ENVIRONMENTAL AND SUSTAINABILITY ISSUES OF INDONESIAN AGRICULTURE

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ABSTRACT

Agriculture in Indonesia intensifies from the swidden to very intensive systems and expands rapidly, including to steep slopes and peatland areas. These have implications to the environment and the system's sustainability. Cereal and pulses-based farming systems uses moderate amount of chemicals and thus poses little threats to water quality. However, these systems encroach into steepland accelerating erosion and depleting soil fertility. Intensive vegetable farming applies around 50 Mg/ha of barnyard manure, 300 kg/ha of N, and high rates of pesticides, posing a threat to water quality in the downstream areas. Plantation develops very rapidly, including to forest and peatland areas. Conversion, to plantation crops, of forest (with 132−300 Mg C/ha) decreases, but of shrub (with 15−40 Mg C/ha) and *Imperata* grassland (with < 5 Mg C/ha) increases the carbon stock to 30−50 Mg/ha. The traditional tree-crop-based agriculture, characterized by a mixture of several species, reduces erosion and maintains relatively high carbon stock and biodiversity. Lowland rice (paddy) system, currently covering around 7.9 million ha area, has been practiced sustainably for thousands of years. Despite providing food security and various environmental services, this system is under tremendous pressures of conversion to industrial and settlement areas. Meanwhile, some 20 million ha peatland of Indonesia is being converted at a rate of 1.3% annually for agriculture and silviculture. The carbon-rich land rapidly emits carbon once it is cleared and drained. Indonesian agricultural development is challenged by the demand to keep a high level of production with minimal negative impacts to the environment. This can be achieved by prioritization of low carbon stock land for agricultural expansion, rationalization of fertilizer application, minimization of intensive agricultural expansion to steepland, and safeguarding paddy field from conversion.

Keywords: Agriculture, steepland, peatland, erosion, plantation, carbon stock

ABSTRAK

Masalah lingkungan dan keberlanjutan pertanian Indonesia

Pertanian di Indonesia berkembang dari sistem perladangan berpindah sampai sistem yang sangat intensif dan meluas secara cepat, termasuk ke lahan marginal berupa lahan berlereng curam dan lahan gambut. Perkembangan ini berimplikasi terhadap lingkungan dan keberlanjutan pertanian. Pertanian tanaman pangan semusim dan kacang-kacangan menggunakan bahan kimia dalam jumlah rendah sampai sedang, namun sistem ini meluas ke lahan berlereng curam sehingga meningkatkan erosi dan menurunkan kesuburan tanah. Pertanian sayuran yang intensif menggunakan pupuk kandang hingga 50 Mg/ha dan nitrogen hingga 300 kg/ha N serta pestisida dalam dosis tinggi sehingga mengancam kualitas air di daerah hilir. Perkebunan meluas secara pesat, termasuk ke lahan hutan dan lahan gambut. Konversi ke perkebunan dari hutan (dengan 132−300 Mg C/ha) menurunkan, tetapi dari belukar (dengan 15−40 Mg C/ha) dan padang alang-alang (dengan < 5 Mg C/ha) meningkatkan simpanan karbon menjadi 30−50 Mg/ha. Sistem pertanian tradisional berbasis pohon-pohonan dengan campuran berbagai jenis tanaman relatif ramah lingkungan karena menurunkan erosi serta meningkatkan simpanan karbon dan keanekaragaman hayati. Sawah dengan luas sekitar 7,9 juta ha sudah dikelola secara berkelanjutan selama ribuan tahun. Walaupun berperan menjamin ketahanan pangan dan menghasilkan berbagai jasa lingkungan, lahan sawah mengalami tekanan untuk beralih guna menjadi area industri dan perumahan. Lahan gambut yang luasnya sekitar 20 juta ha mengalami konversi dengan laju sekitar 1,3%/tahun untuk pengembangan pertanian dan silvikultur. Karbon yang tinggi pada lahan ini teremisi secara cepat bila hutan gambut dibuka dan didrainase. Pembangunan pertanian Indonesia dituntut untuk menghasilkan produksi yang tinggi dengan dampak negatif lingkungan serendah mungkin. Hal tersebut dapat dicapai dengan memprioritaskan penggunaan lahan dengan stok karbon rendah untuk ekstensifikasi, rasionalisasi penggunaan pupuk, meminimalkan ekstensfikasi pertanian intensif ke lahan berlereng curam, dan mengamankan lahan sawah dari konversi.

Kata kunci: Pertanian, lahan berlereng curam, lahan gambut, erosi, perkebunan, cadangan karbon

Agriculture (food crops, plantation, and animal husbandry) contributes to around 11.3% of 2009 Indonesian Gross Domestic Product (GDP) and agriculture in combination with forestry and fisheries employs around 38% of the total 108 million labor force (aged 15 years and above) (CBS 2011). The harvest area of food crops was around 20 million ha in 2009. Assuming the harvest index of 1.5, around 13.30 million ha of the 183 million ha land area have been allocated for various kinds of food crops. Total area of all kinds of plantation crops was around 20.5 million ha in 2009 and for horticultural crops was around 1.24 million ha in 2002 (no data was provided for later years) (Ministry of Agriculture 2011). Assuming no change in horticultural areas since 2002, a total of about 34 million ha land is being used for various kinds of agriculture.

Most of paddy fields are owned by individual farmers. Most of annual upland farms are also possessed by individual farmers, but some farms are located in the steep slope areas within the government forest jurisdiction without secure land tenure to farmers. Most of coconut, rubber, coffee, cacao, and pepper are owned and managed by smallholder farmers. Tea, part of rubber and oil palm are managed by government or private estate companies. Average farm size in Java is only about 0.25–0.5 ha and in the outer islands ranges from 0.3–2 ha, although there are a few 'landlords' possessing larger areas.

The demands for agricultural and non-agricultural lands are very high and increasing due to the high population (around 237 million people in 2010) and high growth rate of 1.3% annually (CBS 2011). On the other hand, some agricultural lands, especially paddy fields, are converted to non-agricultural uses (Agus *et al.* 2006a; 2006b). In consequence, farming encroaches to marginal steeplands and peatlands. Because of its existence in the fragile environment (low fertility soils, high rainfall, and steep slopes) some forms of agriculture threaten the environment.

With the growing environmental problems, more care should be given to the land to reduce the environmental risks and, at the same time, sustain satisfactory level of production. This paper discusses Indonesian land potential, development of agriculture, environmental and sustainability implications of agricultural development and policy implications.

LAND RESOURCES

Soils

The soils of Indonesia are formed from various parent materials under variable climatic and topographic conditions. These factors have led to the formation of various types of soils. About 9.6% of 188 million ha Indonesian land consist of Entisols (mostly in the drier areas of East Nusa Tenggara), 37.5% Inceptisols (in all islands), 24% Ultisols (in the wetter areas of Sumatra, Java, Kalimantan, Papua), 7.5% Oxisols (in the wetter areas of Sumatra, Java, Kalimantan, Papua), and 1.1% Spodosols. About half of the Inceptisols and Entisols are shallow and infertile, while most of Oxisols, Ultisols, and Spodosols are acidic and infertile. These make up to about 55% of infertile soils of Indonesia, excluding about 7% of Histosols (distributed in Sumatra, Kalimantan, and Papua) (Subagjo *et al.* 2000) that are mostly infertile and environmentally susceptible. More recent studies of Wahyunto *et al.* (2003; 2004; 2006) estimated around 21 million ha of Histosols.

Under the swidden agriculture systems, the low fertility soils can only support one or two consecutive annual crops under no fertilizer application after which they need to be fallowed or fertilized for fertility rejuvenation and maintenance. With low intrinsic fertility of these soils, the fallow period will be relatively longer compared to soils with high weatherable mineral reserves such as Inceptisols (Eutrudepts), Mollisols, Vertisols, Andisols, Alfisols, and some of Entisols (Orthents and Fluvents). The more fertile soils such as Alfisols, Andisols, and some Vertisols, in general, have been used for agriculture and other uses, leaving mostly less suitable ones for future extensification.

Landform

About 26% of Indonesian land are mountainous (> 30% slope), 20% are hilly (15–30% slope), and 13% are rolling (8–15% slope) (Table 1). These steeplands are susceptible to erosion, especially when planted to annual crops. Only about 40% of Indonesian areas are relatively flat to undulating with slopes ranging from 0 to 8%.

Table 1. Landform and slope distribution of Indonesian land.

Landform	Slope (%)	Area (%)
Others	-	1
Flat	0 - 3	23
Undulating	3 - 8	17
Rolling	8 - 15	13
Hilly	15 - 30	20
Mountainous	>30	26

Agricultural lands are scattered from flat to mountainous areas. Intensive agriculture, like vegetable farming, widespreads on hilly and mountainous areas because of crop suitability in higher elevation, aggravating the land slide and erosion.

Water Resources

Water availability is one of the major key elements in agricultural intensification and extensification. In general, the total amount of water is not a problem for Indonesia, but the distribution is uneven and often unpredictable. About 83% of Indonesian land have annual rainfall of > 2,000 mm (Table 2). During the rainy season from November to April, rainfall amount and intensity are often so high and erosive affecting the sustainability of steepland agriculture. For example, the flooding rain of the 31st of January 2008 in Jakarta was in part caused by 370 mm rainfall; an amount normally received in one month during the rainy season.

AGRICULTURAL DEVELOPMENT AND ENVIRONMENTAL AND SUSTAINABILITY ISSUES

Upland Agriculture

Shifting cultivation

The upland agriculture of Indonesia has evolved from the very traditional form of swidden (shifting cultivation) farming to intensive annual and perennial crop-based farming (van Noordwijk *et al.* 2008). In the shifting cultivation, farmers plant

Table 2. Average annual rainfall in major islands of Indonesia.

Island	Percent area based on annual rainfall (mm)				
	> 5,000	3,500–5,000	2,000–3,500	1,000–2,000	< 1,000
Sumatra	0.8	21.5	71.5	6.2	–
Java	1.9	12.6	56.0	29.5	–
Bali, NTB, NTT	–	2.1	16.3	69.6	12.0
Kalimantan	–	29.0	66.3	4.7	–
Sulawesi	–	23.0	66.1	30.9	0.8
Maluku	–	1.7	71.9	26.4	
Irian Jaya	10.3	33.7	40.3	15.7	

Source: BMG (1994).

hill paddy where forests are cut down and burned. This method of farming can only last for about 1–3 years before weed encroaches and/or soil fertility declines due to nutrients off-take with harvest. Farmers are then moving further to open forest and farm on the new piece of land for a few years. If the practice continues it turns more and more primary forest into grassland, including *Imperata cylindrica* grassland (Garrity *et al.* 1997). The practice of shifting cultivation in part is aimed at claiming a right for possessing land. As farmers' fields expand further and further away from their homesteads, ability to claim more land is limited by labor shortage.

As the population increases the fallow period is shortened and hence satisfactory soil rejuvenation is difficult to reach under the no input system. Continuous farming system, is then starts, initially in high population density areas such as Java. The most likely avenues after shifting cultivation transform to permanent agriculture are rubber plantation, annual crop-based farming, mix (intercropping of annual in the perennial crop-based) farming, and smallholder plantation.

Data on the distribution of shifting cultivation are not easily available. Some of the temporary fallow and woodland areas likely belong to the shifting cultivation. Currently this practice is mainly found in Papua and Kalimantan and to a much lesser extent in Sumatra and Sulawesi.

Annual upland crops

Annual upland crops (including maize, peanuts, soybean, cassava, and sweet potato) area scattered from relatively gentle to steep slope areas. Where the tenure is long term and secure and farm labor is not limited, the practices of soil conservation such as bench terracing and hedgerow system are common (Agus 2001). However, annual upland crop system also encroaches into very steep (> 45%) slope areas within the government forest jurisdiction, in which farmers are unlikely conserve the lands due to high cost of soil conservation and tenure insecurity. They can potentially engage in conservation farming systems if long term tenure security is warranted (Agus and van Noordwijk 2005).

Vegetable farming is usually found in the high elevation areas which also coincide with steep slopes. The centers of vegetable production are distributed in deep and fertile volcanic soils (Andisols) in the highlands of Java and Sumatra. Infiltration capacity of these soils is usually high, but the high rainfall, coupled with steep slopes cause erosion and landslides under unprotected lands. Sediment yield could reach as high as 87 Mg/ha/year from the steep slope, terraced vegetable farming areas (Table 3).

Fertilizer application also varies in vegetable farming, ranging from low to

Table 3. Runoff coefficient (RC), sediment yield (SY) and bed load percentage observed from different catchments in Indonesia as cited by van Dijk (2002) from several references.

Land use	Catchment size	Period of measurement	RC (%)	SY (Mg/ha/year)	Bed load (%)
Forested					
Rainforest	45 km^2	3 years	–	7	–
Rainforest	1–45 km^2	–	–	4–7	–
Rainforest	–	–	–	4	–
Mixed plantation forest	3–12 km^2	3 years	2–6	0.4–4	1–10
Pine plantation	18 ha	–	–	0.4–2	–
Agathis plantation forest	20 ha	–	–	4	10
Teak forest	79 km^2	1 year	–	73	–
Other land uses					
Vegetables on steep terraces	10 ha	3 years	17	42–75	–
Vegetables on steep terraces	3 ha	4 months	12	87	5–10
Logged pine plantation forest	32 ha	–	–	34	–
Logged rainforest	–	–	–	51	–
Mixed (agriculture, forest)	12–22 km^2	3 years	3–10	10–12	8
Agriculture on bench terraces	8–20 ha	1 year	3–9	19–25	5
Agriculture on bench terraces	18 ha	–	–	12–14	74–80
Agriculture on bench terraces	0.1–125 ha	6 years	6	40	30

very high and often excessive rates. Under the very high input system, manure and urea applications per crop of cabbages could be as high as 70 Mg/ha and 300 kg/ha, respectively. This high fertilizer application may pose a threat to water quality of the downstream areas. So far, however, research on water quality and improved vegetable management technique is lacking.

Tree-Based Crop Farming

Perennial tree crop plantations are managed either by government or private estates (oil palm, rubber, and tea) or by smallholders (rubber, coconut, coffee, cocoa, and pepper). The smallholder plantations, except for oil palm, are usually characterized by a mixture of various tree species, thus maintaining reasonable level of carbon stock (Table 4) and biodiversity. Many of the smallholder oil palm and rubber plantations are under the coordination or the 'plasma' (schemed smallholders) of estate plantation in the "nucleus estate" scheme.

With increasing international and domestic market demands, areas of oil palm plantation increased about two folds from 3.4 million ha in 2000 to 8.2 million ha in 2009. Likewise, the area for cocoa increased from 0.7–1.5 million ha in the same time period. Meanwhile, the changes in areas of other plantation commodities were relatively sluggish (Figure 1) because of little economic incentives.

Permanent tree-based farming such as coffee plantation is effective in reducing soil loss. Engineering approach of soil conservation such as bench terracing is only effective in the first couple of years in reducing soil loss during which time the soil surface is relatively exposed to direct rain drops. In the following years, as the coffee tree canopy develops, there was no more effect of the bench terracing on erosion reduction (Table 5).

A study in Ungaran, Central Java showed that micro-catchment planted to annual crops (*tegalan*) tended to have a higher water yield (discharge) compared to those planted to perennial crops (Figure 2).

With a light rain intensity at the beginning of the event, from 13:18 to 13:54 hour there was measurable discharge already occurring for the *tegalan* catchment. When the rainfall intensity increased and reached the peak at 14:12 the increase in *tegalan* catchment discharge followed and the peak of the discharge was reached at 14:30, which was only 18 minutes following the peak of rainfall intensity. The discharge from the other two catchments occurred 6 minutes later than that of *tegalan* catchment. From the hydrograph it is also noticeable that the total water discharge per unit area (area below the discharge graph) coming out of the *tegalan* catchment, was considerably higher than that of rambutan catchment and slightly higher than that of Kalisidi catchment. Kalisidi catchment showed a very long tail in its hydrograph indicating a slower release of the stored infiltrated water (Figure 2).

Negative environmental impact of rapidly growing plantation, such as oil palm, can be minimized by prioritizing the development on low carbon stock lands.

Table 4. Time-averaged carbon stock of selected land-use systems.

Land use systems	Carbon stock (Mg/ha)	Reference, remarks
Primary forest (Indonesia)	300	Palm *et al.* (1999)
Secondary forest (Central Kalimantan, Indonesia)	132	Brearly *et al.* (2004)
Shrub	15	Prasetyo *et al.* (2000)
Imperata grassland	2	Palm *et al.* (2004)
Oil palm (Indonesia)	40	Van Noordwijk *et al.* (2010)
Rubber agroforest (Indonesia)	68	Averaged from Palm *et al.* (2004)
Coconut	60	Adjusted from 98 t/ha according to IPCC (2006)
Jatropha	10	June *et al.* (2008) based on Niklas (1994)
Tea	28	Adapted from Kamau *et al.* (2008)
Sugar cane	9	Soejono (2004), modified
Shaded (multistrata) coffee	51	Hairiah dan Rahayu (2007)
Cacao	58	IPCC 2006 (Lasco 2002)

Note: In all cases, the error is around 20–40%.

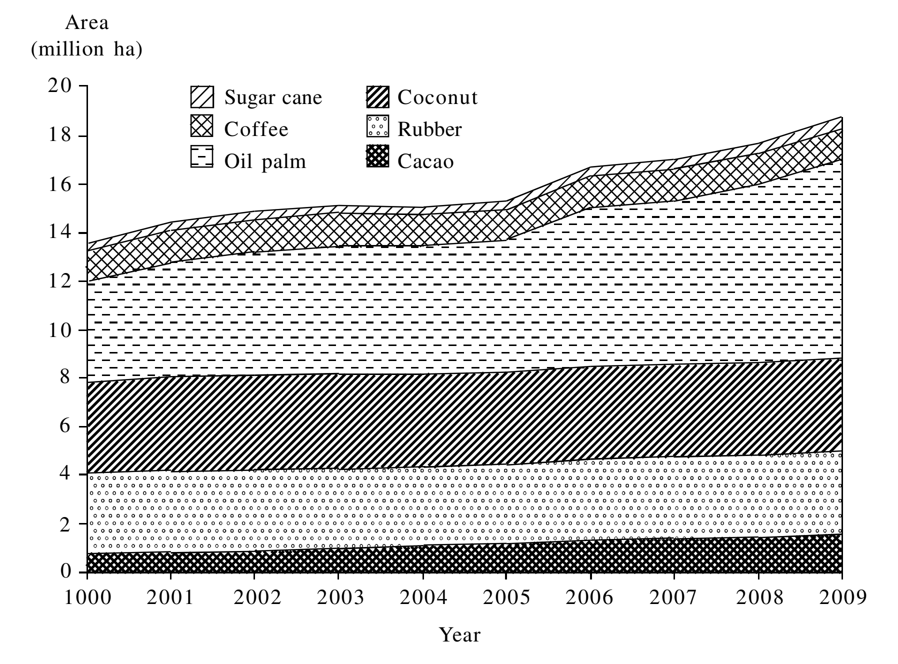

*Figure 1. Development of plantation areas in Indonesia, 2000–2009 (*Ministry of Agriculture 2011*).*

Table 5. ***Effects of bench terrace and hedgerow planted along terrace lips on soil loss at coffee farm in Jember, East Java on land with 31% slope and annual rainfall of 2,768 mm during the first four years after coffee planting.***

Treatment	Soil loss (Mg/ha/year)			
	Year 1	Year 2	Year 3	Year 4
Control (no terrace)	25.80	17.75	0.55	0.88
Bench terrace	1.51	1.17	0.35	0.82
Terrace + *L. leucocephala*	3.03	1.19	0.28	0.82
Terrace + *V. zizonioides*	1.90	0.61	0.28	0.83
Terrace + *M. macrophylla*	0.33	0.88	0.21	0.83

Source: Pujiyanto *et al.* (2001).

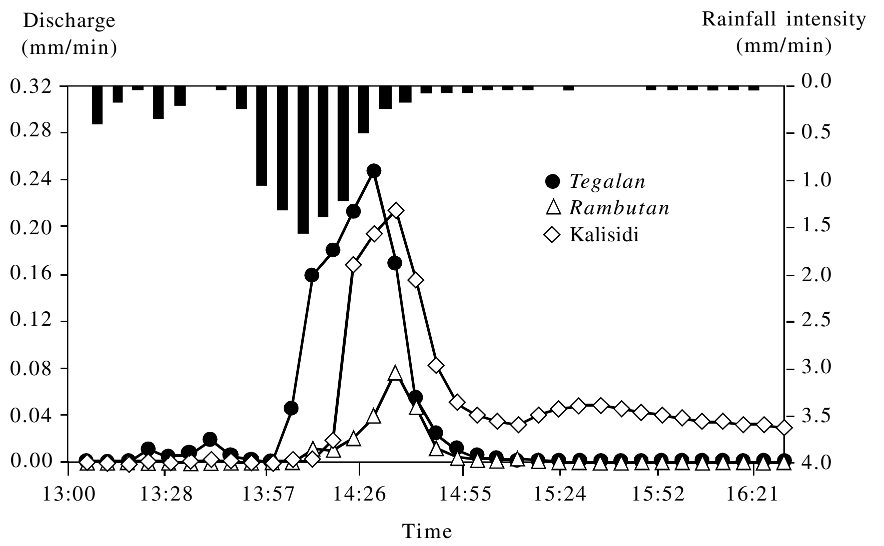

Figure 2. *The relationship between rainfall intensity and runoff water discharge from* tegalan*, rambutan, and Kalisidi catchments for a rainfall event of 7 February 2001.* Tegalan *catchment* (*1.1 ha*) *was covered by annual crops, rambutan catchment* (*0.9 ha*) *was covered by rambutan* (Nephelium lappaceum)*, and shrub and Kalisidi catchment* (*13 ha*) *was covered by rambutan. Total rainfall during this event was 56 mm.*

For example, based on Table 4, conversion of primary forest for new oil palm plantation areas decreases the carbon stock from around 300 Mg/ha to around 40 Mg/ha. However, if *Imperata* grassland is used, instead of primary forest, the carbon stock increases from < 5 Mg/ha to around 40 Mg/ha.

Lowland Rice

Lowland rice agriculture is important not only as a producer of more than 95% of rice supplies in Indonesia, but also important to maintain watershed services. The environmental services provided by paddy field include reduction of erosion, water storage and preservation, heat mitigation, and reduction of nitrate concentration in the water bodies. In addition, paddy field plays a key role in maintaining food security and terraced paddy field added to the beauty of rural landscape (Agus 2006; Agus *et al.* 2006a; 2006b). The intrinsic characteristics of paddy field make this system the most sustainable despite thousands of years of use under monoculture and intensive planting (Kyuma 2004).

Despite the multifunctionality, paddy field in Indonesia is under tremendous pressures of conversion to settlement and industrial areas. Between 1981 and 2006, the average annual conversion was about 90,000 ha. Development of new lowland rice area offsets the converted areas until early 1990s, but recently the rate of conversion far exceeding that of development caused the reduction in total lowland rice area from 8.4 million ha in 1993 to 7.8 million ha in 2006. The investment that has been spent for infrastructure and unsurpassing high productivity of well irrigated paddy fields in Java compared to that of the newly developed ones in the outer islands, have been wasted because of conversion (Agus 2006). Much of the environmental and food security services that paddy farming systems are providing have been ignored or not well understood by stakeholders. Law No. 41/2009 regulates the mechanisms for maintenance of highly productive paddy field. This law imposes disincentive measures against conversion and incentive measures for farmers and land holders to maintain their paddy field. Stringent implementation of this law will be the key for maintenance of paddy field to safeguard food security.

Peatland Agriculture

Some 20 million ha Indonesian peatland store about 40,000 Mt carbon (Wahyunto *et al.* 2003; 2004; and 2006). Under natural condition, peatland is a net carbon sink. Once it is cleared and drained, especially if it involves fire, the rich carbon stock easily emits to the atmosphere. Hooijer *et al.* (2006) estimated that, emission increases about 0.91 Mg CO_2/ha/year for each centimeter increase in drainage depth. This relationship, according the authors, is applicable for the drainage depth ranging from 20–120 cm.

Emission from Indonesia's peatland, and land use and land use change and forestry (LULUCF) was estimated to be more than 50% of the total country's emission of about 1.92 Gt/year (Boer *et al.* 2010). However, there are lots of uncertainties in the current estimates of emission from peatland, including:

- Difficulties in determining the distribution and intensity and thus the volume of peat burned of fire-related emissions.

- Limited or no groundtruthing of carbon stock in remote peat dome because of low accessibility. In Papua, for example, no peat survey has been conducted.
- High variation in drainage depth, but it is often generalized.
- Peat forest is often influenced by the drainage of adjacent agricultural and plantation areas, but is often assumed as non-drained.
- Different methods of carbon stock and emission estimates lead to the difference in the data.

Draining of peatland lead to its surface subsidence which occurs simultaneously in two forms; compaction which is a very rapid process in the first few weeks of peat draining and decomposition which continues depending on the drainage depth. Peat loss due to decomposition could be as high as 3 cm annually depending on the drainage depths (Agus and van Noordwijk 2007). The severe subsidence hinders its long term use because of difficulties in water management.

In some cases, using peatland for agriculture may provide economic benefits. But if the subsidence is very rapid, the system is not sustainable because the peat surface can become lower that the average surface of the surrounding water bodies. In some other cases, such as that in part of the One Million Hectare Rice Mega Project in Central Kalimantan, farming can not sustain, simply because of poor soil fertility. Whereas, the environmental functions of the area was also much reduced in terms of accelerated CO_2 emission, the affected hydrology and the loss of biodiversity.

The future challenges are how to have a better planning in developing peatland for agriculture. The recent moratorium of new license for peatland development (Inpres 10/2011) provides opportunity to re-evaluate the strategies and guide-lines for the use of peatland for agriculture.

PILICY IMPLICATIONS AND THE NEED FOR FUTURE RESEARCH

Table 6 summarizes the issues of Indonesian agriculture and how they imply on agricultural policy. For steepland annual upland agriculture facilitating farmers to implement conservation agriculture will be the key to sustainability. This could be attained by providing farmers with secure or semi-permanent tenure. The farmers should be rewarded for implementation of watershed conservation. In general, it was understood that lack of socio-economic incentives in farming, in contrast with a very high incentives in industrial sector has lead to agricultural land conversion. For lowland rice, the challenge ahead will be how to implement incentive and regulatory measures such that it can continually provide and improve the various services important for the public.

The emerging issue of emissions from peatland calls for the international attention to verify carbon stock and emission data. The properties of peatland are spatially variable and temporally dynamic once it is cleared and drained. Intensive and coordinated efforts are needed for research in this area to reduce the current level of data uncertainties.

CONCLUSIONS

Indonesian agriculture intensifies as well as extensifies with the increasing needs for food and fiber. Agricultural land

Table 6. Environmental and sustainability issues and policy implications for the development of agriculture in Indonesia.

Ecosystem/farming system	Environmental issues	Sustainability issues	Policy implications
Upland			
Swidden farming/shifting cultivation	Loss of biodiversity and CO_2 emissions	Weed encroachment and decline in soil fertility	Facilitation of permanent (especially tree based) agriculture
Annual upland crops (rice, maize, peanut, soybean, cassava)	Erosion and sedimentation if practiced on steep slopes	Soil fertility decline and conversion to settlement areas	Ensuring secure land tenure and subsidy for soil conservation
Vegetable farming	Erosion, landslide, agro-chemicals pollution to the water bodies	Conversion to settlement areas	Provide appropriate fertilizer recommendation and improvement of the landscape by government
Plantation	Relatively stable, decrease in biodiversity during forest conversion	Relatively sustainable	Facilitate smallholders with quality planting materials and infrastructure such that they can rehabilitate of low carbon stock land such as *Imperata* grasslands
Lowland rice (paddy field)	Stable and providing multi-functional services	Under tremendous pressure to conversion	Formulation of regulatory measures to increase incentives in farming and strictly control paddy field conversion
Peatland agriculture	Subsidence (floods), loss of biodiversity, CO_2 emissions	Very low fertility, flooding and thus abandonment	Prioritizing agriculture on mineral soil as much as possible and developing sustainable peat management

encroaches to less suitable land resources including steepland and the carbon rich peatland.

Depending on the trajectories, land use change may cause net CO_2 emission or net CO_2 sequestration. The use of high carbon stock forest and peatland should be minimized and that of low carbon stock shrub and grassland be prioritized in the current national efforts to mitigate climate change.

Lowland rice (paddy) system is under pressures of conversion to industrial and settlement areas. If this trend continues this threatens food security. Strict enforcement of the Law No. 41/2009, coupled with intensification and extensification program will be a key to food security.

Farmers must be facilitated to transforms annual crop-based agriculture on steepland to a more sustainable tree-based systems. This could be realized by providing secure tenure to the farmers and technical assistance for sustainable land and agricultural management.

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