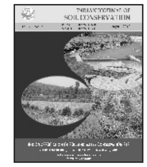
Vol. 46, No. 3, pp 273-282, 2018
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Assessment of soil erosion in sub tropical ecosystem of Meghalaya, India using remote sensing, GIS and RUSLE

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ARTICLE INFO

Article history:
Received : August, 2018
Revised : November, 2018
Accepted : December, 2018

Key words:
Geo-spatial technique,
Geo-statistics,
Hydrology,
Spatial assessment,
Soil erosion

ABSTRACT

Erosion is one of the major threats to the soils that limits its productive capacity. Soil erosion in Jirang block, Ri-Bhoi district of Meghalaya under sub tropical eco-system was assessed using revised universal soil loss equation (RUSLE) in geographic information system (GIS). In the study, IRS P6 LISS IV data of the study area was used to prepare land use/land cover (LU/LC) map by visual interpretation technique and digital elevation model (DEM) was generated from Cartosat-1 data, which was further used to develop slope, contour, flow direction and flow accumulation maps. Thematic raster layers of RUSLE factors (R, K, LS, C and P) were computed and used to estimate average annual soil loss in GIS (ArcGIS 10.0). The results showed that about 30% area is subject to severe (20.1-40.0 t ha^{-1}yr^{-1}) to extremely severe (>80.0 t ha^{-1}yr^{-1}). Based on the severity of soil erosion in the block, Umkadhar, Mokirson, Mauling and Dagiya Parbat villages have been categorized under high priority zone with severe (20.1-40.0 t ha^{-1}yr^{-1}) to extremely severe (>80.0 t ha^{-1}yr^{-1}). The soil erosion was found to be higher near to the 1st and 2nd order streams where soil conservation measures are imminent. The study demonstrated that use of geospatial technologies in combination with RUSLE is a comprehensive approach for spatial assessment of soil erosion for better resource planning.

1. INTRODUCTION

Soil erosion can be defined as the detachment and transportation of soil (Tideman, 1996). Soil erosion is a hazard in a tropical country like India with an agrarian economy. Soil erosion by water is the most important type of soil degradation occupying 56% of world wide area affected by human-induced soil degradation, whereas, the area affected by wind erosion occupies 28% of the degraded terrain mainly occurring in Asia and Africa (Oldeman *et al*., 1991; Oldeman, 1994; Bai *et al*., 2008). In India, about 57% of the total geographical area (TGA) is suffering from various forms of degradation - water erosion, wind erosion, chemical and physical deterioration (Dutta *et al*., 2014). According to National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) about 120.72 M ha area is suffering from various kinds of land degradation, it includes area affected by water erosion 82.5 M ha, wind erosion 12.4 M ha, salinity/alkalinity 6.7 M ha, soil acidity 17.9 M ha and 1.0 M ha is under other complex problems (Maji *et al*., 2010). Sheet erosion is ubiquitous in India (Tideman, 1996). On the other hand, accelerated rate of soil erosion through rill and gully erosion has become yet another endemic problem (Singh and Dubey, 2002). Many human induced activities, such as mining, construction and agricultural activities (like shifting cultivation) disturb land surfaces resulting in accelerated soil erosion. So it is very difficult to assess its economic and environmental impacts accurately because of its extent, magnitude, rate, dynamic nature and complex processes associated with it (Lal, 1994). Soil erosion causes reduction in land/soil quality, loss of top soil and decrease in the content of soil organic matter and thereby to the loss in crop yield. Soil erosion induces high runoff rates and low soil permeability which in turn leads to less water availability for the crops (Lal, 2001).

The North Eastern hilly region of India is characterized by heavy soil erosion, loss of soil fertility and deforestation causing acute environmental degradation and severe ecological imbalance (Sachchidananda, 1989). Shifting cultivation or slash and burn agriculture (*Jhum*) in its more traditional and cultural integrated form, is an ecological and economically viable system of agriculture as long as population densities are low and *jhum* cycles are long enough to maintain soil fertility (Anon, 1992). With ever increasing population pressure on land and their dietary requirement, *jhum* cultivation becomes very devastating in nature. In North-East India, the average annual loss of top soil, organic carbon, P_2O_5 and K_2O due to shifting cultivation were to the extent of 40900, 702.9, 0.15 and 7.5 kg ha^{-1}, respectively (ICAR, 1983). Agriculture under this system is practiced in steep slopes after removing the forest vegetation and thus is susceptible to excessive soil erosion. Besides this, washing of fertile top soil and exposure of rocks due to soil wash as a result of shifting cultivation have been reported from Garo hills of Meghalaya state in India (Goswami, 1968).

There are several erosion models, which are used to estimate soil erosion and to develop optimal soil erosion management plans, such as universal soil loss equation (USLE) (Wischmeier and Smith, 1978), water erosion prediction project (WEPP) (Flanagan and Nearing, 1995), soil and water assessment tool (SWAT) (Arnold *et al*., 1998) and european soil erosion model (EUROSEM) (Morgan *et al*., 1998), which have been used over many years. Among these models the USLE was developed by the United States Agricultural Research Service, has remained the universally accepted method of estimating soil erosion for nearly 40 years (Dennis and Rorke, 1999; Kinnell, 2000). The USLE model has been widely applied at the watershed scale on the basis of the lumped approach (Griffin *et al*., 1988; Dickinson and Collins, 1998; Reddy *et al*., 2004) to catchment scale (Jain and Kothyari, 2000; Jain *et al*., 2001). The revised and updated version of USLE (Renard *et al*., 1997) is known as RUSLE. Although the RUSLE has the same empirical principles as the USLE, it provides more accurate estimation of soil loss. This is because RUSLE has numerous improvements, such as monthly factors, incorporation of the influence of profile convexity/concavity using segmentation of irregular slopes, and improved empirical equations for the computation of LS factor (Foster and Wischmeier, 1974; Renard *et al*., 1991). The soil loss map of Meghalaya was prepared by following USLE method by Dutta *et al*. (2014). However, RUSLE has not been used in the Meghalaya Plateau of North Eastern hill region, which provides more precise estimation of soil loss. Therefore, a study has been undertaken in Jirang block of Ri-Bhoi district, Meghalaya to assess the soil loss due to water erosion using RUSLE in GIS.

2. MATERIALS AND METHODS

Study Area

The Jirang block in Ri-Bhoi district of Meghalaya is a part of the North Eastern region of India and lies between 25°47′17.16″ N to 26°05′22.56″ N latitudes and 91°20′40.56″E to 91°51′41.4″E longitudes, which covers an area of 714 sq.km (Fig. 1). It is bounded by Assam state in the north, Umling block in the East and West Khasi Hills district in the South. It has elevation ranges varying from 60 to 980 m above mean sea level (amsl) and has a mean annual rainfall of 2395 mm. The Jirang block is one of the remotest blocks of the Meghalaya state with sparse population. The area has a very

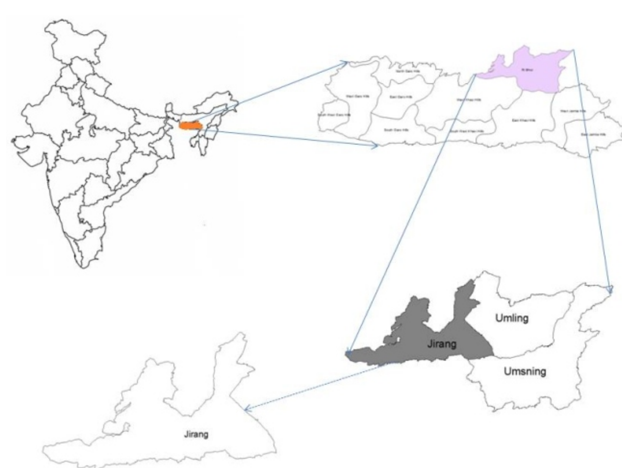

Fig. 1. Location map of Jirang block

complex landforms and topography varying from denudational hills to valley plains. Soil depth varies from deep to very deep. The dominant soil texture is characterized by fine-loamy to fine. The slope articulate with egregious rainfall makes the area more vulnerable to soil erosion. The study area is rich in its abundant species of flora from open shrub (grass) to pine forest in the plateau region and rest is covered mostly by tropical moist deciduous to evergreen forest. The most important flora is *Bambusa plymorpha*, *Bambusa tulda*, *Dendrocalmas spp*., *Musa spp*. The deciduous forest species are sal (*Shorea robusta*), teak (*Tectona grandis*), etc.

Data Used

Digital data of IRS P6 (Resourcesat-2) LISS IV sensor with a spatial resolution of 5.8 m acquired from National Remote Sensing Centre (NRSC), Hyderabad was used to prepare LU/LC map through visual image interpretation techniques. DEM (10 m spatial resolution) was generated from Cartosat-1 stereo pair data sets and the same was used to develop slope (degree), flow direction and flow accumulation thematic rasters. The details of the digital data have been shown in Table 1.

Computation of Revised Universal Soil Loss Equation (RUSLE) Factors

The RUSLE quantifies soil erosion using five factors of eq. 1 (Wischmier and Smith, 1978; Renard *et al*., 1997).

$$A = R \times K \times LS \times C \times P \quad ...(1)$$

Where, A is the average annual soil loss per unit area (t $ha^{-1}yr^{-1}$), R is the rainfall and runoff factor (MJ mm $ha^{-1}yr^{-1}$), K is the soil erodibility factor (t ha $MJ^{-1}mm^{-1}$), LS is the topography factor, C is the cover and management factor and P is the support practice factor.

Thirty years (1983-2013) rainfall data was procured from the meteorological observatory of ICAR-Research Complex for the North Eastern Hill Region from which the rainfall erosivity factor (R) was estimated. The rainfall erosivity factor is the erosivity of rainfall events and is defined as the product of two rainstorm characteristics: kinetic energy (E) and the maximum 30 minute intensity (I) (Wischmeier, 1959). In the present study the eq. 2 was employed to compute R-values (Dutta *et al*., 2014).

$$R = 79 + 0.363\,x \quad ...(2)$$

Where, x = Mean annual rainfall (mm).

The soil resource information is available at 1:10,000 scale for the study area (Jena *et al*., 2016), was used for calculation of soil erodibility factor (K) for each soil mapping unit. Soil erodibility factor is a measure of potential erodibility of a particular soil under a set of condition. This factor quantifies the cohesive character of a soil type and its resistance to dislodging and transports due to raindrop impact and overland flow sheer forces (Tirkey *et al*., 2013). Some of the intrinsic soil properties that influence the soil erodibility are soil texture, stability of soil structure, soil permeability, infiltration, organic matter and soil mineralogy. The best way to get erodibility factor (K) for a particular soil type is through field measurements on a unit plot, which is expensive and time consuming. Wischmeier and Smith (1978) used soil properties to estimate K-values and presented a nomograph for this purpose, which was employed to estimate K-values in the study area using the eq. 3:

$$K = 1.2917\,[2.1 * 10^{-4} M^{1.14} (12-a) * 3.25\,(b-2) + 2.5\,(c-3)/100 \quad ...(3)$$

Where, M= Percent silt * (100-percent clay); a = percent organic matter; b = the soil structure code used in soil classification; c = the profile permeability code.

For computing K-factor, the database was generated in the field study. The study area has textural variations from fine loamy to fine. The soil structure was estimated from field observation and the textural data generated after laboratory analysis (Piper, 1966) was used to assess the permeability. Then the numerical codes were assigned for both the characteristics (Sinha and Joshi, 2012) and K-factor was calculated.

The LS factor can be estimated from several available relationships (Wischmeier and Smith, 1978;

Table: 1
Details of the digital data used

Satellite	Sensor	Date of Pass	Path	Row
Resourcesat-2	LISS-IV	09/02/2013	110	53C
		05/03/2013	110	53D
Cartosat-1	PAN-A/F	02/02/2012	602	278
		08/12/2014	603	277
		21/11/2007	603	278
		30/10/2007	604	277
		30/10/2007	604	278

Moore and Burch, 1986a and 1986b; McCool *et al*., 1987 and 1989; Moore and Wilson, 1992; Desmet and Govers, 1996). Among these, units stream power theory is best suited for integration with the GIS and which is calculated using eq. 4:

$$LS = (A/22.13)^{n} (Sin\,B/0.0896)^{m} \quad \ldots(4)$$

Where, A is the up-slope contributing factor, B is the slope gradient in degrees.

RUSLE uses both the factors, L and S and are combined to give the topographic factor LS (Jha and Paudel, 2010). The precision with which it can be estimated depends on the resolution of the DEM (Simms *et al*., 2003). The combined topography (LS) factor was computed rather than the individual slope length and slope angle because the slope length factor was replaced by up slope contributing area (Moore and Burch, 1986a; Mitasova *et al*., 1996; Desmet and Govers, 1996).

The LS factor for RUSLE was computed using the eq. 5 and the raster calculator in ArcGIS (ESRI, 2010) was used to build an expression for estimating LS, based on flow accumulation and slope steepness (Mitasova and Mitas, 1999).

$$LS = ([\text{Flow Accumulation}]*\text{Cell size}/22.13)^{0.6}\ (\text{Sin}\ ([\text{Slope of DEM}]*0.01745)/0.0896)^{1.3}*1.4 \quad \ldots(5)$$

The C-factor measures the effects of all inter-related cover and management variables (Renard *et al*., 1997). Several authors have worked on soils with various types of vegetative covers to find out C-factor (Singh *et al*., 1981). In the present study, LU/LC map was prepared from the LISS IV satellite data of February and March, 2013, which provided comprehensive mapping of LU/LC classes (NRSC, 2006). The values of C-factors were assigned to the different LU/LC classes in the study (USDA, 1972; Rao, 1981; Pandey *et al*., 2007; Narain *et al*., 1994; Roose, 1977; Singh *et al*., 1981) (Table 2).

The erosion control practice factor is the ratio of soil loss using the specific practice compared with the soil loss using up and down hill culture (Kirkby and Morgan, 1980). The erosion control practices usually included in this factor are contouring, contour strip cropping, terracing, conservation tillage, crop rotation, fertility treatments and the retention of residues.The conservation and support practice factor (P-factor) values for each LU/LC classes of the study area were assigned depending upon the major conservation practices adopted (Narain *et al*., 1994; Roose, 1977; Singh *et al*., 1981). Similarly, the P-factors were assigned to the different LU/LC classes in the study area (Table 3).

Spatial Assessment of Soil Erosion Using Geo-statistics and GIS

The computed values of R, K, C and P were converted to 10 x 10 m grid so as to maintain uniform cell size at par with spatial resolution of Cartosat-1 DEM. The LS factor map was already in 10 x 10 m grid format as it was derived from the 10 m DEM. The generated rasters of RUSLE factors were integrated in GIS to estimate the soil loss of Jirang block in a spatial domain (Fig. 2). The RUSLE was applied through raster calculator and all the factor layers were multiplied to derive the soil erosion map. The soil

Table: 2
Cover and managementfactor (C) values used in assessing soil erosion

S.No.	Cover and Management (C)	C-factor value
1.	Agriculture, Crop land	0.5
2.	Current shifting cultivation	0.8
3.	Terrace cultivation	0.5
4.	Plantations	0.02
5.	Scrub land	0.6
6.	Land with open scrub	0.7
7.	Wasteland	1.0
8.	Built up	1.0
9.	Evergreen forest	0.004
10.	Deciduous forest	0.008
11.	Scrub forest	0.05
12.	Dense scrub forest	0.08
13.	Water bodies	0

Table: 3
Erosion control practice factor (P) values used in assessing soil erosion

S.No.	Erosion Control Practice	P-factor value
1.	Agriculture, Crop land	0.5
2.	Current shifting cultivation	1.0
3.	Terrace cultivation	0.5
4.	Plantations	0.8
5.	Scrub land	1.0
6.	Land with open scrub	1.0
7.	Wasteland	1.0
8.	Built up	1.0
9.	Evergreen forest	1.0
10.	Deciduous forest	1.0
11.	Scrub forest	1.0
12.	Dense scrub forest	1.0
13.	Waterbodies	1.0

erosion map thus generated in GIS indicates the spatial distribution of soil loss in terms of t $ha^{-1}yr^{-1}$. Average soil loss per pixel was calculated as the product of each pixel value multiplied by pixel area.

Hydrology Analysis

The Cartosat 1 DEM (10 m) of the study area was given fill operation to generate a completely smooth raster surface. This fill layer was used for deriving flow direction and flow accumulation layer. Then flow accumulation and flow direction layer were used as inputs in conditional tool to generate conditional flow accumulation layer where in a value of 1 indicate cells representing a stream and null value indicate no stream cells. The conditional flow accumulation and flow direction layers were used as inputs to generate stream order (Strahler stream order) and converted to feature class. The feature layer showed upto 9th order of streams which were reduced up to 3rd order of streams by giving query in the definition queries.

3D Analysis of Soil Erosion and LU/LC

The raster layer of soil loss and vector layers of LU/LC and drainage were used for generating a 3D view in ArcScene to identify erosion prone areas with respect to their LU/LC, slope and drainage pattern. Due to complex elevation variation of the study area, contours with 50 m interval were generated from Cartosat 10 m DEM. From this 50 m contours, DEM was again generated using triangular irregular network (TIN), which helped to get smoother DEM. This smoothened DEM was in turn used for overlaying soil erosion, drainage and LU/LC maps to have a better interpretation of soil erosion across different slopes and LU/LC.

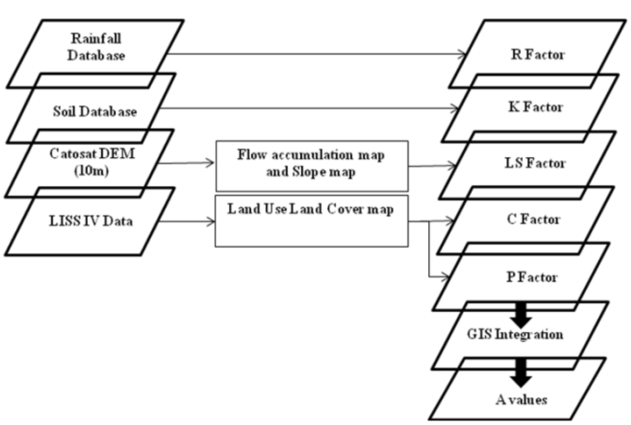

Fig. 2. Flow chart of methodology for assessing average soil loss

3. RESULTS AND DISCUSSION

RUSLE Factors

The rainfall erosivity factor (R-factor) for block was found to be 950 MJ mm $ha^{-1}yr^{-1}$ in the block. It was uniform for the study area. The soil erodibility (K-factor) reported to vary from 0.09 to 0.32 t ha $MJ^{-1}mm^{-1}$ in the block. The low (<0.10) and high K (0.30-0.40) values were observed in valley plains, which covers 3.24% of the study area. The soils are mostly sandy clay loam, silty clay loam and silty clay in texture. Whereas, plateaus and hills were having K-values ranged from 0.10 to 0.30 t ha $MJ^{-1}mm^{-1}$ (96.76% of TGA). In higher landforms, the soils are mostly loam, clay loam and clay in texture. K-values of <0.1 were obtained sporadically in the study area, whereas, Umtasor, Umpirtha and Umkangsiar villages had higher K-values (0.30-0.40). The other villages of the block had K-values ranging from 0.10 to 0.30 (Fig. 3a).

The topography factor (LS factor) ranged from 0.5 to 15 in the block. The lower LS factor values of <1 have been mostly noticed in valley plains as well as on the flat tops of the plateaus and hills covering 28.08% of TGA. The lower LS value was observed in Umtasor, Umpirtha, Purana Nongbir, Umtur and Umkangsiar villages. The LS factor values of 1.0-3.0 observed in the adjacent landforms of valley plains, plateaus and hills where slope percentage varied from 3-10% (gently sloping to moderately sloping) covering 11.80% of TGA, which are interspersed with other LS factor of the study area. The LS factor values in 10 to 33% slope (strongly sloping to steep) was found in the range of 3.0 to 10.0. The highest LS factor values (>10.0) were observed in very steep (33-50%) to extremely steep slopes (>50%) covering 28.70% of TGA. The highest LS factor of >10 have been observed in Raniari, Rajabala, Mokerson, Teekilabam, Lowki, Mawkyndah, Nongprut and Mauling villages (Fig. 3b).

The cover and management factor (C-factor) in Jirang block encompasses land use, which includes forest, scrub lands, wastelands and agricultural lands. The C-values of the block ranged from 0.004 to 1.0. C factor of <0.0051 was noticed mainly in eastern and small portion of the northern part of the block covering an area of 11.97%. The values 0.0051-0.01 are located in eastern part of the block stretching from North to South with an area of 63.23%. The values 0.01-0.1 were found in the north eastern part of the block covering 10.07%. However, the highest values of

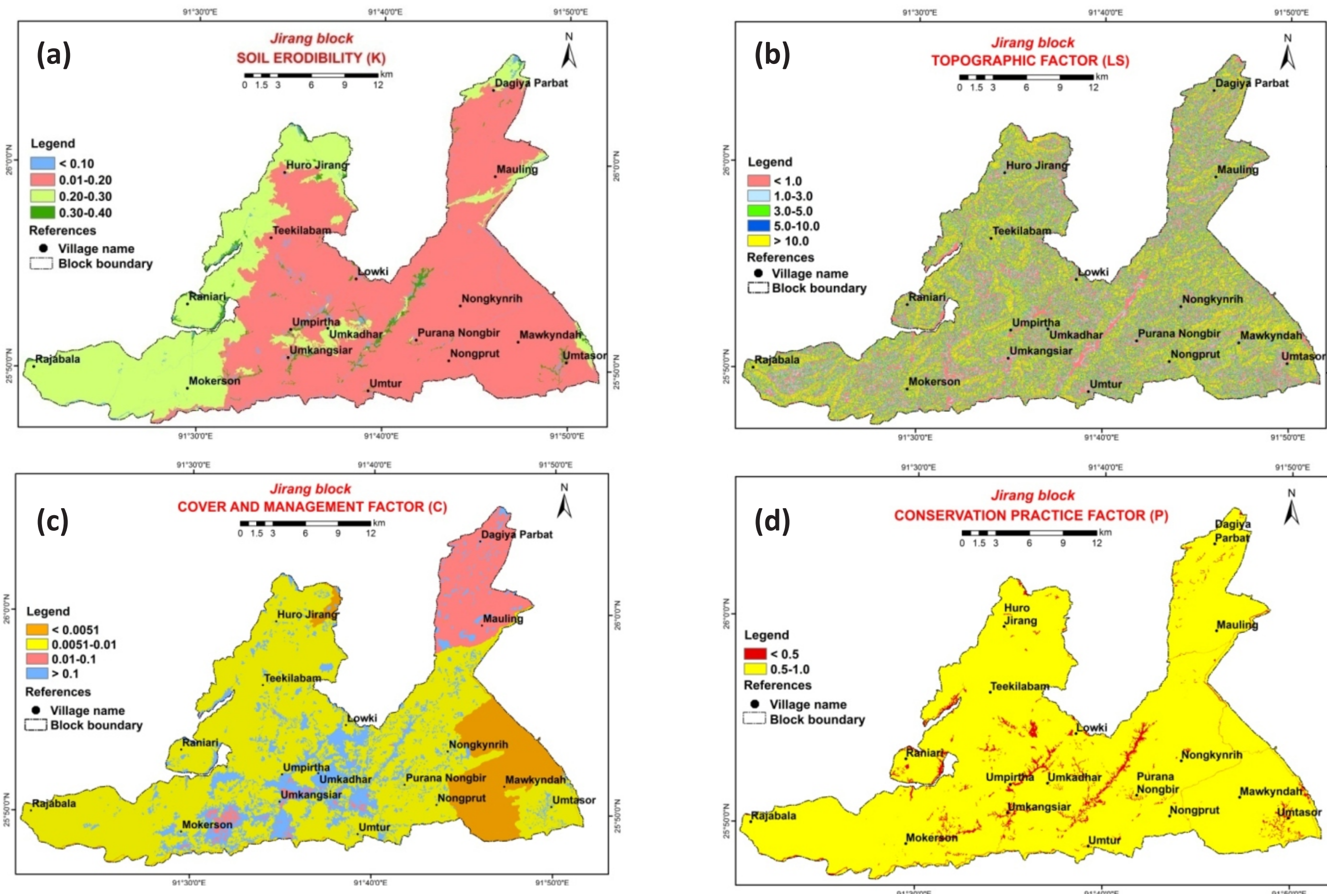

Fig. 3. Computed K (a), LS (b), C (c) and P (d) Factors for Jirang block

>0.1 were observed in central part of the block (Umpirtha, Umkadhar, Umkangsiar and Mokerson villages) covering an area of 14.73% of TGA (Fig. 3c).

The conservation practice factor (P-factor) in Jirang block ranged from 0.5 to 1.0, the lowest values (<0.5) were observed in valley regions where agricultural lands were mainly confined and very less in coverage, found in Umkangsiar, Umpirtha, Umkadhar and Umtasor villages covering an area of 3.25% of TGA. The highest values (0.5-1.0) were observed in rest part of the block, which covers an area of 96.75% of TGA (Fig. 3d). Adoption of suitable conservation measures like afforestration, prevention of short term *jhum* cultivation, in slopes contour bunding, terrace farming and contour cultivation help to reduce the top soil loss due to water erosion.

Spatial Assessment of Soil Erosion

The soil erosion was assessed spatially by integrating the rasters of R, K, LS, C and P-factors in GIS. Seven soil erosion classes namely very slight (<5.0 t $ha^{-1}yr^{-1}$), slight (5.0-10.0 t $ha^{-1}yr^{-1}$), moderate (10.1-15.0 t $ha^{-1}yr^{-1}$), moderately severe (15.1-20.0 t $ha^{-1}yr^{-1}$), severe (20.1-40.0 t $ha^{-1}yr^{-1}$), very severe (40.1-80.0 t $ha^{-1}yr^{-1}$) and extremely severe (>80.0 t $ha^{-1}yr^{-1}$) were identified in the block (Fig. 4). The study showed that the study area has an average annual soil loss of 36 t $ha^{-1}yr^{-1}$. Many authors have followed similar classification system in defining the soil loss classes in India (Challa *et al*., 2001; Sahoo *et al*., 2005; Reddy *et al*., 2013 and 2016). Analysis showed that very slight (<5.0 t $ha^{-1}yr^{-1}$) and slight (5.0-10.0 t $ha^{-1}yr^{-1}$) classes covered mainly in the eastern side and sporadically in the western side of the block with an area of about 44.17 and 13.07%, respectively. However, area under moderate (10.1-15.0 t $ha^{-1}yr^{-1}$) and moderately severe (15.1-20.0 t $ha^{-1}yr^{-1}$) soil loss was noticed in only 7.41 and 5.11% of TGA, respectively. Severe (20.1-40.0 t $ha^{-1}yr^{-1}$) and very severe (40.1-80.0 t $ha^{-1}yr^{-1}$) soil loss was observed in the extreme eastern part of the block where elevation is sharply reducing towards Assam. The area under severe and very severe soil loss was noticed in 10.19 and 6.41% of TGA, respectively. Extremely severe (>80.0 t $ha^{-1}yr^{-1}$) soil loss was noticed

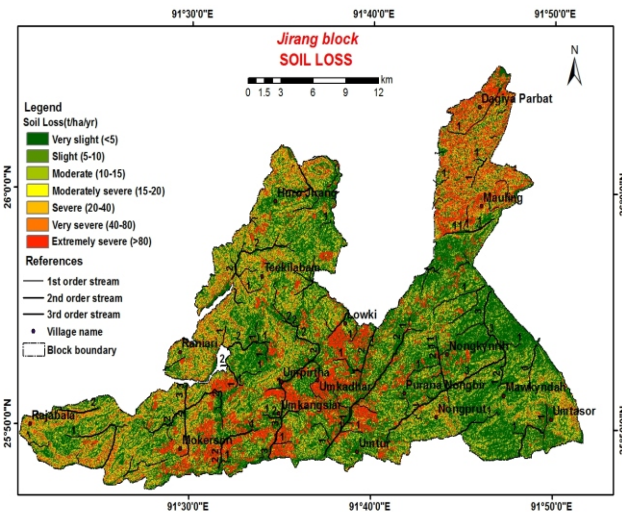

Fig. 4. Soil loss map of Jirang block

Table: 4
Status of soil loss in Jirang block

S.No.	Soil loss (t $ha^{-1}yr^{-1}$)	Area (ha)	Area (%)
1.	Very Slight (<5.0)	31535	44.17
2.	Slight (5.0-10.0)	9335	13.07
3.	Moderate (10.1-15.0)	5294	7.41
4.	Moderately severe (15.1-20.0)	3650	5.11
5.	Severe (20.1-40.0)	7274	10.19
6.	Very severe (40.1-80.0)	4574	6.41
7.	Extremely severe (>80.0)	9738	13.64
	Total	71400	100.00

in central, southern and north eastern part of the block. The extremely severe soil loss was observed on very steep to extremely steep slopes covering an area of 13.64% of TGA (Table 4). There was no trend in the soil loss across north to south and east to west due to complexity in the topography. The maximum soil loss was found near the 1st and 2nd order streams where the slope is more (Fig. 5a). In the steep slopes soil gets detached easily at the time of rainfall and gets transported with the runoff leading to excessive soil erosion in this region. The 3D analysis of average soil loss showed soil erosion was severe to extremely severe in slopes which were under scrub land and wasteland with minimum vegetative cover (Fig. 5a and b). Even high slopes are less prone to soil erosion particularly in the eastern and some part in the western side of the block, this might be attributed to adequate canopy cover (forest).

Soil erosion in the Jirang block of Ri-Bhoi district, Meghalaya is due to both natural causes like water erosion and anthropogenic activities like deforestration, stone quarries and shifting cultivation, which accelerated the process of soil erosion. There is a need to develop site specific conservation strategies to preserve soils production potential, sustain productivity, conserve *in-situ* rainwater, minimize soil erosion, moderate flood downstream, harvest and recycle inevitable runoff and ensure environmental security (Handbook of Agriculture, 2009).

Thus the study indicates that the entire area contributed to soil erosion with little contribution from agricultural fields. Hence, if the soil erosion from the agricultural land continues, it may lead to the physical, chemical and biological soil degradation and thereby rendering the cultivable land unfit for cultivation. The soil erosion may increase in future due to increasing human activities in the area in form of cleaning forest to bring more area under traditional shifting cultivation. So the combination of both engineering and non-engineering measures for soil conservation can thwart soil erosion in this region. Thus, the estimated soil loss of the study area through RUSLE model would be of immense help to adopt site-specific suitable conservation measures to minimize the severity of soil erosion.

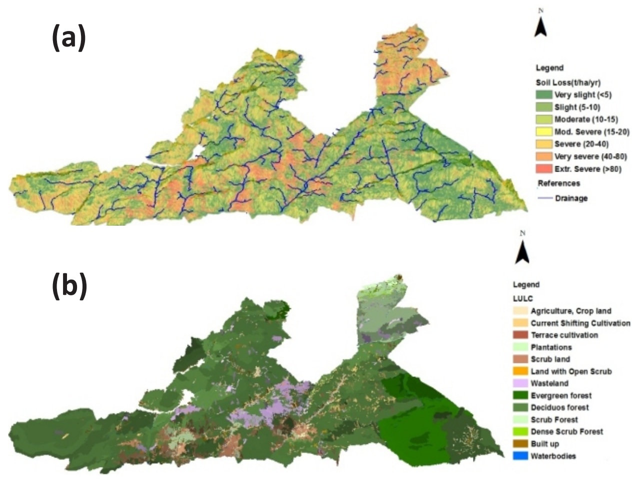

Fig. 5. 3D view of soil loss (a) and land use/land cover (b) of Jirang block

Suggested Soil and Water Conservation Measures for Erosion Susceptible Areas

Based on the severity of soil erosion, Umkadhar, Mokirson, Mauling and Dagiya Parbat villages have been categorized under high priority zone, where soil and water conservation measures need to be adopted on priority. The villages like Raniari, Teekilabam, Rajabala, Umtasor, Nongprut and Lowki were categorized under medium priority, whereas, Nongkynrih, Purana Nongbir, Mawkyndah, Umtur, Huro Jirang and Umpirtha villages were grouped under low prioritized zone. Agronomic measures on cultivated lands like contour farming, tillage practices, multiple cropping and mulching are recommended on mildly sloping inter hill valleys (<3%) with objective of maximizing conservation of *in-situ* rainfall for sustained and higher production. Mechanical measures like contour bunding, graded bunding and bench terracing could be the better options, where slope is more than 3% in arable lands. Tree based farming practice has a long tradition among indigenous people of Meghalaya, where trees are integrated extensively in the crop production practice according to the agro-climatic conditions. The summits and steep slopes should be covered with tree species to minimize the exposure of soil to rainfall, which causes splash erosion. The different farming practice like Khasi pine based farming practice, Tea based farming practice, MPTS (multipurpose trees and shrubs) based farming practice, Bamboo based farming practice and Bamboo-arecanut-betel based farming practice could be adopted on the wastelands located on the side slopes (Fig. 5b) to minimize the severity of water erosion (Jeeva *et al*., 2006).

4. CONCLUSIONS

The spatial assessment of soil erosion in Jirang block, Ri-Bhoi district, Meghalaya showed that about 30% area is subject to severe to extremely severe soil erosion. The average annual soil loss in the study area using RUSLE method was found to be 36 t $ha^{-1}yr^{-1}$. Spatial assessment of soil erosion in large scale using remote sensing, GIS and RUSLE enabled to identify most susceptible areas as erosion hazard zones in order to adopt suitable engineering and non engineering measures at village level for sustainable soil and water conservation in the study area. It was observed that the erosion was high near the 1st and 2nd order streams. The study demonstrates that use of remote sensing, GIS and RUSLE model can be considered as a powerful tool in the assessment of soil erosion and identification of the erosion prone areas. The planners, managers and policy makers can effectively use the results obtained from the study to develop site-specific agronomic and mechanical soil and water conservation strategies, particularly in high erosion risk areas to minimize the soil loss and preserve soils for sustained productivity at the village level.

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