Utilization of wetlands for agriculture in the last few decades shows rapid development. However, the growing issue of climate change and global warming in line with broad and rapid development of wetland is envisaged by potentially increasing greenhouse gas emissions and pollution. Therefore, implementation of environmentally benign farming system needs to be realized. The basic concept of environmentally benign or friendly farming in the context of wetland agriculture is the ability and efforts to maintain agricultural production (yields and economics) at a certain optimum level. This concept is highly dynamic concerning the nature of wetlands in relation to its historical development for farming and current choice versus global demand. The choice is related to the government's strategic policy to protect and feed the people that continue growing. Meanwhile, the demand in respect to the international concern is related to the world issues and the efforts to reduce greenhouse gas emissions and development of green economy. Wetland farming system consists of biophysical and socioeconomic elements interlinked with each other. Biophysical elements include subsystems of soil, water, plants, pests and diseases, and environment. Socio-economic elements include comparative advantage, public perception, and sociological conditions. Environmentally friendly farming in the context of wetland agriculture develops as a result of the interaction between biophysical and socio-economic elements. Efforts to be addressed to support the implementation of environmentally friendly wetland farming systems are: (i) improving land and crop management system, (ii) increasing in value added, (iii) strengthening institutions, and (iv) policy support.

INTRODUCTION

Utilization of wetlands for agriculture has been taking place since the 13th century at the era of Majapahit Kingdom (Darmanto 2000). In the period 1950-1980 Indonesia is rice importing countries. To minimize the import, the Indonesian government expanded the area of food crop in wetland area targeted 5.25 million ha in Kalimantan and Sumatra for 15 years through the Tidal Rice Project (P4S). The P4S project is supported by the transmigration programs for the poor in Java and Bali to Kalimantan and Sumatra settlement. However, the use of wetlands increases public concerns in relation to environmental issues, land degradation, and poverty. Stronger environmental issues are related to climate change and global warming along with the rapid development of oil
palm and rubber plantations in the wetland area that allegedly has the potential to increase greenhouse gas emissions (Agus and Subiksa 2008; Suryatmojo 2012).

This paper reviews agricultural practices in wetland in the context of environment-friendly farming. Environmentally friendly farming is a perspective to see the extent farmers’ of effort or ability dealing with the current demands and interests. Implementation of environmentally friendly farming systems requires a well planning for moving forward.

**POTENCY AND USE OF WETLAND**

Wetland area in Indonesia reached 33.4 million ha consisting of 20.14 million ha of tidal land and 13.30 million ha of swampy areas. However, the suitable area for agriculture is estimated 13.70 million ha which consists of 9.53 million ha of tidal land and 4.17 million ha of swampy areas. Wetland area which has been utilized is only about 5.27 million ha which consists of 2.27 million ha opened by government for transmigration settlement units and 3.00 million ha opened by local community independently (Noor 2004). The results of potential land analysis from ten provinces showed that by the optimalization of the land supported by technology innovation and good cultivation management can obtain additional production of 3.5 million tons of grain per year (Noor and Nursyamsi 2012). In addition, about 20% or an area of 2.0 to 2.5 million ha of peat and swamp lands has developed into oil palm and rubber plantations spread across Kalimantan, Sumatra and Sulawesi. Agronomically and economically, wetland and peatland are also feasible for the development of oil palm and rubber plantations as it can provide a profit for farmers and entrepreneurs. It is just necessary required a wise land management in order to remain environmentally friendly. Thus, future wetlands areas are likely to be the source of new economic growth and source of foreign exchange.

Integrated farming systems between food crops and annual crop (oil palm) can be done by increasing the distance between the line width of the oil palm, so that the rice become a supporting plant. This model becomes mutually beneficial integration, so concerns of further decrease of rice land area that reduces rice production can be overcome.
ADVANTAGES OF WETLAND FOR FUTURE FOOD PRODUCTION

Improved Food Production Opportunities

Of wetland that has been opened by the government, 2.44 million ha has been utilized, i.e. for rice (1.182 million ha), estate crops (0.499 million ha), ponds (0.441 million ha), and other uses such as settlements and roads (0.320 million ha). Projections of additional rice production by relying only on wetland from 10 provinces can be about 3.5 million tons of paddy rice per year by land optimization through increased cropping intensity and the use of abandoned land (Noor and Nursyamsi 2011).

Although a target of rice production according to the initial plans for the development of an area of 5.25 million ha still cannot be reached as expected, the role of wetlands cannot be ignored. At least, the availability of wetland that has been reclaimed (3,767,571 ha) can be optimized and some of them that are unutilized (1,335,782 ha or 35.45%) can be used to increase domestic rice production. Moreover, it is still available potential wetlands that have not been reclaimed (7,075,794 ha). Based on land availability map of Balai Besar Penelitian dan Pengembangan Sumber Daya Lahan Pertanian in year
2009, of 30.7 million ha of potential land, approximately 7.0 to 7.9 million ha of which are available for extension (idle “bongkor” wetland not included).

Availability of Technology

The successful development of wetlands for agriculture, especially rice has been achieved by several tidal swamp areas like in South Kalimantan (Terantang in Barito Kuala district and Kurau in Tanah Laut district), in South Sumatra (Telang and Karang Agung in Banyuasin district), in Central Kalimantan (Terusan in Kapuas district), and fresh swamps in South Kalimantan (Babirik in Hulu Sungai Utara district). One or two areas of 17 provinces that has wetlands become a central of rice production. The success of various regions in the utilization of wetland for increased production is numerous and not all are presented in this paper. However, the efforts to become wetland as barns in some areas are supported by technological innovations generated by IAARD and several other institutions, including universities.

Technology innovations for wetland management as well as rice cultivation techniques are available and farmers’ experiences in using wetland are more than enough. However, some are worth and important to be concerned, i.e. (1) transfer of technology requires the characterization and identification of development areas, (2) facilities and infrastructure of water management (water gates, ponds), farm roads and agricultural machinery (tractors) are available, (3) farmers institutions and capital are exist, (4) seeds, fertilizers, pesticides are accessible, and (5) there are markets and competitive price.

Policy and Implementation

Accelerating the development of wetlands is determined by policy support (political will) from the government, including legal institutions and efforts to improve community awareness. In this case, the findings of research or technological innovation play an important role.

AGRICULTURAL PRACTICES IN WETLAND

Wetland farming system consists of biophysical and socioeconomic components which are interlinked with each other. Biophysical component includes land resources as a medium for plants, pests and diseases, climate and infrastructures. Socio-economic biophysical includes human resources as the main actors or agents of changes having perceptions and sociological conditions that may affect attitudes and behaviors. Environmentally friendly farming in the context of wetland is a natural system that is developed as a result of the interaction between biophysical and socio-economic elements. The following descriptions are some biophysical and socio-economic conditions of wetlands for agricultural uses.
Biophysical and Environmental Conditions of Wetlands

Soil subsystem

Soil in wetlands as a medium for plant growth has various constraints. In general, land suitability classes of wetlands are conditional suitable with mild to severe limiting factors, and some are not suitable for agriculture. Wetlands have highly fragile; as such their intensive use or recklessly land clearing may create many problems, especially acidification (pH 2 to 3), elevated levels of toxic elements such as Al, Fe, Mn, organic acids, and sulfides. Some of wetlands have low nutrient status; particularly those are intensively for land for food crops. Acidification processes and nutrient deficiency (nutrient shortage) are often occurred after reclamation of wetland and then use it for longtime without proper management.

Water management is the main key in opening or reclamation of wetland for plant growth; as such plant can grow well without flooded in rainy season or drought in dry season. Reclamation system at early stage to drain the water could also cause over drainage and irreversible drying. Opening or reclamation of wetlands should be followed by constructing water gates in order to maintain water level, so that the soil remains moist or wet.

In traditional agricultural practices, especially in using wetlands for seasonal crops, organic matter management and minimum tillage known as tajak puntal hambur system, together with the applications of ash, salt and animal manures have been practiced widely. This management is practiced by farmers in response to wetland conditions. However, under the conditions of limited availability of fertilizers (as well as expensive) some farmers no longer apply fertilizer on farmland based on recommended dose, or their partially just fertilize the land with fertilizer N (urea) only, or with N and P without K fertilizer. These practices cause a decrease in the production of biomass or yield and accelerate land degradation (Noor 2012)

Water subsystem

Water management is a key to successful utilization of wetlands for agriculture. Water sources come from rain, rivers, seas, forests and swamps of adjacent streams or flood from upstream. Water quality depends much on water circulation or replacement that occurs periodically from tidal water and floodwater from upstream areas such as in fresh wetlands. In general, water quality at high tide or rainy season is better than those at low tide or dry season. Water quality at low tide or dry season is more acidic (pH 2-3), and high levels of sulfate (SO₄), organic acids, and Fe²⁺ (Anwar and Mawardi 2011).

Management practices, especially in areas that have been reclaimed equipped with water gates, some water gates have been damaged and are not functioning so that the water flows freely causing drought at dry season. Constructing floodgates or ponds (dam
overflow) by local communities should always be encouraged widely to prevent drought (EMRP 2009; Noor 2010). In addition to conserve water, ponds also prevent fires and land degradation, especially those used for annual crops. To increase cropping or planting intensity (IP) for food crops, water management systems are very important and absolutely necessary.

**Plant subsystem**

Various crops that are now growing in wetlands are the result of adaptation and domestication of wild crops by farmers in the long time period. In present agricultural practices, the use of local varieties of food crops and annual crops are widely possible. Although their low productivity, local varieties are known for their availability and accessibility and required not much fertilizers. Until this time, the production of local varieties is still relatively low.

Introducing new superior varieties or clones require an alteration in crop cultivation and farmers’ mindset that may be confronted by local habits and customs. The use of high-yielding rice varieties by farmers in wetlands agriculture is still low, or around 10-15%, and about 85-90% of the farmers still use local varieties because of some considerations, i.e. (i) the seeds are easy to obtain because most farmers develop their own seeds, (ii) the selling price is more expensive and marketable, (iii) it does not require intensive care and much fertilizers, (iv) its ability to resist pests and diseases are quite good, and (v) it has long-lived (11 months) giving opportunities for farmers to do another works outside farmland. The use of high yielding varieties are often challenged by: (i) limited support of infrastructure for water system service and mechanization for some land preparation, (ii) low price of agricultural products, and (iii) the availability of fertilizers and pesticides at the right time, quantity and quality.

**Pest and disease subsystem**

Pests and diseases infestation in wetlands is quite high, among others are rat, plant hopper, blast, white pests, and stem borers, especially for food crops. The use of pesticides does not seem to help much; even worst it kills also natural pest and disease enemies if it uses excessively. Pest management to control the outbreak of certain pest due to environmental disturbance is often faced by unsupported cultivation systems that are managed in traditional way. Agricultural practices like food crops (rice) with different planting time, small scale of farmland and inadequate fertilizer inputs weaken plant vigor that are susceptible to pests and diseases. In addition, the use of crop varieties that are susceptible to pests and diseases and limited plant rotation become the main factor for not optimal yields. Moreover, expensive of pesticides makes farmers reduce the dose and intensity of spraying resulting increasing levels of pests and diseases incidents.
Environment subsystem

The changes of natural wetland ecology are associated with climate change and global warming. Climate change triggered by increasing emissions of greenhouse gases (GHG) (CO$_2$, CH$_4$, NO$_2$) in wetlands becomes a global concern, thus wetland management and utilization, especially peat lands, gains special attention. Increasing activities in using wetlands for various purposes are alleged to boost GHG emissions that affect climate change. Wetlands have biomass with around 200 tons of carbon that can be a source of emissions when burned or decomposed (Rahayu et al. 2005 in Harsono, 2012). Therefore, management of wetland should be based on mitigation of GHG emissions. Some research reported that water management by maintaining the water table at a depth of 30 cm or less can reduce GHG emissions and prevent fires. Application of local chicken manure can also lower GHG emission. The use of certain varieties such as pineapple with low GHG emission is encouraged since it is known as a highly adaptive plant in wetlands with acidic soil conditions (pH 2-3) and poor drainage or in thick peat lands, which can yield 3 t of pineapple ha$^{-1}$ (Noor 2004).

Socio-economic Conditions of Wetland Agriculture

Comparative advantage

Background and policy direction on the opening of wetlands for agriculture in the beginning (1982-1999) devoted to increase food crop production, especially rice to strengthen food security at that time. But long before that, actually wetlands have been developed by the local community with a variety of annual crops such as coconut, rubber, cocoa, citrus and oil palm. The fact that some farmers have changed their commodities from food crops to other crops is an indicator that rice is no longer attractive or lower advantage compared to other crops. Currently, most wetlands for rice farming have been converted to non-agricultural purposes.

The expansion of oil palm and rubber plantations by private companies increased rapidly in the last ten years (Noor 2012). In one hand, fast development of these plantations provide a rapid impact on socio-economic development, but in another hand it may reduce national food production in the future because some of productive wetlands are converted or not optimized for food production.

Public perception

Controversy about the use of wetlands for agriculture is still strongly sensed by public in general. Improper management of previous Peatland Mega Project (PLG) in Central Kalimantan also increases negative perceptions and conceals its potential use for agriculture. Reports on the failure of transmigration in this Mega Project with increasing growth of poverty in this location add further the length of bad record of wetlands for
agriculture (Levang 2007). However, gradually it realizes that the successful use and development of wetlands is strongly influenced by well understanding of the nature and characteristics of wetlands prior to opening the land for agriculture. Inadequate experience in technical and strategic development of wetland raises many problems that are difficult to solve quickly and appropriately.

**Sociological conditions**

The development of society globally has a consequence in increasing various regulations and policies. The authority to handle the wetlands is not merely the domain of the Ministry of Agriculture, but is also areas of the Water Resources at the Ministry of Public Work and the Environment at the Ministry of Environment. These conditions increase the complexity of the future development of wetlands. The involvement of many agencies or institutions, in one hand may provide a comprehensive, holistic and integrated solutions approach in handling various aspects according to each responsibility and power, but in another hand it may also promote overlapping tasks and works.

The use of wetlands is also become a global issue related to the environmental problems in terms of climate change. The government's commitment to reduce GHG emissions as much as 26% by his own efforts or 40% by external funding has been able to temporarily stop the clearing of forests and peat lands for plantation, particularly oil palm (Presidential Instruction No. 10/2011). This opportunity is expected to be used for the improvement of wetland management system and intensification of the lands that already exist.

**ENVIRONMENTALLY FRIENDLY WETLAND AGRICULTURE**

The basic concept of environmentally friendly farming in wetland agriculture is the efforts to maintain agricultural production at a minimum level. This concept is highly dynamic concerning the nature of wetlands in relation to its historical development for farming and current choice versus global demand. The choice is related to the government's strategic policy to protect and feed the people that continue growing. Meanwhile, the demand in respect to the international concern is related to the world issues and the efforts to reduce greenhouse gas emissions and develop green economy. At the field level, to achieve environmentally friendly wetland agriculture it requires a proper land resources management to meet adequate food production, conserve natural resources, and at the same time maintain environmental quality. This requirement can be achieved by: (i) improving land and crop management systems, (ii) increasing the value added, (iii) strengthening institutional cooperation, and (iv) government policy.
Improvement of Land and Plant Management Systems

Management of wetlands should be regulated and directed to follow an integrated system in single management unit. Zoning of wetland areas (macro to micro) is required to eliminate the effects of development that may arise in the region and surrounding areas. Referral for the zoning is based the interests that include areas for conservation (forests/protected areas, peat land with thickness 3 m depth or more, peat dome, distinctive regions as protected habitats) and areas for regional development (coastal and adaptive areas, areas for agriculture and fisheries). In agreement to the characteristics of wetlands, the smallest management unit could be based on the characteristics of the hydrological units (swamp/river/watershed).

Added Value Increase

Most management systems in agriculture, fisheries, livestock in wetlands is still labor intensive and traditional. The use of technological innovation is still limited. Even if technological innovations have started to be introduced, only few of them are adopted and it is also limited to some components, such as the use of recommended varieties, dosage of fertilizers, and tractors for land preparation. This may one of the reasons less interest of the younger generation to agriculture, particularly in wetlands that are often muddy and dirty.

Improvement in cultivation technology, including proper cropping pattern of farming with diversification of commodities (e.g. citrus and rice - paddy - crops - vegetables) and diversification of farming such as crop - livestock integration (rice-chicken, rice-fish) can increase farmers’ income. In line with the diversification of commodities, opportunities to increase farmers’ income can also be achieved by secondary product processing, so this added value can benefit the farmers. Other added value is the utilization of agricultural waste, such as rice straw for mushroom, animal feed, even biogas for domestic use.

Strengthening Institutional Cooperation

Implementation of environmentally friendly farming systems or sustainable agriculture cannot be separated from the involvement of the stakeholders and institutional cooperation at national and local levels. The cooperation includes institutions of policy makers, extensions, and research and development. Currently, the institutional cooperation is still limited to the level of communication and is expected to further progress to the level of implementation. The efforts to change and improve the way of cultivation and cropping patterns as well as the implementation of technological innovations are expected to include always various stakeholders (institutions at various levels).
Government Policy

Government empowerment in terms of policy to implement environmentally friendly farming systems in wetlands is very important. Nowadays, government concern and commitment to develop wetland is still discontinuous (inconsistent). Regional autonomy basically gives an opportunity for local governments to take advantage of widely use of wetlands for food and energy (plantations). However, encouragement and support by the government is still required.

An interesting example is the planning of Government of East Kalimantan and Bulungan to utilize Delta Kayan, Bulungan district, East Kalimantan province for food production, known as Delta Kayan Food Estate (KADAFE). KADAFE first harvest at 26 November 2012 is reported to yield rice with average productivity of 6.65 tons (GKP) ha$^{-1}$ or 5.75 tons of grain ha$^{-1}$ (equivalent to 3,607 tons of rice ha$^{-1}$). The yield achieved is quite high. When it is calculated with rice price about Rp.8,000/kg, the result is Rp.28,856,000. In addition, KADAFE also harvest chili with a productivity of 0.75 kg plant$^{-1}$. Of the 700 plants (with a total yield of 525 kg) and price about Rp 20,000 kg$^{-1}$, it yielded Rp. 10,500,000. Total revenue from rice and chili farming reaches Rp. 39,356,000. If the production cost of growing rice and chili is Rp. 7,000,000, then the farmers earn about Rp. 32,000,000 season$^{-1}$. This income is not included the revenue from fish and vegetable crops (eggplant). This Delta Kayan area has the opportunity for 3 planting seasons per year. In this project, the local government engaged partnerships with several companies that have investments in East Kalimantan.

FUTURE RESEARCH DEVELOPMENT OF WETLAND

Research required to support future development of wetlands should be directed to or focus on: (1) mapping the potential land and recommendation to develop wetlands per district/sub-district as a basis for development planning of wetlands; preparation of wetland Planting Calendar in various climatic conditions; mapping of disaster prone areas related to climate change, (2) producing adaptive crop varieties, its propagation and spread on a large scale to the wetlands areas, (3) generating models of regional water system (macro and micro) as the basis of wetland water management, including the dynamics water level predictions model, and macro and micro water balance, (4) generating appropriate cultivation technology to improve land productivity, lower GHG emissions, and economical, (5) modification of agricultural mechanization tools to be user and environmentally friendly as well as economical, including efficient and effective water gate models, (6) formulation of organic and bio-fertilizers (in situ) to remediate “bongkor” swamp land, including the development of nano-technology for fertilizers, (7) creating institutional models and the empowerment of farmers to wise use of wetland for agricultural, and (8) the dissemination of technological innovations in wetland
management to stakeholders and users, through the national and international cooperation partnerships, visitor plots, and seminars.

CONCLUSIONS AND POLICY IMPLICATIONS

(1) Wetland farming systems are developed along with human intervention through technology, including the development of actor or principal agent attitudes, which originally use wetland is just to meet the family needs, then became a profit oriented (agribusiness).

(2) Wetland farming system consists of interrelated biophysical and socioeconomic elements. Biophysical elements include: (i) land subsystems, (ii) water, (iii) plants, (iv) pests and diseases, and (v) environment. Socioeconomic elements include: (i) comparative advantage, (ii) public perception, and (iii) sociological conditions. Environmentally friendly farming in the context of the nature of wetland system are formed as a result of the interaction between biophysical and socio-economic elements.

(3) The efforts needed as the hopes to create environmentally friendly wetland farming systems in supporting wetlands for future food production are: (i) improving land and crop management systems, (ii) increasing the value added, (iii) strengthening institutional cooperation, and (iv) government policy, including policies in the conduct of the study.

(4) Strengthening research which includes mapping of potential wetland resources, recommendation to develop wetland as a basis for planning, planting calendar, generating models of regional water system and its management, producing adaptive crop varieties and cultivation technologies to improve land productivity with GHG emissions, formulation organic and bio-fertilizers to remediate “bongkor” unproductive wetland, including the development of nano-technology for fertilizers, empowering productive farmers institution and dissemination of appropriate technological innovation for wetland management.

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