Assessing the historical forest Encroachment of Kodagu region of Western Ghats, South India using remote sensing and GIS

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Abstract

The present study is focused on RS and GIS based assessment of forest encroachment in Kodagu district of Karnataka for the year 1990, 2000 and 2010 using Landsat TM/MSS for 1990 and 2000, and IRS LISS III for the year 2010. It's located in the south-western part of Karnataka state, geographically stretched between 11^0 56' to12^0 52' N and 75^0 22' to76^0 12' E, with a total area of 4101.21 Km^2. The study revealed that the encroachment in reserve forest area accounts for 291.6 ha, 284.8 ha and 173.7 ha respectively for the year, 2010, 2000 and 1990. The highest encroachment is being noticed in Somavarpet, Kushalnagar ranges in Madikeri division and major encroachment is witnessed moist and dry deciduous, other plantation and mixed forest plantation. The major factors accelerating are expansion of agriculture, plantations, rapid growth of urbanization, development of utility services, population dependency of forest livelihood and poverty.

Keywords: Western Ghats, Forest types, Encroachment, Zonal classification, Land use Land cover

Introduction

The forests are playing a vital role in regulating the climate and biodiversity conservation despite providing livelihood benefits to millions of people living in and around the forests.The forests of the Western Ghats region of peninsular India have undergone significant transformations over the past century (Ref). The nature, extent and causes of these transformations have been due to deforestation, over grazing, forest fire, rapid urbanization, encroachment for agriculture, etc. Hence the forest management requires an understanding of the spatial and temporal patterns using remote sensing data and Geographical Information system (GIS) techniques. Recently many researchers (Wendy and William, 2012, Sakthivel, 2010, Francesc Montane, 2010, Daniel Ayalew, 2007) have used the remote sensing data to assess the forest cover. Very few studies used RS & GIS technique to analyze the forest encroachment patterns (Iftekhar and Hoque, 2005).

The Western Ghats of India is a biodiversity hotspot (Myers, 1988) and many areas in Kodagu region have been recently declared as UNESCO sites. Kodagu region of the Western

Ghats has mostly evergreen forests (Pascal, 1988) and is known for rich flora (Keshavamurthy, 1990) and fauna (Mittermeier et al. 2005). Various studies have documented ecology and biodiversity of forest, agro-ecosystem and sacred groves of Kodagu (Pascal & Ramesh, 1987; Ambinakudige & Sathish, 2009; Sunil et. al. 2012). Forest encroachments have been reported for Kodagu region, but different perceptions are there on extent of encroachments. Hence, an effort has been made in the present study using remote sensing and GIS to assess the extent of encroachment in reserve forest area and present condition in the forest area of Kodagu district of Karnataka state, both temporally (viz. 1975, 1990, 2000 and 2010) and spatially (i.e., division-wise). Further, ground truthing was undertaken to understand the causes of forest encroachment in the region.

Study Area

In Karnataka, most of the dense forests are located along Western Ghats region, which is declared as one of the biodiversity hotspots of the world (Mayers, 1988). Karnataka State has a recorded forest area of 43,356.45 Km^2, which is 22.60% of its total geographical area but, the land actually covered by forest is 33,238.47 Km^2, accounting to 17.33% of its total geographical area. Forested area is further classified into dense Forest (40% and above crown density) accounting to 28,144 Km^2; open Forest (10% to 40%) and scrub Forest (less than 10% density) accounting to 15,212 Km^2; Mangroves forest account for 3 Km^2 (FSI, 2009) and rest of the forest land is not covered by forest.

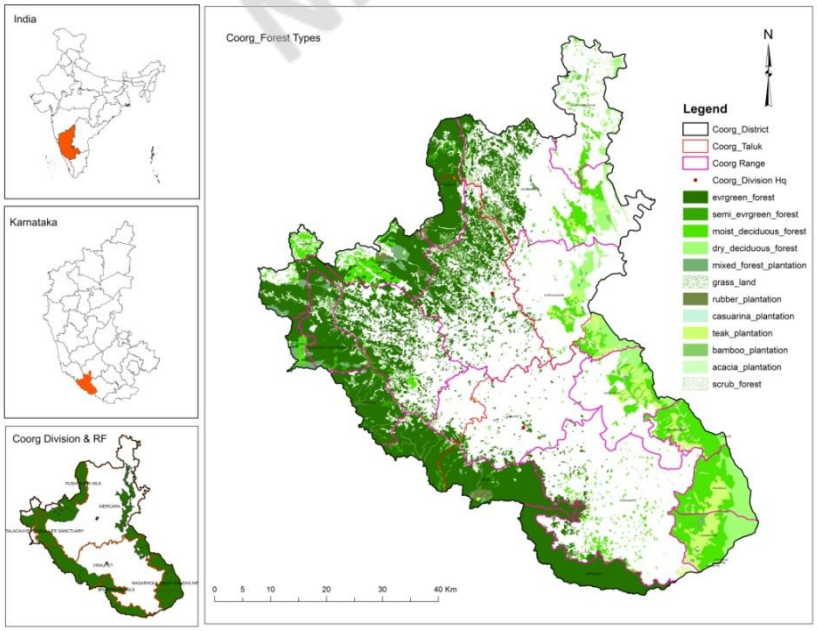

Fig 1. Location map of Kodagu district showing Taluk, Division, Range and reserve forests boundaries along with Land Use / Land cover classification

Kodagu, known by the name of Coorg, is a land of beautiful and brave hill station and tourist attraction place, considered to be rich with wildlife and has three wildlife sanctuaries and one national park. The study area is extending from 11^0 56' North to12^0 52' North and 75^0 22' East to76^0 12' East, with a total area of 4,102 Km^2 and elevation varying from 900m to 1715 m (Fig 1). Climate in the region varies with altitudinal gradation and distance from the equator. Mean temperature range from 20°C in the south to 24°C in the north with an average rainfall of 3000–4000 mm. The western slopes of the mountains experience heavy annual rainfall (with 80% during the southwest monsoon from June to September), while the Eastern slopes are drier; rainfall also decreases from south to north. The district is divided into the two forest divisions, namely Madikeri and Virajpet which include three wildlife sanctuaries (viz., Bramhagiri, Talakaveri, and Pushpagiri WLSs) and one national park (i.e., Nagarahole National Park). Two divisions of Coorg district are further divided into 14 ranges, 43 section and 79 beats. As per the census 2001 and 2011, the population is 548561 and 554762 respectively. The economy of district depends mainly on agriculture, plantations and forestry in addition to tourism. Primarily to coffee production and other plantation crops, characteristically and historically, paddy fields, ginger crops and meadows are found on the valley floors, with agro forestry in the surrounding hills. The coffee agro-forestry systems of Kodagu are one of the richest agro-forest in the world.

Materials and Methods

Materials used

a) Survey of India Topographical map sheets()of 1: 50,000 scale
b) Satellite imageries of the year 1975, 1990, and 2000 (LandSat TM/MSS) and 2010 (IRS IC/ID LISS III / IV) on 1: 50,000 scales were procured from National Remote Sensing Centre (NRSC), Hyderabad.
c) Remote Sensing and GIS Software Packages
d) Site specific interviews, 2010
e) Software's used: ERDAS (version 9.1) and ARC GIS (version 9.2).

Methodology

The procured satellite data were digitally geo-rectified and processed using ERDAS (version 9.1) employing polyconic projection parameters (Spheroid Name: Everest; Datum name: India (Bangladesh). Different thematic maps such as land use/land cover, drainage network, soils and forest type and vegetation map, etc., on 1: 50,000 scale were also prepared using

ERDAS (version 9.1) and ARC GIS (version 9.2). These were later fine-tuned with respective satellite images, which accounts for greater degree of details and latest information. Further, the major settlement location was also generated as point coverage from SOI topomap. Moreover, the forest working plan reports and administrative maps were also taken into account.

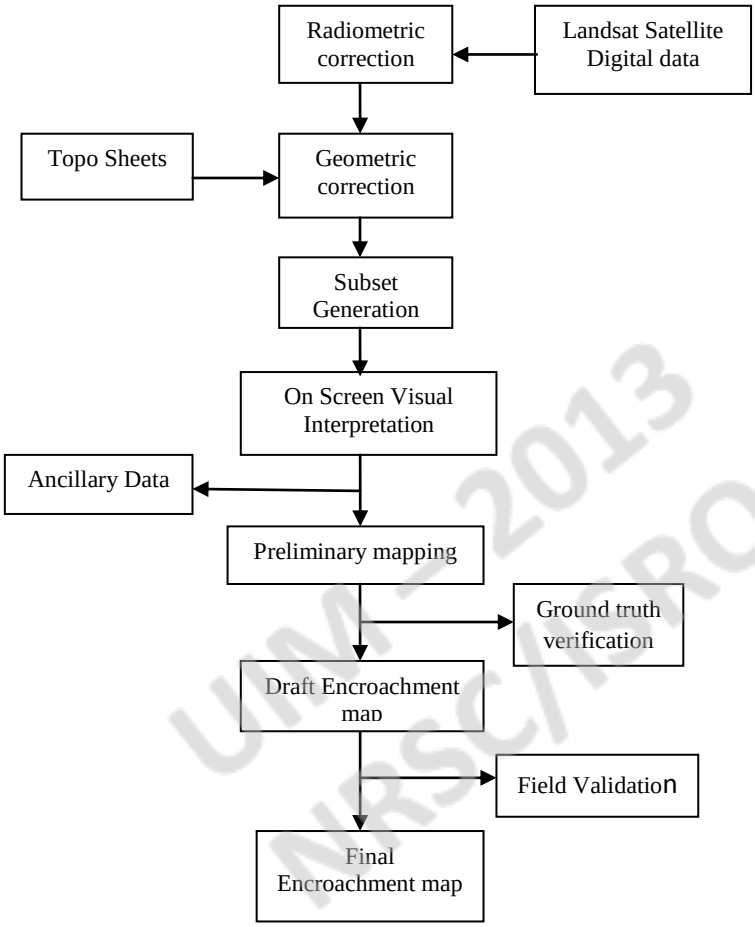

Fig 2: Methodology adopted for preparing Encroachment Map

Approach to assess forest encroachment

A systematic study has been undertaken on the basis of original reserve forest boundaries indicating the locations through scrutiny of forest and revenue department records The extent of damage both to the canopy cover and density has been understood by overlaying satellite imageries with Survey of India topomap, French forest institute maps and Forest Department working plan maps, etc., after ground truth verification. This information was transferred onto GIS platform for database creation for ready reference (**Fig 2)**. Field visits have been undertaken to assess the encroachments patterns, such as crop grown, trees retained, period of cultivation and other human induced driver on the forest within the reserve forest area. In Kodagu, the encroached forest area **(Fig 3)** has been categorized into large (> 10 ha), medium (5-10 ha) and small (<5 ha), based on the extent. In

each taluk, for each zonal category, 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 Kodagu forests consists of 246 sq km of very dense forest, 2114 sq km moderate dense forest, 951 sq km open forest and 1.70 sq km of scrub forest (FIS-2009). The major forest types evergreen, semi-evergreen observed in the hilly area of Pushpagiri wildlife and some parts of Somavrpet, Sampje, Talakaveri wildlife, Bhagamandala and Mundrote ranges Makut, Bramhagiri wildlife and Srimangala ranges very highly distributed **(Fig 1)**. In some parts of Verjpet and few pockets of Ponnampet we can observe the ever green and semi evergreen forest but moist deciduous forest highly concentrated in this ranges. In the some parts of lower hilly area of Sampje range Nagarhole wildlife area, Thithimathi, Kushalnagar and some parts of Somarpet range moist deciduous and dry deciduous forests are distributed. Grass land situated along the hilly ranges namely Pushpagiri, Sampje Talakaveri and Bhagamandala ranges of Madikeri division. Only few pockets of area is under Scrub Forest mainly situated Somavarpet and Verajpet divisions. **Table 1** shows extent of different forest types in Kodagu district.

Kodagu district is having very high dense forest cover in Karnataka. **Table 2** shows the forest density for different vegetation types prevailed in the district. Accordingly, evergreen forest types is the predominant vegetation type in the district accounting for 49.45% followed by moist deciduous forest (19.17%), dry deciduous forest (10.85%) and semi-evergreen forest type constitute only 1.94 % of the total forest cover. Remaining 18.58 % of area is composed of different plantations. Of the 49.45% of evergreen forest type cover in Kodagu district, 52.41 and 30 % of the area are having a forest density of 40-70 % and > 70% respectively. It is the moist deciduous forest types with 40-70 % density and dry deciduous forest types with 25-40 and 40-70 % density next to evergreen forests which cover major part of the district.

Accordingly, the Pushpagiri, Talakaveri Bramhagiri Bagamandala, Sampje, Mundrote, Makut, Sirimangala range having very highly dense evergreen forest concentration from >70%, 40% to70. In Somavarpet, Madkeri, Bagamandala and Verajpet and Ponnampet ranges having 25% to 40%, 10% to 25% and <10% concentrated. Less than 10 % to 20% cover Evergreen Forest and Semi Evergreen forest covers <10% to >70% at Pushpagiri, sampje, talakaveri Mundrote and Makut distributed. In Shanivarasanthe, Kushalnagara,

Thithimathi, Anechowkur, Kalhalla and Nagrhole range have more than 10%, 20% to 70% of moist deciduous forest concentrated and also dry deciduous forest distributed its density ranges between 10% to 70 % along the border side of Mysore district **(Table 2)**. The Scrub forest mixed plantation, Eucalyptus, Rubber Plantation, Casuarinas Bamboo Plantation Acacia Plantation and teak plantation mainly distributed along the Madikeri and Virajpet division.

Table 1. Land Use / Land cover classification of Kodagu district-2006

LULC classification	Area (Sq. Km)
Evergreen Forest	911.48
Semi Evergreen Forest	35.75
Moist Deciduous Forest	353.38
Dry Deciduous Forest	200.05
Grass land	142.30
Scrub-Forest	1.69
Eucalyptus Plantation	6.70
Rubber Plantation	13.38
Casuarinas Plantation	4.01
Bamboo Plantation	2.16
Acacia Plantation	9.16
Mixed Forest Plantation	40.95
Other Forest Plantation	1.67
Teak Plantation	108.75
Others	13.33
Total	**1844.75**

Table 2. Forest Density of Kodagu district for the year 2006

Forest type	Density (%)	Area (Sq.km)	%	Area (Sq.km)
Evergreen Forest	<10	16.31	1.79	911.48 (49.45%)
	>70	273.44	30.00	
	10-25	31.20	3.42	
	25-40	112.79	12.37	
	40-70	477.74	52.41	
Semi Evergreen Forest	<10	0.04	0.11	35.75 (1.94 %)
	>70	3.50	9.79	
	10-25	0.67	1.87	
	25-40	6.09	17.03	
	40-70	25.45	71.19	
Moist Deciduous Forest	<10	12.60	3.57	353.38 (19.17 %)
	>70	2.12	0.60	
	10-25	20.63	5.84	
	25-40	53.31	15.09	
	40-70	264.72	74.91	
Dry Deciduous Forest	<10	6.78	3.39	200.05

	10-25	22.98	11.49	(10.85%)
	25-40	97.70	48.84	
	40-70	72.59	36.29	
Others	----	342.41	----	342.41 (18.58 %)
Total area				**1844.57 (100 %)**

Extent of Encroachment

As per the detailed analysis carried out and the through ground verification, it is found that the major cause for encroachment in the district is agriculture expansion and detailed distribution of encroachment under each forest type is given in the **Table 3**. Based on these boundaries, the area under encroachment has been derived as per GIS database. Based on the reserve forest boundary on SOI toposheets, the encroachment was assessed using Landsat TM/MSS for 1975, 1990 and 2000 and IRS-1D LISS-III data for 2010 both spatially and temporally. The data generated was processed under the geographical information system for storage, analysis and retrieval. The district forests have been divided into two divisions namely Madkeri and Verajpet with 14 Ranges, 43 section and 79 beats. The areas of reserved forest boundary mapped based on SOI topomaps was 31137 ha. These forms the base data for our study area the forest encroached were identified as 291.6 ha, 284.8 ha, 173.7 ha and 45.7 ha for the year 2010, 2000, 1990 and 1975 respectively **(Table 3).** It was observed that these forest encroachments vary from 0.94 %, 0.91%, 0.56% and 0.14% respectively, more Encroachment was observed in the year 2000 compared to 2010.

Table 3. Extent of Forest Encroachment in Kodagu District

Sl No	Taluk	Geographical Area (sq km)	Forest Area (ha)	Forest Type of encroached area	Encroached Forest Area (ha)			
					1975	1990	2000	2010
1	Madikeri	1445.22	581	Evergreen to semi-evergreen	21.8	82.8	87	89.6
2	Virajpet	1654.14	7913	Moist and dry deciduous	20.9	79.5	185.6	189.3
3	Somvarpet	1001.85	22643	Moist and dry deciduous	3	11.4	12.2	12.7
TOTAL		**4101.21**	**31137**	-----	**45.7** (0.14%)	**173.7** (0.56%)	**284.8** (0.91%)	**291.6** (0.94 %)

Among the three decadal analyses, rate of forest encroachment was maximum during transition period from 1975 to 1990, accounting to 128 ha. For 1990 to 2000 period, the extent of encroachment got reduced to 111.1 ha, which further remained almost unchanged, with slight increase of 6.8 ha during the period from 2000-2010. Though Kodagu district is having good biodiversity and wildlife habitation, the encroachment of forest area is very less compared to other district of Karnataka. The highest Percentage of encroachment is found in madikeri division inhabiting semi evergreen forest, moist and dry deciduous forest types along with and other forest plantations. The major factors accelerating for encroachments directly attributed to agricultural expansion, where as in indirect encroachment local encroachers do not live in the encroached land rather lease or rented out the land to other may be local or migrant encroachers.

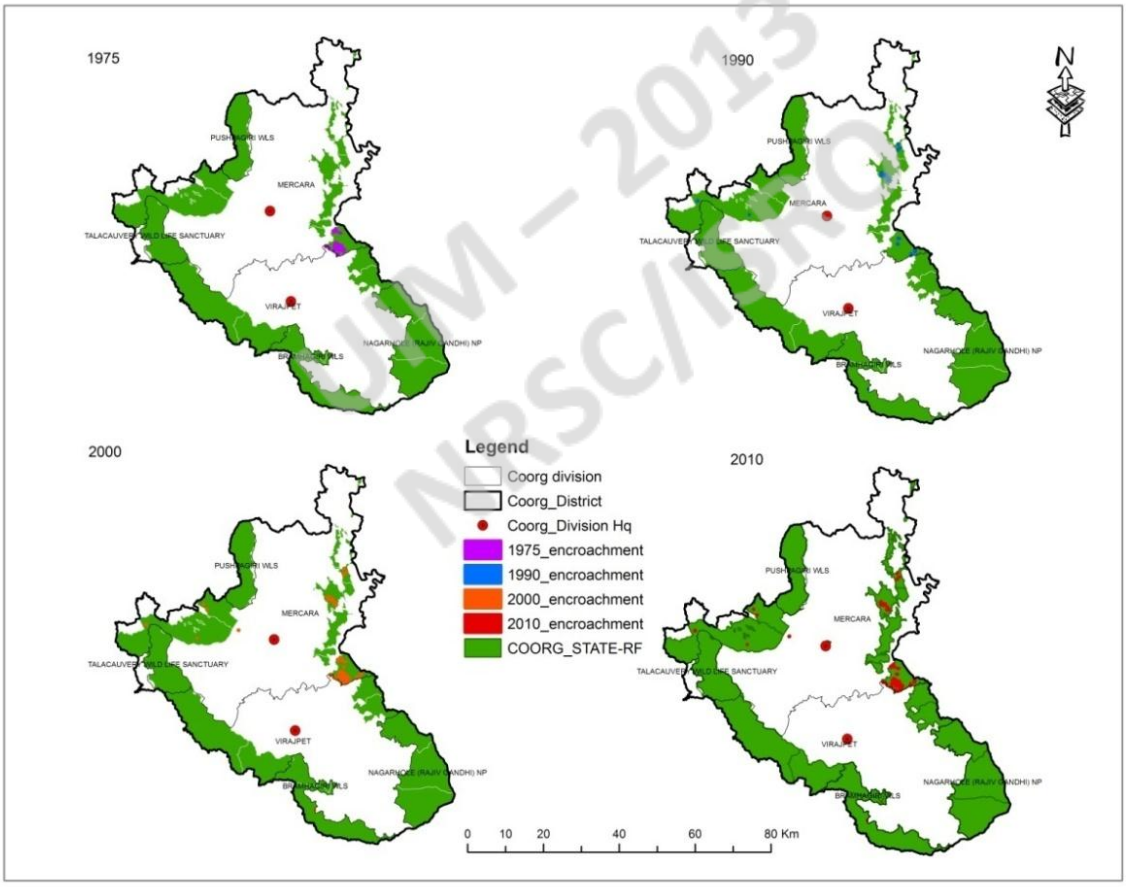

Fig 3. Forest Encroachment as Interpreted Using 1975, 1990, 2000 and 2010 Satellite data of Kodagu District

In Madikeri, Smapje Bagamandala ranges having high reserve forest area were classified under lowest encroached forest area. Moderate encroachment was observed in Ponnampet and Madikeri ranges while highest forest encroachment was noticed in Kushalnagar and

Somvarpet ranges in Somvarpet taluk. Based on the field survey, the encroachment pattern was mainly observed very near villages and towns. Higher encroachments were observed in moist and dry deciduous forest in the above mentioned ranges. In 1975, encroachment was very low because of low population and less urbanization. However, from 1990 onwards, encroachment pattern drastically changed because of the rapid growth of population, poverty, unscientific agricultural practices, search for agriculture land / fuel-wood / timber and development of transportation networks. The encroachment pattern which was 0.14%in 1975 drastically increased thereafter accounting to 0.56%, 0.91% and 0.94 % of total forestland encroached for the year 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) and it is evident that the ratio of small, medium and larger encroachments almost remained the same for the year 2000 and 2010. In the year 2010, the encroached area that are categorized under small, medium and large classes are 38.43, 31.99 and 221.19 ha respectively (**Fig 4**).

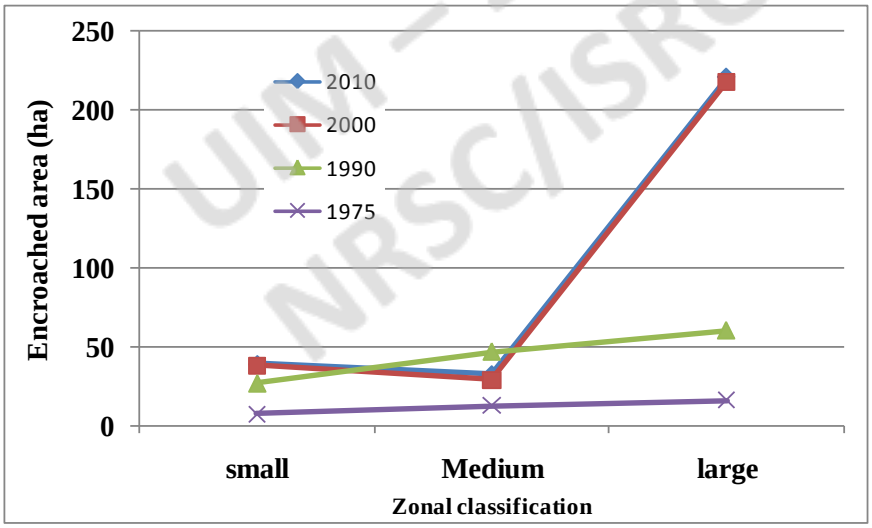

Fig 4. Zonation classification of forest encroached area for the year 1975, 1990, 2000 and 2010

In Bangladesh, encroachment pattern, types and causes are associated with the community socio economic status, limited land availability and unemployment has been identified as the major proximate causes of encroachment (Iftekha and Hoque, 2005). Rabindar *et al* (2010) reported that loss of dense forest at an annual rate of 0.53% in the Western Ghats region of Maharashtra, but the rate of degradation may not be uniform. The change in forest cover exhibits a great deal of variation in both spatial and temporal context maybe a result of different strategies and efforts by the forest department and due to the change in climatic

conditions and other socio-economic factors. Jha *et al* (2000) reported that the deforestation of Western Ghats for different regions over different time periods, an annual rate of degradation of 0.8% and 1.5% for dense forest and open forest respectively, in their study covering southern extents of Western Ghats spread in three southern states, Karnataka, Kerala and Tamil Nadu from 1973 to 1995. Menon and Bawa (1997) had 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) had reported a 0.28% loss in forest cover per annum in the Western Ghats of Kerala during the period of 30 years beginning in the late 1950s. Forest-dwelling tribal communities or people who live in the vicinity of forests are the main encroachers. They use forestland for cultivation on two accounts, firstly, forestlands are considered to be more fertile and secondly forestlands are in vicinity of their habitations. Hence, the encroachment on forestlands is generally followed by diversion of forestland to agriculture use.

Conclusion

The forest encroachment in Kodagu district was assessed for the year 1975, 1990 2000 and 2010 and accordingly it was delineated that the rate of forest encroachment was maximum during transition period from 1975 to 1990 followed by 1990 to 2000. Major portion of the encroached forest area are categorized under large / high class for all the three decades and higher encroachments was mainly observed in moist and dry deciduous forest in the district. In Madikeri, Smapje Bagamandala ranges having high reserve forest area were classified under lowest encroached forest area. Moderate / medium encroachment was observed in Ponnampet and Madikeri ranges while highest forest encroachment was noticed in Kushalnagar and Somvarpet ranges in Somvarpet taluk. Based on the field survey, the encroachment pattern was mainly observed very near villages and towns. It is also observed that good natural regeneration in the abandoned cultivated areas, which can grow as a good forest in the future. They also get their medicines from forests. They collect gums, resins, various seeds, fruits and leaves to sell in the market and fulfill their needs. These patches need a detailed study for protection and conservation so as to control the re-visit to the same spot for cultivation within RF boundary.

Acknowledgement

We thank Ministry of Environment & Forests, Government of India for financial assistance and Karnataka Forest Department for granting permission for ground truthing. We thank NRSC, Hyderabad for providing satellite imageries.

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