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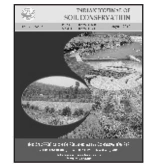

Prioritizing areas for soil and water conservation in Punjab Shivaliks

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ABSTRACT

Soil erosion affects sustainable agricultural development throughout the world. Controlling soil erosion would be a major challenge in coming years due to drastic changes in land use and land cover. To prioritize areas for soil and water conservation, present study was carried out in three forest divisions of Punjab *viz*., Gurdaspur, Dasuya and Garshankar. The current status of forest in these divisions was determined using IRS 1 C LISS IV imageries of the year 2015. It was found that moderately dense and open forests are prevalent in these forest divisions. Moderately dense forest was maximum in Dasuya (31.78%) followed by Gurdaspur (29.20%) and least in Garshankar (11.28%) forest division. Open forest were higher in Garshankar (35.03%) and least in Dasuya (21.92%) forest division, out of total forest area under Punjab Land Preservation Act (PLPA) of respective divisions. In Gurdaspur forest division, 44.33% area is under moderate category of soil erosion; in Dasuya, 56.46% is under severe erosion and in Garshankar, 32.61% area is under very severe erosion, out of the total PLPA area of respective divisions. Such spatial assessment and mapping of land cover in erosion prone areas are essential for planning and execution of efficient soil and water conservation measures and watershed management.

1. INTRODUCTION

Soil erosion continues to be a major environmental problem with regard to changing land use/land cover (LU/LC) in India and elsewhere around the world and changing climatic patterns are exacerbating the problem (Amore *et al*., 2004). Significant alteration of land cover through large scale deforestation and expansion of land for other purposes is acting as a key driving factor for accelerated soil erosion (Karamage *et al*., 2016; Lee *et al*., 2017). Estimation shows that about 5334 mt of soil is being eroded annually from India (Narayan and Babu, 1983). The rate of erosion of this valuable natural resource is largely governed by a multiple of factors like rainfall, runoff, slope, land cover, and the adoption of conservation measures (Solanki and Singh, 1996; Subudhi *et al.,* 2018).

Shivalik hills are one of the youngest mountain ranges running parallel to the Himalayan ranges. North-western Shivalik region (lower Himalayas) is generally upto 1000 m elevation and it covers an area of 3.33 M ha. In Punjab, it extends from $30^{\circ}25'54''$ to $32^{\circ}32'00''$N latitudes and $75^{\circ}19'36''$ to $76^{\circ}55'13''$E longitudes. Total area covered is 5470 sq km including 110 sq km of entire union territory, Chandigarh area (Yadav *et al*., 2015). Due to peculiar geological formations, Shivalik hills are more prone to erosion. The steep slopes and undulating terrain gives rise to more runoff and accelerated soil erosion during monsoon season. To protect the hilly areas of Punjab Shivaliks from further degradation and also to rejuvenate the barren areas, closure was advocated (Holland, 1928) which led to formation of PLPA of 1900. This act regulates the right of the landowners of the region. Clearing or breaking of land and quarrying, grazing or collection, removal of tree and removal of grass *etc.* are regulated by Department of Forest and Wildlife through PLPA act 1900. Singh *et al*.

(1992) had reported soil erosion of >80 t ha^{-1} yr^{-1} in the Shiwalik region. Recent estimates indicate that nearly 39% area of the Indian Himalayas has potential erosion rates of >40 t $ha^{-1}yr^{-1}$ (Bhattacharyya *et al*., 2016), which is alarmingly high. To control surface runoff and soil erosion in Punjab Shivalik, Department of Forest and Wildlife have executed afforestation and other soil and water conservation activities in these regulated areas (PLPA areas) under various schemes like Integrated Watershed Development Project I and II and Japan Bank for International Cooperation (1996-2007).

A study carried out in four watersheds of Punjab Shivalik, covering region of Ropar, Dasuya, Garhshankar and Hoshiarpur showed that the runoff from the sub watersheds before treatments varied from 40.3% to 50.4% of rainfall (Grewal *et al*., 1999). The effort by Forest Department had led to conservation and increase in biodiversity of the areas under PLPA (Jerath *et al*., 2006).

Shivalik hills are one of the eight most degraded ecosystems of India and hence require continuous protection and soil and water conservation measures to protect them from further degradation (Agrawal *et al*., 2002). Kushwaha and Yousuf (2017) and Kishor *et al.* (2014) stressed that prioritization of various micro-watersheds on the basis of morphometric analysis and soil erosion risk maps is necessary to plan soil and water conservation measures at watershed scale in order to conserve the natural resources. The combined use of Remote Sensing, GIS and erosion models have been shown to be an effective approach for estimating the severity and spatial distribution of erosion. Thus, the objective of the study was prioritizing areas requiring more intensive SWC measures in three forest divisions of Punjab Shivalik.

2. MATERIALS AND METHODS

Study Area

The study area falls under subtropical climate dominated by dry subtropical forest, with chir pine forest in Gurdaspur area. Most of the rainfall (70-80%) is received during monsoon (June to October).

Data Collection and Processing

In the present study, IRS 1 C LISS IV imagery (resolution of 5.8 m), of the year 2015, was used for preparation of forest cover map. For preparation of soil loss map, the published soil loss map (scale 1:250000) of Punjab state (Pal *et al*., 2016) was used as a base. The soil loss map of Punjab was geo-referenced, the maps of three divisions were extracted and different soil loss classes were demarcated for Gurdaspur, Dasuya and Garshankar divisions.

The base map of the study area was prepared by digitizing Survey Of India (SOI) toposheet. Remote sensing analysis of satellite data included acquisition of satellite data, geo-referencing, data loading, data processing, image rectification and ground truthing. The digital image processing was performed on ERDAS IMAGINE 2014 version of software. The image processing involved three main steps namely (i) detection of various features in the image (ii) discrimination of distinctive shapes and spatial patterns (iii) image classification. Different forest cover classes were identified on the basis of the spectral responses and finally forest cover maps were prepared.

Preparation of Soil loss Maps of Three Divisions

Universal Soil Loss Equation

Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) was used for estimation of soil loss of Punjab state. The equation predicts losses from sheet and rill erosion only. It computes soil loss for a site as a product of six factors. The soil loss equation is:

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

Where, factor A is computed soil loss in tonnes per hectare per year (t $ha^{-1}yr^{-1}$); factor R is rainfall factor in Mega Joules-millimetre (MJ-mm) per hectare-hour-year (ha-h-yr). It is calculated as the product of storm energy times the maximum 30 minute storm intensity and summed up for all storm in a year; factor K is soil factor and measure of inherent erodibility of a given soil under the standard condition of the unit USLE plot maintained in continuous fallow and tilled condition. It is measured in unit Mg-ha-h/ha-MJ-mm; factor L is slope factor and is the ratio of soil loss from the field slope length to that from standard plot (22.13 m) length under identical conditions; factor S is slope steepness factor and is the ratio of soil loss from the area with specified factor C is cover and management factor and is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow; factor P is support practice factor and the ratio of soil loss with a support practice like contouring, bunding or terracing to that with straight row farming up and down the slope. The details of procedure for generation of soil erosion map have been described by Pal *et al*. (2016).

Three forest division of Punjab *viz*., Gurdaspur, Dasuya and Garshankar were taken for the study. Out of 104 sub-watersheds in Punjab Shivaliks, about 70 sub-watersheds fall in the three selected divisions (Singh *et al*., undated). Digital satellite data was imported and geo-referencing was performed in UTM coordinate system.

Punjab soil erosion map (scale 1: 250000) prepared for the whole of Punjab (Pal *et al*., 2016) was taken and area of interest (PLPA area of three forest divisions) was extracted from soil erosion map. Soil erosion were categorized into six classes *viz*., very slight (<5 t $ha^{-1}yr^{-1}$), slight (5-10 t $ha^{-1}yr^{-1}$), moderate (10-15 t $ha^{-1}yr^{-1}$), moderately severe (15-20 t $ha^{-1}yr^{-1}$), severe (20-40 t $ha^{-1}yr^{-1}$) and very severe (>40 t $ha^{-1}yr^{-1}$). Areas falling under different categories of soil erosion in the forest divisions were marked and separate maps for each forest divisions were prepared. Areas under different categories of soil erosion classes were calculated for prioritizing the areas which are more prone to soil erosion and hence require soil and water conservation measures.

3. RESULTS AND DISCUSSION

Forest Cover Status

The forest cover map of PLPA areas in three forest division is given in Figs. 1-3. It was found that moderately dense and open forests are prevalent in these forest divisions. In Dasuya forest division, maximum (31.78%) area is under moderately dense forest followed by Gurdaspur (29.20%) and least in Garshankar (11.28%). Open forest in PLPA area were higher in Garshankar (35.03%) and least (21.92%) in Dasuaya forest division. To bring back the eroded areas due to unrestricted grazing and browsing, protection of the forest area is the most suitable choice. Changes in forest cover has received greatest scientific attention in recent years as it is directly linked with carbon sequestration potential and hydrological regimes in present changing climatic scenarios (Townsend *et al*., 2008). Therefore, monitoring and assessment of the forest cover change while sustaining the production of essential resources has become a major priority with researchers, land managers, and policy makers. Due to increase in forest cover through PLPA, a total of 396 species of birds have been recorded from the Shivalik area, of which four are globally threatened and about 156 species are under Wildlife Protection Act (Jerath *et al*., 2006).

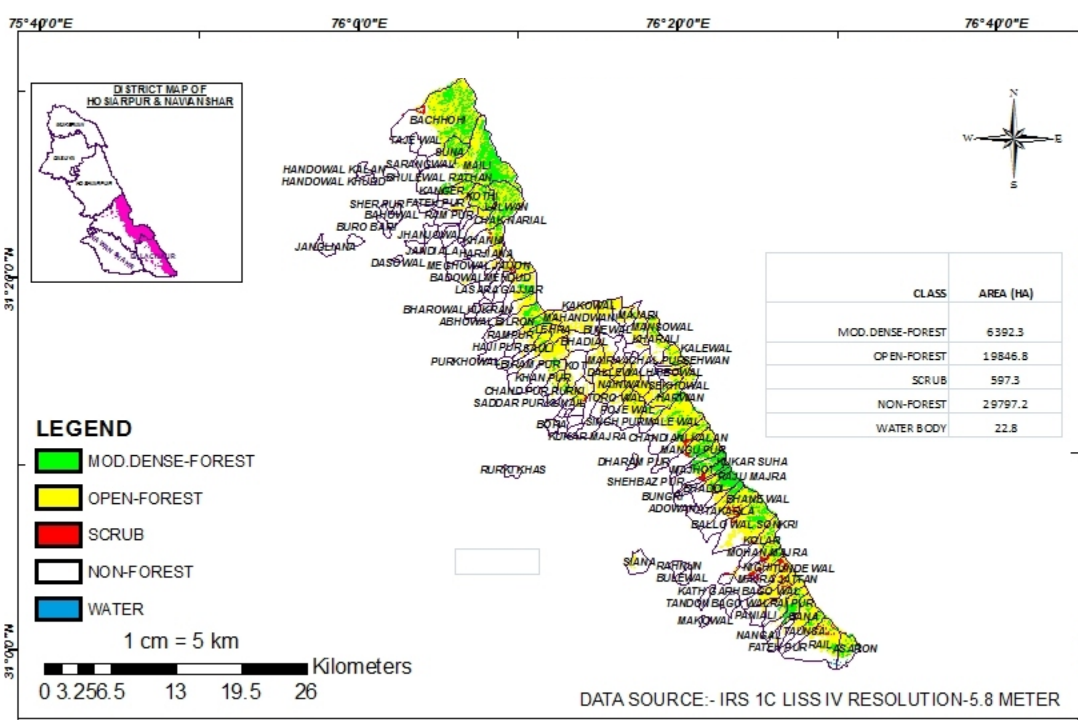

Fig. 1. Forest cover map of PLPA areas for Garshankar forest division

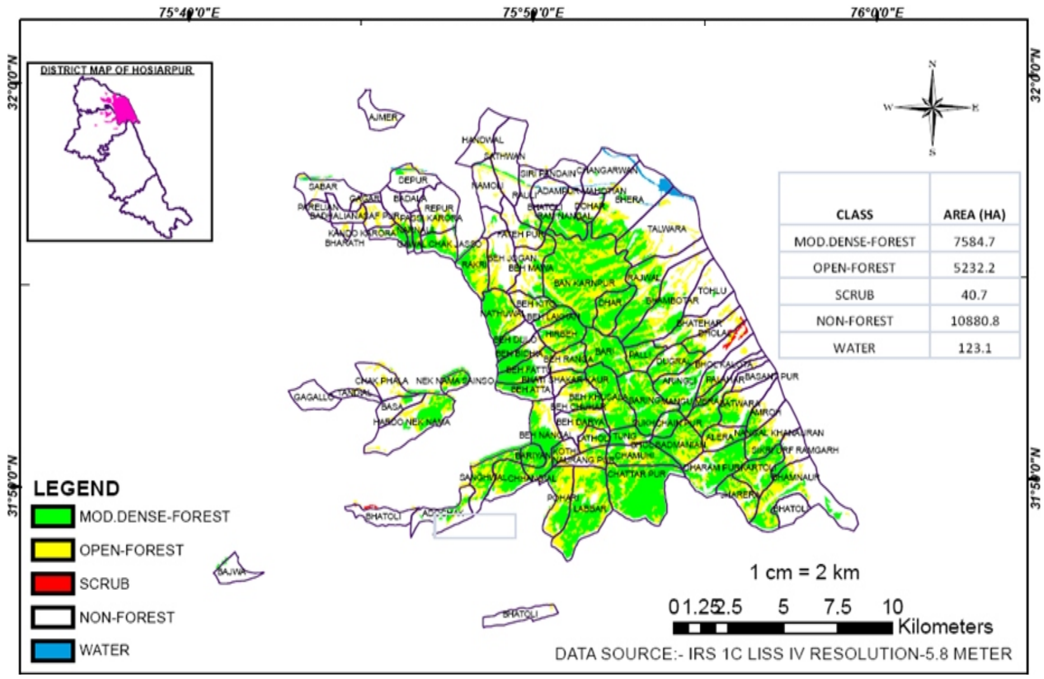

Fig. 2. Forest cover map of PLPA areas for Dasuya Forest Division

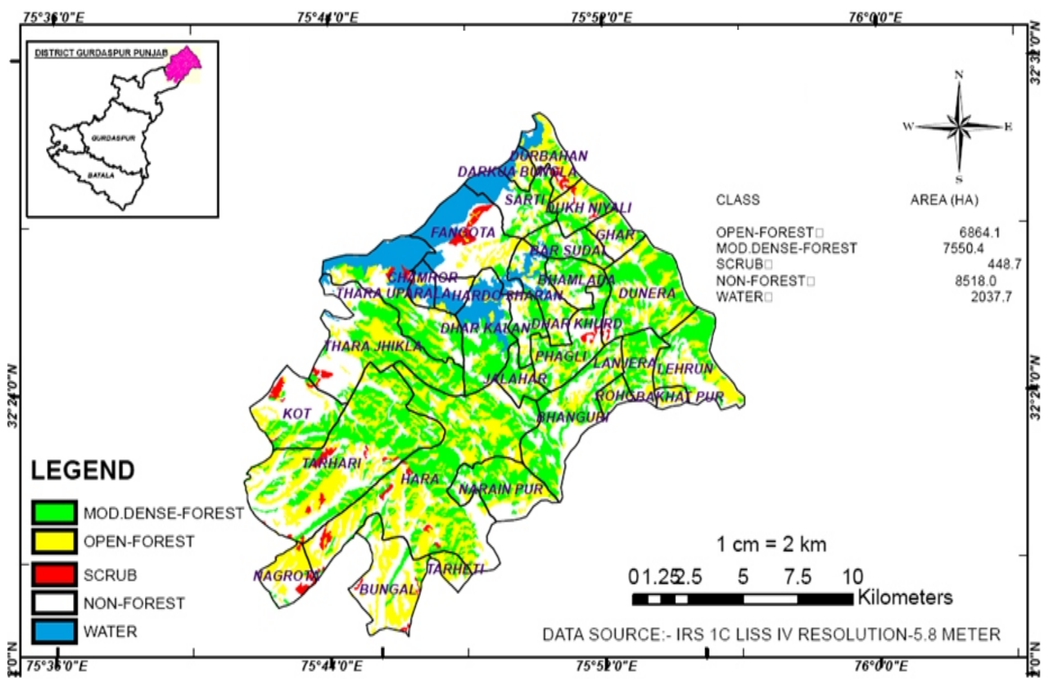

Fig. 3. Forest cover map of PLPA areas for Gurdaspur Forest Division

Potential Soil Erosion

Potential soil erosion maps for PLPA areas of three forest divisions are given in Figs. 4-6. In Gurdaspur forest division, 44.33% area of PLPA is under moderate category of soil erosion followed by moderately severe category (24.50%). Very severe category was not found in Gurdaspur division (Fig. 7a). In Dasuya, maximum area (56.46%) was under severe erosion followed by moderately severe (22.77%) and least area was in very slight (0.95%) category of potential soil erosion (Fig. 7b.). In Garshankar, 32.61% area of the PLPA is under very severe category closely followed by severe (30%) category. The least area in the division is under moderate category of soil erosion (4.75%) (Fig. 7c).

Priority-wise large scale adoption of soil and

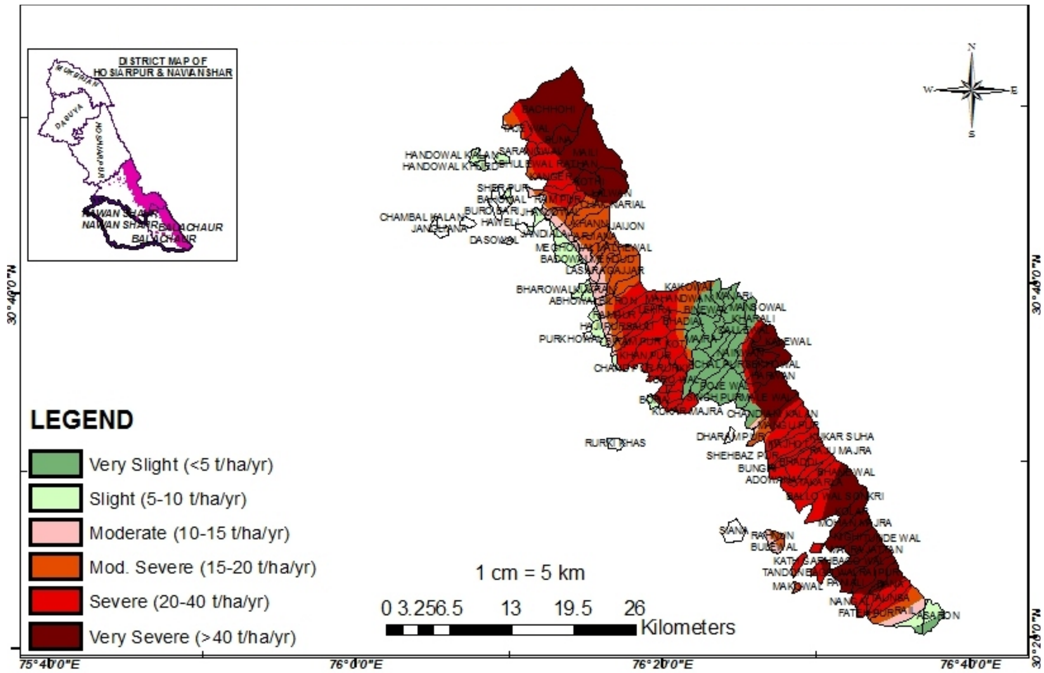

Fig. 4. Soil loss map of Garshankar forest division

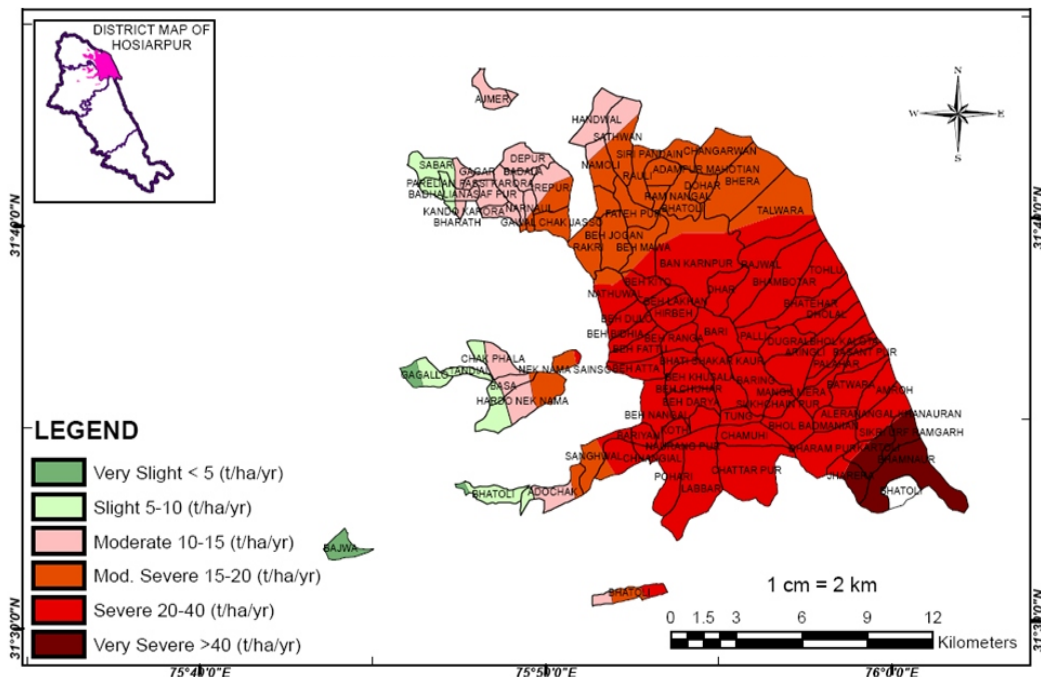

Fig. 5. Soil loss map of Dasuya forest division

water conservation measures will not only reduce soil erosion but also increase availability of both surface and groundwater for downstream settlements. It will further decrease the effect of droughts and environmental hazards. The present study highlights the extent and distribution of forest cover and areas having potential soil erosion in the study area. This method of analyzing critical areas is simple and easy to implement in GIS environment. Chowdhury (2006) reviewed spatial methodologies and applied similar methodology for analysis of deforestation in Mexico. However, there is also increasing recognition of the fact that process of land cover change needs to be viewed as a mosaic of land use drivers as they interact in a complex manner and give rise to distinctive patterns of change (Petit and Scudder, 2001;

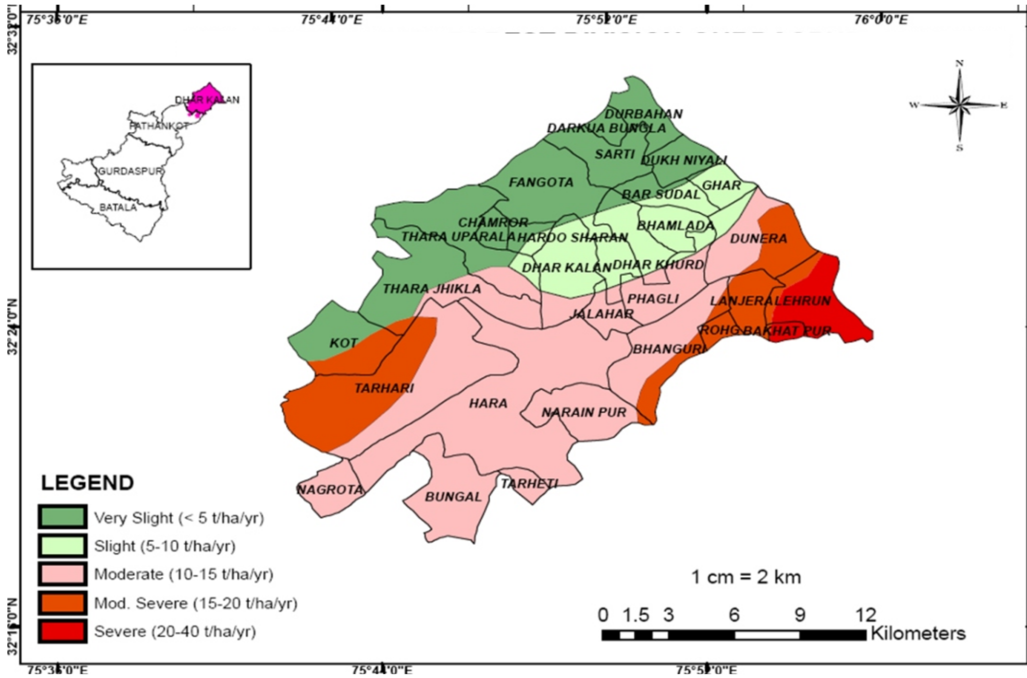

Fig. 6. Soil loss map of Gurdaspur forest division

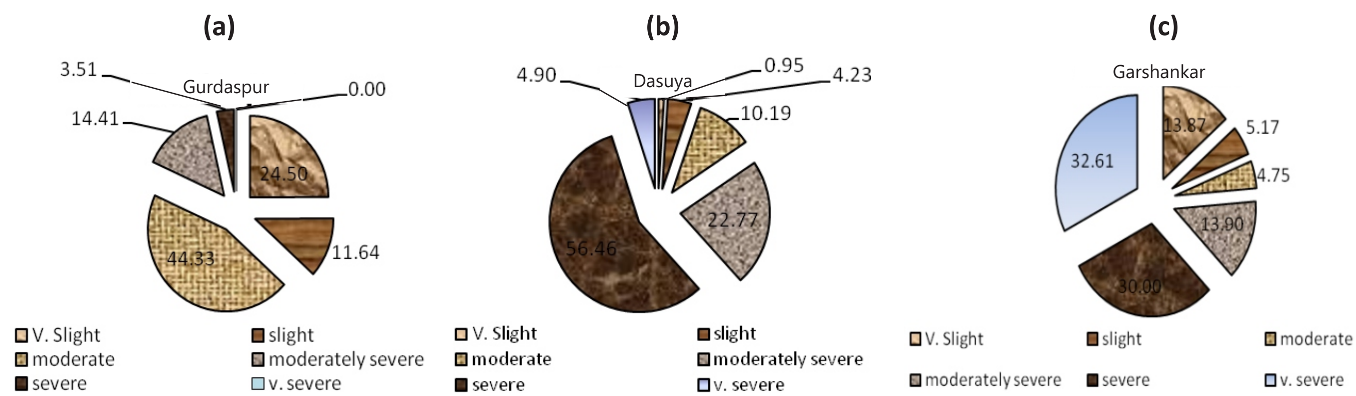

Fig. 7. Percent area under different category of potential soil erosion a) Gurdaspur b) Dasuya c) Garshankar forest divisions

Southworth *et al*., 2002; Nagendra *et al*., 2003; Rout *et al*., 2015).

4. CONCLUSIONS

The study reveals that about 50% of PLPA area in all three forest divisions falls under severe to very severe soil erosion category. Adopting intensive mechanical measures and maintaining/increasing forest cover in these areas would help in protecting these vulnerable areas from further degradation. The information derived from the present study can be effective for adaptation of proper management strategies and conservation measures on a micro level to control soil erosion in Punjab Shivalik. The information generated will help Department of Forest and other state agencies to divert more efforts for soil and water conservation in areas which falls under severe and very severe category of soil erosion.

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