Environmental Services of Agriculture and Farmers' Practices Worth Rewarding

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Agricultural functions in producing food, timber, fiber, and various other marketable products have long been known by policy makers and the population at large. Other functions of the agricultural landscape, however, such as environmental services, food security, employment of about 40% of the 99 million labor force in Indonesia, buffer of the country's economy at times of crisis, and maintenance of rural amenities get less recognition than they deserve. This paper reviews environmental services as part of the multifunctionality of agriculture and discusses whether rewarding farmers for those services is justifiable. Discussion is focused on the major agricultural systems including lowland rice, annual upland farming, smallholder plantation, and monoculture estate, as well as on conservation practices within the systems. The main indicators discussed include soil erosion and sedimentation, flood mitigation, carbon sequestration, and biodiversity. As forest is converted to agricultural lands, some of its environmental services disappear. The nature of the succeeding agricultural systems determine the degree of recovery of the services. Further conversion of agriculture to industrial and settlement areas, results in subsequent and mostly irreversible disappearance of agricultural environmental services. Lowland rice fields can filter sediment from the surface flows in a landscape and contribute to flood mitigation; two important functions in areas upstream of flood-prone areas. Smallholder plantations, characterized by complex agroforestry systems, sustain various positive functions including erosion control, flood mitigation, carbon sequestration, and biodiversity. Monoculture tree-based systems are low in biological diversity but they can still contribute in sequestering carbon, flood mitigation and erosion control. Annual crop-based farming systems

have relatively low erosion control, flood mitigation, biodiversity and carbon stock. Intensive vegetable farming, being mostly distributed on steep slopes with high chemical inputs, threatens water quality in the area downstream and may contribute to sedimentation depending on the overall filter functions of the catchment. With the high and increasing population pressure, the demands for using the lands, including the less suitable ones for agriculture as well as for settlement and industry, also increase and the environment is more and more threatened. Therefore, the environmental services become scarcer and more precious. Farmers' services in the forms of practicing environmentally benign farming systems and implementation of conservation practices such as life fences, grass strip, and modification of micro relief (sediment pits, terraces, furrow-ridging) within a fragile environment deserve recognition and rewards from the beneficiaries. Furthermore, the government can increase effectiveness of incentives for two-pronged (economic and environment) practices, for example, by realignment of the funds of national land rehabilitation movement.

Introduction

Beyond its primary function of supplying food, fiber and other marketable products, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation and preservation of biodiversity, contribute to food security and maintain amenities of rural areas (OECD, 2001; Agus and Manikmas, 2003). Agriculture is a safety net for employment and source of income of about 40% of 99 million Indonesian workforce (BPS, 2004). These additional functions (multifunctionality) are not recognized in the current market system and mostly remain external to government policy decisions. Intensification (the use of more labour, energy and agricultural inputs per unit of land to achieve higher outputs per unit area) and extensification (the use of a larger area) of Indonesian agriculture has been able to increase the production of food and fiber although the total production has not met the demands of the entire ever-increasing population, and thus import is inevitable to fill the deficits.

Agriculture produces positive environmental functions - at least in many cases environmental degradation is not as severe as it might be, although these positive aspects are usually not recognized and rewarded as such. Policies in natural resource management systems that enhance the positive and minimize the negative functions are the key to the sustainable use of natural resources.

Environmental services and other functions are essentially contributions made to society at large free-of-charge by farmers, the majority of whom still remain among the poorest and marginalized communities. There are many disincentives in farming in the forms of recurrent market failures, policies biased towards non-agriculture, unavailability or unaffordability of agricultural inputs, and problems with infrastructure and marketing. Farmers also face hardships because of unpredictable weather and pests and disease problems.

So far, there has been limited documentation on environmental functions of agriculture in Indonesia. Deeper and more convincing research-based knowledge is necessary to increase awareness among policy makers as well as the entire communities on the multifunctionality of agriculture. Comprehensive study and policy papers on the improvement of positive functions and reduction of negative externalities will hopefully lead to a more judicious and unbiased policy formulation, i.e. the policies that can promote practices for both economic and environmental improvements. This paper discusses environmental services of different agricultural systems and practices and systems that deserve rewards.

Environmental services of agriculture

There are many kinds of environmental services that agriculture can provide. These include the functions of erosion control, flood mitigation, water preservation, heat mitigation (Agus *et al*., 2001), preservation of biodiversity, and carbon sequestration. The following section will discuss selected functions.

Erosion and sedimentation under different land management systems

Sutono *et al*. (2003) used the universal soil loss equation (USLE) to calculate annual soil loss under different land use systems in the Citarum River Basin (Table 1). Please note that the results of this equation apply to a particular scale of measurement and cannot be directly used to estimate net soil loss from larger areas, as landscape-level deposition in 'filter' areas can reduce the net soil loss per unit area. The plot-level prediction used primary and secondary available data in the river basin area and as such, not only land use and management systems (soil cover and management systems, the C and P factors) differed but also other factors such as slope, rainfall erosivity, and soil erodibility depending on the spatial variation of the latter properties. In general, it was shown that the annual upland crop system has the highest soil loss, followed by intercropping of annual upland crops with trees.

The annual upland crop system in general is a rotation or a relay planting of food crops such as cassava, maize, peanuts, soybean and upland rice or intensive vegetable farming systems that usually coincides with steep slopes. Because of minimum soil protection by crops most of the year, these annual upland farming systems are very prone to erosion. Tea plantation gives rather high soil loss because of incomplete soil cover which lead to a high crop factor, the 'C' factor, apart from the fact that it is also usually found on steep slope areas. Paddy fields and forest have the lowest soil loss because of terrace and dike systems of the former and the thick and multi-storeyed vegetation of the latter.

Van Dijk (2002) reviewed literature data on catchment scale erosion research (Table 2) that show a general agreement with the predicted values in Table 1. In general, forest catchments have the lowest sediment yield except for teak forest (with almost clean understorey). Vegetable based system have the highest sediment yield. The systems associated with intensive annual cropping on steep slopes also contribute to a high bed load in the streams and rivers due to a limited filter function of the catchment.

The role of trees and grass strips

Under similar rainfall amount and pattern (the research catchments were within 1 km radius), Agus *et al*. (2002) derived sediment yield data from Tegalan (a 1.1 ha catchment dominated by annual upland crops), Rambutan (a 0.9 ha catchment covered by 10 year old Rambutan, Nephelium lappaceum trees), and Kalisidi (a 13 ha catchment also covered by rambutan but with some annual crop planting on the lower part of the catchment) (Figure 1). The total sediment yield for Tegalan, Rambutan, and Kalisidi catchments were 20, 1.7, and 2.9 Mg ha^{-1} under annual rainfall of 3800 mm indicating that orchard farming can substantially reduce soil loss.

Because of the high sediment yield under intensive annual upland crop the use of fodder grass in conjunction with cattle fattening activity was introduced in December 2001 and the result shows a reduction of sediment yield for Tegalan in 2002 compared to 2001 (Figure 1). Total annual rainfall was slightly lower in 2002 than 2001 (3100 mm vs 3800 mm). As the grass cover develops, its effectiveness in controlling erosion is increasing. On the other hand, cassava planting on the part of the floor of Rambutan orchard in Kalisidi catchment (because of encroachment by local villagers) loosens soil aggregates and exposed it to rain and canopy drops and thus contributed to the increase in sediment yield.

Similar to the case of Rambutan, coffee also contribute in decreasing soil loss. Based on plot-scale experiments, Pujiyanto *et al.* (2001) showed that soil loss was very high for plots without any conservation measures in the first two years after coffee planting because the canopy cover is relatively limited. During the first two year period, conservation practices such as bench terrace and hedgerows were effective in reducing erosion. Beginning in the third year, however, soil loss became negligible due to effective canopy closure and conservation measures did not give any effect whatsoever (Table 3).

Table 1. Predicted soil loss of different land use systems in Citarum River Basin.

Land use	**Catchment**		
	Saguling (uppermost)	**Cirata (upper)**	**Jatiluhur (lower)**
	Mg ha^{-1} yr^{-1}		
Forest	0.1	0.2	0.1
Intercropping of annual crops with trees	8.4	15.4	36.9
Rubber plantation	-	8.8	11.4
Paddy field	0.3	0.4	1.4
Shrub	1.1	1.6	0.5
Annual upland crops	22.0	61.3	40.1
Tea plantation	23.1	26.9	9.6

Table 2. 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 measure-ment	RC (%)	SY Mg $ha^{-1}yr^{-1}$	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 k 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%

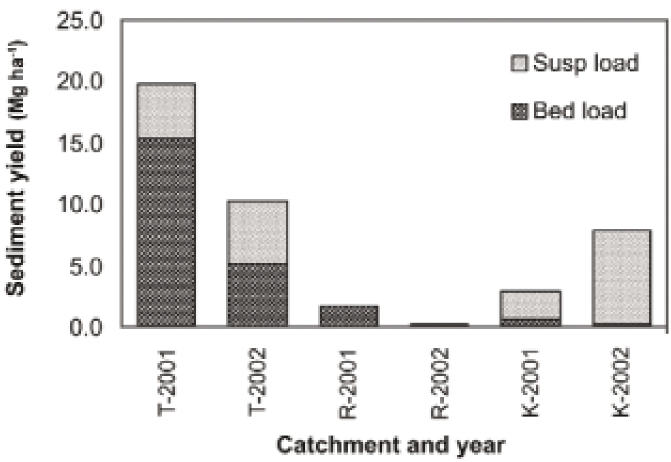

Figure 1. Suspended load and bed load yielded in 2000/2001 (denoted as 2001) and 2001/2002 (denoted as 2002) rainy seasons for Tegalan, T (annual upland catchment); Rambutan, R (rambutan orchard catchment); and Kalisidi, K (rambutan orchard catchment with some cassava on the floor). (Agus *et al*., 2003).

Table 3. Effects of bench terrace and hedgerow planted along terrace lips on soil loss at coffee farm in Jember, East Java on land with slope of 31% and annual rainfall of 2,768 mm during the first four years after coffee planting).

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

a) Source: Pujiyanto *et al*. (2001).
b) In one column, numbers followed by common letter are not significantly different as tested using the Tukey test at the 5% significance level.

Widianto *et al*. (2002) based on erosion measurement in Sumberjaya, West Lampung, evaluated soil loss under forest and different stages of coffee development. This plot-scale measurement was conducted at scattered location and therefore, the effect on soil loss is not only determined by land use and coffee growth stages, but could also be by variation in rainfall amount and soil properties. Nevertheless, the trend in soil loss as found by Widianto *et al*. (2004) is in agreement with that of Pujianto *et al*. (2001) (Table 3).

In Sumberjaya sub district, Lampung, Dariah *et al*. (2004) recorded similarly negligible (less than 2 Mg ha^{-1} yr^{-1}) soil loss under 3 year coffee cover and annual rainfall amount of 2400 mm and the slopes of 50-60%. As such, different conservation techniques they tested did not give significant effects. Earlier on, Gintings (1982) measured soil loss at the same sub district for six month period with the rainfall of 1338 mm on slopes reaching 60%. The author found that soil losses for the six month period were 1.9, 1.6, 1.3, and 0.3 Mg ha^{-1} respectively for land covered by 1, 2, and 16 year old coffee and by virgin forest. The whole year soil loss is expected to be no more than twice as much since average annual rainfall is about 2400 mm.

These research findings consistently show that tree-based systems is an effective erosion control measure. Coffee and rambutan cases, above, exemplify the systems that are not only environmentally save, but also relatively profitable.

Paddy Field as a sediment filter

Soil loss measurement from terraced paddy field system in Ungaran, Central Java, on land with major slope of about 25% revealed that sediment leaving the paddy system is very small (<1.5 Mg ha^{-1} $season^{-1}$) and more than 50% of the erosion occurred during and shortly after tillage operation (Table 4). During the erosion observation, mud (particles and aggregates suspended during tillage) transported to only a few terraces downward and this means that particles reaching the stream originate from only a few series of plots / terraces above the streams. Water flow only occur when the water level in the plot exceed the normal water level of 5 cm during the vegetative stage of rice plant. If water level during and shortly after tillage operation can be controlled such that no or only little outflow of water is allowed, erosion from paddy field could further be minimized. Table 4 also shows a net sediment deposit in the paddy field. This means that paddy field can function as a landscape filter.

Table 4. Amount of sediment entering and leaving a series of 18 terraced paddy fields (ranging in size between 12 to 358 m^2, with a total area of 2515 m^2 in two rice seasons (first season was 31 October 2001 to 31 January 2002 and second season from 16 March to 1 July 2002).

Variable	Rice season	
	First	Second
Duration of observation (day)	62	69
Sediment budget:		
Total sediment entering the system from irrigation canal (Mg ha^2)	3.4	6.2
Total sediment leaving the system (Mg ha^2)	1.4	0.8
Total sediment leaving the system during tillage operation (Mg ha^2)	0.7	0.6
Net sediment deposition (Mg ha^2)	2	5.4

Source: Adapted from Kundarto *et al.* (2002).

Water retention

Agus *et al.* (2001) estimated water retention capacity of several land use systems in Citarum watershed in West Java and Agus *et al.* (2003) evaluated the flood mitigation role of paddy farming for the same case study area using the replacement cost method and the travel cost method.

Water retention capacity (Buffering capacity, BP) is the watersheds capacity to absorb and hold (rain) water. Only rainfall in excess of this water retention capacity will flow as runoff water during and shortly after every rainfall event (Nishio, 1999). The water retention capacity includes water that can be absorbed by soil pores, water that can be stored by ponding on the soil surface, additional water that can be stored by paddy fields, dams, etc. and water intercepted by plants. In essence, this property indicates the flood mitigation capacity of each land use systems. Agus *et al.* (2003) found that tree-based farming systems maintain most of the flood mitigation capacity exerted by forest. Paddy fields, with their terrace and dike system behave like small dams in collecting and ponding water and thus have similar water retention capacity as tree-based agricultural systems (Figure 2).

Furthermore, Agus at al. (2003) discussed that the marketable products of the 157,000 ha paddy field within the 696,000 ha total area of the watershed represented a total value of around $181 million annually and the value of flood mitigation role accounted for about 10% of this amount (about $18 million per year). The total values of flood mitigation, conservation of water resources, soil erosion control, organic waste disposal, rural amenities, and heat mitigation accounted for about 51% of the marketable rice value (about $92 million per year). The current market system only recognizes rice as the product of agriculture and ignores the by-products (externalities).

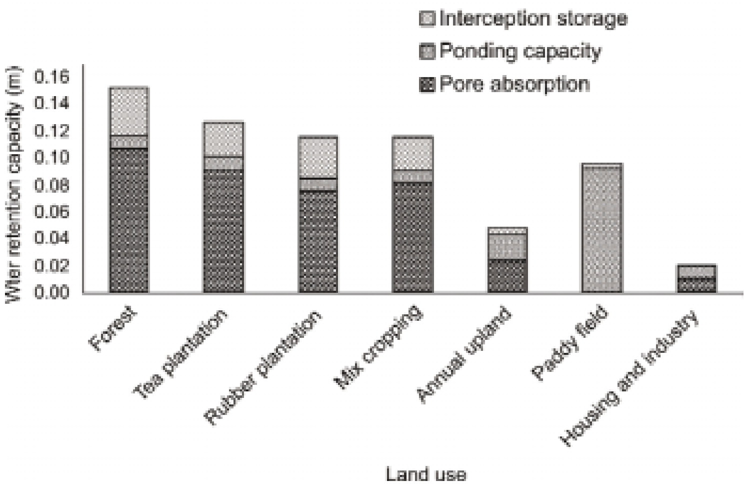

Figure 2. Water retention capacity (capacity of the system to hold water temporarily before runoff occur) of different land use systems in Citarum River Basin (Agus *et al.*, 2003).

Carbon sequestration and biodiversity

The main source of CO_2 in Indonesia is forest conversion which, in many cases, involves burning (Ministry of Environment, 1999). CO_2 emission from forest conversion is much higher than from fossil fuel combustion.

Among agricultural land uses, tree-based farming systems have the highest while annual food crop system have the lowest carbon stock (Table 5). Efforts to maximize carbon storage include diversification of food crops with trees or the adoption of agroforestry system. For coffee system in Lampung Sumatra, the mean annual increment of C-stock of mixed coffee systems is about 1.9 Mg ha^{-1} yr^{-1} during a typical production cycle, and that of a monoculture coffee system was about 1.0 Mg ha^{-1} yr^{-1} (Tomich *et al.*, 2001; van Noordwijk *et al.*, 2002). Combination of various crops in complex agroforestry systems are common under smallholder farmers not only in Sumatra and Kalimantan where the so called "rubber agroforest" or "rubber jungle" is common, but also in Java where the annual food crop are planted in association with various species of perennial tree crops.

In the forest margin of Sumatra, plots of traditional agroforestry systems can inhabit plant species approximating the number of species in forest. As agriculture intensifies it is dominated by monoculture farming system that, in many cases, have negative impacts in sustaining biodiversity (Table 5).

Practices worth rewarding and mechanism for technology selection

Land us systems differ in the environmental services they provide, depending on the specific management practices used. Practices that deserve rewards are those producing services needed by the community. For example, if flood is the recurrent and growing problems in the downstream, then every practices for increasing or at least maintaining the water retention function of the landscape, deserve rewards. In this case, linking the problems with the farmers' practices that can maintain or increase services to solve such problems is an essential process. This process include identification of watershed-specific problems, identification of interventions that have been or could be done by the farming community to solve or alleviate the problems, selection of most do-able practices and provision of guidance and incentives for implementing new practices. Location-specific solutions developed by farmers themselves, with or without external support, are superior to the conventional blanket recommendations. The 'extension' challenge is to facilitate and speed up the process of local learning.

Table 5. Carbon sequestration and biodiversity for the Forest Margins of Sumatra

Land use	Carbon sequestration	Biodiversity
	Time averaged C stock (Mg ha^{-1})	Plant species/ standard plot
Natural forest	254	120
Community- based forest management	176	100
Commercial logging	150	90
Rubber agroforest	116	90
Rubber agroforest w/ clonal planting material	103	60
Rubber monoculture	97	25
Oil palm monoculture	91	25
Upland rice / bush fallow rotation	74	45
Continuous cassava degrading to Imperata	39	15

(adapted from Murdiyarso *et al*., 2002)

Participatory rural appraisal - a survey technique in which farmers and extension workers communicate iteratively about the local farming systems, including the prospects and constraints - has officially become a standard procedure in the technology-selection process of development projects in Indonesia. However, in practice, recommendations found in many demonstration units or development projects have not reflected the diverse biophysical and socio-economic backgrounds of farmers but appear to be still dominated by standard recommendations. For example, slope gradient has been regarded as the main criterion for determining the number of trees per unit area. Lands with slopes gentler than 25%, between 25 and 40%, and steeper than 40% are 'reinforced' with 100, 200 and 400 trees ha^{-1} to give 25%, 50% and 100% tree canopy cover, respectively (unpublished 1996 Regreening and Reforestation Guidelines issued by the Central Guidance Team of Regreening and Reforestation). Wider issues, such as existing tree stands, subsistence mode of farming, insecure land tenure that forces farmers to invest in activities with fast returns, and inaccessibility to markets, have not been fully considered in technology selection. Tree planting is acceptable to farmers as long as it does not distort existing annual crop based farming. For those with insecure land tenure, however, getting a fast return on their investment is a lot more important than any other consideration (Agus, 2001).

Management options should address the main issue at stake, and thus start from thorough analysis of cause-effect relations, but should also be viewed from their effect on farmers' basic necessities. Thus, it's very important to have an open and transparent dialogue or negotiation among stakeholders to analyze the problems, possible causes, and problem-solving or alleviating options (van Noordwijk at al., 2004; this volume). Examples of links between watershed problems, causes and management options are given in Table 6. Some of the causes of the problems are natural. These include untypical long dought or excessive

Table 6. Selected watershed problems, causes and management options

Problems	**Possible Causes**	**Problem solving or alleviating options**
Significant reduction of water volume (subsidence of water level) in lakes	Long drought	Implementation of drought mitigation measures
	Artificial increase of volume of water output from the lake, such as through dredging of river bed or tunneling water out of lake for hydroelectricity, industry and irrigation.	Increasing inflow into the lake by reducing evapotranspiration in the lake catcment. Sparing water use
Decreased capacity of lakes and dams	Erosion (including stream bank erosion) from the watershed, followed by sedimentation.	Improving plant cover in the catchment Grass strips Establishment of riparian zone Protection of unstable stream bank
Flood	Excessive rainfall	Construction of flood mitigation structures such as dam and flood canal
	Reduced water retaining capacity, reduced infiltration capacity	Enhancement of infiltration and percolation through construction of water retardation ponds and pits Increasing water consumption in the catchment, for example, by tree planting Protection of soil aggregate breakage by mulching, plant cover, and maintenance of plant litter on soil surface
	Clogging of or insufficient drainage system	Maintenance and construction of new drainage system.
	Sedimentation	Improvement of landscape filter through plant cover, life fences, agroforestry, paddy field systems, etc.

rainfall. Some causes are anthropogenic, including improper land use, artifical intervention of ecosystem balances such as by channelling water out of lake.

Conclusions and policy implications

With a high population pressure and growth of 1.6% per year, there is a strong pressure for intensifying agricultural systems and for extending agriculture even to unsuitable steep slopes and marginal lands for producing enough food, wood and fiber and for providing income opportunities. At the same time, land is also needed for settlement, industrial and infrastructural developments. As land from forest is converted to agriculture and agricultural lands are converted to other non agricultural uses, many environmental services tend to disappear and thus the services will become more precious necessities.

Different agricultural systems provide also different environmental services. Smallholder plantations, characterized by complex agroforestry systems, sustain various positive functions including erosion control, flood mitigation, carbon sequestration, and biodiversity. Monoculture tree-based systems lose numbers of species although it can still contribute in sequestering significant amount of carbon, mitigate flood, and control erosion. Intensive paddy farming system has been able to control erosion to a level as low as that of forest. Monoculture annual crop-based farming systems have a low erosion control, low biodiversity and carbon stock but techniques to develop the systems into a more environmentally-benign practices are available, although are not necessarily affordable by farmers.

Traditional agricultural systems and practices maintain significant services, but farming faces lots of disincentives related to supplies, marketing and infrastructures. Since the needs for agricultural products and environmental services are increasing and both are not mutually exclusive, rewarding the farmers, as the environmental service providers, is indeed justifiable. The beneficiaries of the services and government should participate in this endeavor. Government support could be realized through realigning of the current budget of land rehabilitation and conservation to a more problem solving and people oriented approach such that it can contribute in increasing environmental services while providing a better livelihood for farming communities.