# Spatial Relationship of Suburb, Road and River in respect to Forest Canopy Density Change Using GIS and RS

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***Abstract*** Many studies states that improperly uprising of infrastructure may cause leading the forest degradation and canopy reduction in many tropical forest of Asian countries. Other studies revealed that habitat destruction and fragmentation, edge effects, exotic species invasions, pollution are provoked by roads. Similarly, environmental effects of road construction in forests are problematic. Similarly, many researches have been indicated that roads have a far greater impact on forests than simply allowing greater access for human use. Moreover, people using river as means of transportation hence illegal logging and felling cause canopy depletion in many countries. Therefore, it is important to comprehend the study about spatial relation of road, river and suburb followed by temporal change of forest canopy phenomena. This study also tried to examine the effect of road, river and suburb in forest canopy density change of Terai forest of Nepal from year 1988 to 2001. So, Landsat TM88, 92 and 001 and FCD (Forest Canopy Density) mapper were used to perform the spatial relation of canopy density change. ILWIS (Integrated Land and Water Information System) which is GIS software and compatible with remote sensing data was used to execute analysis and visualize the results. Study found that influence of distance to suburb and river had statistically significance influenced in canopy change. Though road also influenced canopy density much but didn't show a statistical relation. It can be concluded from this research that understanding of spatial relation of factors respect with canopy change is quite complex phenomena unless detail analysis of surrounding environment. Hence, it is better to carry out comprehensive analysis with other additional factors such as biophysical, anthropogenic, social, and institutional factors for proper approach of their effect on canopy change.

**Key Words:** GIS, Remote Sensing, Forest Canopy Density, Spatial Relationship

## 1. Introduction:

Forest canopy refer to the proportion of the ground covered by the vertical projection on to it of the over all vegetation canopy (Howard, 1991). Forest canopy is essential to environmental and economic health, providing additional cooling, increasing property values, improving air/water quality, and contributing to a more beautiful, friendlier, and livable community (Morrow, Young, & Roberts, 2001). Forest area and its changes is an important and, supposedly easily measurable indicator for sustainable management of resources in larger areas (Kleinn, 2001). Importantly forest canopy can be used to understand and measure the forest condition efficiently from satellite images (Urquizo, Hussin, & Weir, 1998). Nowadays, forests cover more than one quarter of the world's of total land area, excluding polar regions. More than 50% of the forests are found in the tropics and the rest are temperate and boreal (coniferous northern forest) zones (GCP, 2005).?Human influences to transform forested lands in to another are one of the great forces in global environmental change and loss of biodiversity. 13.5 million hectares of tropical forest is cleared annually for agriculture, pasture, timber products and infrastructure development (FAO, 2001; Geist and Lambin, 2002).

Canopy density is a dynamic process, continually changing in response to disturbances (IDAHO, 2005). Population pressure, political instability, economic development activities are the major factors contributing to deforestation and forest degradation which could potentially affect forest canopy (Hussin & Sha, 1996). Forest canopy of tropical influence by infrastructure such as railways, roads, electricity power line, and channels, quarrying and mining (Longman & Jenik, 1974).?Forest fragmentation by roads in Central Africa showed that 42% of forest area in the six countries is within 10 km of a road and more than 90% is within 50 km of a road (Source: WRI Earthtrends). So, the literature review reveals many studies have been carried out about influence of environmental factors in forest coverage. So far, still very few studies have been indicated the spatial relationship of environmental factors (road, river and suburb) in relation to canopy change pattern in pixel base analysis. In this respect, information on the existing land use pattern, its spatial distribution is a pre-requisite for planning, utilization and formulation of policies and programs for making any micro and macro-level developmental plan. It is therefore important to analyze the determining factors of canopy density change on a smaller and local scale before proceed the intervention. The main objective of this study is compare the spatial and temporal change of canopy density over 1988-2001 with respect to various environmental (roads, settlements, and river) factors on the local level using GIS and RS technology.

## 2. Material and Methods

### 2.1 Material and Methods

Study area locates in the Chitwan district of Central Development Region (83( 54′ 45″ and 84( 48′ 15″ East longitude and 27( 21′45″and 27(52′30″ North latitude). It is the forest corridor linking the Himalayan middle mountain to the Royal Chitwan National Park. Forest resources are the richest and almost pure stands of (Shorea robusta) Sal in this area. Other types of forest are mixed hardwood and reverine forest interspersed by (Accacia catechu) Khair, (Dalbergia sissoo) Sissoo, (Terminalia tomentosa) Asna and (Adina cardifolia) Karma with mixed forest and grassland in shallow depression and along riverbank. This area was selected for this study because of highly populated surrounding forest and road, suburb and, rivers are also densely interspersed in this area result in strong correlation of canopy density change with environ -mental factors.

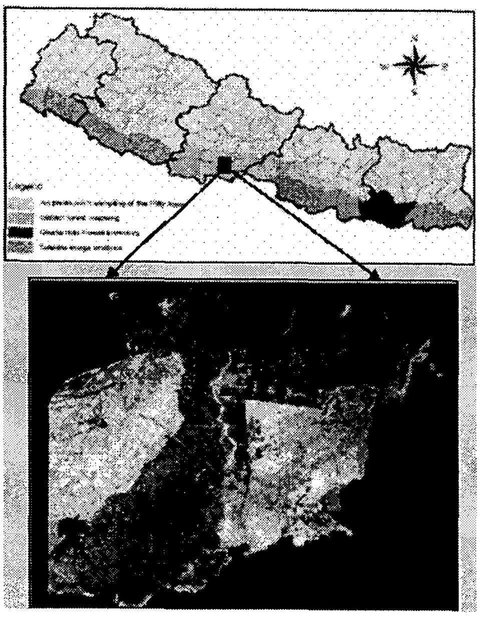


Fig.2.1 TM1992 (FCC351) of Chitwan district Nepal, showing study area site

## 2.2 Data used in this analysis

Landsat TM images of 1988 (Oct 12th), 1992 (May 7th) and 2001 (Oct 24th) with the seven bands (1-7) covers almost all part of the Chitwan valley (study area) were used for study. However, TM88 and 001 were more reliable for change performance with factors because of seasonality. Similarly, Topographic maps of 1994 (1: 25000) of Chitwan district published by Survey Department of HMG of Nepal were used for georeferencing of Landsat TM images and six topographic map (topo-sheet) having scale 1:25000 were used for digitizing road, river and suburb maps of study area.

Apart from these FCD Mapper (Semi-expert system) version 1.15 used for processing of remotely sensed data, ILWIS version 3.1 was used for GIS operations and the spatial analysis for the change detection with responsible factors. Microsoft word, SPSS, Excel and Minitab were used for the data analysis, graphics, Various statistical tests, correlation analysis and so on.

## 2.3 Image and map processing

Geometric correction of the images is very important step of the image processing. It is helpful to establish the relationship between row and column numbers with real world co-ordinates. Remotely sensed images in raw format contain no reference to the location. In order to integrate these data with other data in a GIS environment, it is necessary to correct and adapt them geometrically (ITC, 2001b). So, Landsat TM of 1988 was geo-referenced using Topographic map (1: 25000) 1994 and the accuracy was checked with Topo-sheets.In the process of geometric correction for Landsat TM image of 1988, Oct 24th eight points were identified and matched with points on the Topo-sheet obtained sigma = 0.221 pixel. Similarly, Landsat images of 1992 and 2001 were geo-referenced using image to-image registration method where 1988 image was taken as a master image. At the same time, using nearest neighborhood method geo-coding of the images was performed.

Similarly, road, suburb, and river maps were digitized from Topographic map. Then digitized maps were converted in the rasterised form using ILWIS software. GIS operation i.e. distance calculation function was used to produce distance maps of road, river and suburb as an output maps. These maps were used for further relationship analysis with canopy change map.

Boundary map was on the other hand, digitized from topographic map of the study area. Segment boundary map was polygonised and rasterised. Finally, a subset maps were made from each band of three-year images using boundary map and map calculation function. These subsets were then exported in bitmap format (BMP) and were used in FCD Mapper. FCD mapper only supports BSQ, BIL and BMP format data. Furthermore, geo-referenced images were in raster format, hence it could not compatible for the FCD mapper. All seven bands of Landsat images were converted to BMP format before proceed for FCD mapper program.

## 2.4 FCD - Mapper and Forest Canopy Density

Forest Canopy Density Mapping model is a combination of Vegetation, Bare Soil, Shadow and Thermal Indices. Rikimaru (1996) propagated an alternative deductive approach, e.g. forest canopy density mapper to estimate the forest canopy density based on four indices derived from Landsat TM imagery.

Based on these four indices eleven canopy density classes 1-10, 11-20 ,21-30 ,31-40 + were obtained. This model involves biophysical phenomenon modelling and analysis utilizing data derived from four indices such as advanced vegetation index (AVI), Bare Soil Index (BI), Shadow Index (SI) and Thermal Index (TI). Forest canopy density in each pixel was calculated using these indices. AVI reacts sensitively for vegetation quantity compared with NDVI. VI response to all of vegetation items where as SI directly related to the forest density. Vegetation and Shadow parameters of a forest are strongly correlated with each other. An increment in vegetation increase shadow as well. Similarly, bare soil and temperature are also correlated. Thermal Index increases as the vegetation quantity decreases. It reacts directly with temperature exposure from the bare lands. Bare Soil Index increases as the bare soil exposure degree of ground increase. After normalization of the data range these indices has been calculated using equations:

If B4−B3 < 0, AVI= 0 (CASE − a) .......................... (1)

If B4−B3 > 0, then AVI = ((B 4 +1) x (256−B3) x B4−B3)1/3 (CASE−b) ........... (2)

BI= ((B5+B3)−(B4+B1)) / ((B5+B3) + (B4+B1)) x 100 +100 ........................ (3)

SI = ((256−B 1) x (256−B 2) x (256−B3)) 1/3 ...................................... (4)

L = L min + ((L max−Lmin)/255) x Q ...................................................(5)

Where:

L: value of radiance in thermal infared

Q: digital record

L max: value of radiance = 1.500 mw/cm2/str (Q=0)

L min: value of radiance = 0.1238 mw/cm2/str (Q=255)

In the other step, VI and BI were synthesized in to vegetation density (VD) value using principal component analysis (PCA) and VI and SI into scaled shadow index (SSI) by linear transformation of

SI. In areas where the SSI value is zero, this represent the forest have the lowest shadow value e.g. 0%. In areas where the SSI value is 100, that means the forest have the highest value of shadow e.g. 100%. Details in Rikimaru (1996), Rikimaru et al. (2002) and FCD - Mapper (2003).

Though system is itself highly advanced, it needs little input by an operator to set the threshold values. It has already tested in some South East Asian countries and got accuracy averaged 92 % over this (Rikimaru, 1996). So, to carry out analysis in this study FCD Mapper software version 1.15 together with ILWIS (Integrated Land and Water Information System) version 3.1 were used.

### 2.5 Spatial relationship of environmental factors with forest canopy density:

To examine the relation between distance from road, suburb, and river with forest canopy density change is main objective of this analysis. These factors were analyzed by using map interpolation. The road, river and suburb maps were digitized, rasterised, interpolated and a continues distance map of each variables were generated. The canopy density map of 1988 and 2001 were crossed with each map (road, river and settlement). Finally, relation was analyzed using map attributes and results were presented in tables and graphs. Furthermore, statistical relationship between forest canopy density change and the distance of three environmental/physical parameters (road, river and settlement) were analyzed using Pearson's correlation analysis technique.

## 3. Results

Mapping of forest canopy density using a biophysical approach is a simple and straightforward method. This method has been used by many researchers and has given different results. The main concept of the analysis is to calculate the percentage of forest canopy density, based on field measurements and reflectance of satellite images. Most of the results from previous research claimed a high correlation between the reflectance and field measurement of canopy density, if the field measurement has been taken at the same time with the satellite overpass. However, In this analysis, some of the images and field measurements were collected at different time. This fact gave another challenge for this research: Can Landsat TM imagery of different season reasonably contribute to forest canopy density mapping over a relatively prolonged period? To answer this question, the main activities of this approach are: (I) selection of existing data of study area from different types of data sets (ii) calculation of the FCD using different indices (AVI, BI, SI and TI) with different band combination of TM image. Another fact is that the canopy density is a dynamic phenomenon. Many biophysical and human disturbances alter canopy density significantly. Based on available data sets, some of the factors were analyzed.

### 3.1 Comparative analysis of forest canopy density change from 1988 to 2001

The estimation of forest canopy density

in the figure 3.1 revealed that there had been major changes in the degraded canopy class 1 (1-20%) and class 2 (21-40%) during the 1992 the differences in forest area cover being 61% and 42.5% respectively. Some area had remained unchanged and same with canopy density classes where as other area had shown dramatic change in canopy density. A dramatic changes is in the class 4 (61-81%) and class 5 (81-100%) moving from 3328 to 4939 ha and 2295 to 3242 ha by 48.6% and 41.3 % respectively has occurred during 1992 to 2001.Where as some area has decreased of canopy density mainly occurred at the edge of forest and around the new settlement during 1992-2001. It is interesting to note that there is no remarkable major change in canopy density between the 1988-2001. Although forest canopy density slightly loss in lower classes however steadily increased in other higher classes in the 2001 compared with 1988. It also shows the change in forest condition is not dramatically observed in 2001 when compared with 1988. Degraded canopy class was the most dominant canopy cover. Fig. 3.2 showed that there was a small change (3.3%) from 1988-92, (5.5%) from 88-001 but surprisingly drastic change (9.2%) from 1992-2001.

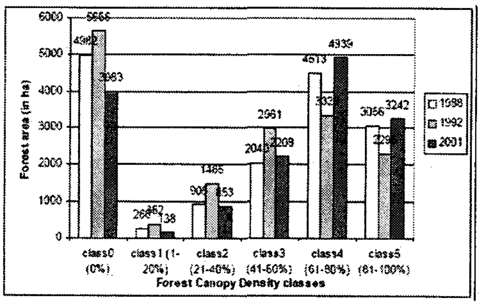



Fig 3.1 Forest canopy density classes distribution in 1988, 1992 and 2001

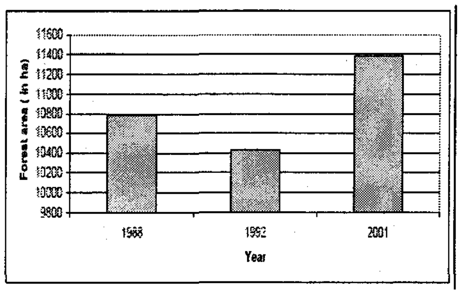



Fig 3.2 Total forest canopy density (in terms of area) in 1988, 1992 and 2001

## 3.2 Relationship between FCD and factors (road, river and suburb)

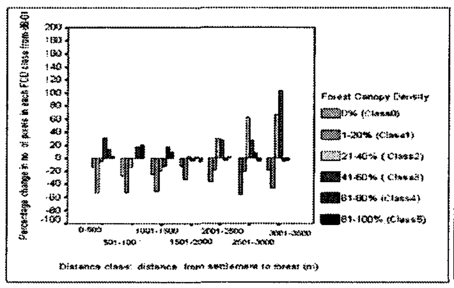


Fig 3.3 shows the % change in no. of pixels in each FCD classes in relation to suburb distance

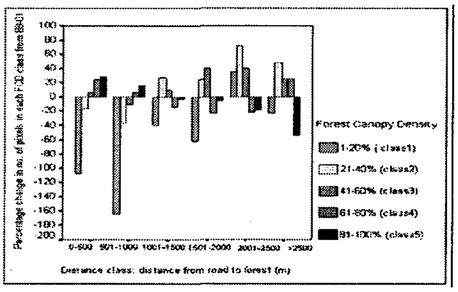


Fig 3.4 shows the % change in no. of pixels in each FCD classes in relation to road distance

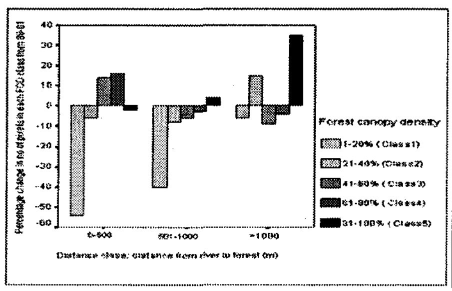


Fig 3.5 shows the % change in no. of pixels in each FCD classes in relation to river distance

### 3.2.1 FCD changed in relation to distance from settled area/suburb

Fig 3.3 shows the relation between each canopy density class and distance from settled area. Although some high density classes have showed some positive change over the period, the lower density classes (class 1 and class 2) within 2000 m distance from suburb were affected more and converted to other class. It shows the sparse vegetation forest cover close to the suburb area (within 2 km) could be vulnerably encroached by the local people. However some positive change in high-density classes suggests that afforestation and conservation program seems to be successful within the easily accessible range. Similarly, high canopy density classes (untouched forest) could possibly be difficult to encroach may be due to effective protection, under direst supervision of community members or terrain, slope, unfertile soil, water scarcity in comparison with low canopy density classes.

### 3.2.2 FCD changed in relation to distance from road

Showing in Fig 3.4 also lower canopy density classes (class 1 and class 2) are remarkably degraded (more than 100%) within close distance (2000) m from 1988-2001. However, some high density canopy classes have positively changed. It shows more encroachment and exploitation of forest product could be easy because of accessibility. Another reason for increasing the canopy density in high class could be more conservation and rehabilitation strategy has been successfully implemented within close distance from the road. Similarly, some protection measure for forest management from authority bodies can easily apply in accessible area than in remote such as community and private forest and demonstration plots. Due to this reason canopy in some classes could have positively changed.

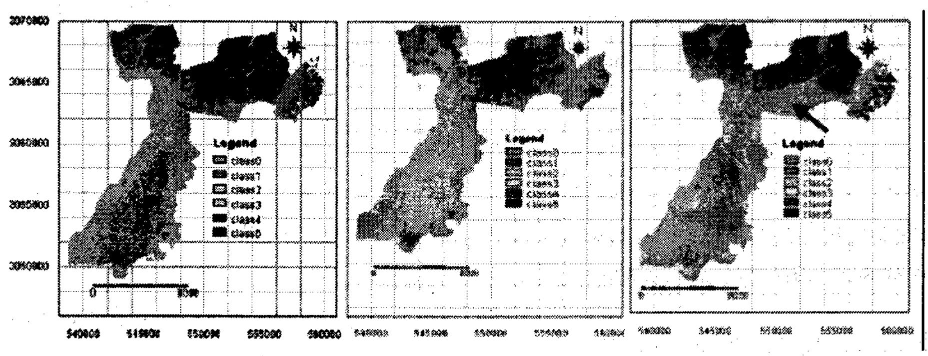
### 3.2.3 FCD changed in relation to distance from river

Fig 3.5 shows the canopy changed relation with distance river. It was observed that canopy in lower density classes (class 1 and class 2) are heavily destroyed within close to river than the farther away. Close distance to river clearly shows in fig 3.5 a remarkable effect on canopy degradation, especially in lower classes (class 1 and class 2). Though it seems in some higher density classes, canopy density has positive changed within 500m from river, canopy density in class 1 (1-20%) is heavily reduced in period from 1988-2001.

## 4. Discussion

### 4.1 Forest canopy density change analysis from 1988-2001

The images analysis showed that the forest degradation and deforestation was more prominent than the conservation and rehabilitation between 1988-1992. It shows the forest condition was comparatively of poor quality in 1992. This result may be due to method used. In particular, seasonality is one of the important factor which could influence biomass calculation of green vegetation and image interpretation. The image of May 17th 1992 has comparatively less vegetation than that of Oct of 1988 and 2001. Because of leaf emergence period of Sal tree is just starting in that season and green pigment in the leaf has not fully developed. Similarly, In Nepal Ministry of Forest and Soil Conservation have been done forest management practice through promisingly focused on Community Forestry and Private Forest since 1988 (MPFS,19888). So, Forest management practice through active participation of local people, capacity building program, development of forest institutions and appropriate legal forest policy might have also positive contribution to increase the canopy density in the recent years. Many other supportive programs launched by HMG/N the ninth five-year plan such as conservation, protection and production increment of forest products in national forest, Wildlife Reserve and National Parks area conservation so on. Furthermore, some NGOs, INGOs and bilateral government agency has also tendency to implement forestry together with nature conservation program at local level might be causes the increment in forest and forest canopy as well. Fig 4.1 and 4.2 shows the canopy change map from 88-001.and indicated the remarkably negative change around settlement and government plan clear felled area.



4.1 FCD map left (1988), middle (1992) and right (2001) showing the spatial location of canopy distribution.

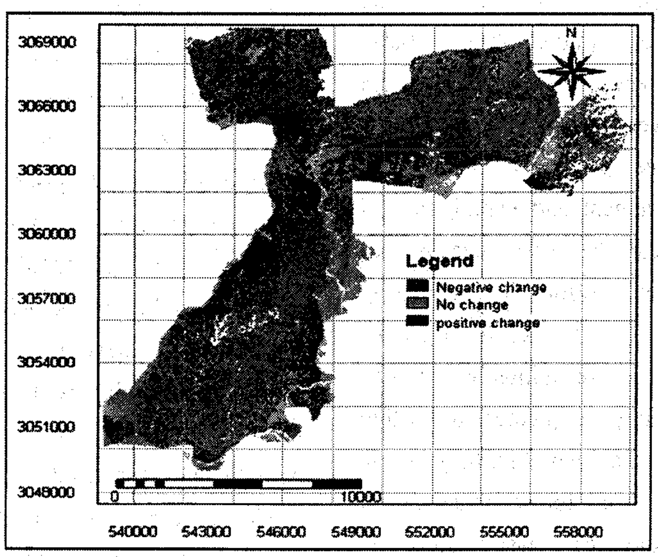
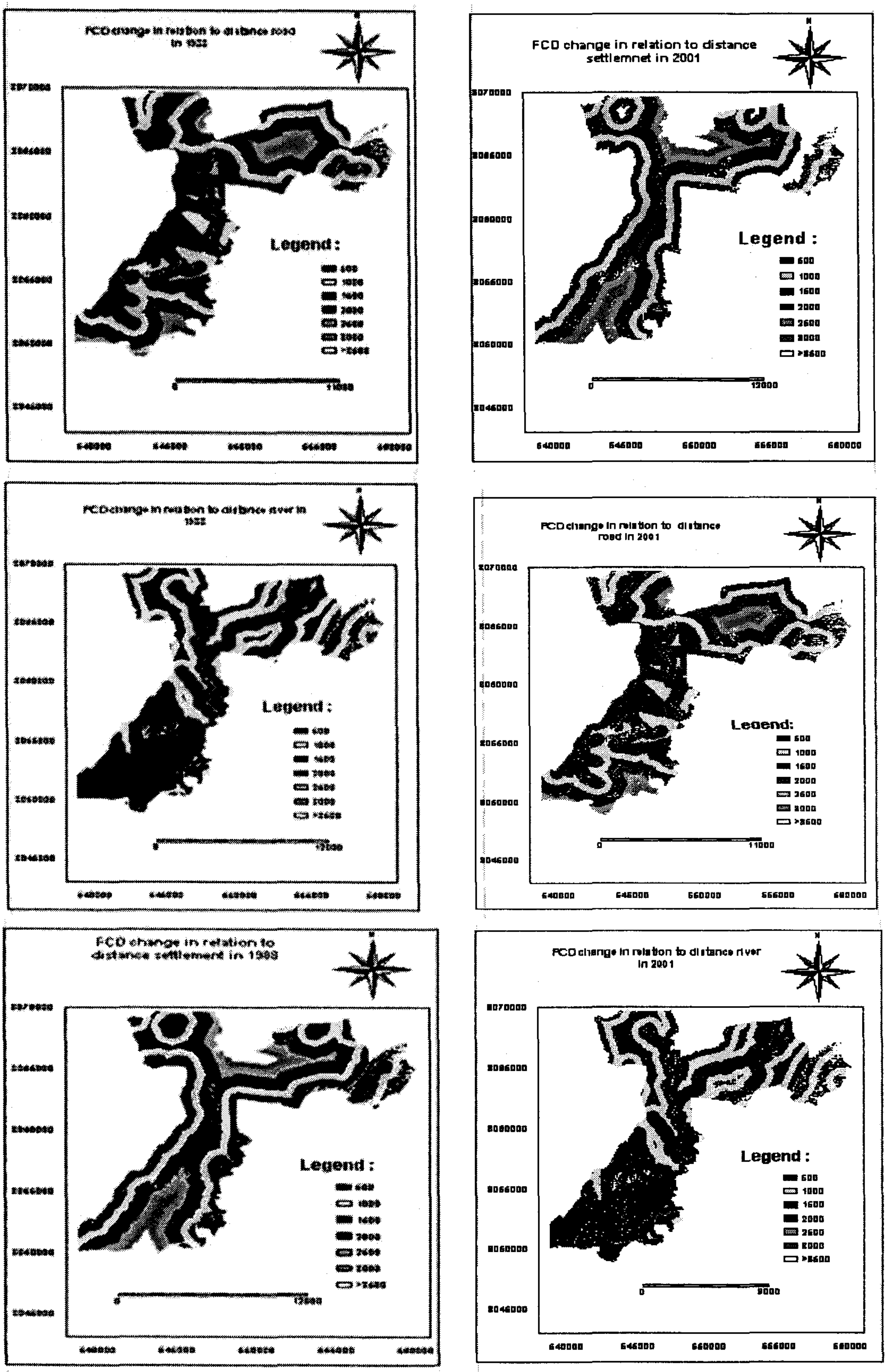



Fig 4.2 Map showing canopy density change from period 1988-2001in study area




4.3 Map of suburb, road and river showing canopy change in relation to distance

**Table: 1. Pearson correlation test for all variables in relation to forest canopy density**

| | | CC | TT | MDBH | MHT | DIST_ROAD | DIST_RIVER | DIST_SETT |
|---|---|---|---|---|---|---|---|---|
| **CC** | Pearson Correlation | 1 | .744** | .561** | .500** | -0.04 | .429* | .449** |
| | Sig. (2-tailed) | . | 0 | 0.001 | 0.003 | 0.822 | 0.011 | 0.008 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **TT** | Pearson Correlation | .744** | 1 | .442** | .462** | 0.074 | .344** | 0.261 |
| | Sig. (2-tailed) | 0 | . | 0.009 | 0.006 | 0.676 | 0.046 | 0.136 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **MDBH** | Pearson Correlation | .561** | .442** | 1 | .847** | -0.199 | -0.032 | 0.197 |
| | Sig. (2-tailed) | 0.001 | 0.009 | . | 0 | 0.259 | 0.858 | 0.263 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **MHT** | Pearson Correlation | .500** | .462** | .847** | 1 | -0.18 | -0.038 | 0.041 |
| | Sig. (2-tailed) | 0.003 | 0.006 | 0 | . | 0.309 | 0.83 | 0.82 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **DIST_ROAD** | Pearson Correlation | -0.04 | 0.074 | -0.199 | -0.18 | 1 | 0.217 | -0.26 |
| | Sig. (2-tailed) | 0.0822 | 0.676 | 0.259 | 0.309 | . | 0.218 | 0.138 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **DIST_RIVER** | Pearson Correlation | .429* | .344* | -0.032 | -0.038 | 0.217 | 1 | .390* |
| | Sig. (2-tailed) | 0.011 | 0.046 | 0.858 | 0.83 | 0.218 | . | 0.023 |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| **DIST_SETT** | Pearson Correlation | .449** | 0.261 | 0.197 | 0.041 | -0.26 | .390* | 1 |
| | Sig. (2-tailed) | 0.008 | 0.136 | 0.263 | 0.82 | 0.138 | 0.023 | . |
| | N | 34 | 34 | 34 | 34 | 34 | 34 | 34 |

| Forest Canopy Density class | 0-500 | 501-1000 | 1001-1500 | 1501-2000 | 2001-2500 | 2501-3000 | 3001-35000 |
|---|---|---|---|---|---|---|---|
| 0% (class0) | -13 | -28 | -25 | -11 | -36 | -57 | -18 |
| 1-20% (class1) | -54 | -53 | -51 | -32 | -18 | -20 | -46 |
| 21-40% (class2) | -5 | -14 | -19 | 3 | 30 | 63 | 66 |
| 41-60% (class3) | 31 | 0 | -12 | -4 | 29 | 28 | 103 |
| 61-80% (class4) | 14 | 17 | 18 | 2 | -4 | 9 | -4 |
| 81-100% (class5) | 3 | 20 | 9 | -5 | 2 | -5 | -4 |

Table 2. Showing % change in no. of pixels (negative or positive) in each canopy class in relation to distance from settled/suburb to forest from 1988–2001

| Distance class: distance from the road to forest (in meter) | | | | | | |
|---|---|---|---|---|---|---|
| Forest Canopy Density class | 0-500 | 501- 1000 | 1001-1500 | 1501-2000 | 2001-2500 | >2500 |
| 1-20% (class1) | -108 | -165 | -41 | -62 | 35 | -23 |
| 21-40% (class2) | -17 | -38 | 27 | 24 | 72 | 48 |
| 41-60% (class3) | 6 | -10 | 9 | 41 | 40 | 25 |
| 61-80% (class4) | 24 | 6 | -15 | -23 | -23 | 25 |
| 81-100% (class5) | 28 | 16 | -3 | -6 | -19 | -54 |

Table 3. Showing % change in no. of pixels (negative or positive) in each canopy class in relation to distance from road to forest from 1988–2001

| Distance class: distance from river to forest (in meter) | | | |
|---|---|---|---|
| Forest Canopy Density class | 0-500 | 501-1000 | >1000 |
| 1-20% (class1) | -54 | -40 | -6 |
| 21-40% (class2) | -6 | -8 | 15 |
| 41-60% (class3) | 14 | -6 | -9 |
| 61-80% (class4) | 16 | -3 | -4 |
| 81-100% (class5) | -2 | 4 | 35 |

Table 4. Showing % change in no. of pixels (negative or positive) in each canopy class in relation to distance from river to forest from 1988–2001

## 4.2 Forest canopy density and environ -mental factors

Table 1. Shows the Pearson correlation test of different variables concern with canopy at (** 0.001) and (* 0.05) levels. Our main objective of this analysis is to examine the spatial relationship of suburb/settled, road and river with canopy density change. Though it's not a very strong relation however it was pixel base analysis and had shown statistically significance. Similarly reveal from analysis and figures and resulted tables shows that canopy density is clearly affected by the distance from settled area, river and road. Combination of these three variables can be used for detection of forest canopy density. In this study it was observed that the cover of forest canopy clearly relates to the extent of human influence in which distance from settled area is the most important factor. Fig 4.3 distance map of each factor clearly showing the canopy destruction is more vulnerable within short diatance. In distance settled area

map has drastic change in same area of 1988 within 500m from the settlement in 2001. Forestlands closer to the road and suburb area are easily accessible and less work time consuming for collection of forest products (Shrestha, 1999). Therefore those area closer to roads and settled area are more vulnerable to the canopy loss. When we compare the changes in canopy density and distance from the suburb area, it can be seen that the situation in those area which area far from the settled area has remained more or less constant during 13 years, whereas the forest canopy density near to the settled area has decreased more and hardly increased ( Fig 3.3 Table 2). In this analysis distance from the road to forest is not statistically significant factor, however close distance of road to the forest is clearly influenced by vulnerably degradation of canopy in lower canopy density classes (Fig 3.4, Table 3). It clearly indicates the area under sparse vegetation (Lower density classes) still away from proper forest management.

Further, in the study area some of the rivers are seasonal and some are perennial. Those area which are isolated by a river, are rather far from forest guard's eye and not regularly inspected by them, hence illegal felling is rather frequent in such areas and canopy density is showing affected by close diatance from river. Similarly, close to river mostly found Khair-sissoo forest and by the nature of forest types itself these forests are sparsely distributed. So, it could be represent the canopy highly degraded in lower class due to sparse (Fig 3.5, Table 4). Moreover, because of commercially valuable these forest species people are more intended to illegal cutting hence canopy could be more affected. Another reason, these forest species have small leaves hence it could be the reason canopy density showing lower by canopy structure. Canopy density is highly affected by structure of the leaves. However, canopy is dynamic phenomenon affected by many causal factors and it could be differ in same place, and different in a landscape.

## 5. Conclusion

- The conversion of high canopy density into lower density rather than the other way around is one of the dominant phenomenons observed in the study area.
- This phenomenon can be detected by using multi temporal remote sensing imagery, GIS and FCD mapping technique. Pixel based (30m*30m) forest canopy mapping with Landsat data is capable of consistently detecting the dynamic of canopy depletion.
- The outcome could be affected by setting threshold value in the process of FCD calculation. In case of large area classification, field together with prior knowledge on image interpretation should be consider to overcome these problems.
- Ii is concluded that some human interference and environmental factors are closely related with alteration of canopy density, distance from suburb area appeared to be most altering factor of FCD followed

by river and road.

- Seasonality is one of the major factors which affects the FCD, must be considered when interpreting the results.
- Based on this analysis, the result of spatial dimension of road, river and human interference to the forest canopy change does not show the sharp distinction. Therefore to explain human dimension of environmental degradation in canopy is complex unless good understanding of others additional biophysical, socioeconomic and institutional factors is executed.

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