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# Assessment of forest encroachment at Belgaum district of Western Ghats of Karnataka using remote sensing and GIS

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**Abstract**

The present study focuses on the assessment of forest encroachment in Belgaum district of Karnataka for the year 1975, 1990, 2000 and 2010 using RS and GIS. The study area is located in the north-western part of Karnataka state, with a total area of 13,415 $km^2$. The study revealed that the forest encroachment is 4245.6, 16133.1, 28304.4 and 29010.0 ha for the year 1975, 1990, 2000 and 2010 respectively. The extent of encroachment in 2010 amounted to 9.66 % in evergreen to semi evergreen, 15.84 % moist deciduous and 74.50 % in scrub forests.The highest percentage of encroachment was in Hukkeri taluk with mixed plantation and the major part was scrubland whose average encroached area was 31.38% over the years. The major factors accelerating encroachments were agricultural expansion, population dependency on forest livelihood, limited land for cultivation, lack of grazing land and poverty.

**Key words**

Deforestation, Encroachment, Forest types, Western Ghats, Zonal classification,

## Introduction

According to Global Forest Resources Assessment, the world's forests cover is approximately 3,952 mha in 2005, which corresponds to about 30% of total land area of the world (FAO, 2005). The total area of all pristine forests of the world is decreasing with an estimated deforestation rate of 14.6 mha per year during the period 1990–2000, mainly by conversion to agricultural land. At the same time, afforestation as well as natural expansion of forests has reduced the net loss of forest area to about 9.4 mha per year, an area still larger than Venezuela (FAO, 2000).

The first and foremost cause of forest degradation is deforestation and encroachment (Capistrano and Kiker, 1995; Rasheed, 1995; Kamal *et al.,* 1999; Salam *et al.,* 1999; ADB, 2002; Ali, 2003; Rasul *et al.,* 2004). Illegal logging and fuel wood collection (Flint, 1994; Rasheed, 1995; ADB, 2002) and, human settlement in forest areas (Salam *et al.,* 1999) are considered as second major source that degrades forest area. The direct cause of deforestation are influenced by economic underdevelopment, inappropriate forest policies and regulation, lack of land usage, uncertainties tenure system and socio-political instability (Mitchell *et al.,* 2004). Besides local encroachers, migrant people pushed by political and ecological forces aggravate the encroachment problem in the hill forests. The agriculture, cash cropping, shifting cultivation, pasture, forest product extraction and human settlement have been identified as the main direct causes of encroachment in South Asian countries (Thapa and Weber, 1995; Saxena *et al.,* 1997). However, the attribute of encroachment has not been reported for Western Ghats region of South India.

Karnataka has a recorded forest area of 43,356.45 $km^2$, which is 22.60% of its total geographical area. The land actually covered by forest is 33,238.47 $km^2$, which constitutes 17.33% of its total geographical area. Dense Forest (40% and above crown density) is 28,144 $km^2$; Open Forest (10% to 40%) and Scrub Forest (less than 10% density) is 15,212 $km^2$; and Mangrove forest is 3$km^2$ (FSI, 2009) and rest of the forest land is not covered by forest.

Many authors opine that remote sensing data can contribute information for a variety of rangeland resource management applications (Bajpai *et al.,* 2009; Le Hegarat *et al.,* 2006; Reis and Yomralioglu, 2006; Panigrany *et al.,* 2010).

Limited land availability and unemployment have been identified as the major proximate causes for encroachment. Iftekhar and Hoque (2005) have put an effort to analyze the causes of forest encroachment in Bangladesh and found that deforestation is a major cause of environmental degradation in tropical countries, with huge population pressure and widespread poverty being the main frontier of deforestation. Karnataka Forest records revealed that 29004 ha of forest area is being encroached in Belgaum district, which comes under Western Ghats region of Karnataka (KFD, 2007). Since there are contradictions from many stakeholders and litigation in courts on extent of encroachment, present study aims to investigate the two decadal forest encroachment patterns and forest quality of the region using remote sensing and GIS techniques.

## Materials and Methods

The Belgaum district is situated in the north-western part of Karnataka state (Fig. 1), geographically located between 15° 23' and 16° 58' N latitudes and 74° 05' and 75° 28' E longitudes, with a total area of 13,415 km$^2$. Belgaum district is divided into two forest divisions namely, Belgaum and Gokak with 15 Ranges, 28 Sections and 118 Beats. Agro-climatologically, the district is divided into three zones, namely high rainfall "Hilly zone", "Northern transitional zone" and "Northern dry zone". The district experiences pleasant winters and hot dry summer (March to May). The normal rainfall received varies from 491 mm to 1859 mm. The maximum temperature ranges from 27ºC to 35.7ºC and the minimum 13.9ºC to 20.6ºC. The major occupation is agriculture.

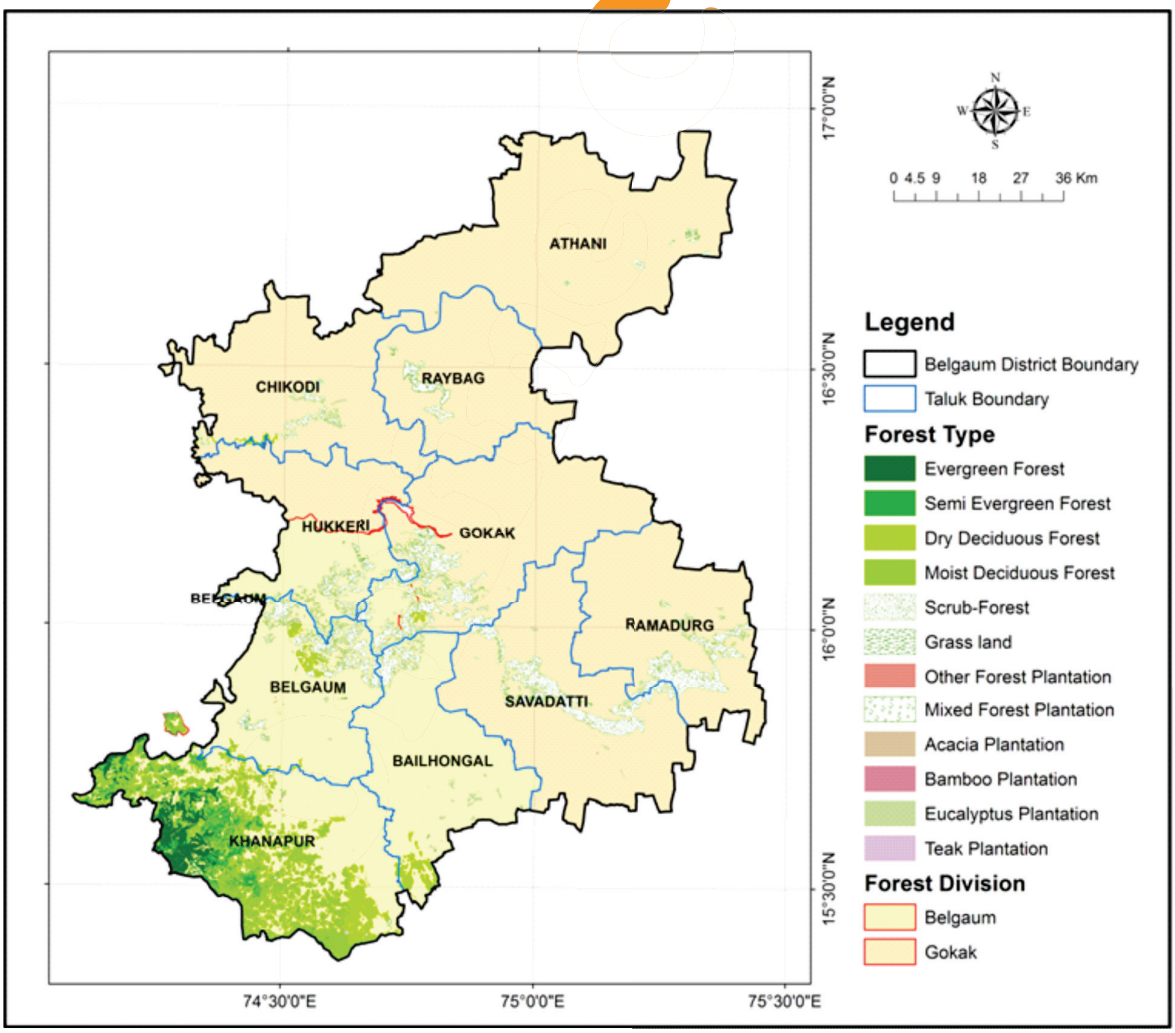


**Fig. 1 :** Location map showing Forest Division and major forest types in Belgaum district of Karnataka

**Preprocessing of topo maps and satellite images :** The Survey of India (SOI) toposheets (47L-3/6/7/8/ 10/ 11/12/13/14/ 15/16, 47P-1/2/3/4/5/6/8, 48I-1/2/5/6/7/9/10/11/13/14/15, 48M-1/2/5/6/) of 1:50,000 scale pertaining to the study area were georeferenced, mosaiced and subsetted to aid further analysis. The Survey of India (SOI) toposheets of 1:50,000 scale were used for geo-rectification of satellite images, creation of cultural features and ground truthing. The forest administrative boundaries extracted from the working plan and wildlife management plan of the Karnataka Forest Department were transferred onto topomaps. Simultaneously, the LandSat TM/MSS data products (P156-R48, P156-R49, P156-R50, P157-R48 and P157-R49 and P157R50) of January 1975 and January 1990 and, LandSat TM/MSS/ETM+ data products (P145R48, P145R49, P145R50, P146R48 and P146R49 and P146R50) of January / March 2000 were procured from online web portal of USGS Global Visualization Viewer (http://glovis.usgs.gov). The IRS P6 LISS-III data of January / February / March / April 2010 (P96-R61, P96-R62, P97-R61 and P97-R62) were purchased from National Remote Sensing Centre (NRSC), Hyderabad. Questionnaire-based site specific interviews were also conducted.

Pre-processing of the acquired geocoded sub-scene of selected study area for 1975, 1990, 2000 and 2010 was performed using ERDAS Imagine (version 9.1). Map to image geo-rectification process was adopted for geometrically correcting the satellite images by obtaining ground control points (GCP) from geo-referenced, SOI toposheets employing polyconic projection parameters[(Spheroid Name: Everest; Datum name: India (Bangladesh)]. Selection of points was done by referring to the image and choosing prominent landmarks. These geo-rectified images were later fine-tuned to account for greater degree of details and information. Later, different thematic maps viz., land use/land cover, drainage network, soils and forest type and vegetation mapping, etc., were prepared in GIS mode using ERDAS Imagine (version 9.1) and ArcGIS (version 9.2) softwares. Further, the major settlement location was also generated as point coverage from SOI topomap. Data on Land Use / Land cover classification and Forest density for Belgaum district procured from Karnataka Forest Department, GoK was used for cross-checking purpose.

**Assessment of forest encroachment :** A systematic study has been undertaken to understand the extent of damage both to the canopy cover and density by overlaying satellite imageries with Survey of India topo map, French Institute forest maps, and Forest Department Working Plan maps, etc., followed by ground verification. This information has been put into GIS platform for digital database creation for ready reference. Field visits was undertaken to assess the encroachment patterns or other details such as crops grown, trees retained, period of cultivation and other human induced drivers. The encroached forest area has been categorized into large (> 10 ha), medium (<10 ha) and small (<5 ha) zones. Three sample plots were laid out for assessing the changes that have taken place during the decades.

## Results and Discussion

**Vegetation Land use / land cover classification and forest density :** In Belgaum 17 $km^2$ of high dense forest, 757 $km^2$ moderate dense forests, 318 $km^2$ open forest and 467 $km^2$ of scrub forest were found in various taluks (FSI, 2009). The major forest types (KFD, 2007) were evergreen, semi-evergreen, moist deciduous and small patches of grass land (Shola) situated along the upper slopes of Kanakumbi and Londa ranges of Khanapura taluk (Table 1 and 2). Dry deciduous forest form a small

**Table 1 :** Vegetation land use/land cover classification of Belgaum district

| Land use/land cover classification | Area ($km^2$) |
|---|---|
| Evergreen Forest | 134.29 |
| Semi Evergreen Forest | 134.30 |
| Moist Deciduous Forest | 613.61 |
| Dry Deciduous Forest | 156.12 |
| Grass land | 5.59 |
| Scrub-Forest | 770.88 |
| Eucalyptus Plantation | 25.05 |
| Bamboo Plantation | 0.40 |
| Acacia Plantation | 15.87 |
| Mixed Forest Plantation | 40.79 |
| Other Forest Plantation | 0.79 |
| Teak Plantation | 1.64 |
| Others | 11530.14 |
| **Total** | **13429.47** |

Source: Karnataka Forest Department, GoK (2007)

**Table 2 :** Vegetation density of Belgaum district

| Forest type | Density (%) | Area ($km^2$) | Total Area ($km^2$) |
|---|---|---|---|
| Evergreen Forest | <10 | 1.84 | 134.29 |
| | >70 | 76.41 | |
| | 10-25 | 0.18 | |
| | 25-40 | 0.14 | |
| | 40-70 | 55.72 | |
| Semi Evergreen Forest | <10 | 1.41 | 134.3 |
| | >70 | 39.29 | |
| | 10-25 | 0.76 | |
| | 25-40 | 9.19 | |
| | 40-70 | 83.66 | |
| Moist Deciduous Forest | <10 | 72.08 | 613.61 |
| | >70 | 0.52 | |
| | 10-25 | 116.75 | |
| | 25-40 | 178.84 | |
| | 40-70 | 245.42 | |
| Dry Deciduous Forest | <10 | 18.75 | 156.12 |
| | 10-25 | 27.4 | |
| | 25-40 | 109.97 | |

Source: Karnataka Forest Department, GoK (2007)

percentage of lower foot of the Eastern slopes or some parts of Belgaum and Chikodi taluk and towards the border of Dharwad district. Scrub Forest extends through Hukkeri, Gokak, Savadatti and Ramadurga taluk and some part of Raybag, Athani and Chikodi (Fig 1). The high dense forests situated at Kankumbi and Londa ranges of Khanapura taluk, where less than 10% to more than 70 % of evergreen forest and less than 10 to 70% covers semi evergreen forest exist. Moist-deciduous forest covered 25 to 70% at Khanapur taluk and only less than 10 % of dry deciduous forest identified. 10 to 25% of moist deciduous and 10 to 40% of dry deciduous forest situated in Belgaum and Bailavangala taluk (Table 2). The Scrub forest and mixed plantation were mainly distributed along Hukkeri, Gokak, Savadatti and Ramadurga taluks and some part of Athani, Chikodi and Raybag taluks.

**Extent of encroachment :** Following ground truth verification it was found that the major type of encroachment were due to agriculture expansion. The forest encroachment using 1968 Survey of India Toposheets was considered as the base year to obtain the reserve forest boundary and satellite data of 1975, 1990, 2000 and 2010 (Table 1) were used to analyze the spatial and temporal changes in encroachment in the district. The areas of reserved forest boundary were mapped based on 1968 topo maps, which has an area of 189929 ha. The forest encroachment was identified as 29004, 28304, 16133 and 4245 ha during the year 2010, 2000, 1990 and 1975 respectively. It was observed that forest encroachment varied from 2.24 to 15.27 % from 1975 to 2010 and majority of encroachment was observed during 1990 and 2000 (Table 3).

The weighted average percentage of encroachment based on the forest types was evergreen forest 1.23 %, semi evergreen forest 3.49%, moist deciduous 12.58%, dry deciduous 13.34 %, mixed 3.49% and scrub forest is 65.87 % with an encroached area of 356.08 ha, 1012.33 ha, 3649.41 ha, 3869.1 ha, 19106.2 ha and 1011.01 ha, respectively (Table 4). The scrub forest stands the highest with a reserve forest area of 75217 ha and the lowest was evergreen forest with 13428 ha in 2010 (Table 4). The highest percentage of encroachment was found in areas with mixed plantation and major part being scrub land whose weighed average percentage encroached area for Hukkeri taluk was 31.38% over the years (Table 3). The major factors accelerating encroachment is agricultural expansion; whereas indirect encroachment is by local encroachers who do not live in the encroached land but lease or rent out the land to others including local or migrant encroachers.

In general Athani, Raibhagh, Chikodi and Ramadurg taluks having less reserve forest areas were least encroached and moderate encroachment was observed in Bailahongala, Khanapur and Savadatti taluks. The highest forest encroachment was in found Hukkeri, Gokak and Belgaum taluks. The entire field survey indicated that the encroachment pattern was mainly at places near villages and towns. Higher encroachments were observed in the southern part of Hukkeri, north-eastern part of Belgaum and south-western part of Gokak taluks. In 1975, encroachment was very low because of low population and less urbanization. However, from 1990 onwards, encroachment pattern drastically changed because of rapid growth of

**Table 3 :** Extent of forest encroachment in Belgaum District for the years 1975, 1990, 2000 and 2010

| Taluk | Forest type of encroached area | Geographical area (ha) | Forest area (ha) | Encroached forest area (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1975 | | 1990 | | 2000 | | 2010 | |
| | | | | Area | % | Area | % | Area | % | Area | % |
| Athani | Scrub Forest | 199513 | 1327.06 | 63.7 | 1.5 | 242 | 1.5 | 282.7 | 1 | 285.5 | 0.98 |
| Bailahongal | Dry deciduous and Scrub Forest | 112233 | 9474.43 | 560.4 | 13.2 | 2129.6 | 13.2 | 2230.9 | 7.88 | 2275.5 | 7.85 |
| Belagavi | Dry and Moist Deciduous forest | 103721 | 21712.77 | 556.2 | 13.1 | 2113.4 | 13.1 | 4461.8 | 15.76 | 4595.6 | 15.84 |
| Chikkodi | Scrub Forest | 126949 | 1336.36 | 84.9 | 2 | 322.7 | 2 | 375.8 | 1.33 | 385.2 | 1.33 |
| Gokak | Scrub Forest | 154308 | 22780.18 | 849.1 | 20 | 3226.6 | 20 | 6692.6 | 23.65 | 6920.2 | 23.86 |
| Hukkeri | Scrub Forest | 99140 | 13343.94 | 1273.7 | 30 | 4839.9 | 30 | 8923.5 | 31.53 | 9102 | 31.38 |
| Khanapur | Evergreen, Semi evergreen, Moist Deciduous forest and Grass land | 172956 | 100667.2 | 72.2 | 1.7 | 274.3 | 1.7 | 2773.5 | 9.8 | 2801.3 | 9.66 |
| Raibag | Scrub Forest | 95874 | 3493.61 | 42.5 | 1 | 161.3 | 1 | 660.7 | 2.33 | 680.6 | 2.35 |
| Ramadurg | Scrub Forest | 121542 | 3913.46 | 106.1 | 2.5 | 403.3 | 2.5 | 694.7 | 2.45 | 707.7 | 2.42 |
| Saundatti | Scrub Forest | 158146 | 11880.41 | 636.8 | 15 | 2420 | 15 | 1208.1 | 4.27 | 1256.4 | 4.33 |
| | **TOTAL** | **1,344,382** | **189929.4** | **4245.6** | **100** | **16133.1** | **100** | **28304.4** | **100** | **29010** | **100** |
| | **Percentage** | ——— | **100** | **2.24** | ——— | **8.49** | ——— | **14.9** | ——— | **15.27** | ——— |

**Table 4 :** Forest type-wise extent of encroachment for the year 2010

| Forest type | Reserved forest area | | Encroached forest area for 2010 | | % of encroached forest area to RF area |
|---|---|---|---|---|---|
| | Ha | % | Ha | % | |
| Evergreen forest | 13428.87 | 7.14 | 356.08 | 1.23 | 15.43 |
| Semi evergreen forest | 13430.23 | 7.14 | 1012.33 | 3.49 | |
| Moist deciduous forest | 61360.68 | 32.63 | 3649.41 | 12.58 | |
| Dry deciduous forest | 15611.85 | 8.3 | 3869.1 | 13.34 | |
| Scrub-forest | 75217.68 | 40 | 19106.2 | 65.87 | |
| Mixed forest plantation | 4078.05 | 2.17 | 1011.01 | 3.49 | |
| Others | 4934 | 2.62 | NA | — | |
| **Total** | **188061.8** | **100** | **29004.16** | **100** | |

population, use of resource, unscientific agricultural practices, search for agriculture land / fuel-wood / timber and infrastructure project. The encroachment pattern which stood 2.24% in 1975 drastically increased thereafter accounting to 8.49, 14.90 and 15.27 % of forest land by 1990, 2000 and 2010, respectively (Table 3). Major portion of the encroached forest area are categorized under high class (i.e., area > 10 ha) for all the three decades (i.e., 1975-90, 1990-2000 and 2000-2010). For year 2010, the encroached areas that were categorized under small, medium and large classes accounted for 2538.86, 2313 and 24152.08 ha, respectively (Fig. 2).

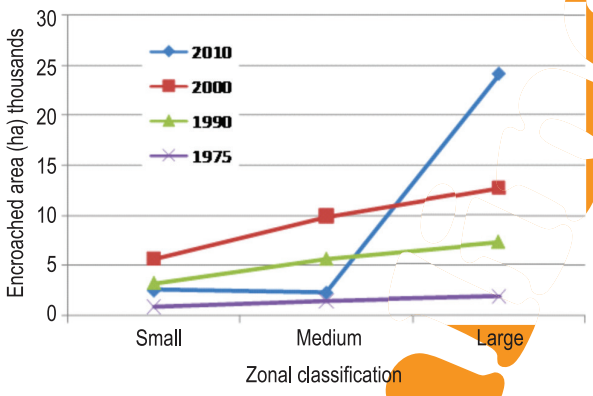


**Fig. 2 :** Zonation classification of forest encroached area in Belgaum district for the year 1975, 1990, 2000 and 2010

The expanding agricultural operation is the key objective behind encroachment in the district and to some extent, animal grazing and wind mills have engulfed part of forest. Very similar sort of scenario also existed in Bangladesh wherein encroachment pattern, types and major causes were associated with community socio-economic status, limited land availability and unemployment (Iftekha and Hoque, 2005). Rabindar *et al.* (2010) reported a loss of dense forest at an annual rate of 0.53% in the Western Ghats region of Maharashtra. The change in forest cover exhibits a great deal of variation in both spatial and temporal context, may be result of different strategies and efforts by the forest department besides change in climatic conditions and other socio-economic factors. Jha *et al.* (2000) reported deforestation for different regions with annual rate of degradation of 0.8% and 1.5% for dense forest and open forest types respectively, in their study covering southern extents of Western Ghats spread in three southern states namely Karnataka, Kerala and Tamil Nadu from 1973 to 1995. Menon and Bawa (1997) reported the annual rate of deforestation in the Western Ghats to be 0.57% for a period of approximately 70 years from 1920s to 90s. Prasad (1998) reported a 0.28% loss in forest cover per annum in the Western Ghats of Kerala during the period of 30 years. It has been concluded that remote sensing and GIS approach is useful in identifying major encroachment pockets of an area.

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