Participatory Geographic Information System for Soil Erosion Management: a Case Study of Phewa Watershed, Nepal

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ABSTRACT

This research integrates stakeholder perceptions of socio-economic determinants of soil erosion with the Revised Universal Soil Loss Equation (RUSLE) to identify and assess the major causes of soil erosion. By application of remote sensing using the Landsat ETM 1995 and 2010 imagery , RUSLE, and Participatory Geographic Information Systems (PGIS) based on Erosion Damage Assessment (EDA), major Land Use Land Cover (LULC) changes over the past 15 years in the Phewa watershed could be identified and quantified, and this information used to assist in soil erosion reduction. The methodologies employed include structured questionnaires, focus groups, stakeholders' sketches, and application of remote sensing and GIS on the RUSLE model. The RUSLE model was applied to find the soil erosion status of the watershed. Soil erosion risk analysis was employed to generate a soil erosion risk map of the study area. The results indicated that the current rate of annual soil erosion in the Phewa Watershed varied from 0 to 206.78 t/ha/yr and the mean annual rate of soil loss was 14.71 t/ha/yr and total average soil loss 181,889 ton/year. Bivariate correlation analysis and stepwise multiple regression analysis revealed that ten socio-economic variables were predictors of soil erosion. The analysis generated five predictive models. The model significantly ($p<0.01$) explained 89% of the variability in soil erosion rate ($R^2 = 0.89$). The study identified that a number of socio-economic variables, viz. household size, farm labour, education, conservation cost, training, membership of organization committees, distance, farm land size, migration, and farm income, were all predictors of soil erosion. Major decreases in dense forest, increases in open forest, and increases in human settlement in the watershed contributed to increases in soil erosion. The PGIS based EDA resulted in different classes of severity (stable, slight, moderate, severe, and very severe) which were consistent with the quantified result of RUSLE, except for the dense forest class in LULC. Erosion hazard maps were developed using 2 different methods: PGIS based on EDA by stakeholders, and the RUSLE model. The maps showed that the soil erosion risk areas were similar in both methods. The use of participatory geographic information system (PGIS) based EDA knowledge, remote sensing (RS) and geographic information system (GIS) technology for conservation practices could help to reduce soil erosion. Stakeholders' perceptions, the RS and GIS technique, and PGIS based on the EDA approach all led to better measures for soil erosion management. Thus, the cause and effects of soil erosion were identified by integrating the stakeholder perceptions of socio-economic determinants of soil erosion, RUSLE and LULC changes. Soil erosion risk assessment represented the foundation of sustainable soil erosion management, and contributed appropriate soil conservation measures taken by experts and stakeholders leading to soil erosion reduction in the Phewa watershed.

Key words: Participatory Geographic Information System (PGIS), Revised Universal Soil Loss Equation (RUSLE), Erosion Damage Assessment (EDA), Socio-economic determinant.

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LIST OF ABBREVIATIONS

AGNPS	Agricultural Non-point Source Pollution Model
AHP	Analytic Hierarchy Process
ANOVA	Analysis of Variance
BD	Bulk Density
CBS	Central Bureau of Statistics
CREAMS	Chemical Runoff Erosion for Agricultural Management System
DEM	Digital Elevation Model
EDA	Erosion Damage Assessment
ERDAS	Earth Resource Data Analysis System
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GO	Government Organization
GIS	Geographic Information System
GPS	Global Positioning System
INRM	Integrated Natural Resource Management
LU/LC	Land Use Land Cover
NGO	Non Government Organization
MMF	Morgan Morgan Finney
PGIS	Participatory Geographic Information System
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
RMMF	Revised Morgan Morgan Finney
SEMMED	Soil Erosion Model for Mediterranean
SPSS	Statistical Package for Social Sciences
SWC	Soil Water Conservation
USLE	Universal Soil Loss Equation
USDA	United States Department of Agriculture
VDC	Village Development Committee
WEEP	Water Erosion Prediction Projects

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CHAPTER I

INTRODUCTION

1.1 Research Background

Soil erosion is the wearing away of the land surface by physical forces such as rainfall, flowing water, wind, ice, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface and deposit them elsewhere. Water erosion is one of the most serious forms of land degradation in the world (Nanna, 1996; Sohan and Lal, 2001). Asia has the highest soil erosion rates of 74 t/ha/year and Himalayan rivers are the major contributors (EI-Swaify, 1997). The growing population in the Himalayan region depends on agriculture with limited natural resources. Landslides, mudslides, collapses of man-made terraces, soil loss from steep slopes, and the decline of forest/pasture areas are the main reasons for land resource degradation in the Himalayan region (ICIMOD, 1994). Nepal has limited natural resources, and the expansion of the population and intensification of agriculture has been especially rapid on Middle Mountain, causing particularly severe soil erosion and sedimentation. The severe soil erosion in the Himalayan regions is due to a range of factors including terrain steepness, deforestation, overgrazing, intensive and subsistence farming and population increase (Shrestha et al., 2004). Landslides, soil erosion and sedimentation are common natural hazards in Nepal because more than 80% of the land surface is covered in mountains. Steep slopes with prevalent, fragile rock-face and concentrated precipitation, combined with dynamic tectonic processes, have made the country highly susceptible to erosion and landslides. Erosion rates range from 800 to 57,000 t per km^2 (Bhusal, 1998). Surface soil erosion due to precipitation on slopes and riverbanks affects almost all parts of Nepal.

The structure of Himalayan region is geologically weak, unstable and hence highly subject to the serious problem of soil erosion. (Jain et al., 2001). It has been observed that areas having a marginal soil cover of agricultural land lose of fertile top soil due to surface and gully erosion (Hofer, 1998). The rate of spatial and temporal distribution of soil erosion depends on the interaction of biophysical and human activities over the land. The degree of soil erosion depends on human activities such as removal of vegetation, rangeland grazing, urbanization and forest fire. Other factors are natural conditions viz. topography (slope angle and slope length) and soil properties (texture, moisture, roughness and organic matter) (Lal, 2001; Sui et al., 2009). The Middle Mountain region of Nepal is a very dynamic environment in terms of geomorphological processes. These regions have naturally high rates of erosion, transport and deposition due to the result of steep topography, structurally weak bedrock and a monsoonal precipitation regime.

A growing world population and the abandonment of large areas of the formerly productive land no subject to salinization or alkalization have caused adverse effects on the land. Soil erosion is a serious problem in a mountainous country like Nepal which is geologically young, with mountainous and rugged surface topography. Soil erosion by running water has been recognized as the most severe hazard threatening the protection of soil as it reduces soil productivity by removing the most fertile topsoil. More than 56% of land degradation is due to water erosion, which reduces the land productivity (Elirehema, 2001). Soil erosion threatens environment and agriculture and has adverse economic and environmental impacts (Lal, 1998).

Flash floods, river bank erosion, deposition of sediments and rising river beds have caused serious erosion problems in the valley below the Phewa watershed. The upper watershed has severe surface erosion problems from unprotected farms: degraded forests, and denuded grazing lands. Severe riling and gulling also occur on poorly managed farms. This is evident in the overgrazed and degraded forests, along the trails of newly constructed motor vehicle-roads where the disposal of rainwater is not properly managed. Consequently, the mountain region has had to contend with severe landslides, in addition to the usual surface and gully erosion.

Erosion may 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 consensus of atmospheric scientists is that climate change is occurring in terms of both air temperature and precipitation. For instance, the year 1998 was likely the warmest of the last 1000 years in the Northern Hemisphere (IPCC, 2001), the year 2001 was second warmest on record (NCDC, 2002), and globally 9 of the 10 warmest years since 1860 have occurred since 1990 (WMO, 2001). Karl and Knight (1998) found that from 1910 to 1996, total precipitation over the contiguous U.S. increased, and 53% of the increase came from the upper 10% of precipitation events (the most intense precipitation). The percent of precipitation coming from 50-mm-or-more rain days also increased. Mean stream flow in U.S. watersheds also increased by approximately 1/6 from 1939 to 1999, and has been related to increasing precipitation (Groisman et al., 2001). Summarizing from over 30 climate and soil erosion related studies for the U.S., SWCS (2003) determined that the research pointed to increasing soil erosion and runoff in the future.

Phewa Lake is in a mesotrophic situation but is going to be in state of eutrophication due to environmental hazards and sedimentation. Therefore, the study of the lake regarding climate change, soil erosion, and sedimentation study is essential. The Participatory Geographic Information System (PGIS) approach concerning stakeholders in the area has not been studied.

Land is one of the major resources for profitable agriculture of the people of the Middle Mountain region of Nepal. The Upland watershed is in a state of physical and biological deterioration with regard to natural renewable resources. About 34% of agriculture land in Nepal suffers from soil erosion through sheet and rill erosion (UNEP, 1997). Very few studies have been done related to erosion issues. In addition, few studies have been done relating to the reservoir capacity and threat to the sustainability of the hydropower and irrigation project. This study area is related to the lake and agriculture, and the effects of soil erosion on the lake and agricultural land.

Some activities were conducted by GOs, NGOs and INGOs for the reduction of soil erosion. However, the problem remains the same. The soil erosion problem in the study area was partly due to the lack of the public understanding, participation and appropriate tools in the watershed area. The Phewa lake conservation action plan (1995) and the development study on environmental conservation of Phewa Lake in Pokhara (2002) could not solve the problem due to lack of public understanding and participation. Participatory methods were applied in the report of the study area but it was not a complete success due to the lack of understanding the real problem of soil erosion to the stakeholders. The Participatory Geographic Information System (PGIS) approach could help to increase understanding of the stakeholders concerning the soil erosion problem in the watershed area.

Participatory GIS is tool for participation and a methodological aid to decision making and helps to better understand environmental issues and challenges related to climate change. This has the potential to strengthen the quality of information, inclusion and implementation of the continuous link between different categories of factors. PGIS allows a combination of different types of scientific knowledge and traditions into one instrument of planning and negotiation (Kenan, 1998; Nedovic-Budic and Godschalk, D. 1996). This approach gives the same validity to all knowledge, and thus enhances the knowledge and skills of marginalized communities who are generally ignored in the planning process (Rambaldi and Weiner, 2004). But conventional GIS do not include certain information such as social exclusion, displacement, narrative conflicts of use of land and water, cultural stories, local politics.

PGIS is usually assumed to be cost-effective. PGIS may have lower standards of precision and accuracy than full-blown GIS due to lower cost. But at present, PGIS is considered to have superior effects in terms of relevance, usefulness, sustainability, empowerment, and meeting good governance objectives due to their eponymous stress on participation and on utilizing local knowledge (McCall, 2004). PGIS will reduce the gap between the stakeholders and planner for the soil erosion management planning and implementation of the soil and water conservation. It will help stakeholders to understand the real problem of erosion. The Participatory GIS approach will be the appropriate tool for the reduction of the soil erosion in watershed area.

Recognition that sharing scientific knowledge with stakeholders is important to involve them in the decision making process (Loevinsohn et al., 2002; Parker et al., 2002). Therefore, participation of farmers and the inclusion of farmers' knowledge in the research experimentation process are important developments in the research process (Gibbon, 1994). The role of human factors, socio-economic and biophysical research methodologies ha covered integrated natural resource management (INRM) research since the beginning of 21st century (Sayer and Campbell 2001; Van Ittersum et al., 2004).

The administrative officer and researcher have their own ideas and the lack of involvement with the stakeholders during the quantification and identification process created a gap between stakeholders and them. Researchers could help by involving themselves during their activities with the participating stakeholders and sharing ideas with each other (Lighfoot, 1989; Conway, 1989). Therefore, the active participation of the farmers could diffuse the problem and enlighten the community with regard to soil erosion conservation activities. Another gap was the haphazard implementation of the watershed concept. Complete participation by the stakeholders is the best way to achieve uniform implementation for soil erosion conservation. Participation of all stakeholders helps to reflect on the problem and motivate for a communal solution.

The aim of this study was to identify the appropriate PGIS approach based on the integration of farmers' knowledge, perceptions and scientific knowledge of soil degradation and use for soil erosion management. This area can be considered particularly significant in Nepal because of the major tourist attractions and natural renewable resources, necessary for the basic needs of the people of the watershed area—the Middle Mountain region of Nepal. A previous study showed that about half of the area of Phewa Lake has been converted into land over the last five decades causing severe environmental problems (JICA/SILT, 2002). However, previous soil erosion studies did not include socioeconomic factors and PGIS approach for soil erosion management. This study aims to assess the status and stakeholders' perception of soil erosion in order to identify socioeconomic determinants of soil erosion, including stakeholders' perception on soil conservation, impacts of land use land cover change on soil erosion, soil conservation impact by using PGIS methodology to reduce soil erosion in the study area.

1.2 Literature Review

1.2.1 Erosion

The process known as weathering breaks up rocks so that they can be carried away by the process known as erosion. Water, wind, ice, and waves are the agents of erosion that wear away at the surface of the earth. Soil erosion consists of the two phase process detachment of individual particles from soil mass and transport by erosive agent like water and wind. Rain splash strikes on the bare soil surface and particles thrown away. The soil is weak due to weathering process by wetting and drying mechanical process and biochemical. Soil is disturbed in tillage operation by people and livestock and further running water and wind contribute for the detachment of the soil particles. Soil loosen by these process easily removed by the transport agents. Soil erosion like rain splash erosion, rill erosion, gully and erosion are based on the hydrological cycle. The severity of the soil erosion depends on the several factors like rain fall erosivity, soil erodibility, slope, slope length, plant cover, and conservation management practice (Morgan, 1995).

In the last decade, there was rapid population growth which made expansion of the urban area and large area used in agricultural. This situation creates the burden for the watershed area and brought floods, debris flows and other slope hazards. Soil erosion is the one of the environmental crises which brings the food crisis (Bewket and Sterk, 2003; Lal, 2001). Severe problems for human sustainability have recognized the adverse influences of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems, and environments (Lal, 1998). Many factors, such as climate, land cover, soil, topography, and human activities makes complex for soil erosion loss. In addition, biophysical parameters, social, economic, and political components influence soil erosion (Ananda and Herath, 2003).

Accurate and timely estimation of soil erosion loss or evaluation of soil erosion risk has become an urgent task. Scientists have been involved in soil erosion research for a long time, and many models for soil erosion loss estimation have been developed (Wischmeier and Smith, 1978; Adinarayana et al., 1999; D’Ambrosio et al., 2001; Veihe et al., 2001; Shen et al., 2003). Fullen (2003) summarized some keynote papers about soil erosion in northern Europe and Lal (2001) highlighted major empirical models for predicting soil erosion loss.

Many researchers have been conducted research in erosion field by applying different models and approaches. Survey methodology for the rill erosion was used in cultivated field of watershed in Ethopiya (Bewket and Sterk, 2003). Some decision support system such as the erosion prediction information system (EPIS) was led by the integration of basic soil erosion equation of USLE, GIS and RS (Millward and Mersey 2001). Slope length factors were calibrated using a Win Grid system. Many models have been developed and some are in the process of being developed. The main categories of erosion models are empirical, conceptual, physical, stochastic, hybrid and ruled based. Most of the models are empirical type. Stochastic models are included random variables having distribution in probability. If all variables free from random variation the model is regarded as deterministic (Roo, 1993).

1.2.2 Erosion Model

Soil erosion models try to simplify the complexity of natural processes (Shrestha, 2007). Models are built by relating the essential factors to the erosion and soil loss through the methodology of the field observation, measurement, experiment and statistical analysis. Many models are available because one model cannot solve the various problems (Gebrekirstos, 2003). Some models are applied for the particular location so the users have to understand concept behind the model before applying to it. Erosion models can be categorized into three groups empirical, conceptual and physical based. The models frequently used are as follows:

1.2.2.1. *Empirical Model*

Empirical models describe the erosion statistically reasonable database relationship between assumed important variables (Kadupitiya, 2002). Empirical models are based on the important factors field observation, measurement, experimentation and statistical technique relating erosion factors to soil loss (Peter, 1992). Empirical model can predict soil erosion quick but it needs long term data (Elirehema, 2001). The mostly used empirical model is USLE. Other models like RUSLE, SLESMA, MMF, and RMMF were modified from USLE.

The Universal Soil Loss Equation (USLE)

United States Department of Agriculture (USDA) developed this model in 1970's. This model used widely in USA and worldwide (Merritt et al., 2003). This model is developed by using statistical analysis of the data from 10,000 plots years from natural runoff and 2,000 plots years artificial rainfall simulators in USA (Wischmeier and smith, 1978). Sheet and rill erosion can be predicted by Revised USLE using the factors R-Climatic erosivity, K-soil erodibility, L and S topography, C, and P land use. It is also upgraded to put additional information since the development of the USLE (Renard, 1997). Long term erosion cannot be calculated because of some limitation. It can predict only inter rill erosion but not gully, channel or stream bank erosion. It can only estimate soil movement particle but ignore sedimentation. Short-term rainfall biases the accuracy of the equation (Merritt et al., 2003).The factors in USLE are calculated as follows:

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

Where R: Rainfall-runoff erosivity factor,

K: Soil erodibility factor

L: Slope length factor,

S: Slope steepness factor,

C: Cover-management factor,

P: Conservation practice factor.

Revised Universal Soil Loss Equation (RUSLE)

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 as in equation (1).

The Morgan Morgan Finney Model (MMF)

This model can predict the annual soil loss from field size area from the slope. It has simple USLE and covers the advance understanding of erosion process (Morgan et al., 1984). This model is physical based empirical model with less data than the other erosion predicts models. It is divided in to two phases i.e. water phase and sedimentation phase. It can be easily applied on raster based GIS (Shrestha, 2007).

Revised Morgan Morgan Finney (RMMF)

This model separates the soil erosion process in two phases: water phase and sedimentation phase. The water phase determines the energy applied for the detached soil particles from soil mass and volume of the runoff. In the erosion phase, rate of soil particles will be detached by the rainfall and runoff with the transporting capacity of the runoff (Morgan, 2001). Difference from the MMF model, soil particle detached by rain drop, account of plant canopy height and leaf drainage are added for soil particle detachment flow (Morgan, 2001).

1.2.2.2. *Physical Based Model*

Knowledge of the fundamental process and laws of conservation of mass and energy is found in physical based model (Peter, 1992). This model consider subtle spatial and temporal changes of contributing factors and are more appropriate for dynamic modeling (Jaroslav et al.,1996). This model includes WEPP, AGNPS, and EUROSEM.

Water Erosion Prediction Projects (WEPP)

It is physical based hydrological and erosion model. This model contains two sub models hill slope version and watershed version. Hill slope version can estimate the soil detachment, deposition along hill slope profile and net soil loss estimated at the end of slope without considering erosion, transportation and deposition processes in permanent channels. This method is applied to surface erosion process to the channel network. It can run for a single storm and continuous simulation.

Agricultural Non-point Source Pollution Model (AGNPS)

This model is used to compute soil erosion within the watershed on grid cell based developed to estimate runoff quality, emphasis on sediment and nutrition transport (Young et al., 1989). It can be linked with GIS for more data integration in watershed environment. Input data for this model include parameters catchments morphology, land use variables, precipitation data (Merritt et al., 2003). The model can extract topographic variables and land surface characteristics from GIS data layers such as contour, drainage lines and watershed boundaries. The large data requirements and computational complexity of AGNPS are the limitation of this model.

European Soil Erosion Model

This model is an event based which design for computing erosion, sediment transport and deposition over land surface throughout a storm. This model can simulate rill and inter-rill erosion with transport of water and sediment from inter-rill areas to rills. It can account effect of leaf drainage and rainfall intercept by vegetation cover. This model can apply to individual fields or small catchments (Shrestha, 2007).

1.2.2.3 *Rule Based Expert System*

These models are based on logical reasoning and construction of the decision rule using the information expressed in if-then form (Kadupitiya, 2002). Expert knowledge of processes occurring in watershed and survey information on topography, soil, water and cover are essential factors in these models. This model is black box of the classical stimulus response model. The model has multiple sub models inside it.

1.2.2.4 *Hybrid Approach*

The hybrid approach modeling is a combined approach of the base reinforcement and relational rule base (Kaddupitiya, 2002). Relational rules can define physical boundaries of each unit and classify straight forwardly up to some extent as high and low erosion risk unit. Water erosion is a complex phenomenon, which is governed by a large number of factors e.g. climatic characteristics, topography, soil properties, vegetation and land management. More Specifically rainfall, erosivity, soil erodibility, slope, land use and conservation measures govern the water erosion in an area (Singh et al., 1992).

1.2.3 Risk

Risk has the different meaning in the different field. Risk is the probable frequency and probable magnitude of future loss. As risk carries so many different meanings there are many formal methods used to "measure" risk. Qualitative definition of the risk leads to statistical estimates but some are more subjective. In many cases a critical factor is human decision making. Mathematical formulation of the risk in statistics, risk is modeled as the expected value as undesirable. In a formula that can be used in the simple case of a binary possibility (accident or no accident), risk is then Risk = (probability of the accident occurring) × (expected loss in case of the accident)

1.2.4 Soil Erosion Risk

The soil erosion risk depends on the erosive power (wind or water), and the exposure of the soil to associated forces. Erosion is managed by balancing the power relationships during a wind storm or rainfall event. In general, remote-sensing data were primarily used to develop the cover-management factor image through land cover classification (Millward and Mersey, 1999; Reusing et al., 2000; Ma et al., 2003). When GIS tools were used for derivation of the topographic factor from DEM data, data interpolation of sample plots, and calculation of soil erosion loss (Cerri et al., 2001; Bartsch et al., 2002; Wang et al., 2003) then land managers and policy makers are more interested in the spatial distribution of soil erosion risk. Different approaches have been used to assess the soil erosion risk, including empirical erosion models (Boggs et al., 2001; Cerri et al., 2001; Bartsch et al., 2002)

A ranking method based on selected indicators such as percentage of bare ground, aggregate stability, organic carbon, percentage clay, and bulk density (Shakesby et al., 2002), and qualitative erosion risk mapping based on the combination of five factors: geology, soil, relief, climate, and vegetation (Vrieling et al., 2002).

1.2.4.1 *Expert Based Methods*

An example of an expert-based approach is the soil erosion risk map of Western Europe by De Ploey (1989). The map was produced according to various experts' judgment in erosion process. This approach has not given clear definition of the criteria according to which areas were delineated (Yassoglou et al., 1998). Factorial scoring approach can be used to assess erosion risk (Morgan, 1995). The CORINE is an example of soil erosion risk assessment of the Mediterranean region (CORINE, 1992). The analysis is based on factorial scores for soil erodibility (4 classes), erosivity (3 classes) and slope angle (4 classes). The multiplied scores give a combined score that represents potential erosion risk. To assess actual soil erosion risk, the potential erosion risk map is combined with a land cover factor (2 classes). CORINE method is based on scores that are assigned to factors related to land cover (9 classes), the soil susceptibility to surface crusting (4 classes), slope angle (8 classes) and erodibility (3 classes). An interesting feature of their method is that it takes into account the different types of erosion which occurs in cultivated areas, vineyards, mountainous areas and the Mediterranean. In this way, the interaction between soil, vegetation, slope and climate is accounted for to some extent.

A problem in most of the methods based on scoring are affected by the way of scores defined and classifying the source data. The results of slope classes' analyses depend on information loss in class limits and number of classes used. If each factor is given equal weight, it is not realistic. If one decides to use some weight, choosing realistic values for the weights may be difficult. The way in which the various factors are combined into classes that are functional with respect to erosion risk (addition, multiplication) may pose problems also (Morgan, 1995).

1.2.4.2 *Model Based Methods*

A wide variety of models is available for assessing soil erosion. Erosion models can be classified in a number of ways. One may make a subdivision based on the time scale for which a model can be used. Some models are designed to predict long-term annual soil losses, while others predict single storm losses (event-based). Alternatively, a distinction can be made between lumped models that predict erosion at a single point and spatially distributed models. Another useful division is the one between empirical and physically based models. The choice for a particular model largely depends on the purpose and the available data, time and money. Jäger (1994) used the empirical Universal Soil Loss Equation (USLE) to assess soil erosion risk in Baden-Württemberg (Germany). De Jong (1994) used the Morgan, Morgan and Finney model (Morgan et al., 1984) as a basis for his SEMMED model. Input variables are derived from standard meteorological data, soil maps, multi-temporal satellite imagery, digital elevation models and a limited amount of field data. In this way, erosion risk can be assessed over large, spatially diverse areas without the need for extensive field surveys. So far the SEMMED model has been used to produce regional erosion risk maps of parts of the Ardêche region and the Peyne catchments in Southern France (De Jong, 1994; De Jong et al., 1998).

Kirkby and King (1998) assessed soil erosion risk for the whole of France using a model-based approach. Their model provides a simplified representation of erosion in an individual storm. The model contains terms for soil erodibility, topography and climate. All storm rainfall above a critical threshold (whose value depends on soil properties and land cover) is assumed to contribute to runoff, and erosion is assumed to be proportional to runoff. Monthly and annual erosion estimates are obtained by integrating over the frequency distribution of rainstorms.

Several problems arise when applying quantitative models at regional or larger scale. Most of the erosion models were developed on a plot or field scale, which provide point estimates of soil loss. When these models are applied over large areas, the model output has to be interpreted carefully. Soil loss model on a single agricultural field cannot produces accurate erosion estimates when applied to the regional scale on a grid of say 50 meter pixels. One should also be aware, of which processes are actually being modeled. For example, the well-known Universal Soil Loss Equation was developed to predict rill- and inter-rill erosion only. Therefore, one cannot expect this model for gully erosion as the dominant erosion type.

Model results give a broad overview of the general pattern of the relative differences, rather than providing accurate absolute erosion rates. Because of this, the availability of input data is probably the most important consideration when selecting an erosion model at the regional/national scale. If sufficient input data are not available, it would not make sense to use a sophisticated model. In the latter case, the only way to run the model would be to assume certain variables and model parameters to be constant. However, the results would probably be less reliable than the results that would have been obtained with a simpler model that requires less input data (De Roo, 1993). Also, uncertainties in the model's input propagate throughout the model, so one should be careful not to use an 'over parameterized' model when the quality of the input data is poor.

The biggest problem with erosion modeling is the difficulty of validating the estimates produced. At the regional and larger scale, virtually no reliable data exist for comparing estimates with actual soil losses.

1.2.5 Climate Change and Soil Erosion

Global warming is leading to change in hydrological cycle including rainfall. The impacts of climate change on soil erosion by water are complex. Impacts of climate change involves change in rainfall amounts and intensities, ratio of rain to snow, number of days of precipitation, plant biomass production, plant residue decomposition rates, soil microbial activity, evapo-transpiration rates, and shift in land use (Nearing et.al, 2004). Soil erosion rate changes due to the change in erosive power of the rainfall (Nearing, 2001; Pruski and Nearing, 2002a).

Climate change studies shows that increased rainfall amounts and intensities will increase the rate of soil erosion. Climate change affects the biomass which changes the impact on runoff and erosion (Pruski and Nearing 2002b). Anthropogenic activities like deforestation, expansion of urban area increases the carbon dioxide and which will help to plant production rate increases. The plant transpiration rate increases the soil surface canopy cover increases in soil and air temperature will cause the faster rates of residue decomposition due to increase in microbial activity. High precipitation will lead to the higher biomass production. Higher temperature may change into higher evaporation rate and will be more rainfall and lead to higher soil moisture level (Rosenzweig and Hillel, 1998). The observed annual trend of temperature rise per decade is 0.41 ^{o}. This is higher rate of temperature rise are imbedded the complex dynamic process such as weather, season, vegetation and hydrological pattern and soil erosion. The change pattern of weather, hydrology, water, vegetation, agriculture and extreme weather events are essential for the climate change. These factors have positive correlation to the soil erosion. Major consequences will be the drought, flood and landslides (MOPE 2004).

Indigenous knowledge can be incorporated into climate change policies which can lead to the development of effective mitigation and adaptation strategies that are cost-effective, participatory and sustainable (Robinson and Herbert 2001; Hunn 1993). Abnormal hail storm, late start monsoon, increased drought incidents, warm wind flow pattern, decrease water resources, change in flowering and fruit time, reduction of some indigenous plants are the local measure of the climate change. These measures can be found based on local knowledge and innovations. The amount of monsoon rains and change in intensity of rains positively correlate with the increase in water induced disasters like floods and landslides (Ministry of Home, quoted in DWIDP, 2006). The temperature increase has both negative and positive impact on agriculture as IPCC (2007) has projected that the potential food production to increase with increase in local average temperature over a range of 1 to 3^0C. The magnitude of soil erosion increases from direct climate change i.e. increase in precipitation. Sometimes decrease crop cover in land like lower maize yields brought the extreme heat and drought under climate change. The planting date changes effects on additional soil erosion i.e. soil loss increase due to later planting date of crops (O'Neal et al, 2005). The indigenous knowledge and climate change factors can be incorporated in the soil erosion risk model by participatory GIS.

1.2.6 Land Use Land Cover and Soil Erosion

Sustainable land resource management can be managed using accurate knowledge of Land Use Land Cover (LULC) features and relative risk of environmental hazards. Much of land in the earth has already been modified except for inaccessible locations (Turner II, et al., 1994). Studies show that LULC change poses significant environmental impacts on soil and water quality, biodiversity, microclimate, methane emission, and CO_2 absorption (Lambin, et al. 2000; Schawb, 1993).

FAO defines land cover as "the observed biophysical cover on the earth's surface," and land use as "the arrangements, activities and inputs that people under-take on a certain land cover type" (FAO, 2000). Changes in the nature of land use activities results in land cover changes and are categorized into two types: modification and conversion (Turner II, 1994). Modification is a condition in which significant change occurs within the patterns of land cover types, while conversion is a change from one cover type to another (Turner II, 1994). Additionally, modification and conversion of land use may be placed into positive or negative contexts, such as an increased or decrease in environmental value. Land use change affects the land cover and vice versa.

In the past, land use has been seen an abstract concept with inadequate emphasis on the physical importance complicated by mixed social, cultural, economic and policy factors. Hence, land use cannot be directly measured with remote sensing and requires visual interpretation, sophisticated image processing and spatial pattern analyses to extrapolate land use data from the land cover information. Agriculture and livestock intensifying, forest harvesting and management, urban and suburban construction are major causes of globally altered land cover by direct human uses (Meyer, 1995). For example, land clearing for agriculture has been a significant and ongoing process (Blair and Dockray, 2004).

There are mainly two categories for LULC change: direct (proximate) driving forces and indirect (underlying) driving forces. Direct driving forces include the immediate actions of local people to fulfill their needs from land use (Geist and Lambians, 2002), such as agricultural expansion, wood extraction, infrastructure expansion and other causes that change the physical state of land cover (Blair and Dockray, 2004). Driving forces mainly operate at the local level (i.e. individual farms, householders, or communities). In contrast, indirect driving forces are fundamental socioeconomic and political processes that 'push' direct causes into immediate action on LULC (Geist and Lambians, 2002). These 'underlying' driving forces include demographic pressure, economic status, technological and institutional factors, and can influence LULC in combination (Geist and Lambians, 2002). Land use constantly changes in response to the dynamic interaction between direct and indirect causes (Geist and Lambin, 2003).

Revised Universal Soil Loss Equation is the most globally applied tool to assess the amount of soil loss per area per year (Kinnell, 2010). Soil loss measurements can be obtained through the multiplication of six key factors, namely climate, soil property, topography, land cover, and conservation practice (Martínez and Sánchez-Bosch, 2000). However, while there are many factors influence on soil erosion, researches pinpoint plant cover and land use as significant indicators affecting the intensity of soil erosion (Mohammad and Adam, 2010). Thus, soil erosion increases due to the changes of land use, such as deforestation, encroachment of agricultural interests, or other causes for the loss of land cover material. Comparably, the increase of forest area or other land covering material can potentially reduce the amount of soil loss. For example, vegetation controls soil erosion by means of its canopy, roots, and litter components and erosion influences vegetation in terms of the structure, composition and growth pattern of plants (Mohammad and Adam, 2010).

1.2.7 Soil Erosion Management

A Revised Universal Soil Loss Equation followed the same formula as USLE which was originally developed for soil erosion estimation in croplands on gently sloping topography (Wischmeier and Smith, 1978), but got several improvements in the determining factors and a broader application to different situations, including forests, rangelands and disturbed areas compared to USLE (Trojacek and Kadlubiec, 2004). RUSLE is a computation method which is used for site evaluation and planning purposes and for assisting in the decision process of selecting erosion control measures. It provides the severity of erosion and numerical results that can validate the benefits of planned erosion control measures in the risky areas (Silleos, 1990).

The RUSLE has broadened its application to different situations, including forest, rangeland, and disturbed areas (Renard et al., 1997). Traditionally, these models were used for local conservation planning at an individual property level and models were usually estimated or calculated from field measurements. The methods of quantifying soil loss based on erosion plots possess many limitations in terms of cost, representativeness, and reliability of the resulting data. Spatial distribution of soil erosion loss can’t provide due to the constraint of limited samples in complex environments and can’t mapping soil erosion of large area. The use of remote sensing and geographical information system (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger areas (Millward and Mersey, 1999; Wang et al., 2003). Combination of remote sensing, GIS in RUSLE model provides the potential soil erosion loss estimation in a cell-by-cell basis (Millward and Mersey, 1999). Boggs et al. (2001) assessed soil erosion risk based on RUSLE using DEM data and land units maps. Bartsch et al. (2002) used GIS techniques to interpolate RUSLE parameters for sample plots to determine the soil erosion risk at Camp Wiliams, Utah. Wilson and Lorang (2000) reviewed the applications of GIS in estimating soil erosion, discussed the difficulty and limitations of previous research and identified that GIS provided tremendous potential for improving soil erosion estimation.

Study in Brazilian Amazonia had an approach for the evaluation of soil erosion risk based on remote sensing and GIS in RUSLE model. This was an effective way to map the spatial distribution of soil erosion risks in a large area. The methods and results described in this article were valuable for understanding the relationship between soil erosion risk and LULC classes and were useful for managing and planning land use that will avoid land degradation. For Brazilian Amazonia, such topics are very important due to current activities involving forest conversion to other land covers (Lu et al, 2004).

1.2.8 Geographic Information System

GIS is used in spatial decision process from top-down development planning due to its hardware, software, expensive data, and high level of technical expertise. GIS provide an opportunity for interdisciplinary work which by raising awareness across different interest groups can avoid dangerous misrepresentations. Chrisman (1987), Harris and Weiner (1995) and Rundstrom (1996) suggest that access to GIS technology in the form of hardware, software, and human expertise are important requirements for full community involvement in community projects employing GIS and are necessary for community empowerment.

Pickles (1995) raised the number of concern about GIS and its general application to societal application. Chrisman (1987) also suggested this point GIS must be accountable economically, politically, socially and ethically and should be developed on the primary principle to ensure a fairer treatment of the information. Taylor (1991) argued that with the increasing popularity of GIS in Geography, has to be retreat from knowledge to data. Mark (1993) defines spatial representation as a set of practices that seek to describe or explain particular geographic phenomena. Taylor (1991) argued that data selection for the GIS database is a subjective process and heavily influenced by the availability of data and the statutory data collection role of organizations. The emphasis on ‘top-down’ expert data and the lack of local, bottom-up data, led Taylor to accuse GIS practitioners of contributing to structural knowledge distortion (Onsrud and Rushton, 1997; Pickles, 1995). Taylor and others also suggested that the heavy emphasis in GIS on technical ‘black box’ quantitative techniques and solutions further removed the technology from the communities potentially impacted by the GIS outcomes. This important point is developed further in this study through the development, and use of, user-friendly graphical tools. Complex variables involved in erosion will make difficult to measure or predict the erosion in a precise manner.

The latest technology in remote sensing could be provided very useful methods of surveying, identifying, classifying and monitoring several forms of earth resources. Remote sensing data can provide accurate, timely and real time information on various aspects of the watershed such as LULC, physiographic, soil distribution, drainage characteristics. It also assists in identification of the existing or potential erosion prone areas and provides data inputs to many of the soil erosion and runoff models. For assessing soil erosion from the watersheds, several empirical models based on the geomorphologic parameters were developed in the past to quantify the sediment yield (Misra et al., 1984; Jose and Das, 1982). The USLE model applications in the grid environment with GIS would allow us to analyze soil erosion in much more detail since the process has a spatially distributed character. An essential theme of PGIS is to acknowledge the broad and specific impacts of GIS on communities and to be aware that GIS could be a marginalizing and disempowering technology (Poore, 1998).

1.2.9 Participatory Geographic Information System

Participatory GIS concept came from NGCIA initiative 19 (NCGIA 1996). Several prior meetings conclude social theoretic perspectives on GIS and its implication. PGIS has a number of key concepts. PGIS can utilize the GIS technology in the need and capabilities of communities that can be involved by development projects and programme. PGIS draws on the diversity of experiences associated with 'participatory development' and involves communities in the production of GIS data and spatial decision-making. Output of the GIS can interpret or contribute by integrating participatory mapping information to modify or update a GIS by capturing local knowledge and combining with traditional spatial information. PGIS methodologies need to be established and field-tested. It is important that PGIS build upon the successes of existing participatory development concepts and methods.

The key roles of the PGIS system can identify as means of integration of isolated qualitative and quantitative information sources; potential aid to conflict resolution, a means of consolidating and sharing ideas. PGIS is development of the social theoretic critique of GIS and a wider discussion of the impact of GIS on Society, and of Society on GIS (Pickles, 1995; Sheppard 1995; Curry, 1998). PGIS recognizes that community empowerment through GIS requires proactive public participation, broader data access and the integration of community knowledge into project development and decision-making. The selection of environmental, cultural, and social data in the GIS database and the representation of those data could heavily influence the outcomes of a GIS project.

Harris et al. (1995) noted that technocrat developed GIS technology is top-down 'expert' knowledge within hierarchical institutional frameworks and that GIS thus captured one official agency version of reality. Harris and Weiner (1996), Pickles, (1995) Sheppard, (1995) suggested that GIS representation, access, local knowledge integration, and public participation should be important components of any PGIS. Epstein et al., (1996) and Ventura, (1995) focused on the institutional legal perspectives of GIS applications and the issues of costs and benefits associated with GIS implementation. Curry (1997) and Onsrud (1997) expressed legal and ethical perspectives and raised issues concerned with access to spatial data and the ethical implications of GIS in social research. Chrisman, (1988) traced the evolution of GIS from its many root and drew on the intellectual history perspectives of GIS applications. During the course of these debates, Harris and Weiner, (1996) and Obermeyer (1995 and 1998) examined how the GIS and Society debate might be explored through the process of empowering communities via a participatory process.

Participatory GIS emphasizes the use of GIS as a bottom-up empowering process for the public and grass roots communities. Sometimes through PGIS can empower and disempowered certain communities (Harris and Weiner, 1996). Further questions were also raised about epistemology, representation, data access, structural knowledge distortion, privacy, data sharing, data ownership, surveillance, and community empowerment (NCGIA, 1996).These debates have pushed GIS technology more towards theoretical arguments in GIS applications.

In general, PGIS is distinguished from GIS through a greater emphasis on community participation. Community participation can be achieved through several means not least in the incorporation of local knowledge and perceptions within a GIS database. By merging both expert and community knowledge PGIS lends itself to community empowerment and collaborative decision-making. One of the goals of PGIS is to involve a wider public participation in development projects and decision-making and to empower the public in environmental decision-making. Weiner et al., (1995) conducted research in South Africa to explore land and agrarian reform a PGIS approach. PGIS has also been used in other community empowerment projects such as that conducted by Dudley (1995) in rural India. Dudley sought to demonstrate the power relationships between local communities and imperial powers in his PGIS and how local-group involvement imperial powers limited in land assessment and resource management.

Participatory methodology has been used since the mid1990s in forestland use management for some time using GIS for community empowerment in forestland use management (Kyem, 1996; Jordan, 1998). GIS-base collaborative use of forestland management study focused on policy issues associated with official use of forestland management practice in Ghana. Kyem (1996) developed a PGIS method and incorporate local community input to support participatory decision-making for new forest policy. PGIS provided an opportunity for stakeholders like foresters and local communities to discuss their differences and learn about each other's preferences. The importance of collaboration of sustainable resource use and participatory methods were used in research on GIS applications in Australia. Three fundamental requirements were concluded for effective community participation in resource planning as follows.

1) There should be effective access to information pertinent to resource-use planning
2) Access must be provided to analytical tools required to make effective use of that information, and
3) A legislative and institutional environment is required to foster effective participation and greater community empowerment.

Several other studies also emphasize the role of GIS in collaborative neighborhood planning projects (Nyerges et al, 2003; Elwood, 2002; Nembrini, 2003) Web-based

GIS also promises to be a powerful tool for community empowerment, data access, data input, and communication between different parties. The rapid development of the internet has created many opportunities for PGIS by serving as an avenue for communication for those involved in GIS and decision support research (Carver, 1998). Kingston et al. (1999) examined the potential of the World Wide Web as a means of increasing public participation in environmental decision making. Kingston provided evidence of the potential and actual benefits of online spatial decision making systems in the UK through three real environmental decision making problems at the local, regional and national scale. PGIS can be applied to reduce the soil erosion by the management of land use, forest and awareness and public participation in the research area. Thus, the literature review shows that one model and technical part cannot solve the problem therefore the PGIS and RUSLE can incorporate the socioeconomic and some environmental factors for the reduction of the soil erosion in watershed.

1.2.10 PGIS Methodology

There are several critical issues that have emerged from the GIS and Society and the PGIS literature that relate to access to information, the representation of societal and environmental issues, deficiencies in incorporating local knowledge (structural knowledge distortion) into GIS databases, and the overall limiting impact of Geographic Information Technologies on community participation in spatial decision making. Harris and Weiner (1996) point out that obtaining greater data access is a double-edged sword for "providing communities with greater access to data about their own areas also simultaneously increases the capability for greater surveillance over neighbors". Thus, empowering community members through GIS technology can also simultaneously disempowered certain community members or groups through both the lack of computer hardware, internet, software peripherals and the critical GIS data. The Internet promises to be a major impact on PGIS and these access issues and it is comprehensively embedded in the methodological approach taken in this study. Harris and Weiner (1996) explored the use of computer-based geographical information through a GIS production process that explicitly recognized the importance of community participation in many forms. In their study, they examined how community voices are digitally represented in GIS and how socially differentiated local knowledge is identified and incorporated into a multimedia GIS. Meredith (1998) conducted community-based research that sought to bring local spatial information into public awareness and build local capacity to manage and use that information. Although these studies tried to improve data dissemination, a number of barriers to information flow will be identified. Central to these constraints is the difficulty in obtaining both local knowledge and conventional GIS data and in providing community access to advanced technologies when the necessities of life are in short supply.

A further aspect of PGIS methodology is to consider how, and to what extent, people, space, place, and the environment are represented in a GIS. In addition, addressing representational issues within a PGIS framework requires that local knowledge that occurs in a variety of diverse qualitative and quantitative forms must also be addressed. GIS provides one form of visualization of spatial data to community leaders, planners, architects, and designers primarily using maps. Alternative forms of representation do exist. An approach taken by Al-Kodmany to address these representational issues in neighborhood planning was the use of artistic representations as a way of integrating local community interests (Al-Kodmany, 1996). Al Kodmany sought to artistically transform neighborhood residents' ideas into quick sketches, and to merge residents' ideas and thoughts into a shared neighborhood vision. This approach provided a means whereby residents could visualize the past, present, and future conditions of the neighborhood and enable them to have a voice in the design of their neighborhood. This approach was not tied to the traditional map. It is informative in suggesting that a range of geo-visualization approaches that can be understood by the public may be worthy of investigation in PGIS. The representation of society and environment in GIS raises a number of concerns about how abstract versions of complex issues are reflected in through GIS. Laituri and Harvey (1995) suggest that while local knowledge and input is recognized as being critical to resource management there has been inadequate integration of this information into management studies. If GIS research is to be conducted with equity between all societal groups in mind then methods are required that enable socially differentiated local knowledge to be incorporated and accessed in GIS. Laituri and

Harvey (1995) question the extents to which traditional GIS adequately represent society and local knowledge.

The integration of local knowledge into GIS then has been recognized as a valuable tool for producing more equitable decision-making practices in community projects (Kyem, 1996; Harris and Weiner, 1998; Meredith, 1998). The linking of GIS and local knowledge can be developed for a variety of regional and community based workshops and public forums that address critical issues in diverse community neighborhood developments and facilitate communication and knowledge exchange between researchers and local stakeholders. To incorporate local knowledge, scholars have used diversity of methods such as workshops, public meetings, mental mapping exercises and the Internet. Efforts to incorporate and utilize local knowledge, however, remain problematic due to a lack of tested methods, cultural differences, lack of trust, confidentiality and privacy issues, and the inability to identify who exactly should conduct and gather such knowledge. According to Katz (1992), the representation of local communities through the use of local knowledge tends to create a power struggle among the parties involved for communities. They are constituted from multiple actors with varying and often conflicting preferences and interests (Katz, 1992). These issues underline the need to question current methodological approaches in GIS technology.

Researchers have used PGIS methodology in community forestry projects (Kyem 1996 & Jordan, 1998) through the incorporation of traditional GIS and remote sensing. These approaches have achieved limited success because of lack of extensive forms of community participation, data input, and less than ideal data representation. Alternative approaches involving a participatory methodology attempt to give voice to a larger and more diverse community. According to Cancian (1992), participatory methodology challenges dominant power relations, reduces inequalities, and fosters empowerment within the research process facilitated through the integration of local knowledge.

Harris and Weiner (1996) initiated a variation of PGIS called Community-integrated GIS (CiGIS) that sought to address the political economy of GIS access and structural knowledge distortion through the GIS integration of community data and expert data by state or non-governmental agencies. The methodology applied by

Harris and Weiner (1996) in South Africa sought to explicitly combine traditional GIS with participatory methods and exposed a number of critical issues for researchers to explore in pursuit of alternative GIS methodologies. Whatever the approach used in PGIS, it is generally accepted that community empowerment can be achieved by providing wider data access and greater opportunity for communities to integrate their voices and concerns in the decision-making process.

Howard (1998) asserts that in order to empower communities, geographic information must be effectively combined with participatory methods. Participatory methods such as workshops create an interactive environment where people can be actively involved in spatial decision-making. Local knowledge integration for the watershed is central to addressing many of the questions raised by PGIS. Tomforde (2003) suggests that local knowledge is generated locally but can be shared regionally or even nationally. The respective locality can be a nation state, a society, a university or a meeting.

A participatory methodology enables community members to become active participants in soil erosion management and adaptation of climate change in their sub watershed. Equitable access to GIS map facilitates a sense of community ownership of data about them and their environment and thereby generates empowerment and increased responsibility. Participatory methods offer ways for researchers to consider issues such as empowerment and marginalization that result from participatory applications of GIS.

1.3 Significance of the Problem

Soil erosion caused by defenestration, faulty agricultural practices and other activities have been major issues of environmental concern. The Middle Hills of Nepal have become a center of attention regarding ongoing defenestration and the subsequent effects of soil erosion on the environment. There is a lack of specific data on soil erosion and productivity relationship; anecdotal evidence seems to indicate that there is a strip of land in the densely populated central east–west valley that has experienced erosion serious enough to reduce the soil productivity by at least 20 % (Drenge, 1992). Human encroachments to the upper and lower streams of Phewa Lake have made large abandonment areas from the formerly productive land. Very few works have been done by using RS and GIS, therefore, this research can find the cause and effects of soil erosion and management through new approach PGIS based EDA for reduction of soil erosion.

1.4 Research Objectives

The general objective of the research is to identify PGIS approach for soil erosion reduction for stakeholders' and policy makers. The study is application-driven with the explicit purpose that the results should have relevance to stakeholders and contribute to improvement in soil erosion reduction management by PGIS methodology. In a broader context, PGIS is a bridge of the domains of remote sensing and GIS-derived (geo-information) biophysical variables and socio-economic variables for the reduction of the soil erosion.

The specific objectives are as follows

1. To identify major biophysical drivers, socio-economic and climatic factors and their trends that influence soil erosion based on stakeholders' perception and scientific reasons.

2. To compare the stakeholders perception on soil erosion risk with the estimated soil erosion explicit.

3. To find the impact of land use land cover on soil erosion of the study area.

4. To estimate a spatially explicit soil erosion risk in the study area by using PGIS for soil erosion management and Revised Universal soil Loss Equation**.**

1.5 Scope and Limitation of the Study

Soil erosion management research using PGIS is an important participatory research work because of the participation of all stakeholders such as farmers, teachers, social workers, politicians and local government administrators. This research will contribute to society in many ways. First, it will contribute for the integration of PGIS and EDA as an innovative methodological framework for incorporating local knowledge with traditional geo-spatial information to study soil erosion susceptibility in Phewa watershed. The major concerns of this research are the issues of local knowledge, context, socioeconomic and erosion damage assessment addressed in the application of PGIS to geographic research and in other disciplines. Hence, PGIS methodology applied the participatory tools and techniques to engage the context of erosion damage assessment to study erosion susceptibility. The centre of this research is PGIS and erosion damage assessment in erosion susceptible areas. The second level of contribution relates to the conceptualization of erosion susceptibility with quantitative analysis as the key in linking participatory methodologies to understand spatial and social differentiation of erosion susceptibility. PGIS and other related technologies were used more effectively within their social and public context.

The study employs PGIS and EDA to understand the dynamics of socio economic and physical factors for an assessment of erosion susceptibility in the study area. With increasing recognition of the vulnerability of agriculture land to erosion, an erosion damage assessment approach emerged to help an alternative way for soil erosion management. An erosion susceptibility conceptual framework disputes conventional explanations of disasters by bringing in the socio-economic and ecological context into the analyses of erosion susceptibility. Future policies and plans are likely to incorporate erosion dynamics and people's perceptions and experiences dealing with erosion.

This study is limited to gullies erosion and the conservation of gullies and involves the Village Development Committee (VDC) and district level policy makers for sheet and rill erosion in plot, as well as catchment soil erosion management. The impact of climate change on soil erosion has had limited study because of the limited data and the present situation.

1.6 Dissertation Outline

This dissertation is divided into eight main *chapters*. The focus of this ***first Chapter*** is to provide the background, research problem, literature review (literature on soil erosion, Erosion model, GIS and Society, and the integration of PGIS and EDA, objectives and brief statement on the methodology used and the contribution of the study. ***Chapter 2*** provides general methodology.

Chapter 3 and chapter 4 identify physical factors and socio economic factors for the soil erosion risk area by RUSLE model and AHP analysis to get the erosion risk for the socioeconomic factors. The soil erosion susceptibility is based on PGIS.

Chapter 5 shows the impacts of land use land cover change on soil erosion. LULC change reflects the socioeconomic condition of the watershed stakeholders. This chapter identified that increasing human pressure on the environment exacerbates soil erosion and that soil erosion can be attributed to LULC change.

Chapter 6 demonstrates the contribution of PGIS based EDA for the reduction of soil erosion. This is done by documenting and analyzing through mental maps, narratives of people impacted by soil erosion. Chapter integrates “local” and “expert” knowledge about the understanding of soil erosion vulnerability. Composite maps are developed to demonstrate the interaction of physical and socio-economic parameters of soil erosion vulnerability.

Chapter 7 demonstrates the application of the PGIS based EDA for the validity test for the research in sub watershed by PGIS tool and economic tool for its validity. Finally, ***Chapter 8*** reflects on the entire study and offers conclusions and research issues for recommendation.

CHAPTER II

2. Research Methodology

2.1 Source of Data

The data listed below in the Table 1 were used for this research

Table 1 Description of the Data Used

Data Description		Scale	Source
Satellite images	Landsat TM,1995 and 2010	30x30m Resolution	Download from Internet
Ancillary data			
	Topographical map	1:25000	Sheet No.2883:12C,12D,16A,16B Survey department of Nepal
	Base map (road, contour, sub watershed boundary)		Prepared from Topo map and Landsat TM ,Silt consultancy report for sub watershed
	DEM(contour)	20m interval	Survey department of Nepal
	Soil map		Forest Resource Assessment Project
	Socioeconomic data: District / Village profile		Village secretary, District development office (2010)
	Demographic data		Central Bureau of statistic(2001), Nepal
	Meteorological data	1996-2010	Department of meteorology
Field data	Soil sample		Field survey
	Socioeconomic data		Field survey
	Ground Control Point		Field survey
	Ground Truth Data		Field survey

2.2 Study Area

The study area, Phewa watershed, is situated in the Kaski district, Gandaki zone of Nepal. This study area covers six VDCs like Sarangkot, Kaskikot, Dhikurpokhari, Bhadaure Tamangi, Chapakot and Pumdi Bhumdi and 7 wards of the Pokhara sub metropolitan city. The rural area is situated in the hill where as the urban areas situated in the Pokhara valley. The eastern part of the watershed is extended from Phewa Lake into 7 wards of the Pokhara sub metropolitan city. The Phewa lake watershed area is located in the south-west corner of the Pokhara valley ($28^{0}11'39''$ N to $28^{0}17'25''$ N latitude and $83^{0}47'51''$ E to $83^{0}59'17''$ E Longitude) which lies relative subsidence zone between the greater Himalaya and Mahabharat range. It covers an area of approximately 123 km^{2} with its east-west average length of 17 km and north-south width of 7 km. Elevation ranges from 793 to 2508 m from sea level. Phewa Lake itself covers about 4.55km^{2} areas. Watershed is divided into 14 sub-watersheds namely Harpan, Andheri, Phirke, Bulaudi, Orlang, Tora, Khapaundi, Khahare, Betani, Lanrak, Thotne, Khahare /Birpani, Handi and Marse/ Chisakhola. The Figure 1 shows that study area.

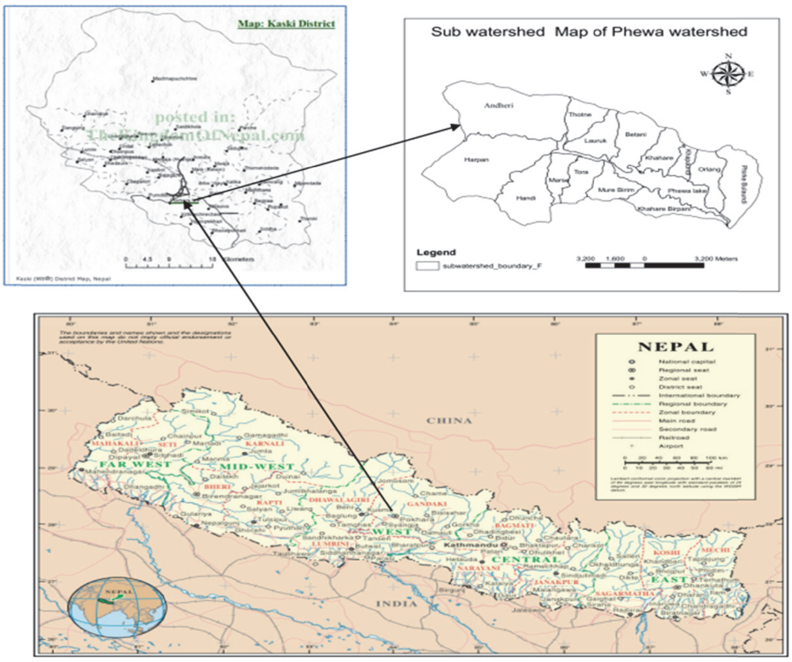


Figure 1 Study Area with 14 Sub Watersheds

2.3 Data Collection

Climate, topography, soil, Land Use Land Cover (LULC) and socioeconomic data are required for this study. The data collection activities were consisted in three phase i) pre-field, ii) field work and iii) Post field final interpretation and modification. The overall methodological used in the study is illustrated in figure 2. Detail processes are described in proceeding section.

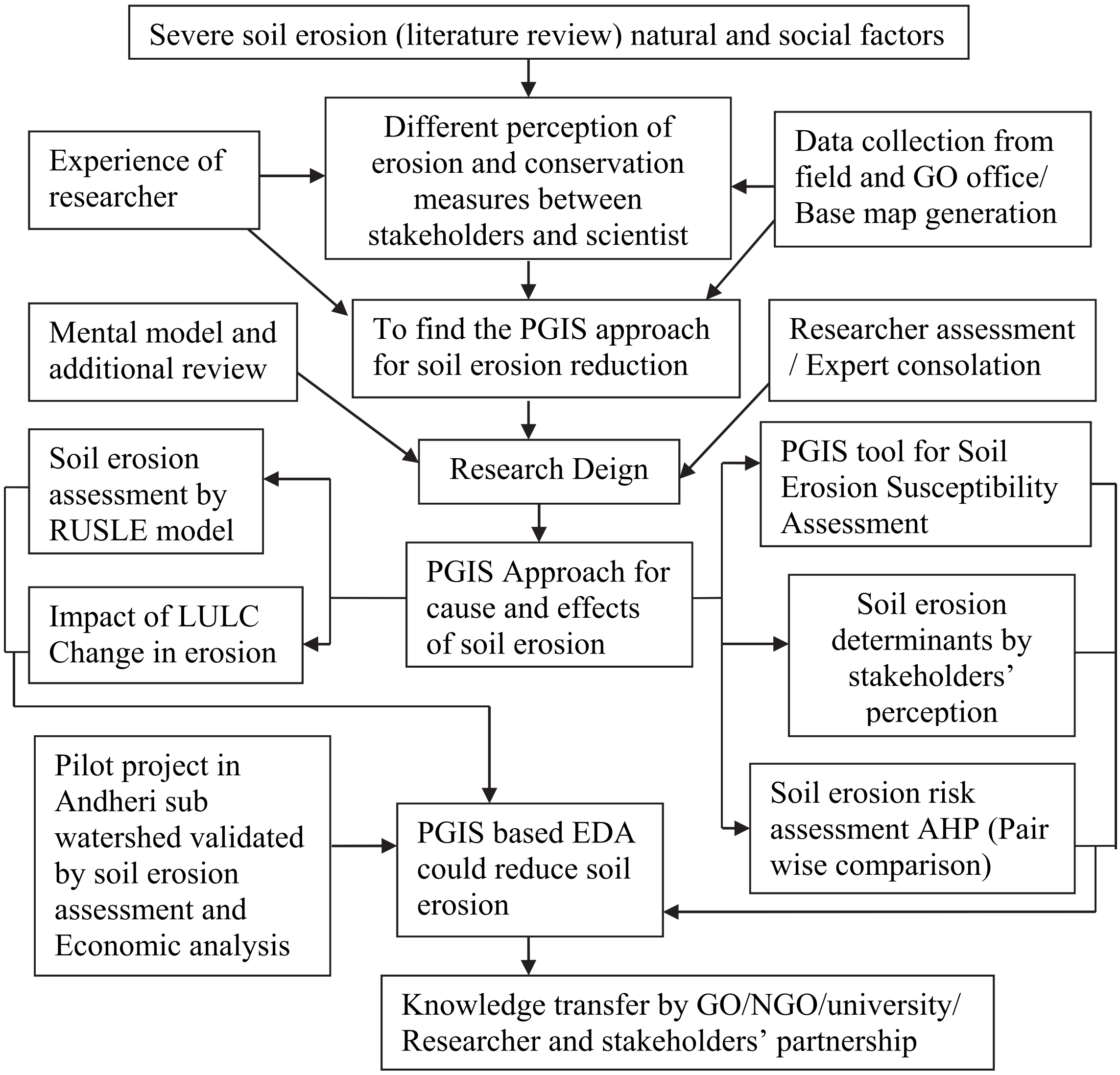


Figure 2 Flow Chart of Overall Methodology

2.3.1 Pre Field Work

The main activities in this stage were literature review, collection of secondary data, topographic map, imageries and create base map. The questionnaire was prepared for socioeconomic data collection. Field work area was selected by visual inspection of the rapid eye, topographic maps and Land sat image.

2.3.1.1 Pre Field Interpretation

Radiometric and geometric corrections were done in pre processing of data before data base generation. Satellite image was performed by monoscopic visual interpretation making use of interpretation keys such as tone, texture, pattern shape, size shadow site and association to derive thematic information.

2.3.1.2 Spatial Data Base Generation

Spatial database generation, the methodology followed for the data preparation of spatial database and spatial analysis for the soil erosion employing to model. Base map (road, river, sub watershed) LULC map, soil and slope map were created by using GIS. The study area was outlined by considering the drainage network using topo sheet from survey department of Nepal in conjunction with satellite imageries to create boundary map of Phewa watershed. The prominent cultural and permanent features like road, river canals and settlement were marked. The Integrated Mission for Sustainable Development (IMSD) guidelines (1989) and field observation for visual interpretation of satellite images were followed to prepare thematic maps like LULC map and soil map.

Different methodology and software were used for creating spatial data. Software such as ArcGIS 10, ERDAS IMAGINE 9.2 was used for creating spatial data, geo-referencing, sub-setting and mosaic of the image.

In the present study, linear features, such as roads and contours were considered as a line feature whereas LULC map, soil map and watershed boundary were created as polygon feature. Settlement and rainfall map were considered as point map. The vector model is very useful for describing discrete features which was created using Arc View software.

Topology is defined as the mathematics of connectivity or adjacency of points or lines that determines spatial relationships in GIS. The topological data structure logically determines exactly how and where points and lines connect on a map. In the present study all the digitized vector layers were cleaned and built in Arc GIS software. The steps of cleaning and building are important so as to remove the data redundancy and maintain spatial relations.

DEM was generated in ArcGIS 10, 3D software using contours, spot height and drainage of the study area with 30 m pixel size by researcher. The DEM was used to generate slope and aspect in same software. The height variation in the study area comprises from 793m (Lake Level) to 2508.81m.

2.3.2 Field Work

In this stage, primary and secondary data were collected. The field work phase began with soil data collection; GPS point collection of the LULC and socio-economic data collection. Climatic data were collected from the meteorological department of Nepal government. Topographic, climatic, soils, socioeconomic data were collected.

Extensive field survey was conducted using GPS to view land use and ground cover of the study area. Actual ground truth was verified on the previous drawn transverse plan for the specific doubtful area. The information was taken from stakeholders of the watershed area for the verification of LULC. Existing land use practices were investigated and training sites different land uses were marked.

Detailed climatic data is required to run soil erosion model. Climatic data was collected from the meteorological station at Pokhara. Daily rainfall, temperature, humidity data were collected for the period of 1995-2010.

2.3.2.1 Socioeconomic Data Collection

Socio economic data were obtained from a report prepared by the village development committee in 2010. The report of the village profile of the village development committee contained data for the whole study area of the Phewa watershed area lies on 6 village development committees and 7 wards of the Pokhara sub metropolitan city, including household number, socioeconomic and the natural resources.

Questionnaires survey was conducted among the different stakeholders' households according to the ratio of the no. of households in 14-sub watershed. The data were collected from the field based household interview using questionnaire. The primary information derived from the questionnaire survey used for this study consisted of the use of protective measures against the soil erosion, sedimentation and landslides. The GPS points of the landslide and sedimentation were projected in the LULC map.

2.3.2.2 Ground Truth Collection

Different land uses were identified on the False Color Composite Map. The tonal variation representing the different land uses were correlated with various features. From the whole study area collection of coordinates pertaining to various features using GPS in the field was carried out. Different type of statistical data and other important information was taken from forest department. Based on the preliminary reconnaissance survey and visual interpretation of the satellite data, land use in the study area was classified as in Table 2.

Table 2 Description of Forest/Land Use Classification Scheme

S.N.	Land Uses	Description
1.	Settlement	Dense population with compare to past 10 years.
2.	Fallow Land	Without vegetation and agricultural crops, soil is very poor in this land. Almost all the cultivation activity is zero. Most of these lands are unproductive.
3.	Open Forest	Forest consist less than 40% in the canopy composition.
4.	Bushy Area	It includes areas covered with Shrubs and Bushes with isolated trees. The tree density is generally low i.e. less than 10 percent tree density and more than 20 % Shrub and Bush. Such areas are found near the villages and along the roadsides.
5.	Terrace Agricultural	Upstream of the study area water sources and soil are not good. Agriculture/habitation is mainly confined in the areas where the water sources and soil conditions are favorable. The major crops are Wheat (*Triticum spp*.), Paddy (*Oryza sative*), Millet, Soybean, maize (*Zea mays*), Potato (*Solanum tuberosum*) etc.
6.	Water Body	The land covered under natural drainage system like river, streams and natural or manmade linear reservoir or ponds and lakes.
7.	Grass Land	Main source for grazing animals. Few grass land are found in study area. Grassland is an open and continuous, grasses are found naturally in the study area.
8.	Dense Mixed Forest	Forest composed of trees of two or more species intermingled in the same canopy forming 40-70% dense canopy and consisting at least 20% canopy other than principle species. The main species are *Schima wallichii, Castanopsis indica, Alnus nepalensis, Woodforida, Pinus roxburghii, Dendrocalamus hamiltonii, Cinnamomum zeylanicum, Dalbergia latiflora, Artemisia vulgaris, etc.*
9.	Waste land	Sandy areas are mostly unfertile. These types of area are found in the river bed side and long term agriculture practice is absent. Quality of soil is poor.
10.	Wet land	Mainly some area near the lake found swampy. This type of area is covered by water and unproductive but some agriculture practice was beginning.
11.	Single crop	In the downstream of study area mainly variety of paddy is growing and irrigation also good summer .The major crops are Paddy (*Oryza sative*),
12.	Double crops	In the downstream of study area mainly variety of paddy is growing and irrigation also good .The major crops are Wheat (*Triticum spp*.), Paddy (*Oryza sative*), maize (*Zea mays*), Potato (*Solanum tuberosum*) etc.

2.3.2.3 Soil Sample Collection

Soil data was collected directly from the field. Soil sample were carried out from mini pits, auger holes and full profiles of representative sites. FAO guidelines were followed for soil description. The soil description data were collected in form developed by Moragn which followed the USDA soil classification system. Soil samples were taken for each horizon at different depth and slope position to evaluate soil landscape relation and soil characteristic properties. Ten soil samples were collected for the laboratory analysis of soil particle distribution, texture, organic matter content, bulk density, moisture content at field capacity to verify the soil map from Forest Resource Assessment (FRA) Nepal.

2.3.2.4 Soil Resource Inventory

Soil profile study was carried out on the study area. Soils profiles were sampled for each horizon and soil classification was performed. Diggings of the soil pit were applied to get a better look at the pedons for examining the vertical exposure of the soil, commonly called a “soil profile”. Reasonably distinct layers known as horizons were observed which was formed under different conditions or environments. Soil properties such as color, texture and structure were used to identify these different layers. Nails and a measuring tape were used to mark and get measured the horizons. Field description of soil profile was recorded into a prescribed form. Diagnostic horizons of each soil profile were observed for soil structure, soil texture, soil color, coarse fragment, parent-material, rooting depth, erosion status, and drainage class including other morphological characteristics. “Munsell book of Colors” were used for registering a soil color, a piece of soil was matched to a colored square and the notations distinguishing three characteristics of the color: hue, value, and chroma as given in book were assigned to the horizons. Similarly, soil’s texture was figured out by feel-method and textural class was assigned. Soil structural units (peds) were described by three characteristics: type (shape), class (size), and grade (strength of cohesion) whereas evaluated by three Structure grades: the distinctness, stability and strength of the peds. Total 10 different soil profiles under various physiographical soil units were studied for pedon description according to soil survey manual of USDA

&FAO guidelines. The various soils profiles were sampled for each horizon and soil classification was performed. Soil samples were collected from the different horizon of the study area. Surface soil texture and organic carbon required to calculate soil erodibility index.

2.3.2.5 Sampling a Soil Core for Bulk Density of Soil

The soil cores samples were taken from its natural condition field by using core sampler (cylindrical metal sampler). Two Samples from each selected site, from the depth of 15 and 30 cm were collected. Method involves the driving of the core sampler vertically into level ground, deep enough, to fill the sampler can in the sampler. Sampler was dug out by means of spade and sample can was removed from it without disturbing the soil core in the can. The extra soil from both the ends of the sampler-can was trimmed off with sharp knife. Sampler-can, along with the soil was weighed. Sample was taken out from can and collected for laboratory analysis.

2.3.2.6 Soil Laboratory Analysis

Soil samples were collected and analyzed in laboratory to generate soil database, for soil erosion assessment (Figure 3). Soil analyses for following parameters were carried out.

1) Determination of Soil Bulk Density (BD)
2) Soil texture analysis
3) Soil organic carbon analysis
4) Estimation of soil erodibility

Figure 3 Photograph of soil profile sample, soil sample collection and laboratory analysis

1) Determination of Soil Bulk Density (BD)

The soil sample cores were dried in an oven at 105^{0}C to determine bulk density based on dry weight. The weights of oven-dried soil sample were weighted in digital balance. After pounding, samples were sieve for stone mass. Stone mass separated were washed from water and weighed each samples. Length 'l' and diameter 'r' of sample-can was measured. The equation $\pi r^2 l$ was used to find the inside volume. The volume of the inside cylinder is equal to the volume of the soil. The weight of the stone was subtracted from the total weight of the oven dried core sample. Bulk density (gm/cm^3) was determined by the equation given by Baruah and Brthakur (1997).

$$\text{Bulk density } = \frac{\text{weight of dry soil (whole core)}}{\text{Volume of the soil (whole core)}} \quad (2)$$

2) Soil Particle Size Analysis

International pipette method was used to perform particle size analysis for soil textural classification. The method employs the Stock's law in order to determine the size of particles. Coarse sand, fine sand, silt and clay content are encompassing the size in mm, 0.2-2.0, 0.02-0.2, 0.002-0.02mm and <0.002 respectively.

3) Soil Organic Carbon Analysis

Soil samples were analyzed for organic matter content. Percent of soil organic matter was estimated from organic carbon, determined by analyzing the soil samples collected from field.

4) Estimation of Soil Erodibility (K -factor)

Soil erodibility index (g / J) is the weight of soil detached from the soil mass per unit of rainfall energy. It is integrated effect of the processes that regulate rainfall acceptance and the resistance of the soil to particle detachment and subsequent transport which is influenced by soil particle. Soil texture is an important factor for influences erodibility. The following formula developed by Wischmer and Smith (1978) was used to estimate soil erodibility based on the characteristics of the soils.

$$K = 2.3 \times 10 - 7 \times M^{1.14}(12 - a) + 4.3 \times 10^{-3}(b - 2) + 3.3 \times 10^{-3}(c - 3) \quad (3)$$

Where, M= Mechanical particle size parameter, equal to percentage of very fine sand (0.1 to 0.05mm) and silt(0.05 to 0.002mm), times the quantity 100- minus percentage of clay i.e. $((\%\,\text{silt} + \%\text{very fine sand}) * (100 - \%\,\text{clay}))$
a=percent organic matter
b=soil structure code (1 for very fine granular, 2 for fine granular, 3 for medium to coarse granular and 4 for blocky, platy or massive).
c =profile permeability class (rapid as 1, moderate to rapid as 2, moderate as 3, slow to moderate as 4, slow as 5, and very slow as 6)

2.4 Image Classification

Supervised classification was applied in ERDAS 9.3 software for LULC classification. Twelve classes were considered namely open forest, dense forest, single crop, double crops, terrace cultivation, barren land, grass land, bush, water bodies, wet land and built up. Training sample collected from the field was defined in as training areas in image by some number of pixels of each class. Signature editor was created to define the classes in ERDAS 9.3 software. The boundaries and number of pixels for each class were into signature editor by using area of interest (AOI) tools. Finally LULC maps of periods 1995 and 2010 were classified.

2.4.1 Land Use Land Cover Map

Land Use Land Cover (LULC) map of the study area was prepared from the satellite images of Land sat TM 1995 and 2010. Satellite images were interpreted for the detail information about land use activities and land cover. The sub watershed map was prepared. This map was used as a standard out line for each sub watershed. Characteristic of land surface of natural and artificial cover were considered to derive the information about the land use activities and land cover for plotting LULC map. Maximum likelihood algorithm selected because of the advantages of considering the centre of the cluster together with shape, size and orientation.

2.4.2 Accuracy Assessment

Accuracy assessment was applied after classification. GPS points were used to validate the result of classification through the confusion matrix /error matrix. Confusion /error matrix consists of row and columns in which row and column represents classification value and fact value from the field respectively. Correctly classified pixels were represented by the diagonal line of the error matrix. The Overall accuracy was calculated from correctly classified pixel divided by total number of pixel checked. The producer accuracy index was produced by dividing the number of correctly classified pixels. Land use classes and validate points with coordinates in the text format were imported as true classes. The users' accuracy index was produced by dividing the total number of correctly classified pixels that belongs to a class by the sum of the values of the rows of the same class.

2.5 Post Field Final Interpretation and Modification

Collected information were correlated and compiled with image characteristics based on the ground truth data and classes and boundaries were refined. Soil map is modified on the basis of the land form physiographic regolith soil pattern. Classified LULC also modified based on the ground truth data.

2.5.1. Digital Elevation Model (DEM)

Contour lines having vertical intervals of 20-meters were taken from the survey department, government of Nepal. The elevation data were processed and graphic simulation was carried out in which an elevation (or Z value) was recorded at each X, Y location to make topographic data usable. Surfacing function in "Image Interpreter" was used to generate a DEM and to represent as a surface or one-band image file where the value of each pixel was a specific elevation value. A gray scale was used to differentiate variations in terrain. Slope map was generated in ERDAS-IMAGINE software by using DEM.

2.5.2 Slope Map

Terrain data was analyzed as a component in complex GIS modeling. Slope is expressed as the change in elevation over a certain distance. In this case, the certain distance is the size of the pixel. Slope function in "Image Interpreter" was used to generate a slope image. Slope is most often expressed as a percentage, but can also be calculated in degrees. Slope image was being color-coded according to the steepness of the terrain at each pixel. Slope map was classified based on USDA criteria given in the Table 3.

Table 3 Map of the Slope Classes of the Study Area

Class	**Slope range in %**	**Slope class**
A	0-1	Nearly level
B	1-3	Very gentle sloping
C	3-5	Gently sloping
D	5-10	Moderately sloping
E	10-15	Strongly sloping
F	15-25	Moderately steep to steep sloping
G	25-33	Steep sloping
H	33-50	Very steep
I	>50	Extremely steep slope

Source: Soil Survey Manual (1971) All India Soil and Land Use Survey Organization, I.ARI, New Delhi.

CHAPTER III

3. Soil Erosion Risk Assessment on the Basis of Biophysical factors

3.1 Background

Spatial modeling is concerned with capturing spatial landscape phenomena and related properties, for representation and manipulation in a GIS. A particular model designed for particular area with specific set of condition might not necessarily be applicable to another area with different situation.

Physically-based models, ANSWER and WEPP require huge data, which is difficult to acquire in mountainous watershed of Himalaya. Similarly AGNPS is also not adapted well enough in mountain conditions (Kettener, 1996). Numerous soil erosion models have been developed, such as the Water Erosion Prediction Project (WEPP) model (Nearing et al., 1989), the Chemical Runoff Erosion for Agricultural Management System (CREAMS) (Knisel, 1980) and the European Soil Erosion Model (Morgan et al., 1990). Among these models, Revised Universal Soil Loss Equation (RUSLE) is one of the most widely-used (Renard et al., 1997; Wischmeier and Smith, 1978) and has been applied in areas of different size sand environmental conditions (Angima et al., 2003).

RUSLE is the most extensively used empirical soil erosion model. The Revised Soil Loss Equation like its predecessor the Universal Soil Loss Equation (USLE) is an erosion prediction model designed to predict the long term average annual soil loss from specific field slopes in specific land management and use systems (Raghunath, 2002). Furthermore it is applicable with surfaces of varying extension, from a small plot to large scales (Irvem et al., 2007). RUSLE is designed for use at the runoff plot or single hill slope scales. The RUSLE model enables prediction of an average annual rate of soil erosion for a site of interest for any number of scenarios involving cropping systems, management techniques, and erosion control practices.

3.2 Research Methods

The research method for this section is summarized in figure 4. The detail process is described in the proceeding section of this chapter.

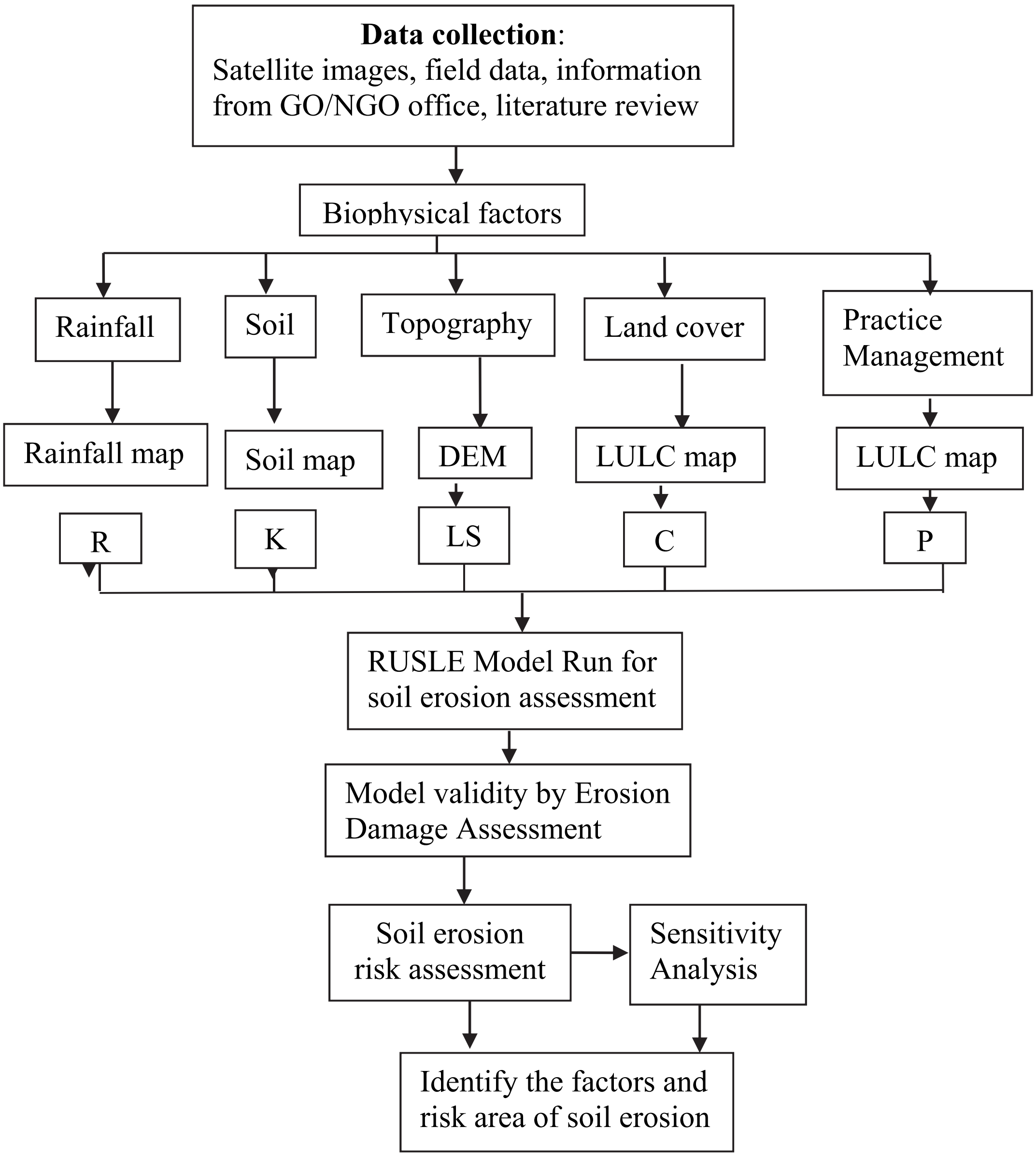


Figure 4 Flow Chart for Soil Erosion Risk Assessment

RUSLE model was selected from the variety of models because of all main factors, which influence soil processes, can be evaluated pretty accurately. In addition to that, it is possible to replace missing detailed data with reliable estimates. Furthermore it is applicable with surfaces of varying extension, from a small plot to large scales.

3.2.1 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.

$$A = R \times K \times L \times C \times P \times S \qquad (4)$$

Where A is average annual soil loss, 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.

Rainfall factor (R-factor)

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.

$$R = 0.0483 \times P^{1.61} \qquad \text{for p<850mm} \qquad (5)$$

$$R = 587.8 - 1.219 \times P + 0.004105 \times P^2 \qquad \text{for P>850 mm} \qquad (6)$$

Where R is R- factor in RUSLE equation, P is average annual precipitation (mm).

Soil Erodibility Factor (K-factor)

Soil erodibility factors define resistance of the soil detachment and transport. Regression equation given by Wischmeier and Smith (1978) is used for the study of soil erodibility (K) factor as in equation (3)

Topographic factors (LS)

LS factors of sheet and rill erosion is based on USDA experiment test plots of 22.1 m and 9% slopes for the effect of slope angle and slope length. There were different methods for determining this equation. It is described in the literature and the powers used vary in different applications from 0.4-0.6 for flow accumulation and 1.0-1.4 for the slope (Lewis et al., 2005; Sims et al., 2003). Sims Version was chosen due to it made sense and easiest to use. As described in Sims (2003), the LS equation is:

$$T = \left(\frac{A}{22.13}\right) \times 0.6 \left(\frac{sinB}{0.0896}\right) \times 1.3 \quad (7)$$

For use in ArcGIS, Sims used the following Map Algebra expression:

$$Pow\left([flow\ accumulation] * \frac{Cell\ size}{22.13}, 0.6\right) * Pow(\sin\left([slope\ of\ DEM] * \frac{0.01745}{0.0896}, 1.3\right) \quad (8)$$

A slope raster was derived from the elevation model and mask tool with the watershed raster as input to limit the slope of the watershed raster to the study area, and did the same with the flow accumulation raster created earlier. These two raster were used in the Map Algebra equation, along with the cell size of "30."

The Cover Factor (C)

The cropping management factor 'C' derives measures from crown coverage, ground cover, crop sequence, length of the growing season and tillage practice etc. There are so many numbers of different ways of managing the growing crops. Vegetation cover intercepts raindrops dissipating their kinetic energy before reaching the ground surface. LULC map of the study area was generated from Landsat TM and Rapide eye satellite data. Layer was converted to C layer through reclassification of each cover type into its corresponding C value.

The conservation factor (P)

The general practice of the farmers in cropland is ploughing and tilling along the contour lines either against the slope length or perpendicular to the slope length. Soil conservation practices slow down the run-off water by protection of crops cultivated on slope against erosion. Conservation practice P can be found from the equation.

$$P = P_c * P_s * P_t \quad \text{(Schwab, 1993)} \qquad (9)$$

Where,

P_c = Contouring factor based on slope

P_s = Strip cropping factor for crop strip width s

P_t =Terrace sedimentation factor (1.0 for no terraces, 0.2 for terraces with graded channels of outlets and 0.1 for terraces with underground outlets).

3.2.1.1 Running RUSLE Model

RUSLE model was executed within ArcGIS environment. R factor was determined by R factor values calculated from the equation (5) and (6) using annual precipitation. Soil erodibility factor K was calculated by equation (3). The topographic LS factor was calculated by the method from Remortel et al. (1991). The C and P factors were obtained from Morgan (2001) and Schwab (1993). RUSLE equation can be considered as naturally occurring factors determining the sheet and rill erosion process together, they can consider as soil loss or potential erosion (t/ha/year) for the area. Multiplying the all RUSLE parameter maps (R-factor map, LS factor map, K factor map, C factor map and P factor map) in raster calculator the soil erosion map was obtained. Figure 2 shows the flow chart of the determinant of soil erosion.

3.2.1.2 Soil Erosion Risk Modeling

Erosion rates of ungauged catchments can also be predicted using RUSLE by using knowledge of the catchment characteristics and local hydro-climatic conditions. The empirical model approach offers the advantages of rapid computation and cost reduction and can easily be used by non-specialists to estimate the relative efficacies of different conservation techniques. However, extrapolation is required to estimate the total cumulative soil loss over time, particularly for cases in which changes in input variables over time are poorly known.

The results from erosion prediction are compared to estimated soil-loss tolerance (*T*) values for the area in question, which denotes the maximum rate of soil erosion that can occur and still permit crop productivity to be sustained economically. An infinite number of slope lengths exist in a field. In RUSLE, erosion can be calculated for several slope lengths and the results averaged according to the area represented by each slope length to obtain an erosion rate for a field. Results from representative fields can be combined to estimate erosion rates for an entire watershed.

3.2.2 Soil Erosion Damage Assessment Method (EDA)

Soil Erosion Damage Assessment (EDA) method is designed for monitoring and assessing soil erosion damage of recent origin (Herweg, 1996). The method is an area-specific approach to soil erosion and allows for semi-quantification of soil erosion. It was used as a tool to assess erosion and to validate erosion predicted by model. The recent erosion damage was assessed by extensive field survey. Damaged field data described the areas adjacent to this field, both upslope mid slope and down slope were recorded using field forms as per the instruction given in EDA-field manual. Selected sites were examined for its characteristics, like soil, slope angle, land management, etc. on each slope by considering these characteristics, erosion-topo-sequences were created covering entire cross-sections of a slope, ideally from hilltops to valley floors. Semi quantitative and even more important, qualitative status (class) about the erosion was studied. It was particularly attempted for only major erosion event and mapping was concentrated on the beginning of the rainy seasons where there was little or no vegetation cover, mid of the rain and end of the rainy season. In order to make comparison of results predicted by RUSLE model with actual erosion damage, the erosion condition was assessed with EDA observations.

3.2.2.1 Identification of Sites for Erosion Feature Study

The field data collection was performed according to physiography (slope) and land use categories for randomized the representation of population. Both visual observations and physical measurements were carried out for the data collection in field as explained below for the following method. The real-world positions of the observed sites in the broader landscape were located using a global positioning system, commonly known as a GPS. Intensive fieldwork was carried out in the catchment during the rainy season (June-Aug) of 2012 and 2013 with the double purpose of collecting input data for the RUSLE model & assessing the actual erosion in catchment. Deposition of soil at the foot slopes and the roads and paths were frequently observed (Figure 5). Visual observation included observing biophysical features such as, land use kinds, crop types, type of erosion proxies, erosion features, and conservation measures.

Figure 5 Depositions of the Soil in the Foot Slope and Roads in Study Area

3.2.2.2 EDA Methodology

There are two ways in EDA methodology:

- Quantification of erosion features i.e. estimation of order of magnitude of soil loss by evaluation of erosion hazard using erosion features. It is a field based assessment of soil erosion.
- Determination of factors and reasons that have influenced or caused erosion damage

3.2.2.3 Erosion Proxies and Features

Some spatial terrain attributes (properties) and landscape factors of erosion are considered to influence the occurrence of soil erosion as erosion proxies. Attributes of the erosion proxies includes

1) Currently defined landscape factors of erosion such as: groundcover, type of crop, slope steepness and soil erodibility and management.
2) Spatial features (manmade or natural) with their properties that drive soil erosion namely: river channels, drainage channel, pathways, road networks, sparse cover, and built-up area etc.

In this thesis, landscape factors, the ground cover (LULC classes) is taken into account, because the study conducted at plot level (Table 4). These proxies are related to soil erosion which can be modeled in GIS due to their spatial properties. Measurement of erosion features within proxies generate data can be analyzed statistically to prove that erosion proxies are linked soil erosion through its features to estimate soil erosion.

Table 4 Erosion Proxies and Features

Landscape unit	**Erosion Proxies**	**Erosion Features**
Field Plot	Maize plot	Flow channel (%)
	Open forest	Surface litter translocation (%)
	Barren land	Depth of rills (cm)
	Dense forest	Depth of root exposure (cm)
	Grass land	Depth of stem wash (cm)
	Paddy field	Depth of Soil movement(cm)

Soil erosion is difficult to measure in normal circumstances; only the effect of soil erosion can be measured and assessed. Soil erosion effects include soil particles that are detached, entrained and deposited in barriers or collected in reservoirs and measured. According to Okoth (2003) features of erosion act as evidence of soil erosion and can be used to quantify the degree of soil erosion (Stocking, 1987; Lal, 1990; Nill et al., 1996).

The effect of erosion is observed by erosion features formed after rain event to characterize the erosion hazard. These specific features (Okoth, 2003) used for evaluating the erosion hazard were used as guidelines to collect data to assess occurrence of soil erosion as given below (Table 5). Following erosion features were used as guidelines to collect data to assess occurrence of soil erosion.

Table 5 Description of Soil Erosion Feature Articulated

S.N.	**Erosion features**	**Erosion Description**
1.	Flow channel (%)	Flow pattern were recorded according to their intensity of occurrence within the field plot in percentage of the site being observed. Rills were only recorded if found to be predominantly occurred in the erosion proxies
2.	Surface litter in (%)	The amount of litter disturb by flowing water was visually observed and expressed as % of movement over unit area on a site
3.	Stem washing	The depth of the recent stem washing was obtained by observing evidence of recent water erosion around the base of the stem
4.	Root exposure in cm	It refers to the depth of recent soil removal around the plant root due to inter rill or channel erosion
5.	Soil moment in cm	Visible scouring (washed) and translocation features observable on the soil surface detect evidence of the soil movement by water. These features were attributed to rain drop erosion and overland sheet wash or inter rill erosion.

Source: Suggested by Clak's (1980) and modified by Okoth (2003)

Erosion feature classification was carried out based on severity classes which are given below (Table 6).

Table 6 Soil Erosion Severities Conditioned by Different Erosion Features

Erosion feature	Severity class				
	Stable	Slight	Moderate	Critical	Severe
Flow channels (%)	0-2%	2-10%	10-25%	25-50%	>50%
Surface litter (in %)	0-2	2-10	10-25	25-50	>50
Soil movement (in cm)	0-1.5	1.5-3.0	3.0-5.0	5.0-8.0	>8.0
Root exposure	0-0.5	0.5-2.0	2.0-3.0	3.0-5.0	>5.0
Stem washing	0-1.0	1.0-3.0	3.0-5.0	5.0-7.0	>7.0
Rills					
Width (in cm)	<10	10-25	25-45	45-80	>80
Depth(in cm)	0-4	4-8	8-12	12-20	>20
Frequency (in m)	10-5	5-4	4-3	3-2	<2

Source: Suggested by Clak's (1980) and modified by Okoth (2003)

3.2.2.4 Statistical Data Analysis

In each observation site, the predesigned form was filled with all collected data. Three replicates of 10 meter transect were measured surface cover percent of soil covered and open surface were measured and expressed as percent of the 10 meter distance. If the current soil erosion status was found then erosion features were recorded according to Table-4.6. Recently occurring soil erosion were observed and recorded to avoid comparison of past erosion process with encountered erosion features on each proxy associate. Recent and Past erosion can be easily distinguished. Stem or roots with freshly washed surface provides contrast with erosion developed during previous season. This clue helps to recognize duration of erosion. Erosion features absent were recorded as zero values. The measurement units were centimeters or percentage and it was measured and averaging the three measurements from different location in the field plot. Topographic erosion features formed over a previous rainy day monitored accumulated effect of erosion. The incidences of erosion feature investigated. The model predicted 10 results at plot level of landscape assessment of erosion hazard topographic erosion features performed to validate the model.

Null hypothesis postulated for statistical testing before analyzing the data were

a) Selected erosion proxies did not relate to the occurrence of soil erosion;
b) If erosion proxies had no statistical significance and erosion differences observed and could have occurred by chance then difference between the individual erosion proxies.

The null hypothesis were either accepted or rejected through descriptive statistics and analysis of variance.

3.2.3 Relation between Erosion Features and Their Occurrence on the Erosion Proxies

Statistical relationship of soil erosion features and their occurrence on the erosion proxies were established by analyzing the collected data in study area. The erosion driver proxies were identified and separated from the disrupting proxies. Occurrences of soil erosion were assessed from the soil erosion features at the field level in the erosion proxies. The six erosion features were soil movement, rills, washed stems, flow channel, exposed roots and translocated surface litter occurred in all field plot level erosion proxies. Analysis of variance and descriptive mean values of the measured erosion on the individual proxies were the type of statistical analysis for data analysis.

The means of measured erosion features were obtained for different erosion proxies without being affected by differences in slope and cover conditions of encountered proxies. Obtained values were tested using the analysis of variance to see whether slope or cover had strong influence on the different means.

3.2.4 Analysis of Variance

Significant statistical difference between the proxies was performed by the analysis of variance. The response variables were the measured values on soil erosion. F-test was performed using the analysis of variance for testing the hypothesis (H_o) to compare the mean values of different factor categories. There was no difference between all the factor categories i.e. erosion proxy group. The test was performed comparing within group variance. Test was performed between group variance ratios from an overall mean by analyzing values of between groups mean sum of squares with within group mean sum of squares. The analysis on desired significance level and degree of freedom of the groups and those of the total population were found as F- test against a standard F statistical table in Snedecor and Cochran (1989). Critical and calculated values were compared to decide on significance levels of the F-test.

3.2.5 Determination of Factors by Erosion Damage

Slope profile factors with spatial units influenced erosion damage. Rainfall, vegetation cover, soil texture, slope angle, land management practices etc. directly influence erosion. Apart from these factors, land management, failure of soil and water conservation structure, or uncontrolled drainage from footpaths or settlement area is hidden problem for soil erosion. Spatial units factors are “out of sight”, which influence erosion damage by run on. Compact sealed surfaces (e.g. footpaths, animal tracks, roads or settlements etc), area with permanent vegetation cover (e.g. grassland, bush or forest etc.) and cultivated areas, (where surface water is not controlled well) are hidden factors. In this methodology, characterization of damaged field using description of the adjacent area, both upslope and down slope was attempted. An *erosion-topo-sequences* profile was generated covering entire cross-sections of a slope; from hilltops to valley floors by observing the “area surrounding the erosion features". The upslope and down slope areas adjacent to damage field were investigated by survey. Observations were recorded based on guidelines given in EDA field manual. The field, where erosion damage occurred was identified as the core of "erosion topo-sequence". Thereafter, the upslope area adjacent to damaged field and lastly, the down slope area, which is adjacent to the damaged field in the view of subsequent damage, were observed. Factors and reasons that influenced erosion damage were determined, as discussed below.

3.2.6 The Field Affected by Erosion Damage

Damage areas were identified based on visible soil erosion features, observations for factors were attempted as in Table 7 and symbols were developed to draw sketch.

Table 7 Guidelines for Identification for Erosion Features

Visible erosion features	**Description for identification**
Puddling or capping effect	The soil surface smoothed by the splash impact of raindrops and by small particles transported by runoff. The aggregates in the topsoil are destroyed and the space in between is filled up by eroded particles.
Rills and gullies	Basically one can distinguish between current features, which will have occurred during the past few rains and those which are older
Accumulations	The soil is deposited where the velocity and transport capacity of the water diminishes. The sediment piles up on top of the original surface and buries crops, seedlings, etc

3.2.6.1 The Sources of Run on Upslope Area

Overland flow and run on contribute to damage Upslope areas. The upper slope area produces a lot of surface water during the rains which acts as a source of erosion damage. If this water enters a cultivated field down slope the process is called run on. Observation showed that where run on enter on the field and causes erosion damage.

- Sealed surfaces compacted can produced the greatest amount of overland flow which prevents water from infiltrating, e.g. footpaths, animal tracks, roads or settlements etc.
- Water is not well controlled in upslope cultivated areas water which can penetrate into another field below.
- Permanent vegetation cover area of grassland, bush or forest with better infiltration produces less overland flow compared to sealed or bare surfaces.

Eroded soil particle is accumulated due to the reduction of water velocity by the vegetation cover. Even though these areas may still drain considerable amounts of water down slope and cause damage.

3.2.6.2 Subsequent Damage on the Down Slope Area

Erosion damage in the down slope was due to runoff impact on further downstream which received water and sediment transported. Damage can be as in following ways:

- Runoff concentrated along field borders, and forms rills, which eventually develop into gullies.
- Rills and accumulations developed on cultivated areas down slope, on grassland, roads and settlements. Production may be affected or cleaning of roads may become necessary.
- The eroded soil suspended in the river pollutes water and watering points.
- Flash floods endanger settlements and farmland downstream.

3.2.6.3 Developing an Erosion-Topo-Sequence for an Area

A semi-quantitative analysis was performed after a mapping of erosion damage. As a first step, an erosion topo-sequence for area was developed. All the observed factors of influence on erosion were summarized and group according to their position on the slope, on damaged fields, upslope, and down slope.

3.2.7 Validation of Model Predicted / Estimated Soil Erosion

Model predicted soil erosion was compared with soil erosion assessed with EDA by evaluating soil erosion features. The soil loss assessed (qualitatively) by using Mean values of observed erosion features on plot level and classified by mode maximum function from soil loss assessed qualitatively will be used to compare the soil loss results spatially predicted at landscape scale by RUSLE model.

3.2.8 Impacts of Climate Change on Soil Erosion

In this study, general impact of climate change on soil erosion correlated to using temporal or spatial analogues at historical data and climatologically gradients. Due to the lack of the sufficient data the trend of analogue study could not find the trend of climate change effects on soil erosion .The present situation is not so severe effects of climate change on soil erosion but in future could be area of study about this aspect. The questionnaire was developed to find the impact of the climate change impact on the soil erosion on stakeholders' perception. The analysis from the questionnaire showed some effects of climate change but not severe. In this study impact of climate change on soil erosion was not studied in detail.

3.3 Result and Discussion

Average soil loss was predicted by RUSLE model using remote sensing and GIS as spatial erosion modeling. Field survey was conducted to acquire and collect all the inputs such as terrain, soil, vegetation parameters related to soil erosion. Model estimated soil loss was validated with field based erosion assessment. Hierarchically approach in soil erosion risk at different scales was also attempted to visualize the scale effect in erosion modeling. The results obtained in the study are presented as below:

3.3.1 Spatial Database Generation

Rainfall factor(R-factor)

Annual rainfall data of 15 years was collected from the 3 meteorological stations of the Phewa Watershed to estimate R factor. The rainfall data and elevation of meteorological stations were correlated to the rainfall due to elevation. Regression technique was applied to obtain the equation for the rainfall map. The equation of the predicted rainfall map was

$$\mathrm{Y} = 0.967x + 2901 \tag{10}$$

Where Y= amount of rainfall (mm) and x is the elevation (m), the above formula was applied on the map calculation function of Arc GIS 10 software. The R-factor map was obtained according to the relationship between elevation and rainfall. The relationship between elevation and annual rainfall is ($R^2 = 0.821$). DEM was used to calculate this map. R value estimation according to equation (3) was varies from 785 to 6845 MJ mmha^{-1} h^{-1}year^{-1}. More rainfall erosivity was observed in the northwest, west and south west of the watershed that coincides with higher elevation and ridge of study area and this is shown with green color in Figure 6. The decreasing R factor has a strong relationship with the decreasing trend of elevation and rainfall from the north, northwest, south west and west ridges to the east and southeast of watershed.

Soil erodibility factor (K-factor):

In this study, 10 different soil samples were collected from horizon having a versatile range of land use, slope gradient and k factor of each unit was estimated by using nomograph (Wischmeier and smith, 1978). Soil erodibility K value was calculated using equations (4) and (5) and soil sample data. The average K value varied from 0.13 to 0.38 t h MJ^{-1} mm $^{-1}$. The K value map was generated to show spatial distribution of erodibility Figure 7. It can be seen that higher amounts of K values coincides ancient lake and river terraces formation that have the greatest sensitivity to erosion as shown with green yellow color.

Topographic factors (LS)

A slope raster was derived from the elevation model and mask tool with the watershed raster as input to limit the slope of the watershed raster to the study area and did the same with the flow accumulation raster created earlier. These two raster were used in the map algebra equation, along with the cell size of “30.” The LS factor was calculated by Equation (5) and (6) by using DEM of the watershed as well as considering the interactions between topography and flow accumulation. It can be seen that the LS factor varies from 0 to 200.5. Some specific areas with steep slopes have greater LS values (such as ridges). The case study area is characterized by decreasing elevation values from north, northwest and west ridges to the southeast (outlet) and south. The spatial distribution of topographic factor (LS-factor) is presented in Figure 8.

The Cover factor (C)

LULC map of the study area was generated from Landsat TM. Thus ‘C’ factor should be calculated by considering different types of vegetation cover. The C-factor value varied from 0 to 1. LULC layer was generated by supervised classification and using the visual Interpretation (VI). Layer was converted to C layer (Figure 9) through reclassification of each cover type into its corresponding C value as in Table 8.

Table 8 The Adopted Value of C for Different Land Use

S.N.	Land covers	Average C value	S.N.	Land covers	Average C value
1	Open forest	0.04	7	Bush and scrub	0.02
2	Double crop	0.37	8	Grass/fallow land	0.03
3	Single crop	0.41	9	Terrace cultivation	0.44
4	Built up land	0.06	10	Waste land /land slide	1.00
5	Water body	0.0	11	Dense mixed forest	0.001
6	Wet land	0.01	12	Barren land	0.9

Source: Roose (1977), Hurni (1987), Morgan (1986), Hashim and Wong (1988) and field observation

The conservation factor (P)

P is calculated for agricultural land only and for all other land was assumed as 1 because there were no any control practices measures (Schwab et al., 1993). The adopted values of P are given in the Table 8 and map in Figure 10.

Table 9 The Adopted Value of The Practice Management in Different Land Use

Land use type	Slope %	Pc	Ps	Pt	P factor
Agriculture	1 – 4	0.55	0.50	0.4	0.11
	5 – 10	0.60	0.50	0.3	0.09
	11 – 20	0.75	0.50	0.5	0.18
	21 – 40	0.95	0.50	0.2	0.0
	> 40	1.00	0.50	0.4	0.20
All		1.00	1.00	1.00	1.00

Sources: Schwab et. al. (1993) and field observation

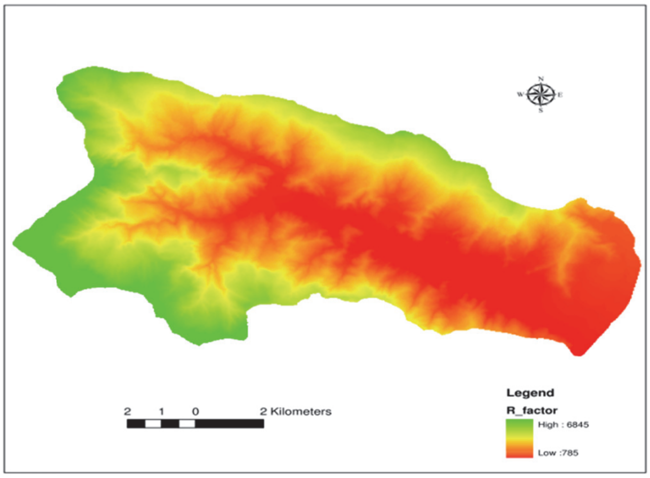


Figure 6 Spatial Distribution of R-Factor

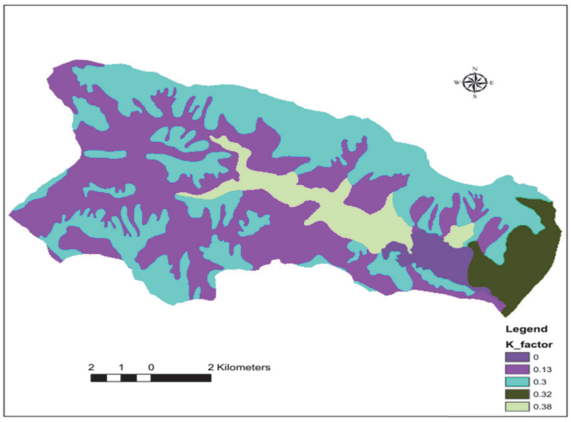


Figure 7 Spatial Distribution of K-Factor

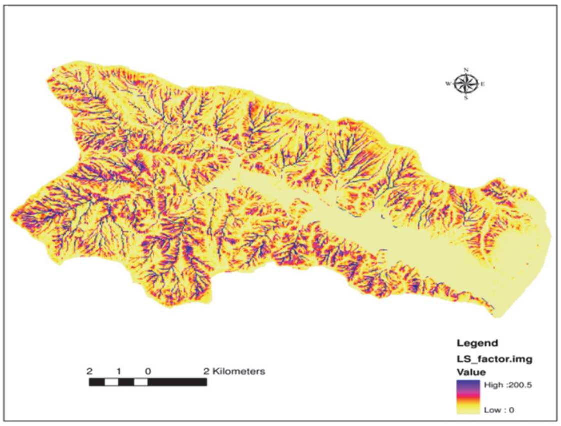


Figure 8 Spatial Distribution of LS-Factor

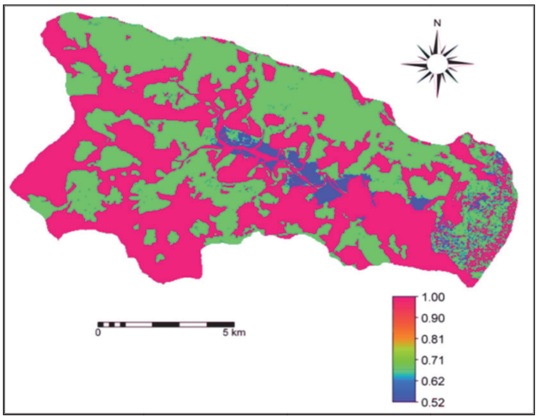


Figure 9 Spatial Distribution of C-Factor

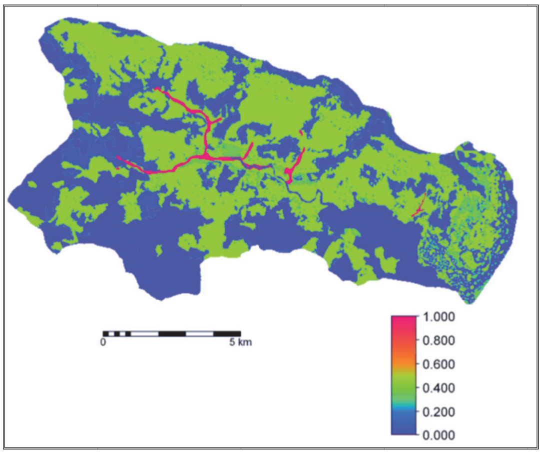


Figure 10 Spatial Distribution of P-Factor

3.3.2 Soil Erosion Estimation in the Watershed

Average annual rate of soil erosion was calculated by using the data rainfall, soil type, topography, crop system and management practice. These data were used in RUSLE model which represents spatial distribution of predicted annual soil loss rates for the study area. The average annual soil erosion rate estimated by RUSLE for study area ranged from 0 to 206.7 t/ha/year (Pixel values). The average annual soil loss of the whole watershed was 14.7 t/ha/year and total average soil loss 181,889 ton/year. The results were correlated with EDA carried out in Andheri sub watershed for validating the proposed method in the study area. Soil erosion calculating in the sub watershed was found to be appropriate and matching. According to the Morgan (1995) the appropriate measure of soil loss over agriculturist thresholds value for soil loss is 10t//ha/year. So according to this threshold, watershed is affected by soil erosion. The assessed average rate of soil loss was classified into six classes of soil erosion risk based on minimum and maximum values and the spatial distribution of each class was presented in the Table 10, Figure 11. Area proportion of the severity categories was tabulated. The results in table showed that about 50.10% of total area of watershed was found under low risk of erosion (<10 t/ha) while rest of the area is under moderate to high erosion risk. In terms of actual soil erosion risk, the study area has 9.83 % moderate (10-15t/ha) and 36.26 % high to very severe erosion risk levels. The spatial pattern of classified soil erosion risk zone indicates that the areas with high and severe erosion risk are located in the most of the northern part with agricultural land region of the study area, while the areas with low erosion risk area are in the southern parts of the study area.

LULC map of the area overlaid with classified risk map to assess the role of the human intervention in the soil erosion risk in the sub watershed. Spatial pattern showed that severe level of soil erosion risk area was distributed on grass land, barren land and waste land. High level of soil erosion was distributed on agriculture land. Spatial pattern of high vegetation and dense forest showed that low soil erosion risk.

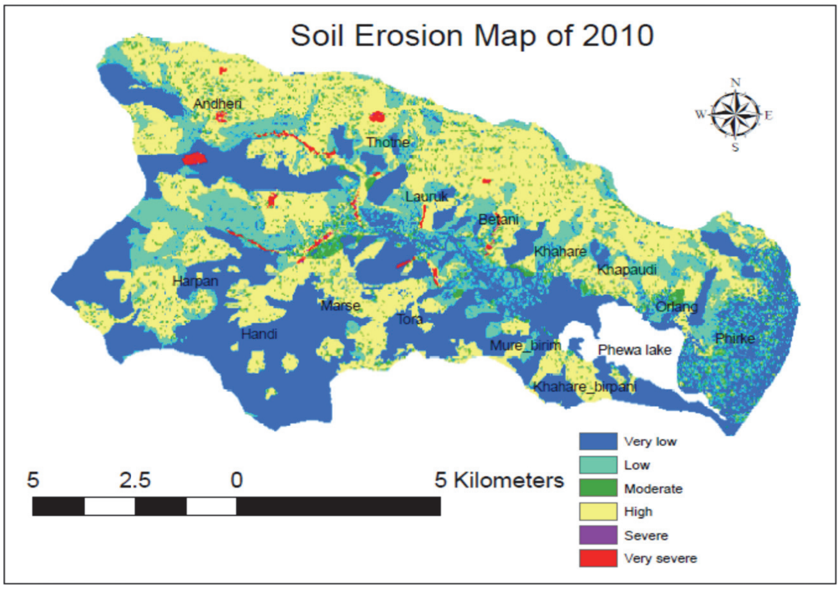


Figure 11 Soil Erosion Maps of 2010

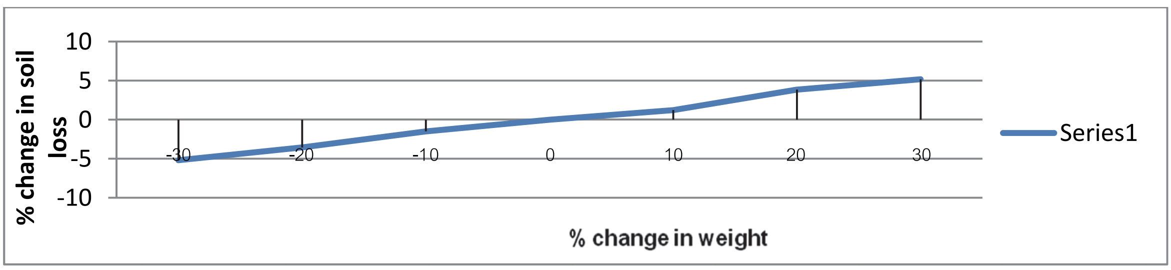
Table 10 Soil Erosion Risk Classes of Soil Erosion Map of 2010

Erosion classes	Average rate of soil loss(t/ha/year)	2010	
		Area (ha)	Area (%)
Very low	<5	4205.3	34.21
Low	5 to 10	1978.5	15.89
Moderate	10 to15	1208.0	9.83
High	15 to 25	4304.3	35.02
Severe	25 to 50	67.6	0.55
Very severe	>50	84.55	0.69
Excluded area(river/stream/lake)		444.2	3.82
Total		12292.28	100

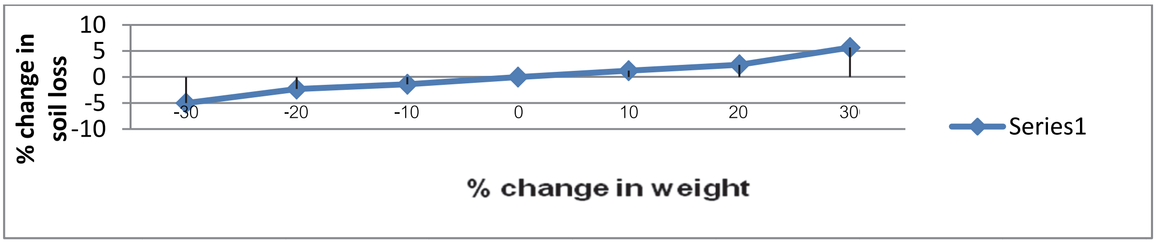
3.3.3 Sensitivity Analysis

There are several approaches available for sensitivity analysis. The rate of change in output variable as change in input factor is defined as the sensitivity analysis (Lane and Ferreira, 1980). The relative importance of the input data can be used by the variation of input data to sensitivity of model response. The greatest influence of the input factor is defined on model output. The sensitivity analysis attempt the rank of the parameter based on overall contribution to change in model prediction. The RUSLE model with five factors runs as base run. Sensitivity analysis was performed by changing the values of the one parameter changing as taken other parameter with the base values. Sensitivity analysis is a procedure for identifying the effects of introduced small changes in the inputs parameters on the outputs (ranking of alternatives). It is also defined as methodological study of the response of selected output variables to variations in parameters or driving variables. This provides valuable information and insight to modelers and model users. Model users refer to sensitivity analysis results to guide their parameterization efforts, using more resources to quantify those parameters to which the model is most sensitive. Several runs of the RUSLE model was conducted with varying input parameters to assess their effects on model output. RUSLE parameters used in the sensitivity analysis are R-factor, K-factor, LS -factor, P_S-factor. Figure 12 (a, b, c, d) shows the sensitivity of RUSLE input parameters value for individual parameters were increased and decreased in the interval of 10% in the range of -30% to +30%, while keeping the other parameters value same from their base values.

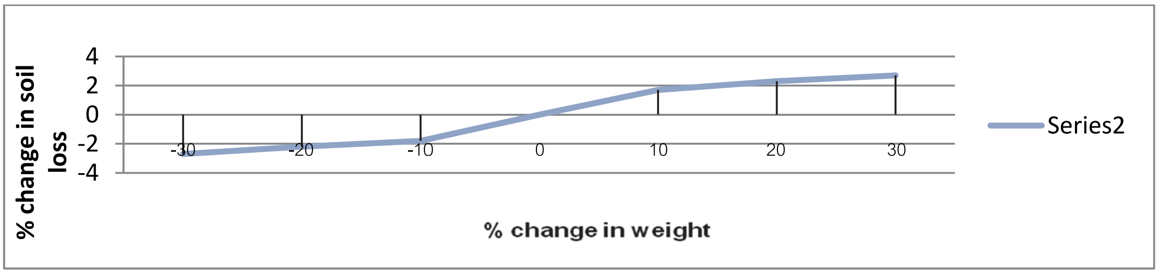
a) LS-factor



b) Ps-factor



c) K-factor



d) R-factor

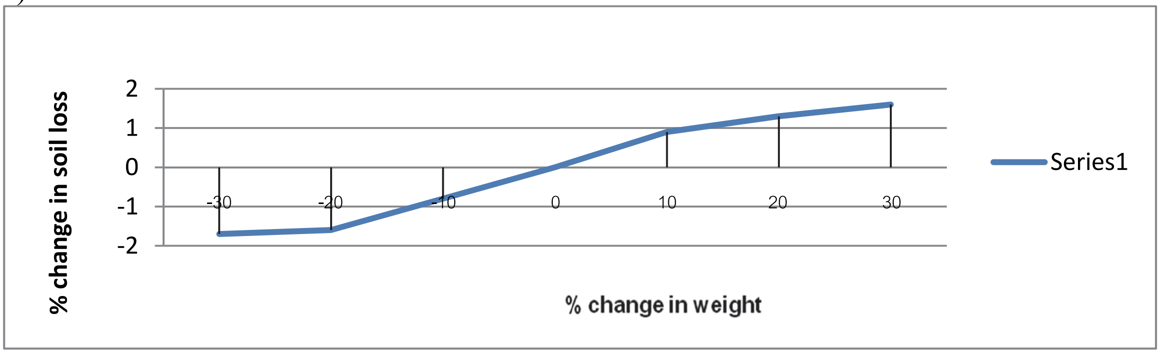


Figure 12 Model Sensitivity to Variation of Parameters by +30% and -30%

Soil erosion calculation of the RUSLE model was found to be the changes of P and LS parameters values changes the soil loss. Thus, 6 more weights are obtained for each parameter, giving 24 possible weight combinations for all the 4 input parameters. Soil erosion was obtained for all the 24 cases and soil loss erosion were compared with that given by base value. These parameters are sensitive to the soil erosion. It was observed that slope length and land use practice were more sensitive parameters due to change in their weight soil loss % change more than other parameters. Figure 9 shows the effect of changing the weights of individual parameter to the soil loss.

3.4 Conclusion

Himalayan terrain has critical problem of soil erosion by water due to anthropogenic pressure on its mountainous landscape. Various human activities disturb the land surface of the earth, and thereby induce the significant alteration of natural erosion rates. Soil resource is important to sustain the productivity in hilly terrain. Livelihood of the people in the Himalayan region is mainly dependent on farming system and especially on subsistence agriculture. Thus quantifying erosion assessment can be core of any decision making and supportive in policy formulation for sustaining the environment.

Soil erosion assessment and mapping of erosion prone area are very essential for soil conservation and watershed management. High risk area has to be prioritized first for management (development oriented) and conservation of natural resources. Hence, it is essential to assess soil erosion risk for soil conservation program. The study evaluated the applicability of an erosion model in mountainous terrain, to determine spatial distribution of soil loss and to analyze the effect of land use, slope exposition and terrace farming on soil erosion. Both qualitative and quantitative approaches were adopted in the present study to assess soil erosion risk. Soil erosion risk mapping was carried out by using GIS base modeling approach in conjunction with satellite remote sensing derived parameters. About 50% of total area of watershed was found under moderate to high erosion risk. Erosion risk indicated less potential of erosion occurring in the southern and western regions of the hilly counties and most of the northern part and central part of the watershed showed the higher potential of soil erosion risk.

The distribution of soil erosion sensitivity is highly coincident with soil erosion intensity, which might be expected. That is, regions of high sensitivity of soil erosion are currently regions of severe soil erosion, indicating that natural factors like precipitation, soil, topography and vegetation have important impacts on the spatial distribution of soil erosion sensitivity. However, in some areas soil erosion intensity and soil erosion sensitivity are not completely coincident, which is due to different levels and interactions of human activities. Soil erosion sensitivity studies primarily analyze conditions based on natural factors, while revealing the impacts due to human activities. It reflects the probability of soil erosion occurrence and indicates the potential for land degradation due to the occurrence of soil erosion. Soil erosion intensity involves a comprehensive set of circumstances on the surface and the combined result or interaction of natural and human factors reflecting current soil erosion conditions. The outcome from sensitivity analyses and adverse human activities dictate the unsustainability of the eco-environment for a given area. Natural factors are underlying conditions of the development and occurrence of soil erosion. Considering natural factors, vegetation is the primary factor affected by human activities. Therefore, altering inappropriate land use management, returning farmland to native forest, remediating commercial forest on hill slopes and strengthening the protection and reconstruction of vegetation are key measures that should be taken to control and prevent soil erosion now and in the future

3.5 Assessment of Erosion Damage

Soil, land use and rainfall characteristics are varied according to locality of landform. Thirty particular localities cannot be used to predict equation based on experimental plots to explored and predict rates of erosion in far locality. A field base approach result provided realistic and rapid way to assess erosion which can be compared in wide range of environment. Qualitative assessment of soil erosion was converted into assessment of soil erosion feature in the field. Qualitatively soil loss erosion feature asses the visible product of the water erosion process which include depth of root exposure, flow channel, surface litter translocation, depth of the rills, depth of stem wash and depth of soil movement.

3.5.1 Field Based Assessment of Soil Erosion by PGIS Methodology

Total 30 plots were observed for assessment of current erosion damage. It included 10 plots in terrace cultivation (maize) and 20 plots under other land use land cover representing the various physiographic units. Other plots were observed five types of erosion proxy groups such as open forest, grassland, dense forest, paddy and barren land.

Ten plots observed under erosion proxy were maize plots. The erosion features were measured in 5 plots belong open forest types and 6 in single crops (paddy). Three plots for each erosion proxy viz. dense forest, barren land and grassland plots were observed. Three observations (replications) for each plot were observed for the six types of erosion features during EDA survey. Each individual erosion feature of mean of three observations was computed for each plot. The mean values of measured erosion features were assigned severity class according to the Table 11 and 12. Severity classes stable, slight, moderate, severe and very severe were express as codes 0, 1,2,3,4 respectively. Maximum mode function of all six types of measured features was assigned by occurrence of severity class.

i) Erosion Proxies and Overall Mean Values of Various Erosion Features

Six types of erosion features were studied to assess the occurrence of soil erosion in six types of erosion proxies (land uses class). The overall mean values of various erosion proxy groups (land use classes) were calculated measured erosion features (Table 11). Relation of soil erosion features with their occurrence on the erosion proxies were established by analyzing data collected in study area

Table 11 Overall Mean Values of Erosion Features Erosion Proxies at the Plot Level

Erosion proxies types Land use/land cover	Sample size (No of plot)	Overall mean values of erosion features					
		Fc	Slt	Rex	Rills	Sw	Sm
Terrace (maize)	10	1.67	1.74	1.16	1.5	1.16	1.46
Single crop(paddy)	6	2.07	2.21	1.89	1.91	1.17	1.52
Grass land	3	1.66	1.65	1.51	1.75	1.05	1.08
Open forest	5	1.11	1.21	1.01	1.59	0.35	0.37
Dense Forest	3	1.34	1.47	1.56	1.57	0.054	0.51
Barren land	3	4.29	4.11	3.45	5.26	3.31	3.31

Where, Fc = Flow Channel (in %), Slt = Surface litter translocation (in %), Rex = Depth of root exposure (in cm), Rills = Depth of rills (in cm), Sw = Depth of stem wash (in cm), Sm = Depth of soil movement (in cm).

Erosion severity was analyzed from the observed mode values of erosion features. Erosion severity was analyzed from the observed mean values of erosion features (Table 12) that one class shifted in advance than the result obtained by mode in almost for all the erosion proxies. Erosion prediction classified based determined mode on maximum function so it would be preferable for the recommendations on soil and water conservation planning to cover erosion risk because PGIS erosion damage is an area specific approach to soil erosion. Erosion feature barren land was observed to characterize severe to very severe erosion in barren land. Grass land had been observed moderate to severe erosion whereas, open and dense forest was observed moderate severity of erosion.

Table 12 Occurrences of Erosion Severity Classes of Various Erosion Proxies

Erosion proxies	Sample size No of plots	Erosion classes				
		Stable	Slight	Moderate	Severe	Very severe
		Mode	Mode	Mode	Mode	Mode
Maize plot	10	2	3	4	1	-
Single crop	6	1	1	3	1	-
Grass land	3	-	1	1	1	-
Open forest	5	1	3	1	-	-
Dense forest	3	2	1	-	-	-
Barren land	3	-	-	1	2	-

ii) Evaluation of Erosion Severity for Different Proxies

The criteria in Table 5 were used to determine the severity class. Overall erosion severity classes were identified by using mode maximum function. Frequencies of occurrence of severity classes were calculated for each erosion proxies. Ranking of soil erosion proxies was determined based on highest severity class and frequency of occurrence of lowest severity class in (Table 13) to distinguish between the drivers and disrupters of erosion. Barren land and terrace cultivation were acting as a first and second rank driver for soil respectively in watershed.

Table 13 Evaluation of Erosion Severity for Different Proxies

Land erosion proxies	Erosion features	Mean	Severity class	Frequency of erosion severity class					Rank of drivers
				Stable (0)	Slight (1)	Moderate (2)	Severe (3)	Very Severe (4)	
Terrace (maize)	Fc	1.67	0	2	6	2	-	-	Second
	Slt	1.74	0						
	Rex	1.16	1						
	Rills	1.5	0						
	Sw	1.16	0						
	Sm	1.46	0						
Single crop (paddy)	Fc	1.89	1	1	3	2	-	-	Third
	Slt	2.21	1						
	Rex	2.15	1						
	Rills	1.91	0						
	Sw	1.17	1						
	Sm	1.52	1						
Grass land	Fc	1.66	0	1	1	1	-	-	Third
	Slt	1.65	0						
	Rex	1.51	1						
	Rills	1.75	0						
	Sw	1.05	1						
	Sm	1.08	0						
Barren land	Fc	4.29	1	*	*	1	2	-	First
	Slt	4.11	1						
	Rex	3.45	3						
	Rills	5.26	1						
	Sw	3.31	0						
	Sm	3.31	2						
Open forest	Fc	1.11	0	1	2	2	-	-	Fourth
	Slt	1.21	0						
	Rex	1.01	1						
	Rills	1.59	0						
	Sw	0.35	0						
	Sm	0.37	0						
Dense forest	Fc	1.34	0	1	1	1	-		Fourth
	Slt	1. 47	0						
	Rex	1.56	1						
	Rills	1.57	0						
	Sw	0.054	0						
	Sm	0.51	0						

Note: Codes 0, 1, 2, 3 and 4 were used to express severity classes, of slight, moderate and severe and very severe respectively (based table 5).

iii) Analysis of Variance (ANOVA)

Statistical significance differences of six erosion proxy factors mean values were tested. The null hypothesis (Ho), no difference between all the factors were tested by comparing mean values of different erosion features. Calculated values were compared with critical F-values (2.31) in order to decide on significance levels of the F-tests. There was difference between the erosion proxies (factor group) and confirmed their relationship between all the erosion proxies and the response variable (soil erosion). It was shown by comparison of F- critical and F-calculated values in Table 14. Analysis showed that there was significant different between the factor group mean (erosion proxies) for flow channel, surface litter translocation, depth of root exposure, depth of stem wash; depth of soil movement. However, no significant difference was found among the different groups of the erosion proxies as F-ratio for the erosion feature of depth of rills was found closer to 1.0. F-test showed for all other erosion features that the means of the sampled erosion proxies has significant difference. The occurrences of the rills do not indicated any difference between the various erosion proxy groups by the result of analysis obtained on the rills.

Shallow, less energetic overland flow or by splash erosion having less erosive impact due to interruption of canopy cover develop strong more energetic channel flow compared to the other erosion features to the fact that occurrence of rills. The channel flow is able to spread vigorously on the soil surface compared to overland flow or raindrop splash impact and thereby obliterating the effect of the proxies (land use) because of its higher velocity and large energy. Rill erosion formation will be not affected by erosion proxies because of difference in their percent canopy cover.

An *erosion topo- sequence* was generated from the characterization of damaged field in both upslope and down slope area. The factors covering cross-sections associated in each observation site contributing for erosion were recorded. Erosion damage occurred field was identified as the core of erosion topo-sequence. Factors and reasons that influenced erosion damage of 30 plots were determined.

Table 14 F-Test for Significance for the Seven Erosion Proxies (Land Use/ Land Cover Classes)

Erosion features	Erosion proxies	Sum of the squares	Degree of freedom	Mean squares	F	Remark
Flow channel (%)	Between groups	19.8	5	3.96	5.40	#
	Within groups	18.3	25	0.732		
	Total	38.1	30			
Surface litter translocation (%)	Between groups	15.3	5	3.06	2.52	#
	Within groups	30.3	25	1.212		
	Total	45.6	30			
Depth of rills (cm)	Between groups	35.4	5	7.08	1.10	*
	Within groups	160.3	25	6.412		
	Total	195.7	30			
Depth of root exposure (cm)	Between groups	12.3	5	2.46	2.74	#
	Within groups	22.4	25	0.896		
	Total	34.7	30			
Depth of stem wash (cm)	Between groups	25.5	5	5.1	6.28	#
	Within groups	20.3	25	0.812		
	Total	45.8	30			
Depth soil movements (cm)	Between groups	20.8	5	4.16	7.70	#
	Within groups	13.5	25	0.54		
	Total	34.3	30			

Where # stand for value greater than 2.31 and * stands for values less than 2.31

F-Critical-2.31	Significance level 0.05
Degree of freedom Group-5	Total population -30

Source: Standard F statistical table as found in Snedecore and Cochran (1989)

Thus, 30"erosion topo-sequence" were developed. Total 16 & 8 plots were observed under cultivated land & forest land respectively. Similarly, total 6 plots under grassland and barren land were observed. All the upslope area contributing to damaged plot was recorded in a sequence for each observation sites, starting from the area immediately adjacent to the damaged field. Thus, "rank importance" of these areas was determined. Likewise, subsequent damage was also recorded in a sequence to determine the "rank severity" of subsequent damage in down slope areas.

The frequencies of upslope factors, which influence erosion damage, were determined. There were 4 erosion-damaged fields observed under the influence of upslope cultivated areas, where surface water penetrates into another field below. Likewise, 6 damage fields were observed under the influence of upslope area with permanent vegetation cover such as grassland, bush and forest.

They caused the damage by draining considerable amount of water down slope. The maximum damaged fields where the cause of damage was the sealed/ compacted surfaces such as footpaths, roads, animal track and stream bank such fields were found. RUSLE Model was run (in MS excel) at each observation site of EDA survey to predict soil loss. The soil loss was estimated and classified into soil erosion severity class. The observation sites were grouped based on from upslope and down slope. The factors in vicinity adjacent to the observed plot were studied and their effects in soil erosion were interpreted / analyzed based on EDA / RUSLE soil loss assessment.

The average soil loss estimated by both RUSLE, and EDA for those damaged field cases from adjacent upslope area was observed. Observed cases and estimated soil loss showed that the factors such as barren land and stream bank contributed to highest severity class of soil loss measured by both RUSLE and EDA, despite low frequency damage. Similarly, for the factor cultivated land and grassland, the soil loss computed by RUSLE falls under moderate erosion class and by EDA it ranges from severe to very severe classes. In the case of forest, 3 damage cases were observed, where EDA and RUSLE both predicted low erosion class. Very lowest frequency of erosion damage was observed for the factor, where soil erosion assessed by both EDA and RUSLE was classified under slight class. Similarly, highest frequency of damage cases were observed for the factor road which was contributing highest severity class of soil erosion assessed by RUSLE as well as EDA. Though, the number of observations of specific upslope factor influences erosion damage cannot give direct clue about magnitude of soil loss. However, understanding about some factor can be highlighted in order to cover risk.

It can be concluded that the road was most frequently observed factor in erosion damage with very severe risk of soil erosion. Similarly, apart from low frequency of run on cases factors like stream-bank and barren land were found contributing in severe and very severe erosion classes. It has been explained by the comparison of estimated soil loss (EDA and RUSLE) and frequency of observed erosion damage. Quantitative estimation of soil loss by water erosion in the study area was modeled by performing spatial soil erosion risk modeling using RUSLE model with the aid of remote sensing and GIS.

3.5.2 Validation of Model Predicted / Estimated Soil Erosion

Model predicted soil erosion was compared with soil erosion assessed with EDA by evaluating soil erosion features which was shown in the Table 15. The variation in soil loss computed at landscape and plot scale. The soil loss assessed by using mean values of observed erosion features on plot level and classified from soil loss assessed qualitatively was used to compare the soil loss results spatially predicted at landscape scale by RUSLE model. RUSLE model predicted soil loss was classed quantitatively into very low (<5t/ha) and low (5 to 10 t/ha). But, EDA assessment cannot be differentiated into very low & low etc. classes therefore severity classes were assigned based on Table 5. Table showed that out of total 10 plots under cultivated land, EDA classified 8 plots moderate while RUSLE predicted critical at landscape scales. However, both EDA & RUSLE classified all the plots under plantation, grass land, open forest, barren land in similar classes of soil erosion.

In the case of dense forest EDA estimated well but RUSLE was underestimating the soil loss. When soil loss estimated in different ways, variation was observed in erosion classes at plot and landscape scales. These results initiated the need of scale consideration in soil erosion. RUSLE model predicted soil loss was classed quantitatively into very low (<5 t/ha) and low (5 to 10 t/ha). EDA assessment cannot be differentiated into very low & low classes therefore severity classes are assigned based on Table 5. It may be attributed to the fact that soil erosion is highly variable in the spatial as well temporal domain. Therefore, soil loss does not occur in a uniform manner in each landscape level.

Table 15 Comparison of Soil Erosion Assessed by EDA and RUSLE

Land use Land cover lasses	Sample size	Occurrence of severity classes of soil loss		
		EDA	RUSLE	
		Erosion classes/ No. of plot assessed	Erosion Classes	Average soil loss(t/ha)
Terrace (Maize)	10	Slight /**2**	Severe	20.29
		Moderate /**6**		
		Severe/**2**		
		Very severe/-		
Single crops(Paddy)	6	Slight /**2**	Severe	18.34
		Moderate/ **3**		
		Severe/**1**		
		Very severe/-		
Bush	3	Slight /**1**	Severe	32.49
		Moderate /**1**		
		Severe/**1**		
		Very severe/-		
Barren	3	Slight /-	Very severe	206.78
		Moderate /-		
		Severe/**1**		
		Very severe/**2**		
Open forest	5	Slight /**2**	Moderate	13.03
		Moderate /**3**		
		Severe/-		
		Very severe/-		
Dense forest	3	Slight /**2**	Stable	4.67
		Moderate /**1**		
		Severe/-		
		Very severe/-		

CHAPTER IV

4. Stakeholders' Perception and Socioeconomic Determinants of Soil Erosion on Soil Erosion Risk Assessment

4.1 Methodology

The methodological flow chart of the stakeholders' perception for soil erosion risk assessment is presented in Figure 13. Detail description is explained in proceeding sections.

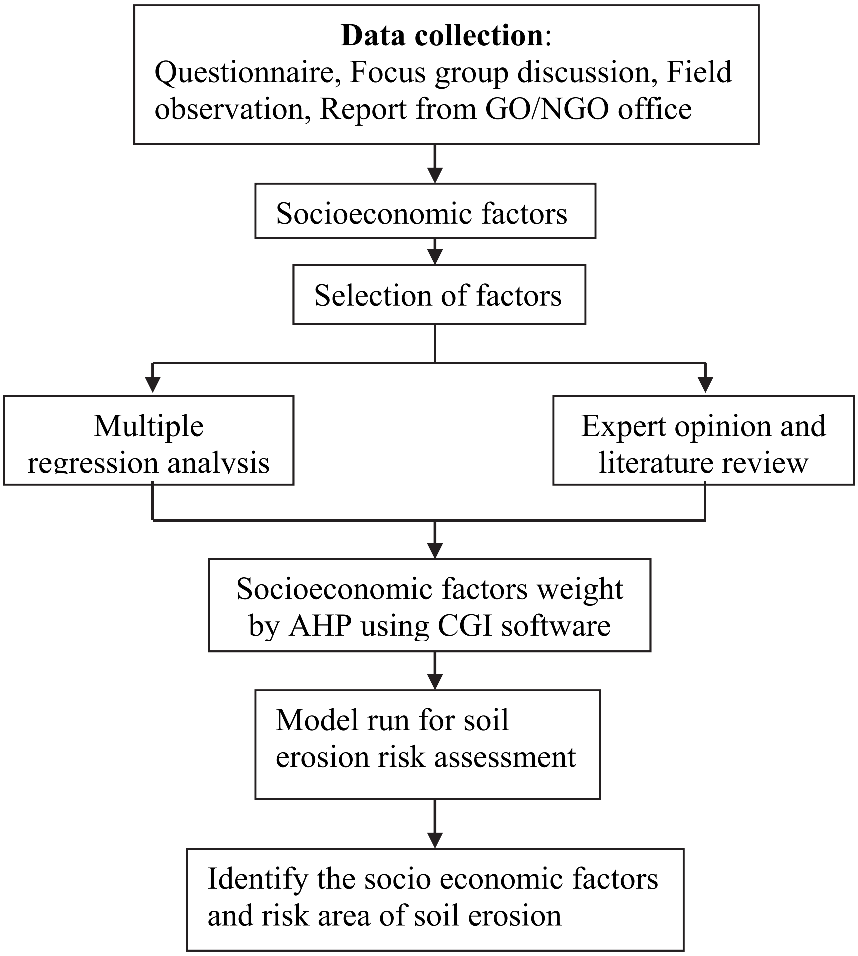


Figure 13 Methodological Flow Chart of Stakeholders' Perception for Soil Erosion Risk Assessment

4.1.1 Collection of Socioeconomic Data

Socioeconomic data were obtained from Village Development Committee (VDC) report (2010). Questionnaires survey was conducted among the different stakeholders' households according to the ratio of the number of households in 14-sub watershed. The data were collected from household interview questionnaires in the field. The primary information derived from the questionnaire survey used for this study consisted of the use of protective measures against the soil erosion, sedimentation and landslides. Rainfall and temperature data were collected from Meteorological department, Government of Nepal Pokhara.

4.1.2 Determination of Sample and Sub Sample

The study area was consisted of 5,395 households (HHs). A sample size of 210 HHs was obtained with sample fraction (k) of 0.05 at 5% significant level, using equation for sample size determination given by Yamane (1967).

$$n = \frac{N}{(1 + N \times e^2)} \qquad (11)$$

Where n is sample size, N is total Households and e is the significant level.

A structured questionnaire (APPENDIX-A) was used to collect information on socioeconomic condition, climatic condition, soil water conservation and soil erosion status from all 14 sub watershed area. All stakeholders like farmers, mothers' group, teachers, social workers, NGO/GO officers, politicians, students were represented proportionally from all sub watershed area from January to March 2012. The questionnaire was design to document the socioeconomic condition, stakeholders' perception on erosion in field, adopted soil and water conservation strategies. The data collection was based on individual interviews, focus group discussion, key informant interviews and field observation. Household survey points were collected by Garmin GPS. The collected points were projected to the map of the study area. Researcher and trained assistance were conducted to collect HHs information. The collected HHs data were analyzed by the Statistical Package for Social Sciences (SPSS) 17.0 software.

4.1.3 Conceptual Model

A synthesis assessment index (S) is introduced to evaluate degrees of risk on soil erosion. S is total effect of all factors on soil erosion expressed as follows:

$$s = \sum_{i=1}^{n} w_i \times s_i \qquad (12)$$

Where S is the synthesis assessment index of the degree of risk on soil erosion; W_i is the comparative weight of the i^{th} factor; S_i is the degree of risk on soil erosion resulted from the i^{th} single factor, and n is the total number of the dominating factors.

4.1.4 Selection of Assessment Factors

Assessment of the factors was determined based on Stakeholders' perception and professional expert judgment and literature review. Questionnaires, focus group discussion information analysis of factors were assessed from field survey. The factors of soil erosion in this study area was included the socioeconomic factors such as size of farm land, migrated population, road construction without conservation, settlement and population density.

4.1.5 Thematic Layers of Factors

Data Preparation

Thematic layers of five factors were achieved through base map generation. These five thematic layers included the size of farm land, migrated population, road construction without conservation, settlement and population density. The information was collected from the VDCs profile (2010) and census data (2002) information collected from the questionnaire survey.

Degrees of Risk of Thematic Layers of Different Dominating Factors

Determination of the degree of risk for each factor to soil erosion is an important assessment process. The expert judgment combining with stakeholders and researcher view, literature review the risk degree of i^{th} factor Si can be decided with number from

0 to1. S_i is set as 0 for little effects on soil erosion and 1 for great effect. Otherwise Si takes a value between 0 and 1 depending on the extent of its effect. The lists of attributes of factors are as in Table 16 and thematic layer as in Figure 15 was calculated based on the literature review and export opinion.

Table 16 Attribute of the Factors in Soil Erosion (after Calibration and Validation)

Farm land size	0-0.2 ha	0.2-0.5 ha	0.5-2ha	>2ha	
Degree of risk	0.6	0.3	0.2	0.1	
Migrated Population	0-5%	5-15%	15-30%	30-60%	>60%
Degree of risk	0.1	0.2	0.3	0.5	0.7
Road Construct (beside distance)	0-10m	20 m	30 m	40m	50m
Degree of risk	0.5	0.3	0.2	0.1	0.05
Settlement (distance)	500m	1000m	1 500m		
Degree of risk	0.8	0.4	0.2		
Population density Person/Km^2	<100	100-200	200-300	300-400	>400
Degree of risk	0.5	0.3	0.2	0.1	0.05

Determination of factor weights by AHP technique

Weights of the factors can only be qualitatively analyzed by experts' opinions initially. AHP technique was adopted to evaluate weight more objectively and accurately as a practical way in which quantitative and qualitative analyses are adequately integrated into a model for investigations of soil erosion. Complex problem is usually decomposed to several layers corresponding to different factors by analysis, judgment and synthesis process. The layers of the factors were placed orderly and different weight of factors can be decided synthetically. The hierarchy of the factors was established to soil erosion. The factors and their significances were compared difference between their levels of importance by numbers 1-9 to indicate differences with reciprocals of those numbers are specified to comparisons with an inverse order of those mutually compared factors (Table 17). Number 1 means that levels of equal importance of both factors while number 9 means level of importance of first factor is extremely higher with respect to second factor. If the number seven is assigned for the level of importance comparisons of C_1 to C_7. It is believed that the level of impotence of C_1 is significantly higher than that C_7 while 1/7 is given to the importance comparisons of C_7 to C_1.

Table 17 Continuous Rating Scale for Pairwise Comparison

Descriptions	Scale
Equally preferred	1
Equally to moderately	2
Moderately preferred	3
Moderately to strongly	4
Strongly preferred	5
Strongly to very strongly	6
Very strongly to preferred	7
Very strongly to extremely	8
Extremely preferred	9

Source: Saaty, T. L. (1980) The Analytic Hierarchy Process, McGraw Hill International

Weights of factors consisting of the components of the eigenvector corresponding to the maximum of eigen values of the synthesizing judgment matrix is shown in the Table 18 and hierarchy of factors for soil erosion is shown in Figure 14. The consistency test can be performed by examine total ratio CR_{total}:

$$CR_{total} = \frac{CI_{total}}{RI_{total}} \quad (13)$$

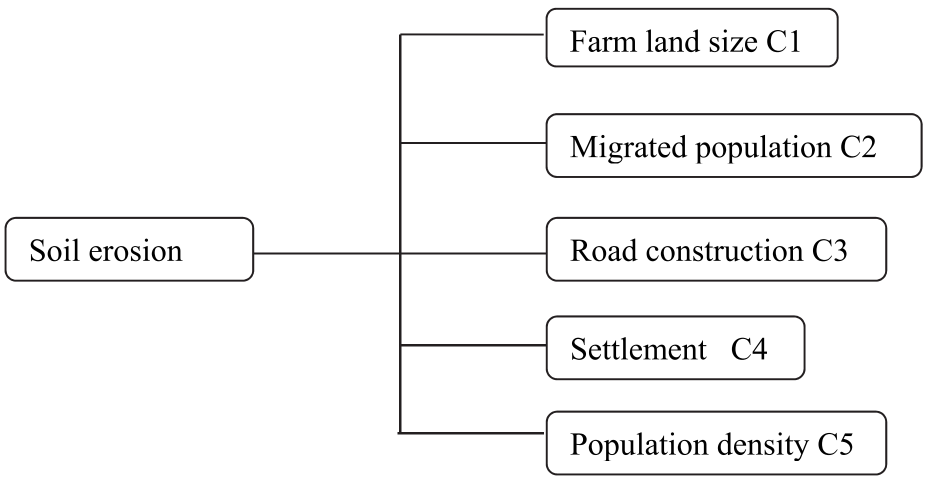


Figure 14 Hierarchies of Factors for Soil Erosion

Table 18 Synthesizing Judgment Matrix of Soil Erosion (after Calibration and Validation)

A	C1	C2	C3	C4	C5	W
C1	1	3	4	5	7	0.464218
C2	1/3	1	4	5	7	0.296124
C3	1/4	1/5	1	3	5	0.13331
C4	1/5	1/5	1/3	1	3	0.0700058
C5	1/7	1/7	1/4	1/3	1	0.0363433

Note: The maximum Eigen value λ_{max}= 5.36442, the consistency index CI = 0.0911053, the random consistency index RI = 1.32, and the consistency ratio $\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = 0.069$.

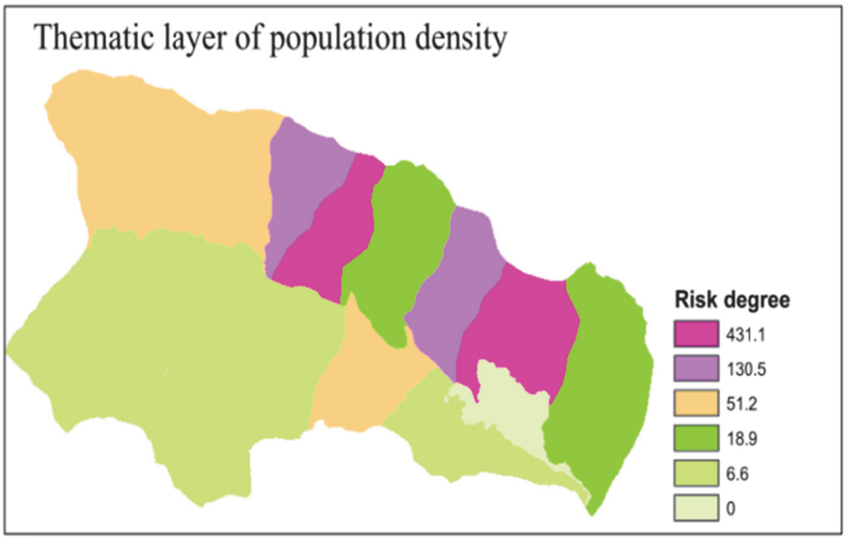
$$CI_{total} = \sum_{j=1}^{5} W_j CI_j \quad \text{and} \quad RI_{total} = \sum_{i=1}^{5} W_i CI_i \qquad (14)$$

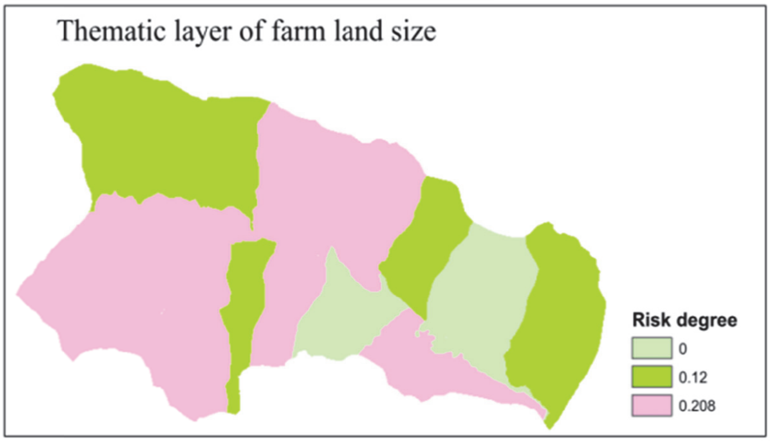
The five thematic layers each of which represent one of those factors as soil erosion by water were superimposed by implementing synthesis assessment model using space analysis function of raster calculator. The average random consistency is given as in Table 19.

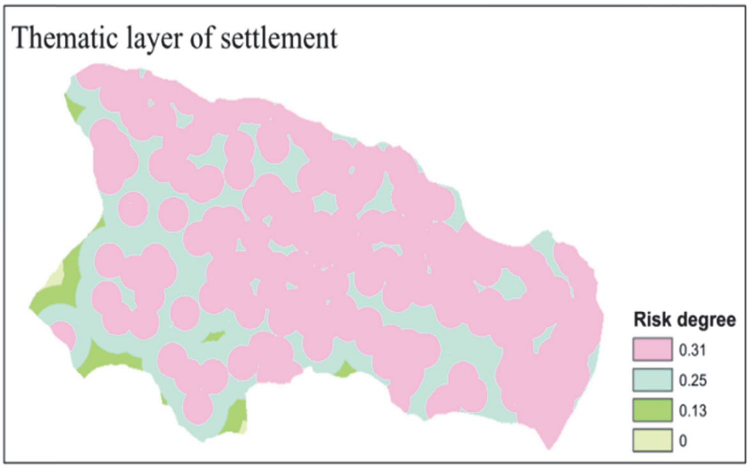
Table 19 Average Random Consistency Index (RI)

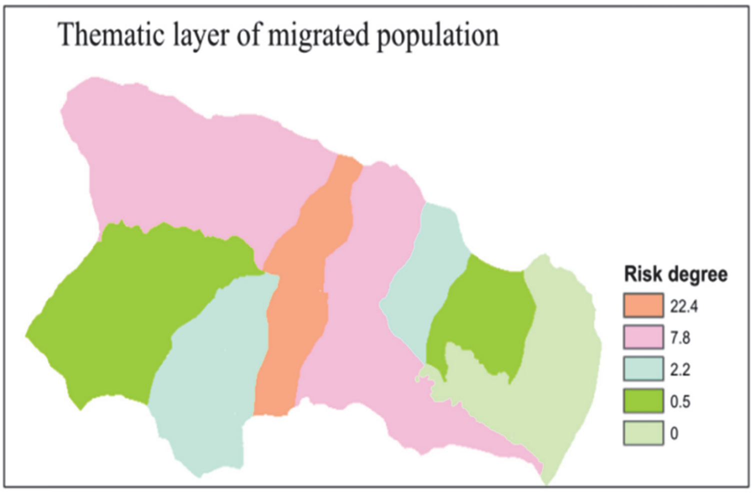
N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Adopted from Permadi (1992)




Thematic layer of farm land size
Risk degree
0
0.12
0.208


Thematic layer of settlement
Risk degree
0.31
0.25
0.13
0


Thematic layer of migrated population
Risk degree
22.4
7.8
2.2
0.5
0

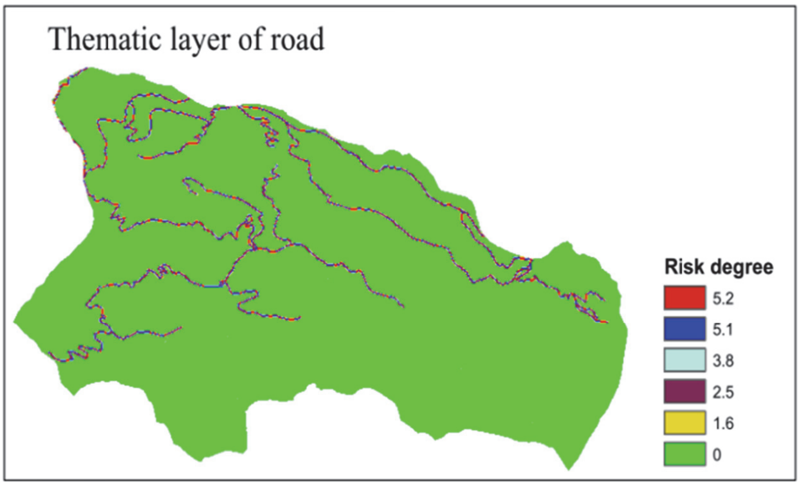


Figure 15 Thematic Layers of Degrees of Risk of a Single Dominating Factor for Soil Erosion

Risk index S ranges were determined based on frequency distribution of soil erosion. Initial pattern model parameters including weights W_i and degree of risk Si were examined to make soil erosion relatively consistent with field observed soil and. The soil erosion levels (6) were performed for comparison between the simulated degrees of soil erosion and field observe degree of soil erosion.

4.1.6 Model Creation and Construction

Each of five thematic layers represent one of those factors were superimposed in synthesis assessment model using space analysis function of map GIS to get soil erosion by water.

Table 20 Degrees of Risk on Soil Erosion, Corresponding Risk Index Ranges and Descriptive Classification

Erosion degree of risk	Risk index S ranges	Descriptive classification
Degree 6	$S > 3.878$	Very severe
Degree 5	$2.561 < S \leq 3.878$	Severe
Degree 4	$1.854 < S \leq 2.561$	High
Degree 3	$1.254 < S \leq 1.854$	Moderate
Degree 2	$0.699 < S \leq 1.254$	Low
Degree 1	$0.019 < S \leq 0.699$	Very low

Risk index values and cut off values were calculated for soil erosion risk level based on frequency distribution analysis. In all, six levels or degrees of risk on soil erosion were demarcated in Table 20 and in figure 16. A degree of risk on soil erosion map was generated. The comparative weights W_i and degrees of risk S_i were only preliminarily assigned in the initial predictive soil erosion assessment model.

As a result, to make soil erosion relatively consistent with field observed soil and initial pattern model parameters including weights W_i and degree of risk S_i were examined. The soil erosion levels (6) were performed for comparison between the simulated degrees of soil erosion and observe degree of natural soil erosion.

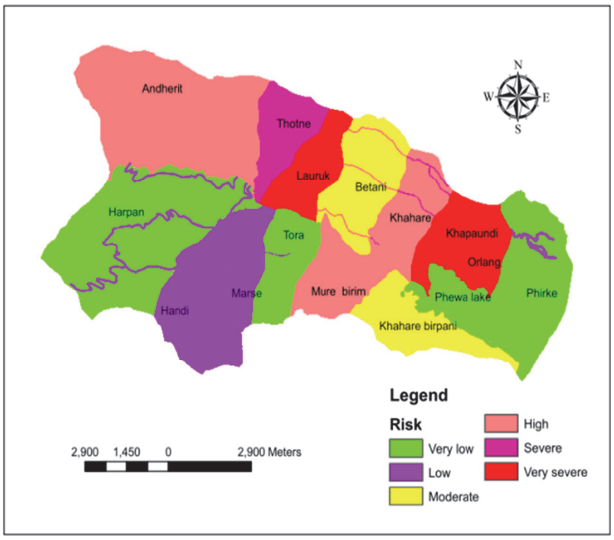


Figure 16 Soil Erosion of Socioeconomic Risk in Sub Watersheds of Phewa Watershed, 2010

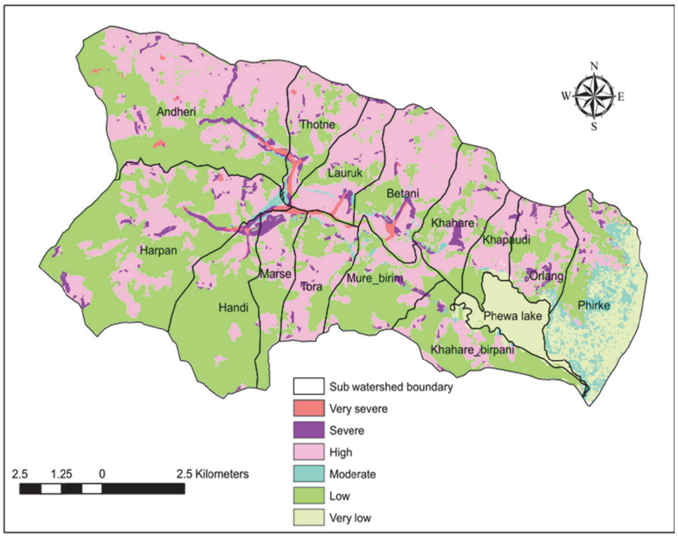


Figure 17 Soil Erosion of Natural Risk in Sub Watershed of Phewa Watershed, 2010

Overall, complete matching between the observe degree of natural soil erosion and simulated erosion degrees at 95% target points was targeted and final calibrated model was as shown below:

$$S = \sum_{i=1}^{n} W_i \times S_i = 0.464S_1 + 0.296S_2 + 0.133S_3 + 0.07S_4 + 0.036S_5 \quad (15)$$

Where, S_1–S_5 represents degrees of risk on soil erosion by water with regard to size of farm land, migrated population, road construction without conservation, settlement and population density respectively. Statistically 95% confidence interval for accuracy was expected using the calibrated model because of overall 95 matching was targeted.

4.2. Result and Discussion

The initial model has certain error due to the degrees of risk Si and comparative weights Wi which were determined by involving certain subjective components. The initial model was following by two essential modeling step model calibrations and validation. The high risk area should be emphasized for matching between observed and simulated degree of risk. In fact, model construction is an iterative process but current model is achieved based on limited field data and compare with the model run on RUSLE. Further refinement may be needed if more field data are available.

The proposed approach was applied for general idea not specific result of risk assessment due to lack of precise field data because of the factors may differ and the corresponding comparative weight W_i and degree of risk S_i need to be determined on the site condition. The risk area was validated in natural soil erosion risk map generated by EDA method to compare with risk map of socioeconomic factors. The 14 sub watershed situation was distinguished by the comparison socioeconomic and physical factors map. Soil conservation measure will prepare on the basis of factors effect on soil erosion risk.

Two maps (Fig 16 and 17) showed that the natural risks map and socioeconomic risk map and compared. Some sub watershed showed similar risk but some sub watershed were different it means that socioeconomic data has not represent all spatial location. So it should be revivified and direct for the analysis of the causes of soil erosion concept and measurement to represent the watershed. The statistical methods were used to find the other hidden factors which can't show in map. So, PGIS map, socioeconomic map, natural risk map of soil erosion and statistical calculation help to find out the conservation of soil erosion in the watershed. The next step is the PGIS for the soil erosion mapping for the real understanding to the stakeholder. Socioeconomic conditions for the soil erosion make the brain storming for the causes of soil erosion. The density of population and migrated population could not be precisely represented spatially and size of the land survey could not be done in plot level only percentage of the land size was used due to the time frame which also could not relate the problem precisely. This socioeconomic data representation could be effective in the further improvement of the data representation precisely for spatial location. Sub watershed such as Phirke, Handi, Khahare/Birpani and Khapaundi has similar result as the RUSLE model (natural risk) and socioeconomic model other sub watershed in table 21 and figure18 shows as follows:

- Tora, Harpan and Marse showed low in socioeconomic but moderate in RUSLE.
- Mure/Birim lies on the high risk in socioeconomic but very low in RUSLE.
- Thotne showed the severe in socioeconomic but high risk in RUSLE.
- Khahare, Andheri, and Betani showed the highest degree of risk in RUSLE but high and moderate in socioeconomic model.
- Orlang showed severe in socioeconomic but moderate/high in RUSLE model.
- Lauruk showed in very severe in socioeconomic but, it is severe in RUSLE.

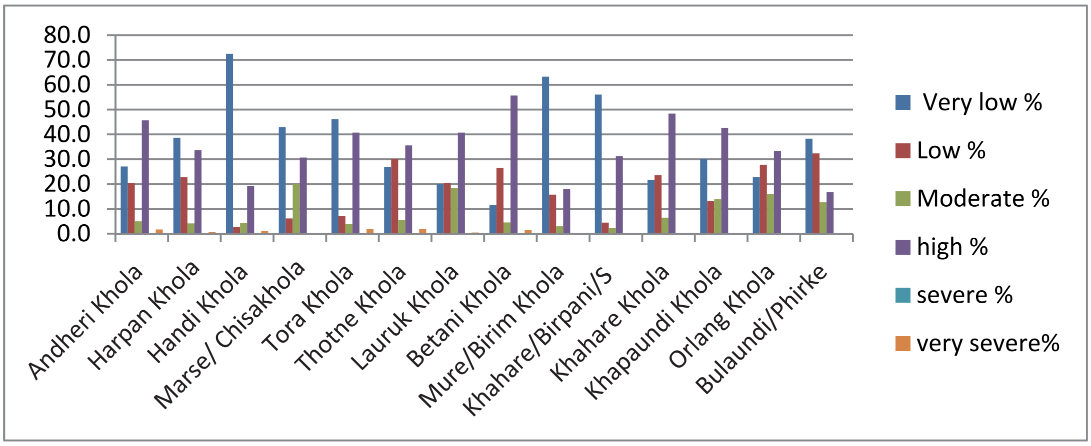


Figure 18 Soil Erosion Risk in Sub Watershed of Phewa Watershed in 2010

Table 21 Soil Erosion Risk in Sub Watershed of Phewa Watershed in 201

	Sub watershed area	Very low	%	Low	%	Moderate	%	High	%	Severe	%	Very severe	%
Andheri (ha)	2081.6	563.0	27.0	426.4	20.5	103.8	5.0	951.1	45.7	1.9	0.1	34.9	1.7
Harpan (ha)	2142.1	827.8	38.6	487.9	22.8	88.4	4.1	722.1	33.7	1.4	0.1	14.8	0.7
Handi (ha)	1062.1	769.4	72.4	29.7	2.8	46.6	4.4	204.9	19.3	0.5	0.0	11.1	1.0
Marse/chi (ha)	398.6	171.2	42.9	24.5	6.1	80.2	20.1	122.2	30.7	0.0	0.0	0.0	0.0
Tora (ha)	488.2	225.5	46.2	34.2	7.0	19.3	4.0	198.9	40.7	1.5	0.3	8.9	1.8
Thotne (ha)	444.1	119.7	27.0	133.8	30.1	24.3	5.5	157.9	35.6	0.5	0.1	8.6	1.9
Lauruk (ha)	687.8	137.2	19.9	140.8	20.5	126.5	18.4	280.0	40.7	0.1	0.0	3.2	0.5
Betani (ha)	867.8	100.4	11.6	230.3	26.5	39.2	4.5	483.2	55.7	1.4	0.2	13.1	1.5
Mure/Birim(ha	458.6	290.0	63.2	72.1	15.7	13.8	3.0	82.9	18.1	0.0	0.0	0.0	0.0
Khare/Birpani/	504.6	282.8	56.0	22.6	4.5	11.3	2.2	157.7	31.2	0.0	0.0	0.0	0.0
Khahare (ha)	481.1	104.5	21.7	113.4	23.6	31.0	6.4	232.6	48.4	0.0	0.0	0.0	0.0
Khapaundi(ha)	369.9	111.4	30.1	48.6	13.1	51.3	13.9	157.9	42.7	0.0	0.0	0.0	0.0
Orlang (ha)	575.7	131.7	22.9	159.8	27.7	91.9	16.0	192.1	33.4	0.0	0.0	0.0	0.0
Bulau/Phirke	1285.9	492.4	38.3	415.6	32.3	162.5	12.6	215.6	16.8	0.0	0.0	0.0	0.0

Overall analysis showed that Mure /Birim, Tora, Betani and Orlang have some different in risk level but in other sub watershed nearly same to both model. The region of the different social and natural risk is due to the pixel based calculation in RUSLE but socio economic model is in sub watershed level. The fusion of these two models by participatory GIS could represent the sustainable management of soil erosion by natural and socioeconomic factors.

4.2.1 Weight Criteria

The questionnaire and focus group discussion and the key informants' interview showed that the following 5 factors out of 21 factors influenced in soil erosion process. These five criteria were arranged in hierarchy for the AHP calculation by the pair wise comparison method to get the appropriate weight for each factor. The weight, maximum Eigen value and CI value were calculated in the open software CGI. All factors were calculated in Arc GIS software in raster calculator. The criteria defined on the basis of combination of expert opinion, stakeholder's opinion and literature review.

1. Farm land size

Farmers who has the marginal land for their work has to think for the alternative income source either use of natural resources or migration for job. Old men and women population stay at home and their working hour in the conservation is less. Many conservation measures such as terraces become impractical when the land is held in small and scattered parcels. This is due to the social and cultural tradition in the study area. Land is divided to family member after the separation from joint family to single family.

Farm size					Weight (Eigen vector)
	0-0.2ha	0.2-0.5ha	0.5-2ha	>2ha	
0-0.2 ha	1	3	5	7	0.565009
0.2-0.5 ha	1/3	1	3	5	0.262201
0.5-2ha	1/5	1/3	1	3	0.117504
>2ha	1/3	1/5	1/3	1	0.055285

Maximum Eigen Value =4.11698 C.I. =0.0389941

2. Migrated Population

Soil conservation work needs the building and maintenance of the terrace for the growing of additional soil perspective crops in rotation and it needs extra labor. Erosion conservation depends on whether the farmer and associated family member can meet the increased labor demand for likelihood of soil conservation measure adaptation (Stocking and Abel, 1992). House hold survey showed that the 90 percent farmers did not have the labor resource to implement the measures. Young men are going to the towns or foreign country to secure additional sources of income. An inadequate workforce is left behind on the farm comprising grandparents whose working life over and young women whose working time limited by duties of housekeeping and child bearing.

Population						Weight (Eigen vector)
	0-10 %	10-20%	20-30 %	30-40%	>50%=50	
0-10 %	1	1/3	1/5	1/7	1/9	0.0333352
10-20%	3	1	1/3	1/5	1/7	0.0633765
20-30%	5	7	1	1/3	1/5	0.128976
30-40%	7	5	3	1	1/3	0.261499
>50%=50	9	7	5	3	1	0.512813

Maximum Eigen Value =5.23748 C.I. =0.0593688

3. Road Construction without Conservation

The rough road construction using excavator increases the soil erosion in mountain. This practice increases the soil erosion forming the more rills and gullies. Roads, tracks and paths can contribute up to half of the total sediment yield in forested catchments (Reid et al. 1981). Cut slopes are particularly vulnerable up to ten times more erodible than fill slopes (Riley 1988). During the construction phase of road results higher volume of peak runoff, shorter times to peak flow and rapid increases in erosion by overland flow, rills and gullies, producing high sediment concentrations. The place where is not put adequate protection measures the increase runoff can enlarge the channel into gully, which over time will extend back upslope and damage the road (Nyssen et al.2002).

Road						weight
	10m	20m	30m	40m	50m	
0-10m	1	3	5	7	9	0.512813
20 m	1/3	1	3	5	7	0.261499
30 m	1/5	1/3	1	3	5	0.128976
40m	1/7	1/5	1/3	1	3	0.0633765
50m	1/9	1/7	1/5	1/3	1	0.0333352

Maximum Eigen Value =5.23748 C.I. =0.0593688

4. Proximity to Settlement

The settlement near by the forest could degrade the land due to the livestock and agricultural activities. The population growth increases the activities in forest and agricultural land which ultimately increase the soil erosion.

Settlement				Weight
Distance from forest	500m	1000m	1500m	
500m	1	3	5	0.636986
1000m	1/3	1	3	0.258285
1 500m	1/5	1/3	1	0.104729

Maximum Eigen Value =3.03851 C.I. =0.0192555

5. Population Density

Higher the population density then higher the pressure on for agriculture land and use of the natural resource .This will increase the soil erosion.

Population Person/Km^2						Weight (Eigen vector)
	<100	100-200	200-300	300-400	>400	
<100	1	1/3	1/5	1/7	1/9	0.512813
100-200	3	1	1/3	1/5	1/7	0.261499
200-300	5	7	1	1/3	1/5	0.128976
300-400	7	5	3	1	1/3	0.0633765
>400	9	7	5	3	1	0.0333352

Maximum Eigen Value =5.23748   C.I. =0.0593688

4.2.2 Socioeconomic and Conservation Determinants of Soil Erosion

Socioeconomic variables are important determinants of soil erosion (Shahriar et al., 2008). So, soil and water conservation planning could be made on the basis of socioeconomic considerations and assessments. Multiple regression analysis technique was employed to understand the major socioeconomic factors contributing to soil erosion in the study area. Multiple regression analysis is one of the multivariate statistical analysis techniques, which can predict changes in the dependent variable in response to several independent variables (Hair et al., 1992). The average rate of soil erosion was identified at sub watershed locality from the generated soil erosion map. The average rate of soil erosion was considered as the dependant variable (Y). Twenty one socioeconomic covariates or independent variables were used in this study to present the full spectrum of conditions for soil erosion in the watershed as described below.

X_1. Household size: Soil conservation depends on the labor availability. The larger family member has more labor than the small family and possibility of future farmer will get more benefit from the conservation investment (Featherstone and Goodwin, 1993).

X_2. Farm labor: The economically active age is 15-64 years in Nepal. Children below 15 and adult above 64 years are dependent. If the dependency ratio is higher then it will have negative affect the soil conservation activities

X_3. Education: Higher level education influences the level of awareness, increase the ability of understanding and utilize the information related to soil conservations measure. (Pender and Kerr, 1998).

X_4. Security of tenure: If farmers have their own farm land, they will invest in the conservation measures than land use in lease. They will not invest in soil conservations measure because of property right to provide individual security of land. (Asrat et al., 2004).

X_5. Land conversion: Agriculture land is more intensive land than natural landscape for soil erosion. Land conversion into agriculture land increases the erosion. Agriculture land has been greatest land transform. World's one third of land is occupied by the crops and grazing (FAO, 2004).

X_6. Conservation cost: If the willingness is higher to invest for soil conservation then the erosion is lower and vice versa (Illukpitiya and Gopalakrishanan, 2004).

X_7. Training: Farmers with training can manage soil and water conservation properly than the farmers without training.

X_8. Indigenous Knowledge: The cropping pattern learns from the elders, practical knowledge and experience learning from the elders lead to increase or decreased erosion. X_9. Memberships in organizations and committees: Knowledge gained from soil and water conservation committees could help to reduce soil erosion (Shahriar et al., 2008).

X_{10}. Professional competencies: Professionals officer with high level experience have much impact on the soil erosion than the ordinary member. High level experience professional committee can help to reduce the soil erosion (Shahriar et al., 2008).

X_{11}. Access to extension officers: Suggestion from the agriculture officer could help for better soil erosion management on farmers land. (Shahriar et al., 2008).

X_{12}. Transportation potential: Transportation networks access to farmlands could induce farmers to adopt soil conservation practices.

X_{13}. Distance: If the farm land near from house and road soil and water conservation will be more effective than far distance farmland.

X_{14}. Awareness of policies: The reliable policies and that may lead to better land use practices which decreases soil erosion.

X_{15}. Farm size: The fragmentation of farmland has its own negative effects to implement soil and water conservation measures. As farmers noted during discussion, constructing terraces or bunds on these small sized farmlands is believed as adding another problem greater than erosion problems. Small and fragmented farm land increases the soil erosion**.**

X_{16}. 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. In addition, permanent migration to urban area mainly in Pokhara has been a continuing process employment opportunities and for comfortable.

X_{17}. Live stock Population: the income sources of the small farmers are the livestock which has the economic support for the farmers. It has negative as well as positive impact in the erosion .Increase in livestock will reduce the land cover vegetation and due to the organic fertilizer from the livestock increases the vegetation but the result will negative effects on the vegetation cover so the soil erosion will be increase due to the increase in live stock population.

X_{18} –X_{21}. 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. Healthy and wealthy farmer can invest for the soil erosion conservation than the sick and less wealthy farmers. (Ervin and Ervin, 1982).

First, the seventeen covariates were used for the bivariate correlation analysis. Following that, the correlated variables were used for the stepwise multiple regression analysis to eliminate the insignificant ($p<0.05$) variables and to select the most important variables determining soil erosion in a behavior model. Table 22 presents the variables with their scaling characteristics used in multiple regression analysis.

Table22 Description of Socio-Economic Variables in Regression Analysis

Variable name	**Value label**	**Value**	**Measurement level**
Dependant			
Y. Soil erosion rate		t/ha/yr	C
Covariates			
X_1. Household Size	1-30	Number	Discrete
X_2. Farm Labor	15-58 Years	Number	Discrete
X_3. Education	≥grade 6	Number	Discrete
X_4. Security of Tenure	0-0.2 ha	0.56	Continuous
	0.2-0.5 ha	0.27	
	0.5-2ha	0.12	
	>2ha	0.05	
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	1-10	Frequency/year	Discrete
X_8. Indigenous Knowledge on Soil Conservation	No	0	Continuous
	Very Low	.25	
	Low	0.5	
	Moderate	0.75	
	High	1	
X_9. Membership soil conservation organizations		Frequency/year	Discrete
X_{10}. Professional		Frequency/year	Discrete
X_{11}. Access to extension officer	No access	0	
	< once/week	0.25	
	Once/week	0.5	
	2-4 Day/week	0.75	
	> 4 Days/week	1	
X_{12}. Transportation potential to farm land	Very difficult to access	0	Continuous
	Difficult to access	0.33	
	Sometimes difficult to	0.66	
	Easy to access	1	
X_{13}. Distance to farm land		Km	Continuous
X_{14}. Awareness of policies (land/water/forest)	No	0	Dummy
	Yes	1	
X_{15}. Farm size	<0.2ha	0.25	Discrete
	0.2-0.5ha	0.5	
	0.5-2ha	0.75	
	>2ha	1	
X_{16}. Migration trend	0-10%	0.03	Discrete
	10-20%	0.06	
	20-30%	0.13	
	30-40%	0.27	

	>50%	0.51	
X_{17}. Livestock population	0-50	Number	Discrete
X_{18}. Financial capital(Rs) per year in thousand	0- 25	0.04	Continuous
	25-50	0.06	
	50-75	0.2	
	75-100	0.3	
	100-150	0.4	
X_{19}. Farm income(Rs) per year in thousand	0-20	0.04	Continuous
	20-40	0.06	
	40-60	0.2	
	60-80	0.3	
	80-100	0.4	
X_{20}. Total household Income(Rs) per year in thousand	0-50	0.04	Continuous
	50-100	0.06	
	100-150	0.2	
	150-200	0.3	
	200-300	0.4	
X_{21}. Farm expenditure(Rs) per year in thousand	0- 25	0.04	Continuous
	25-50	0.06	
	50-75	0.2	
	75-100	0.3	
	100-150	0.4	

The relations between socioeconomic, conservation variables and soil erosion were examined. It was found that all 21 covariates presented in Table 22. 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 18 covariates were included as predictor variables of soil erosion in the final regression model given in the following equation.

$$Y=9.87-0.077X_1-0.671X_2-6.533X_3-1.1413X_6-4.138X_7-0.247X_9+0.067X_{13}+0.538X_{15}-7.35X_{16}-1.413X_{19} \quad (16)$$

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_{15}=Farm land size, X_{16}= Migration, X_{19}=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 farmers get older, it is reasonable to assume that they pay less attention to long-term investments but may still be interested in agricultural activities which do not harm the environment. 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. 90% of respondents reported yearly expenses for soil conservation. 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.

4.2.3 Stakeholders' Perception of Soil Erosion

People well managed common resources such as community forests and open lands than under governments (Ostrom, 1990). Consideration of stakeholders' perception is thus an essential factor when making decisions. Direct and indirect causes of various soil erosion types were assessed based on the results of the questionnaire survey the impacts of soil erosion on ecosystems, the effectiveness of adopted soil conservation measures and the cost of soil conservation measures.

The household survey showed that the six major direct causes of soil erosion: improper soil erosion management and crop management practices, deforestation, urbanization, natural causes (Figure 19). High soil erosion is due to the improper soil management practices like cultivation of unsuitable soils, lack of conservation measures and improper tillage management.

Direct causes of Soil Erosion

The stakeholder respondents of 36% perceived that soil erosion rate high due to improper soil management practices and inappropriate tillage practices.

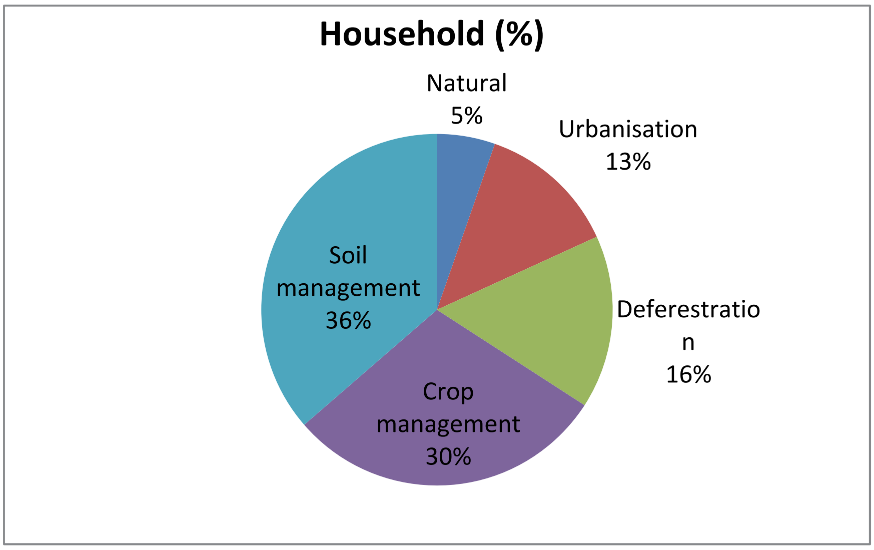


Figure 19 Perceptions on Direct Causes of Soil Erosion

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, and deforestation due to community forest, development of infrastructure like road 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. No other significant earth-slip has occurred thereafter in this sub watershed.

Indirect Causes of Erosion

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, such as introduction of unsuitable alien trees species to the hill slopes areas 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.

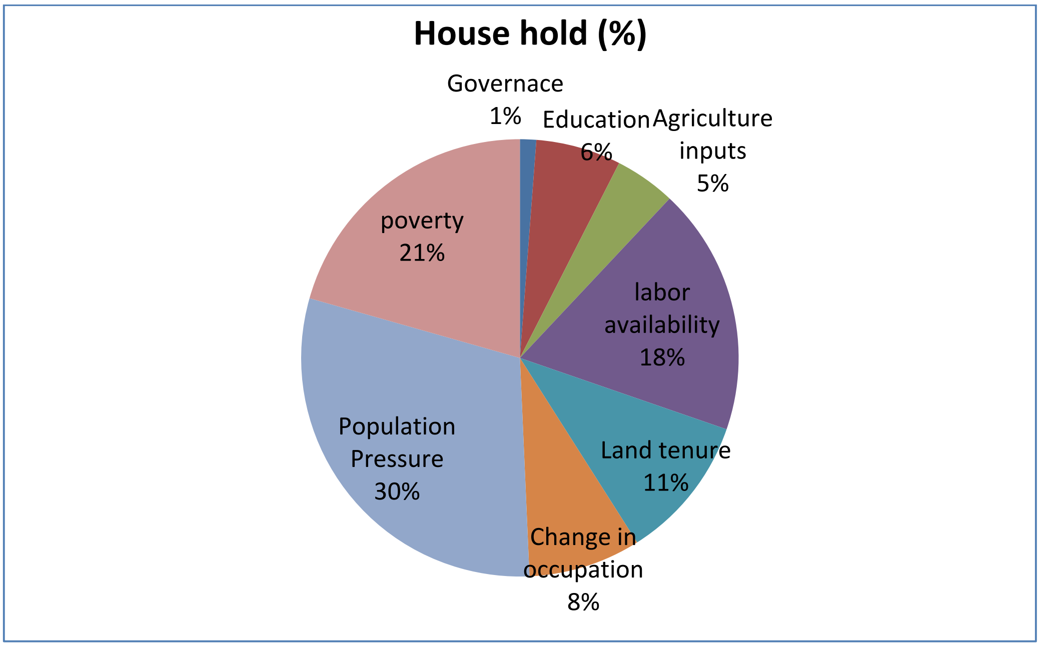


Figure 20 Perceptions on Indirect Causes of Soil Erosion

According to 20 % of respondents, education, change in occupation agricultural inputs and governance were also indirect causes of soil erosion

4.3 Conclusion

The soil erosion risk generated was compared with the soil erosion risk area mapped by the stakeholder perception using AHP. Stakeholder's perception and socio economic data represent the limited knowledge of the soil erosion factor and could not spatially map precisely factors affecting soil erosion including slope, type of the soil and conservation practices, effects on their terrace cultivation and other areas of the watershed. It could not locate all possible erosion prone area this model only showed to the stakeholders' perception and to make understand about the causes of socioeconomic factors soil erosion effects on their farm land. The gap in socioeconomic risk and natural risk could be filled up by PGIS methodology. PGIS map and GIS technology could help to stakeholders understanding about the soil erosion and mange for soil conservation activities in right way. The result of the correlation and regression models showed that soil erosion reduction was significantly influenced by education, farm size, occupation and professional maternal group and forest group. RUSLE model showed the soil erosion risk area which was more different from the stakeholders sketch could correct with knowledge gained from PGIS and GIS technology for their conservation practices in those areas to reduce the soil erosion. Participatory GIS map prepared by the stakeholder's focus group discussion could be corrected and fused the knowledge from the socioeconomic factors of soil erosion and the natural risk factor for soil erosion map and make final map for the soil erosion and could aware to all stakeholders for the conservation practices. Technical and policy support to the stakeholders and their participation on the mapping were recommended as their participation could help the sustainable soil reduction in Phewa watershed. The research findings could lead to possess an important policy implication for soil erosion reduction through participation of all the stakeholders.

CHAPTER V

5. Land Use Land Cover Change Impact on Soil Erosion Assessment

5.1 Background

LULC change reflects socioeconomic conditions. Generation of accurate map for high environmental risk and develop adequate risk prevention measures is important in GIS context. Studies showed that LULC change poses significant environmental impacts on soil and water quality (Lambin, Rounsevell and Geist, 2000; Schwab,1993). Two categories for LULC change are direct and indirect diving forces. Direct driving forces include the immediate actions of local people to fulfill their needs from land use (Geist and Lambin, 2002), such as agricultural expansion, wood extraction, infrastructure expansion (Meyer, 1995) and indirect driving forces are fundamental socioeconomic and political processes that 'push' direct causes into immediate action on LULC (Geist and Lambin, 2002). Underlying driving forces include demographic pressure, economic status, technological and institutional factors, and can influence LULC in combination (Geist and Lambin, 2002).

Many factors influenced soil erosion on research point of view plant cover and land use indicators affecting the intensity of soil erosion (Mohammad and Adam, 2010). Land use change such as deforestation, encroachment of agricultural interests and other causes for the loss of land cover material increased soil erosion. Increase in forest or vegetation area can potentially reduce the amount of soil loss. Erosion rates in the middle mountain region were increased due to deforestation, agricultural expansion, excessive grazing and road networks without conservation measures (Ives and Messerli, 1989; Thapa, 1990). Impact of land use changes help to assess the soil erosion risk, and analyze the impact of land use changed on soil loss in the study area.

5.2 Methods

Erdas Imagine 9.2 was used as a tool for classifying LULC. The database was generated from the satellite images, published and unpublished records supported by primary data obtained from field observation. Two satellite imageries Landsat TM (1995 and 2010) were used to quantify the magnitude and rate of the change as well as the dynamics of major LULC types in the study area downloaded from GLCF website. Methodological flow chart for impact of LULC change in soil erosion is illustrated in figure 21. A detail process is described in proceeding section.

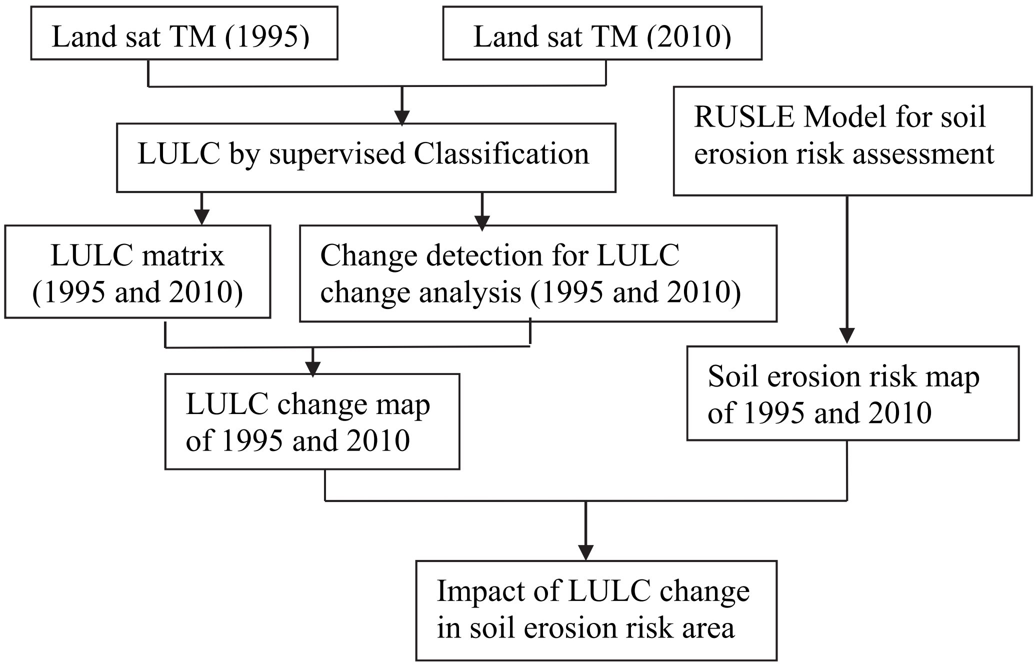


Figure 21 Flow Chart of the Impact of LULC Change in Soil Erosion

Topographic map of 1:25 000 scale was taken from survey department of Nepal government for supervised classification and to assure the rectification of imageries. Garmin GPS were also employed to collect Ground Control Points (GCPs) to aid different steps of image processing and classification for change detection.

5.2.1 LULC Determination and Training Site Selection

Field data collection was conducted in January 2011 for the ground truthing to know the specific characteristic of study area. Topographic map of 1:25 000 scales provided the general overview of the study area. LULC classes were selected from expert's opinion and literature review of the major land features. The different LULC classes such as dense forest, open forest, bush, terrace cultivation, single crop, double crop, barren land, grass land, water bodies, built up and wet land were identified and their coordinate were recorded with a Garmin GPS device to support for the accuracy analysis of classified image.

5.2.2 True and False Color Composite Image Preparation

The image was changed into false color composite to improve the visualization of the image for the prospected classification. LULC features identification and training site selection for supervised classification were used according to the application of each color composite. In this study different false color composite of Landsat TM band (4, 3, 2) and RGB were employed (Figure 22 and 23).

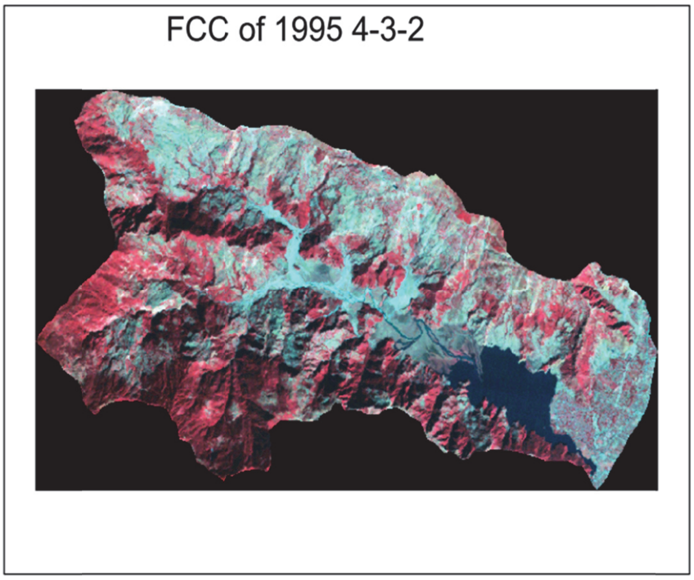


Figure 22 False Color Composite of the Image 1995

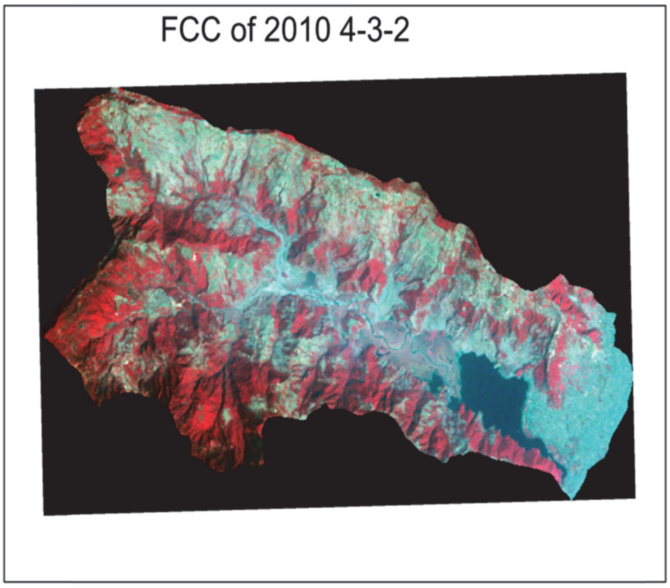


Figure 23 False Color Composite of the Image 2010

5.2.3 Image Classification

Digital image processing operations includes image preprocessing (rectification and restoration), image enhancement and image classification. A more faithful representation of the original scene was created by preprocessing to correct distorted or degraded data. Preprocessing involves raw image data processing to correct for geometric distortions, to calibrate the data radiometrically and to eliminate noise present in the data. Image enhancement is applied to image data for subsequent visual interpretation to display or record the data. Subtle variations in input image data values would now be displayed in output tones for more readily distinguished by the interpreter. Light tone areas would appear lighter and dark areas would appear darker.

Images were cross-referenced with ground truth, topographic map of 1:25 000 and other ancillary data to make the classification as accurate as possible. A nonparametric signature was used based on an Area of Interest (AOI) that defines the specific feature on the image file being classified. The classification has been done repeatedly to make the classification as accurate as possible. Accuracy assessment was applied after classification. Total 125 points field work data were used to validate the result of classification through the confusion matrix /error matrix. Confusion /error matrix consists of row and columns in which row and column represents classification value and fact value from the field respectively. Classified pixels were represented by the diagonal line of the error matrix. The overall accuracy was calculated from correctly classified pixel divided by total number of pixel checked. The producer accuracy index was produced by dividing the number of correctly classified pixels. Land use classes and validate points with coordinates in the text format were imported as true classes. The users' accuracy index was produced by dividing the total number of correct classified pixels that belongs to a class by the sum of the values of the rows of the same class. The confusion matrix was generated by giving the ground truth points from independent source. Accuracy was quantified by developing a confusion matrix for each image and computing the corresponding users' accuracy, producers' accuracy, overall accuracy and the kappa statistic of agreement.

5.2.3.1 Supervised Classification

Supervised classification is the process of using a known identity of specific sites (through combination of fieldwork, maps and personal experience) in the remotely sensed data, which represent homogenous examples of land overtypes to classify the remainder of the image. These areas are commonly referred to as training sites (Jensen, 1996). The maximum likelihood classifier assigns pixel with maximum likelihood into a corresponding class, which is one of the most popular methods of classification in remote sensing. Features can be seen in selecting the appropriate bands a particular image during classification. Table 23 explains the features of the Landsat TM bands for detecting different features.

Table 23 Landsat Image Spectral Bands and Reflectance

Band	Band Name	Application
0.45 – 0.56	Blue	Soil and vegetation discrimination
0.52 – 0.66	Green	Vegetation mapping and cultural/urban features
0.63 – 0.69	Red	Vegetated and non-vegetated mapping
0.76 – 0.90	NIR	Delineation of water body Soil moisture discrimination
1.55 – 1.75	MIR	Vegetation moisture discrimination Soil moisture discrimination
10.4 – 12.5	TIR	Vegetation and soil moisture analysis Thermal mapping
2.08 – 2.35	NIR	Discrimination of mineral and rocksVegetation and moisture analysis

Adapted from http://biodiversityinformatics.amnh.org

5.2.3.2 Accuracy Analysis

GPS points from the field were collected with references produced from map. The accuracy procedures involve the production of references from the field that evaluate the produced classification. This comparison produces an error matrix that is the basis for the accuracy verification process (Congalton, 1991). He also suggests that classes less than ten use from 50 to 60 reference points for the accuracy production. These points’ proportion may be differentiated due to the volume of area occupied by a certain class. In addition to the producer and user accuracy indices, there are other indices produced from the error matrix that involve more complex mathematical operations such as probabilities. One of these indices Kappa statistics enables a generalization of information that allows us to compare classifications produced from different images. According to Lilesand and Kiefer (2000) the minimum level of accuracy in the identification of land cover categories from remote sensor data should be at least 80 %.

5.2.4 Change Detection Methods

The state of an object or phenomenon difference is identified in the process of change detection by observing it at different times. Change detection is useful in land use change analysis, assessment of deforestation and other environmental changes (Bottomley, 1998). Many change detection methods have been developed and used for various applications. They can be broadly divided into post-classification and spectral change detection approaches (Singh, 1989).

5.2.4.1 Post-*Classification Approach*

Post classification is widely applied technique and numerous studies carried out using this technique. In this classification two images from different dates are classified and labeled. The area of change is then extracted through the direct comparison of the classification results. Main advantages of post-classification include: detailed "from to information'' (Chen, 2000). It omits the difficulties associated with the analysis of images acquired at different times of year or sensor. The main disadvantage of the post classification approach is the dependency of the land cover change results on the individual classification accuracies (Chen, 2000). Therefore, it is imperative that the individual classification be as accurate as possible.

5.2.4.2 *Spectral Change Detection Approach*

According to Chen (2000), a large number of techniques are in the spectral change identification category and it rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface. These techniques involve the transformation of the two original images into a new single band or multiband image, in which the area of spectral change is highlighted. Most of these techniques are based on image differencing or image rationing. Advantage of this technique is based on detection of physical changes between image dates. This avoids the errors introduced in post-classification change detection. However, the greatest challenge to the successful application of these techniques is the discrimination of "change" and "no change" pixels.

5.2.5 LULC Change

Satellite imageries Landsat TM (1995 and 2010) of the study area have been imported to ERDAS 9.3 software. Image pre-processing, enhancement, classification were applied on image. Information on land cover condition and quantification of change has been extracted from the classified image over the last one and half decades by using GIS analysis. Post classification comparison method has been applied for change detection and comparison of land cover conditions of two different periods (1995 and 2010). Finally, LULC changes and dynamics have been quantified. The structure of LULC change has been evaluated as in Figure 24.

Major LULC changes were discussed based on change comparison of each class. But this comparison did not provide information about which LULC class goes to where. Thus, change comparison matrix was employed and analyzed to understand the LULC dynamics for each period and whole study period. LULC conversion matrix used to analyze the source and destination of each cover type within the study period. The conversion matrix analysis was conducted in ERDAS 9.3 software and conversion comparison map prepared for (1995 and 2010) in such a way that the columns represented year of source and the rows represented year of destination. Finally, corresponding tables and figures were prepared using Microsoft excel sheet to make the result more explanation.

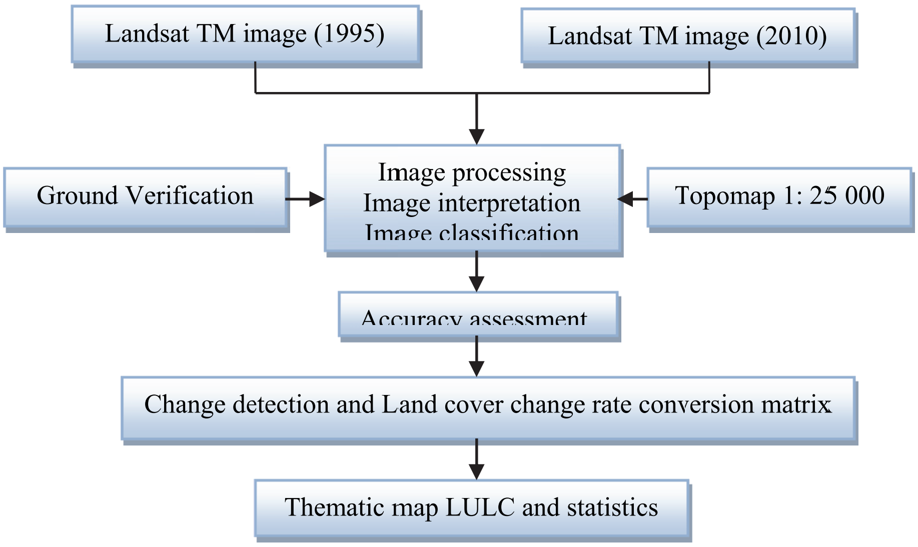


Figure 24 LULC Change Structure

5.2.6 LULC Change Detection Matrix

LULC of the two periods (1995 and 2010) was generated from the satellite imageries using a supervised maximum likelihood classification. Land cover change rate and LULC conversion matrix were employed to find the land cover change. The land cover maps of the two periods were analyzed based on rate of change. It provided trend of land use conversation in terms of time. But this comparison did not provide information about which LULC goes to where or the contribution of each LULC class for the change in spatial extent of the other. LULC dynamics comparison matrix was employed and analyzed for each period. LULC conversion matrix analysis conducted and conversion comparison map prepared for 1995 and 2010 in such a way that the columns represented year of destination and the rows represented year of source. Moreover, corresponding tables and figures were prepared to make the result more explanatory.

5.3 Result and Discussion

5.3.1 Image Classification

LULC maps of the study area were produced for each of the years 1995 and 2010. Kappa coefficient of overall classification was 0.86 and 0.87 for 1995 and 2010 (Table 3). The importance of the use of Kappa analysis for evaluating accuracy is that it provides a means to assess if a classified LULC map is significantly better than a randomly generated map (Pontius, 2000). The producer's accuracy shows that probability of a pixel location of a land use class is correctly shown on the map (Story and Congalton, 1986), ranged between 0.71 and 1.00. The user's accuracy shows that probability of a pixel location on the map correctly identifies the land use class location as in the field (Story and Congalton, 1986) ranged between 0.62 and 1.00 (Table 24). Grassland and waste land are the lowest accuracies among other class.

5.3.2 Accuracy Assessment

Accuracy assessment was applied after classification. Field work data 125 points were used to validate the result of classification through the confusion matrix /error matrix. Confusion /error matrix consists of row and columns in which row and column represents classification value and fact value from the field respectively. Correctly classified pixels were represented by the diagonal line of the error matrix. Overall accuracy was calculated from correctly classified pixel divided by total number of pixel checked. The producer accuracy index was produced by dividing the number of correctly classified pixels. Land use classes and validate points with coordinates in the text format were imported as true classes. The users' accuracy index was produced by dividing the total number of correctly classified pixels that belongs to a class by the sum of the values of the rows of same class. The confusion matrix was generated by giving the ground truth points from different source. Accuracy assessment showed overall classification accuracy 88 %, over all Kappa statistics 0.87 of image 2010 and 87.2% over all accuracy, over all Kappa statistics of 0.87 of image 1995 which are feasible for further application.

Table 24 Classification Accuracy of Classified Land Use

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Open forest	19	18	15	94.1	88.8	18	17	94.4	94.4
Single crop	13	13	12	92.3	92.3	13	12	92.3	92.3
Double crop	17	18	16	94.4	94.4	18	17	94.4	94.4
Wetland	4	5	4	100	80	5	4	100	80
Water bodies	10	8	8	80	100	8	8	80	100
Grass land	7	8	5	71.4	62.5	8	5	71.4	62.5
Terrace cultivation	19	17	16	88.8	94.1	17	16	88.8	94.1
Waste land	6	8	5	83.3	62.5	8	5	83.3	62.5
Bush	7	6	5	75	100	6	6	85.7	100
Barren land	7	7	6	85.7	85.7	7	6	85.7	85.7
Built-up	8	7	6	75	85.7	7	8	75	85.7
Dense forest	9	9	8	88.8	88.8	9	8	88.8	88.8
Total	125	125	108			125	125	108	
Overall classification Accuracy =87.2%						Overall classification Accuracy =88%			
Overall Kappa statistics = 0.86						Overall Kappa statistics = 0.87			

One possible reason for the misclassification of waste land is confusion between actual waste land, construction sites and cleared agricultural land. LULC classification was considered to be satisfactory based on the value of Kappa and overall accuracies 85% or more (Foody, 2002)

5.3.3. LULC Change Analysis

LULC change of the Phewa watershed is discussed below with cover change comparisons of each LULC type over the study years. LULC have undergone significant modifications and conversions over the study years (Figure 25, 26, 27 and Table 25). In 1995, terrace cultivated land, dense forest and open forest constituted a relatively large proportion (38.7 %), (26.59 %) and (13.21%) of the area. These data were considered as a baseline for change detection over the study years.

Table 25 Change of LULC for the Two Years

Classes	1995		2010	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Open forest	1693.5	13.8	2301.5	18.7
Single crop	494.5	4.0	253.4	2.1
Double crop	440.6	3.6	442.1	3.6
Built up	384.3	3.1	797.1	6.5
Water	469.2	3.8	444.2	3.6
Wetland	206.5	1.7	99.0	0.8
Bush	132.8	1.1	147.5	1.2
Barren	83.6	0.7	96.3	0.8
Waste land	162.5	1.3	165.3	1.3
Grass land	70.2	0.6	51.9	0.4
Terrace cultivation	4757.3	38.7	4634.9	37.7
DMF	3397.3	27.6	2859.1	23.3
Total	12292.30	100.0	12292.30	100.0

In 2010, the dense forest declined from 27.6 % to 23.3 %. Despite its relative large size, open forest increased 13. 8% to 18.7%. Double crop, grass land has shown a relatively small decline while built up has experienced an increment from 3.1% to 6.5% during this period. There was a continuous dynamics among LULC (Figure 20). Generally, the following major important changes were observed in the period considered. Firstly, deforestation occurs in all areas but especially occurs on the upper slopes. Secondly, the wetland has been converted to crop and grass land. Terrace agricultural area has been converted to land cover classes particularly waste land and open forest. The cultivated land such as double crop, single crop and terrace cultivated land changed into built up area. Moreover, urbanized settlements have also showed increment. Studies indicated that low productivity of steep slopes land and marginal lands basins were brought under cultivation and plain area near lake urbanized. LULC changes and socioeconomic dynamics have a strong relationship with change in cultivated land, grazing land, fuel wood, settlement, food, energy and livestock for increased population (Abate, 1994). The decrease in dense forest and the increase in population of watershed showed that the transformations of the land cover into land use which accelerates erosion of the watershed.

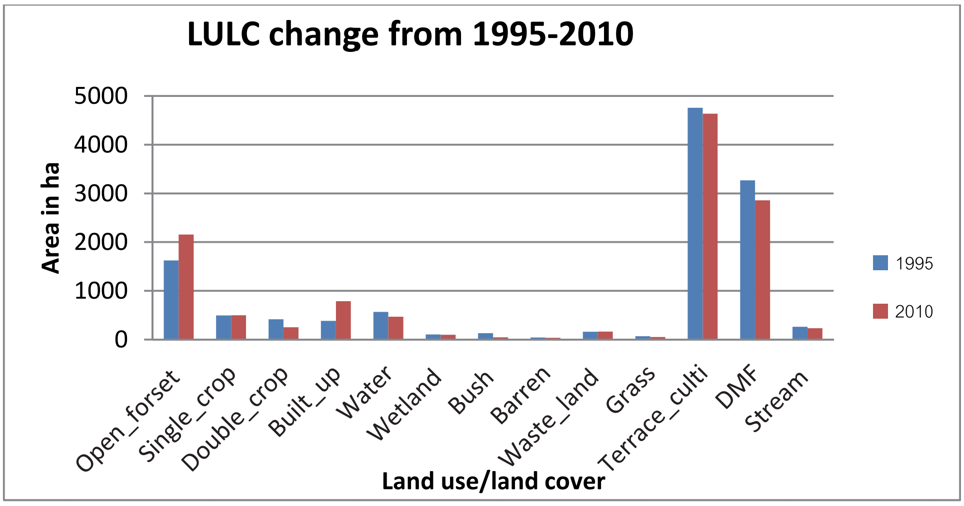


Figure 25 Change of LULC for Two Years.

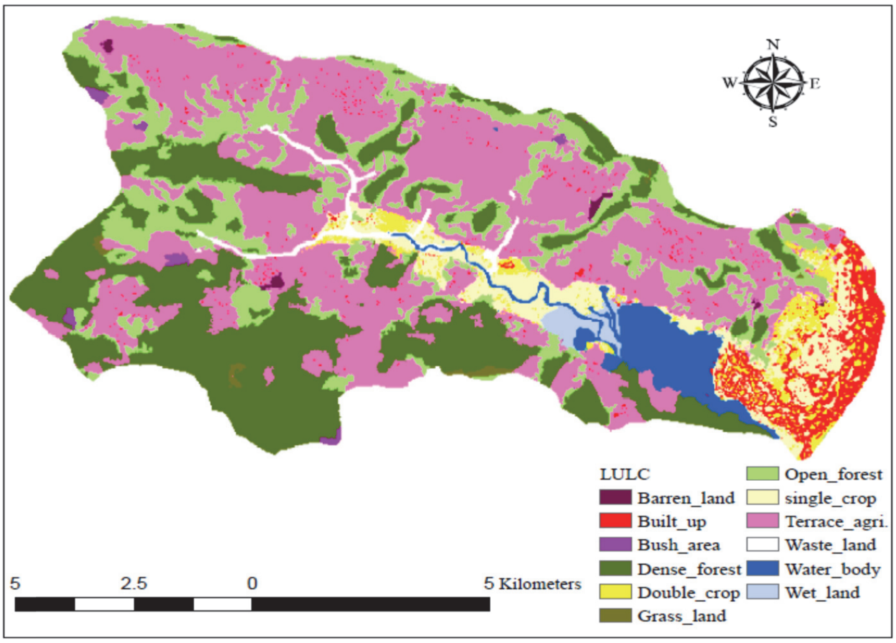


Figure 26 LULC Maps of 1995

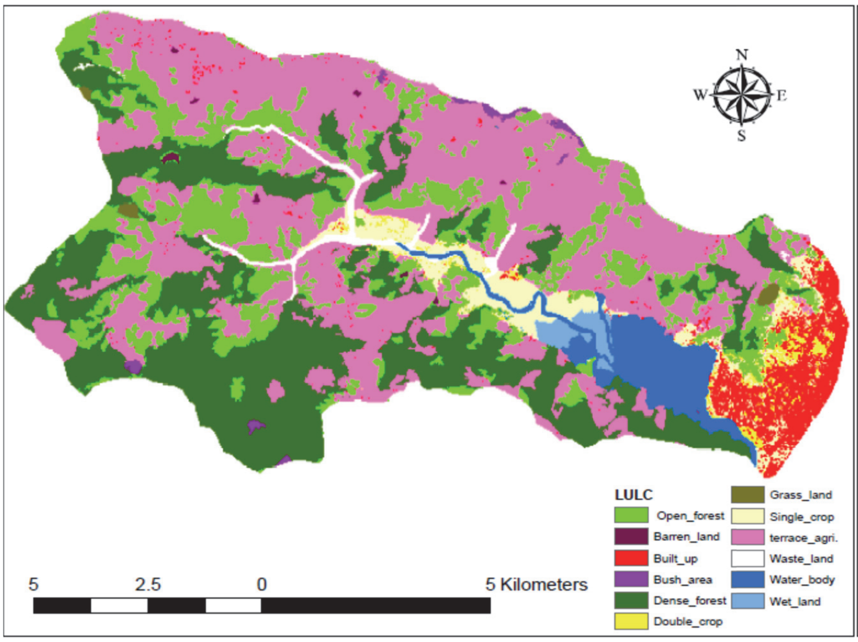


Figure 27 LULC Maps of 2010

5.3.4 LULC Matrix for 1995 and 2010

LULC change matrix of (1995–2010) for Phewa watershed is presented in Table 26. Result showed a significant LULC dynamics during the period (1995–2010). A considerable amount (547.5 ha) of the dense forest cover has changed to different LULC class including open forest (518.41ha) and terrace cultivated land (9.2ha), bush area (15.7 ha) which has resulted in overall reduction in the amount of forest cover. On the other hand the open forest covered an area of 1693.5 ha (13.8%) land in 1995 has exhibited an increment to 2301.5ha (18.7%) in 2010. The matrix result has shown the changes of LULC class in (1995-2010) as follows:

- open forest has acquired additional land area from dense mixed forest (518.41ha), terrace cultivation (96.7ha), grassland (5.5ha), waste land (2.4ha) single crops (6.5ha) and bush area (4.4ha) during this period
- Open forest has changed particularly to terrace cultivation (11.5ha), bush area (6.9ha), single crop (2.3ha) and dense mixed forest (2.7ha).
- Open forest has changed particularly to terrace cultivation (11.5ha), bush area (6.9ha), single crop (2.3ha) and dense mixed forest (2.7ha)

Table 26 LULC change matrix of (1995 – 2010) for Phewa watershed

		1995												Row total (2010)
		OF	DC	SC	BU	WB	WL	BA	BL	WAL	GL	TA	DF	
2010	OF	1665.3	0.4	6.5	0.4	1.1	0.0	4.4	0.5	2.4	5.5	96.7	518.4	2301.5
	DC	1.1	207.6	1.7	0.2	2.6	38.3	0.4	0.2	0.7	0.3	0.0	0.5	253.4
	SC	2.3	12.0	319.0	0.0	2.4	82.8	0.1	0.2	22.3	0.1	0.8	0.1	442.1
	BU	1.4	268.4	96.1	381.8	0.8	0.0	0.2	0.1	0.1	0.6	46.6	1.1	797.1
	WB	0.0	0.7	0.2	0.0	443.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	444.2
	WL	0.0	0.0	0.6	0.0	16.6	81.3	0.0	0.0	0.1	0.4	0.0	0.0	99.0
	BA	6.9	0.0	6.1	0.1	0.0	0.0	114.7	0.1	0.4	0.5	3.0	15.7	147.5
	BL	1.5	0.2	0.1	0.4	0.3	0.0	0.0	75.1	0.0	5.4	13.1	0.2	96.3
	WAL	0.6	4.1	7.9	0.4	1.4	0.5	2.1	3.3	132.3	0.2	11.1	1.5	165.2
	GL	0.3	0.2	0.1	0.0	0.4	2.3	1.9	0.2	0.0	45.5	0.3	0.8	51.9
	TA	11.5	0.7	1.4	0.1	0.5	0.7	8.7	3.1	4.0	10.7	4584.3	9.2	4634.9
	DF	2.7	0.3	0.9	0.9	0.1	0.4	0.5	0.9	0.3	1.1	1.4	2849.8	2859.1
Column total(1995)		1693.5	494.5	440.6	384.3	469.2	206.5	132.8	83.6	162.5	70.2	4757.3	3397.3	12292.3

WL =Wet land, BA= Bush area, BL= Barren land WAL=Waste land, GL= Grass land, TA= Terrace agriculture, DF = Dense forest

- Double crop land (286.91ha) has changed particularly to built-up (268.44ha), single crop (12ha) and waste land (4.1ha).
- Single crop (121.58ha) has been changed particularly to built-up (96.1ha), open forest (6.5ha), wasteland (7.9ha) and bush area (6.1ha).
- Wetland (125.1 ha) has been changed to single crop (82.8ha), double crop land (38.3ha) and grass land (2.3ha).
- Terrace cultivation (172.96ha) land has been changed into waste land (11.1ha), barren land (13.1), built up (46.6ha), open forest (96.7ha) and bush area (3ha).
- Waste land has changed into single crop land (22.3ha), terrace cultivation (4.ha) and open forest (2.4ha) out of (30.3ha) waste land.
- Built up, water body, bush area, barren land, and grass land have relatively small change.

5.3.5 Soil Erosion Risk Assessment

The soil erosion value estimated for 1995 and 2010 were reclassified based on degree of severity into six classes (Table 9).The spatial distribution patterns of the different erosion intensity classes for the different LULC class are shown in Figure 28 and 29, 30 and Table 27. Soil loss risk assessment in the study area by applying RUSLE model revealed that moderate soil loss risk category changes from 1995-2010 as below:

- Moderate soil erosion risk category (10-15 ta/ha/yr) decreased from 2058.32ha to 1207.96 ha area
- High soil loss risk category (15 - 25 t/ha/yr) increased from 2050.65 ha to 4304.25 ha area
- Very low soil loss class (<5t/ha/yr) decreased from 52.71% to 34.21% of the total area.
- Moderate soil loss (10-15t/ha/yr) decreased from 16.74% to 9.83% of the total area.
- Area of low class soil erosion risk (5-10 t/ha/yr) increased from 9.01% to 16.10 % of the total area.

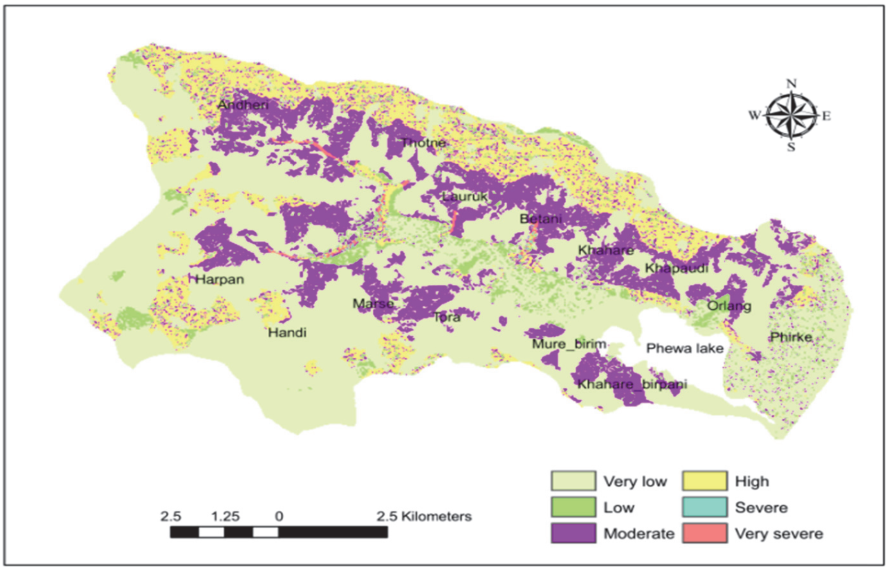


Figure 28 Distribution of Soil Erosion Risk in Phewa Watershed, 1995

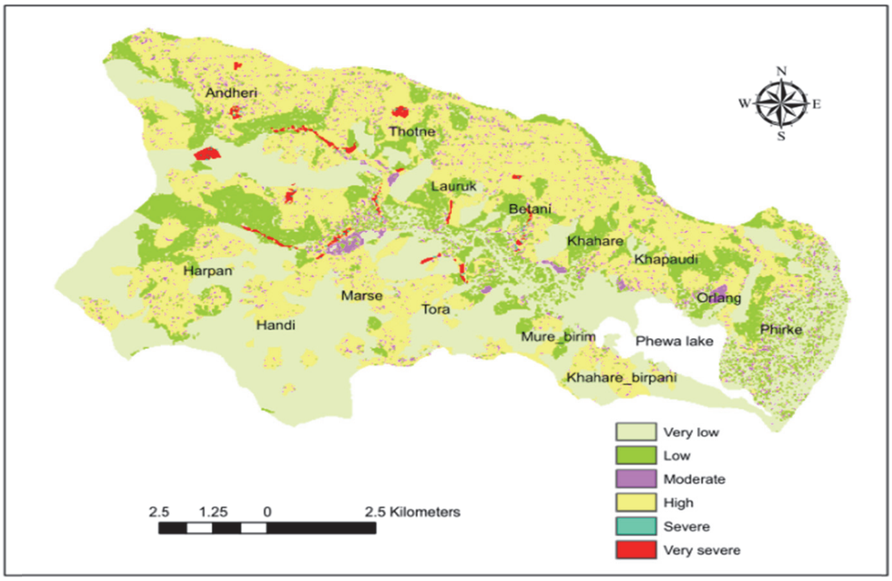


Figure 29 Distribution of Soil Erosion Risk in Phewa Watershed, 2010

High rate of erosion were found along the steep slopes (mountainous) areas and south facing sub-watershed namely Andheri, Lauruk,Thotne, Orlang, Khapaundi and Khahare and its tributaries. Rates of soil transport ranged between 0 and 206.7 t/ha/yr for across each land use. Suggesting that more widespread use of riparian buffers along major rivers would be an appropriate best management practice in this region.

Table 27 Soil Erosion Risk Classes of 1995 and 2010

Erosion Classes	Average rate of soil loss(t/ha)	1995		2010	
		Area(ha)	Area (%)	Area(ha)	Area (%)
Very low	<5	6479.7	52.7	4205.3	34.2
Low	5 to 10	1107.4	9.0	1978. 5	16.1
Moderate	10 to 15	2058.3	16.7	1208.0	9.8
High	15 to 25	2050.7	16.7	4304.3	35.1
Severe	25 to 50	57.7	0.5	67.6	0.5
Very severe	>50	69.4	0. 6	84.6	0.7
Excluded area(river and stream)		469.2	3.7	444.2	3.8
Total		12292.28	100	12292.3	100

This result complements recent studies that have identified riparian areas as critical zones for stream channel stability in Andheri, Lauruk, Thotne, Tora, Orlang, Khapaundi and Khahare sub watershed. Although the forest areas experienced low mean erosion rates, the total erosion from this LULC class was the greatest because it covered the largest area of the watershed. Two other major sources of increased erosion are the barren and waste land LULC classes. The total erosion in the barren land area was 136 t/ha/yr in 1995 and this value was increased to 206.78ta/ha/yr in 2010. Increased erosion risk in barren areas was not surprising because larger barren coverage meant larger areas without protective soil cover and therefore increased risk of erosion. In the case of the waste land areas, erosion rate was increase from 149t/ha/yr to 197t/ha/yr in 1995-2010. The construction activities and urbanization increases the waste land, barren land and deforestation which ultimately increase in soil erosion.

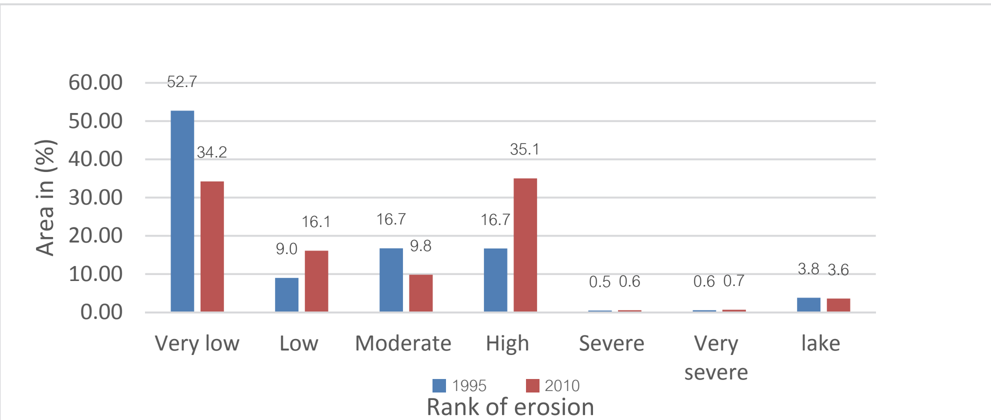


Figure 30 Soil Erosion Risk of Phewa Watershed for 1995 and 2010.

5.3.6 Impact of Land Use Changes on Soil Loss

Deforestation, substitution of forest by crop and decreasing the protective function of the land have led to a dramatic increase in soil loss (Cebecauer and Hofierka, 2008; García-Ruiz, 2010). The effect of land use types on runoff and soil loss can be explained in various ways. First of all, vegetation canopy plays a key role in protecting surfaces from soil loss. Secondly, the litter production and organic matter accumulation could reduce soil-water loss. Litter could weaken the kinetic energy of raindrop and slows runoff velocities and directly protects the surface soil from splash loss, but also conserves surface rainwater due to its strong moisture holding capacity. Thirdly, surface soil particles are physically bounded by the network of roots in topsoil. Soil particles and soil roots matrix are stronger than the soil or roots separately (Gosavi and Tamilmani, 2009; Wei et al., 2007).

Comparison of open forest area in 1995 and 2010 showed the significant increase from 1693.51ha to 2301.50ha. Moreover, the dense forest area in 1995 and 2010 decreased from 3397.29 ha to 2859.11ha. According to the assessment of soil loss risk by applying RUSLE model, high soil loss risk category significantly increased from 2050.65ha to 4304.25ha. in 1995 to 2010 . The built up area increased from 384.34 ha to 797.14 ha and wasteland, barren land slightly increased from 1995 to 2010 which accelerate soil loss. The soil loss risk changes corresponded to the land use changes over 1995-2010 periods. Since, C factor in RUSLE directly depend on LULC and land use had a significant influence on soil loss risk. Therefore, the decrease of the dense forest from1995 to 2010 decrease protective function of the land and led the increase of soil loss risk.

5.4 Conclusion

Phewa Watershed has sufficient natural resources; it is at severe risk due to land degradation caused by inappropriate LULC practices aggravated by local people. The finding of the LULC in Phewa Watershed over the past one and half decades showed that dense forest decreased and shifted into open forest and bush area. Furthermore, urbanized settlements were found to have expanded and intensified at the expense of terrace cultivation, single crop land and double crop land. Generally, the demand for additional land for farming, wood for fuel, and construction due to rapid population growth and urbanization has resulted in deforestation and a reduction of the wetland areas. The mean annual rate of soil loss in the Phewa watershed is 14.71t ha^{-1} yr^{-1}, which identifies a severe rate of degradation. The highest degree of soil loss (above 50 t ha^{-1} yr^{-1}) was found to occur in the upstream and riverbank areas whereby the mountainous topography of the region coupled with high mean annual rainfall was identified as a key factor for the severity of soil erosion. Increasing human pressure on the environment exacerbates soil erosion and that soil erosion can be attributed due to LULC change. Thus, knowledge of LULC provides an unambiguous opportunity to improve soil erosion management and benefit the myriad of stakeholders in Pokhara, Nepal. Thus, an accurate knowledge of LULC provides an unambiguous opportunity to improve soil erosion management and benefit the myriad stakeholders of Pokhara, Nepal.

CHAPTER VI

6. PGIS Tool for Soil Erosion Susceptibility Assessment

6.1 Background

The local people experiences and narratives play an important role for the assessment of soil erosion susceptibility. Their incomes depend on their mode of production, ideology about nature and exploitation of the natural resources. PGIS can capture local experiences, narratives and knowledge of soil erosion vulnerability. PGIS methodology is rather important to the task of representing differential soil erosion susceptibility for four reasons. First, impact of soil erosion susceptibility in participatory dialogue can be brought by PGIS. Second, local politics, socio economic and the distribution of natural resources map can be generated by local communities. Third, PGIS is an approach which helps to understand soil erosion problem. Fourth task is the exploration of people's experiences, perceptions and knowledge in the above issues. PGIS is a "forum around which issues, information, alternative perspectives and decisions evolve" (Weiner and Harris, 1996). PGIS methodology could help communities understanding for coping soil erosion hazard. Advocacy can help to understand the mapping process to save from the danger and within socioeconomic and political context. In this way PGIS could help to disrupt and change maintaining local relations.

The stakeholder and community could view their harmony rather than the opposition with nature. As such, they associate their problem to soil erosion with socio-economic and political developments rather than nature itself. Community mental mapping workshops indicate that degrading effects of economic activities as part of an enforced interaction with nature in their mountainous cultivation.

PGIS acknowledges integrate people's experiences, perceptions and issues of socioeconomic, politics knowledge. This shows that the necessity of understanding the social production of differential soil erosion susceptibility to represent their diverse narratives landscape. In addition, PGIS map from merging community mental maps with other "expert" spatial information help to understand and analyze soil erosion susceptibility. PGIS ensure that participatory methods implanted local perspectives and bottom up representations of soil erosion susceptibility. Researchers and soil erosion management planners can locate high risk groupware concentrated in local mapping with the help of stakeholders. Participatory discussions could provide local perspectives processes which make people exposed in the study sites. In this research, local perspectives erosion susceptibility were sketched by community stakeholders in maps which were based on the topographical map sheets and rapid eye image of the study sites. These were then digitized and geo-referenced for integration with other data sets.

6.2 Methods and Materials

PGIS methodology used a variety of quantitative and qualitative methods to understand individuals' experiences with place. The main goal of the study was representation of PGIS to examine differential social and spatial soil erosion prone area. Therefore, PGIS was employed addressing the limitations of traditional GIS and the conventional approach to soil erosion risk assessment within the context of socioeconomic. In order to address social and spatial differentiation is the maintaining good rapport with research participants for setting up of an appropriate PGIS methodology.

6.3 PGIS Methodology

6.3.1Theoretical Approach

The general approach for PGIS is the operating under a GIS and society and recognizing the importance of the communication and visualizing the multiple experience of place within a participant community. The choice of an appropriate model depends on the both the socio-economic and physical conditions prevailing in the target community. Leitner *et al.* (2002) identified six models for making PGIS available to communities and researcher introduces University-NGO-community partnerships for soil erosion assessment. These are:

- Community based GIS
- University–community- partnerships
- GIS facilities in universities and public libraries

- Map rooms
- Internet map server
- Neighborhood GIS centre

PGIS on the cultural system should produce geographic knowledge as well as local cultural, political and economic context. Local need of the community such as raising funds and long term maintenance of PGIS due to monetary as well as skills can be adopted and implemented in community based PGI. Community has problem to raising fund for maintenance of PGIS. Socio-economic, political and environmental context in the study area can be supported by a University-NGO-Community partnership. This is an appropriate model for implementing PGIS in the study area due to three main reasons.

First, Poor rural communities would need comprehensive PGIS training to be able to manage an in-house PGIS project. In house community PGIS is impossible due to projected costs of procuring PGIS equipment, software, data and training for these poor communities to run an in-house community PGIS. Second, the social positioning of gender, class, ethnicity and race of individuals and households in the Phewa watershed has created limited access to resources for survival. So the, the in-house option of PGIS technology is not appropriate in terms of such poor communities to afford and maintain it. Third, the Western Region Campus, Prthivi Narayan Campus, Institute of forestry of Tribhuvan University and NGO working on environmental sector like Machha Puchchhre Development Organization (MDO) can utilize to implement the University Community partnership model. This study therefore presents an initial attempt to practically foster this partnership. However, the meaningful implementation of this partnership would require more support and planning than could be achieved during the duration of this research. Follow-up mechanisms need to be made with the affected communities in future.

6.3.2 Methodological Approach

PGIS studies can be divided into three parts in several steps such as problem identification, data required and implementation of topographical model. These steps are described below.

6.3.3 Identification of Problem

It is the process of developing PGIS database from integration of the local community perception and experience with traditional GIS to make understand differential social and spatial soil erosion susceptibility. This process is split into series of task to be accomplished in PGIS environment. These are

- Mental mapping of dynamic pressures e.g. use of natural resources
- Mapping of disputed Spaces;
- Mental mapping of soil erosion prone areas;
- Mapping comparison of historical and current spatial strategies of resource access and distribution;
- Mapping of land use land cover patterns; and;
- Area based mapping on the socio-economic data to identify at soil erosion risk.

6.3.4 Data Required

First step towards database development was arrangement of data exiting in the RUSLE model. Quantitative data included household survey and GIS data layers such elevation, geology, rainfall, rivers, roads, LULC, physical/social infrastructure data. Qualitative data collected from interviews, archival searches, focus group discussions and mental maps were also important data sets for this research. A combination of qualitative and quantitative data sets has populated the PGIS database for this research.

6.3.5 Topographical Model

Flow chart showed step by step flow diagram (Figure 31) organizes data in information system. The main purpose is to identify data required for a GIS study to organize the analytical procedures that are performed for an integration of PGIS and socio economic for soil susceptibility analysis.

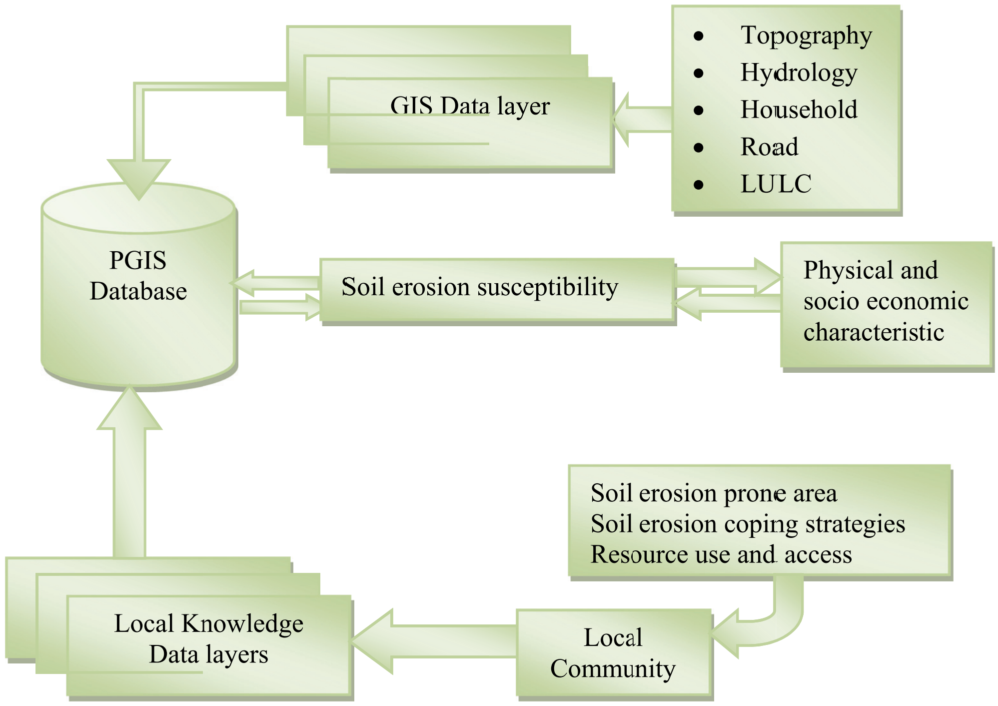


Figure 31 Model of Integration of PGIS and Political Ecology for Differential Social and Spatial Soil Erosion Vulnerability

Nine months of fieldwork was conducted from August 2011 to April 2013 in the communities of Phewa watershed. Machhapuchhre Development Organization (MDO), Dhikurpokhari Community Development Organization (DCDO), VDCs officers and the local community people were introduced to the researcher in 6 VDCs. Research assistants from MDO and DCDO have facilitated access in six village development committees. Differential social permission was granted and explored for case study to administer workshops. Household survey, individual interviews, focus group discussions and mental mapping workshop was done to explore and spatial soil erosion susceptibility in the study area. PGIS frameworks were employed to reveal people's perceptions and experiences about soil erosion for their coping strategies and how they changed over time. Main aim of this research is an examination of differential social and spatial soil erosion susceptibility. Several economic, social and political questions currently possess from the nature of differential soil erosion susceptibility with regard to the problem of soil erosion in the study area.

6.3.6 Framework and Sampling Procedures

Phewa watershed is an ideal context for a study about soil erosion susceptibility due to world's tourist attraction place and economically potential area with nature of devastation ideal context make ideal for this research. Mental mapping workshops were conducted at the sub watershed level. A snapshot of the overall community socio-economic profile, erosion coping strategies and susceptibility were provided by primary household survey. Individual interviews with key informants and focus group discussions provided a platform for historical processes and structures (social, cultural, economic, political and environmental) that have produced and maintained soil erosion susceptibility. The population in this study included all households at Phewa watershed area.

The sample was selected randomly and purposively from the population specified above to include 210 households in watershed from 14 sub watershed according to population proportion. The locations of 210 household points were collected with a GPS in order to know that information from the survey could be attached to these shape files as attribute tables. Snowball and random sampling methods were employed in two different contexts. A practical advantage for gaining access to research subjects that may otherwise be difficult to access without snowball sampling being non probabilistic .

The snowball sampling method were used to identify and select the elderly key respondents who provided information on soil erosion prone areas, historical erosion coping strategies and historical forces enhancing soil erosion susceptibility. Random sampling of the household survey ensured that the population had an equal opportunity to appear in the sample.

6.3.7 Methods for Data Collection

Primary and secondary data were guided by the PGIS methodology for qualitative and quantitative research methods. Five data collection methods were used as follows:

- Literature search;
- Existing Socio-economic Survey;
- Household Survey;

- GPS transect walks, Individual interviews and field Observation;
- Focus Group Discussions and Participatory mental mapping.
- Geographic Information Systems

The section below describes how these methods were used in this research.

6.3.7.1 Literature Search

The criteria for soil erosion zone, conceptual understanding of soil erosion, theoretical background of the soil erosion prone area and the role of socioeconomic and political factors in soil erosion susceptibility assessment were contributed from the book and research journals.

6.3.7.2 Existing Socioeconomic Survey

Socioeconomic survey of stakeholders' socio-economic characteristics (e.g. poverty levels, per capita income, literacy, and population density) were collected which helped to evaluate spatial and social differentiation of soil erosion susceptibility. The profile censuses conducted by VDCs level socioeconomic database were used to evaluate the communities' socio-economic characteristics in 2011. Socio-economic survey from VDCs was an excellent source of data that provided the context of this study.

6.3.7.3 Household Survey

Soil erosion susceptibility was differentiated according to social, economic and physical factors. The survey provided the demographic and socio-economic profile of the households. Household perspective survey is useful to understand a full range of soil susceptibility indicators such as gender, class, income, land size and migration within the community and household. Thus, total 210 randomly selected households were administered socio-economic household survey of the 14 sub watershed.

6.3.7.4 Individual Interviews, GPS Transect Walks and Field Observation

Flexible structured interviews were conducted in 6 VDCs with 3 elders in each and 6 senior VDC officials as key research informants. It was used to enhance flexibility in terms of questioning which elicited information about soil erosion experiences, coping strategies and overall causes of soil erosion and some exploratory data collection. The key informants were identified through snowball sampling during focus group discussions except VDC officials.

Individual interviews provided key historical soil erosion coping strategies, historical socio-economic and political forces enhancing soil erosion susceptibility and perceptions of soil erosion prone areas (Figure 32). Key research participants (i.e. elders) information was helpful in delineating areas of historical resource uses and demarcation during GPS transects walks. The demarcated areas in 14 sub watershed were then overlaid on the respective base maps provided during (Focus Group Discussion) FGDs. Information on physical characteristic and human activity profile were collected on transect walks.

Figure 32 Focus Group Discussions on Demarcation of Study Area and Soil Erosion Prone Areas on their Perception

Images, toposheet interpretation and participant observation were played very important part of data collection particularly qualitative assessment of the physical landscape characteristics and the human activity profile of the broad soil erosion plains of the study area. The information from the mental map in workshop and focus group discussion and spatial information of historical resource management was compared. This information was in turn compared with contemporary resource management strategies in the area. Soil erosion risk perceptions, experiences, key historical and contemporary soil erosion coping mechanisms was documented from interview conducted with key informants and household survey.

6.3.7.5 Focus Group Discussions (FGDs) and Participatory Mental Mapping

Focus group discussion is a small group of people discuss about topic or issues defined by researcher (Cameroon, 2000; 2005). In this study, one to two hours focus group discussions (FGDs) were conducted in three sessions. Interaction between members of the group is one of the main strengths of this method (Cameroon, 2005). FGDs exposed information about people's coping strategies and capacity, role of social networks, institutions and organizations of community's ability to cope with soil erosion. This is the forum of discussion permitted individuals to challenge the interpretation or assumption of other group members and important for patriarchy dominates social relations. PGIS database were prepared by participatory mental mapping and spatially encoded survey to incorporate social and spatial differentiation.

The workshop was conducted by providing 1:25 000 topographic map and land sat image (year 2010) of the watershed and relevant GIS layer prepared in advance to each group. Map reading skill training was given to the participants. Participatory mental mapping workshops involved three activities:

Activity 1 A small group of four or five men and women carried out to entail for mapping soil erosion prone area of study sites (proximity to erosion plains)

Activity 2 Group was involved mapping dynamic pressures and disputed spaces in order to make sense of soil erosion susceptibility issues affecting their lives.

Activity 3 Group involved mapping of historical and existing resource access and ownership.

This exercise documented the sources of the people resources such as wood water and fodder used by the people before and now. Identifying resources control, access and existing situation is important for capacity building and planning soil erosion susceptibility reduction strategies. Mental maps generated from the workshops were geo-referenced and integrated into the PGIS database.

6.3.7.6 Geographic Information System

GIS is used consistent with PGIS methodology in socioeconomic ecology framework to study soil erosion susceptibility. Soil erosion hazards occur in social, political, economic and geographical space. These four dimensions data is bridging due to the power of GIS to define soil erosion susceptibility. It is incorporating traditional "expert" data sets as well as "layman" subjective mental maps. In order to accomplish this task, GIS captured, organized and managed conventional data sets such as elevation, drainage, land-use and socio-economic data. Land use data were prepared from the Land sat image, Rapid eye image and topographic map. Mental maps from the community workshops were integrated into a PGIS database. On the basis of mental maps and ground inspection, physical soil erosion surfaces were created. This together with proximity analysis created surfaces that were then populated with households and other land use data to identify elements at risk. Surveyed households were further characterized on the basis of socio-economic information acquired through the household survey. The household data point with socio-economic vulnerability indicators such as housing conditions and land are converted in spatial context. Vulnerability is also a function of power hierarchies within the social, political and economic spheres, and not merely proximity to soil erosion prone zones.

The Flow chart in Figure 4.1 has represented integration of PGIS with political ecology and how traditional and local information data were used to study social and spatial differentiation of soil erosion susceptibility. This chart showed that correlation of soil erosion zone with physical as well as socioeconomic effects of social differentiation on the distribution of soil erosion. PGIS allows us to integrate social and geographic data in order to understand social and spatial differentiation of soil erosion susceptibility. PGIS database were prepared by the integration of conventional GIS and local information data layers. Integration of local knowledge and GIS data fulfill complementary roles.

6.4 Result and Discussion

6.4.1 Stakeholders' Perspectives on Soil Erosion Susceptibility in the Study Sites

Soil erosion is a matter of stakeholder's perceptions. The views of the stakeholders are important due to their experience and learning form the soil erosion problem. In order to learn from them shared their learning and take soil erosion hazard related decision. The historical perspective of soil erosion susceptibility assessment is important because it can be compared with present or future conditions based on understanding the past. Long histories of unequal distribution of land, inappropriate use of resources were the root causes of soil erosion embedded. PGIS methodology addresses three issues related to soil erosion susceptibility. These conceptual issues are: perspectives on disputed spaces (encroachments), perceptions on soil erosion-prone areas and perspectives about forces shaping natural resource accesses and used of natural resources, control and ownership. Social, economic and political processes that produce differential soil erosion susceptibility come under these conceptual issues.

6.4.2 Perspectives on Land Encroachment and Disputed Spaces

Power relation is marked through disputed spaces which indicate power struggles over environmental resources. Local politics and power relations accelerate soil erosion. Lauruk and Pame are a typical example of a settlement whose morphology has been influenced by topography and the geography of soil erosion susceptible area. Land in this territory was used for pastures, agriculture and collection of building materials from bank of river (Figure 33). The public land and the boundary of the VDC and ward boundary have a problem to use the natural resources mainly in forest resource and building material from the streams. The people collect wood and grass for their daily uses. In the river, political power is used to use the gravel and stone for the building material which is one of the main economic sources of VDC.

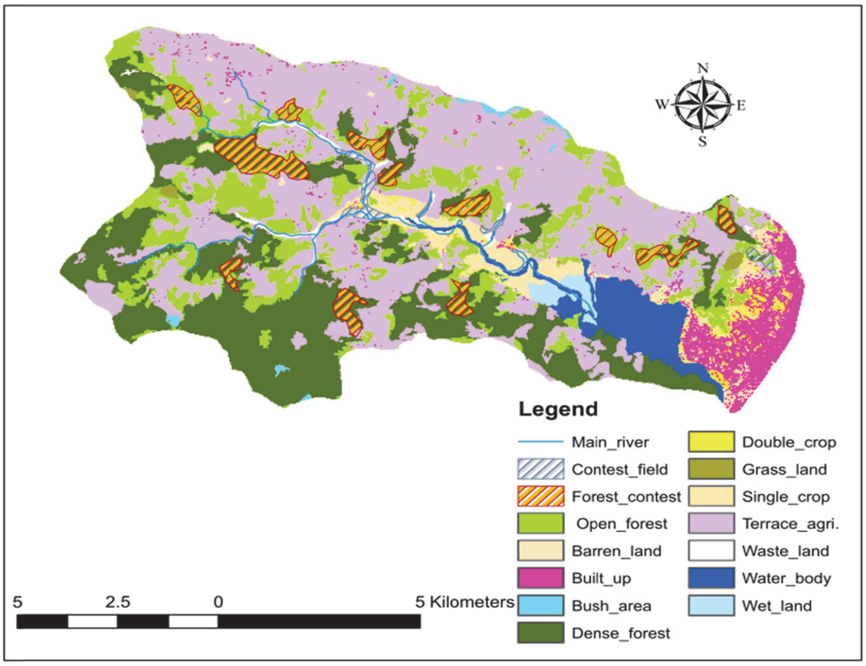


Figure 33 Demarcated Regions of Disputed Spaces and Forest Dissipated in Phewa Watershed

Villages have furthermore exerted development pressure at Pame and Lauruk village. From the group discussions, participants indicated diplomatic and covert acts of resistance as more effective ways of dealing with this conflict than over resistant behavior. Uses of natural resource like forest, woodland and streams used conflict were common in the watershed.

The border area of Bhadaure and Dhikurpokhari VDC has main conflict on forest resource utilization. Now, the people from the Dhikurpokhari are using recourses but Harpan and Chainpur village under Bhadaure VDC claiming to use the forest resources. There are many conflicts in resource utilization issues in between the villages makes more degradation of the forest. The people who are not getting benefit from the natural resources they will not conserve but they always want to use it only. In general, most of the villages have their own community forest and they conserved by themselves. The people whose forest is far distance from their home and near forest of other villagers they wanted to cut fodder, wood without permission. In this way the forest is changing from dense forest to open forest. The degree of soil erosion is increasing due to open forest.

6.4.3 Stakeholders Perspectives on Soil Erosion Prone Areas

Soil erosion susceptibility areas were asked to the stakeholders' knowledge and experience to define and demarcate the geographical space and social space where the people were at risk due to erosion gullies. This task entailed the mapping of areas in the study sites that were prone to erosion. On the basis of community's assessment of erosion-prone areas, discussion with villagers and the ground inspection, three scenarios of combined river proximity, road construction without conservation and soil erosion vulnerability surfaces were constructed. These scenarios were useful tools for erosion map to identify risk and suggest possible soil erosion mitigation strategies but not comprehensive soil erosion-forecasting models (Figure 34). In terms of expert mapping, different elevation breakpoints or pixel values from an interpolated raster surface were selected for watershed mainly because of variations in elevation and location of community perceived ("local') soil erosion-prone areas, the estimated distance proximity of river from the community mental maps, for three scenarios range from 10m for the worst case scenario. In contrast, the estimated river proximity was 20m, 30m breakpoints in river for watershed. The differences in the breakpoints for scenarios in each sub watershed are attributed to variations in elevation, valley configuration and different soil experience and perceptions of communities.

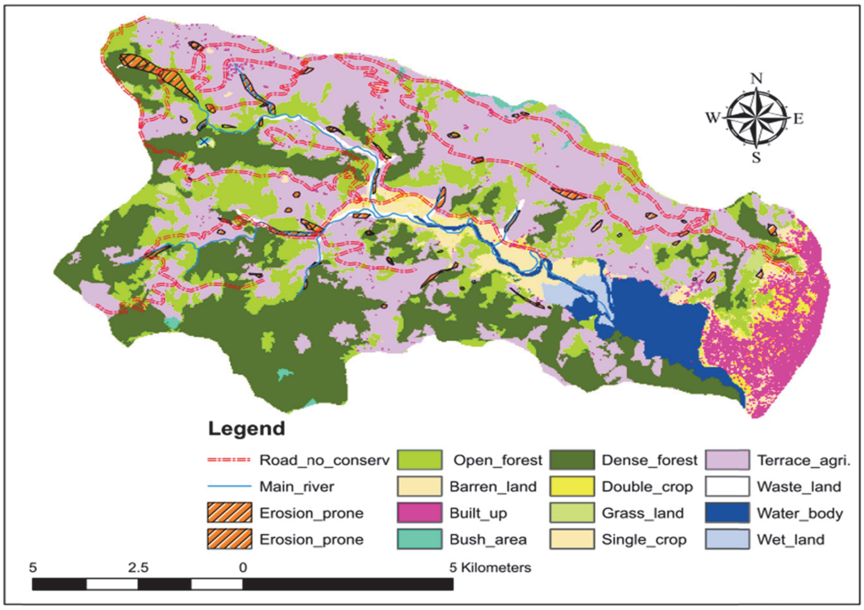


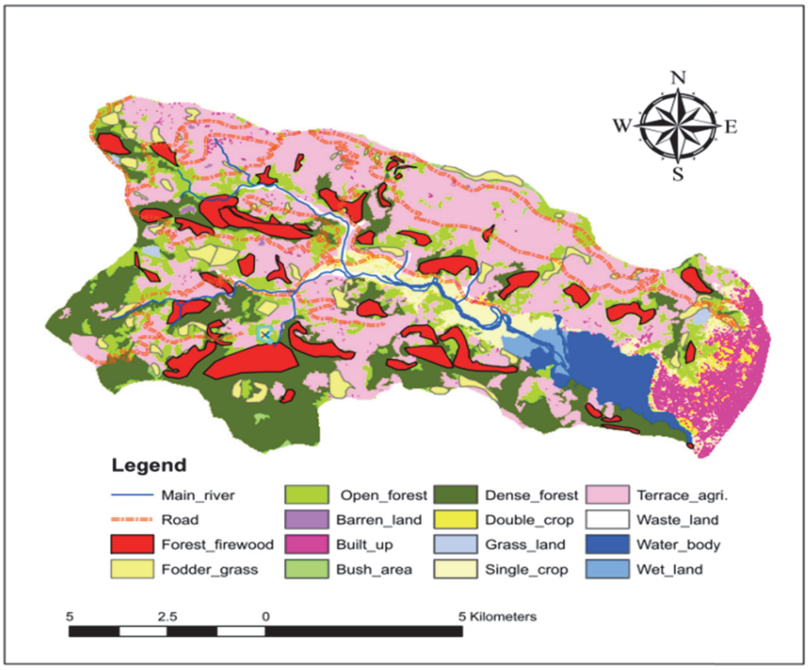
Figure 34 Mental Map of Soil Erosion Prone Areas in Phewa Watershed

The whole process is consistent with the idea that soil erosion susceptibility should be defined by stakeholders who are suffering from erosion. Main transportation roots without conservation and along river and stream demarcate for soil erosion prone area due to the monsoon.

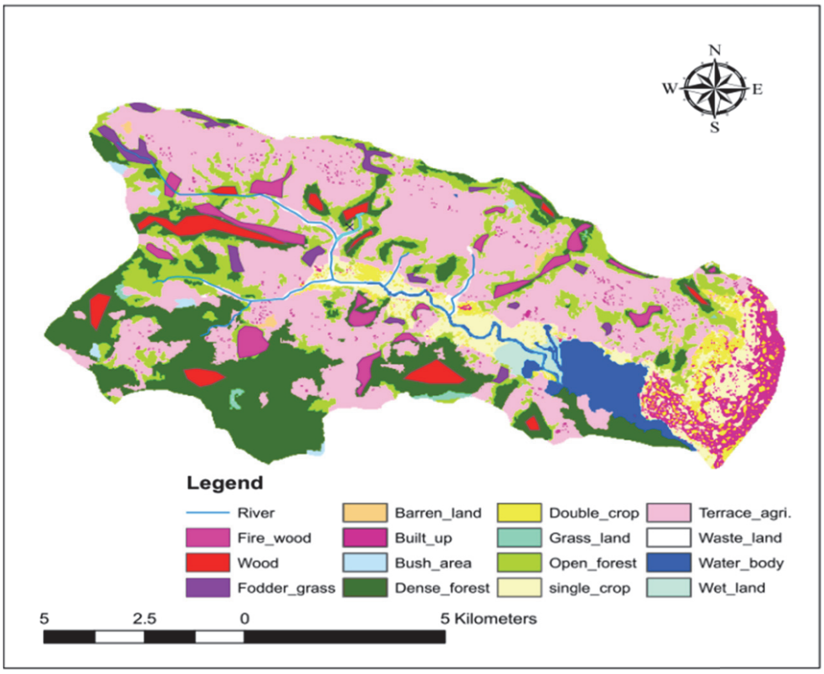
Soil erosion susceptibility areas sketched through mental maps at watershed consist of zones of low-lying, soil erosion prone land in the vicinity of main river streams and small farming areas in the plain. Stakeholders at lower village have a generalized view of the perceived erosion zone which includes drainage and gullies zones. Local knowledge of soil erosion-prone areas has been an important input into the "expert" erosion modeling of space. The output of the integration of the "local" and "expert" knowledge about the geography of erosion susceptibility was then used as a backdrop upon which the social, economic and political space of susceptibility.

6.4.4. Status of the Natural Resources Used in Past and Present.

The ownership pattern of the natural resources in present and past were asked in mental mapping workshop of stakeholders. The assess of the natural resources, location and controlling mechanism is important for capacity building and for developing soil erosion reduction strategies and sensitive to local needs. The two maps show that the resource access area before used to be less than the area now. Over-exploitation of resources due to deforestation, road construction without conservations is likely to cause irreversible environmental stress. According to the forest act, government forests are converted into the community forest after 1996. Forest management system is under communal ownership. The Figure 35 and 36 showed the status of the past and present situation of the forest resources used and construction of the roads.



Figures 35 Forest Access and Construction of the Road Demarcated in 2010



Figures 36 Forest Access and Construction of the Road Demarcated In 1995

Local politics determines the access, use and distribution of the resources in the communal land. Hence, access and ownership of those resources is differentiation by social status and other contextual factors in place.

6.4.5 Integration of Local and Expert Knowledge

"Local" and "expert" knowledge were integrated to assess soil erosion susceptibility based on geographic location, socio-economic and political space. "Local" and "expert" perspectives of soil erosion prone areas were constructed on the basis of physical or geographic vulnerability surfaces for watershed. Then the geographic space was occupied with household, infrastructural and socio-economic data to assess differential soil erosion susceptibility. Income, gender and assets, including land were the socio-economic indicators which were used to demonstrate the contribution of PGIS to the analysis of soil erosion susceptibility.

Differential soil erosion susceptibility depends on the role of physical factors such as geology, rainfall intensity, hydrology, vegetation cover and soil types. All these factors comprise geographic spaces are impart variable of soil erosion exposure and vulnerability on people. Spatial variations of soil erosion exposure in the study area are reliant upon variations in rainfall regimes, geological composition, and vegetation cover and soil types. Elderly people indicate that history of their local knowledge can have a long horizon. It depends on the capacity of stakeholders to describe the experience of soil erosion prone areas. Local people know and have experienced and modified this geographic space.

Raster and vector data sets were created in ArcGIS by using elevation data and DEM. Three scenarios of 10m, 20m, 30m combined river proximity and soil erosion vulnerability surfaces were constructed on the basis of community's estimation of erosion-prone areas, discussion with villagers and the ground inspection (Figure 37). These scenarios are not complete soil erosion-forecasting models but useful tools in places where there are no erosion maps to identify elements at risk and suggest possible soil erosion mitigation strategies. In terms of the construction of 'expert "vulnerability surfaces, variations in elevation and location of community perceived soil erosion-prone areas selected and raster surface interpolated different elevation breakpoints.

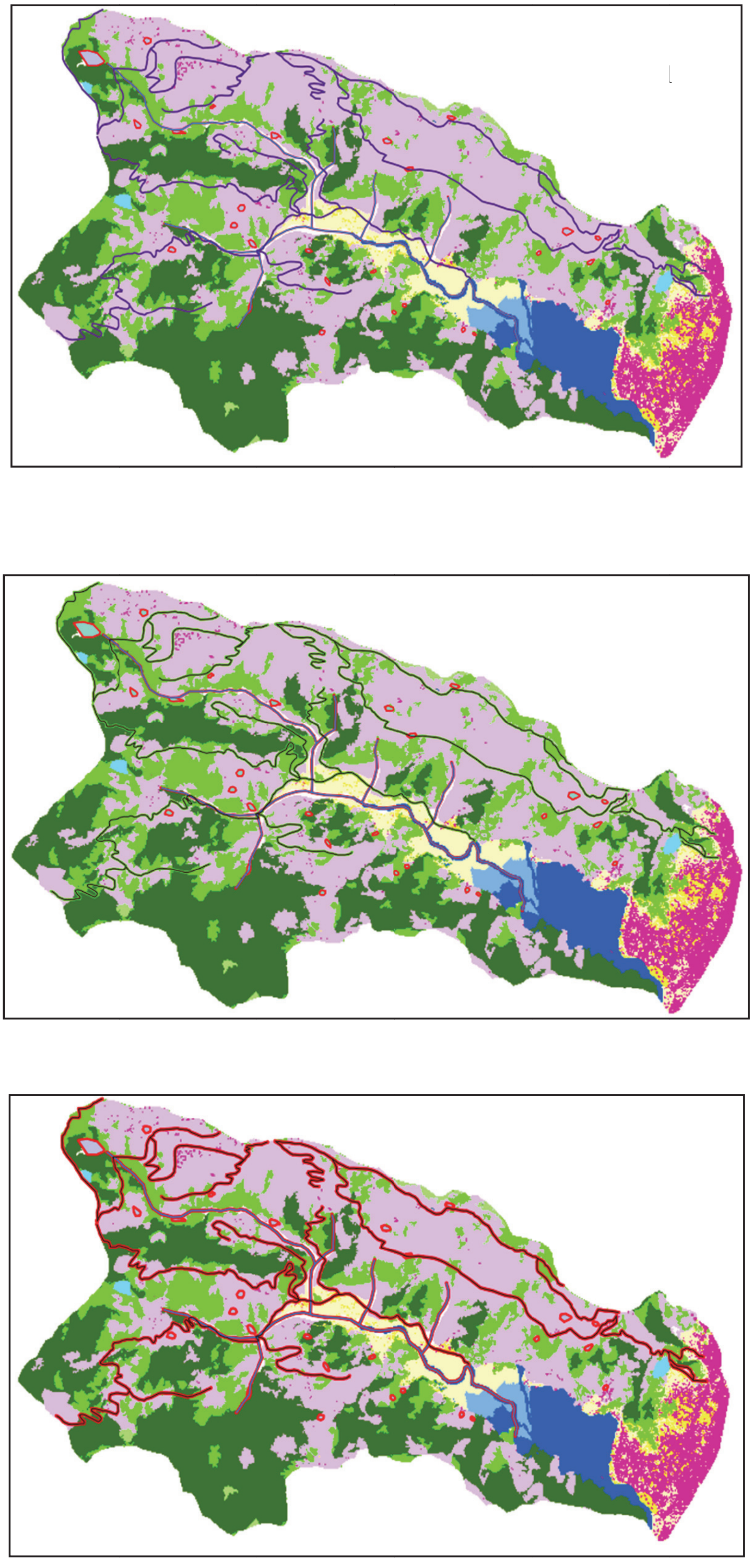


Figure 37 Raster Interpolated Soil Erosion Vulnerability Surfaces: ***Scenarios 1-3*** at Phewa Watershed

The estimated distance proximity of river from the community mental maps and scenarios range 10m from the object was the worst case scenario. In contrast, the estimated river proximity was 20m, 30m breakpoints in river for watershed. The differences in the breakpoints for scenarios in each sub watershed are attributed to variations in elevation, valley configuration and different soil experience and perceptions of communities.

Construction of ‘expert” soil erosion vulnerability surfaces were issued proximity analysis. In this case, locations of elements at risk were analyzed by measuring the distance between object and the river risk location. It is supposed that features closer to the river are likely to be more vulnerable than those far away depending on the magnitude of soil erosion on the spatial autocorrelation. Buffer zones of 30, 20 and 10m from the river were delineated for proximity analysis. Cut off points of soil erosion-prone areas were demarcated with community mental map.

On the basis of “local” and ‘expert’ knowledge” as explained earlier were developed soil erosion vulnerability scenario to evaluate various vulnerability surfaces. More reliable geographic space of erosion vulnerability was due to account of community and expert inputs. Three scenarios decreases as various elevation parameters and buffer distance changed according to geographic soil erosion-prone space. Three scenario models represent soil erosion vulnerability as a dynamic and complex phenomenon. The model was simulated by geographic space in terms of physical exposure changes soil erosion vulnerability.

This events shows that the important of integration of the local knowledge and expert knowledge. A closer analysis of the physical terrains of watershed reveals that in addition to socio-economic factors, a combination of factors such as rugged topography, heavy orographic rainfall, upstream watershed and vast soil erosion are some of the critical factors that are likely to explain soil erosion susceptibility. However, slight differences in topography influence rainfall variability. Physical parameters such as soil characteristics and the valley configuration explain to significant extent soil erosion susceptibility in terms of exposure in watershed. This events shows that the important of integration of the local knowledge and expert knowledge.

6.4.6 Analyzing Differential Soil Erosion Vulnerability for the Study Sites

The function of exposure physical location and coping capacity to soil erosion vulnerability showed that the understanding of people. It also requires an insight into their perceptions, knowledge about hazards and different forms of coping. Conventional explanation of erosion risk has linked with hazard and its impacts at expense of socioeconomic, historical and political expenses to physical domain. However, buildings and agricultural systems is included to the current explanation of vulnerability emphasizes coping capacity and acknowledges the role of geographic space and physical forms of vulnerability (Bankoff and Hilhorst, 2007). This concept of vulnerability highlights to understand its complexities. Soil erosion vulnerability is socially constructed, even though it has a relationship to physical or geographic space. It is distributed as a reflection of social, political and economic power relations. The physical soil erosion exposure and coping capacity are two critical elements of soil erosion vulnerability. On the basis of household data, it is attempted to answer on the location which is exposed and why exposed and their associated coping capacity. This provides the spatial interaction of the physical and human factors that produced differential vulnerability.

6.4.7 Physical and Human Geographies of Differential Soil Erosion Vulnerability

Geographic location and socioeconomic conditions play an important role in erosion vulnerability in the study site. Physical and social attributes make households and objects at vulnerable to soil erosion which are located on erosion plains and nearby gullies (Figures 32). Figures indicate how “local” and “expert” knowledge have augmented each other to delineate erosion prone areas. This map shows that vulnerable erosion area such as household and other physical infrastructures on the basis of geographic location. Analyses of potential relationships between data sets show that risk area of erosion hazard are located in middle part and low land of the watershed. Participants of workshop were asked to delineate erosion prone area to indicate in map they verbally depicted the vivid memory of erosion impact on their agricultural field such as maize, millet and paddy field damage, gullies erosion by water runoff. Differential soil erosion vulnerability based on location is evident on the maps in Figure 38. At sub watersheds households nearby gulley, river is in vulnerable location. Survey households at erosion risk are also indicated on the map. Another significant observation at watershed some households were not included in the mental map of soil erosion but in within the river buffer zone. Integration of the buffer mode land the mental maps spatially broadens the risk profile of households and riparian subsistence agriculture sites which have inhabited erosion zone.

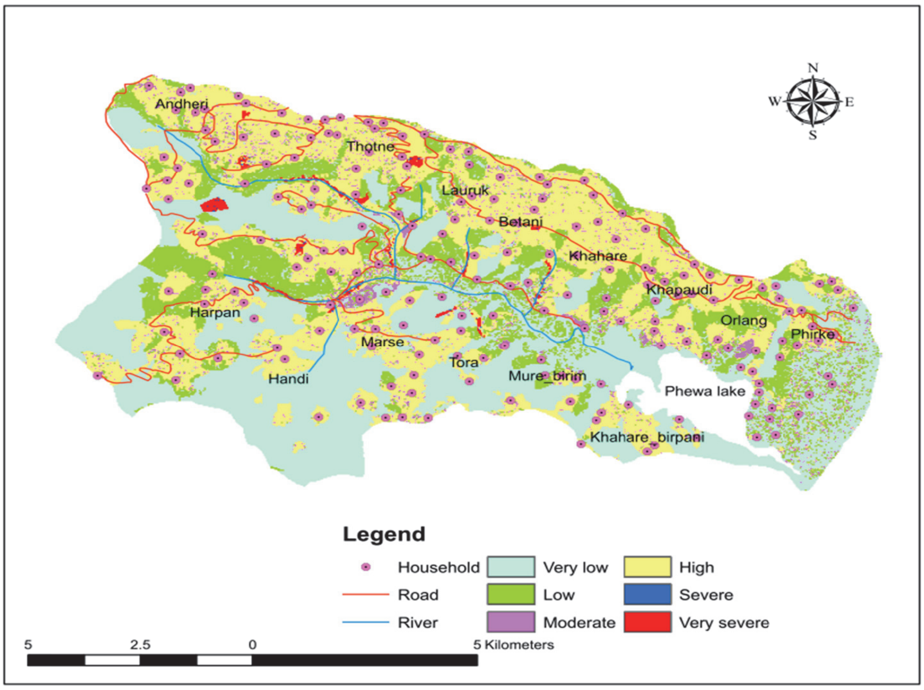


Figure 38 Erosion Vulnerability in Phewa Watershed

6.4.8 A Composite Landscape of Differential Household Soil Erosion Vulnerability

Figure 39 illustrates the combined role of physical and socio-economic characteristic in determining erosion vulnerability in the study sites. This combined role emphasizes the need to look beyond physical geographical vulnerability to understand how social, economic and political processes place people at erosion risk and to ensure that current erosion mitigation policies are addressing important factors that make people more or less vulnerable to erosion. These composite maps were developed to isolate erosion vulnerable area on the basis of household location, income, gender and access to assets including land. The individual factors role in producing erosion vulnerability of study site is addressed. Physical parameters shows the threat of erosion hazard exist and socioeconomic parameters preexisting vulnerability condition.

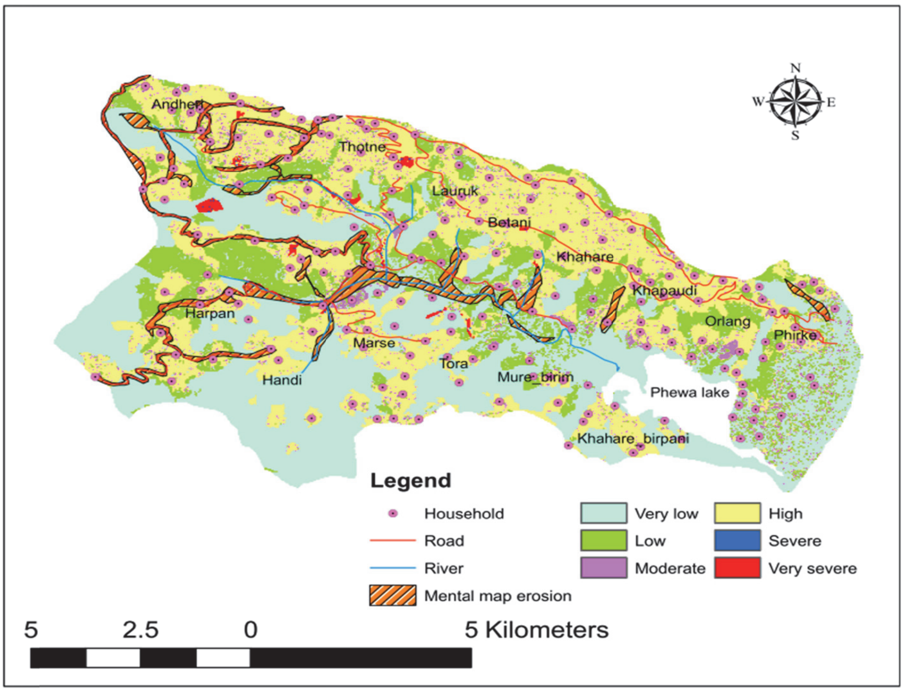


Figure 39 A Composite Map of Household Erosion Vulnerability

Each set of information could help to understand erosion vulnerability for community and decision makers to identify appropriate action for reduction of erosion vulnerability. The figure shows that combined effects of physical and socioeconomic factor for erosion vulnerability. Areas occupying the same geographic space are differentially vulnerable to erosion and variations in coping capacity due to economic condition.

The households in agricultural area, mountain and nearby gullies are vulnerable by location. These areas are vulnerable due to social, economic and political processes that produced differential coping capacity. Stakeholders have different erosion coping capacity according to socioeconomic and political parameters and statuses of differential household resources. Level of assistance for people is according to the impact of erosion. So, by highlighting the vulnerable status it will help to identify appropriate areas of response for decision makers and helps to develop appropriate erosion vulnerability mitigation strategies.

6.5 Conclusion

Community mental maps are dependent on participants' knowledge, experience and impression with cognitive dimension. So these maps should link to activity on space of these communities and could take as absolute maps of erosion vulnerability. These maps reflect community people daily activities on land so it could show the relative representation of vulnerability map in workshop. A different group of participants could have come up with maps that represent different underlying causes of erosion vulnerability and unsafe conditions at sub watershed villages. Mental maps and community narratives represent the critical steps towards understanding differential erosion vulnerability in watershed. Community perceptions, knowledge and power relations provide the means and the explanation which link people through vulnerability to hazards and development. The integration of local and expert knowledge has the means to spatially extend the risk profile of households and communities beyond the buffer. However, Euclidean distance alone cannot adequately define erosion vulnerability but factors such as elevation and ground inspection can enhance the usefulness of a buffer model. Physical and social factors produce erosion vulnerability in agricultural field and infrastructures which is complex and controversial. People are vulnerable due to exposed hazards and a result of marginality which is related to access and income from the natural resources. There is need in the study sites to restructure space economy by develop in programs that will increase the asset base of the vulnerable groups. Erosion hazards in the study area sites are increasing not only because of an increase in erosion magnitude and frequency but because of increasing social vulnerability. It is both the level of development and the way society is structured that determines income and access to resources. Therefore, these factors impact people's differential coping capacity. Erosion vulnerability assessment is still a disruptive activity in a society. Understanding the human dimensions of erosion vulnerability is critical to designing erosion mitigation programs that target the most vulnerable place and groups. Socio-economic information helps assess how quickly or slowly vulnerable people can help to reduce soil erosion impacts.

CHAPTER VII

7. PGIS Tool for Participatory Soil Erosion Mapping in Soil Conservation Planning

7.1. Introduction

Stakeholders can be mobilized by several approaches in soil and water conservation activities. In this research, stakeholders were involved in the soil erosion damage assessment in some plots. Two tools were employed to participate in existing knowledge and expert knowledge in soil erosion mapping and to select soil conservation measures for the benefit of conservation measures in Andheri sub watershed. The first tool involved stakeholders to map soil erosion indicators and determine the soil erosion status in which they plan for soil conservation measures in sub watershed. The net change in one year period of soil erosion status can make them encourage for the future conservation and aware about severe erosion. The stakeholders will be able to identify cause of erosion on the field .They can assist the conservation and adoption decision on severe soil erosion due to run on down slope fields. Farmers approved the soil erosion status map with their own indicators and perceptions.

7.2 Materials and Methods

7.2.1 Location of Study Area

The tools described in this research were developed and applied in Andheri sub watershed, a site that represents the Phewa Watershed area. The catchment is located on west north parts of the Phewa Watershed at $83^0$48’15’’ to 83^0 52’30’’N and 28^0 15’ 5’’ to $28^0$17’28’’ E and at an elevation from 841m to 1920m and area about 2143ha and population 6573 in Dhikurpokhari VDC , Western Region of Nepal (Figure 40).

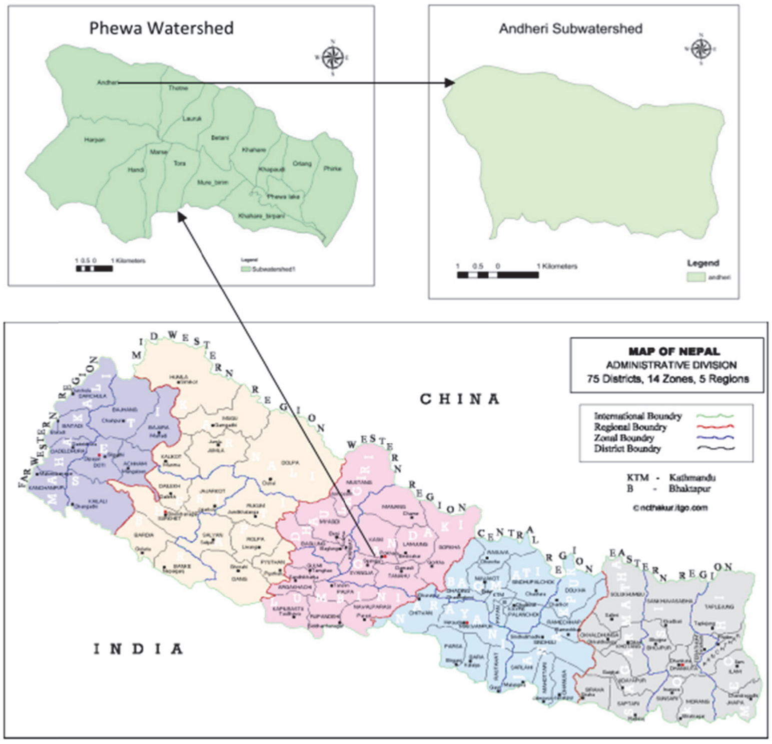


Figure 40 Study Area of Andheri Sub Watershed

7.2.2 PGIS Soil Conservation Planning Tools

Participatory soil erosion mapping tool and Economic survey tool were developed for improved soil conservation planning at sub watershed level. The first tool was developed based on the stakeholders experience on soil erosion and research results during work with stakeholders. The studies identified that farmer and other stakeholders have to make aware of the soil erosion impact of topsoil erosion features in agricultural land in the Phewa Watershed. Soil expert, researcher and stakeholders' knowledge used to map soil erosion indicators. Estimation of soil erosion status was carried out in study area. The input parameters were discussed based on the knowledge of soil erosion by soil expert, researcher and farmers experience and applied as the participatory soil erosion mapping tool.

7.2.3 Description of the PGIS Tool for Participatory Soil Erosion Mapping and Conservation Planning

The PGIS tool consists of six steps (Figure 42), are briefly described henceforth. Andheri sub watershed has selected for soil conservation activities.

Activity 1: Selected key informants from the teachers, farmers, social workers and mothers group member plays important role because of their familiarity with the environment. They will transfer knowledge about this tool to the rest of the community. They were drawn from spatially well distributed households within their respective sub watershed.

Result Activity 1: Focus group discussion member list was prepared.

Activity 2: A focus group discussion was held in which they assess activities and factors of soil erosion effects in their environment. Soil indicator list was generated by the stakeholders (Figure 41). The process of ongoing recent and past soil erosion and types of indicators can be analyzed with association of focus group member. The focus group members were verify during transect walk and can add indicator which was not mentioned during the meeting. The focus group meeting was held after transact walk to present and analyze range of indicators for recommendation.

Figure 41 Focus Group Discussions for Preparation of Field Map

The indicators developed by the current and past erosion events were distinguished by focus group member. Pair wise comparisons method was applied for ranking the indicators with respect to importance to the soil damage. Farmers discussed and justified about the representation of indicator as lower or higher status in soil loss than others.

Result Activity 2: Current and past indicators list of soil erosion was ranking based on the relative severity rankings of farmers' perception.

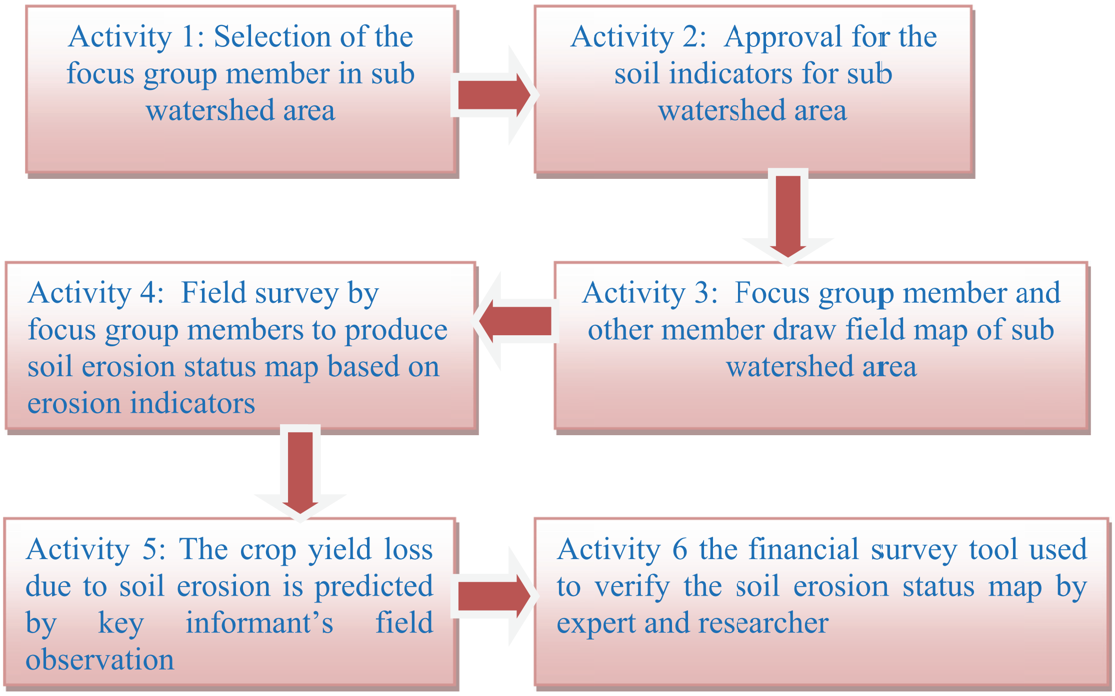


Figure 42 Flow Chart of Soil Erosion Mapping and Financial Survey Tool

Activity 3: Sub watershed map was drawn by the focus group member during meeting with the help of topo map and researcher. During the preparation map stakeholders will able to show the features in the fields in map. The focus groups know the field or identify the field of soil erosion prone area. The experts and researcher were then copy the map from topo map into GIS map.

Result Activity 3: Sub watershed field map of soil erosion prone area was prepared.

Activity 4: The field map was indicated by the erosion indicators evident by the focus group members. Specific types of erosion indicators were recorded in prone field segments during the survey by key informants (Figure 43). The form was filled up. Each field segment erosion status was shown based on degree of indicator by key informants. The soil erosion statuses on the field were showed on the field map. The farmers could verify the estimated accurate erosion severity in the study area. Survey was carried out before rain, mid and end of a rainy season before farmers start harvesting. The soil erosion assessment was done on the Erosion Damage Assessment (EDA) method and soil erosion classes were found.

Figure 43 Foccus Group Member Measuring the Erosion Featutres in Maize Plot

Result Activity 4: Sub watershed class of soil erosion status map.

Activity 5: The experts verified and compared the soil erosion map prepared by model and measurement of soil erosion damaged status. The focus group was clear about the soil erosion factors and soil conservation measure to reduce the soil erosion.

After one year the second to last activities were done and measurement of soil erosion damaged status were find out and compared with last year and calculated degree of improvement in soil erosion in the sub watershed. The focus group was clear about the soil erosion factors and soil conservation measure to reduce the soil erosion. The same activities were done in two years and compare the erosion status due to factors.

Result Activity 5: comparison of the soil erosion of consecutive year

Task 6: After the completion of the indicator survey and soil erosion pattern map, key informants determine the effects of soil erosion on current seasons' crop yield. The crop yield level was level after visit the field based on the erosion status. These levels described the possible percentage of yield loss survey at the harvest time.

Qualitative crop yield loss prediction from farmer was quantified on the basis of erosion map samples of fields under the different erosion status by experts. The crop type was taken same in all sampled fields.

Result Activity 6: Relation between soil erosion class and estimates of crop yield loss.

Result: As a conclusion to the erosion and change in status of the soil erosion damage status, key informants will decide to implement the appropriate SWC measures and soil conservation strategies in the villagers meeting.

7.2.4 Economic Survey Tool

The economic tool was cost and benefit of SWC measures and varied according the status of the different physical and socioeconomic condition of the stakeholders. Stakeholders were involved to calculate the costing of various SWC options on the PGIS based soil erosion mapping tool. The costs and benefits of the SWC measures were compared by benefit and cost of agricultural land in time.

The following was important steps with the brief description.

1) The field location was identified in the map prepared by stakeholders based on participatory erosion mapping tool. The other field characteristic (slope, soil type , farm land) and the economic class of stakeholders based on cost of labor opportunity and crop yield level were determined
2) The cost of construction and maintenance, current state of production were identified and quantified
3) All benefits expected from implementing SWC measures were identified and quantified.
4) There were scenarios discussions with the farmers: an economically feasible option was identified based on result discussion with farmers.

Result: Each farmer situation was measured for cost and benefit for SWC measure over time.

7.2.5. Application of Participatory Soil Erosion Mapping Tool

The researcher, soil expert and NGO officers undertook a major role of facilitating focus group members in the process of applying this tool in 2012 and 2013.Initially NGO officers and VDCs officer led us to introduce community people and the local village leaders of the study area. All the steps in the tool were processed with focus group member. NGO officer showed the area which was failed to convince and implement the soil conservation measures. NGO officer and village leader identified focus group member for our study (Activity1)

The PGIS activities were applied for the erosion indicator ranking according to severity to soil erosion during the last week of December in 2012 (Activity 2). Key informants and farmers meeting were defined field map of study area (Activity 3).
Focus group member carried out PGIS erosion mapping surveyed of the field based on the map prepared by them and the soil indicators approved by the meeting during the rainy season period of June- September, 2012 and 2013(Activity 4). This map knowledge was transferred to other stakeholders in the next meeting to assign the soil erosion status to their individual field (Activity 4). The crop yield loss was asked by the key informants to show the relation of erosion status to the production (Activity 5). The crop yield level with erosion status was shown in the map during the period of June- September 2013(Activity 6) which was experimentally evaluated by researcher.

The threat of soil erosion on the field can be taken from the farmers experience for the best soil conservation option for the field experience erosion. We enquired solution for downstream field which was affected by the overland flow damage. The farmers were suggested the collective action towards the implementation of soil erosion measures to their field.

7.2.6 Application of Economic Analysis Tool

Economic analysis is the important tool and was applied to a sample of farmers of investing in SWC measures. Input parameters of this tool were collected in different soil erosion problem from 30 farmers during the months of June through to September 2013. Three soil erosion classes has identified and visited 10 fields in each class for data collection. Preferred crops and SWC options were established farmers' socioeconomic characteristic and wishes during the visit. For the preferred choice of SWC measures was identified during the discussion of two years costs and benefits for individual farmers.

Two sample farmers were selected from each class to represent the socioeconomic and biophysical setting for the demonstration of the achievement of implication of SWC measures on financial potential which is shown in table 28.

Table 28 Biophysical, Cost and Production Variables of Sample Farmers in Andheri Sub Watershed

Sample farmers	Sample variables					
	Labor cost USD/day	Field area (ha)	Field slope	Erosion class	Field run on (Y/N)	Crop yield (Kg/ha)
Farmer-1	3	0.3	60	High	Yes	880
Farmer-5	3	0.5	30	Moderate	Yes	1250
Farmar-9	3	0.4	35	Moderate	Yes	1030
Farmer-14	3	0.3	20	Low	No	1850
Farmer-21	3	0.2	50	High	Yes	790
Farmer-26	3	0.3	15	Low	No	1600

7.3 Results and discussion

7.3.1. Key Informants selection (Activity 1)

In the study area, village leaders identified 2 men and one woman from each village as key informants. Total 15 key informants of the study area were identified. These key informants played important role in five village of Andheri sub watershed. Female responsibility in household activities made problem to find the gender balance.

7.3.2 Consent List of Soil Erosion Indicators and Their Relative Ranking (Activity2)

The stakeholders ranked the severity of the indicators to the impact of erosion in their soil based on their knowledge of erosion indicator (Table 29). It was observed during focus group discussion they take charge the final decision represented consent because of knowledge on soil erosion process and views of their topsoil erosion indicator. This was based on the argument and knowledge of ranking of the soil erosion indicator among farmers. The farmers made the clear concept by visiting the field and observed presence of gullies, broken soil erosion conservation structures and stoniness as indicator for soil erosion .Splash pedestal, sheet wash, soil texture was also taken as indicators for soil erosion. The ranking of soil erosion damage indicator was done after field observed and made pair wise comparison during the meeting of key informants meeting for relative importance of soil damage.

Key informants differentiated the current or past soil erosion events due to change in erosion indicators. The current soil erosion status was judged based on history of erosion status of particular field. Farmers were able to recognize their field situation of soil erosion due to change in topsoil characteristics and soil productivity.

Table 29 Consent List of Soil Erosion Indicators and Relative Severity Weight Ratio Ranking by Stakeholders of Phewa Watershed

Indicators	Weight Ratio	Severity ranking Order	Current (C) or Past (P) Indicator
Gullies	0.31	1	P
Broken SWC measures	0.22	2	C
Stoniness	0.16	3	P
Rock exposure	0.11	4	P
Rills	0.07	5	C/P
Root exposure	0.06	6	C
Sedimentation	0.04	7	C
Sheet wash	0.03	8	C
Splash pedestals	0.02	9	C

Where severity ranking of 1=high erosion and 9= low erosion

Maximum Eigen Value =10.396 C.I. =0.174495

7.3.3 Farmers' Response: Drawing Soil Erosion Status Map of Sub Watershed (Activity 3 and 4)

Sub watershed map was sketched by key informants together with the sub watershed stakeholders with their knowledge of the local physical environment. Severity of soil erosion status was resulted in field delineations by the key informants' field by field survey (Figure 44). Key informants and stakeholders' knowledge of soil erosion indicators were used to identify high or low erosion classes in Table 29.

The soil erosion map showed that the three class of erosion categories high, medium and low according to key informants perceptions'. High erosion class in hill slope, mid and bottom part of the hill, moderate and low erosion occurs in the upslope area. Gullies, rocky out crops, stoniness land along the stream a hill sides was shown high erosion status by Key informants.

Figure 44 Maize Plot Erosion Feature and Rill Dimension Measurements of Barren Land after Rainfall

The soil erosion mapping map was verified by the villagers into significant reactions. The key informants' perception erosion classification was checked with the map prepared by RUSLE model. The farmers saw the situation of erosion in their field and got the chance to improve the soil loss in their field. They understood that the cause of fertile land laying the valley bottom.

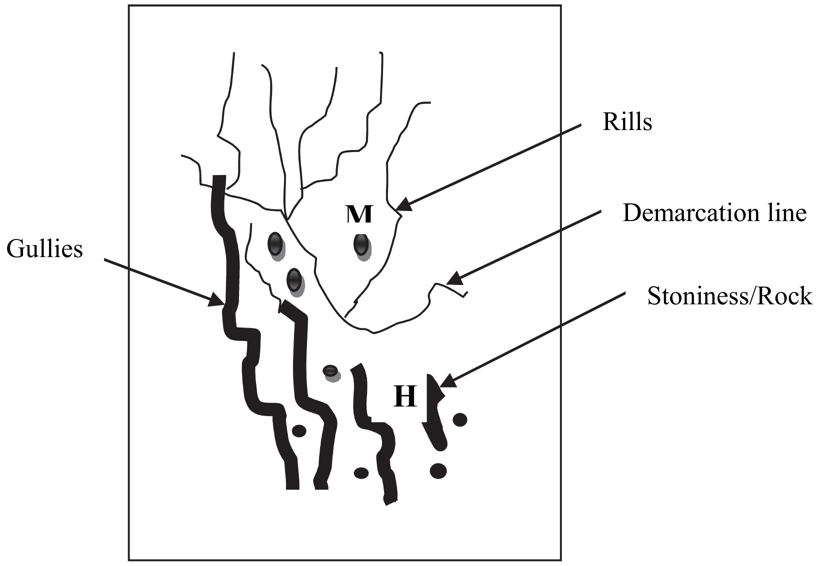


Figure 45 Non uniform Spatial Context of Erosion Indicator as Estimated by Farmers on Site Assessment

Current rate of soil erosion scenario showed that upland field could be improved by implying the upland farmers cared the erosion conservation otherwise erosion scenario might be worsen in near future.

7.3.4 SWC Plans and Crop Yield Loss According to Erosion Class (Activity 5 and 6)

Farmers perceived soil erosion classification on the basis of crop yield losses. High soil erosion status was defined in high crop yield losses checked by key informants with severe soil erosion indicators (Figure 46). Topsoil erosion features and affected crop production perceived equally on differences in soil type and topographic position on key informants observation. Estimated crop yield losses in steep mid slope slightly differ from the valley bottom area due to upslope eroded topsoil. Crop yield of each erosion classes were established from field experiment to quantify the farmers' prediction (Table 30).

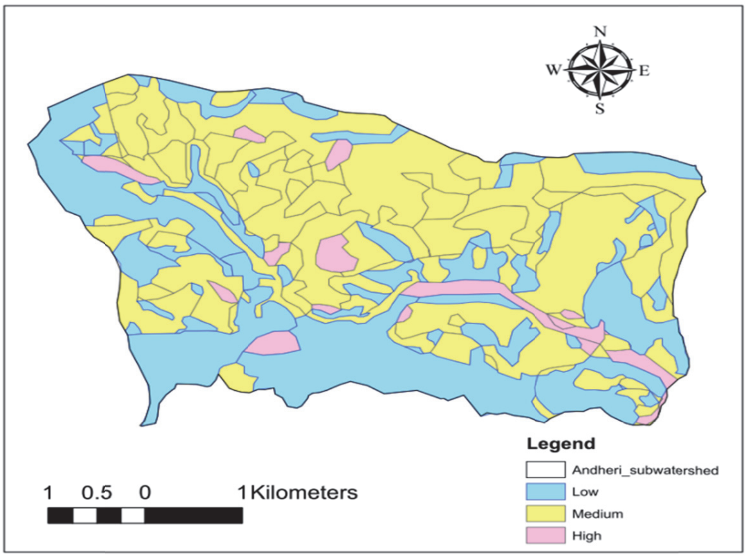


Figure 46 Andheri Sub Watershed Soil Erosion Status Map based on Farmers' Views and Soil Erosion Indicators

The field experiment established the ranges of yield loss matching with farmers' predication as 25% for low erosion loss field and 50-100% for high erosion loss field. The experiment showed that 80 % of the area had high and moderate soil erosion level for maize crop yield level of region at least 1.35/ha. These findings showed that importance of farmers on ongoing soil erosion and restoration of lost soil fertility. Vanclays (1997) observed that farmers seemed powerless in the problem due to severe form of land degradation instead of undertaking recovery action. Alternative field were looking for cultivation by farmers instead of recover the eroded land.

Table 30 Percentage of Loss Grain Yield in Different Soil Erosion Class and Mean Grain Yields

Erosion class	Farmers' predicted crop yield loss (%)	Mean crop yield (Measured in Kg ha^{-1}) *	Yield Loss range (Measured in %)
High	50-100	1350 (0.90)	60-80
Moderate	25-50	1670 (1.23)	30-60
Low	<25	2690 (1.54)	1-30
Control#	-	3.08 (1.61)	0

This is reference soil where erosion is perceived to have had minimum effects; *Values of standard deviation from the mean.

Soil erosion map was prepared with participation of the stakeholders perception recommended the specific SWC measures according to soil erosion classes, slope categories and public areas (Table 31).The stakeholder recommendation was not separated the individual and community conservation activities. It was due to the bad experience of the group work only for the beneficial on their own land not in the public land it was convinced by the PGIS for the effects of public soil erosion in their land also. So PGIS helped to contribute the SWC in community level.

However, they observed during the current erosion damage observation each of them realized that extend of overland flow damage from one field to the adjacent fields of the neighbors and public areas such as school compounds, village roads and besides public building compounds.

Table 31 Different SWC Measures of the Erosion Class and Public Land on Stakeholders' Recommendation in Adheri Sub Watershed

Soil erosion class	Slope steepness condition and public area types	Type of SWC measures suggested
Low	Flat-gentle	GS, R&C+mulching , Hedgerows
Moderate	Gentle	GS, hedgerows
	Steep-very steep	GS
High	Steep-very steep	GS, BT, BT+GS, R&C, vegetated COD , HT+GS
Public lands	village roads without conservation	Good drainage, grading/ leveling, fill pot-holes
	Institutions(Government office, Schools, Temples etc)	COD, leveling, lawn grass, broad level BT

GS=grass strips, LT=Level terrace, BT=Bench terraces, COD=Cut-off-drains, R&C=Ridge and channel, HT= Hill terrace

7.3.5 Cash Flow Analysis

Six farmers were selected based on the socioeconomic and biophysical setting for possible three SWC measures for cash flow analysis (Table 31). According to priority of community people three SWC measures were used for SWC planning by planner in the region. Cost and benefit analysis was important to show the farmers from different socioeconomic background for adopted three SWC measures. The present cash flow of each six farmers could be the way of comparing current earned benefit as considering adopting alternative land management option.

The year zero shows the cash flow before use of investment for SWC and year one shows the cash flow after invest to the SWC measures. Negative cash flow shows the income is less than the investment. Before the investment of the SWC two farmers were benefited all other were in loss. After the SWC measure applied farmers were benefited from the income of maize, vegetable, fodder grass or equivalent of milk and manure from cattle.

All farmers except two (F5 and F14) had to earn extra money for construction of SWC measures for damage plot due to run on from upslope (Table 31). The analyses of adopting bench terrace and stabilized with grass strip compensate the benefits for all farmers though we can't compare farmer to each other. The investment cost was relatively less for adopting grass than other two SWC measures. Farmers F5 and F14 were realized that first year positive return by high crop yield due to the adoption of grass strip. During the discussion most of the farmers preferred start with grass strip and tillage practice like ridge, channels and tilling of least cost based on their biophysical and socioeconomic condition. Adaptation of the grass strip measures helped to improve the financial income of the farmers. This showed that the conservation practice with wide appreciation of financial implication. The farmers were socially encourage and suggested to construct cut off drains that were not able to apply infield SWC measures. SWC measure cost were analyzed and showed to the farmers before implementation. The farmers could recognize the cost of upslope conservation and its offsite effects to down slope area. This could be helpful to show the need of SWC measures plan in sub watershed more than individual farm scale. This could at least help farmers from hill slope scale share in the some conservation structures. The overall activities motivated stakeholders to participate and share their knowledge for soil erosion conservation.

After reflecting on the sub watershed soil erosion scenario, awareness of soil erosion severity was extended among the community members and discussing its impact on crop production. Soil erosion and source of surface overland problem were identified and developed the best measures from the collective brainstorm session on tool improved. The similar problems of neighboring farmers were enhanced team spirit and familiarity among them.

Table 32 Cash Flow Chart of Selected Farmers for twoYears

Farmer	Current #	BT+GS		HT+GS		GS	
		Year 0 *	Year 1	Year 0	Year 1	Year 0	Year 1
F1	-300	2810 (13)	3900	3620 (12)	2800	990 (12)	1600
F5	2200	2620 (17)	5300	3400 (18)	4200	1560 (18)	3600
F9	-400	2290 (15)	3000	4800(15)	2400	1300(16)	2000
F14	2300	1890 (0)	4900	2320(0)	4500	1090(0)	3470
F21	-900	1870(9)	1200	3810 (9)	1100	1210 (9)	910
F26	-200	1640(0)	2,700	2520(0)	2450	1220(0)	1770

#reflects cash flow without SWC measures; * Cash flow (NRS) among the different SWC options

The table showed that Bench Terrace (BT), Hill terrace (HT), Grass Strip (GS) soil conservation investment showed the farmers income was increasing than before they did not use conservation measures. This observation could encourage to farmers to apply the conservation measures. Mapping of sub watershed area and participating in the soil erosion conservation planning activities farmers could understand the problems and solution and improve the SWC activities and support for soil erosion reduction.

7.4 Conclusion

Two participatory tools showed that key stakeholders' knowledge of local ecology brings awareness of the status of soil erosion indicators and soil erosion status to community. Stakeholders identified the fields or hill slopes suffering from the severe soil problem with help of tools and make the common view of soil erosion impacts on soil productivity. The study showed that the farmers' evaluation of soil degradation scenario was accepted by the farmers than evaluation conducts by outsiders. Their idea during the soil erosion mapping tool was the source of runoff that damage down slope field could be identified the collective planning of SWC measurement in sub watershed. Stakeholders' identified the SWC plan for sub watershed. The economic tool showed that the farmers ability to take decision when they are aware of current and future financial position with or without SWC situations. Farmers planning capacity was demonstrated by the application of economic tool to manage financially suitable SWC measures according to their socioeconomic and biophysical setting rather than overriding blanket recommendation from expert. Collective implementation of conservation measures was only perceived practical and socially feasible at hill slope scale rather than catchment scale for infield conservation activities. Economically suitable SWC could be planned by the farmers for practically perceive socioeconomic and biophysical settings than intervening recommendation from experts. The adaptation of these tools could help the SWC project in many ways. Firstly, farmers' insight self-evaluations of problems and solutions could help to increase expert-generated acceptance of recommendations. Farmers accepted only after they have been evaluated by the individual farmers' knowledge and beliefs because of farmers tend to be skeptical of extension messages. Secondly, hot spot of soil erosion were targeted initially by project resources and thereafter less degraded area of sub watershed.

CHAPTER VIII

8. Conclusion and Recommendations

8.1 Conclusion

Himalayan terrain has a critical problem of soil erosion by water due to anthropogenic pressure on its mountainous landscape. Various human activities disturb the land surface of the earth and thereby induce a significant alteration of natural erosion rates. Fertile soil is important to sustain productivity in the hilly terrain. Furthermore, the livelihood of the people in the Himalayan region is mainly dependent on farming, especially on subsistence agriculture. Thus, quantifying erosion assessment can be the core of any decision making and supportive in policy formulation for sustaining the environment. Soil erosion assessment and mapping of erosion prone areas are essential for soil conservation and watershed management. Qualitative and quantitative approaches were adopted in the present study to assess soil erosion risk. Soil erosion risk mapping was carried out by using the GIS base modeling approach in conjunction with satellite remote sensing derived parameters. About 50.10% of the total area of watershed was found to be under a very low risk of erosion (<10 t/ha) while rest of the area is under a moderate to high erosion risk. Considering the pattern of spatial distribution, the soil erosion risk indicated less potential of erosion occurring in the southern and western regions of the hilly counties in Bhadaure Tamagi, Chapakot and Pumdi Bhumdi VDC sub watershed. Most of the northern part and central part of the watershed showed the higher potential of soil erosion risk mainly in Dhikurpokhari, Kaski kot and Sarangkot VDCs' sub watershed.

Soil erosion intensity can be viewed as a comprehensive set of circumstances on the surface: a combined result or interaction of natural and human factors. The outcome from sensitivity analyses and adverse human activities dictate the un-sustainability of the eco-environment for a given area. Natural factors are underlying conditions of the development and occurrence of soil erosion. The soil erosion problem indicated by the erosion model was used for stakeholders' perception on soil erosion. This map was compared with the soil erosion risk area map prepared by the stakeholders using AHP; the result was similar to the erosion model. The gap in socioeconomic risk and natural risk could be filled up by PGIS methodology. PGIS map and GIS technology helped the stakeholders' understanding of soil erosion and soil conservation management. The result of the correlation and regression models showed that soil erosion reduction was significantly influenced by education, farm size, occupation and the professional maternal group and forest group.

The RUSLE model showed the soil erosion risk area and stakeholders sketch could be corrected using knowledge gained from PGIS and GIS technology for their conservation practices in those areas to reduce the soil erosion. The participatory GIS map, prepared by the stakeholder's focus group, could be corrected and fused the knowledge of socioeconomic factors and natural risk factors for a soil erosion map to help all stakeholders' awareness of conservation practices.

Knowledge of LULC change and their relative environmental risks is important for effective and sustainable land resource management. Phewa Watershed, Pokhara, Nepal. LULC change impacts on soil erosion should be made a priority issue in order to devise effective control mechanisms and suitable land management practices. The finding of the LULC in Phewa Watershed over the past decade and a half showed that dense forest had decreased and shifted into open forest and bush area. Furthermore, urbanized settlements were found to have expanded and intensified at the expense of terrace cultivation, single crop land and double crop land. Demand for additional land for farming, wood for fuel, and construction due to rapid population growth has resulted in deforestation and a reduction of the wetland areas. Increased human settlement exacerbates soil erosion. Thus, an accurate knowledge of LULC provides an unambiguous opportunity to improve soil erosion management and benefit the myriad stakeholders of Pokhara, Nepal. Considering natural factors, vegetation is the primary factor affected by human activities. Therefore, altering inappropriate land use management, returning farmland to natural forest, remediating commercial forest on hill slopes, and strengthening the protection and reconstruction of vegetation are key measures that should be taken to control and prevent soil erosion now and in the future.

Community mental maps are dependent on participants' knowledge, experience and impression with cognitive dimension. So, PGIS maps linked to activity space of communities and could take as absolute maps of erosion vulnerability. Mental maps and community narratives of different groups of participants represent different underlying causes of erosion vulnerability and unsafe conditions at sub watershed villages. Community perceptions, knowledge and power relations provide the means and the explanation which link people through vulnerability to hazards and development. Physical and social factors created erosion vulnerability in the agricultural field and infrastructures. Erosion hazards in the study area sites were increasing not only because of an increase in erosion magnitude and frequency but because of increasing social vulnerability. It is both the level of development and the way society is structured that determines income and access to resources. Understanding the human dimensions of erosion vulnerability is critical to designing erosion mitigation programs that target the most vulnerable place and groups. Socio-economic information helped to assess how quickly or slowly vulnerable people can help to reduce soil erosion impacts.

Application of participatory GIS tools showed that key stakeholders' knowledge of local ecology brings awareness of the status of soil erosion indicators and soil erosion status to community. Tools helped the stakeholders to identify the fields or hill slopes suffering from severe soil problems and to make a common view of soil erosion impact on soil productivity. The study showed that the farmers' evaluation of the soil degradation scenario was more easily accepted by the farmers than outsiders who conducted the same evaluation. Their idea, during the soil erosion mapping tool, was the source from the observed field which was identified and could be the collective planning of SWC measurement in sub watershed. Stakeholders' identified the SWC plan for the public land as well as for public houses. Economically suitable SWC could be planned by the farmers for practically perceive socioeconomic and biophysical settings than intervening recommendation from experts. The financial tool showed that to motivate the stakeholders to adapt suitable soil conservation measures, they should use their own observations and not follow recommendations from expert only.

The adaptation of these tools could help the SWC project in many ways out of these mainly in two ways. Firstly, the farmers' insight into self-evaluation of problems and solutions could help to increase expert-generated acceptance of recommendations. Farmers tend to be skeptical of outside opinion and accepted recommendations only after they have been compared with the individual farmers' concepts.

Thus this research identified the soil erosion status of the watershed by the application of RS and GIS technology and participatory GIS based EDA in the technical as well as socioeconomic aspect. The PGIS approach could reduce soil erosion by finding the real cause and effect to minimize gap between understanding the problem and the solution for soil erosion between researcher, scientist and stakeholders.

8.2 Recommendations

The findings of the study showed that the study area was under continuous LULC dynamics and the study area is prone to soil erosion. The model showed that the erosion risk area of the watershed and the factors which affect soil erosion. PGIS based EDA tools helped to understand and implement the findings and minimize the gap between the stakeholders' and scientists' understanding. Therefore, stakeholders, responsible bodies, including land managers and others, which have interest in related issues, should incorporate it during land use planning, soil and water resource conservation and management practices. As a result, the following recommendations are suggested for sustainable of agriculture and soil erosion management.

- The findings of this particular research suggest that land degradation in the steeper slopes is severe which needs urgent land rehabilitation intervention such as forestation programs, terracing and other remedial solutions for the Phewa watershed.
- Soil erosion is a potential problem, mainly because of the mountainous nature and high mean annual rainfall, which exposes the soil as a whole and renders it susceptible to erosion. Basically, man cannot modify rainfall erosivity and soil erodibility factors. However, as the slope gradient and slope length factor is dominant in the magnitude of potential soil erosion in the area, it is possible to modify them through soil conservation practices at a small scale on agricultural land using detailed field assessment.
- Creating awareness among the society concerning optimum use of natural resources, conservation systems, driving forces including population pressure

and their respective benefits is vital for sustainable land resource management. Therefore, the local managers and responsible sectors in the Phewa watershed emphasize the importance of participation of the local communities in conservation activities and decision making.

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APPENDICES

APPENDIX A

Interview Schedule on Participatory GIS for Soil Erosion Management: a Case Study of Phewa Lake Watershed, Nepal-2012

Name:-

Age: Stakeholder's type:

Address:-

…………………………………………………………………………………….

Sub watershed:-……………………………………Village ………………………

Field perform

Date	Place	Topo sheet
Geo coordinate :	Latitude	Longitude
General land use type		
Altitude:	Aspect:	Terrain:

1. The composition of household member in your house

Population Age	Male	Female
0 - 15		
15 -60		
60 over		

2. The household occupational structure

Agriculture		Service		Labor		Industry		Teaching		Hotel & teashop		Students	
Male	Fe	Mal	Fe	Male	Fe	Male	Fe	Male	Fe	Male	Fe	Male	Fe

Fe= Female

3. Education Status of family member

School years	Male	Female	School years	Male	Female
Illiterate			Secondary		
Primary			Higher secondary		
Lower secondary			Campus/University		

4. Resource inventory of farming land

	Bari	Khet	Kharbari	Private forest	Total land
Ropani					

5. What type of soil character is in your field?

a) Grey b) dark grayish and yellow c) brown and black

d) yellowish brown e) dark reddish f) brown

6. What is the soil depth of your field?

a) 0-10 b) 20 -30 Cm c) 30-40 Cm d) ………….

7. What type of slope is in your field?

	Bari	Khet	Kharbari	Private forest
Irregular				
Steep				
Plane level				

8. Are there some problems in your Bari /Khet?

a) Topsoil Erosion b) No of landslide in Bari

c) No. of landslide in Khet … d) No of land slide in private forest

9. How do you perceive intensity of soil erosion with your Khet/ bari farming?

a) Organic matter decline b) Erosion c) Slope

d) Compaction f) Landslides g) Contamination

10. Have you invested to improve the farmland? Yes/no

11 .How much do you invest to improve the farmland per year?

12. What type of conservation adaptation have you adapted?

a) Terracing b) check dam c) Drainage

d) Planting grass in landslide e) wall on the farmland

13. Have you made any changes in cropping pattern? If yes, list the crops and its nature?

Crop type	Before 10 years	Now	Why
Cereal crop			
Oily crop			
Vegetables			
Fruits			

14. Livestock in your household

No of live stock / Live stock	Before 10 years	Now
Cattle		
Buffalo		
Goat /Sheep		
Pig		

15. What are the reasons of change in livestock population?

a) Human resource b) Lack of Pasture land c) shifting the job d) others…

16. Do you use chemical fertilizer and green manure in your farmland? If yes,

Chemical fertilizer ……. kg and green manure……… kg per year.

17. How do you raise your cattle (please, put a check mark within the provided parentheses?

No of animals before 10 years	No of animals now
Grazing on pasture land	Grazing on pasture land
Grazing on private fallow land	Grazing on private fallow land
Grazing on forest	Grazing on forest
Collecting fodder from forest	Collecting fodder from forest
Silage	Silage

18. Are there any changes in quantity and location of grazing area?

Before 10 years	No of animals now
Grazing on pasture land in …………..%	Grazing on pasture land…………..%
Grazing on private fallow land ………..%	Grazing on private fallow land…….%
Grazing on forest …………………%	Grazing on forest…………………%
Collecting fodder from forest………..%	Collecting fodder from forest………%
Silage …………%	Silage ……………………%

19. Income from different sources (In Rs):

Farm income	In Rs	Off farm income	In Rs
Cereal crop		Service	
Vegetables		Daily wedges	
Live stock			
Total			

Rs = Rupees ($ 1 = Rs 80)

20. Is your farm produce good enough food to meet family need? Yes/No, If not how many months sufficient …

21. Have your family member changed profession from agriculture to non-agriculture? If yes why and what?

22. Is the forest area diminishing in your surrounding? Yes/No if yes, main causes are a) Illegal cutting b) Forest fire c) Over grazing d) Unfavorable climatic conditions e) Others

23. Forest resources

Forest resources	Before 10 years	Now
Fire wood in Kg per day		
Timber in cubic feet per year		
Litter in kg per months		
Grass in kg per day		
Fodder in kg per day		
Medicinal herbs		

24. Which and how much fuel is used in your house per month?

a) LP gas …….Per year b) Bio gas c) Fire wood…. kg per day d) Electricity ….unit

25. Do you think that the following activities increase the intensity of soil erosion?

a) Construction of the road and building c) Agricultural activities

b) Forest degradation d) grazing e) others

26. Have you collected any information from a map of soil erosion education earlier?

Yes/No if yes a) Soil erosion location b) Soil conservation c) Forest conservation d) Climate change e) Conservation activities by agencies

27. What are the remedial works practiced in your sub-watershed in 10 years?

a) No of Check Dam construction… b) Plantation area…...ropani

c) Conservation of forest ….ropani d) water ways …………in meter

28.. Have you realized any change in other climatic condition in 10 years?

a) Dew formation b) Acid rain c) Hailstorm d) Storm e) Fog formation

29. Have you ever observed some change of water resources in your locality? Yes/No If

	Increased % in 10 year	Decreased % in 10 years
Water Spring		
Level of pond		
Flow water in Stream		

30. Have you faced any kind of weather related disaster (WRD) from last 10 years?

Disaster	No of times	Disaster	No of times
Long drought		Hailstorm	
Flood		Acid rain	
Landslide		Forest fire	
Storm			

31. What do you think about the causes of soil erosion?

a) Climate b) Soil c) Topography d) Lithology e) Land cover

f) Lack of appropriate practices in agriculture g) Soil erosion rate

h) Construction activities

32. In your experience, what is the most effective soil erosion control device we can adopt?

33. Do you work part or full time on your field? Full/part time how many hours per day…

34. Is there any related course on soil erosion/climate change in your textbook? Yes /no

If yes, what type of education is in your course?

35. Have you involved in some activities related to forest conservation /agricultural practices/climate change? Yes/No if yes, what type of activities?

36. Do you think some particular problems should be included in the course?

37. What is your perception in climate change and soil erosion problem in your locality?

38. Have you taught any agricultural, climate change and soil erosion related course in your school? Yes /No, If not what kind of education is needed in school level curriculum?

39. Have you involved in some income generation activities in your group? Yes/No

If yes what type of income generation activities ……………………………………

40. How many tourists will come in your hotel per year?

41. Which and how much fuel is used in your hotel per month?

a) LP gas … b) Bio gas c) Fire wood….kg d) Electricity ….unit

42. Do you have any training regarding environmental conservation? Yes/No, how many times within 10 years ………………..

43. Have your business income extended any construction activities? Yes/no,
No. of building … No of furniture …

44. How long have you been here?

45. What sort of activities is conducted by your office related to the climate change/soil erosion and agricultural activities in 10 years?

a) Awareness… b) Check dam …. c) Tillage management …………..

d) Construction of road …Km e) construction of building …

f) Agricultural training… g) Education ….h) Others

47. Is there any conflict on natural resource consumption between stakeholders'? Yes /No If yes, what type of conflict is there?

APPENDIX B

Field Survey for Soil Erosion Assessment

Obs. No.		**Village:**			**District:**		**Date: / /**	
GPS	**Lat**			**Long**			**Altitude :**	
Land form / Physiography								
Site characteristic	**Surface coarse fragments:**							
Terrain slope (%)	0-3	3-5	5-8	8-15	15-25	25-33	33-50	>50
Erosion Features								
FC	Slt	Rex	Rills	R f	SW	Sm	Gullies	Gf
Rills	Length (cm)	Width (cm)	Depth (cm)	frequency				
Gullies								
Soil depth (cm)	<10	10-25	25-50	50-75	75-100	100-150	>150	
Stoniness (%)	<15(slight)		15-40(moderate)		40-75(severe)		>75(very severe)	
Field Size	**Length**		**Width**					
Land use/land cover	**Cropland**: current fallow /permanent fallow / **Forest:** open (<10%)/moderate (10-40%)/dense forest (40-70%)/very dense (>70%) **Forest Type:**							
Conservation practices	Terracing /Bounding/Grass bounding /stone bounding /							
Erosion features	Rill/gullies and other …………………………………………………..							
Past erosion class	Slight(e_1)/moderate(e_2)/severe(e_3)/very severe(e_4)						Field Photo No.	
Soil layer	Coarse Fragments (%)			Soil color (moist)			Sample No.	
0-15cm								
15-30cm								
30-50cm								
>50cm								
Soil classification								
Soil drainage class	Excessive /well/moderate well /poor/very poor							
Land capabilities class	Class I/ Class II /Class III /class IV				Class V/Class VI/ Class VII/class VII			
Remarks								

Note: Rex-Depth of root exposure (cm), Slt-surface litter translocation (%), Fc= Flow channel (%), Gf- gully frequency, Rf = rill frequency, SW=Depth of stem wash (cm), Sm=Depth of soil movements (cm)

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