STAKEHOLDERS' PERCEPTION OF PGIS TECHNOLOGY FOR SOIL EROSION MANAGEMENT OF PHEWA WATERSHED IN NEPAL

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ABSTRACT: Participatory GIS (PGIS) has been tailored to answer specific geographic questions at the local level and its modes of implication vary considerably across space range in field based and qualitative approach. PGIS is becoming an effective methodology for incorporating community knowledge into spatial decision-making processes. This study explores different socioeconomic and physical driving factors influencing soil erosion management on Phewa Watershed of Nepal. Structured questionnaires survey and focus group discussion were applied to collect necessary information from different stakeholders. The GIS map of high soil erosion areas of the study area was prepared based on the stakeholders' perception on the topographic map of 1:25, 000.The PGIS map and regression model then predicted the locations and the driving factors for the high soil erosion areas which include schooling of the household respondents, traditional agricultural practice, migration of the stakeholders' family member, family member occupation on the off farm, lack of the appropriate conservation practices. This study showed that the PGIS discussion through the multi stakeholders communities based on the local groups are the best option to enhance soil erosion reduction and conservation in the Phewa Lake. Planners and policy makers can realize the participation of local stakeholders' for better understanding of the real problems, capacity building for the reduction of soil erosion and soil conservation by PGIS in the middle mountain watershed of Nepal.

INTRODUCTION

Soil erosion is a serious problem in a hilly country like Nepal, which has geologically young, 'sloppy' and fragile mountains and built with rugged surface topography. The rate of spatial and temporal distribution of the soil erosion depends on the interaction of physical and human circumstances**.** Erosion may also be exacerbated in the future in many parts of the world because of climatic change towards a more vigorous hydrologic cycle (Amore et al., 2004). The soil erosion depends on the human activities such as removal of the vegetation, rangeland grazing, urbanization and forest fire. Instead of human activities another reason for the soil erosion is natural condition viz. topography (slope angle and slope length) and soil properties (texture, moisture, roughness and organic matter) (Lal, 2001; Sui et al., 2009).

Phewa lake watershed territory consists of acidic, moderately fine textured and non-stony clay (LRMP, 1983). Colluvial deposits can exceed 15 m in the depth owing to the mass movement near Pame (Ramsay, 1985). Soils with loamy skeletal texture are found in hilly areas (Mulder, 1978). Sand, silt and clay are found in the area. Bright reddish, dark reddish, brawn and dark brawn soils are found in the different parts of the Phewa lake watershed area (Lamichhane, 2000). Estimated annual sedimentation deposit in whole Phewa Lake varies from 175,000 to 225,000 m^3 .

A growing world population and the abandonment of large areas of the formerly productive land as a result of erosion converted into salinization or alkalization in land. Phewa Lake is in mesotrophic situation and going to on state of eutriphication due to the environmental hazards and sedimentation. Watershed has the problem of flood and landslide due to hill slope and the deforestation. The previous study could not address the all related issues in soil erosion and sedimentation. This study is integrating participatory GIS approach for the generation of rule and policy as well as perception of all stockholders to soil erosion. The objectives of this study is to locate the erosion hot spots and land slide effects on soil erosion and sedimentation and the effects of climate change in soil erosion and sedimentation.

Phewa watershed area can be considered as an important watershed in Nepal because of the most attractive tourist destinations and represent the middle mountain region which has economically important region of the country. The previous study shows that about 5 decades time period half of the area of the Phewa Lake converted into land. There are the severe problems converting from lake into land due to the soil erosion, sedimentation and land encroachment and other human activities. Most soil erosion research does not take into account socioeconomic factors of soil erosion. Hence, this study aims to assess both the status and stakeholders' perception of soil erosion, and to identify socioeconomic determinants of soil erosion and comparison of the stakeholders' perception on soil erosion area and the soil erosion spot from the soil erosion model.

MATERIAL AND METHODS

Data were collected from a variety of sources in both digital and analog formats as well as from field, and from a household questionnaire survey. The basic data used were:
Satellite Data: Land sat ETM+ images of resolution 30x30 m of 1995 and 2010, Rapid eye image of resolution 5x5m of 2010.
Meteorological data: from Meteorological department, Government of Nepal
Census data: Central Bureau of statistics (CBS 2002), Government of Nepal
Topographic Map of 1:25 000 from survey department, Government of Nepal
Information from the household questionnaire survey was collected

The Phewa lake watershed area is located in the south-west of the Pokhara valley ($28^0 7'$ N to $28^0 12'$N latitude and $84^0 5'$E to $84^0 10'$ E Longitude). This watershed is spread fully or partially of six VDCs (Sarangkot, KaskiKot, Dhikurpokhari, Bhadaure Tamagi, Chapakot and Pumdi Bhumdi) and the southwestern part of the Pokhara sub- metropolitan city of Kaski district. It covers an area of approx.123 km^2 and the length and width of the east–west oriented watershed is about 17 and 7 Km respectively. The surface area of the Phewa Lake is 4.43 km^2 and depth varies from 8.6m to 19 m. The terrain is ranging from 793m to 2508m above sea level. The mean annual rainfall in the study area for the past 10 years from 2001 to 2010 is 4325.75mm. More than 80% of the annual rainfall occurs during the monsoon season in the months of June to September. The months from October through May are generally very dry season. The annual average temperature is 21.99^0 C. The study area is the representation of the middle hill region of Nepal.

DATA PREPARATION

Socio economic data were obtained from the questionnaire survey carried out in watershed area. The questionnaire survey was conducted to evaluate the impact of soil erosion due to the socio economic, climatic and anthropogenic factors. 310 questionnaires were collected from the 14-sub watershed area of stakeholders like farmers, mothers' group, teachers, social workers, NGO/GO officers, politicians, students. The collected data was based on individual interviews. The primary information derived from the questionnaire survey was climatic, anthropogenic and socioeconomic factors.

Secondary data socio economic data from village profile report contained the number of household, the number of families, income of the families, land use and land cover in Phewa watershed area. Demographic information about the Phewa watershed area such as rainfall, temperature and the list of soil erosion from the watershed area were analyzed. The soil erosion data were collected from the Government office and NGO. Six focus group discussions were conducted between the stakeholders' farmer, teacher, politician, mothers' group member and NGO/GO officers, students' participatory approach for soil conservation practices and soil erosion mapping on the watershed area.

Sampling procedure and questionnaire survey

The study area consists of 5395 households (HH) in 6 Village Development Committee (VDC) and Pokhara sub-metropolitan city (Census of 2002). A sample size of 310 HHs was obtained with sample fraction (k) of 0.07 at 7% significant level, using equation for sample size determination given by Yamane (1967).

$$n = \frac{N}{(1 + N \times e^2)}$$

Where n is sample size, N is total households and e is the significant level.
The sampled HHs from downstream and upstream areas of the watershed was interviewed from January to marach 2012. A structured questionnaire was used to collect information on socioeconomic condition, soil water conservation and soil erosion status from all 14 sub watershed area for the representation of the participatory approach from all stakeholders' and watershed area proportionally. The questionnaire was design to document the socioeconomic condition status, stakeholders' perception on soil erosion on their field, adopted soil and water conservation strategies. Interviews were conducted by the researcher with the help of assistants, who had been trained by researcher. The collected HHs data were analyzed by the Statistical Package for Social Sciences (SPSS) 17.0 software.

Assessment of soil erosion

The acceptable limit of soil erosion is needed for the sustainable management of the watershed by adopting appropriate land management and climate change adaptation for the agricultural practices. This requires quantitative information of soil loss and the information from the different stakeholders' local knowledge about adaptation of the climate change. The revised universal soil loss equation (RUSLE) model is used for estimating soil losses using five factors including rainfall erosivity factor, soil erodibility factor, slope length steepness factor, crop cover factor and crop management practice factor. This model estimated soil erosion of sheet and rill types.

Revised Universal Soil Loss Equation (RUSLE) model

The RUSLE model is the extended version of Universal Soil Loss Equation (USLE) which is an erosion prediction model designed to predict the long term average annual soil loss from the specific slope in specified land use and management system (Renard et al.,1991). The product of five factors quantifies the soil erosion by the RUSLE model.

$$A = R \times K \times L \times C \times P \times S \qquad (1)$$

Where A is average annual soil loss (tones/ha/yr), R is rainfall and run off erosivity factor. K is soil erodibility factor, L is slope length factor, S is slope steepness factor, C is cover and management factor, P is erosion control practice factor. LS combines both L and S factor to give the topographic factor LS.

R-factor can be calculated on rainfall intensity. 20 years of rainfall intensity data are recommended to use for the calculation of R- factor in average. Mean annual rainfall data could be used to R- factor estimation in absence of the long term rainfall intensity data for at least assessing relative erosion rates for different management, crop and soil condition (Renard and Freimund 1994). The equation proposed by Morgan (2001) (Equation 2) and Renard and Freimund (1994) (Equation 3) are generally accepted for mountainous tropical climate.

$$R = (9.28 \times P - 8.8838) \times 0.102 \times I_{30} / 173.6 \qquad (2)$$

$$R = 0.0483 \times P^{1.61} \quad \text{for p<850mm}$$
$$R = 587.8 - 1.219 \times P + 0.004105 \times P^{2} \quad \text{for P>850} \qquad (3)$$

Where R is R- factor in RUSLE equation, P is average annual precipitation and I_{30} is the maximum 30-hr rainfall intensity.
Soil erodibility factor (K-factor): A digital soil map was collected from department of land resources in Arc/info format. The soil map was reclassified according to three soil sample in study area.
LS factor were derived from the topographic data and C and P factors were selected from the literature.

Preparation of PGIS map

The focus group discussion from the different stakeholders sketches high soil erosion and landslide area on topographic map based on local knowledge about the soil type, slope and anthropogenic factors like grazing, construction of road without conservation practices deforestation etc. The high soil erosion area map is prepared by GIS based on sketch topographic map.
Quantitative data from the personal interviews as processed on the Statistical Package for Social Science (SPSS) frequency table were generated for the general information. Chi-square tests were applied to analyzed categorical data. Correlation were used to identify inter dependence among various factors influencing the soil erosion. High Soil erosion spot and landslide is mapped by participatory GIS i.e. mapped into the topographic map and later it is prepared on

ARC GIS 9.3 software. The analysis was due to the physical factors like Rainfall, slope, soil properties, organic matter and conservation practices and cover management.

RUSLE model was used to find the soil loss in the watershed with the help of the physical factors data from the related agencies to find the soil loss tone per year. This soil loss map and the PGIS mapped for the hot spot soil erosion were compared and analyzed.

Socioeconomic determinants of soil erosion

Socioeconomic variables are important of soil erosion (Shahriar et al., 2008). Socioeconomic consideration and assessment is way for decision on soil and water conservation. Multiple regression analysis can be applied to understand the major socioeconomic factors contributing to the soil erosion in the study area. Multiple regression analysis is multivariate statistical analysis technique, which can predict changes in the dependent variables in response to several independent variables (Hair et al., 1992). The soil erosion rate by the RUSLE model was considered as the dependent variable (Y). Socioeconomic covariates independents variables were used in this study to present condition of soil erosion in the watershed as below.

X_1.Household size: As soil conservation activities are labor intensive, large households are capable of investing more in conservation than small households. (Featherstone and Goodwin, 1993).

X_2.Farm labor: In Nepal, people between 15 and 64 years of age are considered as economically active family members while children below 15 years of age and disabled members and elders (65 years or above) are considered as dependent family members.

X_3.Education: Education influences the level of awareness. Increasing education level increases farmers' ability to obtain and utilize information related to soil conservation measures (Pender and Kerr, 1998)

X_4.Security of tenure: Security of tenure will have a positive effect on farmers' decision to invest in soil conservation measures. Conversely, when a system of property rights fails to provide individual users with sufficient security to reap future benefits from their investments, they may decide not to undertake such investments (Asrat et al., 2004).

X_5.Land conversion: Areas under agriculture are in general subject to more intensive erosion than natural landscapes, such as forest. Land conversion for agriculture is thus associated with increased soil erosion. The study area is not an exception.

X_6. Conservation cost: Any conservation requires investment. Willingness to invest in soil conservation results in less erosion and vice versa (Illukpitiya and Gopalakrishanan, 2004).

X_7.Training: Farmers with proper training in soil and water conservation are able to better manage soil erosion problems than farmers who do not have proper training.

X_8.Indigenous Knowledge: Farmers develop indigenous knowledge through practical experience about cropping system which play role for increase and decrease erosion.

X_9.Memberships in organizations and committees: Knowledge gained through membership in soil and water conservation committees can help to deal with soil erosion (Shahriar et al., 2008).

X_{10}. Transportation potential: Improved access to farmlands through better transportation networks can induce farmers to adopt soil conservation practices.

X_{11}. Distance: Distance is also an important factor of access. Soils and water can be managed more easily when farmland is located at close proximity to the household.

X_{12}. Awareness of policies: Awareness of policies on land, water and forests may induce farmers to decide on actions that are in line with these policies and that may lead to better land use practices supported by such policies.

$X_{13.}$ Farm size: The fragmentation of farmland has its own negative effects to implement soil and water conservation measures. Small sized farmlands are believed as adding another problem greater than erosion problems.

$X_{14.}$ Migration trend: Periodic-out migration is a major source of income in the rural area of the watershed area. The adult male member from the farm labor and lower class people, who are main labor force in farm, has a trend to go abroad for employment. This trend reduces the agricultural young farm labor which helps to increase the soil erosion in the watershed area.

X_{15} –X_{18}. Financial capital, farm income, total household income and farm expenditure: These four variables can be considered as economic factors affecting farm production or soil conservation. Wealthy farmers are less likely to make risk-averse decisions. Further, when a farmer has sources of income other than farming, he/she can be expected to invest more in soil conservation practices (Ervin and Ervin, 1982)

RESULT AND DISCUSSION

Soil erosion rates from the model

RUSLE model has been applied to calculate the potential erosion in Phewa watershed area.

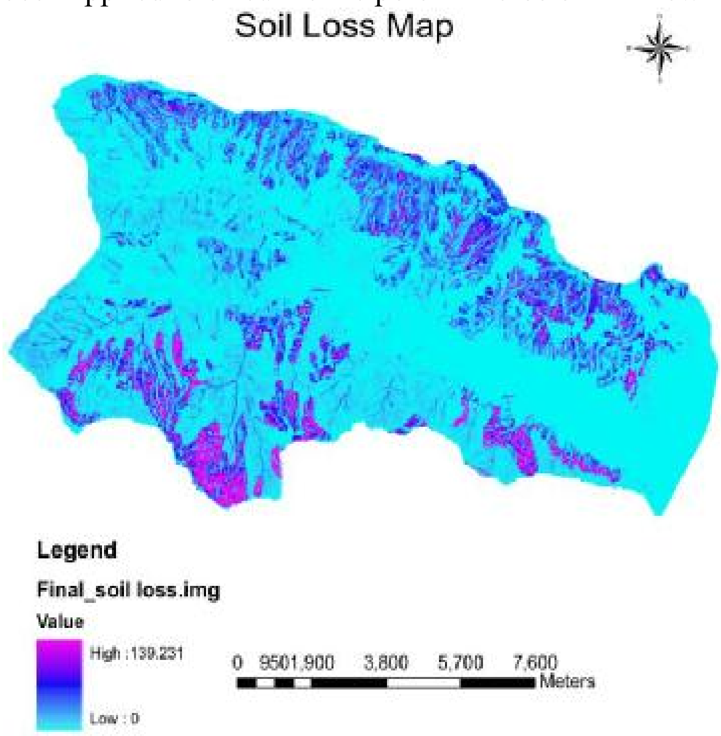

Fig1: Soil loss map in study area

The map (Fig1) showed that mountain, foot of the mountain and agriculture land has potential soil erosion area. Total mean annual rate of soil loss in the Phewa watershed is 12.86 t /ha /yr. Annual soil loss rates are varies from 0 up to 139.231 ton/ha/yr in watershed areas. Total annual soil loss is 139231ton/year in watershed area.

Table1 Description of socioeconomic variables used in multiple regression analysis

Variable name	Value label	Value	Measurement level
Dependant			
Y. Soil erosion rate		t/ha/yr	Continuous
Covariates			
X_1. Household size		Number	Discrete
X_2. Farm labor	15-64 years	Number	Discrete
X_3. Education	≥ grade 6	Number	Discrete
X_4. Security of tenure		Hectare	Continuous
X_5. Land conversion	Forest-agriculture	1	Dummy
	Agriculture-forest	0	
X_6. Soil conservation cost	Yes	1	Dummy
	No	0	
X_7 .Training on soil		Frequency/year	Discrete
X_8.Indigenous knowledge on soil conservation (index) [a]	No	0	Continuous
	Very low	.25	
	Low	0.5	
	Moderate	0.75	
	High	1	
X_9. Memberships in soil conservation related organizations and committees		Frequency/year	Discrete
	< Once/week	0.25	
	Once/week	0.5	
	2-4 Days/week	0.75	
	> 4 Days/week	1	
X_{10}.Transportation potential to farm land (index) c	Very difficult to access	0	Continuous
	Difficult to access	0.33	
	Sometimes difficult to access	0.66	
	Easy to access	1	
X_{11}. Distance to farm land		Km	Continuous
X_{12}. Awareness of policies (land/ /water/forest)	No	0	Dummy
	Yes	1	
X_{13}.Farm size	<0.2 ha	0.25	Discrete
	0.2- 0.5ha	0.5	
	0.5-2ha	0.75	
	>2ha	1	
X_{14}.Migration trend		Number	Discrete
X_{15}. Live Stock Population		Number	Discrete
X_{16}.Farm income		Rs.	Continuous
X_{17}.Total household income		Rs.	Continuous
X_{18}.Farm expenditure		Rs.	Continuous

Soil erosion in the study area by PGIS

Stakeholders group sketch the soil erosion area in topographic map based on their knowledge and experience of the field. Sketch topographic map was used to make GIS map which is given as below in Fig 2.

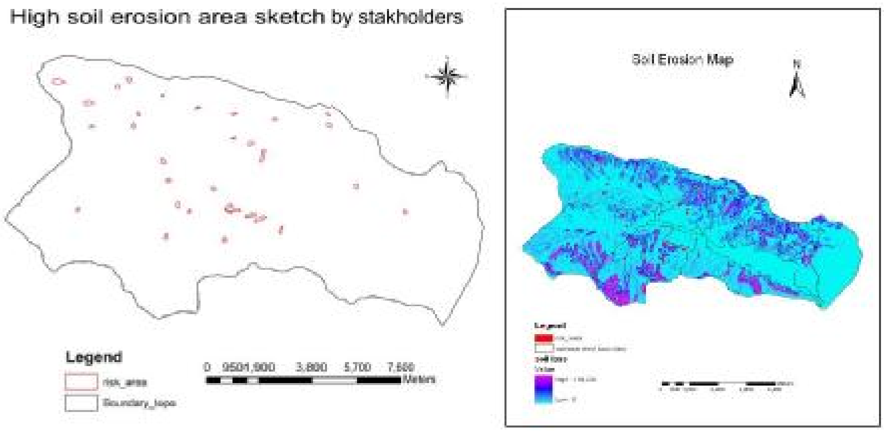

Fig 2: Comparison of the PGIS soil erosion area and soil erosion map by RUSLE model

Stakeholders' perception of soil erosion

The house hold survey showed that the six major direct causes of soil erosion: improper soil erosion management and crop management practices, deforestation, urbanization, natural causes, industry. The higher rate of soil erosion is 139t/ha/yr due to the improper soil management practices like cultivation of unsuitable soils, lack of conservation measures and improper tillage management.
36% of the stakeholder respondents perceived that high soil erosion rate is due to improper soil management practices and inappropriate tillage practices. Improper crop management practices, like reduction of plant cover, nutrient mining and shortening of fallow period were perceived by 29.2% of respondents as causes of soil erosion. Deforestation due to community forest, development of infrastructure like road was perceived by 15.8% of the respondents, and urbanization and natural catastrophes by 18%. In 2005, a massive landslide in the Orlang sub watershed area had resulted innumerous environmental and socioeconomic problems.

Indirect causes of soil erosion are equally important as these tremendously affect soil erosion through direct causes. Population pressure, poverty, labor availability, land tenure, people's education and awareness, agricultural inputs and governance issues were perceived as major indirect causes. About 50.7 % respondents perceived population pressure and poverty as major indirect causes of soil erosion, whereas labor availability and land tenure were perceived as indirect causes by nearly 29% respondents. According to 20 % of respondents, education, change in occupation agricultural inputs and governance were perceived indirect causes of soil erosion.

Socioeconomic and conservation determinants of soil erosion

The relation between socioeconomic, conservative variables and soil erosion were examined, it was found that all 18 covariates presented in Table 1. Three (X_5, X_{12}, and X_{18}) variables had a significant correlation with soil erosion. The significance was at 0.05 confidence levels for all variables. The stepwise multiple regression technique was applied, 10 out of 15 covariates were included as predictor variables of soil erosion in the final regression model given in the following equation.

$$Y=9.87-0.077X_1-0.671X_2-6.533X_3-1.1413X_6-4.138X_7-0.247X_9+0.067X_{13}+0.538X_{16}-7.35X_{17}-1.413X_{18} \quad (7)$$

Where, Y= Soil erosion rate, X_1=Household size, X_2=Farm labor, X_3=Education, X_6=Conservation cost, X_7=Training, X_9=Membership of organization committees, X_{13}=Distance, X_{16}=Farm land size, X_{17}= Migration, X_{18}=Farm Income.

In the above model, all variables were significant at 0.05 confidence level. The obtained multiple correlation coefficient (R^2) of 0.895 indicated a strong association between predictor variables in the model and soil erosion. Below is a brief account of the significant variables as socioeconomic and conservation determinants of soil erosion. The variables, household size and farm labor have a negative effect on soil erosion in the model. A higher number of family members can provide more farm labor and soil conservation activities. Young farmers may be more educated and more knowledgeable about innovative farming practices and thus more aware of soil problems and available solutions (Illukpitiya and Gopalakrishnan, 2004). As shown by the model, education and training have a negative effect on soil erosion. Education, which includes gaining knowledge on consequences of soil erosion and on soil conservation measures, is an important variable governing the decision-making processes in soil conservation (McDowell and Sparts, 1989). Membership in organizations and committees has a negative effect on soil erosion. This variable explain the level of cooperation and social coherence, which reflects farmers' ability to organize themselves into groups, influence development planning and budgeting activities, or obtain formal credit or market access that is conducive to soil conservation (Shahriar, 2008). The cost of conservation was found to have a negative relation with soil erosion. On the other hand, distance and size of the farm land were positively related with soil erosion in the model. Farmers close to their land have better opportunities to implement conservation activities than farmers far away from their land. Financial capital and farm income have a negative effect on soil erosion. These variables indicate credit availability for farming activities, i.e. if credit availability is high, farmers can invest more in soil conservation (Illukpitiya and Gopalakrishnan, 2004). Conservative activities are easier to manage in bigger farm size. Migration trend has a negative effect on soil erosion. Adult manpower from the farm labor migration reduces the farm labor.

CONCLUSION

The findings of this study have important policy implication for the soil erosion reduction by participation of all the stakeholders. The soil erosion hot spot is mapped by the stakeholder who helped for the conservation of the soil in watershed. Stakeholders know the physical factors affecting for the soil erosion are slope, type of the soil and conservation practices. The result of the correlation and regression model showed that the soil erosion reduction is significantly influenced by education farm size and family member occupation and membership on the groups like Cooperative, mothers group and forest group. The RUSLE model had showed the soil loss spot which was somehow similar to the participatory GIS map prepared by the stakeholder's focus group discussion. The generic rule for the finding technical and policy support to the stakeholder and their participation on the mapping make clear concept factors affecting for soil erosion and their participation makes the sustainable soil erosion reduction in Phewa watershed.

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REFERENCE

Arakel, A.V., 1995. Towards Developing Sediment Quality Assessment Guidelines for Aquatic System: An Australia Perspective. *Aust. J. Earth Sci.* 42, pp.335–369.

Arakel, A.V., Loder, T., McConchie D. and Paille, C., 1993. Environmental Consequences of Land Degradation in Coastal Drainage Basins of North Queensland, Australia: Influence of Farming Practices. *Land Degrad. Rehabilit*, 4, pp. 99–112.

Barrow C.J., 1991. *Land degradation.* Cambridge University Press, Cambridge

Edwars, K. Soils Formation and Erosion Rates in Soils, Their Properties, and Management, Ed. by P. E. V.Charman and B. W. Murphy (Sydney Univ. Press, Melbourne, 1991), pp. 36–47

Erskine W. D., and Saynor M. J., 1996. The influence of Waterway Management on Water Quality with Particular Reference to Suspended Solids, Phosphorus, and Nitrogen, Wangaratta

Erskine, W. D., 1985. Downstream Geomorphic Impacts of Large Dams: the Case of Glenbawn Dam, New South Wales, Appl. Geogr. 5, pp.195-210.

Ives, J.D., Messerli B., 1989. The Himalayan dilemma: reconciling development and conservation. Routledge, London

JICA/SILT, 2002. Conservation Development study on the environmental conservation of Phewa Lake in Pokhara, Nepal. Final report submitted by SILT Consultants to JICA/ Nepal, Kathmandu.

Jose,C.S., Das, D.C. 1982. Geomorphic prediction models for sediment production rate and intensive properties of watershed in mayurakshi catchments, in: proceedings of the international symposium on hydrological aspects of mountainous watershed held at school of hydrology, university of Roorke, pp 15-23.

Morgan, R.P.C. (2001) A simple approach to soil loss prediction: a Revised Morgan-Morgan-Finney model. Catena 44, 305-322.

Misra N., Satyanarayana T., Mukherjee, R.K., 1984. Effects of topo elements on the sediment production rate from sub watersheds in upper Damodar valley .J Agr Eng (ISAE) 21(3), pp. 65-70 conservation technologies: economic and diffusion explanations. Rural Sociology 42:208-220.

Nowak, P.J., 1987. The adaptation of Conservation technologies: economic and diffusion explanations. Rural Sociology 42 pp.208-220

Lal R. 2001. Soil degradation by erosion. Land Degradation and Development, Vol. 12, pp. 519–539.

Lamichhane, D.B., 2000. Phewa Lake Watershed Area: settlement and environmental Appraisal .pub. K.B.Lamichhane, lakeside, Baidam, Pokhara, Nepal

Pokharel, S. conservation of Phewa Lake of Pokhara, Nepal

Pringle A. W., 1986.Causes and Effects of Changes in Fluvial Sediment yield to The North-East Queensland Coast, Australia, Ed. D. Hopley Townsville.

Renard, K.G. and Freimund, J.R. (1994) Using monthly precipitation data to estimate the R-factor in the revised USLE. Journal of Hydrology, 157, 287-306.

Robetson, A. and Lee Long W., 1990. The influences of Nutrient and Sediment Loads on Tropical Mangrove and Sea grass Ecosystems," in Proceedings of the Workshop on Land Use Patterns and Nutrient Loading of the Great Barrier Reef Region, Townsville, 1990, Ed. by D. Yellowlees. pp. 197–209.

Sui J., He Y.and Liu C. 2009, Changes in sediment transport in the Kuye River in the Loess Plateau in China. International Journal of Sediment Research, Vol. 24, pp. 201–213.

Woods L., 1984.Land Degradation in Australia Australian Government Publishing service, Canberra