# FOREST VEGETATION / LANDUSE CHANGE DETECTION AND IMPACT ASSESSMENT IN PART OF WESTERN HIMALAYA

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**KEY WORDS:** Forest, Landuse, Change, Impact, Remote sensing , GIS

**ABSTRACT**

Himalayan mountain ranges, which represent nearly 18% of the total area of Indian sub-continent, play an important role for the maintenance of environmental set up of the country. The exploding population pressure has created the adverse changes and subsequent impact in the total eco-system of this region. In the present study, aerial photographs of the year 1960 and Landsat Thematic Maper False Colour Composite image of the year 1985 were interpreted for detecting the changes on forest vegetation and landuse categories identified on both of them. These categories consist of Oak, Deodar, Pine, Miscellaneous, oak- Deodar, Oak-Pine, degraded forest, scrub/shrub, agriculture, habitation and lime stone quarries. The dynamics of changes within forest vegetation /landuse categories has been assessed by creating the database of the maps and subsequent analysis under GIS domain. The ground realities of changes and impact of those changes have been verified and ascertained respectively through field observations and site specific interviews. The study revealed a total change of 27 % out of a total area of 64.12 $Km^2$ during the year 1960-85. The changes have mainly taken place in the form of its depletion/degradation of forest vegetation and expansion of settlements. It is significant to note that most of the changes (70% out of total change) have occurred in the Oak forest area and among all the types of changes, forest degradation is the highest one. The impact of changes has been severe for the existing agro-ecosystem, as the productivity of agricultural crops has gone down considerably with the passage of time.

## INTRODUCTION

Forest is a biological unit having a vast social organisation of living communities at work. These forest communities have a vital role in maintaining balanced eco-system of the world. India has been endowed with an immense variety of forest resources. However, with continuing pressures of an exploding population and the subsequent growing needs of industries, food, fuelwood, fodder, small timber etc., depletion and degradation of forests and subsequent adverse changes in ecosystem are taking place.

Himalayan mountain ranges, which represent nearly 18% of the total area of Indian sub-continent, starting from 200 Mt. altitude rise with 92 peaks over 8000 Mt. above msl., are geologically young and the environment is fragile. There are a number of factors, which have been damaging the forests and agro-ecosystem such as overgrazing, mining, extraction of fuelwood, fodder and timber and the constructional activities particularly on steep slopes. The environmental degradation of this region is affecting the whole country due to the down stream affect of flood and siltation. The relevance of the present study is the alarming rate of adverse changes in the Himalaya. The lack of precise information with respect to these changes and their impacts is a major constraint for planning, development and prudent use of natural resources.

Assessment and monitoring of forest vegetation\land use changes have greatly been facilitated by the advancements of (optical) satellite remote sensing technology (Hoffer, 1986 & Sader et. al., 1985). However, more number of studies have been carried out by using the aerial photographs, Landsat TM and Indian Remote sensing satellite (IRS-1A & 1B) data for the achievement of better accuracy and detailed classification results (Pant & Singh, 1992; Pant et.al, 1995; Pant & Kharkwal, 1995, Roy & Singh 1992, Kushwaha, 1990). But all these studies are independent of impact analysis through site specific interviews. The present study is based on remote sensing & GIS techniques supplemented with ground truth information from site specific interviews. Forest vegetation and land use /land cover changes have been defined as the spatial and structural changes in the form of forest degradation and depletion, reducing the forest density and species diversity and the extension of arable land and other land use types inside the natural cover after its disturbance. The objectives are:

- To assess the spatial and structural changes in forest vegetation along with the changes in landuse/land cover types.
- To find out the impact of changes on the rural agro-ecosystem.

## STUDY AREA

Mussoorie, a hill station and tourist attraction, is situated on the ridge and side slopes of outer Garhwal Himalayan range of Uttar Pradesh, India. It lies between the geo-coordinates 30$^o$ 24' North to 30$^o$ 30' North and 77$^o$ 59' East to 78$^o$ 10' East. (Fig. 1) The area consists of hilly and mountainous terrain with minimum and maximum elevation 700 m and 2277 m. respectively. The climate is generally sub-tropical to temperate on higher elevation (more than 1800 m). The average highest and lowest rainfall recorded at Mussoorie during the period 1987-96 is 5957 mm and 190 mm/year respectively. The mean minimum and mean maximum temperature of 10 years duration were recorded as 17.23$^o$ C and 9.97$^o$ C. There are three distinct seasons viz., Monsoon, winter and summer. Winter is mostly cool and of long duration from November to March. Snowfall occurs mostly above the elevation range of 1800 m. Forest vegetation consisting of Oak (Quercus leucotrichoflora), and Deodar (Cedrus deodara) mostly covers the area. The vegetation in general and the Oak forest in particular of the study area have heavily been altered and degraded by human activities.

## MATERIAL AND METHOD

### Data & Material used

- Survey of India Topographical map sheets,
- Aerial photographs of the year 1960 on 1: 60,000 scale (Average.)
- Landsat TM false colour composite image (bands 2,3&4) on 1:62,500 scale, year 1985
- Site specific interviews, 1997
- GIS Package
- Spread sheet

## METHODOLOGY

### Land cover mapping

Both the aerial and satellite data were interpreted stereoscopically and visually in conjunction with Survey of India maps, ground truth information and on the basis of image. An intensive ground truth study was carried out to develop criteria for the preparation of interpretation key for both satellite image and aerial photographs. A standard of classification has been developed as -Forested land under the classes Oak, Deodar, Pine, Oak-Deodar, Oak- Pine, Degraded forest, Scrub/shrub, and non-forested land under Agriculture, Habitation and Lime stone quarry. The interpreted details were transferred into base map (1:50,000) through Zoom transferscope. The maps were subsequently reduced to the required size and were fairly drawn.

### Change detection

The fairly drawn maps for the year 1960 and 1985 were digitized and rasterised in GIS. The area for each category of mapping units was calculated through histogram generation and tabulation (Table 1). The operation `map cross` was performed for the raster maps of 1960 and 1985 to find out the spatial change in the resultant change map (Fig. 1). The change mapping units were reclassified into 5 categories of changes (Fig. 2) consisting of areas of 1) no change 2) forest degradation 3) conversion of forest /scrub into agriculture 4) settlement expansion/other economic activities and 5) new plantation/regeneration/abandoned fields. In order to find out the pattern of change and unchanged categories the map was again reclassified and merged with a segment map showing roads and locations of main habitations.

## Sampling Design

Stratified random sampling technique, the technique which is most recommended for acquiring ground cover/land use information, was applied. Based on the variability among the cover types, 100 samples were determined and distributed proportionately within each change as well as unchange category on the photocopy of change map. Further distribution with respect to the location of each sample plot on each mapping unit was made randomly. The random location of each sample plot was determined on 1:50,000-scale map containing the change mapping units.

## Preparation of Questionnaires

A form showing the basic information linked with the forest vegetation and landuse changes and their impact was prepared. A checklist for site specific interview was prepared as a part of semi-structured interview conducted in rapid rural appraisal techniques. The questions were given consideration of optimal ignorance and of analytical diversity, the main characteristics of Rapid Rural Appraisal (RRA) techniques.

## Field data Collection and Analysis

The site-specific interviews were conducted at each of the randomly selected sample points within the change strata. Site specific means that the interviews were not conducted in the homestead, but in the change areas, so that cross checks could be carried out. The size of the selected samples varied from place to place depending upon the terrain condition and clear visibility. Generally it varied from 400 $m^2$ to 10,000 $m^2$ It was tried to explore and diagnose the most important ecological and landuse problems along with the potentials by establishing the RRA characteristics of **Iteractive, Innovative, Interactive, and Informal communication in the field.** Field data of 100 samples were entered in a Spreadsheet and sorted in accordance to change categories and other criteria.

# RESULTS AND DISCUSSION

## CHANGE DETECTION

### Forest Vegetation and Landuse Change Dynamics

The Forest vegetation and landuse change map (Fig. 1) reflects the conversion of one forest vegetation and landuse class into another during the period 1960 and 1985. The analysis (Table 1) shows that Oak forest has been subjected to maximum change through reduction in density after heavy biotic influence. The extreme of this degradation reaches the stage of scrub/shrubby vegetation (Table 2). The percentage of this degradation is estimated as highest. The habitation has mostly been expanded in Oak forests. The Oak forest has also been converted into agriculture to an extent greater than other forest types. Almost all encroachments were observed amidst or at the fringe of Oak forests. Mining activities are mostly being carried out amidst degraded and scrub/shrub forest and have caused negative impact on the surrounding areas.

### Classification of Forest Vegetation and Landuse Change Types

The reclassified change dynamics map containing 4 change and 1 un-change categories (Fig. 2) and their analysis (Table 3) show that the maximum area viz., 46 $Km^2$ or 72 % of total area falls under No Change category followed by forest degradation as 16 % of the total area. Ground observations revealed that under the No change category, certain floristic and structural changes which were well identified on the ground, have not been detected through remote sensing due to their small extent or poor spatial and spectral resolution Forest degradation includes the conversion of all high density (>40% in the present study) forests into degraded/under stocked forests and conversion of degraded forests into scrub/shrub. Conversion of forests /scrub/shrub into agriculture includes the conversion of all types of natural vegetation cover into agriculture irrespective of its density of cover. Expansion of settlements and other economic activities include the conversion of any kind of landuse /land cover types into settlements /construction, mining/quarrying, orchards generating the source of income. New plantations, regeneration, succession, abandoned agricultural fields are considered the positive changes in the natural eco-system and are thus categorised separately.

| Forest vegetation & Land use Classes | AREA (Km2) 1960 | AREA (Km2) 1985 | Change (Km2) | % change out of total area in 1960 | % change out of total change |
|---|---|---|---|---|---|
| Oak | 25.4 | 19.5 | 5.9 | 23.3 | 34.3 |
| Deodar | 0.6 | 0.7 | 0.1 | 16.7 | 0.6 |
| Pine | 0.3 | 0.4 | 0.1 | 33.3 | 0.6 |
| Miscellaneous | 3.7 | 2.5 | 1.2 | 32.4 | 7.0 |
| Oak-Deodar | 3.7 | 3.4 | 0.3 | 8.1 | 1.7 |
| Oak-Pine | 11.2 | 10.0 | 1.2 | 10.7 | 7.0 |
| Degraded forest | 11.1 | 11.3 | 0.2 | 1.8 | 1.2 |
| Scrub/shrub | 2.6 | 5.7 | 3.1 | 1.2 | 18.0 |
| Agriculture | 1.3 | 3.6 | 2.3 | 176.9 | 13.3 |
| Habitation | 4.1 | 5.7 | 1.6 | 39.0 | 9.3 |
| Lime Stone Qry. | 0.0 | 1.2 | 1.2 | 0.0 | 7.0 |
| **Total** | **64.0** | **64.0** | **17.2** | **26.9** | **100.0** |

Table 1. Forest vegetation and landuse changes, year 1960-85

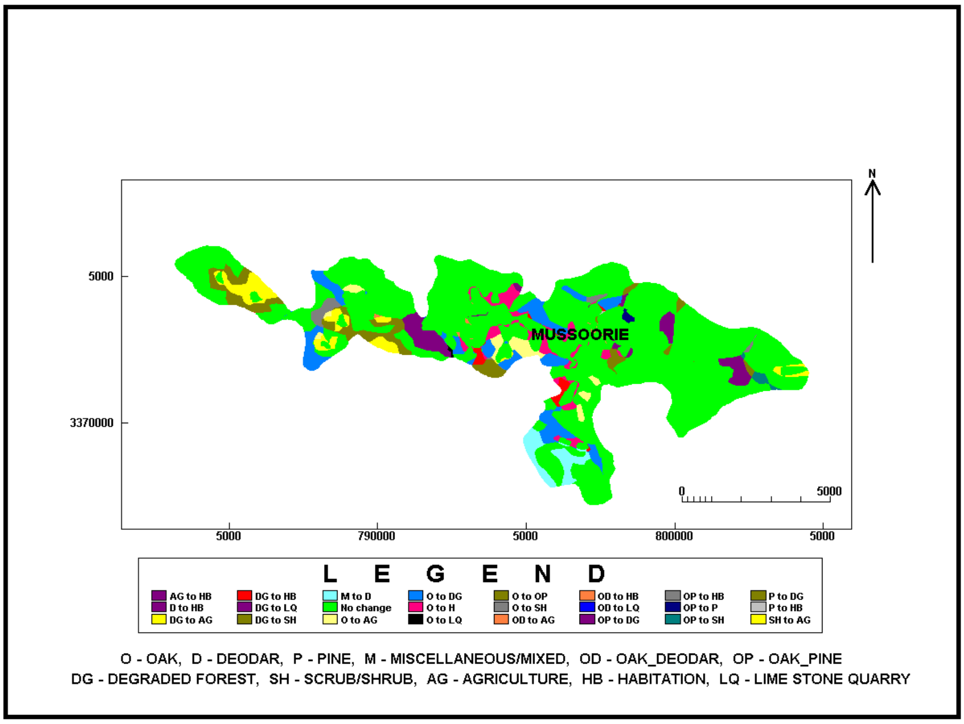


Figure 1. Forest vegetation and landuse chenge dynamics, year 1960-85

| Conversion of one class to another | Area ($km^2$) | % of total area |
|---|---|---|
| No change | 46.3 | 72.3 |
| Pine to Degraded forest | 0.0 | 0.0 |
| Oak to degraded forest | 4.2 | 6.5 |
| Oak to Scrub/shrub | 0.6 | 0.9 |
| Oak to Agriculture | 1.1 | 1.7 |
| Oak to Habitation | 1.8 | 2.8 |
| Oak to Lime stone quarry | 0.0 | 0.0 |
| Oak to Oak-Pine | 0.5 | 0.8 |
| Oak-Pine to Pine | 0.1 | 0.2 |
| Oak-Pine to Degraded forest | 1.2 | 1.9 |
| Oak-Pine to Scrub/shrub | 0.2 | 0.3 |
| Oak-Pine to Habitation | 0.0 | 0.0 |
| Oak-Deodar to Agriculture | 0.0 | 0.0 |
| Oak-Deodar to Habitation | 0.1 | 0.2 |
| Oak-Deodar to Lime stone qry. | 0.0 | 0.0 |
| Degraded forest to Agriculture | 1.7 | 2.7 |
| Degraded forest to Habitation | 0.5 | 0.8 |
| Degraded forest to Scrub/shrub | 2.8 | 4.4 |
| Miscellaneous to Deg. Forest | 1.4 | 2.2 |
| Deg. forest to Lime stone qry. | 1.1 | 1.7 |
| Agriculture to Habitation | 0.1 | 0.1 |
| Pine to Habitation | 0.0 | 0.0 |
| Scrub/shrub to Agriculture | 0.3 | 0.5 |
| Deodar to Habitation | 0.0 | 0.0 |
| **TOTAL** | **64.0** | **100.0** |

Table 2. Forest vegetation and landuse change dynamics, year 1960-85

| Type /category of changes | Area($km^2$) | % change |
|---|---|---|
| No change | 46.3 | 72.3 |
| Forest degradation | 10.4 | 16.3 |
| Conversion of forest /scrub into agriculture | 3.1 | 4.9 |
| Settlement expansion/other economic activities | 3.6 | 5.6 |
| New plantation/regeneration/abandoned fields | 0.6 | 0.9 |
| **Total** | **64.0** | **100.0** |

Table 3. Forest vegetation and landuse change types, year 1960-85

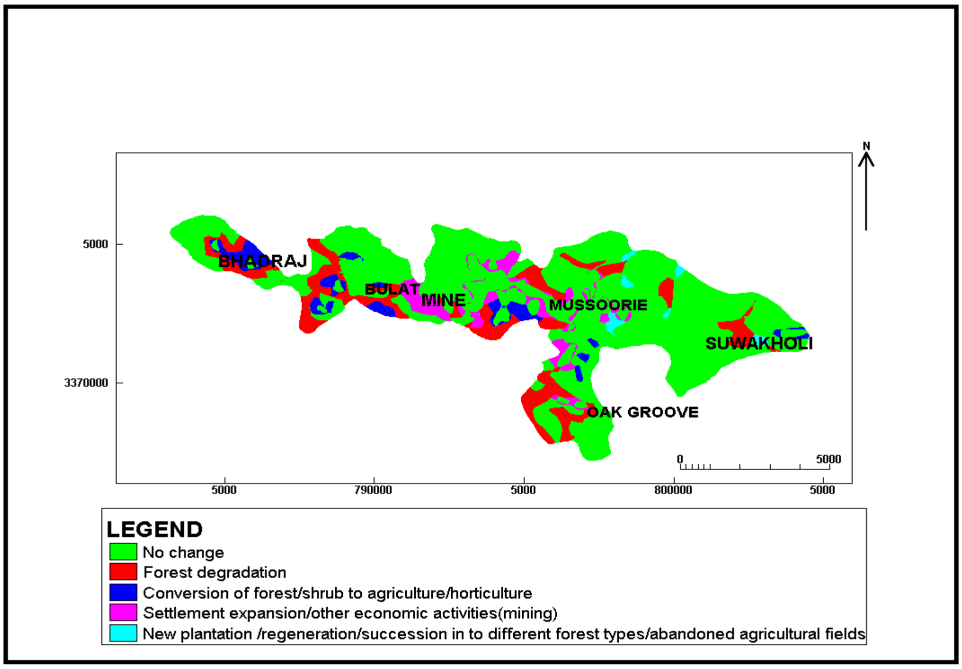


Figure 2. Forest vegetation and landuse change types, year 1960-85

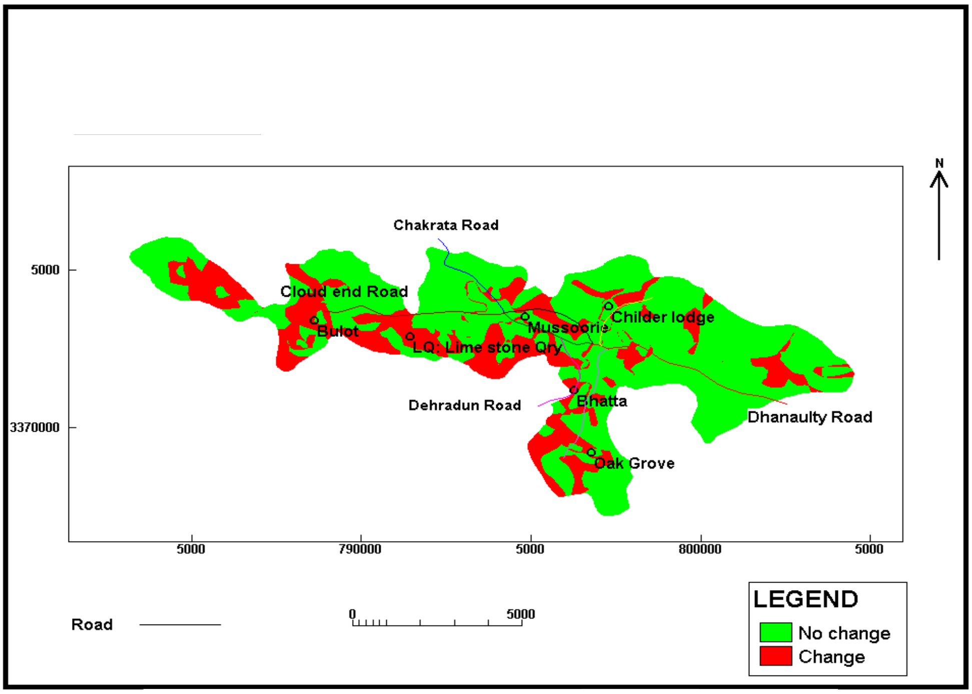


Figure 3. Landuse/land cover change map, year 1960-85

**Landuse /land cover Change Pattern**

The spatial distribution of Change and No Change categories indicate their pattern in different locations (Fig. 3). The map shows that most of the changes have taken place surrounding the villages and Mussoorie town area and along roadsides. Out of total 64.0 $km^2$ area of Mussoorie municipality , 17.2 $Km^2$ or 26.9 % of total area has undergone changes. The maximum change has taken place in Oak forests followed by scrub/shrub, agriculture, habitation, and Oak -Pine, Miscellaneous and others in descending order (Table 1). The Mussoorie town area itself increased by 39 % during 35 years or 1% per year. Almost all these changes are negative. The increase in Pine forest and decrease in Oak forest indicate retrogression of forest quality due to high biotic pressure causing a drier condition of land.

**Impact of Changes**

The present and past conditions, the positive and negative trends experienced by the people of the area, traditional indigenous knowledge of the key informants and the available secondary information indicate that the impacts are in descending order of magnitude of less rainfall, less yields, less ground / spring water, less wildlife in forest area and more wildlife close to the village area (in average less) , violent and untimely rainfall, less snowfall and high temperature (Table 4). All these are negative impacts towards the surrounding environment and the existing agro-ecosystem.

| Type of negative impacts | No of responses | % of total Responses |
|---|---|---|
| **Less rain fall** | 43 | 24.1 |
| **Less yield** | 40 | 22.5 |
| **Less ground/spring water** | 36 | 20.2 |
| **More and less wildlife** | 21 | 11.8 |
| **Violent and untimely rain** | 19 | 10.7 |
| **Less snowfall** | 11 | 6.2 |
| **High temperature** | 8 | 4.5 |
| **Total** | **178** | **100.0** |

Table 4. Impact of forest vegetation and landuse changes

## ACCURACY ESTIMATION

Accuracy estimation has been carried out based on the ground verification of 95 points distributed over all the classes of map showing forest vegetation and landuse change dynamics. The field conditions of 1960 and 1985 have been assessed on the basis of site specific interviews and direct field observations. The distribution of points was carried out in accordance with the proportionate area of each class. The analysis of confusion matrix reflected the overall accuracy of 85.%. . But the accuracy is considerably increasing when the change mapping units are merged into 5 change types.
The maximum accuracy has been estimated as 100% where degraded forest was converted into lime stone quarry followed by no change, Oak to degraded forest, Oak to habitation, degraded forest into scrub/shrub and all others in descending order

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