LAND USE CHANGES AND THEIR EFFECTS ON ENVIRONMENTAL FUNCTIONS OF AGRICULTURE

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ABSTRACT

*With the current pace of development and ever-increasing population pressure, there is a rapid change in land use from forest to agriculture and from agriculture to industrial and housing areas. In most cases, these changes are irreversible, but the negative impacts on environment could be minimized if land allocation is arranged properly and complied by all stakeholders. We studied, in 2001 and 2002, land use changes and their actual as well as potential impacts. We also evaluated environmental roles of sawah (*lowland rice field*) in the Citarum River Basin, West Java, using the replacement cost method. The study revealed that for Citarik Sub-watershed in West Java and Kaligarang Watershed in Central Java, areas of forest and mixed (*multistrata*) cropping have significantly decreased while industrial and housing areas increased with time and these have resulted in a decrease of both watersheds' water buffering potential in the last few decades. Even though the areas of sawah remain almost unchanged because of development of new sawah areas during the same time period, but the conversion has caused prolonged and more serious Indonesian dependence on imported rice. Sawah system contributes significantly to flood mitigation, conservation of water resources, soil erosion prevention, waste disposal, and heat mitigation. The total replacement cost of environmental services of sawah, for the variables employed in this study, was about 51% of the marketable rice products. This amount could be regarded as a free service contributed by farmers to the surrounding society. Low rice price and profitability in agriculture, relative to that of industrial and service sectors, seems to be the main disincentives for maintaining sawah. Considering the significant environmental services and food security role that sawah can offer and that attainment of a higher level of rice self sufficiency is important for Indonesia, these research results call for formulation of measures to control sawah and other productive land conversion.*

ABSTRAK

Dengan laju pembangunan seperti sekarang ini yang disebabkan peningkatan jumlah penduduk, maka terjadi perubahan penggunaan lahan yang pesat dari hutan

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menjadi lahan pertanian dan dari lahan pertanian menjadi areal perumahan dan industri. Pada umumnya perubahan ini tidak dapat balik (bergerak satu arah), namun dampak negatif perubahan penggunaan lahan terhadap lingkungan dapat diminimalkan bila penggunaan lahan ditata secara tepat dan dipatuhi oleh semua pihak terkait. Dalam tahun 2001 sampai 2002 telah diteliti perubahan penggunaan lahan dan dampak potensial serta aktual perubahan penggunaan lahan. Dalam penelitian ini juga dipelajari fungsi lingkungan lahan sawah di daerah aliran sungai Citarum Jawa Barat, dengan menggunakan metode *replacement cost*. Penelitian ini menunjukkan bahwa, untuk sub-daerah aliran sungai Citarik di Jawa Barat dan Kaligarang di Jawa Tengah, areal hutan dan sistem multistrata (campuran tanaman tahunan dengan tanaman semusim) sudah sangat berkurang, sedangkan areal perumahan dan industri meningkat seiring dengan berjalannya waktu. Hal ini berdampak pada penurunan daya daerah aliran sungai menahan air. Walaupun luas sawah relatif tetap karena adanya pencetakan sawah baru selama periode yang sama, namun alih fungsi lahan sawah memperlama dan memperparah tingkat ketergantungan Indonesia terhadap beras. Sistem sawah berkontribusi nyata dalam mitigasi banjir, konservasi sumber daya air, pengendalian erosi, pendaur-ulang sampah organik, dan mengurangi pemanasan udara, dan fungsi ini akan hilang atau menurun dengan menciutnya luas sawah. Biaya pengganti (*replacement cost*) total jasa lingkungan yang diberikan sawah berdasarkan variabel yang digunakan dalam penelitian ini adalah sekitar 51% dari nilai jual beras dari sawah yang ada di dalam daerah aliran sungai. Nilai ini dapat dianggap sebagai sumbangan gratis dari petani padi terhadap masyarakat sekitarnya. Nilai jual padi serta tingkat keuntungan yang rendah dalam bertani padi dibandingkan dengan sektor industri dan jasa merupakan disinsentif utama untuk mempertahankan sawah. Mengingat pentingnya sumbangan sawah terhadap lingkungan dan ketahanan pangan, serta pentingnya bagi Indonesia untuk mencapai swasembada beras, hasil penelitian ini menyarankan dibangunnya strategi kebijakan untuk menanggulangi konversi sawah dan lahan pertanian lain yang berproduktivitas tinggi.

INTRODUCTION

Besides producing marketable products, agricultural systems play key roles in food security, affects (many in a positive way) the environment in retaining water in a landscape and thus reduction of flood intensity, minimizing soil loss, maintaining rural socio-cultural values, reducing unemployment, contributing to the country's economy, and reducing rural poverty (OECD, 2001; Yoshida, 2001). These roles, subsequently will be called multifunctionality, are not yet understood and as such only short term economic benefits have been considered in land use and land management. Productive agricultural lands, including paddy fields [(subsequently will be called sawah as suggested by Hirose and Wakatsuki (2003)] have been converted. During the period of 1981 to 1999, about one million ha (accounted for almost 30%) of paddy field in Java and about 0.6 million ha (about 17%) near the development centers in the outer islands have been converted to non agricultural uses (Table 1). This conversion clearly increases the country's dependence on rice import. With the average yield of 6 t of unhusked rice ha^{-1} $year^{-1}$ (based on assumed average of 1.5 harvests per year) the level of rice production should have been about 9.6 million tons higher than the current level had this 1.6 million ha not been converted and the development of new rice field occurred at the same pace as shown in Table 1 (Mulyani *et al.*, 2003). With this difference, Indonesia should have been self sufficient in rice.

The investment that has been spent for infra-structure and unsurpassing high productivity of well irrigated paddy fields in Java compared to that of the outer islands, have been wasted because of the conversion.

Table 1. Paddy field conversion in Indonesia from 1981 to 1999

Region	Area in 1981	Converted	Addition	Balance
	ha			
Java	3,491,000	1,002,055	518,224	-483,831
Outer islands	3,567,000	625,459	2,702,939	2,077,480
Indonesia	7,059,000	1,627,514	3,221,163	1,593,649

Source: Adapted from Irawan *et al*. (2001)

Food security, which is usually translated to self sufficiency, access to food by all citizens, and food safety is one of the most important aims in agricultural development. However, disincentives in agriculture, including low profits, uncertainty to access to enough supplies, and market failures, run counter to the self-sufficiency regaining target; a one time success in 1984. Conversion accelerates and the current controlling laws and regulations do not seem to be effective. Thus, there is a need to understand externality functions of agriculture, especially those related with environmental protection.

This paper synthesizes results of Year 1 and 2 Indonesian Case Study on Multifunctionality of Agriculture under the auspices of the project on the Evaluation of Multifunctionality of Paddy Field as has been reported in Agus *et al*. (2001) and Agus *et al*. (2003). Year 1 (2001) study was about land use change and how it affects the water buffering capacity and potential soil loss. Environmental evaluation as conducted in Year 1 was continued with economic valuation in the second year. Special attention was given for sawah as one of the presumably most environmentally benign systems.

LAND USE CHANGES AND ENVIRONMENTAL IMPACTS

Land use changes in Citarik and Kaligarang watersheds

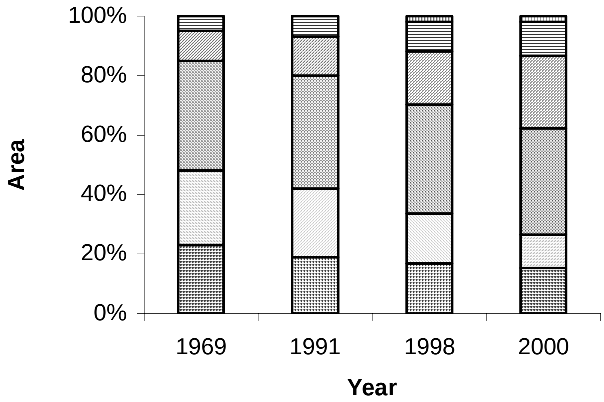
Wahyunto *et al*. (2001) conducted a study in Citarik sub-watershed in West Java having an area of about 26,370 ha and Kaligarang watershed in Central Java having an area of 20,080 ha. These watersheds are undergoing rapid changes in terms of urban and industrial developments. Their study was based on aerial photograph and thematic maps interpretation and followed by a series of ground truth activity. The maps depicting land use condition at different times were compared and land use changes were estimated using a geographic information system (GIS) and the result is summarized in Figure 1.

In 1969, land uses in Citarik Sub-Watershed included forest and bush (23%), mixed cropping, i.e. annual upland in association with various perennial tree crops (25%), sawahs (37%), upland annual crops (10%) and housing and home garden (5%). Forest proportion decreased to 19% in 1991 and further decreased to 15% in 2000. Sawah area also decreased in the last 30 years although the decrease is insignificant compared with that of forest due to development of new sawah areas that can not be depicted in Figure 1. For the whole Java, however, the addition of new sawah areas is clearly depicted in Table 1.

The area of annual upland crops increased with time and it generally derived from mixed (multistrata) systems and forest lands. Meanwhile, along with population growth, the housing/urban areas as well as industrial areas have been expanding. Unfortunately, the map interpretation of Wahyunto *et al*. (2001) showed that the developments of industrial and housing areas have been taken place on highly productive sawahs and other agricultural lands. Field observation in the Citarik sub-watershed clearly showed that most textile factories are located in the middle of irrigated and highly productive sawah areas.

In Kaligarang watersheds, the proportion of forest was already low (11%) in 1939 and it further decreased to about 9% in 2000. However, although with some level of ground check, the forest area may have been confused with mixed upland cropping areas in the aerial photograph and satellite imagery interpretations. Annual upland areas had a low proportion because most annual upland crops are planted in association with trees. Like in Citarik sub-watershed the upland agricultural areas decreased significantly and sawah decreased at a rate lower than that of upland. Meanwhile housing and urban development encroached into agricultural lands and, in turn, this gave pressure for further forest conversion.

A. Citarik sub-watershed



B. Kaligarang watershed

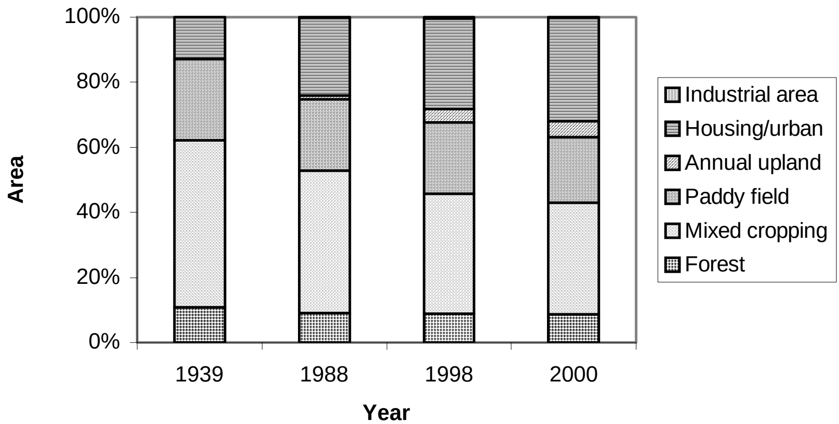


Figure 1. Land use changes of Citarik sub-watershed (area 26,370 ha) and Kaligarang watershed (area 20,080 ha) (adapted from Wahyunto *et al*., 2001).

The rate of conversion of agricultural lands into non-agricultural utilization tends to increase with time because of the following reasons (Agus *et al*., 2001):

- Involvement of various agencies in the issuance of land conversion permits has weakened the control of conversion.

- Law enforcement is very weak in controlling land conversion.
- Autonomy/devolution has often been interpreted by district government as a greater opportunity to increase the (short term) local government revenues that can easily be generated if more lands are used for industrial and urban development purposes.
- Sawah/agricultural land conversion for industrial and housing areas has been seen by local farmers as an opportunity to find higher paying and a little higher ‘social status’ jobs.
- Selling sawah is considered as an opportunity to earn cash for investment in other sectors.

Land use change and the environment

Water retention potential

Conversion of forest to agricultural lands and from agriculture to housing and industrial areas is almost irreversible. However, some forest functions could be maintained in agricultural lands. Tree based systems, agroforestry and sawah systems maintain significant forest functions. When further conversion occurs, i.e. from agriculture to industrial and housing areas further diminishing of forest function occurs. Multifunctionality aspects such as food security could still partially be maintained if the conversion does not sacrifice highly productive agricultural lands. Examples below elaborate the consequence of land use changes on water retention function and soil loss.

Water retention function or water buffering potential, *BP*, is watershed capacity to absorb and hold (rain) water such that that portion of water does not flow as runoff water (Nishio, 1999). This includes water that could be absorbed by soil pores, stored on soil surface, and additional water that could be stored by sawahs, dams, etc., and water intercepted by plants.

In Japan, average *BP* values for dry cropland, grasslands, orchard, forest, and sawah are 0.04, 0.02, 0.11, 0.18, and 0.15 m, respectively. This means that during heavy rain, 1 ha of dry cropland can store about 400 m^3 of water, and grassland, orchard, forest, and sawah can store respectively 200, 1100, 1800, and 1500 $m^3\ ha^{-1}$ before runoff takes place. Housing compound and other land uses that leave only small portion of soil surface pervious to water absorption have a much lower water buffering function. Dam and irrigation network contribute to the water buffering function based on their capacity and normal water level.

Using the same method as that of Nishio (1999), Tala'ohu *et al*. (2001) calculated *BP* for different land use systems for Citarum watershed using the equation:

$$BP = (TPS - FC) * \mathrm{AZ} + PC + IC \qquad [1]$$

where *TPS* is the percentage of total soil pore space, *FC* is percentage of soil water content at field capacity, *AZ* is the depth of absorption zone or virtual rooting zone, *PC* is surface ponding capacity, and *IC* is plant canopy interception capacity. In their calculation initial water content is assumed as high as water content at field capacity and the difference between total pore space and FC is assumed as effective water absorbing pores. The value of *IC* depends on the nature of vegetation. Forest cover has the highest value and bare soil surface has zero value. Interception capacity for tree and shrub covers ranges between 0.002 and 0.076 m for one rainfall event. Annual interception loss of rain water in the Appalachian Mountains varies from 15 to 26 % of annual rainfall, i.e. corresponds to 0.30 to 0.50 m (Kimmins, 1987). Tala'ohu *et al*. (2001) assumed *IC* as high as 0.035 m, 0.010 m, 0.05 m, and 0.003 m for forest, mixed cropping, annual upland crops, and sawahs, respectively.

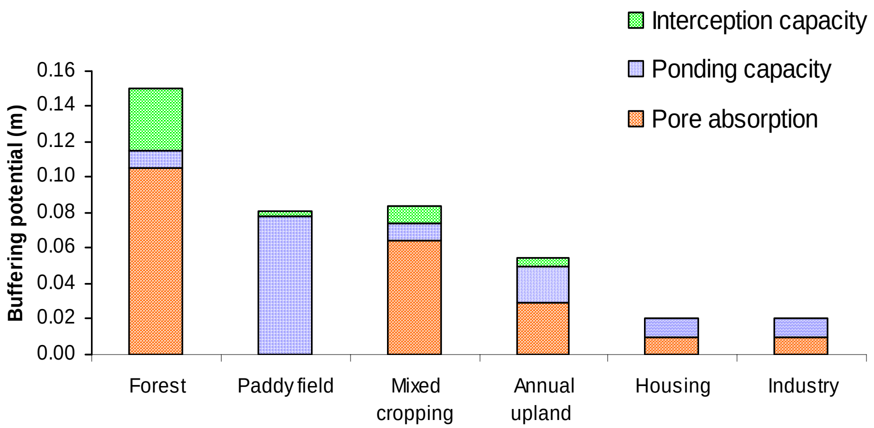


Figure 2. Buffering (water retention) potential under several land use systems in Citarum River Basin, West Java

Results of calculation are presented in Figure 2. The data shows that forest in these Java watersheds have BP values of about 0.15 m (150 mm), sawah has about 0.08 m (80 mm), mixed (multistrata) systems have about 0.09 m (90 mm), annual upland system has about 0.06 m (60 mm) and housing and industrial areas have about 0.02 m (20 mm). This means, if the antecedent water content for a rain event is the field capacity, significant runoff will occur under forest, sawah, multistrata, upland, and housing areas when rainfall is significantly higher than 150, 80, 90, and 60, and 20 mm, respectively. As such, if more and more land is converted from forest to agriculture and from agriculture to urban and industrial development, the same amount of rain will cause a greater runoff, and thus higher chance for floods.

This figure however, operates better in small size watershed. In the larger one, the complexity of rainfall and soil variability, existence of concave areas, as well as the longer travel time for water to reach rivers and streams will make the prediction more complicated and in general the direct effect of land use will be less significant although the trend remains the same.

Soil loss

Soil loss for each land use was predicted with an empirical equation, the *universal soil loss equation* (USLE) developed by Wischmeier and Smith (1978). The USLE is designed for plot scale and in many cases in Indonesia it overestimates the amount of soil loss due to insufficient validation. Nevertheless, it gives valuable relative comparison, rather than the absolute values of soil loss under different management and crop cover systems.

Sutono *et al*. (2001) explains how each of the USLE factor calculated for their case watersheds and the result of calculation is presented in Table 2. In general, soil loss of ≤ 8 t ha^{-1} $year^{-1}$ is considered as tolerable although the tolerable limit depends on soil properties. The deeper the soil, the higher its tolerable limit is. Table 2 shows that only forest and sawah areas have the predicted soil loss within the tolerable limit while for other land uses it is order(s) of magnitude higher than those of forest and sawahs. The value of predicted soil loss values of mixed cropping (combination of perennial tree crop and annual upland crops) and annual upland land uses is predominated by the high *CP* values (during the turn over crop period soil surface is exposed to rain drops and this gives a high C value), while for the bush of the case watershed, it is, by coincidence, dominated by the high *SL* values in the study area. Sawahs have a very low *CP* values because of their terrace and dike systems.

Sedimentation from sawahs occurs only during and shortly after land preparation, transplanting, and weeding. In most other time, the amount of sediment from sawahs is negligible. Sawahs also tend to have net positive sediment gain such that sawahs could function as a landscape filter of sediment coming from upland in the upslope (Sinukaban *et al*., 2000).

Table 2. Predicted soil loss (t ha^{-1} $year^{-1}$) of different land use systems in Citarum River Basin

Land use	Dam catchment			
	Saguling	Cirata	Jatiluhur	Citarum Hilir
Forest	0,13	0,24	0,14	0,24
Mixed (multistrata) cropping	8,40	15,40	36,86	30,68
Rubber plantation	-	8,85	11,39	40,75
Housing	0,03	0,02	0,15	0,02
Sawah	0,33	0,40	1,45	1,13
Shrub	1,12	1,61	0,47	0,95
Annual upland field	22,02	61,31	40,05	35,66
Tea plantation	23,11	26,94	9,65	33,48

Source: Sutono *et al.*, 2001.

VALUATION OF MULTIFUNCTIONALITY OF SAWAH USING THE REPLACEMENT COST METHODS

Citarum river basin, with an area of 694,900 ha, has three dams – Jatiluhur at the north, Cirata in the middle, and Saguling in the south. These dams have a very central role for industrial as well as agricultural developments and this justifies the selection of this study site. The three dams generate electric power for Java and Bali. Land use is variable and dominated by mixed farming (combination of annual and perennial tree crops), upland farming, and sawahs (Table 3).

Valuation of multifunctionality of sawah

Since the parameters of the multifunctionality of agriculture have many dimensions and each has different units, an attempt was made to convert the non-marketable values into the monetary term using the replacement cost method (RCM) (Agus *et al.*, 2003) as explained by Yoshida (2001). Furthermore, estimation of marketable values of agriculture used statistical data. Similar studies were conducted among others by Chen (2001) using the contingent valuation method (CVM) for Taiwan and by Eom and Kang (2001) for Korea. RCM is an indirect estimation of the costs for restoration of environmental services if certain forms of agricultural lands (in this case sawahs) are abandoned or converted to other uses.

Table 3. Land use in Citarum river basin and in catchments filling into the dams of Saguling, Cirata and Jatiluhur in 2001

Land use	*Catchments/river basin area*			
	Saguling	Cirata[1)]	Jatiluhur[1)]	Citarum[1)]
	ha			
Pond and mangrove	0	0	0	9,685
Sawah < 8 % major slope	49,145	71,219	74,101	100,120
Sawah > 8% major slope	27,033	44,955	47,739	57,518
Tea plantation	7,807	10,790	10,790	10,971
Rubber plantation	0	1,608	3,037	7,767
Annual upland	41,868	68,827	69,010	116,753
Mixed (multistrata) farming	42,453	96,287	111,427	201,898
Housing and industrial areas	24,633	27,092	27,355	46,159
Shrubs and under-utilized land	1,544	19,349	29,374	52,570
Forest	58,522	62,177	63,358	68,655
Protection forest	0	3,448	3,448	5,446
Dam (inundated areas)	4,581	9,937	17,356	17,356
Total	257,586	415,689	456,995	694,898

Source: Wahyunto *et al*. (2003).
1) Area of Cirata catchment includes the entire area of Saguling catchment and so forth for Jatiluhur catchment and Citarum river basin.

Study by Wahyunto *et al*. (2001) for Citarik sub-watershed as well as other studies revealed that most of sawah conversion occurred near the urban or suburban areas and that the main successive land uses are housing or urban development and industrial areas. As shown in Table 1, about 1 million ha of sawah in Java has been converted to non agricultural uses between 1981 and 1999. This area is equivalent to about 30% of sawah area in Java. In Agus *et al*. (2003) study, with sawah as the central land use, last two decade's scenario was used as the basic assumptions:

1. 30% of the sawah in Citarum will decrease within the next two decades due to sawah conversion.
2. The main successive land uses are urban and industrial areas as has been revealed by other studies.
3. Emphasis was given to positive environmental services (positive externalities) of sawahs. The negative externalities would be negligible if sawah is managed properly, for example, agrochemicals are not used excessively.

4. Methane and nitrous oxide gas emission is a potential negative externality from sawahs, but valuation of its replacement cost is rather complicated and thus discounted from this report.

The terms evaluated included flood mitigation, conservation of water resources, erosion prevention, organic waste disposal, heat mitigation, and rural amenities.

Flood mitigation function

Sawahs surrounded by dikes temporarily store water at times of heavy rain, and discharge it gradually into downstream rivers and surrounding areas. In this way, they function as mini dams and thus prevent or mitigate the damage which might otherwise be caused by floods. Upland fields, on the other hand, store rainwater temporarily in porous soil layer as well as intercept rain water in its canopy. Some temporary ponding of waters occur in the upland fields because of soil surface roughness. This role played by agricultural land is called the water retention function or flood mitigation function.

Evaluation of the replacement cost of water retention capacity of sawahs is based on the cost of constructing a dam which would fulfil the same function of water control. The value of the temporary water retention capacity of porous soils is based on the replacement costs, which may be incurred by a dam. In this calculation it is assumed that if sawahs are converted, the succeeding land use will either be housing and industrial areas, and to a negligible extent, annual upland farming. Replacement cost for flood mitigation, $RC_{F,}$ if 30% of sawah further decrease in the next two decades was calculated as:

$$RC_F = (Pi_{pf} - P_{ui}) * A * CR * (D_c + M_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[2]$$

Where

Pi_{pf}	=	Water retention capacity of sawahs [m]
P_{ui}	=	Water retention capacity of urban and industrial areas [m]
A	=	Area of sawah in Citarum [m^2]
CR	=	the land conversion rate within the next two decades, which is assumed equal to 0.3 for this case study.
D_c	=	Depreciation costs of a dam per unit of water stored [$ m^{-3} $year^{-1}$]
M_c	=	Maintenance cost of a dam per unit of water stored [$ m^{-3} $year^{-1}$]

Flood prevention function was calculated using Equation [1] based on the difference in water buffering capacity of sawah and that of housing and industrial areas. Buffering capacity calculation was exemplified in Figure 2.

A survey at the three dams gave the values of dam construction cost, life storage, and life span of the dams. From this number, dam depreciation and maintenance costs were calculated using Equation [2]. The replacement cost of flood mitigation function is as high as US$ 5,431,495 per annum. This means that this amount will be spent in year 2020 for additional dam construction to mitigate flood if 30% of existing sawah will have been converted.

Function of conserving water resources

Sawahs receive rainfall and irrigation water. The outputs from the sawahs include direct runoff, evapo-transpiration and percolation. Part of the percolated water (in this case assumed 75%) reaches the rivers through underground flow and eventually reaches dams. The rest of the percolated water recharges the ground water. Those waters from sawah recharging the ground water and reaching the dam as well as the runoff water that flows to the river and reaches the dam are called the conserved water and the corresponding role of sawah is called water conservation function. Valuation of water conservation function using the RCM is as follows:

$$WC_{(river)} = (RO + LSS) * S * A * CR * (D_c + M_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Where

$WC_{(river)}$	=	Water conservation replacement cost of excess irrigation and rain water received by sawahs that eventually reaches the river and dam [$ year^{-1}]
RO	=	Thickness of runoff coming from sawah that ends up in dams [m year^{-1}]
LSS	=	Thickness of sub surface flow, i.e. a portion (assumed 75%) of water percolating from sawah area that ends up in dam through lateral flow [m year^{-1}].
S	=	Correction factor of runoff and subsurface flow of water that actually reaches the dam(s) in the downstream area, assumed as high as 10%.
A	=	Area of sawahs [m^2]
D_c	=	Depreciation costs of a dam per unit of water stored [$ m^{-3} year^{-1}]
M_c	=	Maintenance cost of a dam per unit of water stored [$ m^{-3} year^{-1}]

Estimation of *S*, however is complicated and thus, while Equation 3 gives an understanding of the component of water conservation function, it is not very practical.

And

$$WC_{gw} = D * A * CR * W_p \qquad [4]$$

Where

WC_{gw}	=	Water conservation replacement cost of percolating water reaching the ground water [\$ year^{-1}].
D	=	Amount of water draining from sawahs and recharging ground water [in water thickness, m year^{-1}].
A	=	Area of sawahs [m^2]
W_p	=	Price of drinking water (difference between purchasing tap water from well water) [\$ m^{-3}]

and total replacement cost for water conservation RC_{wc} is calculated as:

$$RC_{WC} = WC_r + WC_{gw} \qquad [5]$$

Water conservation replacement cost of excess irrigation and rain water received by sawahs that eventually reaches the river and dam for Citarum river basin as calculated using Equation [3] is $15,098,229

And using Equation 4:

WC_{gw} = $271,536

and thus the total water conservation value is:

$RC_{\mathbf{WC}} = WC_r + WC_{gw}$ = $15,369,765

Function of erosion prevention

Soil erosion under sawah is negligible (comparable to that of forest land) regardless of the major (macro) slope of the land (Agus *et al*., 2003; Table 2). Other land uses, besides sawah and forest, have a much higher soil loss. If sawahs are converted to urban and industrial areas, it will create almost impermeable soil surface on areas used for building and paving and thus increase runoff and erosion on the exposed surface. In this calculation it was assumed that if sawah is converted, soil loss increases to at least as high as that of upland farming areas. The difference in the volume of soil loss from the upland farming system with that of sawah was estimated and given a monetary value based on the cost which would be incurred by constructing a dam to filter and retain sediments. Replacement cost for soil erosion prevention function (RC_E) is calculated as follows:

$$RC_E = (E_u - E_{pf}) * A * CR * SDR * (D_c + M_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots[6]$$

E_u = Estimated soil loss (erosion), in thickness unit, from upland farming areas [$m^3\ ha^{-1}\ year^{-1}$]

E_{pf} = Estimated soil loss from sawah in unit thickness [$m^3\ ha^{-1}\ year^{-1}$]

A = Area of sawah [ha]

SDR = Sediment delivery ratio, assumed equal to 0.1

D_c = Depreciation costs of a dam per unit of water stored [\$ $m^{-3}\ year^{-1}$]

M_c = Maintenance cost of a dam per unit of water stored [\$ $m^{-3}\ year^{-1}$]

Based on calculation using Equation [6], the replacement cost of 30% of sawahs in Citarum in preventing erosion was about $8,173 per annum.

Function of organic waste disposal

Organic (biodegradable) wastes such as plant residues and human wastes from non agricultural activities can be applied to agricultural lands such as sawahs as compost or as fresh organic matter. This practice decreases waste disposal costs compared to disposing biodegradable organic wastes to dumpsites. Organic materials returned to the fields to some extent can supply nutrients and increase soil organic matter content in the soil. Several assumptions applied for this practice:

- Separation of wastes into biodegradable and non biodegradable components has been adopted by the community.
- An institution for monitoring and evaluating the toxic components in the wastes such as heavy metals and recalcitrant toxic substances has been established and functioning.

The replacement cost for waste disposal (RC_{wD}) could be calculated by either one of at least the following two ways:

a. Reduction of transportation cost of wastes had the wastes been applied to agricultural areas in the vicinity of waste sources rather than transported it to distanced dumpsites.

$$RC_{WD} = O_W * T_W * R_{OW} * A * CR * T_C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [7a]$$

where

O_w = Proportion or percentage of biodegradable organic wastes from the total city and domestic wastes. In this case, it is assumed as high as 50%.

T_w = Total city and domestic wastes produced annually [$t\ year^{-1}$]

R_{ow} = the rate of biodegradable wastes that could be applied to sawahs in such a way that will not cause negative detrimental effects such as nitrogen immobilization [t ha^{-1} $year^{-1}$].
A = Sawah area within the case study area [ha]
T_C = (Difference in) transportation cost of applying the wastes in sawahs near the sources versus dumping to dumpsites [\$ t^{-1} $year^{-1}$]

b. Retribution collected by the municipal government for waste disposal. Replacement cost for waste disposal (RC_{WD}) is calculated as:

$$RC_{WD} = O_W * HH * Rw \quad \text{[7b]}$$

O_w = Proportion or percentage of biodegradable organic wastes from the total city and domestic wastes. In this case, it is assumed as high as 50% [unit less].
HH = Number of household in the study area
R_w = Annual retribution paid by each household to the municipal government [\$ HH^{-1} $year^{-1}$]

Because of more reliable data for retribution cost of waste disposal, then equation 7b was used for this calculation. Note that currently separation of degradable from non degradable wastes is not yet a custom in the area, nor is the application of organic city and domestic wastes for agriculture. Calculation is merely based on the assumption that part of the wastes could potentially be used for agriculture. Based on this method the result of calculation of waste disposal function of 30% of sawah in Citarum river basin as given by Agus et al. (2003) was \$243,761 per year.

Function of heat mitigation

Replacement cost for heat mitigation is calculated based on the fact that as sawahs are converted to urban and industrial areas, there is an increase in air temperature. The loss of cooling effect of sawah is replaced by the community by utilizing artificial cooling systems such as fan and air conditioner. Replacement cost for heat mitigation, RC_{HM}, is calculated as:

$$RC_{HM} = \{F * (M_f + D_f) + AC\,(M_{AC} + D_{AC})\} * A * CR \quad \text{[8]}$$

where

F = Number of fan in the study area
M_f = Maintenance cost of a fan [\$ $year^{-1}$]
D_f = Depreciation cost of a fan [\$ $year^{-1}$]
AC = Number of AC in the study area

M_{AC} = Maintenance cost of an AC [\$ year^{-1}]
D_{AC} = Depreciation cost of an AC [\$ year^{-1}]

Measurement of air temperature in three districts at similar elevation, but different land uses showed that day (afternoon) temperature was the highest at urban centers and the coolest in areas with mixed (multistrata) farming. Sawah area is about 2^{o}C cooler than the urban areas. The use of air conditioner (AC) and/or fan could be partially related to temperature increase in the urban areas; i.e. because of forgone benefits of cooling of air temperature that could be offered by sawah, the community restores the cooler temperature by utilizing the artificial cooling systems. The estimation shows that about $1,278,880 will be spent annually for cooling off of air temperature and this amount was attributed to the heating up of air temperature because of agricultural land conversion.

Function of preserving rural amenities for recreation and relaxation

Agricultural lands not only constitute beautiful agricultural landscape, but also create unique natural, cultural, and social environments attracting those living in urban areas to visit. The calculation of replacement cost of rural amenity is simply the sum of transportation and lodging costs of people visiting agricultural areas per unit of time.

Attempts were made by Setiyanto *et al*. (2002) to estimate the value of rural amenity. In their calculation, replacement cost of rural amenity was estimated using the equation:

$$RC_r = (Tn*Tr*Ct*Et) + (Ht*Hr*Ch*Eh) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [9]$$

The definition and calculation using Equation [9] is given in Table 4 and according to this estimate the replacement cost for the 30% sawah area is about $5.5 million per year.

Table 4. Value of rural amenity and relaxation of sawah in Citarum river basin

Code	Item	Unit	Value
Tn	Total number of tourist	Person Year^{-1}	1,943,370
Tr	Proportion of tourits visiting rural area	%	27
Ct	Correction coefficient of tourist that truly visit agricultural areas	%	21
Et	Expenses for the visit	\$ Person^{-1}year^{-1}	156
Ht	Number of home coming people	Person	422,217
Hr	Proportion of home coming people to rural areas	%	16
Ch	Correction coefficient of A	%	14
Eh	Expenses required for homecoming	\$ Person^{-1} year^{-1}	120.64
RC_r	Replacement cost for rural amenities	\$ Year^{-1}	18,232,623
	Replacement cost for expected 30% of converted area	\$ Year^{-1}	5,469,787

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

Estimation of marketable value of agriculture

Marketable economic values of agriculture in Citarum river basin, based on statistical data from the Central Bureau of Statistics, was analyzed and presented by Mayrowani *et al*. (2002). The estimated sum of marketable values of agricultural products was about $442 million annually and that of sawah alone was about $181 million. If 30% of existing sawah areas were converted to non agricultural uses, the reduction in revenue from sawah would be as high as $54,402,800 (Table 5). In addition, there will be about $27.8 million loss in the forms of environmental services if the sawahs are converted. With this figure, the total replacement costs of environmental services from sawah are about 51% of the marketable rice products. This translates to society’s enjoyment at no cost of environmental services at the value of about 51% of revenue from rice produced in the same area. Based on this figure, it is justifiable to increase incentives to the mostly poor paddy farmers. While increasing rice prices will potentially cause social and political coercion, internalizing these positive external benefits in the form of policy reform (price increase and improvement of inputs availability as well as improvement of infra-structure are perhaps the wiser approach).

Table 5. The value of multi-functional roles of agriculture in Citarum River Basin, West Java based on calculation using the replacement cost method and its comparison with marketable values

Function	Value ($ year^{-1})
Marketable/tangible values	
Estimated total marketable value of sawah in Citarum	181,342,667
Loss of revenue from paddy field had 30% sawahs been converted	54,402,800
Non marketable/intangible values (of 30% of existing sawahs)	
1. Flood mitigation function	5,431,495
2. Conservation of water resources	15,369,765
3. Soil erosion prevention function	8,173
4. Function of organic waste disposal	243,761
5. Rural amenity preservation function	5,469,794
6. Heat mitigation	1,278,880
Total non marketable value	27,801,868
Non marketable/marketable value (%)	51

CONCLUSIONS

1. Land use conversion occurs mainly from forest to agricultural land and from agricultural land to industrial and urban and settlement developments. A large portion of new industrial and housing development has taken place on productive, well irrigated sawah areas and this means a waste of heavy investment that has been made by the government.
2. Soil loss from sawahs and forests falls within the ‘tolerable limit’ and water retention (buffering potential) for forest is the highest and that for sawahs is comparable to those of plantation and mixed cropped lands. Since the change in land use occurred towards land use with lower buffering potential, the predicted total buffering potential of both studied watersheds decreased with time and this could be inferred to more frequent floods.
3. The main disincentives to maintain sawahs is that rice price is very low and, in turn, land rent for sawahs has been considerably lower than that of industrial and urban uses. Considering the multi functions of sawahs, policy makers should increase incentives to paddy farmers.

4. Agricultural multifunctionality valuation using the replacement cost method shows that sawah system contributes significantly for flood mitigation, conservation of water resources, soil erosion prevention, waste disposal, and heat mitigation. The total replacement costs of environmental services from paddy farming in Citarum river basin for the parameters evaluated were about 51% of the marketable rice products and this amount could be considered as farmers' environmental services to the community. For this level of service, farmers deserve some reward in the form of incentives to make paddy (sawah) farming a little more attractive.

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