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GEOSPATIAL MODELING TO ASSESS GEOMORPHOLOGICAL RISK FOR RELENTLESS SHIFTING CULTIVATION IN GARO HILLS OF MEGHALAYA, NORTH EAST INDIA

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Abstract

Due to shifting cultivation, the overall structure and composition of ecological condition is affected, hence landscape study becomes important for maintaining ecological diversity and appropriate scientific planning of any area. Garo hills region of northeast India is suffering from Geomorphological risk like sheet erosion, landslide etc. due to the age old tradition of shifting cultivation in the fragile hill slopes aided by other anthropogenic activities. The present study was conducted to examine the role of shifting cultivation for deforestation and degradation with variant of slope and elevation to relate vegetation cover with slope and elevation in the Garo Hills landscape of Meghalaya using temporal remote sensing data of 1991, 2001 and 2010. It revealed that there is decrease in dense forest and open forest during the 1st decade while areas under dense forest and non-forest increased in 2nd decade. This increased forest area is confined in the high slopes, which are inaccessible. The study shows increase in shifting cultivation near-about double fold in high slope and more than a double fold in the high altitudinal area in last decade, which is negative sign in terms of Geomorphological protection.

Keywords: Shifting cultivation, Slope, Elevation, Garo hills, Remote sensing, GIS

Introduction

Shifting cultivation is regarded as one of the traditional methods for cultivation in hilly areas of tropical regions in which forest vegetation is cut and burned on site. The site is cultivated for food crops and when the final crop is harvested; the site becomes fallow and is allowed to regain its natural forest cover (Yadav, 2013; Momin, 1995). Shifting cultivation is considered to be well adapted in tropical climates and soils, and accessible to small farmers because of its low cost. To achieve balanced nutrients in traditional shifting cultivation systems requires long fallow periods, which are difficult to maintain in current context of strong demographic pressure (Lawrence, *et al.*, 2010; Vielhauer, *et al.*, 2004; Sommer, *et al.*, 2004). In North-East India, increasing human population density has resulted in the practice of an unsustainable form of shifting cultivation that includes shortening of the fallow period as well as permanent conversion of forest to permanent agricultural land expansions. First, among the general and main causes of deforestation are human population pressure and an increasing demand of land for agriculture and timber products from forests (Cayuela, *et al.*, 2006), resulting habitat degradation, biodiversity loss, and ecological instability (Yadav, 2011).

Garo hills districts of Meghalaya are endowed with rich biodiversity in both term flora and fauna, with the increasing of population there is pressure exerted on these natural resources for the livelihood, as there is hardly any alternative available (Yadav, *et al.*, 2013a). This unsustainable form of practices leads to soil erosion, runoff and loss of forest vegetation and threatens the survival of flora and fauna (Yadav, *et al.*, 2013b; Bochet, *et al.*, 2004). The physical environment including climate, geology, topography, plant succession, and species extinction and evolution is often regarded as one of the most important factors controlling the heterogeneity of the landscape in mountain areas. On the other hand, runoff can change soil properties and the micro-geographical environment, vegetation growth, succession and vegetation distribution, which cause vegetation change (Huaiyu, 2010). Disturbances like shifting cultivation, landslide, floods, urbanization, forest fires, and ecosystem modification are responsible for deforestation and degradation. However, several studies highlight the negative consequences of shifting cultivation, including: greenhouse gas emissions, pulmonary illness caused by smoke, accidental damage or destruction of crops and homes (Ketterings and Bigham, 2000; Frizano, *et al.*, 2003; Denich, *et al.*, 2005 Lawrence, *et al.*, 2010 Sarma, *et al.*, 2013), loss of biodiversity, accelerated deforestation (Fearnside, 1991) accelerated loss of nutrients, soil erosion and mercury leaching into aquatic ecosystems (Farella, *et al.*, 2006; Roulet, 1999).

Land use and land cover (LULC) studies are an important module to understand global land status. It shows present as well as past conditions of the earth surface and it is a central component and strategy for managing natural resources and monitoring environmental changes (Yadav, *et al.*, 2012 b). Forest cover changes are particularly related to increase of population, urbanization and intensive agriculture (Verburg, *et al.*, 1999). On the other hand, demographic and socio-economic considerations also play a vital role in LULC and landscape pattern (Kammerbauer and Ardon 1999; Yadav and Sarma 2013). Land is becoming a scarce natural resource due to very high demand of agricultural products and ever increasing human population. Hence, information on LULC and possibilities of their optimal use is essential for the selection, planning and implementation of this resource to meet the increasing human demands. Landscape ecology is the study of patterns and structures across dynamic temporal and spatial scales. Spatial patterns observed in landscapes result from complex interactions between biotic and abiotic processes and disturbances that occur within environment (Turner, *et al.*, 2001). As change occurs in the landscape, the overall structure and composition of the ecological community is affected, hence the importance of the study related to landscape is increasing for maintaining the ecological diversity. Among different environmental factors that produce landscape patches, slope and elevation are important parameters that provide varieties of topographical features. Garo hills region of northeast India is severely affected by sheet erosion mainly because of the age old tradition of shifting cultivation in the fragile hills slopes aided by other anthropogenic activities. Shifting cultivation is regarded as one of the main drivers of deforestation (Sarma and Barik, 2010). The heavy rainfall (3000 mm per annum) during summer accelerates the erosion rate in the areas which are free from vegetation cover. Vegetation is one of the major factors controlling soil erosion, while most soil erosion occurrences are due to removal of vegetation and topsoil (Bochet and Garcıa-Fayos, 2004). The practice of shifting cultivation is reported to account for 60 percent forest losses worldwide each year (Lele, *et al.*, 2008). Vegetation and land characteristics of Garo hills are heavily influenced by jhum activities, which have greatly increased in recent decades with increase in human population, resulting in severe fragmentation of previously undamaged forest tracts (Singh, *et al.*, 2011).

The study of the slope is an important parameter as it not only provides the variety of topographical features but also provides evidence for the interpretation of complex form of the existing landscape and reflects the evolutionary history of the existing landscape (Fairbridge, *et al.*, 1968). Slope determines the factors for soil development, soil loss due to weathering, mining operations or agricultural practices (Sarma and Barik, 2010). Elevation pattern of landscape have been responsible for many factors like climate, isolation, species-area effects, historic events and biomass productivity of landscape patches (Acharya, *et al.*, 2011; ICIMOD, 2001). Geospatial techniques have been used to monitor the land use changes and have an important role in study of biodiversity as well as in determination of natural resources (Yadav, *et al.*, 2013b). Satellite remote sensing technology with multi-sensor capabilities offers multi-scale information on landscape composition and configuration (Joseph, 2009). Geospatial technology has further improved the efficiency of mapping the LULC with respect to slope and elevation pattern at landscape level. Thus, integration of these techniques can form a potential tool for proper LULC mapping and change detection. Digital Elevation Models (DEMs) digitally demonstrate the earth's surface and potential tool for terrain analysis at the various spatial and temporal scales. A DEM has been used to describe distribution of terrain components which contribute the spectral response, identify sites for field work (Walsh, 1987), geographically stratify training areas or homogenous regions (Franklin, 1990), and provide topographic normalization of Landsat imagery (Civo, 1989). In the present study, DEM and Landsat imagery (TM and ETM) are integrated for Geospatial Modeling to assess Geomorphological risk for relentless shifting cultivation in Garo Hills of Meghalaya, north-east India.

Study Area

The study area belongs to biogeography zone 9B (north-eastern India) and occurs between latitude 25°9´ to 26°1´ N and longitude. 89°49´ to 91°2´E. Elevation ranges from 100 to1500 m amsl. The Garo Hills of Meghalaya have three districts East Garo Hills, West Garo Hills and South Garo Hills. The highest point of Garo Hills is the Nokrek peak with an altitude of above 1412 meter. The southern face of the plateau is marked by deep gorges and abrupt slopes, at the foot of which a narrow strip of plain land runs along the international border with Bangladesh. The Garo Hills have many caves and lakes. All the principle rivers flow towards Bangladesh plains in the south and the Brahmaputra valley in the north and the west. The important rivers of the north group are the Kalu, Ringgi and the Didak. The important rivers of the southern group are the Bhogai, Dareng etc. The landscape of the region is mostly rolling plateau with extremely steep south-facing slopes (Fig. 1).

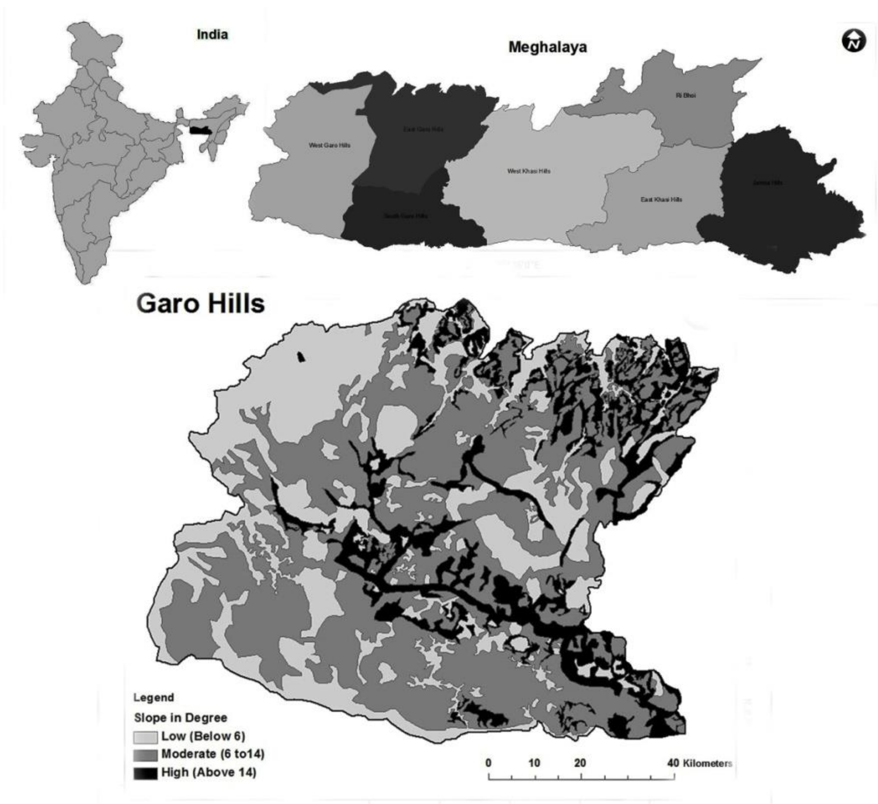


Figure 1: Study area map with various slope features

Garo Hill's societies are predominantly dependent on the forest resources for their livelihood. The mining activities have brought in the desired effect of economic growth but on the other hand, affected the environment in a variety of ways, which contributed to its degradation (Sarma and Yadav, 2013). People are depending on natural resources and also on meat (Hilaluddin, *et al.*, 2005). Being relatively under-developed compared to other regions of the country, opportunities for alternative livelihoods are limited. Main land use classes of Garo Hills are protected area, managed forest and privately-owned Garo community land. The Government manages only 15% of total land in protected area and reserved forest. The remaining land belongs to local Garo communities, widely use for Jhumming and as source of non-timber forest resource.

Materials and Methods

To asses role of shifting cultivation for deforestation and degradation study temporal remote sensing imagery of 1991, 2001 and 2010 were utilized while for generating digital elevation model 2001 base year was considered (Table 1). The imageries were registered on 1:50000 scale using relevant topographical maps of Survey of India (SOI) The GIS and image processing software used were ArcGIS 10, Erdas Imagine 2011 and Quantum GIS 1.6. Field verification was done during 1st February to 11th April 2012. Accuracy assessment of the classification scheme is given in Table 2.

Table 1: Details of Landsat satellite imagery used for the study

Path & Row	1991	2001	2010
138 42	17 January	15 December	6 February
137 42	17 January	11 February	30 January
137 43	5 February	26 December	30 January

Table 2: Accuracy of assessment of supervised classification

Year	Overall classification accuracy	Overall kappa statistics
1991	87.36%	0.78
2001	85.94%	0.77
2010	92.19%	0.85

Four LULC classes' viz., dense forest (more than 40% canopy cover), open forest (10% to 40% canopy cover), non-forest (less than 10%) and current jhum had been delineated for the study area (FSI 2005). For slope three categories of high (above 14 degree), moderate (6 to 14 degree) and low (below 6 degree) were considered. For elevation high (above 900 m), moderate (300 to 900 m) and low (below 300 m) categories are fixed.

Results and Discussion

Area statistic trends of LULC in different slope and elevation categories in different years in Garo Hills are in Fig. 2 and 3. It is found that in all the years the area under open forest (6,649 sq. km**,** 6,365 sq. km and 4,307 sq. km) has the highest coverage which is followed by non-forest area (2,155 sq. km and 2,846 sq. km) for 2001 and 2010. There was a decrease of 284 sq. km open forest during 1st decade (1991 to 2001) and 2,058 sq. km open forest during 2nd decade (2001 to 2010) while areas under non-forest increased by 641 sq. km and 1,591 sq. km respectively. The area of dense forest decreased in the 1st decade (461 sq. km) and increased in the 2nd decade (218 sq. km) Fig 2D and 3D (see in the graph of dense forest category). This may be due to the efforts put by government and other organizations who are working for the regeneration of the natural forests of Garo Hills. This increase is found mostly in the moderate and high slope areas. Loss of open forest areas was found in all the slope categories where highest loss found was in low slope category of both decades. Similar trend is followed by non-forest areas.

The high slope and elevation areas were not utilized for shifting cultivation in 1991 but it reported in 2001 which is vulnerable in terms of sheet erosion. In fact the areas under shifting cultivation in the high slope areas increased during the 2nd decade in considerable proportion (27 km^2) (Fig. 2C and 3C) (see in the graph of 2C and 3C of shifting cultivation category). Maximum areas of dense forest are concentrated in the high (130 km^2) and moderate (365 km^2) elevation area which is mostly inaccessible. Open forests are dominating in the moderate and low elevation areas. Non-forest area was maximum in the low elevation areas. It is observed that in the high altitude area the current jhum increased by more than double fold during 2001 and 2010 (Fig 3C).

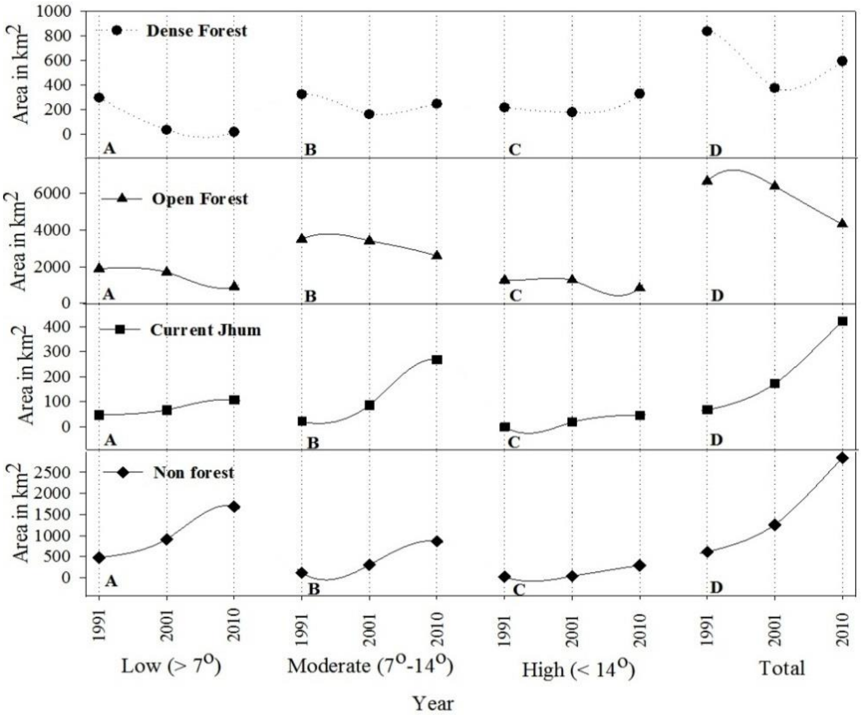


Figure 2: Area statistics of LULC in different slope (in Degree) category of Garo Hills, 1991 and 2001 and 2010.

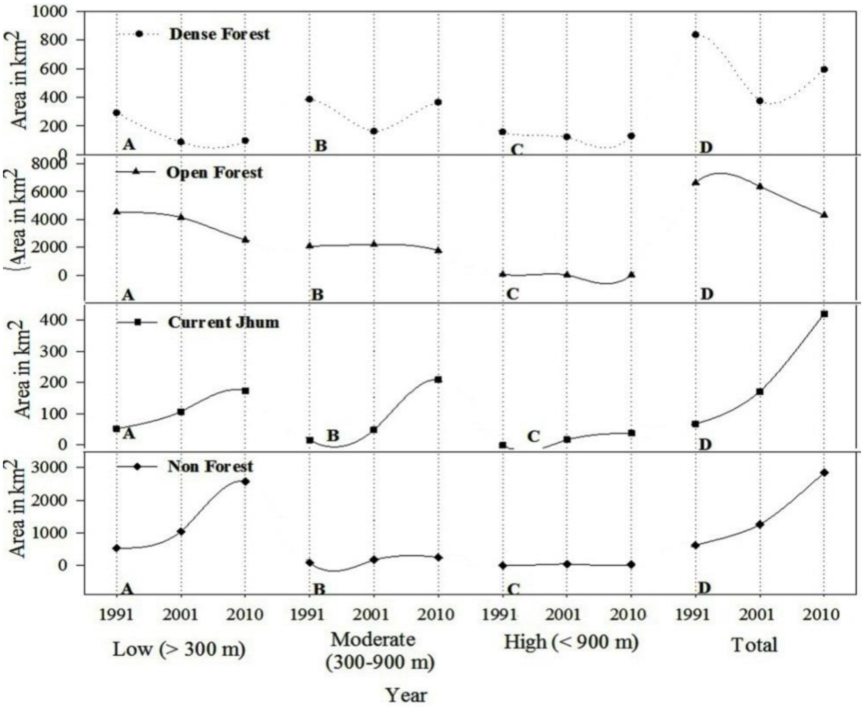
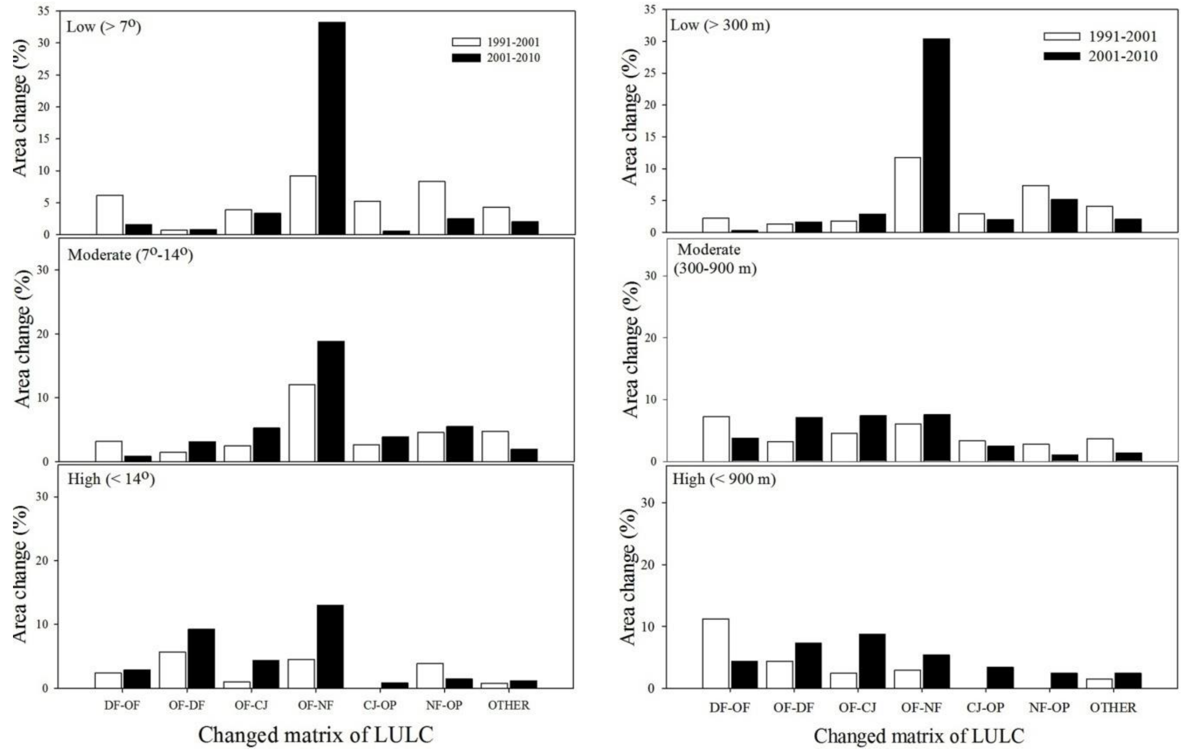


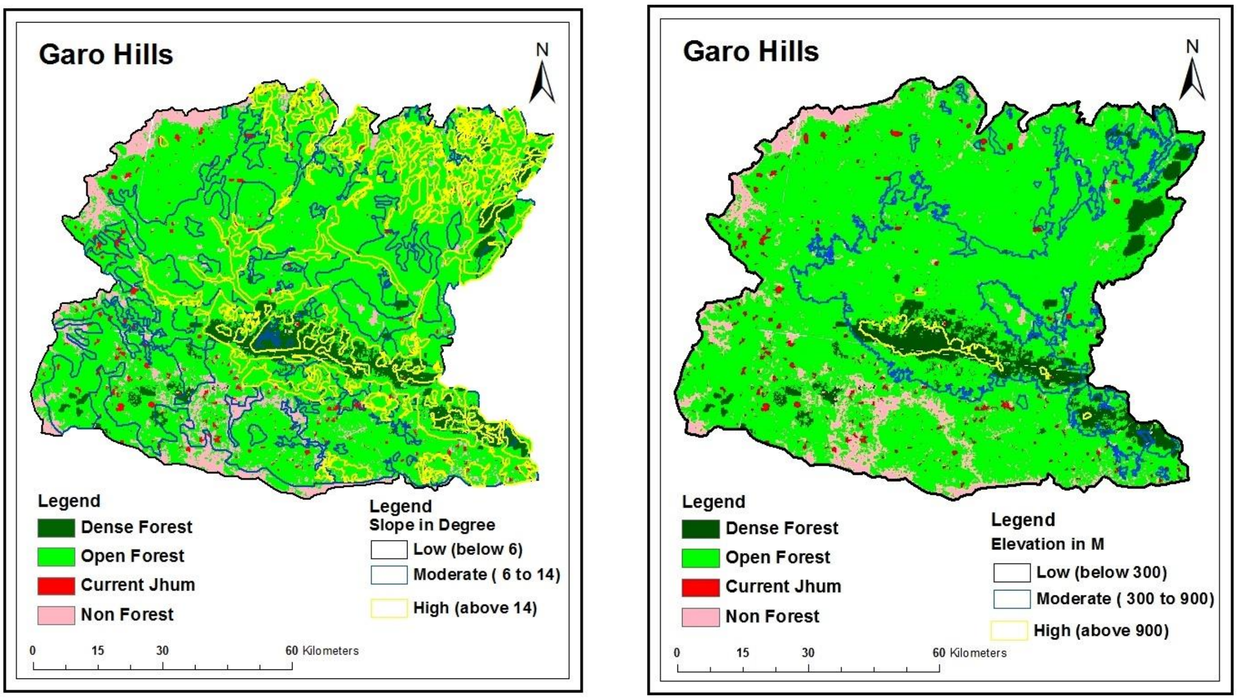
Figure 3: Area statistics of LULC in different elevation (in meter) category of Garo Hills, 1991 2001 and 2010.

Change matrix result indicated high intensity of shifting cultivation which is moving toward high slope and elevation zone of landscape. Here, land use/cover change matrix was categorized in eight class's viz., dense forest to open forest, open forest to dense forest, open forest to current jhum, open forest to non-forest, current jhum to open forest, non forest to open forest, no changes and others (i.e. dense forest to current jhum, dense forest to non forest, current jhum to dense forest and non forest to dense forest) with respect to different slope and elevation categories. Conversion of dense forest to open forest occurred in all the slope categories. The alteration from open to dense forest predominated in the moderate and high slope categories. Maximum change from open to non-forest is in the slope categories of low and moderate. There was considerable change from current jhum to open forest mostly in the moderate slope category. The maximum change between dense to open and open to dense occurred in the moderate slope and elevation area. Changes in other categories from open forest are found mostly in moderate and low elevation areas. In these two zones changes only occurred from jhum to open forest (Fig. 4 A and B).



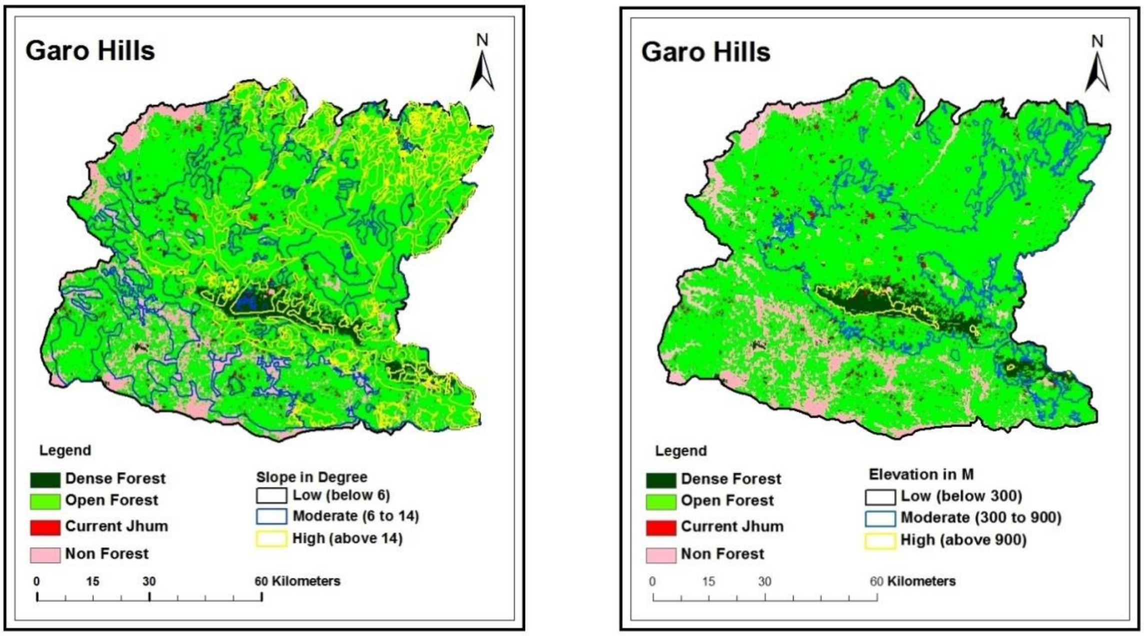
(A) **(B)**

Figure 4: Area statistics of change matrix in respect to slope (A) and elevation (B) of Garo Hills landscape year 1991-2001 and 2001-2010.



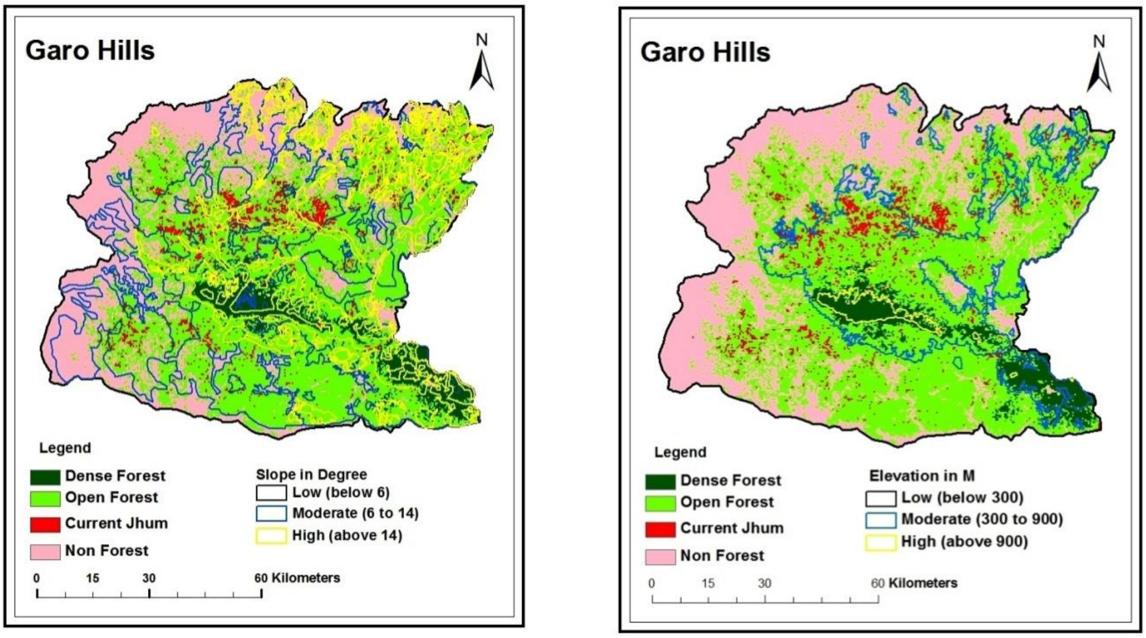
(A) **(B)**

Figure 5: LULC in different slope (A) and elevation (B) categories for 1991



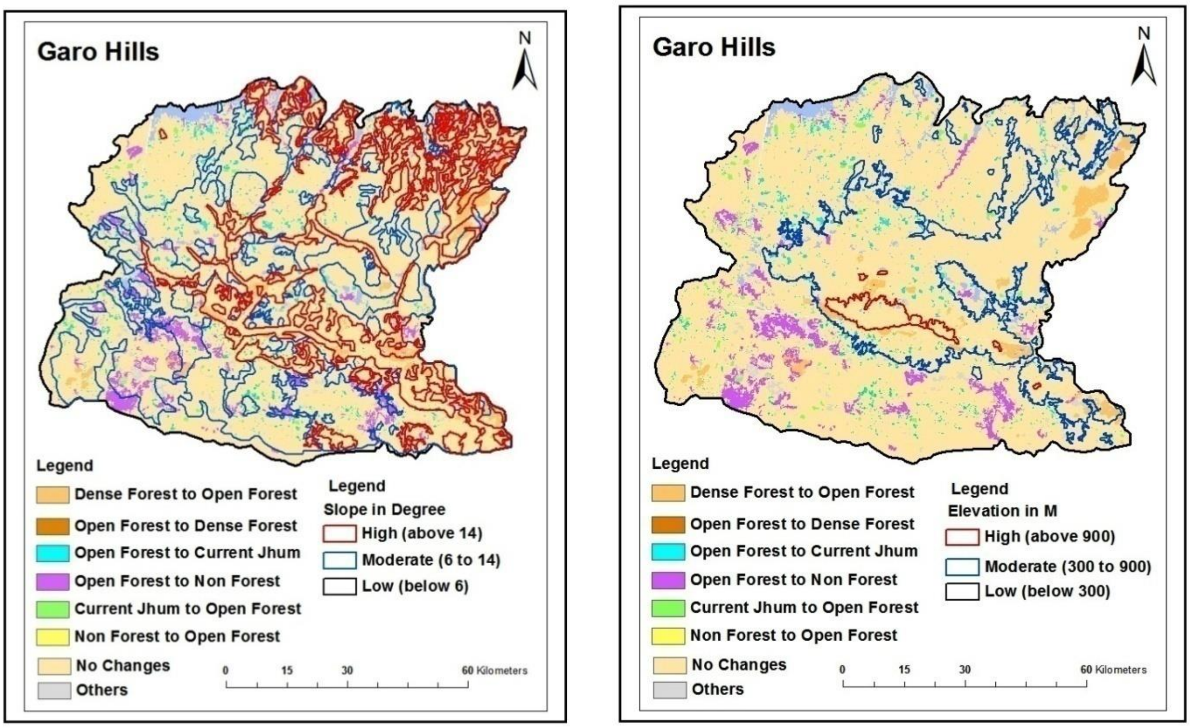
(A) (B)

Figure 6: LULC in different slope (A) and elevation (B) categories for 2001



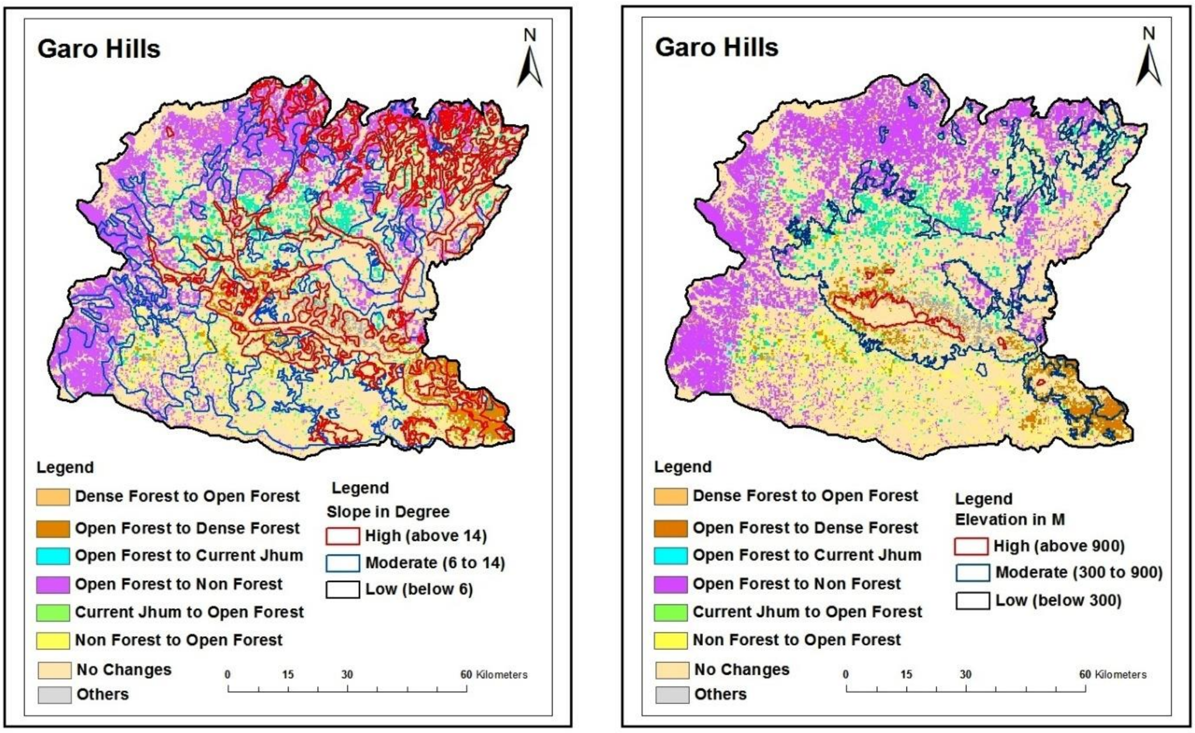
(A) (B)

Figure 7: LULC in different slope (A) and elevation (B) categories for 2010



(A) (B)

Figure 8: Change matrices during 1991 and 2001 in terms of slope (A) and elevation (B) categories



(A) **(B)**

Figure 9: Change matrices during 2001 and 2010 in terms of slope (A) and elevation (B) categories.

The forest cover map with different slope and elevation category for 1991, 2001 and 2010 are presented in the Fig 5, 6 and 7 and the change matrix of each LULC classes during the two decades in Fig. 8 and 9. Result of the study showed that dense forest is confined mostly to the inaccessible areas whereas the other three types fall mainly in the moderate and low slope and elevation range. The primary forest of the landscape have been devastated to a great extent by age old tradition of shifting agriculture which is extensively practiced in the hilly regions of northeast India (Ramakrishnan, 1992). In the present study, the proportion of open forest and non forests increased with decrease in slope. These areas represent a mosaic of degraded landscape owing to the low slope of the area. This finding is similar to an earlier study (Susana and Mario, 2004), who reported that deforestation may be widespread in areas where slopes are relatively gentle. There is general trend in mountain ecology that with increasing altitude there exists good ecological conditions (Hamilton, *et al.*, 1999). This criterion is fulfilling in the present study. The findings of the present research reflect the similar results of (Ramesh, *et al.*, 1997) who concluded that deforestation process characterized by removal of the smallest and most accessible forest patches, followed by other developmental and livelihood activities. People even go for shifting cultivation for their livelihood in the areas where consequences could be vulnerable in environmental protection point of view (Sarma and Barik, 2010). Deforestation may be widespread in an area where slope is relatively mild in nature (Semwal, *et al.*, 2004). Their finding is very much supportive to the present research. Whereas, studying relationships between geomorphology and tree density revealed all type of trees in all slope categories but density was high in the stable landforms despite slope variations (Smith, *et al.*, 2005).

Conclusions

Geomorphological risk for relentless shifting cultivation in Garo hills concept emphasizes landscape fragmentation, risk of sheet erosion mainly because of age old shifting cultivation and connectivity issue that motivates modern notation of biodiversity conservation. The study presented here introduced landscape dynamics design metrics within spatial optimization framework. The design framework is motivated by analysis of deforestation landscape driven by incremental forest patch removal- underlying dynamic attribute to tropical deforestation in aspect of slope and elevation. Vegetation is one of the major factors controlling soil erosion, while most soil erosion and runoff occurs due to the removal of vegetation and topsoil. The threats of soil runoff and soil erosion due to jhumming can affect the vitality of native vegetation due to loss of necessary nutrients and soil features needed for their natural survival. Change matrix result indicates dynamic character of landscape. To achieve balanced nutrients in traditional shifting cultivation system require long fellow period, which are difficult to maintain in current context of strong demographic pressure. The districts have witnessed the conversion of forests to other non-forest areas during the last decade. This alteration needs to be checked immediately.

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