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# Landscape Dynamics in Relation to Slope and Elevation in Garo Hills of Meghalaya, India using Geospatial Technology

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# Landscape Dynamics in Relation to Slope and Elevation in Garo Hills of Meghalaya, India using Geospatial Technology

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*Abstract* - 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 hill slopes aided by other anthropogenic activities. Slope and elevation are important parameters that provide varieties of topographical feature for ecological patches. Vegetation is one of the major factors controlling soil erosion, while most soil erosion occurrences are due to the removal of vegetation and topsoil. Change matrix result indicates dynamic character of landscape.The present study is conducted to examine the landscape dynamics to relate vegetation cover with slope and elevation in three Garo hills districts of Meghalaya using temporal remote sensing data of 2001 and 2010. It is revealed that there is decrease in open forest during the study period while areas under dense forest and non-forest increased. This increased forest areas are confined in the high slopes which are inaccessible. Considerable portionsin the vulnerable slopes are utilized for shifting cultivation which could be devastating. The present study shows more than a double fold increase in shifting cultivation in the high altitudinal area which is negative sign in terms of environment protection. Conversion of dense forest to open forest occurred in all the slope categories while 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 moderate andlow. There is considerable change from current jhum to open forest mostly in the moderate slope category. The maximum exchange between dense to open and open to dense occurred in the moderate slope and elevation areas.

*Keywords : change matrix, GIS, jhum, northeast india, remote sensing.*

## I. Introduction

Landscape dynamic is concerned with the effect of spatial heterogeneity on ecological process. The physical environment including climate, geology, topography, plant succession, species extinction and evolution is often regarded as one of the most important factors controlling this heterogeneity of the landscape in mountain areas. Disturbances like shifting cultivation, landslide, floods, deforestation, urbanization, forest fire, and the ecosystem modification are responsible for landscape dynamics (Zimmermann & Eggenberg, 1990). Land use/ coverstudy 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.,* 2012a). Landscape ecology is the study of patterns and structures across temporal and spatial scales. Spatial patterns observed in landscape result from complex interactions between biotic and abiotic processes and disturbances that occur within environment (Turner *et al.,* 2001). As changes occur in the landscape, the overall structure and composition of ecological community is affected, hence the importance of the study related to landscape is increasing for maintainingthe ecological diversity. Among different environmental factors that produce landscape patches slope and elevation are important parameters that provide varieties of topographical features (Sarma and Barik, 2010). The study of the slope is important not only it 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 landform (Fairbridge, 1968). Elevation pattern of landscape have been responsible for many factors like climate, isolation, species-area effects, historic events and biomass productivity of landscape patches (ICIMOD, 2000 and Acharya*et al.,* 2011).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 Fayos, 2004 and Yadav*et al.,* 2012b). The shifting cultivation accounts for 60 percent global forest loss each year (Lele*et al.,* 2008) and in northeast India annual forest loss is about 10,000 sq.kmdue to this unhealthy practice. The total area affected by shifting cultivation (locally known as jhum) in northeast is estimated to be 44,000 sq.km (Singh, 1990). The jhum cycle in northeast has been decreased from 20 to 30 years in the past to about 5 years (Toky and Ramakrishnan, 1981)and in many areas even up to 3-5 years (Sarma, 2010a). Vegetation and land characteristics of Garo hills of Meghalaya, northeast India are heavily influenced by jhum activities (Figure 1) which have greatly amplified in recent decades with increase in human population, resulting in severely

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fragmenting previously undamaged forest tracts (Singh *et al.,* 2011).

Remote sensing and geographical information system (GIS) coupled with computer programs allow to use landscape ecological principle for biodiversity characterization more efficiently (Yadav*et al.,* 2013). This technology has improved the efficiency of land use/ cover mapping and change detection with respect to slope and elevation pattern at landscape level. Digital Elevation Model (DEM) is a potential tool for terrain analysis at the varied spatial and temporal scales. The objectives of the present study include generation of slope and elevation maps of Garo hills districts of Meghalaya, preparation of land use/ cover maps for two different decades and to examine the dynamic relationships of slope and elevation with land use/ cover using temporal remote sensing data.


*Figure 1 :* Photograph showsthe base in different slopes for cultivation after removing the vegetation by slushing and burning in Nokrek biosphere reserve of Garo Hills

## II. Study Area

The Garo Hills of Meghalaya consist of three districts viz., East Garo Hills, West Garo Hills and South Garo Hills (Figure 2). The districts are bordered in the north and west by Assam state, south by Bangladesh and east by West Khasi Hills district of the state. The districts are highly dissected with irregular terrain. The highest point of Garo hills is theNokrek peak with an altitude of 1,412m above msl. The total area of Garo Hills districts is 8,167 sq. km, which is 36.4 percent of the total area of the state(Sarma, 2010b). The soil of the districts is red loam and is poor in silica but rich in clay forming materials. The soil is generally loamy but often found clay to sandy loam. The surface horizon which is about 30 cm thick has colours ranging from reddish brown to dark reddish brown. The soils are rich in organic matter and nitrogen but deficient in phosphorous and potassium and they are acidic in reaction (Sarma and Barik 2012). The climate of the area is monsoonic and directly influenced by the south-west monsoon (Sarmaet al. 2004). The vegetation of Garo hills could be broadly classified into tropical and subtropical types depending on the altitude. The tropical vegetation is found up to an elevation of about 1000 m (Sarma et al. 2005).

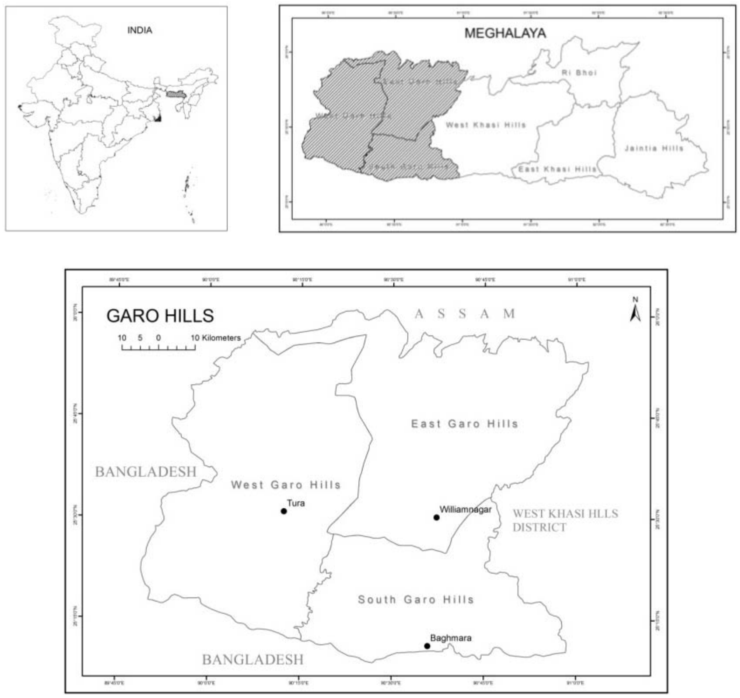



*Figure 2 :* Location of the study area

## III. Materials and Methods

For landscape dynamic study temporal remote sensing imagery of 2001 and 2010 were utilized while for generating digital elevation model 2001 base year was considered (Table 1). The satellite images with bands (7) were stacked to prepare an FCC of bands 3(Red), 2(Green) and 1(Blue). The relevant topographic maps and image were geometrically rectified in 1:50,000 scale using geographic projection system UTM; speroid and datum used were WGS 84 with UTM zone 45N. The GIS and image processing software used are ArcGIS 10, Erdas Imagine 2011 and Quantum GIS 1.6. The paradigm for the study is described in Figure 3. Field verification was carried out during 1$^{st}$ February to 11$^{th}$ April 2012. Accuracy assessment of the classification schema is given in Table 2.

*Table 1 :* Details about the satellite imagery used for the study

| Path & Row | Data Type | Date Production |
|---|---|---|
| 138& 42 | Landsat TM | 15-12-2001 |
| 137& 42 | Landsat TM | 21-11-2001 |
| 137& 43 | Landsat TM | 26-12-2001 |
| 138 &42 | Landsat ETM+ | 06-02-2010 |
| 137 &42 | Landsat ETM+ | 30-01-2010 |
| 137 &42 | Landsat ETM+ | 30-01-2010 |
| 137 &42 | LiDAR STRM (DEMs) | 2001 |

*Table 2 :* Accuracy of assessment of supervised classification

| Year | Overall classification accuracy | Overall kappa statistics |
|---|---|---|
| 2001 | 85.94% | 0.77 |
| 2010 | 92.19% | 0.85 |

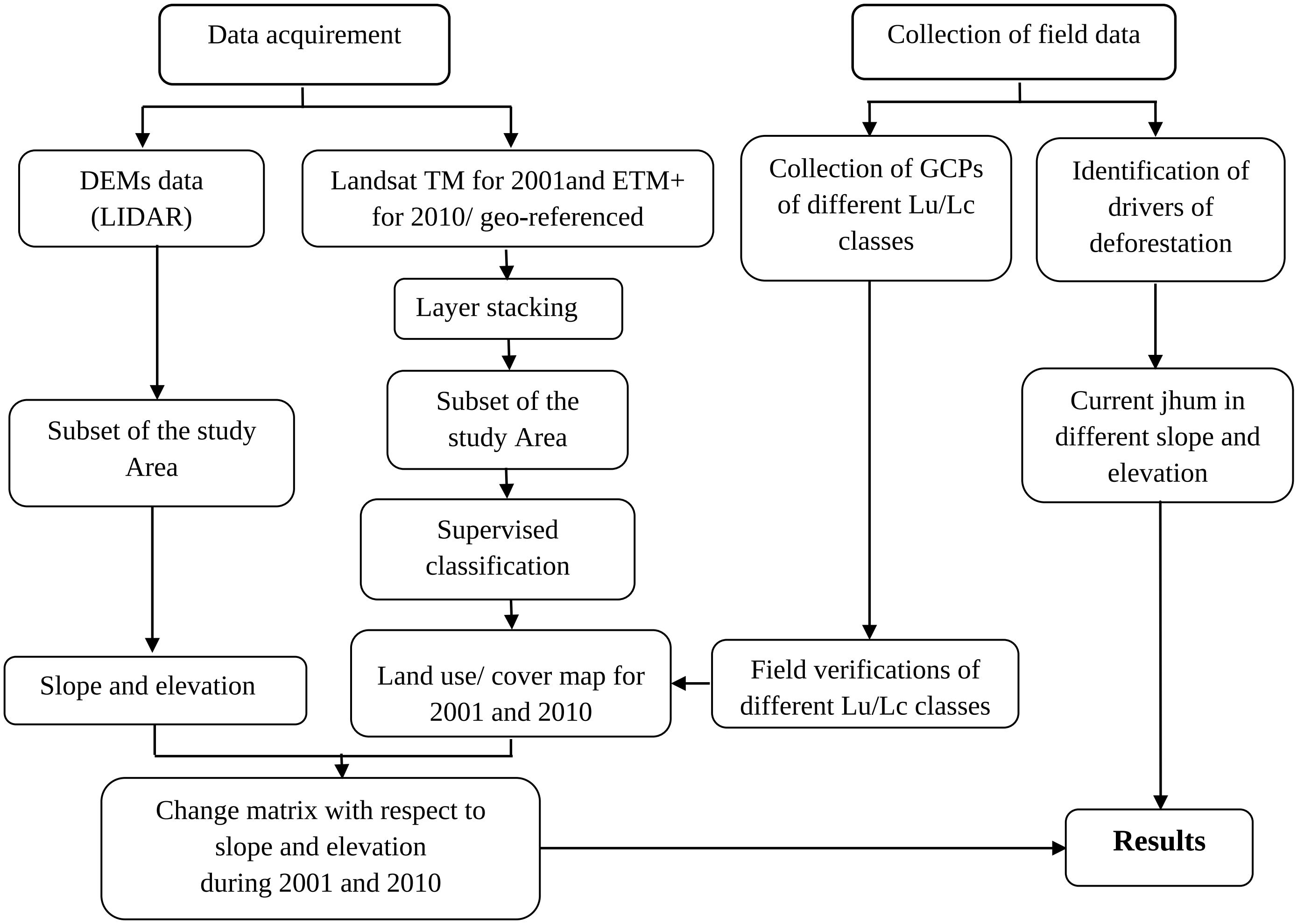



*Figure 3 :* Paradigm for assessing the landscape dynamics in relation to slope and elevation

## IV. Results

Four land use/cover classes viz., dense forest (more than 40% canopy cover), open forest (10% to 40% canopy cover),non-forest (less than 10%) and current jhumhave 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) are considered. Accordingly for elevation high (above 900 m), moderate (300 to 900 m) and low (below 300 m) categories are fixed.

It is found that in both the years the area under open forest (6,365 sq.km and 4,307 sq.km) has the maximum coverage which is followed by non-forest area (2,155 sq.km and 2,846 sq.km). There is a decrease of 2,058 sq.km open forest during the period while areas under non-forest increased by 1,591 sq.km. The area of dense forest increased in the decade(218 sq.km). 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 areas under moderate and high slope areas. Loss of open forest areas is found in all the slope categories where maximum loss found in low slope category. Similar trend is followed by non-forest areas. The high slope areas are also utilized for shifting cultivation which is vulnerable in terms of sheet erosion. In fact the areas under shifting cultivation in the high slope areas increased during the decade in considerable proportion (Table 3). Maximum areas of dense forest are concentrated in the high and moderate altitudinal areas which are mostly inaccessible. Open forests are dominating in the moderate and low elevation areas. Non-forest areas are found in excess in the low elevation areas. It is observed that in the high altitude the jhum area increased in more than double fold during 2001 and 2010 (Table 4).

Change matrix result indicates dynamic character of landscape. Here, land use/cover change matrix was categorized in eight classes 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, no changes and others 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 is considerable change from current jhum to open forest mostly in the moderate slope category. The maximum exchange between dense to open and open to dense occurred in the moderate slope elevation areas. Changes in other categories from open forest are found mostly in moderate and low elevation areas. In these two zones only changes occurred from jhum to open forest (Table 5 and Table 6).

*Table 3 :* Area statistics of LULC in different slope (in degree) category of Garo hills, 2001 and 2010

| Land use/cover class | Slope Year 2001 | | | Total | Slope Year 2010 | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Area in $km^2$ in low | Area in $km^2$ in moderate | Area in $km^2$ in high | | Area in $km^2$ in low | Area in $km^2$ in moderate | Area in $km^2$ in high | |
| Dense forest | 35 | 162 | 178 | 375 | 18 | 247 | 328 | **593** |
| Open forest | 1,697 | 3,403 | 1,265 | 6,365 | 897 | 2,576 | 834 | **4,307** |
| Current jhum | 67 | 86 | 19 | 172 | 107 | 268 | 46 | **421** |
| Non-forest | 913 | 306 | 36 | 1,255 | 1,690 | 866 | 290 | **2,846** |
| **Total** | **2,712** | **3,957** | **1,498** | 8,167 | **2,712** | **3,957** | **1,498** | **8,167** |

*Table 4 :* Area statistics of LULC in different elevation (in meter) category of Garo hills, 2001 and 2010

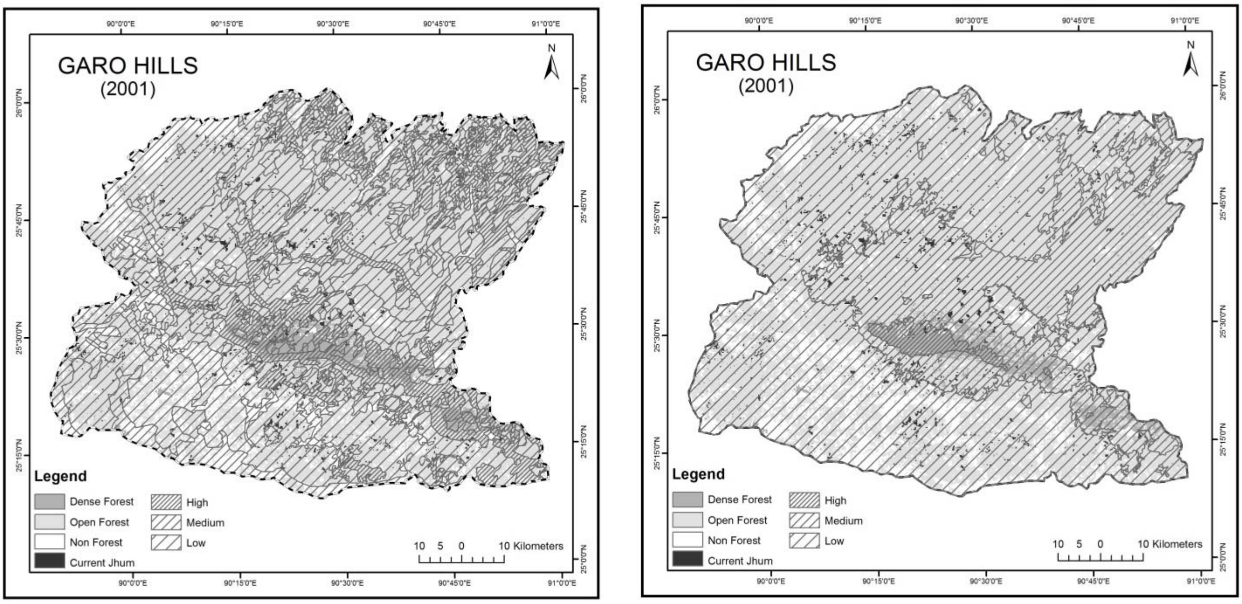
| Land use/cover class | Elevation Year 2001 | | | Total | Elevation Year 2010 | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Area in $km^2$ in low | Area in $km^2$ in moderate | Area in $km^2$ in high | | Area in $km^2$ in low | Area in $km^2$ in moderate | Area in $km^2$ in high | |
| Dense Forest | 88 | 163 | 124 | **375** | 98 | 365 | 130 | **593** |
| Open Forest | 4,146 | 2,197 | 22 | **6,365** | 2,534 | 1,762 | 11 | **4,307** |
| Current Jhum | 107 | 48 | 17 | **172** | 174 | 209 | 38 | **421** |
| Non-Forest | 1,040 | 173 | 42 | **1,255** | 2,575 | 245 | 26 | **2,846** |
| **Total** | **5,381** | **2,581** | **205** | **8,167** | **5,381** | **2,581** | **205** | **8,167** |

*Table 5 :* Area statistics of change matrix in respect to slope of Garo hills landscape

| Changes in land use/cover | Year 2001 to 2010 | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Low | | Moderate | | High | | |
| | Area in $km^2$ | Area in % | Area in $km^2$ | Area in % | Area in $km^2$ | Area in % | |
| Dense to open forest | 43 | 1.59 | 34 | 0.86 | 43 | 2.87 | 120 |
| Open forest to dense forest | 22 | 0.81 | 124 | 3.13 | 139 | 9.28 | 285 |
| Open forest to current jhum | 90 | 3.32 | 208 | 5.26 | 65 | 4.34 | 363 |
| Open forest to non-forest | 902 | 33.26 | 746 | 18.85 | 195 | 13.02 | 1,843 |
| Current jhum to open forest | 14 | 0.52 | 152 | 3.84 | 13 | 0.87 | 179 |
| Non-forest to open forest | 67 | 2.475 | 217 | 5.48 | 22 | 1.47 | 306 |
| No changes | 1,519 | 56.01 | 2,400 | 60.65 | 1,003 | 66.96 | 4,922 |
| Others | 55 | 2.03 | 76 | 1.92 | 18 | 1.20 | 149 |
| **Total** | **2712** | **100** | **3,957** | **100** | **1,498** | **100** | **8,167** |

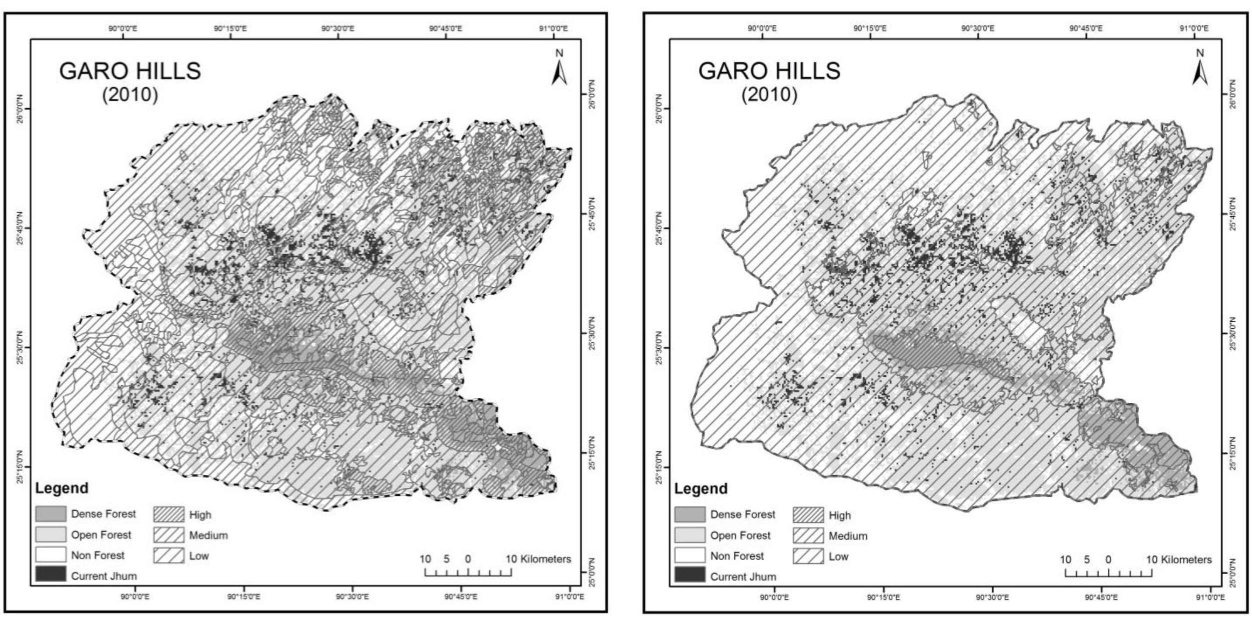
*Table 6 :* Area statistics of change matrix in respect to elevation of Garo hills landscape

| Changes in land use/cover | Year 2001 to 2010 | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Low | | Moderate | | High | | |
| | Area in $km^2$ | Area in % | Area in $km^2$ | Area in % | Area in $km^2$ | Area in % | |
| Dense to open forest | 14 | 0.26 | 97 | 3.76 | 9 | 4.39 | 120 |
| Open forest to dense forest | 87 | 1.62 | 183 | 7.09 | 15 | 7.32 | 285 |
| Open forest to current jhum | 154 | 2.86 | 191 | 7.40 | 18 | 8.78 | 363 |
| Open forest to non-forest | 1,637 | 30.42 | 195 | 7.56 | 11 | 5.37 | 1,843 |
| Current jhum to open forest | 108 | 2.00 | 64 | 2.48 | 7 | 3.41 | 179 |
| Non-forest to open forest | 275 | 5.12 | 26 | 1.00 | 5 | 2.44 | 306 |
| No changes | 2,996 | 55.68 | 1,791 | 69.39 | 135 | 65.85 | 4,922 |
| Others | 110 | 2.04 | 34 | 1.32 | 5 | 2.44 | 149 |
| **Total** | 5,381 | **100** | 2,581 | **100** | 205 | **100** | **8,167** |



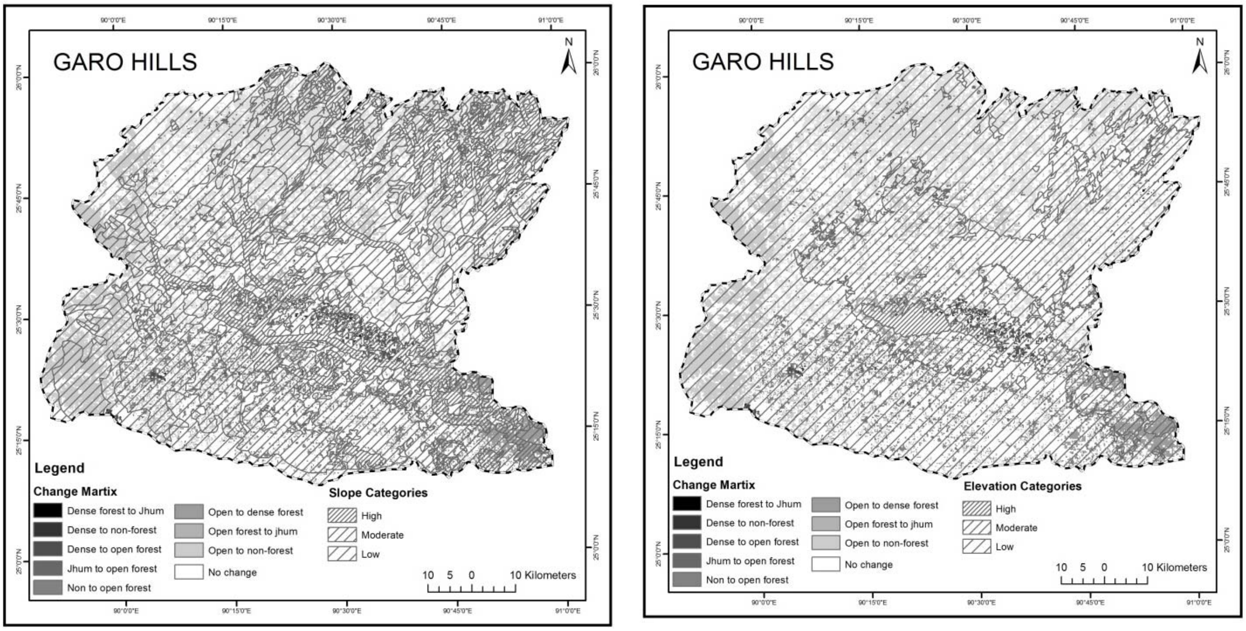

(A) (B)

*Figure 4 :* Land use/cover in different slope (A) and elevation (B) categories for 2001




(A) (B)

*Figure 5 :* Land use/cover in different slope (A) and elevation (B) categories for 2010




(A) (B)

*Figure 6 :* Change matrices during 2001 and 2010 in terms of slope (A) and elevation (B) categories

## V. Discussions

Based on Landsat TM (2001) and Landsat ETM+ (2010) data fourbroad types of land use/ cover were observed for the two different years in Garo hills. Classifications of these satellite imagery show that dense forest is confined mostly to the inaccessible area whereas other three types fall mainly in the moderate and low slope and elevation. The primary forest of the districts have been destroyed to a great extent by age old tradition of shifting agriculture which is extensively practiced in the hilly regions of the northeast India (Ramakrishnan, 1992; Yadav*et al.,* 2012). This activity has led to the development of a variety of successional plant communities ranging from open forest to recently abandoned shifting cultivation fields (Prabhu, 2004). In the present study, the proportion of open forestand non-forests increased with the decrease in slope. These areas represent a mosaic of degraded landscape owing to the gentle slope of the area. This finding is similar to that of Susana & Mario (2000) who reported that deforestation may be widespread in areas where slopes are relatively gentle. There is general trend for 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 stressed that deforestation process characterized by removal of the smallest and most accessible forest patches, followed by other developmental and livelihood activities. The present study is supported by Sarma and Barik (2010) who revealed that even vulnerable slopes are not spared from shifting cultivation consequences of which could be devastating. Semwal*et al.* (2004) revealed that deforestation may be widespread in an area where slope is relatively mild in nature. Balaguru*et al.* (2003) established while relating vegetation with slope angles of Shervayan hills of Eastern Ghats that number of species increases with increasing degree of slopes. Their finding is very much supportive to the present research. Whereas, Smith *et al.* (2005) while 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.

## VI. Conclusions

Garo hills districts support animpressive forest cover which is mainly concentrated in inaccessible areas and theseshould be conserved for biodiversity. It was observed in this study that the remote forest areas are also slowly encroached by the local people for shifting cultivation, mining and other activities. The districts have witnessed the conversion of forests to other non-forest areas during the last decade. This alteration needs to be checked immediately. After shifting cultivation the fallowland should be allowed to regenerate at least 15-20 years before another cycle. The short cycle not only effects soil fertility but also exposes the top soil for erosion. Further, the conversion of forest areas into other land use should be properlyplanned. The most important step that needs to be undertaken to prevent the area from further deterioration is to educate the people and make them aware of the consequences of the effect of deforestation, mining and shifting cultivation.Landscape dynamics study is important to understand and assess the changes in natural resources due to various natural and anthropogenic reasons. The findings of the present study could be useful for management authority for making strategies for management of natural resources and monitoring its changes in due course of time. Temporal remote sensing data with detailed field observation could be an authentic tool for studying the landscape dynamics in any part of the globe which are environmentally fragile.

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