ENVIRONMENTAL CONSEQUENCES OF LAND USE CHANGES IN INDONESIA

F. Agus, Wahyunto, S.H. Tala'ohu and R.L. Watung
Soil Research Institute, Bogor, Indonesia.

Abstract
Land use is rapidly changing in Java and there has been concern over increased frequency and intensity of floods, as well as increasing erosion and sedimentation. This research, under the umbrella of multi-functionality of agriculture, assessed flood mitigation and erosion control functions of land use systems. Erosion was also measured under terraced paddy field. Results showed that with the changes of land use, erosion protection and flood mitigation functions of the watershed decrease. The nature of the succeeding agricultural systems determines its ability to maintain some of these environmental functions. Paddy farming has an ability to filter sediment in a landscape and contribute to flood mitigation, but this land use system, has been subjected to rapid conversion to industrial and housing areas. Tree based farming systems, especially multi-strata systems commonly found among smallholder farmers, have the flood mitigation and erosion control functions close to those of forest. With smaller farm size and insecure tenure systems, due to population pressure, however, there is a reduction of tree-based, multi-strata farming and an increase of annual crop-based farming areas even on steep lands resulting in the decline of erosion control and flood mitigation. These results suggest a need for the protection of paddy field and permanent cover tree-based systems.

Additional Keywords: flood mitigation, erosion control, multistrata, paddy farming

Introduction
Analysis of land use change in Citarik (in West Java) and Kaligarang (in Central Java) watersheds has clearly shown a rapid decline of forest and tree-based and an increase in annual crop-based farming and housing as well as industrial areas (Wahyunto *et al.*, 2001). Forest is inarguably the most environmentally save land use system. Pressure to produce enough food and fiber to meet the ever increasing demands, as caused by a rapid population growth, however, has caused inevitable land use conversion. Once the forest is cut, its function is very unlikely fully recovered. Successive land use systems vary in their functions to restore forest functions.

Floods and soil erosion are among the most widely recognized environmental problems as forest lands are converted to agriculture. Intensive annual upland agricultural systems are usually associated with greater susceptibility of landscapes to flood (greater maximum river discharge), higher erosion and sedimentation. Further conversion from agriculture to housing and industrial centers worsens floods and erosion. However there are agricultural systems and their managements through which productivity can be maintained while environmental functions of agriculture can be (at least partially) improved.

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 environmental functions. This information will be useful, not only for farmers in selecting farming practices, but also for the government in their policy formulation, and for the community at large in their support for environmental protection. This paper presents flood mitigation and erosion control functions of different land use systems, and discusses the practices that can meet two pronged objectives: farmers' livelihood and environmental protection.

Materials and Methods
This study, conducted from 2000 to 2002 comprises of estimation of flood mitigation function and erosion control functions in selected watershed in Java. Many watersheds in Java have undergone rapid land use changes (Wahyunto *et al.*, 2001) because of higher population density (Agus *et al.*, 2003).

Flood mitigation function (water retention capacity)
Flood mitigation function, estimated by water retention capacity, WRC, is the watershed capacity to absorb and hold (rain) water such that that portion of water does not flow as runoff water and thus does not contribute to flood. This includes water that can be absorbed by soil pores, stored by soil surface, stored by paddy fields, dams, and water intercepted by the plant canopy (Nishio, 1999). Tala'ohu *et al*. (2001) calculated *BP* as:

$$BP = (TPS - FC) * AZ + PC + IC$$

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 water absorption zone, *PC* is surface ponding capacity, and *IC* is plant canopy interception capacity. 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. For paddy field, the ponding capacity was estimated by the difference between the dike height and the normal water level. The value of *IC* depends on the nature of vegetation. 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, multi-strata cropping, annual upland crops, and paddy fields, respectively. The values of *TPS* and *FC* were derived from the soil moisture release curves from core samples taken from representative locations representing each main land use.

Erosion and sedimentation

Sediment yield estimate were generated from literature. Soil loss of paddy field was measured in two rice seasons from terraced paddy field. From an 18 series of terraced paddy field having the total area of 2515 m^2, water inlet and outlet from each terraced were installed with V-notch weirs made of galvanized iron sheets. Water level at the inlets and outlets of each plot was recorded two times daily and rating curve for the relationship between water level and discharge was developed using a float. During and after soil manipulation (plowing, puddling, transplanting, weeding, and fertilization) intensive water samples were collected for sediment concentration measurement using the gravimetric technique. Less frequent (weekly) sampling was taken during the time when sediment concentrations are expected to be low. From sediment concentration and water-discharge data, the sediment entering and leaving the paddy field were calculated.

Results and Discussion

Flood mitigation

Assumed values of variables used in the calculation of flood mitigation are presented in Table 1 and the water retention capacity (WRC) of several land use systems are presented in Figure 1. Forest had the highest WRC meaning that under the same amount and intensity of heavy storm, catchments under forest retain the highest amount of water and thus the areas in the downstream is less likely flooded compared to similar catchment with agricultural or urban land uses. Paddy field and multi-strata farming had lower WRC than forest, but much higher than that of upland farming areas. Urban and industrial centers had the lowest WRC. This implies that conversion of paddy field areas to non agricultural uses as is occurring in Java (Agus *et al.*, 2003) is likely to increase the threat to flood in the downstream. Actual hydrological data from Sumberjaya, Lampung, Southern Sumatra, revealed that as forest lands are converted to coffee farms, river flow became higher despite a constant or slightly decreasing annual rainfall (Meine van Noordwijk, pers. comm.)

Table 1. Assumptions of depth of absorbing zone (*AZ*), ponding capacity (*PC*), assumed interception capacity (*IC*), and water retention potential (*BP*) in Citarik Sub-watershed.

Land use	***AZ***	***PC***	***IC***
	------------------------- m ---------------------		
Forest	0.50	0.010	0.035
Paddy field	na	Measured	0.003
Multistrata and tree based farming	0.30	0.010	0.010
Annual upland	0.20	0.020	0.005
Housing/industry	0.10	0.010	0.000

n.a. = not applicable as paddy field is saturated during most of planting seasons.

Erosion control function

Forest is the most benign land use systems in term of the lowest level of sediment it contributes to the streams (Table 2). When forest or pine forest is cut, erosion increases and thus sediment yield dramatically increase. Multi-strata farming systems can control erosion and thus sedimentation effectively. The level of sedimentation under multi-strata systems approaches that of forest. Annual crop based systems, especially vegetable farming on steep land, is a fragile systems and it has a low control of erosion and sedimentation.

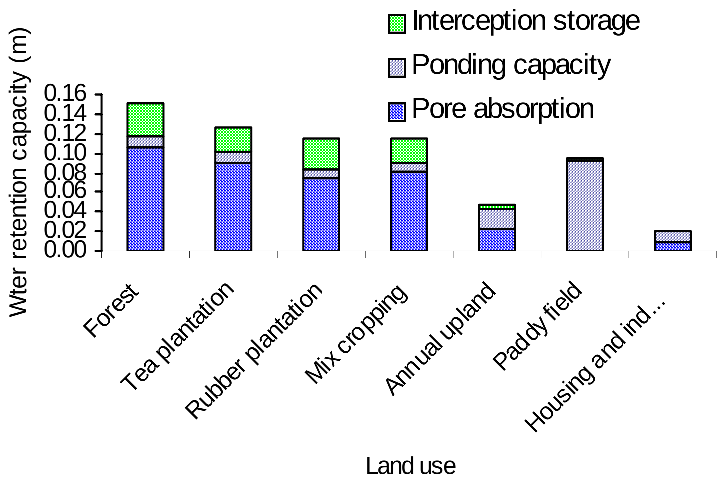

Figure 2. Water retention capacity (capacity of the system to hold water temporarily before runoff occur) of different land use systems in Citarum River Basin (Agus *et al*., 2003).

Table 2. Sediment yield from different catchments in Indonesia as cited by van Dijk (2002) from several references.

Land use	Sediment yield (t $ha^{-1}yr^{-1}$)
Rainforest	4-7
Logged pine plantation forest	34
Multistrata agriculture	10-12
Annual crop based agriculture on bench terraces	19-25
Vegetables on steep slopes with terraces	42-75

Under the traditional irrigation system, the water sometimes is loaded with sediment. However, terrace paddy field systems can trap most of the sediment in such a way that only a small fraction of the sediment actually leaves the paddy field system. Furthermore, erosion in terrace paddy fields is usually associated with tillage and other operations that can cause dispersion and suspension of soil particles. This small sediment output can still further be minimized by stopping the water outflow during tillage operation

Table 3. 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**
Total sediment entering the system from irrigation canal (t/ha)	3.4	6.2
Total sediment leaving the system (t/ha)	1.4	0.8
Total sediment leaving the system during tillage operation (t/ha)	*0.7*	*0.6*
Net sediment deposition (t/ha)	2	5.4

Conclusions

After forest has been converted to agriculture, there are threats to increasing flood and erosion and sedimentation. Flood mitigation and erosion/sedimentation control functions of forest can be restored by developing tree based and/or multi-strata farming systems and/or developing, or at least maintenance of existing paddy field areas. Paddy fields can function as sediment filters in a catchment, as the terrace and dike systems facilitate deposition of transported sediment.

Acknowledgements
This research was funded by Ministry of Agriculture, Forestry and Fisheries, Japan and coordinated by the Association of Southeast Asian Nations Secretariat.

References
Agus, F., R. L. Watung, H. Suganda, S. H. Tala'ohu, Wahyunto, S. Sutono, Adi Setiyanto, H. Mayrowani, R. Nurmanaf, and M. Kundarto. 2003. Assessment of environmental multifunctions of rice paddy farming in Citarum River Basin, West Java, Indonesia. Paper presented in the *3rd Working Group Meeting of the ASEAN-JAPAN Project on Multifunctionality of Paddy Farming and its Effects in ASEAN Member Countries, Phnom Penh, Cambodia, 27 February to 1 March 2003.*

Nishio, M. (1999). Multifunction Character of Paddy Farming. Second Group Meeting on the Interchange of Agricultural Technology Information between ASEAN Member Countries and Japan, 16-18 February, 1999, Jakarta.

Tala'ohu, S.H., F. Agus, dan G. Irianto. 2001. The Relationship of land use change with water buffering capacity in Citarik and Garang Watersheds. pp. 93-102. *In Proceedings National Seminar on the Multifunction of Paddy Fields*. Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, Bogor. (In Indonesian).

Wahyunto, M. Zainal Abidin, A. Priyono and Sunaryo. 2001. Perubahan penggunaan lahan di DAS Citarik, Jawa Barat dan DAS Garang, Jawa Tengah (Landuse change in Citarik Watershed West Java and Garang Watershed Central Java). pp. 39-63. *In Proceedings National Seminar on the Multifunction of Paddy Fields*. Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, Bogor. (In Indonesian).