Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.6, No.1, 2016

Soil Erosion Hazard Modeling Using Remote Sensing and GIS Tool: A Case Study Namgnen Watershed in Phongsaly Province of Laos
An Application of Universal Soil Loss Equation (USLE) with Transport Limiting Sediment Delivery (TLSD) Concept

Dr. Kaona Boupha[1] Dr. Khamphad Sourinphomy[2]
1.Department of Irrigation (Ministry Agriculture and Forestry)
2.Asc Pro.Vice-Minister Agriculture and Forestry Government of LAOS

Abstract
The major factors responsible for soil erosion include factors such as rainfall, soil type, vegetation of the area, topographic and morphological characteristics. Due to the spatial variation of rainfall and catchment heterogeneity, surface erosion and sediment yield are much variable. This study is undertaken the use of empirical Universal Soil Loss Equation (USLE) with transport limiting sediment delivery (TLSD) concept to compute soil and sediment outflow in GIS environment. This involves remotely sensed and other related data for assessing the vulnerable soil erosion area within the watershed.

To compute soil erosion and sediment outflow in GIS using USLE with TLSD concept, the catchment was divided into smaller grid cells of 50m x50m to account for catchment heterogeneity by considering smaller grid cell as hydrologically homogeneous area. Grid thus formed was categorized as cells lying on overland and channel areas based on channel initiation threshold in order to differentiate the processes of sediment erosion and delivery in them. In the study, GIS is used for generating representative raster layers based on various factors such as rainfall erosivity, slope length/gradient, soil erodibility and conservation practices for estimation of spatial distribution of soil erosion.

In addition to this, Landsat TM imagery is utilized to produce a land use/cover map of the study area. The land use/cover map was then used in USLE model. The empirical USLE model calculates the soil loss on each cell as a function of the rainfall – runoff erosivity and the soil erodibility factors. This is then modified with the factors of topography, cover management and the support practices. The rate of sediment transport from each of the discritized cell depends upon the transport capacity of the flowing water. The eroded sediment was routed from each cell following the defined drainage path to the catchment outlet.

The concept of transport limiting sediment delivery (TLSD) was used for determination of spatial distribution of transport capacity of flow within the watershed and the total sediment yield at the watershed outlet. The Normalized Difference Vegetation Index (NDVI) is used for determination of spatial distribution of transport capacity factor used in TLSD equation. Thus the total amount of sediment coming out to the outlet is the sediment yield of the catchment.

The Namgnen watershed with a hydrological perspective is very significant with dense channel network of rill and gullies and significant alluvial. Further, results indicate that areas within a watersheds having high topographic factor with waste land and agricultural land and areas near first order stream produce more erosion. However, spatially computed soil removal from most of the catchment area is limited to 0-5 tons/hectare/year except few pockets which produce more sediment yield, indicating most of the areas in the catchment fall within tolerable limits of soil erosion.

INTRODUCTION

Soil erosion is serious problem though out the world. Globally 1,964.4 M ha of land is affected by human-induced degradation (UNEP, 1997). Of this 1,903 M ha are subject to soil erosion by water and 548.3 Mha, soil erosion by wind (Pal and Samanta, 2011).

In Laos, the prevailing cropping system until the 1990's was Sweden (slash-and-burn) cultivation of upland rice with one year of cultivation and eight year of fallow period. Rice cultivation period resulted in 5.7 tones ha^{-1} yr^{-1} of sediment being generated while fallow periods generated only 0.4 tones ha^{-1} yr^{-1}. Under that system, the mean annual sediment yield was therefore 0.9 tones $ha^{-1}yr^{-1}$. At the end of the 1990's, this system was replaced with longer cultivation and shorter fallow periods (i.e two years of cultivation followed by two fallow years) and the mean annual sediment yield increased to 3.1 tones $ha^{-1}yr^{-1}$. During these period, farmers experienced difficulty in the controlling weed competition within their rice fields. Consequently they gradually replaced upland rice with maize, which led to the production of nearly double the amount of sediment (11.3 tones $ha^{-1}yr^{-1}$). Overall, this change of system and replacement of crop, led to an approximate increase in mean annual sediment yield (5.9 tones $ha^{-1}yr^{-1}$) of 600%. In contrast, the improved fallow trial produced only 0.1 tones ha-1yr^{-1} of sediments, and continuous direct sowing and mulch-based conservation agriculture produced 0.7 tones ha^{-1}yr^{-1}. Economic and the technical constraints (the need for herbicide usage to remove grass) are currently limiting the adoption of the direct sowing system. But the improved fallow system seems to have a higher chance for the farmer's growth.

Watershed management has become an increasingly important issue in many countries including Laos. Concerned governmental authorities and non-governmental institutions find difficulties in appropriate management for improving living standards of people living in the mountain areas in Laos. Better concepts and approaches related to watershed management have experienced a vast change during the past few years but yet there is no universal methodology for achieving effective resource and watershed management (Naiman et al., 1997; Bhatta et al., 1999). For ensuring an environmentally sustainable development, a sustainable utilization and conservation of forest resources at community or watershed level is considered as one of the major rural development components.

Inventory on soil erosion hazard is vital for effective soil conservation plans of a watershed for sustainable development. The potential utility of remotely sensed data in the form of aerial photographs and satellite sensors data have been well recognized, in mapping and assessing landscape attributes controlling soil erosion such as physiographic, soil, land use, land cover relief and soil erosion pattern.

There is a potential of GIS technology for the soil erosion hazard assessment. Soil erosion hazard is mostly assessed by Using Universal Soil loss Equation (USLE) (Campbell, 1979). Recently, several study showed the potential utility of GIS technique for quantitatively assessing soil erosion hazard based on USLE predicated erosion soil loss. Cruz (1992) developed a concept (scalogram modeling) and utilized this concept for upland agriculture suitability assessment using soil and terrain parameter. A GIS based integrated modeling approach utilizing soils cape, terrain and climatic parameters controlling soil erosion is only the effective means of practical assessment of soil erosion hazard.

Major factors responsible for soil erosions are rainfall, soil type, and vegetation, topographic and morphological characteristics. These are found to have spatial variability. Therefore, surface erosion and sediment yield quantities are found to have large variability due to the spatial variation in rainfall and catchment heterogeneity. A recent and emerging technology known as Geographic Information System (GIS) can be used to efficiently manage spatially discretized data such as topography, soil, land use/ land cover etc, for sediment yield modeling and for quantification of heterogeneity in the topographic and drainage feature of a catchment (Shamsi, 1996). The relative vulnerability of watersheds can be assessed with respect to time-independent factors like soil type, topography and morphology in the areas where the data on rainfall and sediment yield is scarce (Jain and Goel, 2002). The study therefore, undertaken to use widely accepted empirical Universal Soil Loss Equation (USLE) to compute soil erosion and sediment outflow in GIS environment utilizing remotely sensed data and other relevant data to assess the vulnerable areas of soil erosion in the watershed.

The general objective of this study is to identify the critical erosion producing source area within the study area and measures used for the effective implementation of the watershed development program. The study demarcates areas which are more vulnerable to soil erosion in the watershed. This work will be much fruitful to the concerned authorities for making better management plans such as a forestation plan, terracing of agricultural land etc. Further, the study also covers identification of the critical erosion producing in source areas within the Namgnen watershed for effective implementation of watershed development programme.

The study also covers other Specific objectives which include quantification of soil erosion and sediment yield in spatial domain using USLE and transport limiting sediment delivery concept (TLSD). Secondly, identification of critical erosion prone watershed areas based on soil erosion result by USLE model and TLSD concept. Thirdly, prioritization of source areas/ watersheds based on soil erosion severity. Thus, this work will benefit to the concerned authorities and institutional involved in Lao or any other parts of the world to better understand the problem.

CASE STUDY OF NAMGNEN WATERSHED BOUNTAI DISTRICT, PHONGSALY PROVINCE OF THE LAO, PDR

The Phongsaly Province

Phongsaly Province is the most northerly and the least accessible province in the Lao PDR. Located around 870 km by road from Vientiane capital, it is bordered to the south by Oudomxai province to west and north by China and to the east by Vietnam (Figure. 1). Access is via road or by air to Luangprabang or Oudomxai and then by road along the Nam Ou river from Luangprabang or Muang Khoa. Other, alternative road access is through China via Luangnatha province. Generally it can take up to three days to reach Phongsaly from Vientiane, Capital of Lao.

For the Namgnen watershed outlet in Ban Naway far from Boutai District central along the road Boutai to Namorn District of Oudomxay Province. The watershed area cover 16 targets village as: Ban Plailack, Ban Naway, Ban Namark, Ban Mojisand, Ban NamKoun, Ban Aneng, Ban Houengway, Ban Namhin, Ban Namban,

Ban Borharh, Ban BorNoi, Ban LongnaiKhao, Ban Longnaimay, Ban Phankai, and Ban Chalongmai, The population in 2007 was around 3,519 peoples.

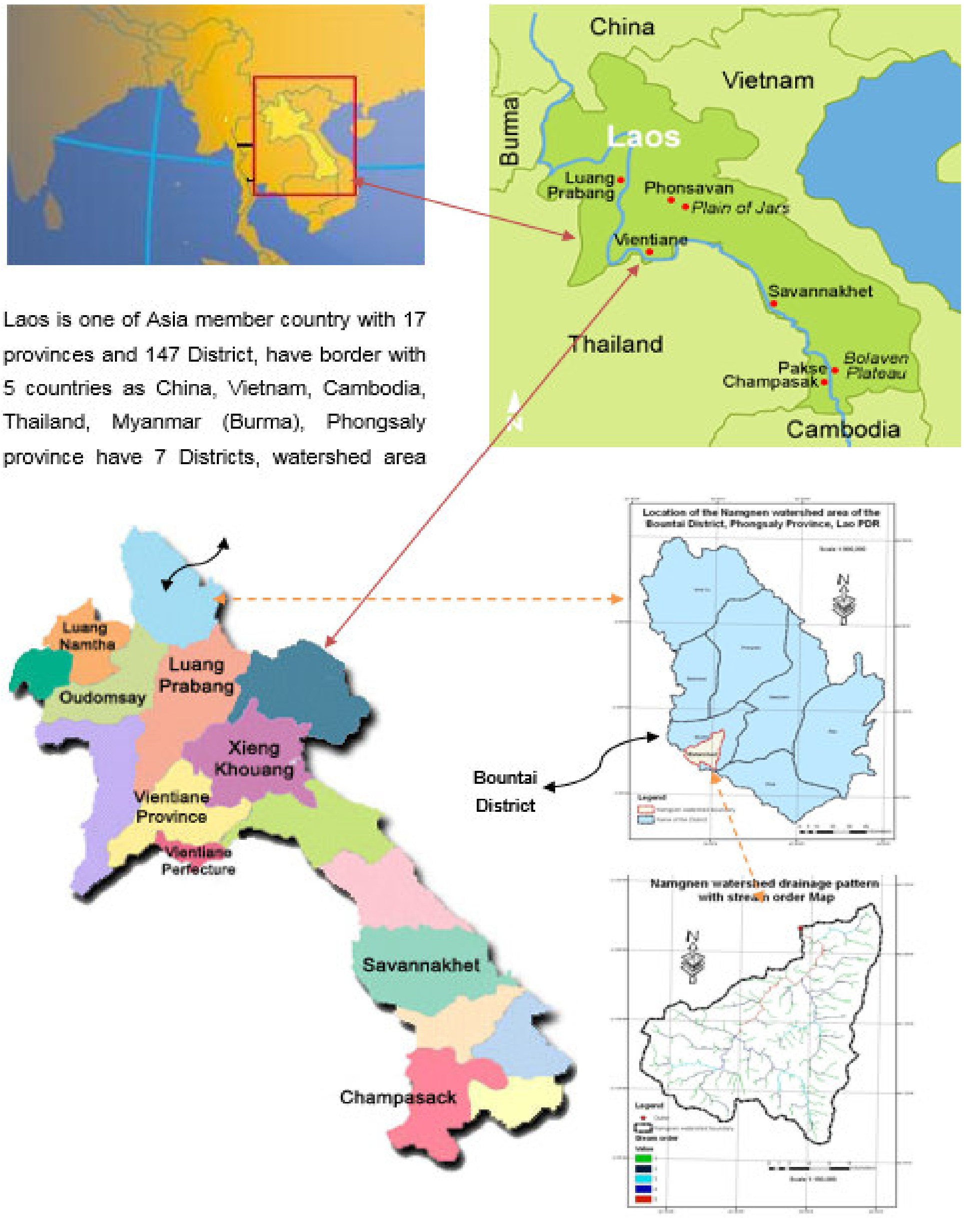

Figure. 1: Location Map of the Namgnen watershed Based in Bountai District Phongsaly Province of the Lao PDR

Climate:

Phongsaly province receives 1,500-2,000 millimeters of rainfall per year and varies by location and altitude. Fog and low cloud can hang over Phongsaly at any time of the year and sometimes for several consecutive days in the cold seasons. The climate can vary locally due to topography (Table. 1).

Table 1: Mean monthly climatic parameters for study watershed.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall(mm)	16	28	41	103	189	290	366	389	171	96	64	26
AV.Day.length Hrs	11.7	12.2	12.7	13.4	13.9	14.2	14.1	13.6	13.0	12.4	11.9	11.6
AV.Max.Daily Temp C	23	25	27	29	28	26	26	26	26	25	23	20
AV.Min Daily Tem C	6	6	10	13	17	18	18	18	17	15	11	6

Source: 1991-1996 station hydrology phongsaly

Topography and Soil:

Phongsaly province is situated approximately 21 degree North latitute and longitude 102 degree west. The altitude varies from 300 meter in the valleys and up to 2,200 meters towards hills above mean sea level. Most rivers flow into the Nam Ou River, a major tributary of the Mekong River.

The soil differs in texture, structure and fertility but appear very prone to erosion during heavy rainfall especially if natural vegetation has been removed. The mountain range is geologically recent and soil erosion and landslides are common due to the steep slope and soft subsurface strata.

Basis constrains and Potentials of the Namgnen watershed to be adopted for soil erosion hazard:

The study area constitutes a mountainous watershed in Namgnen valley of Bountai District Phongsaly Province Lao PDR and lies between 21’8” to 21’24” E latitude and 101’48” to 102’4” N longitudes with total area of Watershed is approximately 31,709.32 ha..

It has sub-tropical climate with mean annual rainfall varying from 1,321 to 3,549 mm (hill and piedmont plains area) with annual temperature of 18^0 C. The soil moisture and temperature regimes are characterized by udic and hypeerhermic and thermic in mountains. The elevations of the highest and lowest point are 540 m and 1640 m above mean sea level. The various types of data used in this study are multi-temporal satellite from LANSAT TM, survey of Laos topographical maps (1:100,000) prepare by EU-PFCRDP, agro meteorological data of rainfall and air temperature recorded at meteorological stations. Also, laboratory analyzed soil data of organic matter, soil texture of soil sample collected from soils cape units of the area were also used.

The development of the watershed is not uniform. The lowland valley stretching from Naway village to Ban Khoung Village near border China and local market centre is one of the most fertile and economically important areas of watershed. Semi-urban centre are directly connected to National forest conservation valley near International border, have alternative sources of energy, and alternative source of income in addition to agriculture. This high variability in the ecological and economic conditions makes the watershed an appropriate site to study land use dynamics and other factors associated with it.

The Namgnen watershed:

The Namgnen watershed is selected for the study which constitutes a mountainous and rolling farmland of the foothill watershed in Namgnen valley of Bountai District Phongsaly Province Lao PDR and lies between 21’8” to 21’24” E latitude and 101’48” to 102’4” N longitudes. Most part of the watershed is mountainous region covered by forest and upland cultivation. Since these streams were carrying a large amount of sediment, the several conservation measures were taken to check the siltation of the outlet at point Namgnen river in Ban Naway including contour trenches, silt-arresting dam, wear of the irrigation activity, planting of forest species and grasses, terracing in the agricultural land and linking of the two major streams to divert the flow away from the boat club at the outlet. Though these conservation measures were effective in arresting a large amount of sediment, the outlet continue taken to receive sediment from watershed area, which is being removed by water flooding along the river to the basin.

Hydrologically, the watershed is very significant with dense channel networks of rill, and gullies, and significant alluvial, results in the lower slopes of these hills and mountain ranges. The streams have deposited thick debris over the rocky debris over the rocky surface to form buried pediment, with the accumulation of Aeolian deposits against the granite hills. These pediments have formed undulating surfaces at places. The remaining part of the basin is formed of alluvial deposits which are being utilized for agricultural activity and at present these are under mono-culture. The banks of the major river have younger alluvial deposits and are being used as double cropped lands

Hydrometeorology of the watershed:

The climate of the Namgnen watershed is sub-humid with a mean maximum temperature of 28^0 C in June and minimum temperature of 6^0 C in January. The average annual rainfall is around 1,868 mm, with a maximum of 3,549 mm and a minimum 1,321 mm of the total rainfall per year duration from 1991 to 2007. 80% of the precipitation is received during the monsoon season from June to September. Average daily evaporation ranges from 0.8 mm per day in September to 4.0 mm per day in March. The climate can vary locally due to topography. Monthly rainfalls from 1991 to 2007 for phongsaly station are shows in the Table. 2.

Table 2: Monthly Rainfall from 1991-2007 (mm) in Station Meteorology Phongsaly

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1991	21.0	20.8	44.2	76.8	43.1	334.7	1476.0	140.5	1153.0	97.2	50.0	91.4	3548.7
1992	30.6	52.2	NT	26.5	120.4	213.6	903.6	294.5	773.3	111.4	43.3	47.2	2616.6
1993	5.0	13.0	38.8	82.8	334.9	192.0	194.9	273.2	118.7	57.5	NT	10.1	1320.9
1994	2.2	NT	93.1	74.0	215.7	408.5	329.3	200.4	54.2	107.7	42.7	42.5	1570.3
1995	45.0	6.4	24.8	27.4	65.1	394.7	256.0	362.4	76.6	112.8	54.8	2.6	1428.6
1996	NT	45.6	NT	60.8	164.6	190.3	418.1	404.0	155.3	79.2	39.7	61.9	1619.5
1997	7.0	5.0	108.2	96.6	84.9	88.8	806.9	251.1	293.7	99.1	16.5	36.0	1893.8
1998	NT	5.5	91.8	34.2	214.4	277.1	384.7	212.9	158.8	63.5	14.7	61.8	1519.4
1999	53.2	30.9	17.5	85.3	268.8	173.1	330.7	452.7	124.3	81.9	43.9	43.8	1706.1
2000	21.1	43.9	22.6	81.9	298.8	237.1	377.2	283.6	141.7	155.4	NT	28.4	1691.7
2001	14.1	45.0	89.3	72.1	209.7	276.9	428.0	217.1	131.4	208.8	67.2	1.0	1760.6
2002	74.5	230.0	25.3	50.7	288.6	255.7	450.0	321.9	49.5	197.9	109.4	52.8	2106.3
2003	11.7	249.0	93.3	60.6	101.2	331.3	114.0	400.8	166.2	60.2	NT	5.8	1594.1
2004	28.1	235.0	43.9	89.6	267.4	135.3	238.4	379.1	174.9	26.6	77.3	1.8	1697.4
2005	7.7	17.0	182.5	106.3	129.5	300.6	342.5	960.7	160.2	82.8	48.2	60.9	2398.9
2006	14.0	301.0	46.6	119.6	162.7	74.8	293.6	336.3	117.4	10.1	10.6	218.7	1705.4
2007	42.0	11.0	NT	193.6	178.8	143.9	446.6	333.3	131.9	58.3	35.9	NT	1575.3
Total	377.2	1311.3	921.9	1338.8	3148.6	4028.4	7790.5	5824.5	3981.1	1610.4	654.2	766.7	31753.6
Average	22.2	77.1	54.2	78.8	185.2	237.0	458.3	342.6	234.2	94.7	38.5	45.1	1867.9

Generation of thematic layer of the database:

The collected data are used for preparation of the various thematic maps as spatial data base. The GIS database created for the Namgnen watershed focused on attributes and data necessary to run the USLE model. Thematic layers viz. watershed boundary, drainage network, soil, and digital elevation data on 1:50,000 scale maps have been digitized and transferred and encoded as GIS layer in Arc Map GIS package.

The process of computerization is a complex procedure involving manual data entry, digitization of map/maps or scanning, followed by factorization, editing, labeling and cleaning of digital maps, topology building, and attachment of attribute data with maps etc. The point information such as spot highs have also been digitized and generated as point layers. The checking of these spatial maps has been performed with respect to other data layers by overlaying technique and refined mutually as part to standardization of the data base. The errors due to digitization and miss-mapping are removed in this process. In the present study cell size (50 x 50) m is considered as basic operational unit for the soil erosion analysis.

There are alternative to use of a converted topo plotter. A popular alternative with GIS users is to generate DEMs from the contour such as the SPOT stereo model. Software packages such as GIS for extracting elevation data from SPOT grid cell 50 meter personal computer are commercially available. Besides topo data, the data extraction process requires ground control points, with can be measured in the field by GPS (global positioning system) with differential correction. The quality of such DEMs depends on the software package and the quality of the inputs. The GIS packages use raster data that are imported from DEMs. Based on a proprietary format ESRI grids are either integer or floating-point. An integer grid has a value attribute table that stores cell values. A floating-point grid may not have table berceuses of its potentially large numbers of records. ESRI software can convert a floating-point grid to an integer grid and vice versa.

The relief and Namgnen watershed delineation:

Watershed relief is the difference in elevation of the outlet and elevation of the most remote point in the watershed. The elevation of the most remote and lowest point at outlet is around 1640 m and 540 m respectively. The relief of the watershed is 1000 m. The map of the watershed prepare by using Arc Map GIS technique, TauDEM terrain analysis Toolbar to analyze difference in elevation from DEM Creating watershed. As defined by topography, a watershed is an area that drains surface water to common outlet. A watershed is a hydrologic unit that is often used for the management and planning of natural resources. The objective to uses watershed as a general tern, rather than as a specific class in the watershed boundary is to refer to the process of using DEMs and raster data operation to delineate watershed and to derive topographic features such as stream net works.

Watershed boundaries are drawn manually in the topographic map. The person who draws the boundaries uses topographic features on the map to determine the locations. In the Namgnen watershed, TauDEM terrain toolbar programs are also used to derive watershed from DEMs in the computer.

Delineation of the watershed can take place at different spatial scales (Band et al. 2000). Large watershed cover stream system and small stream within the smaller watersheds. Delineation of the watersheds can be area-based or point-based. An area-based method divides a study area into a series of the watershed for each selected station, or a dam. Whether area-or point-based, the automated method for delineating watersheds follows a series of steps, starting with a filled DEM.

The first step is to demarcate watershed for each stream section. The inputs in the methods involve the flow direction and the stream link raster. A denser stream network (i.e, based on the smaller threshold value), will have more but smaller watersheds does not cover the entire area of the original DEM. The missing areas around the rectangular border are areas that do not have flow accumulation values higher than the specified threshold value.

Delineating watersheds is the upslope area contributing flow to given location. Such an area is also referred as a basin, catchment, sub watershed, or contributing area. A sub watershed is simply part of hierarchy, implying that a given watershed is part of larger watershed.

The watershed function uses a raster data of flow direction to determine contributing area (ESRI). In this study, we use a flow accumulation threshold or the pour point to delineate watersheds. Pour points of the watershed will be the junction of a stream network derived from flow accumulation. Therefore, a flow accumulation raster must be specified as well as the minimum number of cells that constitute a stream (the threshold value). When a dataset is used to define a watershed, the features identify the pour points.

THE SOIL EROSION MODEL

Background Soil Loss Estimation Models:

There are various predictive equation have been developed by several investigation but there are various limitation. Hence, do not provide suitable means for assessing the soil loss from a specific area. In 1940, Zing developed a soil loss prediction equation for hill slope, considering the steepness of slope and slope length, the equation given as:

$$Q_s \propto \tan^m \theta . L^n \quad \text{----------- (1)}$$

In which, Q_s is the soil loss expressed as per unit area.

θ is the gradient angle,

L is the length of slope,

m and n are constants and the value of $m = 1.2$ and $n = 0.6$,

The computation of soil loss using above equation (1) was limited only to steepness of the field that is not justifiable. Apart from slope steepness and slope length, the soil loss is also affected by several other factors viz, climatic characteristics, soil characteristics, crop management and conservation practices. Thus, these factors must be considered for soil loss estimation.

In this regard, the effect of climatic factor in terms of rain fall erosivity index by Musgrave (1946) and Crop management factor taking into account off effectiveness of different growth stages of the crop on soil loss was introduced by Smith (1958). Similarly, the effects of conservation practices and soil erodibility on soil loss were also evaluated later on. Ultimately by taking all these factors into account, a predictive equation was developed for estimating the soil-loss, called as Universal soil-loss equation (Wishmeir and Smith 1965, 1978).

The Universal Soil Loss Equation is given as:

$$\mathbf{A} = \mathbf{R} \times \mathbf{K} \times \mathbf{LS} \times \mathbf{C} \times \mathbf{P} \quad (2)$$

Where:

A is average annual soil loss rate (tone $ha^{-1}yr^{-1}$),

R is rainfall erosivity factor (MJ $mmha^{-1}h^{-1}yr^{-1}$),

K is soil erodibility factor (tone $ha^{-1}MJ^{-1}mm^{-1}$),

LS is topographic factor,

C is crop management factor,

P is conservation supporting practice factor.

Equation (2) is requires in evaluating raster difference factors appearing in it. Also catchment hater generation, there factor very in the spatial domain. In the present study such spatial variability is considered by discrediting catchment into square grids of 50 m size in the GIS layer. A general schematic for computation of soil erosion is presented in Figure. 2.

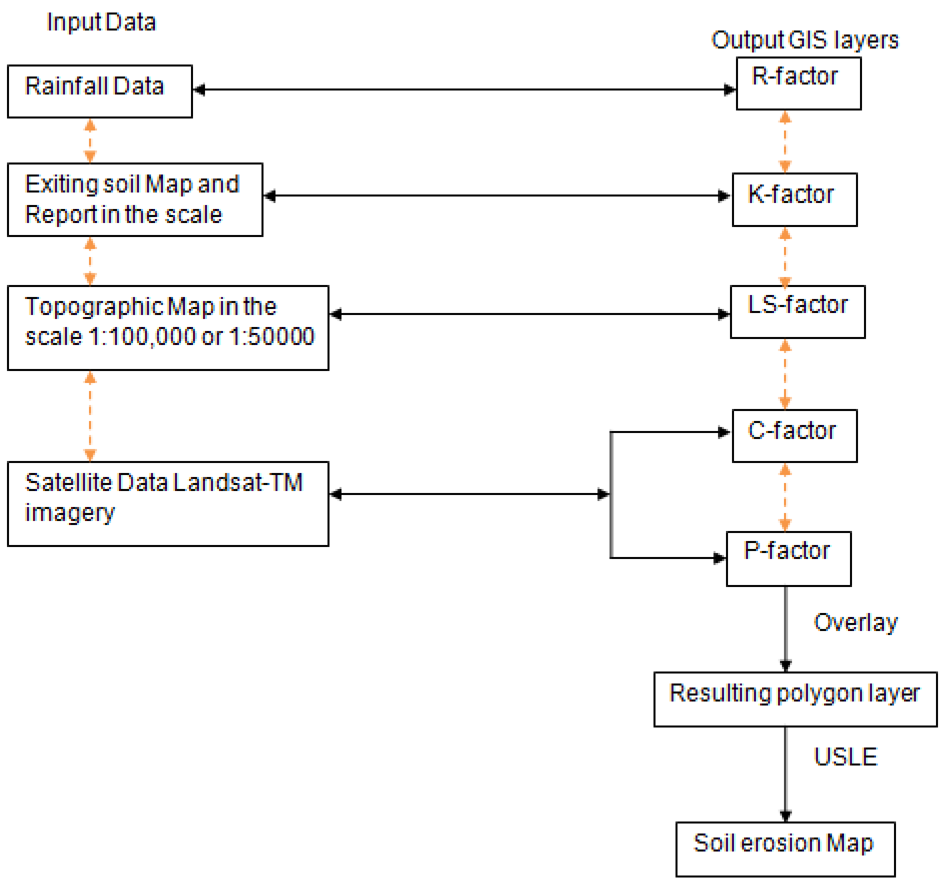

Figure. 2: Schematic Flow Chart of GIS application to soil erosion Mapping.

Development of model database for USLE:

Rainfall erosivity (R):

The erosivity factor of rainfall (R) is a function of the falling raindrop and the rainfall intensity and is the product of kinetic energy of the raindrop and the 30-minute maximum rainfall intensity. This product is known as the erosion index (EI) value. This value gives very good correlation for the estimation of soil loss and reliable estimate for the potential rainfall erosivity. In the present study, R was computed by analyzing the available rainfall charts of different years available from rain gauge station located in the watershed. As the selected area is small (31709.32ha), the spatial distribution of R was assumed to be uniform.

The value of R for the Namgnen watershed is not available but can be computed using formula as (Source: FAO world soil resource):

$$\mathbf{R} = 117x\,(1.00105)^{Mar} \qquad (3)$$

For Mar<2000mm

Where:

Mar = mean annual rainfall in mm. in the Namgnen watershed.

We can generated annual erosivity from Annual rainfall average 17 year from 1991 to 2007 = 1867.9 mm detail in Table 2. Monthly Rainfall in Station Meteorology Phongsaly province,

Therefore **R** factor from formula = 830.84.

Soil erodibility factor (K):

Soil erodibility factor is closely related to the various soil properties by virtue of which, a particular soil becomes susceptible to get erode, either by water or wind. Physical characteristics of the soil greatly influence the rate at which difference soils are eroded. Some more important soil properties include soil permeability, infiltration, rate soil texture, management etc.

Size and stability of soil structure, organic content and soil depth, also affect the soil loss in the large extent. The soil erodibility factor (K) is expressed as tonnes of soil loss per hectare per unit rainfall erosivity index, from a field of 9 percent slope and 22 meters as field length. The erodibility factor (K) is determined by considering the soil loss from continuous cultivated fallow land without the influence of crop cover. For soils containing less than 70 percent silt and very fine sand, the soil erodibility factor was determined using the following equation given by Foster et al. (1991):

In the study area, universities from Japan and NAFRI Vientiane of the Laos surveyed soil profiles in year 2005 and taken disturbed and undisturbed soil samples from each soil horizon at the regular intervals at depth on every site except the mountain area. Additional samples were also collected from the summit of the mountain and its mid-slope-area that had not been used for cultivation more than 40 years in March 2006. Moreover, infiltration tests using an artificial rainfall simulator were performed on the foot slope of moderate-yielding field. All soil samples were sent to Japan for soil property analysis. Based on the analysis of soil survey, soil map of the study area was prepared and used in this study. Details of particle size distribution found for each experimental site is given in Table. 3.

Table 3: Soil particle size distribution at each experimental site,

Experimental field	Slope position	Texture	Particle size distribution (g Kg$^{-1)}$		
			Clay	Silt	Sand
Low Yield	Upper slope	Silty Clay loam	247	467	286
	Mid-slope	Light Clay	319	378	302
	Foot slope	Clay loam	221	388	391
Moderate Yield	Mid-slope	Heavy Clay	522	312	166
	Foot slope	Clay loam	240	267	494
Moderate Yield	Mid-slope	Light Clay	445	412	143

Resource: Houay Pano watershed No4 2001-2005

A simple nomograph has been developed by Wischmeier et al., (1971) to determine the K value using five soil parameters. All five soil parameters need to be known viz. percentage silt (MS; 0.002 – 0.05 mm), percentage of very fine sand (VFS; 0.05-0.1 mm), percentage of sand greater than 0.1 mm, percentage of organic matter content (OM), structure (S) and permeability (P). An analytical relationship for the nomograph by Wischmeier et al., (1971) is given by the equation.

$$K = 7.59 * \frac{2.1*10^{-4}(12-OM)*M^{1.14} + 3.25(S_1-2) + 2.5(P_1-3)}{100} \quad (4)$$

OM is Percentage of organic matter content, M = (% of MS + % of VFS)* (100 – %CL), CL is the clay particle (< 0.002 mm), S1= the soil structure code used in soil classification and P1 = the profile permeability class. Representative soil samples from many locations in the watershed area were collected and analyzed for determination of textural classes. Base on the relative proportion of soil erodibility factor was estimated in tone $ha^{-1}MJ^{-1}mm^{-1}$.

For estimation of soil erodibility factor, soil parameters for representative soil classes were used in above equation (4). Computed values of soil erodibility factor are presented in Tables 4 and 5 for study watershed. Spatial distribution of soil erodibility factor is presented in Figure. 3.

Table 4: K factor Data (Organic Matter Content)

Textural Class	Average	Less than 2%	More than 2%
Silty Clay Loam	0.032	0.035	0.030
Heavy Clay	0.017	0.019	0.015
Clay Loam	0.030	0.033	0.028

Table 5: Rang K Value.

No	Rang (K Value)	Class
1	Less than 0.095	Very Low
2	0.095-0.113	Low
3	0.113-0.148	Average
4	0.148-0.165	High
5	More than 0.165	Very high

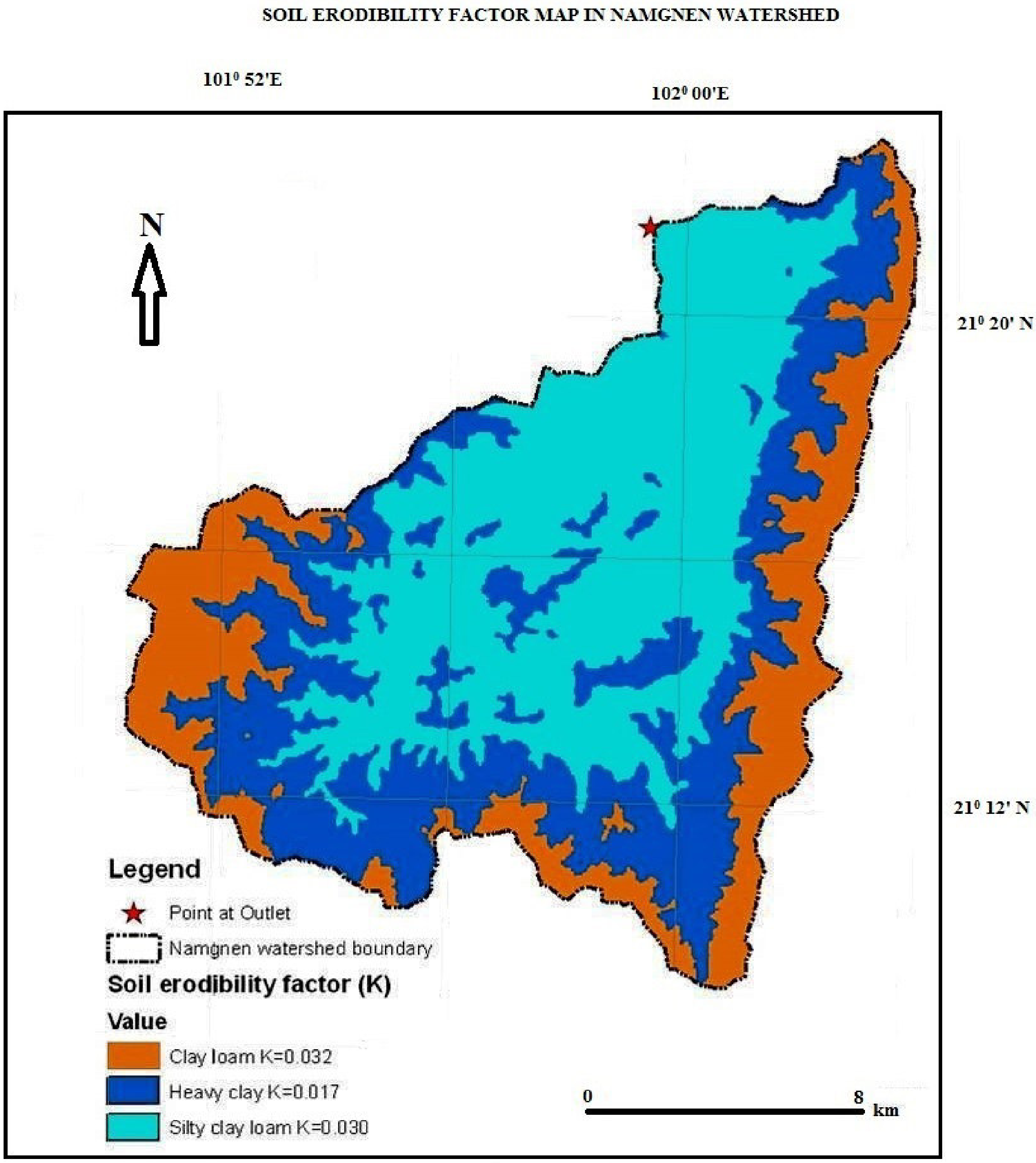

Figure. 3: Soil erodibility factor (K)

Topographic factor (LS):

Length and steepness of slope factor are combined together, is termed by a specific name as topographic factor, which is defined as ratio of soil loss from a field having specific steepness and length of slope (i.e. 9 percent slope and length 22 m) to the soil loss from a continuous fallow land. LS Factor was derived with the help of Arc Info GIS using the formulation proposed by Moore and Burch (1986) as:

$$\mathbf{LS} = \left(\frac{A_s}{22.13}\right)^m \left(\frac{\sin\beta}{0.0896}\right)^n \qquad (5)$$

Where:

- $\mathbf{A_s}$ = slope upslope contributing area;
- $\boldsymbol{\beta}$ = the slope angle exponent;
- $\mathbf{m}$ = the slope length exponent;
- $\mathbf{n}$ = the slope steepness exponent;

The exponents (m) and (n) are estimated to be 0.6 and 1.3, respectively. When implement in a raster-based in

GIS, the LS factor for each cell can be calculated from the slope and the catchment area of the cell (Moore and Wilson 1992; Moore and Wilson 1994; Gertner et al. 2002).

Traditionally, the LS factor is computed using topographic maps which is tedious and error prone job. In the present study, the LS factor is computed using DEM of the watershed. Various operations such as filling of depressions, flow direction and flow accumulation operations were performed to use equation (5) for computation of LS factor. A filled DEM or elevation raster is Void of depressions. A depression is a cell or cells in an elevation raster that are surrounded by higher-elevation values and thus represents an area of international drainage. Although some depressions are real such as quarries or glaciated potholes, many are imperfections in the DEM; therefore depressions must be removed from an elevation raster. A common method for removing a depression is in to the crease it cell value to the lowest overflow point out of the sink (Jenson and Domingue, 1988). The flat surface resulting from sink filling still needs to be interpreted to define the drainage flow. One approach is to impose two shallow gradients and to force flow away from higher terrain surrounding the flat surface toward the edge bordering lower terrain (Garbrecht and Martz 2000). Figure. 4 shows filled DEM of the study area.

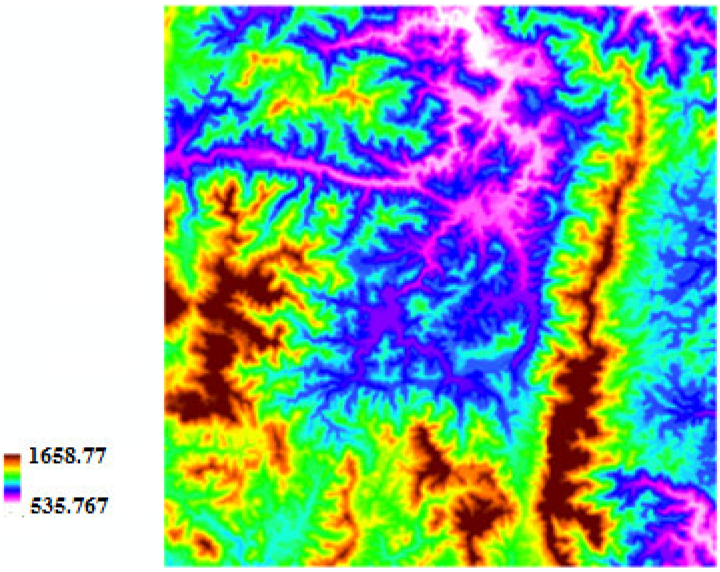

Figure. 4: Filled DEM

A flow direction raster show the direction of water will flow out of each cell of a filled elevation raster. A widely used method for deriving flow direction is the D8 method used by Arc GIS, the D8 method assign a cell's flow direction to one of its eight surrounding cell that has the steepest distance-weighted gradient. Figure. 5 depicts flow direction map of the study catchment.

A flow accumulation raster tabulates for each cell the number of cells that will flow to it. The tabulation is based on the flow direction raster with the appearance of a spanning tree. A flow accumulation raster records how many upstream cells will contribute drainage to each cell (the cell itself is not counted). A flow accumulation raster can be interpreted in two ways. First, cells having high accumulation value generally correspond to stream channels where as cell shaving an accumulation value of Zero generally correspond to ridge lines. Secondly, if multiple by the cell size, the accumulation value the drainage area. A flow accumulation raster with darker symbols represents higher flow accumulation values. The flow accumulation function calculated flow as the accumulated weight of cells flowing in to each down slope cell in to the output raster. If no weight raster is provided, a weight of one is applied to each cell and the value of cells in the output raster will be the number of cells that flow in to the each cell.

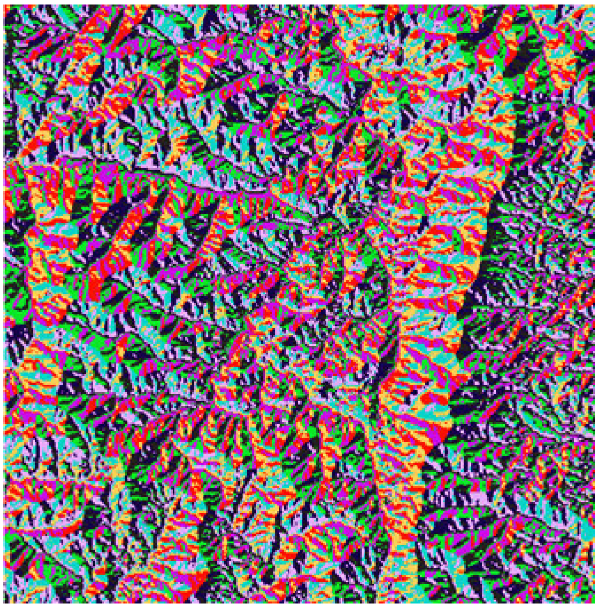

Figure. 5: Flow Direction

A stream network can be derived from a flow accumulation raster. The derivation is based on a threshold accumulation value. A threshold value of 500, for example means that each cell of the drainage network has a minimum of 500 contributing cells. Given the same flow accumulation raster a higher threshold value will result in a less densse stream network and fewer internal watersheds than a lower threshold value.

The effect illustrates of the threshold value, and show flow accumulation raster, the stream network based on a threshold value of 500 cells and the stream net work based on a threshold value of 100 cells (Figure. 6).

The threshold value is a necessary input to watershed analysis, but the choice of a threshold value can be arbitrary. Ideally, the resulting stream network from a threshold value should correspond to a network obtained from traditional methods such as from high-resolution topographic map or field mapping (Tarboton et al 1991). A threshold value between 100-500 cells seems to best capture the stream network in the area.

The topography affects the runoff characteristics and transport processes of sediment on a watershed scale. Steepness of the land slope influences the soil erosion in several ways. In general, as steepness of the slope increases, the soil erosion also increases because the velocity of runoff increases with increase in the field slope, which allows more soil to detach and transport them along with surface flow surface detention of water, is also reduced as slope increases. The depth of water collected on a level field dissipates the kinetic energy of falling rain drop and ultimately reduces the soil detachment, but it is not happen on steep slope. Utilizing maps for upslope contributing area derived from flow accumulation map and slope map, the map for LS factor is computed and presented in Figure. 7.

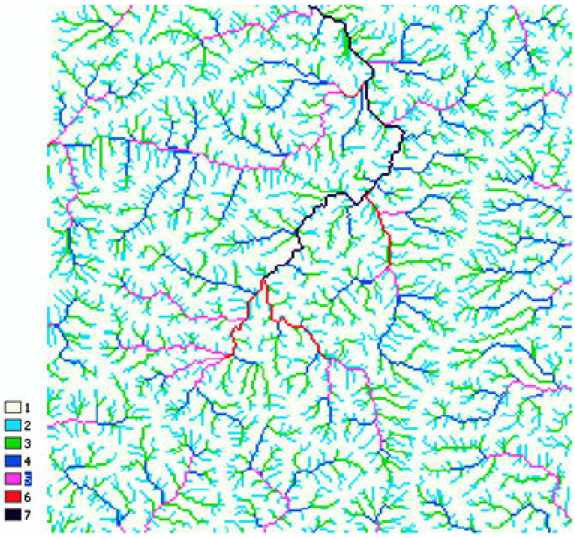

Figure. 6: Stream Network

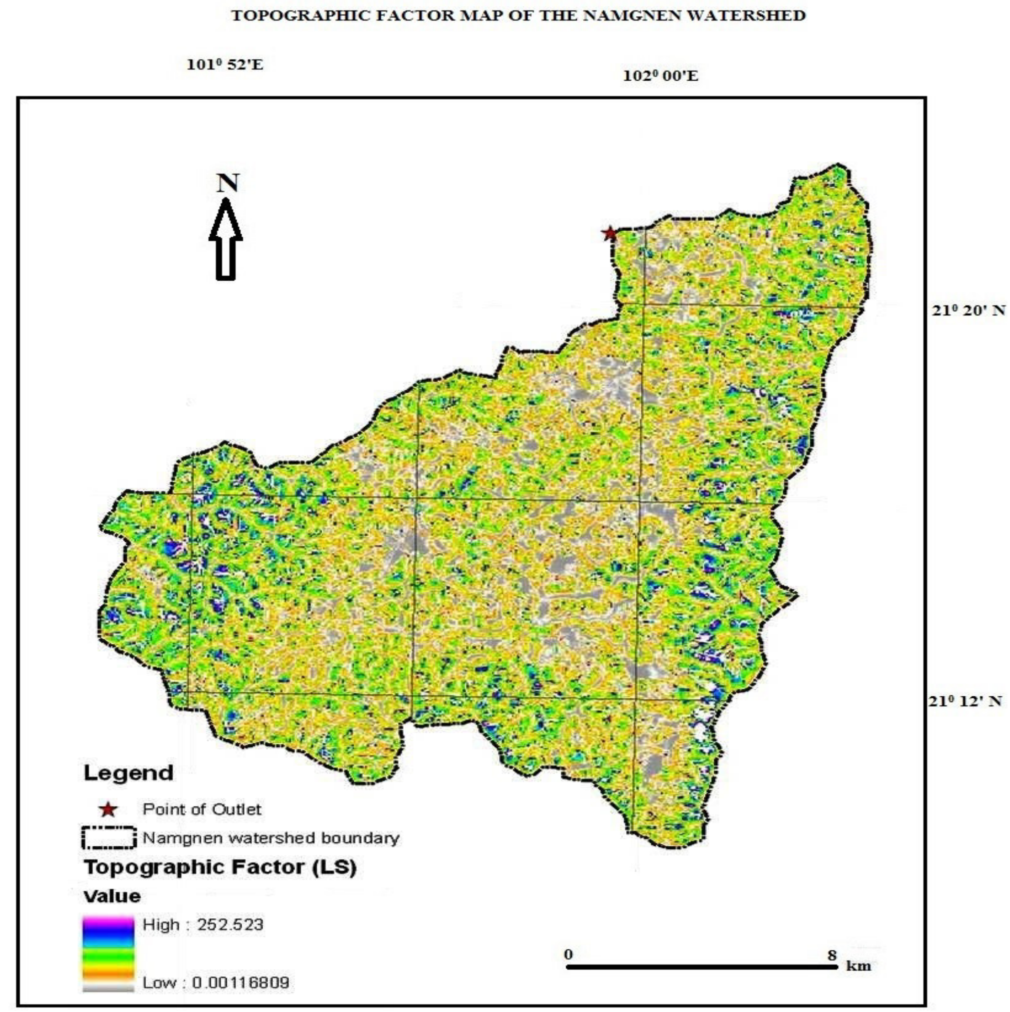

Figure 7: Topographic factor (LS)

Crop management factor (C):

For assigning crop management factor, land use/land cover map was prepared using the digital data for a LANDSAT TM image of watershed. Supervised classification was performed in ERDAS imagine environment for preparing land use/land cover map. Further, smoothing and editing of pixels, was performed. The watershed is characterized by three main land cover and land use type. This includes forest, waste and agriculture land. But in the watershed, some other features are also includes in the present study. An unsupervised classification was performed for the Land use and Land cover (Figure. 8).

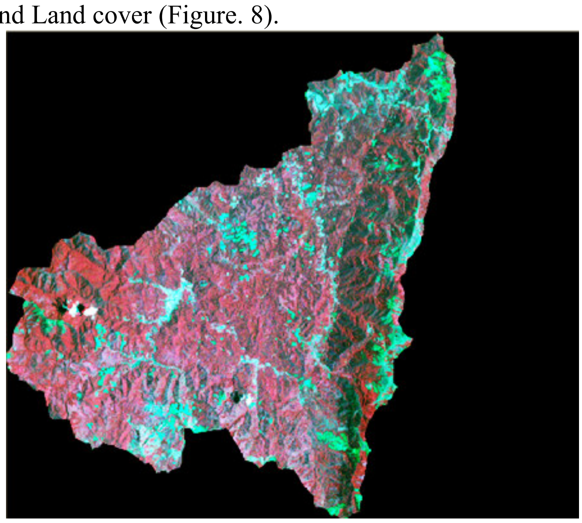

Figure. 8: Unsupervised Classification (ISO data) in dialog box opens of the Land use and Land cover

The analyses must compare the classified data with some form of reference data (such as larger scale imagery or maps) to identity informational value of the spectral classes. Thus, in the supervised approach, we define useful information categories and examine their spectral separability in the unsupervised approach to determine spectrally separable classes and then define their informational utility. The quality of the classification depends upon the analysis's understanding of the concepts behind the classifiers and overall knowledge about the land cover types of the area.

In the Namgnen watershed, land used and land cover area as the case, we can generate by two type as land use cultivated land and forestry land which include the combined effect of cover, crop sequence, productivity Level, Length of growing season, tillage practices, residue management and the expected time distribution of erosive rain storm with respect to seeding and harvesting of the locality.

The interpretation of the satellite imagery was carried out in ERDAS imagine environment. In the Phongsaly Provincial of Agriculture and Forestry, EU-PFCRDP and analyses knowledge about the watershed were used for the land use/land cover. The finally process classification adopt in crop management factor was assigned for different land use patterns (Table. 6). The magnitude and the spatial distribution of crop management factor are shown in Figure. 9.

Conservation Practice Factor (P):

Conservation Practice Factor is defined as the ratio of soil loss for a given conservation practice to the soil loss. Obtained from up and down the slope, the conservation practice consists to be mainly contouring, terracing and strip cropping, in which contouring appears to be most effective practice on medium slope ranging from 2 to 7 percent. The soil loss from contouring ranges about one half of the total soil loss that occurs from up and down hill farming system.

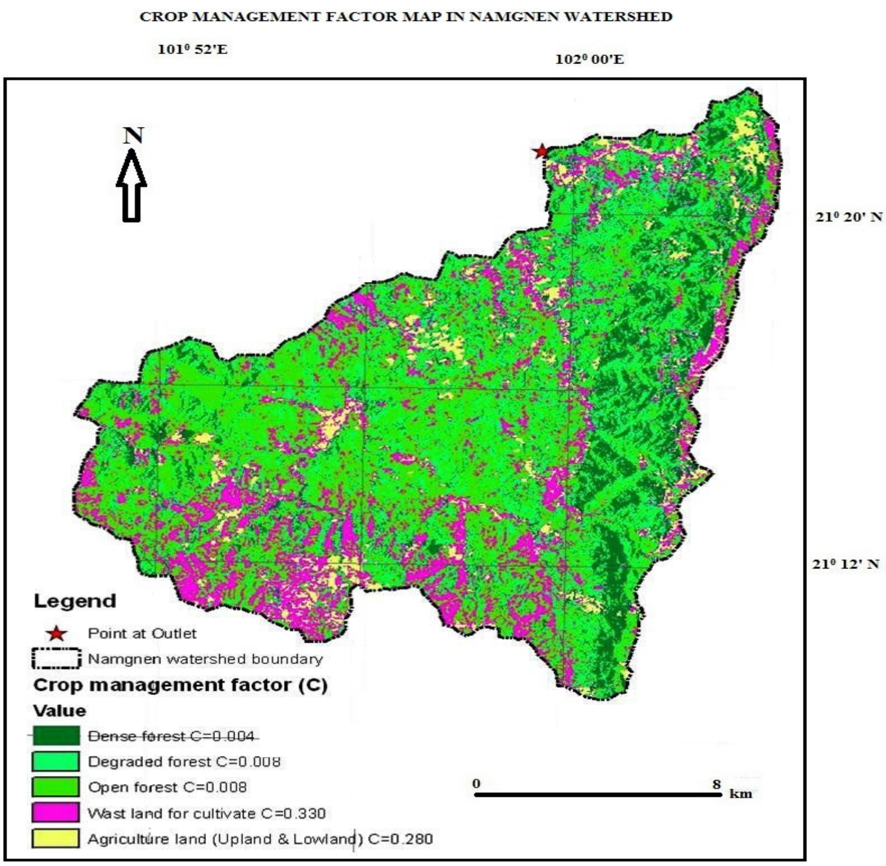

Figure. 9: Crop management factor (C)

Table 6: Land use/Land cover statistic of the study area:

SN	Land use	Area (ha)	Percent area	C-value
1	Dense forest	4574.66	14.42	0.004
2	Degraded forest	8636.07	27.24	0.008
3	Open forest	10526.80	33.20	0.008
4	Waste land for cultivating	6323.97	19.94	0.330
5	Agriculture for upland and Lowland	1647.82	5.20	0.280
	Total =	31709.32	100.00	

In general, in the study Namgnen watershed generates by two type land use which reflects the combined effect of cover, crop sequence, with supporting to the corresponding loss with up and down slope cultivation. Since, in the major conservation practices are followed except low height in some of the agriculture area only the (P) factor we can take equal to value of 1 for all land use and land cover categories for simplicity.

Estimation of the gross soil erosion map

The GIS layer of the parameter such as rain erosive from annual rainfall in Namgnen watershed area should be multiplied with the soil erosion potential map by the GIS Layer as KLSCP. In the Namgnen watershed area, raster calculation also used in Arc map package version 9.2 to get gross soil erosion map of the individual cells. Figure. 10 shows the gross erosion map of the study watershed. As can be seen from Figure. 10, most parts of the watershed area are showing low to medium erosion. High erosion is observed at the waste land for cultivation and agriculture Upland and Low land near the point outlet in Ban Naway village with high topographic (LS) factor value in the grid cell area Namgnen watershed.

THE SEDIMENT YIELD MODEL

The eroded sediment from each grid follows a defined drainage path from a particular cell to the outlet of watershed following hydrological flow paths. The rate of sediment transport from each of the discretized cell depends upon the transport capacity of the flowing water (Meyer and Wischmier, 1969). The sediment outflow from an area is equal to soil erosion in the cell plus contribution from upstream cells, if transport capacity is greater than the sum. However, if transport capacity is less than the sum of soil erosion in the cell and contribution from upstream cells, then the amount of sediment exceeding the transport capacity gets deposited in the cell and sediment load equal to transport capacity is discharged to next downstream cell (Meyer and Wischmier, 1969). The concept is depicted schematically in Figure. 11 for computation within the GIS.

Sediment transport Capacity

The sediment transport capacity of overland flow is the maximum flux of sediment that is capable to transport. Sediment transport is an important process in the watershed soil erosion as it determines the amount of soil removed. Water can transport sediment in the form of bed load and suspended load. Water flow is also often subdivided in overland flow and channel flow or stream flow which is a distinction that is relevant to sediment transport as well there are several differences between stream flow and overland flow. Overland flow is much shallower. Shallow flow exhibits undulation so that flow conditions are changing continuously (Alonso et al, 1981; singh 1997).

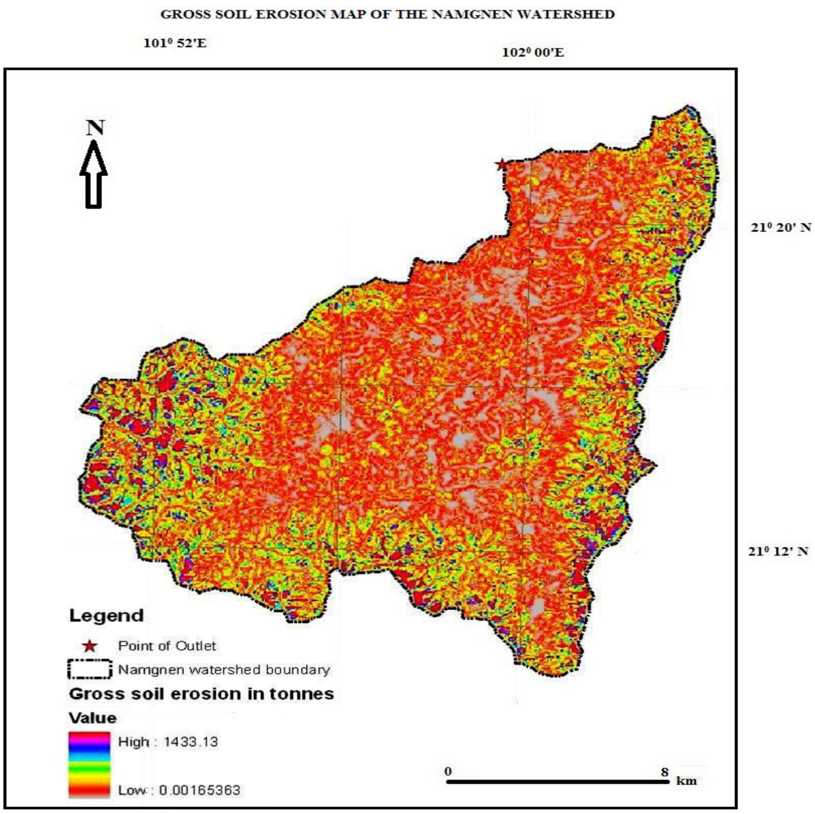

Figure. 10: Gross soil erosion in prone zone.

Overland flow is much more influenced by surface roughness and raindrop impact (Alonso et al, 1981;

singh 1997; Abrahams et al, 2001). Siltation and even suspension might be limited in overland flow because of the small flow depth so that the bed load transport is likely to be the dominant mode of transport (Julien and Simons, 1985; Singh 1997). In upland areas, soil surfaces are usually more cohesive than in alluvial channel

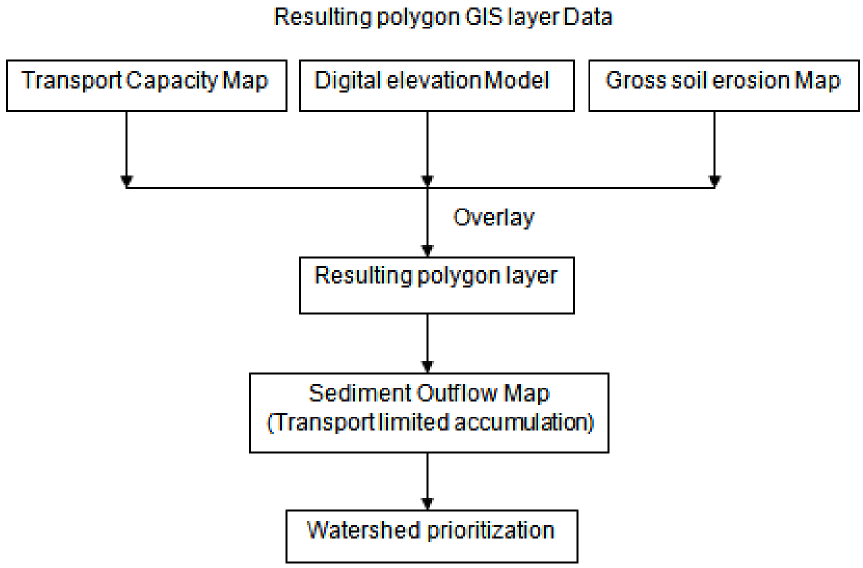

Figure 11: Schematic Flow Chart of GIS application to sediment Outflow.

(Singh 1997). Overland flow is often laminar, while stream flow is usually turbulent (Julien and Simons 1985). Slopes are usually much steeper in the case of overland flow than in the case of stream flow (Govers, 1992).

Most of the physically based soil erosion models contain a sediment transport equation. Many of the existing models use either a bed load or a total load formula originally developed for rivers. Other soil erosion models use simple empirical formula.

Rudi Hessed et al. (2007) evaluated the suitability of a number of transport equations for use in the erosion modeling under steep terrain such as the gully catchments of the Chinese Loess plateau. Vlassion (2005) presented three mathematical models for the estimated of the sediment yield due to soil and stream erosion at the outlet of a basin; this was then compared with the available sediment amount in the main stream of sub-basin with the sediment transport capacity stream flow.

Hafzullah and Kavvas (2005) reviewed the existing erosion and sediment transport models developed and watershed scales. After comparison of nine sediment transport formulas, suggested to use Yalin's (1963). Equation for computing the sediment transport capacity for overland flow. Nearing et al (1989) used a simplified function of the hydraulic shear stress acting on the soil for calculating the sediment transport capacity of flow,

Out of the gross computed in (As discussed earlier) for each of the discretized grid cell, only part or whole of it can out flow from its location to next downstream cell or outlet depending on the transporting capacity sediment yield on area of the flow water following a defined drainage path (Meyer and Wischmeier, 1969). The sediment outflow from area is equal to soil erosion in the cell plus contribution from the upstream cells if transport capacity is greater than this sum. However if transport capacity is less than amount of sediment excess of sediment transport capacity get deposited and sediment load equal to transport capacity is discharged to next downstream cell. Many relations exist in literature to estimate mean annual sediment transport capacity. Based on the study following equation for computation of mean annual sediment transport capacity was proposed and same with adopt in case study also (verstraeten et al 2007).

$$\mathbf{T_C = K_{TC}\, R\, K\, A^{1.4}\, S^{1.4}} \qquad (5)$$

Where:

T_C Is transport capacity in cell area.
K_{TC} Is transport capacity coefficient for cell area.
R is rainfall erosivity factor.
K is Soil erodibility factor
A is the upslope contributing area per unit contour length in cell area.
S is the slope gradient in cell area.

The coefficient (K_{tc}) reflects the vegetation component within transport capacity, since (K_{tc}) is strongly depended on land use/land cover types. It is to co-relate it with some vegetative index value of the area to get the spatial distribution of transport capacity coefficient. To do this, used remotely sense images is proposed. It is known that the reflectance of any area depend on land cover present and vegetation reflects most in near infrared region (NIR). The differential reflectance in these bands provides a means of monitoring density and vigor of green vegetation growth using the spectral reflectivity of solar radiation.

Using this property, many indices have been developed in past and can give a perspective on presence of vegetation in a cell. These indices have also been used to estimate factors which depend on land cover present. For example: Van der knijff et al. (2002) assessed monthly cover management factor values for Italy using advanced very high resolution radiometer imagery (AVHRR) by relating normalized difference vegetation index (NDVI) with cover management factor (C). The (NDVI) is the image transformation based on the normalized difference between Near-infra Red (NIR) and visible Red (VR) bands using software ERDAS IMAGINE 9.2 and expressed as:

$$\boldsymbol{NDVI} = \left(\frac{\mathbf{NIR - VR}}{\mathbf{NIR + VR}}\right) = \left(\frac{\mathbf{Band\ 4 - Band\ 3}}{\mathbf{Band\ 4 + Band\ 3}}\right) \quad (6)$$

The ranges of values for NDVI vary from -1 to +1 where vegetated areas will typically have value greater than zero and negative value indicate non-vegetated surface features such as water barren lands, ice, snow or clouds. Typically higher +ve value for a pixel in NDVI image indicate more vigor or dense vegetation and vice versa. Vegetation NDVI typically ranges from 0.1 up to 0.6, with higher values associated with greater density and greenness of the plant canopy. Surrounding soil and rock values are close to zero while the differential for water bodies such as rivers and dams have the opposite trend to vegetation and the index is negative.

In the present study, an empirical relation between NDVI and K_{tc} for a cell sized area proposed by Jain and Das (2009) has been used. The mathematically (K_{tc}) is expressed as (Jain and Das, 2009)

$$\mathbf{K_{tc}} = \beta * \mathrm{Exp}\left(\frac{\mathbf{-NDVI}}{\mathbf{1-NDVI}}\right) \quad (7)$$

Where:

NDVI is the NDVI value for cell area.

β is a scaling factor to be determined through calibration.

Map depicting K_{tc} values is given in Figure. 12.. This depicts a flow diagram to compute sediment transport capacity for different grid cells within a GIS system (Figure 13). Figure. 14 depicts transport capacity map for study watershed.

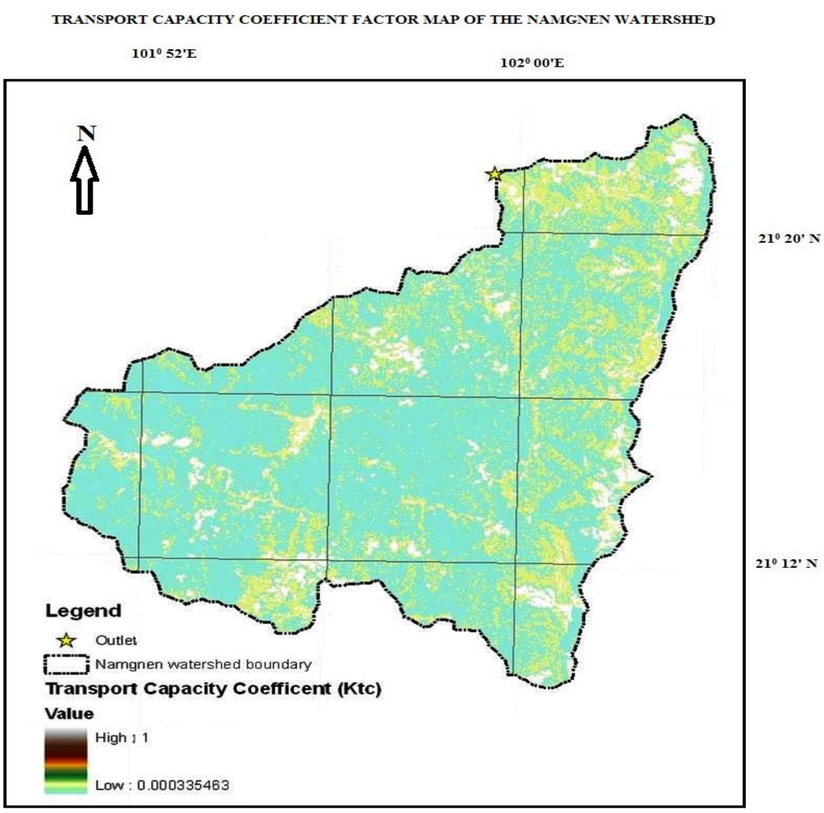

Figure. 12: Transport capacity coefficient (K_{tc})

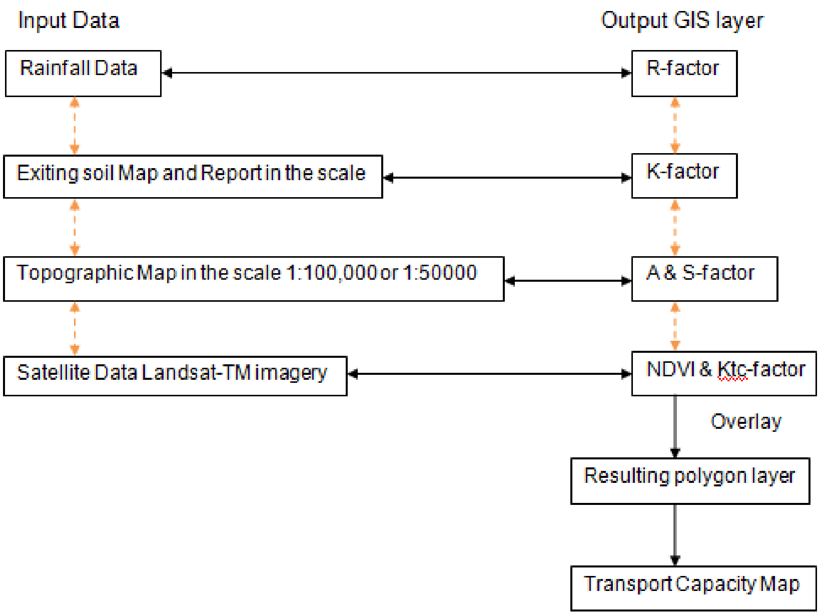

Figure 13 Transport limiting sediment outflow:

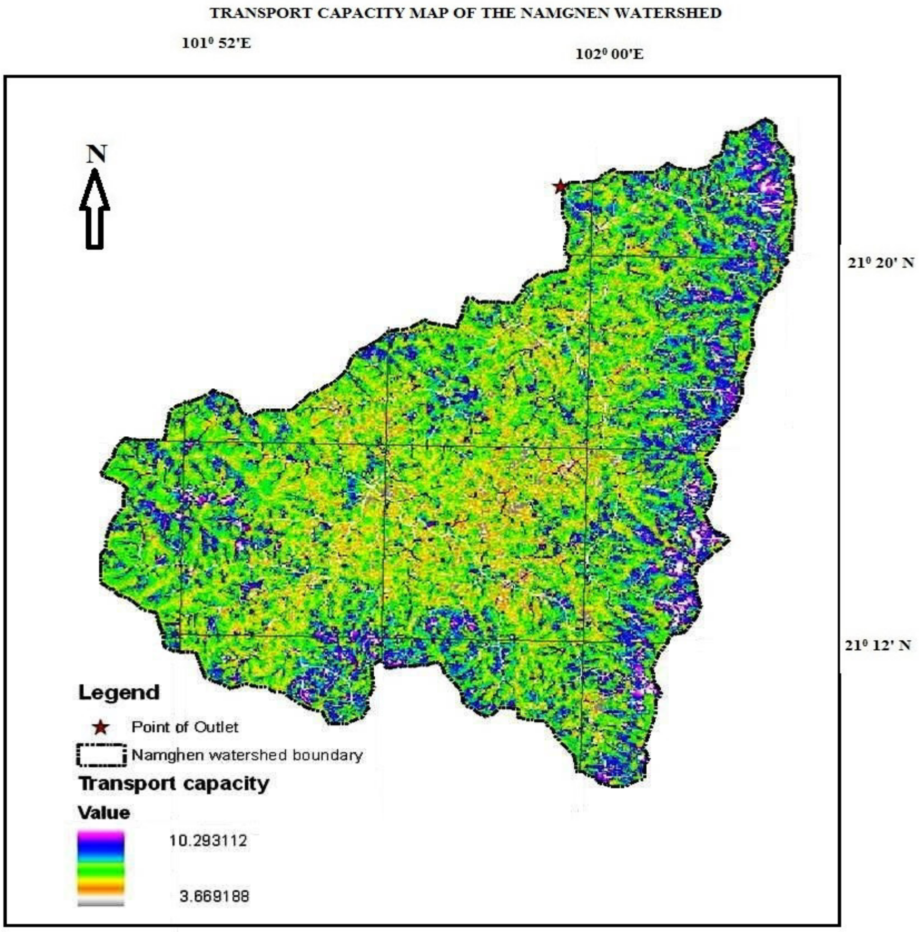

Figure. 14: Transport capacity map

A transport limiting sediment delivery applies to the situation where there is a supply of substance (e.g. erosion) and capacity for transport of the substance (e.g. sediment transport capacity). This concept accumulates the substance flux subject to the rule that the transport out of any grid cell is the minimum of the total eroded sediment (i.e. transport in to that grid cell plus gross erosion of that grid cell), and the transport capacity. There is deposition if the transport capacity is less, and then total eroded sediment as stated below other wide there will be net erosion in the grid cell.

This function applies to the situation where there is a supply of substance (e.g. erosion) and capacity for transport of the substance (e.g. sediment transport capacity). This function accumulates the substanc (7) subject to the rule that the transport out of any grid cell is the minimum of the transport in to that grid ce the transport capacity. There is then deposition in the amount of the difference.

$$T_{out} = \min(E + \sum T_{in}, T_{cap}) \quad (8)$$

$$D = E + \sum T_{in} - T_{out}$$

Here:

E is the supply (sup) and

T_{cap} the transport capacity (tc).

T_{out} at each grid cell becomes

T_{in} for down slope grid cells and is reported as Transport limited accumulation (tla).

D is deposition (tdep).

The sediment delivery map was prepared using the transport limiting sediment delivery concept by overlying the layers of gross erosion sediment transport capacity and flow direction layer in Arc Map version 9.2. Figure. 15 depicts sediment outflow map of the study watershed. The pixel value in sediment outflow map corresponding to outlet point denotes total sediment outflow from the Namgnen watershed.

The watershed priority areas (Sediment source and sinks):

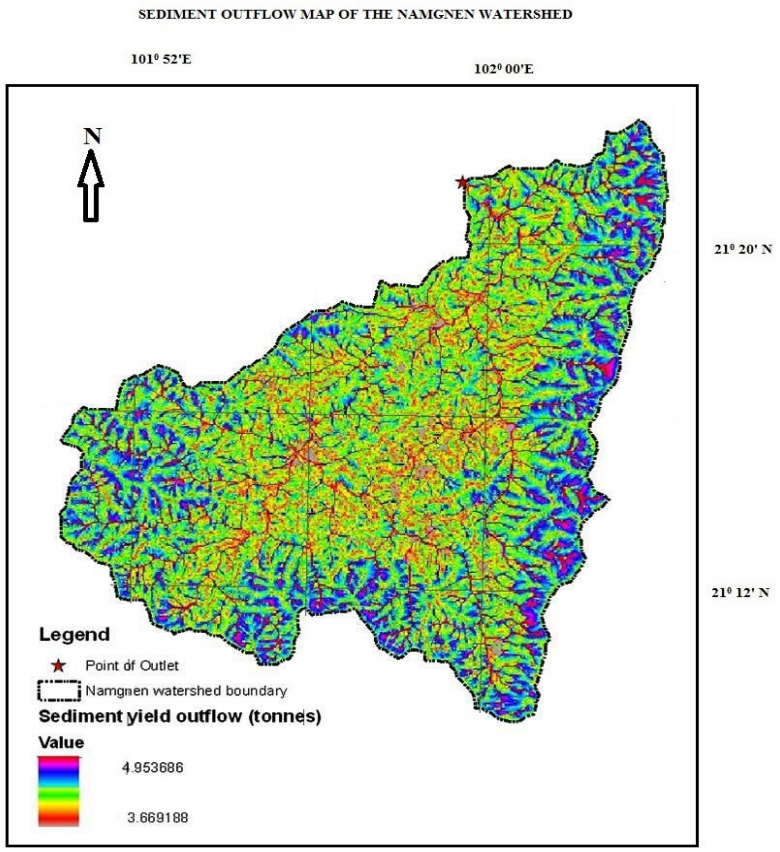

Figure. 15: Sediment yield outflow map

A net erosion map is calculated by subtracting the deposition from each grid cell from the gross erosion raster data from each grid cell. Negative values are near zero (0) on the Net erosion map in the area where sediment deposition occurs (i.e. true sediment deposition). Whereas, positive values correspond to grid cells with net sediment erosion. Consequently difference between total values of erosion and net soil loss can be defined.

Finally, annual sediment yields estimated on cell basis, all the grid cells of the watershed were regrouped into the following scales of priority:

- Deposition range from (- xxx- 0 Tonnes/ha/Year).

- Slight erosion range from (0 - 5 Tonnes/ha/Year)
- Moderate erosion range from (5 - 10 Tonnes/ha/Year).
- High erosion range from (10 - 20 Tonnes/ha/Year).
- Severe erosion range from (20 – 50 Tonnes/ha/Year).
- Very severe erosion range from (>50 Tonnes/ha/Year).

The spatial distribution of the net soil erosion and net deposition in the Namgnen watershed area on the cell basis (Figure. 16), including land used classification with steepness slope land and all the area having first order stream network are identified as high true net erosion zone i.e. more than 5.00 tonnes/ha^{-1}/yr^{-1}. This indicates that they have undergone severe erosion due to undulating topography and faulty method of cultivation practices. In fact, the topography plays a critical role in controlling soil movement in the watershed. It is observed that the area under slight erosion class is range from 19.33% to 13.14% (Table 7). The total areas cover are classified as moderate high, severe and very severe erosion zones varying from 7.35% to 27.65% and can be called as under critical erosion prone zone area in Namgnen watershed in (Table. 8). Therefore these areas need immediate attention from soil conservation point of view depending upon priority levels. The Namgnen watershed area should be treated with suite vegetative and structural measures. Thus effective watershed planning and management should be adopted for the development. Further, there must be a close coordination of vegetative and structure control measuring and best combination should be decided to tackle the problems of the Namgnen watershed in an integrated manner.

Table 7: Area under different class of soil erosion in Namgnen watershed

Total Area	Sediment yield in tones per ha in Namgnen watershed in years 2007					
	deposition	(0-5)	(5-10)	(10-20)	(20-50)	(>50)
In (100%)	19.33%	13.14%	7.35%	11.70%	20.83%	27.65%
31,709.32	6,129.41 ha	4,166.60 ha	2,330.64 ha	3,710.00 ha	6,605.05 ha	8,767.62 ha

From the Table 8 as various vegetative measure and physical conservation measure has been under difference land use are given in Table 6. Similarly, soil loss due to application of conservation measure differs 6 factors in USLE model.

Table 8: Percentage area needs priority attention in Namgnen watershed.

Total Area Nangnen watershed	Sediment yield in tones per ha in Namgnen watershed in years 2007		
	Deposition	(Range from 0-5)	(more than 5)
In (100%)	19.33%	13.14%	67.53%
31,709.32 ha	6,129.41 ha	4.166.60 ha	21,413.31 ha
Needs	Prioritization		Area requiring attention

Soil loss tolerance:

The term soil loss tolerance (T-value), define as the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. The magnitude of T-value affects the soil productivity on the soil condition. The Table 9 shows a guideline for assigning soil loss tolerance value (T) to soil having different root depth. However, the soil loss tolerance may vary from 0-5 Tonnes/per-ha-/per-year, depending upon the soil type depth and various physical property of the topography generally a 5 Tonnes/per-ha-/per-year is allowed on deep permeable and well drained soil.

Note: Renewable soil means soil with favorable substrata that can be renewed by tillage. Fertilizers Organic matter and other management practices Non renewable soil mean soil with unfavorable substrata such as rock or soft weathered material that cannot be renewed economically or by management or treatment practices.

Table 9: Soil loss Tolerance:

No	Rooting Depth (Cm)	Soil loss tolerance (Tonnes/ha/Year)	
		Renewable	Non Renewable
1	0.00 to 7.5	2.2	2.2
2	7.5 to 45	4.5	2.2
3	Above 45	6.7	4.5

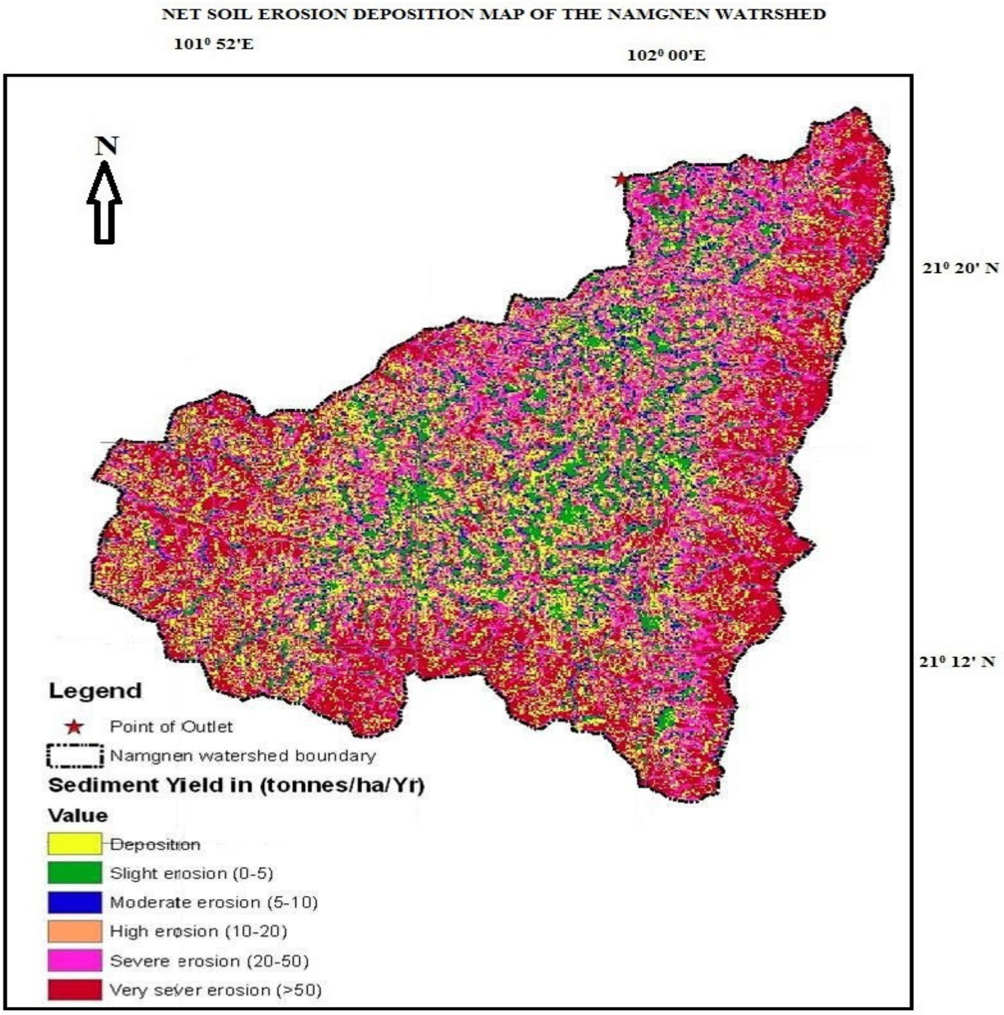

Figure. 16: Net erosion composition map.

CONCLUSIONS

The deterioration of the soil as in the study area i.e Namgnen watershed can be controlled effectively by adopting soil conservation for treatment measure in the watershed. If spatial distribution of soil erosion is known, then vulnerable areas contributing to soil erosion in spatial domain have been determined using USLE model coupled with transport limited sediment delivery. Arc GIS package was used to efficiently manage spatially discredited data such as topography, soil, Land use or Land cover land etc. for sediment yield modeling and for quantification of heterogeneity in the topographic and drainage feature of the catchment. ERDAS imagine package was used to analysis remote sensing data on image processor to generated land used and land cover data with other factors. The use of GIS and remote sensing data enabled the quantitative estimation of morphological parameters and determination of the spatial distribution of the USLE parameters.

Further, various thematic layers representing different factor of USLE were generated and overlaid to compute spatially distributed gross soil erosion maps in the Namgnen watershed. An empirical relation is proposed and demonstrated for its usefulness for computation of land vegetation dependent transport capacity factor by linking it with normalized difference vegetation index (NDVI) derived from satellite data. The concept of transport limited accumulation was formulated and used in Arc GIS for generating maps for transport capacity; gross soil erosion was routed to the catchment outlet using hydrological drainage paths resulting in generation of transport capacity.

Limited sediment outflow maps in the study provide the amount of sediment flowing from a particular grid in spatial domain. A comparison of the observed and computed sediment yield reveals the proposed method to compute sediment yield with reasonable accuracy. In addition to this, maps for deposition of the sediment were also generated for identification of areas vulnerable to silt deposition in the catchment. The deposited sediment was found to occur at grids where transport capacity was low, mostly lying to the sides of some of the stream reaches. Superimposition of sediment deposition map over gross erosion map led to areas vulnerable to soil erosion and deposition. Such maps are important in planning conservation and control measure.

The proposed USLE based approach was found to be mimicking sub-watershed-scaled soil loss quite realistically and logically there by suggesting its immense application potential for priority area identification in the test watershed. As in contrast to the proposed USLE model, morphometric analysis assigned reverse priorities to about 32.47% of the test sub watershed. Therefore, it is concluded that the morphometric analysis method of the Namgnen watershed prioritization technique could not account for realistically the impact of varied rainfall, Land uses and soil types, found in the sub watershed, on their soil erosion generating potential. Thus the proposed USLE based modeling approach proved useful tool for identification of priority areas for soil management within the test catchment.

The Variation in the results is due apparently to variation in the values of each of the factors used. In the particular the slope classes and the C factor for more comparable result decisions regarding reasonable factor values must be made.

In the conclusion, the potential soured of the prediction error is in selecting factor value. It is possible to spatially and qualitatively analyze multi-layer of the data within a watershed using GIS in combination with remote sensing can provide systematic site in dynamic manner for decision-support system.

Though, most of the area fell within the slight 13.14% and moderate category 7.35% of erosion hazard severity. Some slight erosion was observed in rain fed lowland paddy field and so on. Moderate erosion was mostly seen in upland area. About 11.70% of the watershed had a very slight erosion hazard. Nearly 48.48% of the watershed areas have to extremely severe erosion. Such area found in foothills covered in dipterous carp forest. To shed its leaves during the dry season, allowing rain to splash directly on the soil surface and detach soil particles. The soil loss and sediment yield were also computed for each type of land use type. The results as a guide as to what kind of the conservation measure and agronomic practices should be adopted in the area, Two factors will be consider of the treatment and protected soil loss and sediment yield, The C is the crop management factor while P is the erosion control practice or conservation factor. Interviews conducted during the field survey indicated that little or no land management is practiced in the area. Hence, the said two factors will be important for the soil erosion hazard.

Acknowledgement

Author want to acknowledge all the people associated with this work, directly or indirectly. We thanks people of Lao PDR for cooperation with us during our field time, otherwise this study will not be completed.

REFERENCES

1. Soil and water conservation Engineering By: R. Suresh.
2. Schwab, G. O., Fangmeier, D. D., & Elliot, W. J. (1994). Soil and Water Conservation Engineering. *J. ENVIRON. QUAL*, *23*.Hydrology and the management of the watersheds By: Kenneth N.Brook, Peter Flollott, Hans M. Gregersen and Leonard F.Debano.
3. Constantinesco, I. (1976). *Soil conservation for developing countries*. Rome: FAO.Engineering Hydrology By: K.Subramanya.
4. Chow, V. T., Maidment, D. R., & Mays, L. W. (1988). *Applied hydrology*.
5. Watershed Planning and management Course By: Mekong Secretariat and International Development programs of the Australian University and Colleges.
6. Second Conference: International Sustainable Slope Land and Watershed management Vientiane Laos by: NAFRI.
7. Jain, S. K., Kumar, S., & Varghese, J. (2001). Estimation of soil erosion for a Himalayan watershed using GIS technique. *Water Resources Management*,*15*(1), 41-54.
8. Pandey, A., Chowdary, V. M., & Mal, B. C. (2007). Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing. *Water resources management*, *21*(4), 729-746.
9. Jain, M. K., & Kothyari, U. C. (2000). Estimation of soil erosion and sediment yield using GIS. *Hydrological Sciences Journal*, *45*(5), 771-786.
10. Khan, M. A., Gupta, V. P., & Moharana, P. C. (2001). Watershed prioritization using remote sensing and geographical information system: a case study from Guhiya, India. *Journal of Arid Environments*, *49*(3), 465-475.
11. Overall work plan Phongsaly project forest conservation and rural development ALA/94/22.
12. Technical specifications of master Map Phongsaly province prepared by: The EU-PFCRDP mapping team.
13. Kang-Tsung Chang. Fourth edition introduction to Geography information system in Chapter 19. GIS Models and Modeling.
14. Tarboton, D. G. (2005). Terrain analysis using digital elevation models (TauDEM). *Utah State University, Logan*.
15. ERDAS Customer Education by: ERDAS Imagine 9.2 Leica Photogrammetric Suite 9.2.
16. Van, N. T. T., Ha, N. T., & Ha, N. M. (2004). Soil Erosion Mapping with Universal Soil Loss equation and

GIS/ARVIEW. *Nong Nghiep Va Phat Trien Nong Thon*.
17. Hydrologic analysis, Release 9.2 Last modified May 2, 2007. From: http://www.ESRI.com.
18. Remote sensing and image interpretation fifth Edition by: John wiley & Son (Asia), PTE. LTD. Singapore All rights severed.
19. Global land cover facility, Earth science data interface visit website: http://glcf.umiacs.umd.edu.
20. Lansat 7 Science data User handbook. From: http://Landsathandbook.gsfc.nasa.gov.
21. Watershed management and upland development in the Lao PDR. A synthesis of Policy issues. (Nathan. Badenoch. World resource institute April 7, 1999).
22. Ferro, V., & Minacapilli, M. (1995). Sediment delivery processes at basin scale. *Hydrological Sciences Journal*, *40*(6), 703-717.
23. Moore, I. D., & Wilson, J. P. (1992). Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation. *Journal of soil and water conservation*, *47*(5), 423-428.
24. Moore, I. D., & Burch, G. J. (1986). Physical basis of the length-slope factor in the Universal Soil Loss Equation. *Soil Science Society of America Journal*,*50*(5), 1294-1298.
25. Moore I.D. Grayson. R.B. & Ladson. A.P. (1994) Digital terrain modeling. In Beven. K.J & Moore. I.D. (Eds). A review of Hydrological. Geomorphological and Biological application. Chichester. John wiley & Son, 249pp.
26. Abrahams, A. D., Li, G., Krishnan, C., & Atkinson, J. F. (2001). A sediment transport equation for interrill overland flow on rough surfaces. *Earth Surface Processes and Landforms*, *26*(13), 1443-1459.
27. ISRIC: World soil information (World soil data center for soil).
28. Gautam, A. P., Webb, E. L., Shivakoti, G. P., & Zoebisch, M. A. (2003). Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agriculture, ecosystems & environment*, *99*(1), 83-96.
29. UNEP (1997) World Atlas of Desertification. 2nd edition Arnold London.77.
30. Pal, B., & Samanta, S. (2011). Estimation of soil loss using remote sensing and geographic information system techniques (Case study of Kaliaghai River basin, Purba & Paschim Medinipur District, West Bengal, India). *Indian Journal of Science and Technology*, *4*(10), 1202-1207.
31. Campbell W J (1979). In book on*Satellite Hydrology* (Eds. M Deutsch, Wiesment D R and Rango A); American Water Research Association, 616–621 pp.
32. Cruz, R.A.D. "The determination of suitable upland agricultural areas using GIS technology," Asian pacific Remote Sensing J.,5,123-132(1992).
33. Jain, S. K., & Goel, M. K. (2002). Assessing the vulnerability to soil erosion of the Ukai Dam catchments using remote sensing and GIS. *Hydrological Sciences Journal*, *47*(1), 31-40.