiting the formation of methane (Schultz *et al.* in Setyanto *et al.* 1999). In addition to reducing methane emissions, the application of ZA fertilizer and tablet urea was able to produce grain of IR 64 higher than that of prilled urea at the same N dose (120 kg N ha^{-1}).

Plants absorb N in the form of NH_4^+ (ammonia) and NO_3^- (nitrate), where nitrate is quickly lost during the nitrification process either through leaching and runoff or N loss from the applied N fertilizer can reach 60% during the denitrification process. During the nitrification-denitrification process, N is lost in the form of N_2O (Pandey *et al.* 2014) which is one of the causes of the low efficiency of using nitrogen fertilizers in rice field.

The application of organic matter with a low C/N ratio to paddy fields tends to emit lower methane than that with a high C/N ratio (Wihardjaka *et al.* 1999). Application of organic matter at a dose of 5 t ha^{-1} generally increases methane emissions in paddy fields, but manure provides lower methane emissions than fresh rice straw and green manure of *Sesbania sp.* leaf.

The application of organic matter increases the yield of rainfed rice. Applying rice straw can reduce N2O emissions, namely fresh straw and decomposed straw can reduce N_2O emissions by 49.2 and 59.9% *(padi walik jerami)* and by 32.9 and 28.2% *(padi gogorancah)* (Wihardjaka 2011a).

Integration of Food Crops and Livestock

Integrated crop-livestock system *(SITT)* consists of three main components, namely agricultural land, livestock, and a livestock waste processing unit/biodigester. This system is a closed system so that carbon is not released into the earth's atmosphere and can be utilized as efficiently as possible with the concept of zero waste. *SITT* is an integrated cycle among components of food crops, livestock, waste management oriented towards improving soil productivity, crops and livestock, soil fertility, utilizing renewable energy, and suppressing greenhouse gas emissions, especially methane (CH_4) and nitrous oxide (N_2O). (Wihardjaka *et al*. 2013).

Cattle produce organic fertilizer to increase soil fertility and crop production, while crops can provide feed for livestock production. Biogas is a gas produced from anaerobic activity from organic materials such as livestock manure, humans, domestic waste and others. Biogas as renewable energy contains CH_4 and CO_2 gases. Utilization of biogas is a very important mitigation effort because the CH_4 gas in biogas can be managed and not emitted into the atmosphere. The gas released can be used as fuel in the household, thereby reducing the consumption of fossil fuels (kerosene, coal, etc.). Biogas waste, ie manure that has lost its gas (slurry) is an organic fertilizer that is very rich in nutrients needed for plant growth and development. Cow dung compost produced from biogas can reduce methane emissions from rice plants by 59.1% compared to fresh straw that is directly immersed in rice fields (Wihardjaka *et al*. 2013).

Adaptation is an activity that is prioritized because it is related to food security and life. Mitigation is inventoried as co-benefits from the adaptation activities carried out. Many adaptation practice activities are in synergy with mitigation activities, in addition to increasing production, they can also reduce emissions. This practice needs to be prioritized in mitigation efforts.

REMEDIATION OF AGROCHEMICAL-CONTAMINATED AGRICULTURAL LAND

The excessive use of agrochemicals, especially chemical pesticides, leaves residues in the soil, water, and is transported into agricultural products, which will significantly reduce the quality of the environment and endanger the health of humans and other living things. Exposure to pesticides in the long term will interfere with the health of eye, skin, respiratory, heart, digestive and nervous systems (Rola and Pingali 1993 in Sutriadi *et al*. 2019). Continuous use of inorganic fertilizers can increase the accumulation of heavy metals in the soil, especially Pb and Cd. The accumulation of Cd metal in the human body can cause damage to organs and metabolic systems, including: proteinuria, emphysema pulamonium, low Hb concentration, brittle bones, neuritis, and is carcinogenic, especially in the lungs (Wihardjaka and Harsanti 2018).

Several efforts to overcome polluted agricultural land, to control environmental pollution, and to obtain healthy and quality agricultural products are through technological innovations, including remediation by using ameliorant materials, microbes that degrade toxic hazardous materials, heavy metal accumulator plants; implementation of integrated pest control *(IPM)*, and the use of environmentally friendly pesticides/vegetable pesticides.

Agricultural Land Remediation With Ameliorant

Amelioration through the application of organic matter aims to adsorp toxic compounds in the soil. The high carbon content in ameliorant material can reduce pesticide residues in soil and water. Dry compost, husk charcoal, activated husk charcoal, and activated coconut shell charcoal have high Iodine adsorption, each of which is 222.7; 312,3; 405.5; and 1,191.8 mg g^{-1}, and was able to adsorb insecticide residues of aldrin, lindane, heptachlor, dieldrin, and chlorpyrifos in water, so that insecticide residues of aldrin, lindane, heptachlor, dieldrin, and chlorpyrifos were not found in the runoff water (Ardiwinata *et al*. 2005).

Remediation technology by presenting ameliorant is one of the efforts to recover land contaminated with heavy metals, in order to obtain agricultural products that are healthy, quality, and safe for consumption. Provision of humate from cow dung, municipal waste, and Rawapening peat was able to reduce Cd in rice straw higher than other ameliorants, which were 87.21 each; 86.09; and 80.07% compared to that of the control. The provision of vermicompost of tea waste, zeolite, and humate of cow dung was able to reduce Cd metal in rice by 97.85; 95.70; and 94.62% (Mulyadi *et al*. 2012).

Remediation of Agricultural Land by Utilizing Microorganisms

In-situ bioremediation using compost organic fertilizer is very effective, because microorganisms in compost are able to degrade pesticide residues in the soil. Fertilization treatment with mixed compost provided an effective bioremediation reaction against mancozeb pesticide residues. The pesticide residue from each spraying dose on day 35 remained 0.25%-1.7% or lower than 0.003 ppm (Setiyo *et al*. 2011).

Remediation using microbes is effective in reducing the concentration of pesticide residues in paddy fields. Phosphate solubilizing bacteria *(BPF)* was able to reduce carbofuran in paddy soil up to 99.6%. Pseudomonas mallei and Trichoderma sp were able to reduce residues of organochlorine insecticides dieldrin, endosulfan, DDT, and heptachlor (Harsanti *et al*. 2011).

Utilization of activated charcoal from agricultural waste is one of the remediation methods to reduce the level of pesticide residue in the soil, where activated charcoal from corn cobs is more effective in reducing organochlorine residues aldrin and lindane than activated charcoal from coconut shells. Enriching activated charcoal with microbial consortia was more effective in reducing the level of pesticide residues than activated charcoal without microbial consortia (Harsanti *et al*. 2013).

Coating urea with biochar and activated charcoal was able to reduce hexachlorobenzene and endrin residues by 22.4% compared to prilled urea. Types of biochar and activated coconut shell charcoal can affect the effectiveness of urea in reducing hexachlorobenzene and endrin residues. Enrichment with indigenous microbes was able to increase the effectiveness of urea coating with biochar and urea coating with activated coconut shell charcoal to decrease hexachlorobenzene by 33.1% and decrease endrin by 33.6% (Wahyuni 2014).

Remediation using coconut shell is effective in reducing dieldrin residues in the soil, while corn cobs based remediation agents were effective in reducing dieldrin residues in rice. Urea coating with activated coconut shell charcoal enriched by microbes can reduce dieldrin residue in the soil by 100%, while microbe-enriched activated corn cob charcoal urea and microbe-enriched corn cob biochar urea can reduce dieldrin residue in rice samples by 100% (Poniman *et al*. 2017).

Implementation of Integrated Pest Management *(PHT)*

Integrated pest control technology *(PHT)* is a concept that is more directed at an approach that relies on the role of agro-ecosystems, especially domestic biological resources such as natural enemies, botanical pesticides, biopesticides, the use of resistant varieties, intercropping systems, the use of companion planting, ecosystem management with crop cultivation, sex pheromones and synthetic attractant to support environmentally friendly and sustainable pest control technology.

PHT needs to be revitalized with a more operational concept in its implementation. By managing the agricultural environment appropriately through a combination of various control technologies that are not pesticides, and maintaining the ecosystem, the pest population during one growing season can be strived to always be at a level that does not bring economic losses to farmers. In such circumstances, of course, farmers no longer need to use pesticides and simply entrust with environmentally friendly pest control. Controlling pests and diseases with synthetic pesticides is still needed but it must be the last alternative, if environmentally friendly control technology is not able to overcome the increase in the pest population that has exceeded the control threshold. The synthetic pesticides can be used to reduce the pest population to a balance limit but must be selective and not to kill non-target insects such as natural enemies.

Regulations related to agrochemicals, especially pesticides, have been reviewed and changes are made in regulations mainly related to pesticide registration. Ministry of Agriculture Regulation No. 39/Permentan/SR.330 of 2015 states that one active ingredient can only be used for a maximum of 3 formulations for one registration application, resulting in a decrease in formulation from 3,541 in 2015 to 3,207 in 2016. Subsequently, it is issued the Minister of Agriculture Regulation No. 43 of 2019 concerning pesticide registration, including restrictions and prohibitions on certain active ingredients for pesticides so as to reduce the number of registered pesticide formulations to 2,710 by 2020.

Government Regulation No. 7 of 1973 concerning Supervision of the Circulation, Storage and Use of Pesticides which is deemed no longer appropriate with current developments has been revised. Ministry of Agriculture Regulation No. 107/SR.140/9/2014 concerning Pesticide Control has revised the previous regulation in which supervision is carried out from the stages of Procurement, Circulation, Storage, Utilization and Destruction. Although the regulation has been improved, its implementation in the field is still weak due to the limited number and capacity of supervisors. Pesticide supervision, especially those that do not have distribution permits, is not only the responsibility of the government, but also the community, as well as the private sector so they should cooperate in controlling them (Yufdy 2017).

The use of Environmentally Friendly Pesticides

One implementation of the concept of environmentally friendly agriculture is the use of environmentally friendly pesticides. Environmentally friendly pesticides are pesticides that have the ability to control pests and diseases (plant-disturbing organisms) but these pesticides are decomposed more quickly, have relatively low toxicity to animals, do not leave residues in the environment or products so that they are relatively safe for humans and the environment.

In order to reduce the use of pesticides (synthetic chemical pesticides), the application of botanical pesticides or other natural pesticides is being promoted throughout the world. Vegetable pesticides are organic pesticides derived from plants (Sutriadi *et al*. 2019). The use of biological pesticides containing the active microbe *Bacillus thuringiensis* which is able to control caterpillar pests, *Tricoderma koningii* to control rubber root fungus and wilt in chilies. In addition to biopesticides, vegetable pesticides, namely pesticides made from plant materials, can be used to support the implementation of environmentally friendly agriculture. Plants that can be used as vegetable pesticides include *kecubung (Datura metel L.)* leaves, neem leaves, lemongrass leaves, *secang (Caesalpinia sappan L.)* leaves, garlic bulbs, *lempuyang gajah (Zingiber zerumbet Smith)* and *lempuyang emprit (Zingiber amaricans Bl.)* rhizomes, and so on (Atmojo 2007). These findings show the potential of natural pesticides that are environmentally friendly to support the efforts to maintain production in achieving food self-sufficiency.

In the concept of environmentally friendly agriculture, pest control prioritizes the use of pesticides that are safe for the environment such as biopesticides/biological pesticides. Several biological pesticides that have been developed by the Indonesian Agency for Agricultural Research and Development include vegetable pesticides from neem seeds or leaves which have the active ingredients of *azadirachtin*, *brotowali (Tinospora cordifolia)*, *tegari (Dianella nemorosa Lam)*, and tobacco stem waste. The development of plant-based pesticides is currently combined with other biological materials such as the vegetable-based pesticides *LASEKI (Laja, Sereh Wangi, and Ki pait)* applied by West Java Assessment Institute of Agricultural Technology *(BPTP Jawa Barat)* and the neem and cow urine biopesticide *(SEGARTAN-PB)* developed by Indonesian Agricultural Environment Research Institute *(Balingtan)* for pest prevention. However, in conditions of high pest and disease attack, the use of synthetic pesticides is still needed for pest and disease control as an effort to maintain and achieve food self-sufficiency, but their use must be wise and appropriate (right type, right quality, right target, right time, right dose, and right utilization).

CONCLUSIONS

Environmentally friendly agriculture is an agricultural system that manages all agricultural resources and inputs of farming systems wisely to achieve optimum productivity and economic benefits, but has low risk to the sustainability of agricultural resources and the environment. In principle, there are four things that are currently the focus of environmentally friendly agriculture, namely ensuring land and crop productivity and profits for farmers; reduced environmental risks; ensuring the quantity and quality of agricultural products in a sustainable manner, as well as reducing GHG emissions.

In general, environmentally friendly agricultural strategies lead to synergy and integration between technologies, optimization of resources and production inputs which are carried out through three approaches, namely: (1) Anticipation, adaptation and mitigation approaches in the context of global warming and climate change, (2) Mitigation approach, overcoming, and remediation in the context of the edaphic and biological environment, (3) Approaches to conservation and reclamation or restoration in the context of degradation of land, water and ecosystem resources.

Indonesia has a commitment to focus on reducing GHG emissions in the agricultural sector of 0.008 Gt CO_2-e (independent) or 0.011 Gt CO_2-e (through international cooperation) in 2020 which has been stated in Presidential Regulation No. 61 of 2011. The operational policy for handling the impacts of climate change in the agricultural sector is to prioritize the principle of adaptation by synergizing climate change mitigation actions in the agricultural sector and taking into account local wisdom (location-specific) and the realization of food sovereignty and improving farmers' welfare. GHG mitigation technology is a technology that can reduce GHG emitted from an emission source. Mitigation strategies in agricultural cultivation technology, especially rice, has the potential to provide high economic benefits while reducing GHG emissions.

Excessive use of agrochemicals, both chemical pesticides and inorganic fertilizers, leaves residues in the soil, water, and is transported into agricultural products that can degrade environmental quality and endanger human health and other living things. Several efforts to restore polluted agricultural land, control environmental pollution, and obtain healthy and quality agricultural products are through technological innovations, including remediation by using ameliorant materials, bioremediation by utilizing microbes that degrade toxic hazardous materials, heavy metal accumulator plants; implementation of integrated pest control *(OPT)*, and the use of environmentally friendly pesticides such as vegetable pesticides and biopesticides.

Minister of Agriculture Regulation No. 107/SR.140/9/2014 concerning Pesticide Control is still weak in its implementation in the field, so it is necessary to strengthen regulations in pesticide registration and supervision by increasing the number and ability of supervisors in routine monitoring of pesticide circulation in *saprodi* (production facilities) shops in stages starting from the sub-district, district/city to the provincial level and monitoring the negative impacts on public health and the environment due to pesticide management. Support for research activities and development of strategies for adaptation, mitigation and restoration of polluted lands is expected to increase the economy while producing healthy agricultural products and environment. Various regulations and policies on the implementation of environmentally sustainable agriculture, the socialization and implementation in the field must be strengthened with the support of an agricultural environmental information system that is easily accessible to users.

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