Research article

Land Conservation of Upland Hills with Severe Erosion – Promoting Field Schools to Increase Farmers' Awareness

MUHAMMAD AQIL
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: agiltokyo@yahoo.com

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

Received 1 December 2010 Accepted 5 March 2010

Abstract Lack of knowledge and understanding of farmers about the risk of erosion have contributed to the rapid degradation of watersheds in Indonesia. Research was carried out to identify the topography and extent of land use in the upstream Bengawan Solo watershed to determine interactions between topographic characteristics and land use that could explain the effect of agricultural expansion in hill areas on erosion occurrence. An erosion model was applied to calculate the erosion risks using Geographic Information System (GIS). Slope and land use assessments showed that more than 60% of the soil loss occurred on upland and mixed crop areas under moderate to steep slopes. Field investigation indicated that many farmers used to grow maize and cassava in the hilly areas that are tilled repetitively and mostly left without vegetation cover. Moreover, farmers are not making efforts to use land conservation measures. Thus, these areas need immediate attention for soil and water conservation activities to prevent further land degradation. A land conservation map was created to identify land use features as well as recommended conservation measures which should be applied in order to limit further watershed degradation. Farmer field schools are proposed to increase farmer awareness on the negative effects of soil erosion and the benefits of practicing soil and water conservation.

Keywords upland hills, erosion, GIS, farmer field school

INTRODUCTION

Environmental-related problems, especially erosion, are major issues faced by developing countries such as Indonesia. Increased illegal logging and inappropriate land conversion to expand the agriculture area have contributed to an increase in the number of critical watersheds in recent decades. In 1984 the number of critical watersheds in Indonesia was estimated at 22. However, according to the latest survey the number of critical watersheds has increased to 108, or 6-fold, within two decades (Ministry of Forestry, 2009).

High population growth has led to pressure on land resources. Moreover, lack of knowledge and understanding by local people about the dangers posed by the illegal exploitation of forests and ways of ignoring the rules of land conservation have also accelerated land degradation. This phenomenon is now faced by Wonogiri Regency which is the case study in this research. Uncontrolled land conversion in the upland and hilly areas has accelerated the occurrence of landslides, floods and droughts in downstream areas. In addition, agricultural practice in the upland and hilly areas has led to a decline in the productivity of upland fields as cropland is more prone to erosion because they are tilled repetitively and mostly left without vegetation cover. Soil erosion levels in this area are still high and farmers are not making efforts to construct or maintain soil and conservation works. The Regional Development Agency of Wonogiri Regency has reported a strong relationship between forest conversion and erosion, explaining the need to detect and assess land conversion systems as a first step in erosion evaluation.

In the present work, an attempt is made to assess the topography and extend of land use over the watershed in order to find the relationship between topographic characteristics and land use that could explain the effect of land conversion on erosion occurrence. Furthermore, farmer field schools are proposed to increase farmer awareness of the negative effects of soil erosion and the benefits of soil and water conservation.

MATERIALS AND METHOD

Because of the high erosion levels, a research area was selected in the Wonogiri Regency of Indonesia. Wonogiri is located between latitudes 7º 32' S and 8 15' S and longitudes 110º 42' E and 111º 18' E. A map of the study area is shown in Fig. 1. This area has a monsoon climate with an average annual precipitation of 2773 mm. Topography of the area includes elevations from 115 to 1300 m. Major soil types are Latosol, Meditreran, and Andosol (Soewarno and Hardjosuwarno, 2008). Dry land farming, paddy field and forest dominate the land use system in the river basin, which account for more than 70% of the area. Widespread soil conservation measures have been implemented in the area but these are in a poor state due to a lack of maintenance by farmers who are expecting local government assistance.

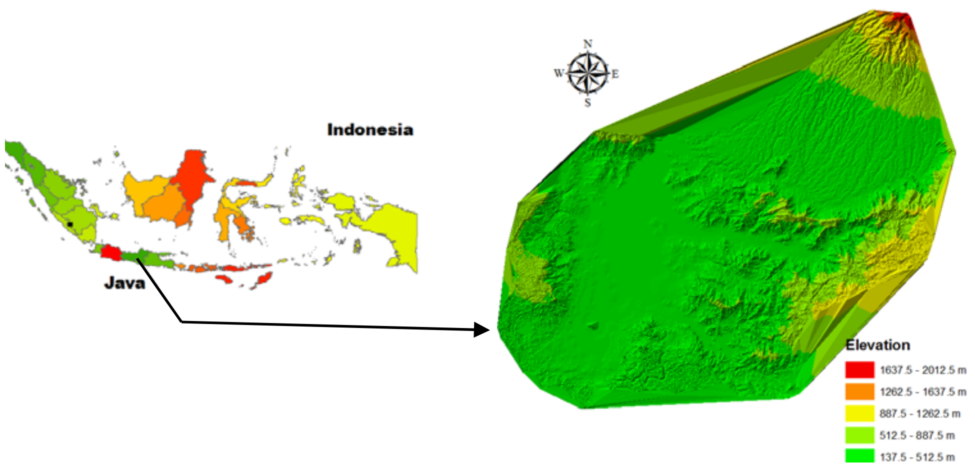

Fig. 1 Map of the study site under consideration

A survey was undertaken from January to May 2009. Various types and sources of data were collected including satellite image soil attribute data from the National Soil Survey Office, land use and climate data. This information was used to identify the source of erosion as well as to develop conservation strategies. Interviews were also conducted with local farmer about their perceptions of soil erosion and the constraints of the present existing soil and water conservation measures.

Data processing was implemented using the Revised Universal Soil Loss Equation (RUSLE) in a GIS raster system. RUSLE computes the average annual erosion expected on hillslopes by multiplying several factors together as: A = R.K.L.S.C.P, where A is the computed annual soil loss (t/ha/yr); R is the rainfall erosivity factor (MJ mm/ha h); K is a soil erodability factor (t/ha/MJ mm); L is a slope length factor; S is a slope steepness factor; C is a cover management factor; and P is a supporting practices factor. The values of these factors are determined from field and laboratory experiments (Renard et al., 1997; Lal, 2001).

After obtaining information on the relative magnitude and spatial distribution of soil erosion and potential soil erosion sites, we expand the analysis to create a land conservation map to protect the watershed from degradation.

RESULTS AND DISCUSSIONS

Farming practice on slope areas and its effect on soil erosion

Soil erosion in this study area has become one of the important factors affecting land degradation and sedimentation deposition on the river. The results indicated that some regions of the watershed have been identified as high erosion potential zones. To distinguish the level of erosion based on the slope steepness the area was classified into four classes, namely 1. gentle slope (0-25%), 2. moderate slope (25-35%), 3. steep slope (35-50%), and 4. very steep slope (>50%). Through slope assessment in the GIS environment, the estimated distribution of erosion by soil class is shown in Table 1.

Table 1 Soil loss and coverage area under different slope class

Slope class	Soil loss (ton/ha/yr)	Percent (%)	Coverage area (ha)	Percent (%)
Gentle	53.75	9.17	133410	72.49
Moderate	185.36	43.38	45393	24.66
Steep	207.73	35.43	3565	1.94
Very steep	70.51	12.03	1676	0.91

Most of the Wonogiri watershed has erosion values of 53.75-207.73 ton/ha/yr, with most values in the range 185.36-254.31 ton/ha/yr, having a climatologically moderate to high erosion potential. In addition, more than 60% of the total amount of erosion occurred on the moderate and steep slopes. Most of the erosion occurred from November to March as this area is tropical where monsoon winds bring heavy rainfall during that period. During these months rainfall intensity reaches 150-200 mm/day, which can cause considerable soil erosion.

As land use practice has a strong relationship with the erosion occurrence the five land uses, i.e. mixed agriculture, settlement, upland crop, paddy field, and forest, were investigated to determine the effect of land use on soil erosion, as shown in Table 2. The computed soil erosion decreased in the following order: upland crop, mixed agriculture, settlement, forest and paddy field. The average computed amount of soil erosion under upland crop and mixed agriculture contribute more than 90% of the total soil loss.

Table 2 Soil loss and coverage area under different land use

Land use	Soil loss (ton/ha/yr)	Percent (%)	Coverage area (ha)	Percent (%)
Upland crop	223.12	52.26	20854	12.12
Settlement	6.45	1.71	28990	16.85
Mixed agriculture	143.96	38.24	67115	39.02
Paddy field	2.96	0.79	30318	17.44
Forest	3.00	0.80	25041	14.55

The major reason for high erosion in the area of upland and mixed agriculture was the rapid expansion of agricultural activities in hill areas (Veldkamp and Verburg, 2004). Most of the crops (upland and annual) were cultivated in hill areas which are more prone to erosion. Rapid population growth and reduced land availability in the flat areas have forced cultivation of crops (including maize, cassava and beans) in areas of moderate to steep slopes. In addition, high profits due to increased upland crop market prices have attracted more farmers to cultivate land more intensively, shorten the fallow periods and till the land repetitively. This results in land left without vegetation cover that accelerates soil erosion.

Proposed land conservation area map

One of the challenges for the farmers living in the watershed is how to best manage their land without adverse effects on the environment. To help farmers limit or reduce further land degradation and its depleting effect on productivity, a proposed land conservation map has been created through overlaying erosion risk on land use maps. Risk assessment using GIS was conducted to classify five conservation areas, namely A, B, C, D and E as shown in Fig. 2 and Table 3.

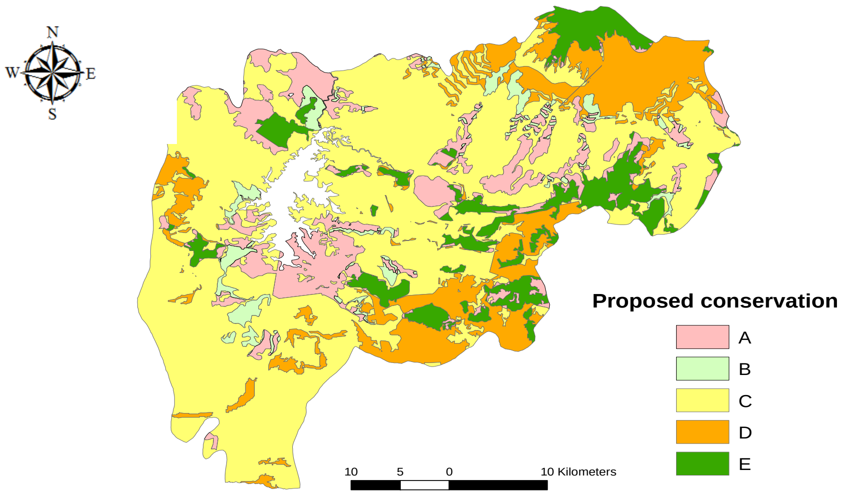

Fig. 2 Recommended land conservation for the study area

Table 3 Proposed land conservation map for the study area

Land type	Existing land features	Area (ha)	Recommended land use/land conservation
A	Very low erosion level	22891	No specific conservation efforts required
B	Settlement areas with low to moderate erosion level	6412	• A grassed waterway to reduce erosion and catch nutrients • Carry out settling ponds construction in the drainage area • Individual terrace construction
C	Agricultural areas with low to moderate erosion level	106783	• Cover crop-any annual plant grown as monoculture • Crop rotation or Crop sequencing- growing dissimilar types of crops in sequential seasons • Ridge terrace construction
D	Agricultural areas with high to severe erosion level	31085	• Strip farming-alternate strips of closely sown crops with strips of row crops • Contour farming- practice across a slope following its elevation contour lines • Drop structure construction • Community based soil erosion management program should be introduced
E	Agriculture on mountainous areas and forest	16969	• Change upland agriculture into agroforestry • Reforestation of the very steep area (slope>50%) • Engineering construction such as check dam and gully control • Community based soil erosion management program should be introduced

In Table 3 each different type of conservation contributes to a specific type of treatment. However, attention should be paid to land types D and E as these areas are the most critical, and should be treated immediately in order to maintain the sustainability of hydrological function. Farmers growing upland crops (mainly maize) in these areas are advised to practice strip or contour farming across a slope, as this system helps to stop erosion by creating natural dams for water and preserving the strength of the soil. In addition, drop structure construction helps to stabilize steep waterways and reduce gully erosion.

In addition, areas of land type E should be restricted from any upland farming activities such as maize or cassava. Instead, local farmers may be advised to pursue a practice encouraging environmental sustainability such as agroforestry in the border forest areas which buffer the more intensively deforestation. Furthermore, very steep areas (slope >50%) should be reforested to recover destroyed forests.

Enhancing farmer awareness through farmers field schools

The best way to permanently conserve eroded land is to work closely with an established education program in farming communities. Farmers field schools (FFSs) on soil and water conservation are proposed to help farmers obtain a deeper understanding of environment problems and their causes. This program brings together concept and methods from agro-ecology, experimental education and community development (FAO, 2002; Ministry of Agriculture, 2008).

The FFS is a group-based learning process with activities involving simple experiments, regular field observation and group analysis. The knowledge gained from these activities enables farmers to make their own locally-specific decisions about environmentally friendly crop management practices. The curriculum of FFS involves a wide range of environmentally friendly crop management such as tillage practices (direction and conservation tillage), crop rotations, use of organic fertilizer to manage soil fertility, use of crop residues, and soil and water conservation structures (terraces, drop structure). This curriculum is built on the assumption that farmers can only implement conservation measures once they have acquired the ability to carry out their own analysis. Organizing FFS requires a facilitator for the activities associated with farming practices. A flow diagram of FFS implementation is shown in Fig. 3.

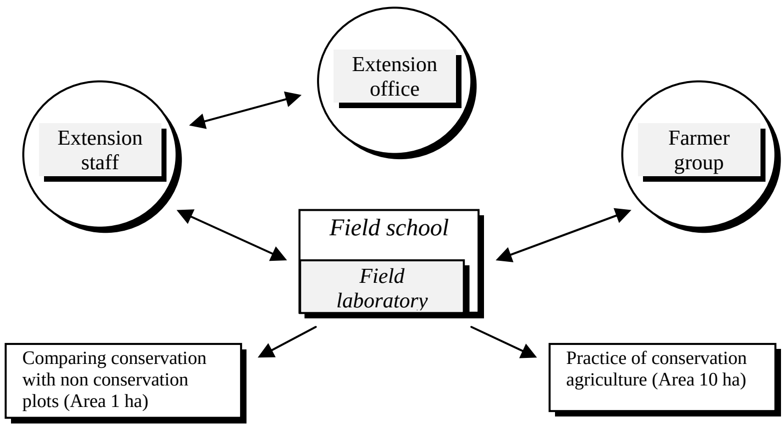

Fig. 3 Flow diagram of FFS on soil and water conservation

Fig. 3 details the role of a facilitator in the various FFS activities. In general, the facilitator introduces an activity, clarifies the process, sets participants to work, asks questions as groups make their presentations, and summarizes presentations underlining the important points that were learned during the exercise. The field facilitator (extension or researcher) organizes all activities from beginning to the end of the crop season. Participants of FSS are farmers living within the area around 10 ha. Farmers are divided into several small groups of 15 to 20 to maximize participation. Of the 10 ha of FFS land, 9 ha will be managed by farmer groups and the remaining 1 ha is used as a field laboratory with field guides managed by the extension/researcher.

Working with 15 to 20 member teams, farmers enter and make observation/experiment in the field laboratory plot (±1 ha). Once a week, participating farmers will come to the field laboratory to make observations and analyze the problems occurred. They are expected to compare these problems with the existing realities in the field. If there are differences in appearance between the conditions in a field laboratory with the field school, farmers are expected to have been able to explain. At harvest, the participants compare the crop yield or other conservation measures (e.g. erosion rate, soil quality) of the study samples (field laboratory) with the larger field (field school) in which the supporting study is conducted. Thus, the experience and lessons gained from the field laboratory can be a reference for farmers and motivate them to continue applied conservation measures in their own fields.

CONCLUSION

Agricultural practices in upland and hilly areas have resulted in seriously declining land productivity as cropland is more susceptible to soil erosion. The erosion model was applied to assess the effect of farming practice in slope areas on the occurrence of erosion. Through slope and land use assessments we found that more than 60% of the soil loss occurred on upland crops and mixed agriculture under moderate to steep slopes. Field investigation indicated that many farmers grow maize and cassava in the hilly areas that are tilled repetitively and mostly left without vegetation cover. Moreover, farmers are not making efforts to maintain land conservation measures. Thus, these areas need immediate attention for soil and water conservation activities to prevent further land degradation. One of the challenges for the farmers living in the watershed is how to best manage their land without any adverse effect on the environment. A land conservation map was created to localize land use features and recommended conservation measures which should be applied in order to limit further watershed degradation, as well as depleting agricultural productivity. Farmers field schools are proposed to increase farmer awareness of the negative effects of soil erosion and the benefits of practicing soil and water conservation.

ACKNOWLEDGEMENTS

The authors extend grateful thanks to the Japan Society for the Promotion of Science (JSPS) in providing the postdoctoral research fellowship enabling research in Japan.

REFERENCES

FAO (2002) Ten years of IPM training in Asia-From farmer field school to community IPM. Food and Agriculture Organization of the United Nations, Italy.

Lal, R. (2001) Soil degradation by erosion. Land Degradation and Development, 12, 1-8.

Ministry of Agriculture (2008) Field school of integrated crop management on maize. Ministry of Agriculture, Indonesia.

Ministry of Forestry (2008) Annual report on watershed condition in Indonesia. Ministry of Agriculture, Indonesia.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C. (1997) Predicting soil erosion by water - a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). USDA-ARS Handbook No. 703. United States Government Printing Office, USA.

Soewarno and Hardjosuwarno, S. (2008) Sedimentation control: Part 1. Intensive measures outside of Wonogiri Reservoir, Central Java. Journal of Applied Sciences in Environmental Sanitation, 1, 9-17.

Veldkamp, A. and Verburg, P.H. (2004) Modelling land use change and environmental impact. Journal of Environmental Management, 72, 1-3.