

Land use dynamics and Floral diversity of Southern Montane Wet Temperate Forests in Chikmagalur, Central Western Ghats, India.

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The Western Ghats is rich biodiversity region considered as one of the 35 biodiversity hotspots (also one among eight hottest hotspots of biodiversity) of the world (<http://www.conservation.org>). The region with a wide forest types ranging from tropical wet evergreen forests to grasslands is a repository of flora and fauna evident from the occurrence of over 4,000 species of flowering plants (38% endemics), 330 butterflies (11% endemics), 156 reptiles (62% endemics), 508 birds (4% endemics), 120 mammals (12% endemics), 289 fishes (41% endemics) and 135 amphibians (75% endemics). The forests of Western Ghats, in view of their floristic diversity and numerous multipurpose species, are considered as storehouse of economically important plants. The tropical climate complimented by heavy precipitation from southwest monsoon and favorable edaphic factors create an ideal condition for the rich biodiversity, which can be seen only in few parts of the world. These forests which lost their earlier aura of sacredness (during community-based management regime) did not get any special consideration from the state and were subjected to routine forestry operations to meet state needs, harming their special biodiversity preserved through ages.

The stretch of Central Western Ghats ranges from 12° to 15° covering areas of Coorg district, Hassan, Chikmagalur, Shimoga upto south of Uttara Kannada. Chikmagalur district of Karnataka state is situated in the heart of the Western Ghats region. The Malanad region consists of Western Ghats chain from where many rivers originate and the inland plain region of Deccan plateau. Such regions always have high priority for conservation, primarily for the diversity and for the provision of the ecosystem goods and services.

Chikmagalur, a malnadu district of the Karnataka State with a geographical area of 7201 sq.km is situated in the mid-south-western part of the State at 12° 54' 42'' and 13° 53' 53'' N and 75° 04' 46'' and 76° 21' 50'' E (Figure 1). A large area of this district is 'malnad', i.e., a largely forested

hilly region of heavy rainfall. Its greatest length from east to west is about 138.4 kilometers and from north to south 88.5 kilometers. It is bounded on the east by the Tumkur district, on the south by the Hassan district, on the west by the Western Ghats which separate it from the Dakshina Kannada district, on the north east by the Chitradurga district and on the north by the Shimoga district. The district takes its name from the headquarters town of Chikmagalur, which literally means *younger daughter's town*- Chikka Magala Ooru (in Kannada). Situated in a fertile valley south of the Baba-Budan hill range is the headquarters town of the district. The town enjoys a healthy climate. The average annual rainfall of 1772 mm. Kadur taluk receives the lowest rainfall of 620 mm whereas Sringeri receives the highest rainfall amounting to 3773 mm.

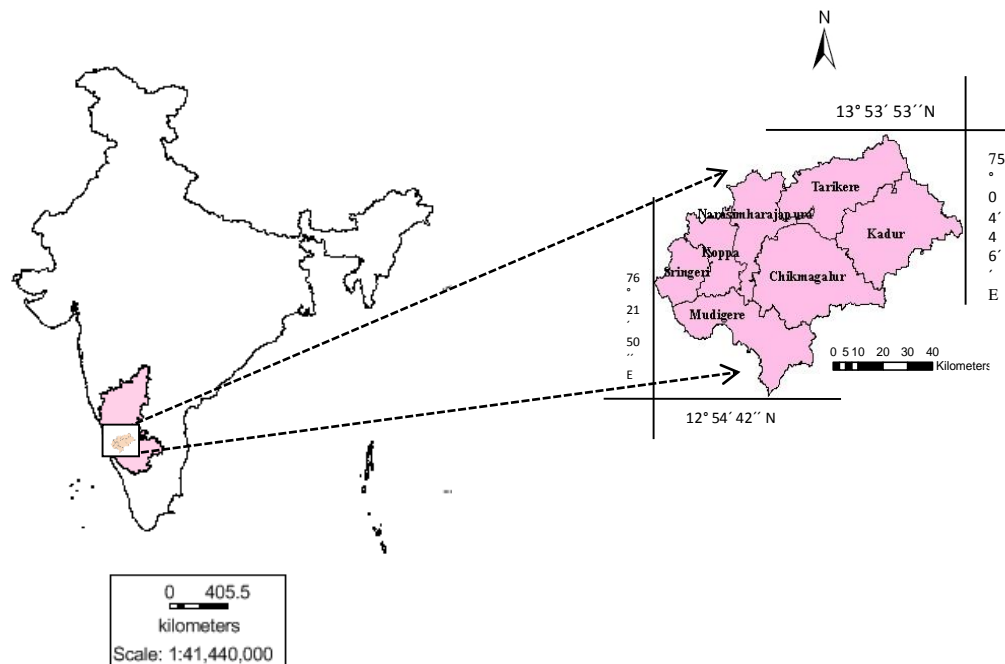


Figure 1: Study region - Chikmagalur district, Karnataka State, India

Landscape Dynamics and fragmentation

Landscape refers to the heterogeneous land features composed of sets of interacting ecosystems and is characterized essentially by its dynamics that are partly governed by human activities (Ramachandra et al., 2012). Human induced land cover and land use changes are considered as one of the pervasive sources of alteration on Earth's surface (Houet et al., 2010). Land cover and land use (LULC) changes essentially influenced by the enhanced anthropogenic activities.

Consequences of land use changes poses a serious threat to ecological sustainability of the region (Ramachandra and Uttam Kumar, 2011).

Fragmentation in landscape and especially in forests is a serious threat. Fragmentation implies division of landscape into smaller parts which results in uneven separation, size and disconnectivity between population and similar ecosystems (Forman 1995; Griffiths et al, 2000). Fragmentation of an ecosystem tends to cause constriction of patch area and terminate the flow of resources among the patches (Rutledge 2003). Forest fragmentation is process of isolation of forest patches which results in change of composition, structure, extent and spatial patterns through human induced activities (Roy et al., 2013). Fragmentation of landscape have been quantified by change in spatial characteristics and configuration of remaining patches (Saunders et al. 1987). Various ecological effect of forest fragmentations are loss of species populations, increased isolation of remnant populations, inbreeding (Laurance et al. 1998, Boyle 2001), enhanced human-animal conflicts, decline in ecosystem goods and services, etc. This necessitates understanding of the causes of forest and habitat fragmentations, in order to evolve effective management strategies for conservation. Remote sensing (RS) data acquired through space borne sensors available post 70's at regular intervals can be used as one of the major tools to understand LULC dynamics and quantify the extent of forest fragmentation (Gustafson 1998; Turner & Gardner 1991). Remotely sensed (RS) data in conjunction with geographic information systems have been successfully utilized to quantify forest loss as well as forest fragmentation (Jha et al., 2005). Temporal analysis of the spatial data provides an idea of the extent of changes happening in the landscape. Land use details derived from temporal RS data offer potential for assessing the changes in land uses, forest fragmentation and its impact on ecology and biodiversity (Ramachandra et al., 2011). Categorization and understanding of forest fragmentation using spatial data (RS data) provides a picture of the degree and extent of fragmentation, which are useful for conservation of the affected habitat fragments (O'Neill et al., 1997).

The satellite data of Landsat series Multispectral sensor, thematic mapper and IRS LISS III sensors for four decade period (1976 to 2009) were acquired from Global Land Cover Facility (GLCF), (United States Geological Survey (USGS), Earth Explorer, Glovis websites and Bhuvan website as indicated in Table 1.

Table 1: Details of the data used in the analysis

Data used	Resolution	Acquisition data	Purpose
Landsat Series Multispectral sensor	57.5m	17/11/1976	Land cover, Land use analysis and Fragmentation analysis
Landsat Series Thematic mapper	28.5m	02/01/1991 and 20/12/2000	Land cover, Land use analysis and Fragmentation analysis
IRS LISS III	23.5m	15/12/2009	Land cover, Land use analysis and Fragmentation analysis
Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales			To Generate boundary and Base layer maps.
Field visit data –captured using GPS			For geo-correcting and generating validation dataset
Google earth and Bhuvan			For digitizing various attribute data and as validation input

Assessment of landscape dynamics involved (i) Temporal analysis of land cover and land use using remote sensing data, (ii) Quantification of natural forests, (iii) Assessment of extent of forest fragmentation due to encroachment (subsequent changes in land uses). The procedure followed to assess landscape dynamics is outlined in Figure 2. Spatiotemporal changes of land cover and land use (LULC) were analysed using temporal remote sensing data with geospatial techniques. Spatial data acquired through space borne sensors at regular intervals since 1970's aid in monitoring of large areas and enable the change analyses at local, regional scales over time (Wilkie and finn, 1996). Remote sensing data along with field data collection using pre-calibrated GPS (Global Positioning system) help in effective land use analysis (Ramachandra et al., 2012).

The remote sensing data obtained were geo-referenced, rectified and cropped pertaining to the study area. Geo-registration of remote sensing data (Landsat data) has been done using ground control points collected from the field using GPS and also from known points (such as road intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India.

Remote sensing data requires preprocessing like atmospheric correction and geometric correction in order to enable correct area measurements, precise localization and multi-source data process of referencing an image to a geographic location (real earth surface positions) using GCP'S

(ground control points). Landsat satellite 1976 data have a spatial resolution of 57.5 m x 57.5 m (nominal resolution) were resampled to 28.5 m comparable to the 1991- 2009 data which are 28.5 m x 28.5 m (nominal resolution).

LAND COVER ANALYSIS Land cover is the first level of classification method that helps in understanding land cover types of the region broadly. The vegetation indices indicate the extent of the vegetation and soil in the region. In this study, the Normalized Difference Vegetation Index (NDVI) was used to calculate the land cover types. The vegetation change analysis for multi-temporal data can be done using NDVI (Ramachandra et al 2009, Ramachandra et al., 2011). NDVI is calculated using Near Infrared and Red Bands data using equation (1), NDVI values ranges from -1 to 1. The negative value indicates the non-vegetation and presence of built-up, water, sand etc. The increasing positive value from 0 indicates the presence of vegetation, higher value close to 1 indicates thick vegetation.

$$NDVI = \frac{NIR-IR}{NIR+IR} \dots \dots \dots (1)$$

LAND USE ANALYSIS

This involved i) generation of False Color Composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15% of the study area and uniformly distributed over the entire study area, iii) loading these training polygons co-ordinates into pre-calibrated GPS, iv) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, v) supplementing this information with Google Earth, vi) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment.

The land use analysis was carried out with training data using supervised classification technique based on Gaussian Maximum Likelihood algorithm. The supervised classification approach preserves the basic land use characteristics through statistical classification techniques using a number of well-distributed training pixels. Gaussian Maximum Likelihood classifier (GMLC) is appropriate and efficient technique based on “ground truth” information for classifier learning. Supervised training areas are located in regions of homogeneous cover type. All spectral classes in the scene are represented in the various subareas and then clustered independently to determine

their identity. The following classes of land use were examined: built-up, water, cropland, open space or barren land, and forest. Such quantitative assessments, will lead to a deeper and more robust understanding of land-use changes for an appropriate policy intervention. **GRASS GIS** (*Geographical Analysis Support System*), a free and open source software having the robust support for processing both vector and raster files accessible at <http://wgbis.ces.iisc.ernet.in/grass/index.php> is used for the analysis.

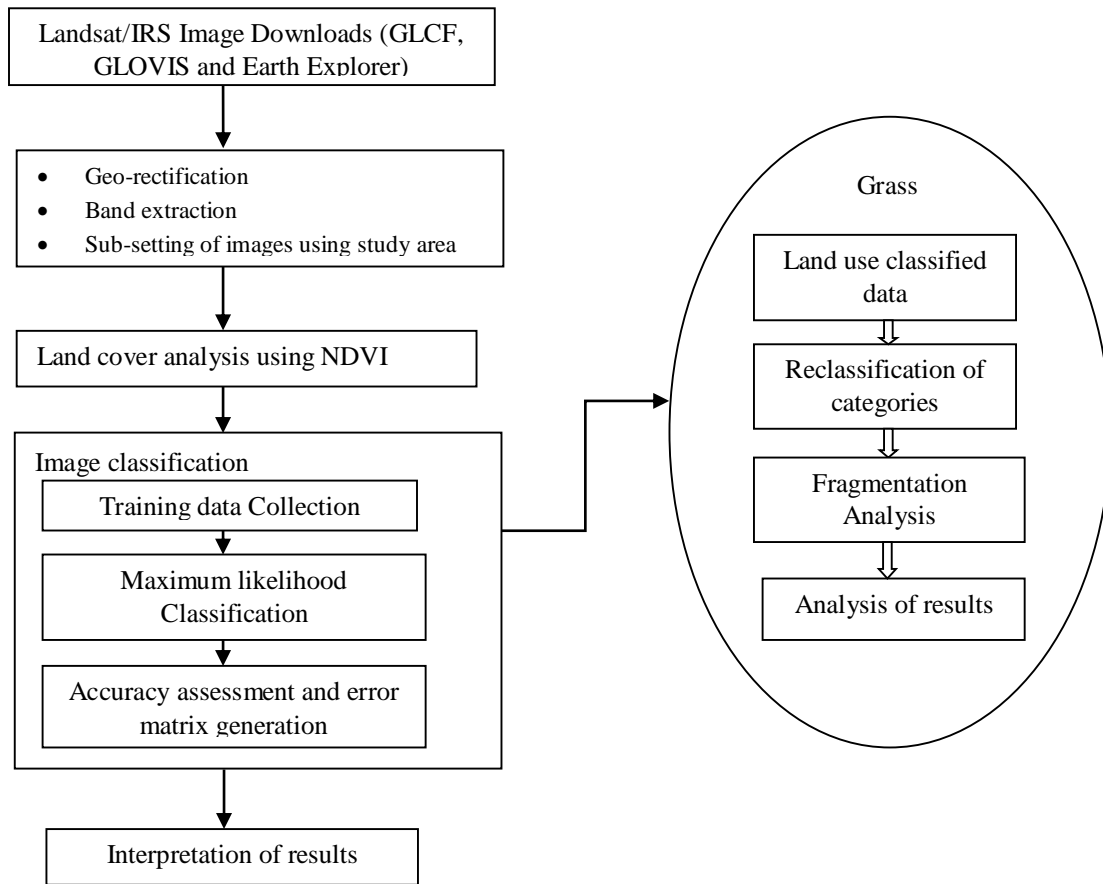
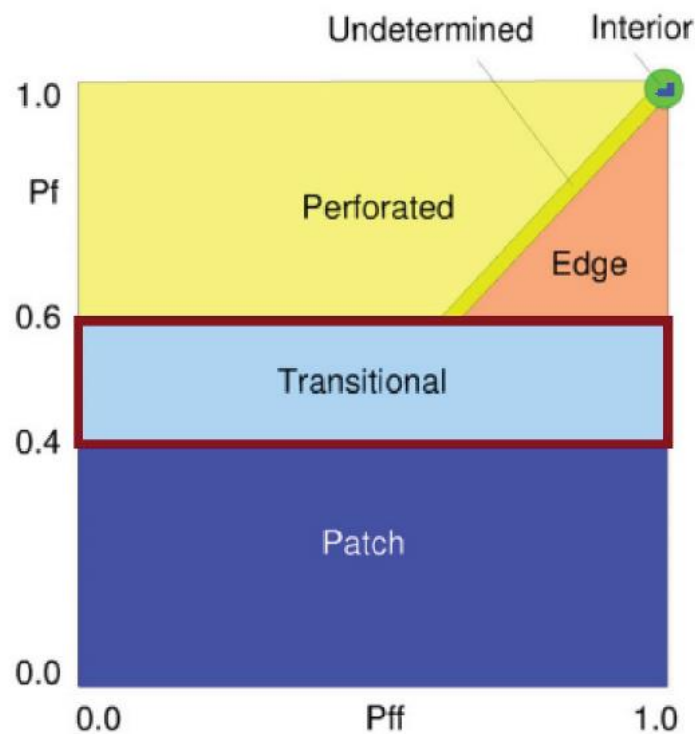


Figure 2: LULC and fragmentation analysis

Forest fragmentation analysis was performed to quantify the type of forest in the study area patch, transitional, edge, perforated and interior based on the classified images of Chikmagalur district. Forest fragmentation statistics and the total extent of forest (pf) and its occurrence as adjacent pixels (pff) is computed through fixed-area window (3x3) considering central pixel and its surrounding pixels (Riitters et al., 2000, Ramachandra et al., 2011). The result is stored at the location of the central pixel. Thus, a pixel value in the derived map refers to between-pixel

fragmentation around the corresponding forest location. Forest fragmentation category at pixel level is computed through P_f (the ratio of pixels that are forested to the total non-water pixels in the window) and P_{ff} (the proportion of all adjacent (cardinal directions only) pixel pairs that include at least one forest pixel, for which both pixels are forested). P_{ff} estimates the conditional probability that given a pixel of forest, its neighbor is also forest. Based on the knowledge of P_f and P_{ff} , six fragmentation categories derived (Figure 3) are (i) interior, when $P_f = 1.0$, (ii) Patch, when $P_f < 0.4$; (iii) transitional, when $0.4 < P_f < 0.6$; (iv) edge, when $P_f > 0.6$ and $P_f - P_{ff} > 0$; (v) perforated, when $P_f > 0.6$ and $P_f - P_{ff} < 0$, and (vi) underestimated, when $P_f > 0.6$ and $P_f = P_{ff}$.



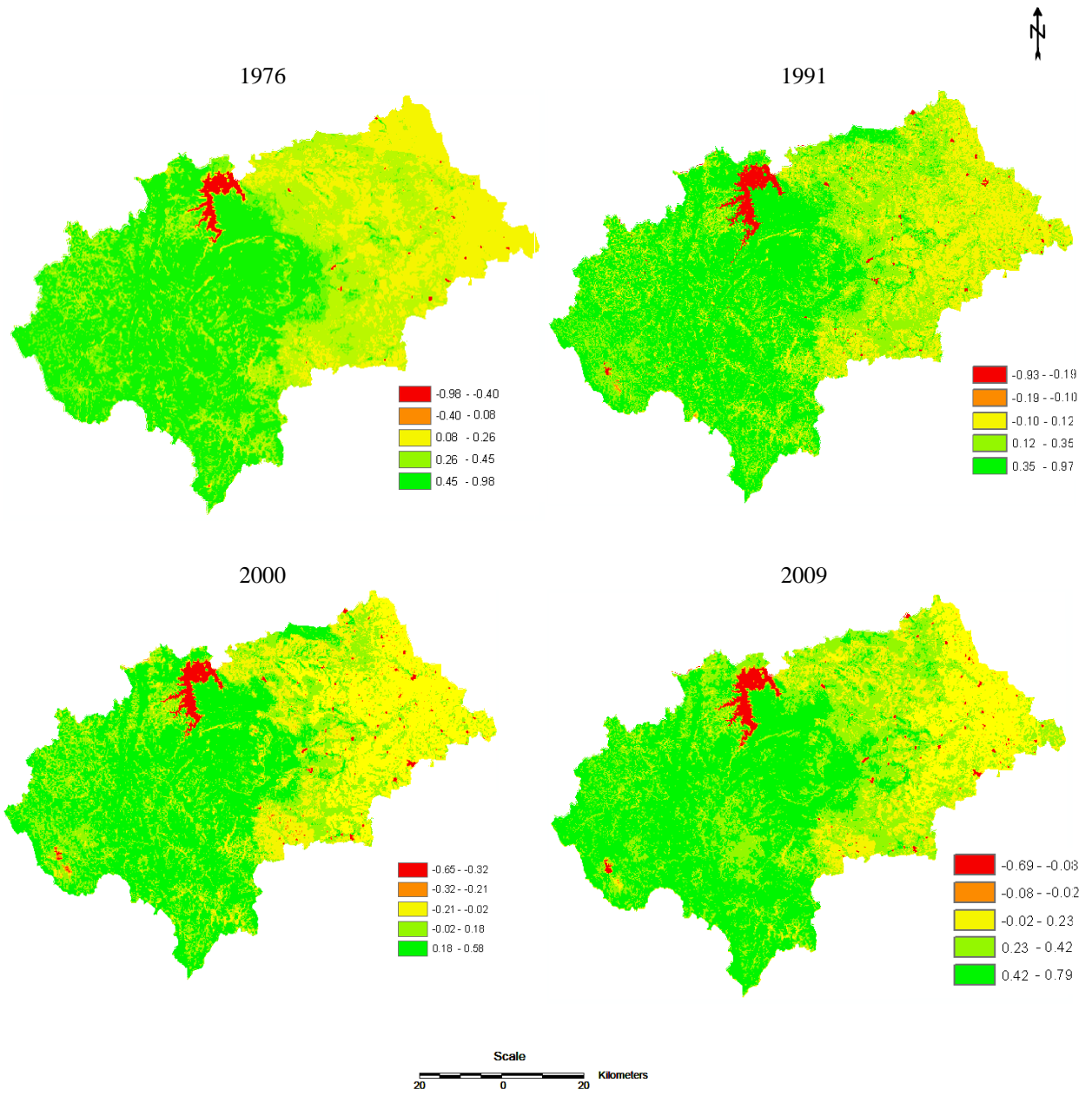


Figure 4: Vegetation dynamics in Chikamagalur

Figure 3: Forest Fragmentation using PF and PFF

Land cover analysis: Land cover analysis through NDVI shows the percentage of area under vegetation and non-vegetation. NDVI is based on the principle of spectral difference based on strong vegetation absorbance in the red and strong reflectance in the near-infrared part of the spectrum. Figure 3.3 and Table 3.2 illustrates the spatio-temporal changes in the land cover of the region, which highlight the decline of vegetation cover from 96.62 (1976) to 93.6% (2009).

Table 2: Extent of vegetation cover during 1976, 1990, 2002 and 2009

Land cover (%)		
Year	Vegetation	Non-vegetation
1976	96.62	3.38
1991	94.43	5.57
2000	94.28	5.72
2009	93.60	6.40

Land use analysis: The changes in the land uses at landscape level during 1976 to 2009 are highlighted in the Figure 5 and Table 3. This shows the decline of forests from 50.74% (1976) to 36% (2009). Table 4 lists category wise land uses in percentage and Table 5 provides the accuracy assessment details.

Table 3: Land use statistics in Hectares

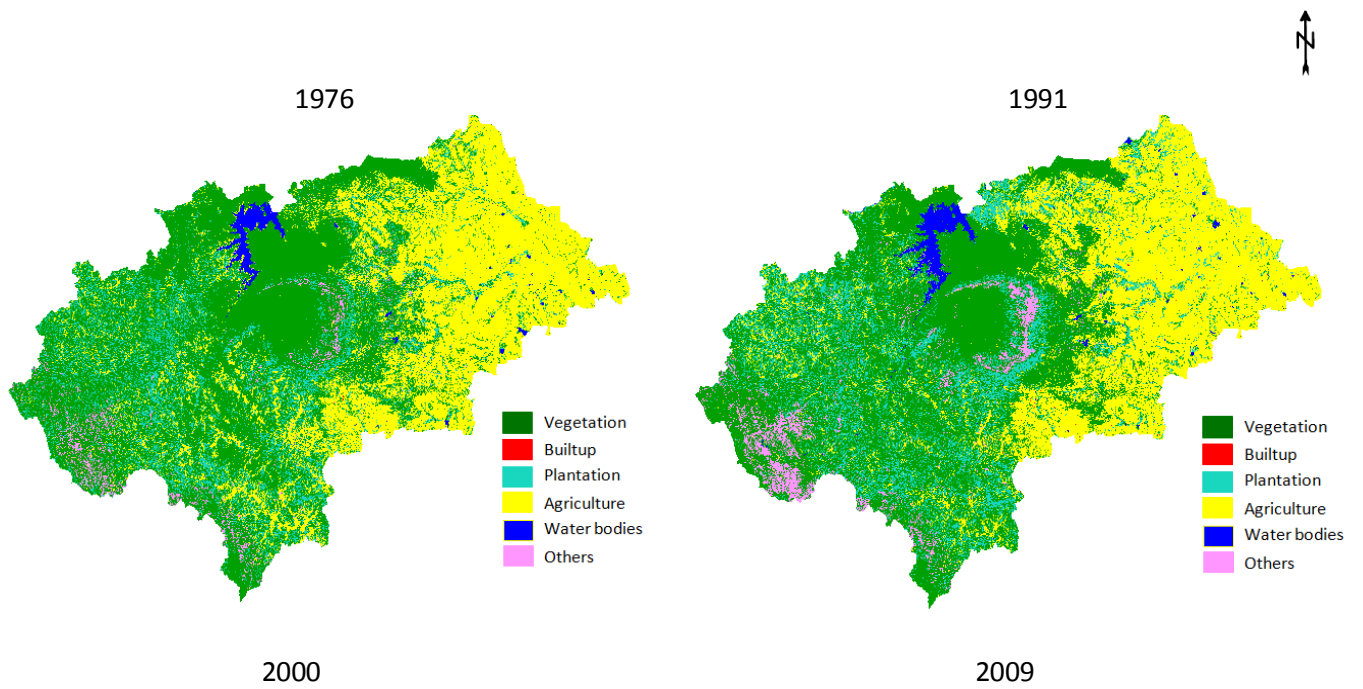
Land use categories (Hectares)						
Years	Forest	Urban	Plantation	Agriculture	Water bodies	Others
1976	365,541.08	365.88	89,105.83	243,307.46	8781.52	14,894.00
1991	344,445.96	1228.60	102,724.69	231,948.04	12,534.45	26,889.70
2000	299,549.97	1548.91	150,583.68	228,137.15	14,240.50	25,790.61
2009	261,520.87	1783.18	171,558.74	238,985.04	13,339.59	32,486.38

Table 4: Land use statistics in Percentage

Land use categories (percentage)						
Years	Forest	Urban	Plantation	Agriculture	Water bodies	Others
1976	50.74	0.05	12.35	33.61	1.21	2.06
1991	47.85	0.17	14.27	32.23	1.74	3.74
2000	41.61	0.21	20.09	31.69	1.98	3.58
2009	36.33	0.25	23.84	33.20	1.85	4.51

Table 5: Kappa and overall accuracy

Year	Kappa Co-efficient	Overall accuracy (%)
1976	0.77	84.43
1991	0.78	86.06
2000	0.80	87.12
2009	0.91	93.43



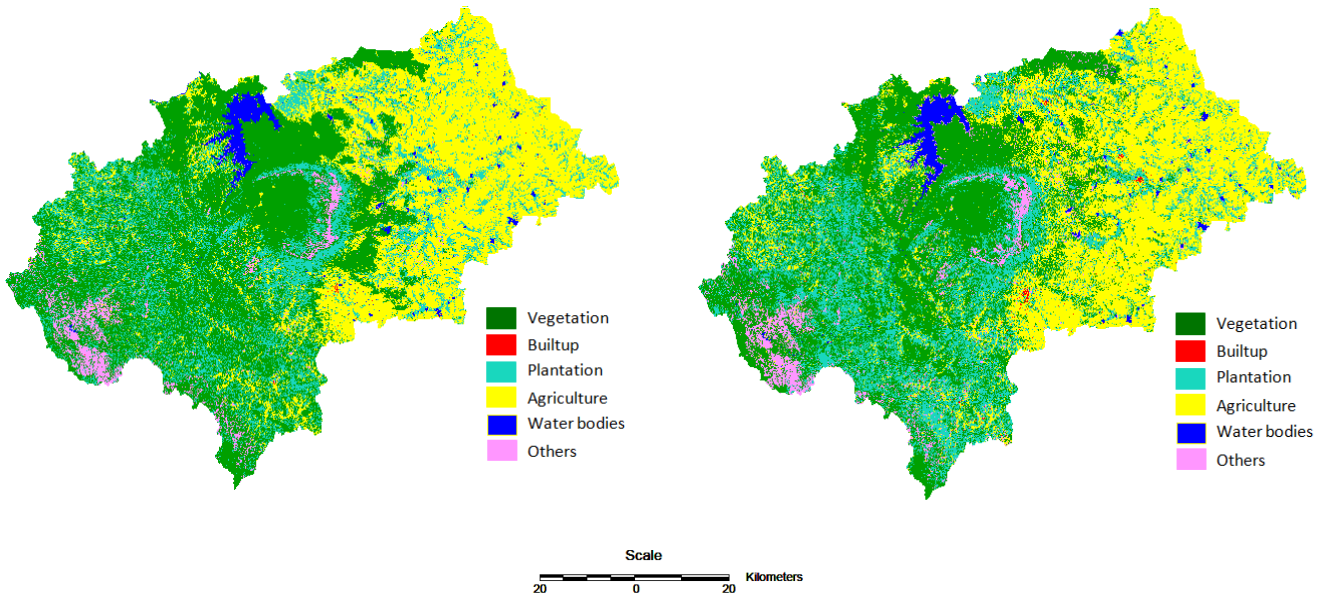


Figure 5: Land use changes during 1976 to 2009 in Chikmagalur

Fragmentation analysis: Land use data (classified data with 4 classes) were used as input to the fragmentation analysis and the analysis was done at district, division and taluk levels. Figure 3.5 illustrates the extent of forest fragmentation while Table 6 provides the summary statistics. Applying forest fragmentation analysis to a time series of land use data provided quantitative assessment of the spatial pattern and trends in forest fragmentation. The analysis indicated that domination of forests receded during 90's with the formation of patch and edge forest in all 5 divisions.

Table 6: Extent of forest fragmentation during 1976 to 2009

Types of fragmentation	1976	1991	2000	2009
Patch	3.51	5.71	5.93	8.74
Transitional	9.43	12.14	13.59	14.79
Edge	29.32	37.23	37.64	35.87
Perforated	5.35	2.35	3.32	3.22
Interior	52.39	42.56	40.40	37.38

Forests in Chikmagalur district are administered through five divisions – Chikmagalur, Koppa, Bhadravathi, Kudremukh National park and Bhadra Wildlife Sanctuary. The quantification of extent of forest fragmentation has been done division-wise for the past four decades to enable the respective division administration to undertake appropriate forest restoration measures to minimize fragmentation of ecologically important ecosystems. Land use changes from forests to non-forests with intensified human interference had been very high especially in Bhadravathi, Chikmagalur division. Interior forest decreased by 94.48 (1976) to 74.4 (2009). In Bhadravathi division interior forest decreased by 52.54 (1976) to 34.31 (2009) and patch increased by 5.73 (1976) to 13.52 (2009). Chikmagalur division interior forest was about of 39.68 in 1976 which was decreased to 23.75 in 2009. Interior forest in Koppa decreased by 52.82 (1976) to 32.27 (2009) and in Kudremukh interior forest decreased by 42.72 (1976) to 35.05 (2009). Figure 7 to Figure 11 represents the forest fragmentation and Table 7 to Table 11 gives statistics for extent of forest fragmentation division wise.

Similarly, the forests of Chikmagalur district are administered through seven taluks – Chikmagalur, Koppa, Kadur, Narasimharajapura, Mudigere, Sringeri and Tarikere. Figure 12 to Figure 18 represents the forest fragmentation taluk wise and Table 12 to Table 18 gives statistics for extent of forest fragmentation. In taluk level forest fragmentation analysis, the interior forest in Chikmagalur taluk decreased by 55.74 (1976) to 38.68% (2009). In Kadur taluk, the interior forest decreased by 15.74 (1976) to 13.34% (2009) and Patch forest increased by 19.76 (1976) to 27.43% (2009). In Koppa taluk interior forest decreased by 45.09 (1976) to 22.83% (2009) and Patch increased by 1.31 (1976) to 10.46% (2009) due to human induced activities. In Mudigere, interior forest decreased by 40.72 (1976) to 27.48% (2009). The Narasimharajapura taluk had massive changes in edge forest due to agricultural activities. Sringeri had 46.87% interior forest in 1976 which decreased to 28.55% in 2009 and Tarikere had interior forest of about 60.60% which decreased to 48.51%.

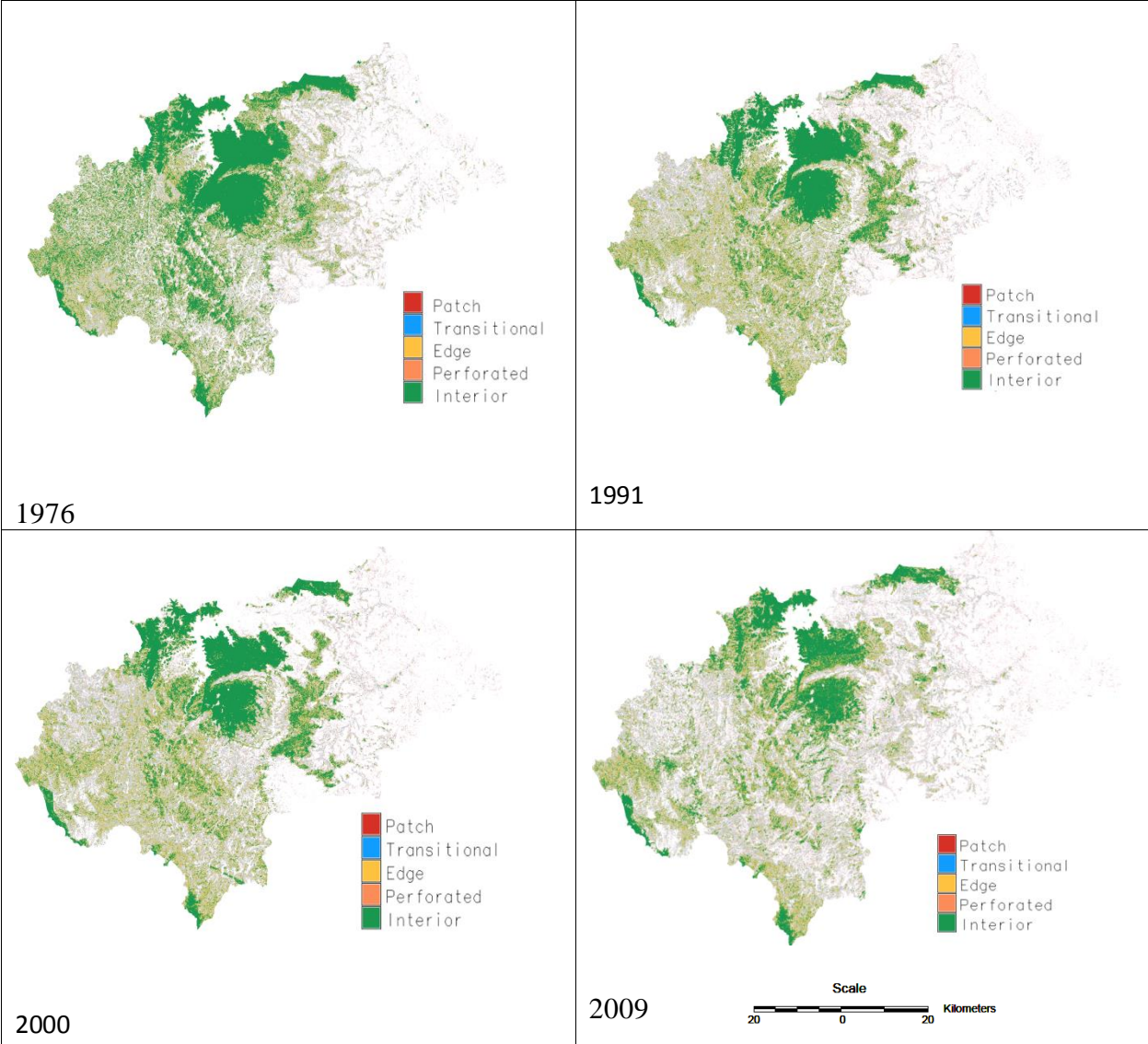


Figure 6: Fragmentation of forests in Chikmagalur

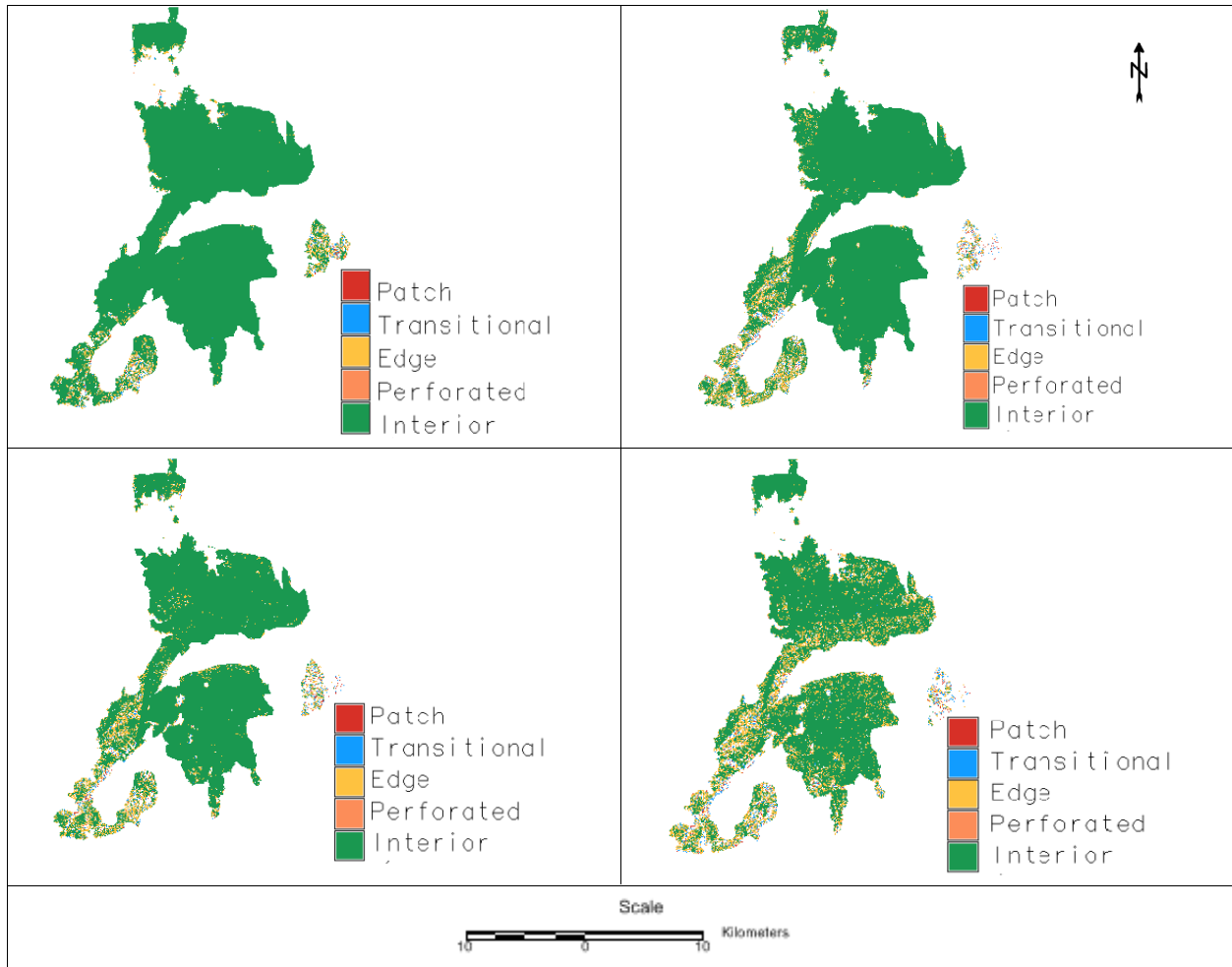


Figure 7: Spatial extent of forest fragmentation in Bhadra Wildlife Sanctuary

Table 7: Extent of forest fragmentation in Bhadra Wildlife Sanctuary during 1976 to 2009

Bhadra Wildlife Sanctuary				
Types of fragmentation	1976	1991	2000	2009
Patch	0.11	0.39	0.41	0.62
Transitional	0.58	1.32	1.35	2.26
Edge	4.40	8.65	9.25	18.71
Perforated	0.42	0.39	0.43	0.66
Interior	94.48	89.25	88.57	77.74

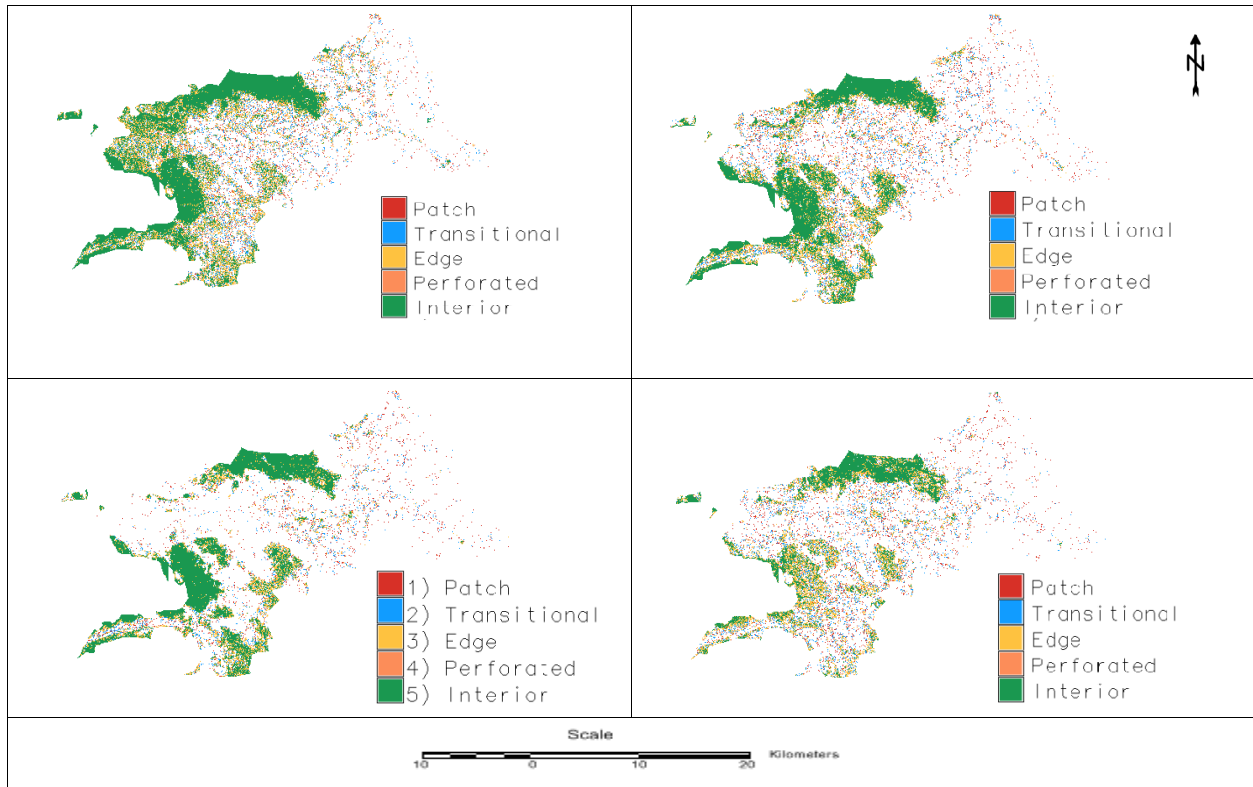


Figure 8: Spatial extent of forest fragmentation in Bhadravathi division (within Chikmagalur district)

Table 8: Extent of forest fragmentation in Bhadravathi division (within Chikmagalur district) during 1976 to 2009

Bhadravathi Division				
Types of fragmentation	1976	1991	2000	2009
Patch	5.73	10.08	8.74	13.52
Transitional	10.43	11.73	9.14	16.54
Edge	27.38	27.63	23.02	32.98
Perforated	3.92	1.92	1.78	2.65
Interior	52.54	48.64	57.30	34.31

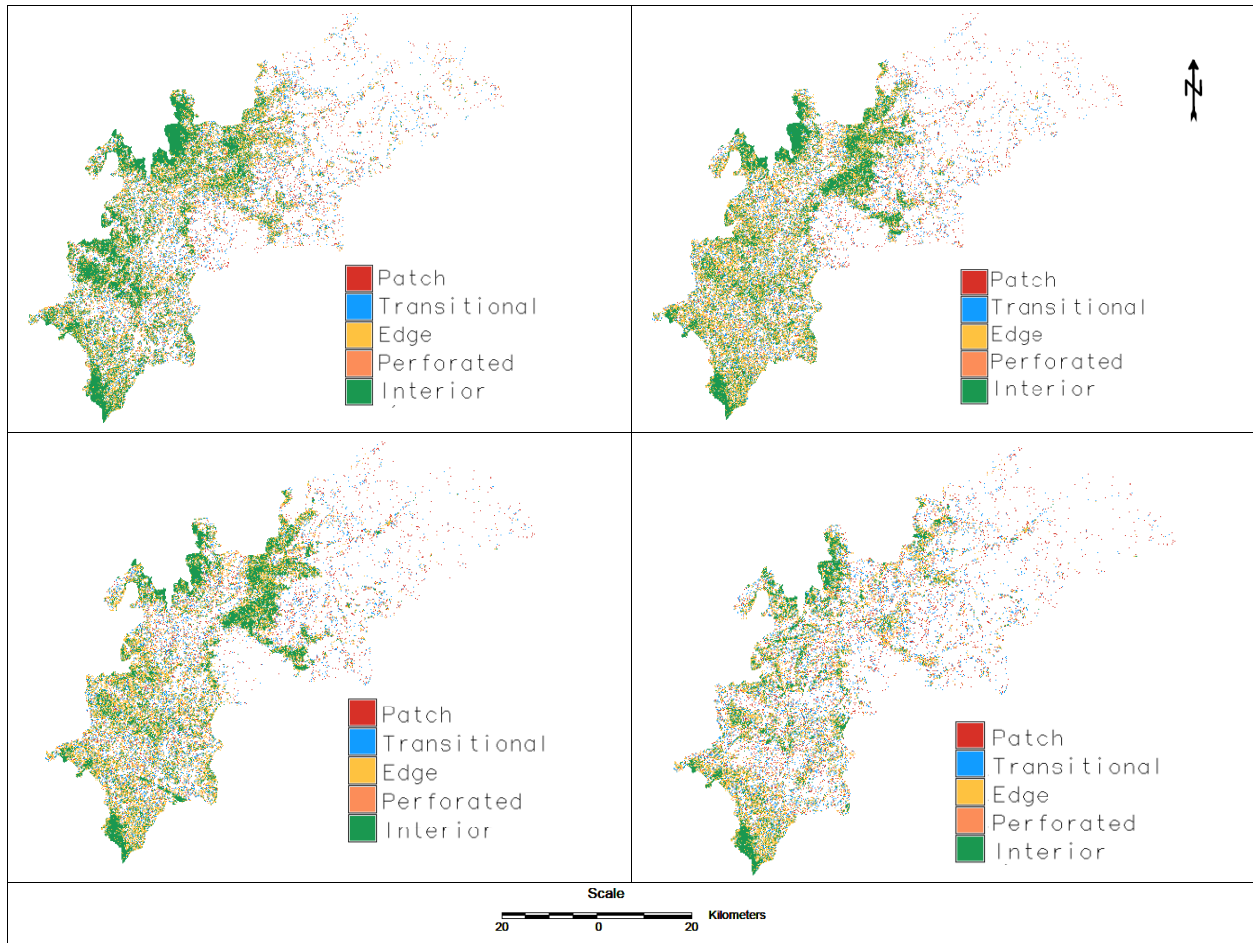


Figure 9: Spatial extent of forest fragmentation in Chikmagalur division

Table 9: Extent of forest fragmentation in Chikmagalur division during 1976 to 2009

Chikmagalur Division				
Types of fragmentation	1976	1991	2000	2009
Patch	6.39	7.47	8.52	13.63
Transitional	13.35	13.93	14.76	19.63
Edge	34.03	42.50	41.11	39.40
Perforated	6.55	2.63	2.83	3.59
Interior	39.68	33.47	32.78	23.75

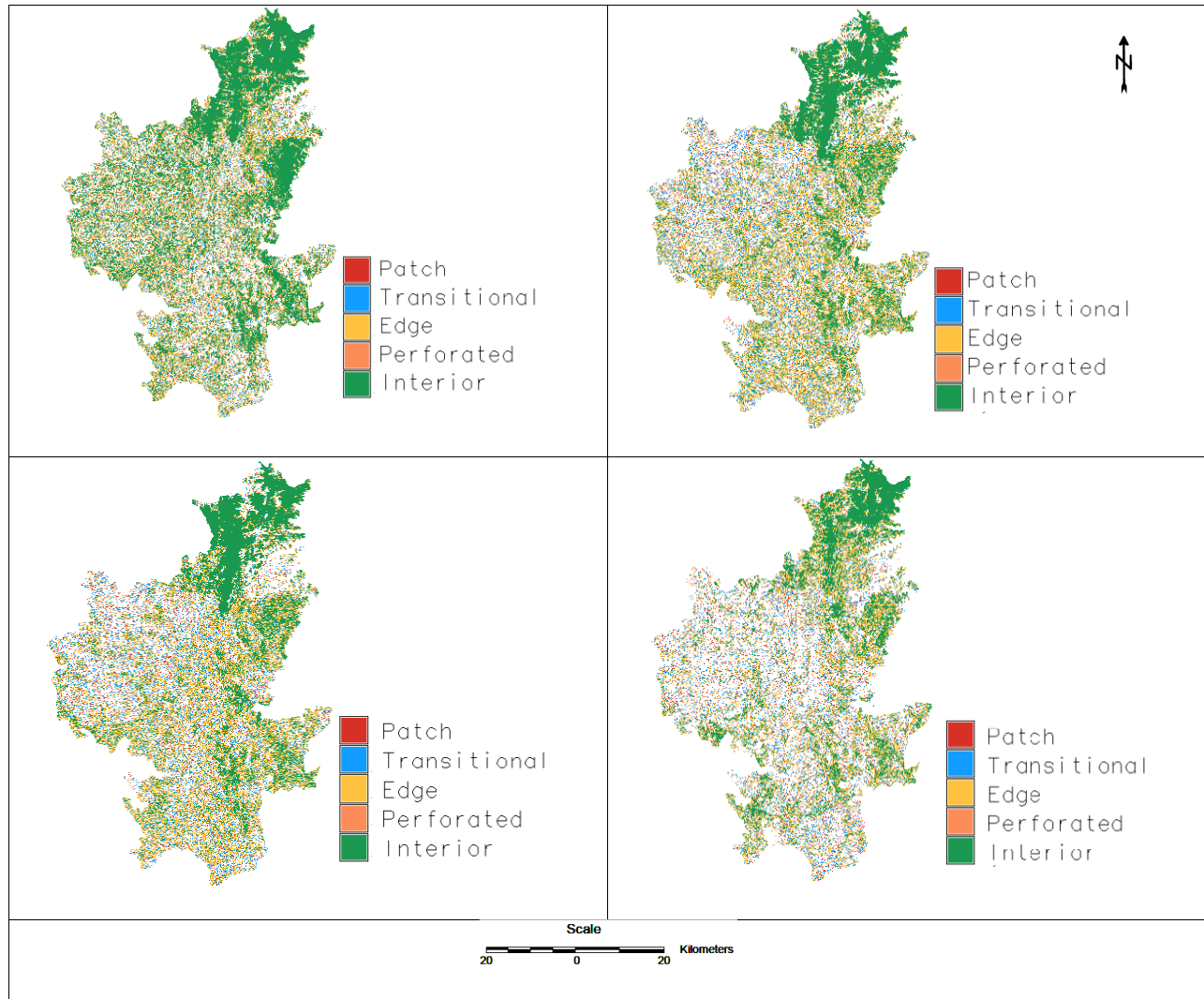


Figure 10: Spatial extent of forest fragmentation in Koppa division

Table 10: Extent of forest fragmentation in Koppa during 1976 to 2009

Koppa Division				
Types of fragmentation	1976	1991	2000	2009
Patch	1.41	4.36	4.97	6.98
Transitional	8.27	13.70	13.99	15.18
Edge	30.77	42.68	42.21	38.65
Perforated	6.72	2.65	2.51	3.92
Interior	52.82	36.62	36.31	35.27

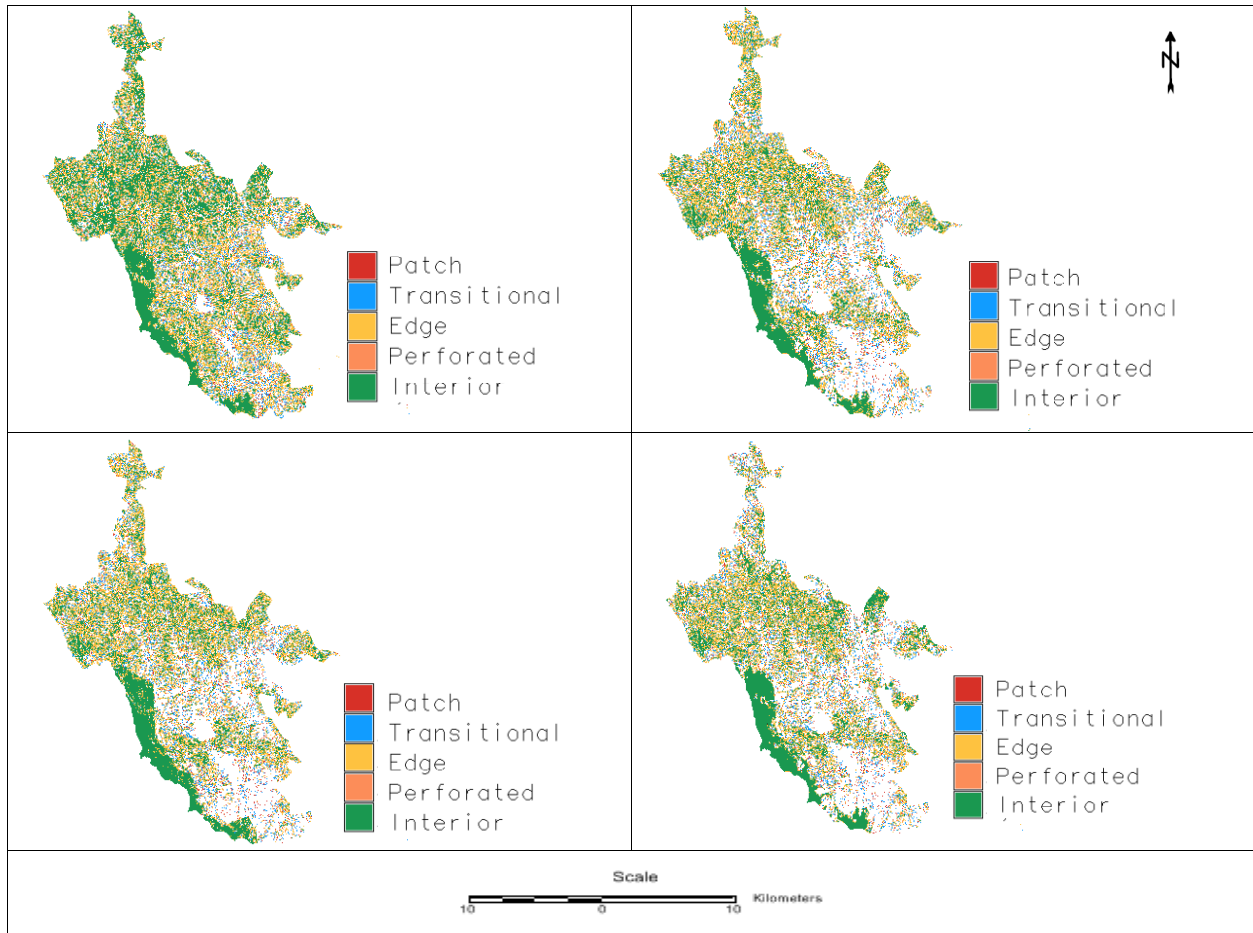
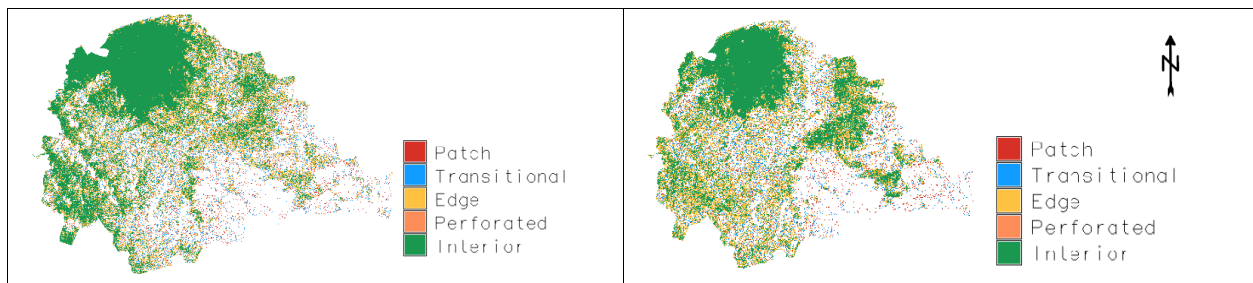


Figure 11: Spatial extent of forest fragmentation in Kudhremukh division

Table 11: Extent of forest fragmentation in Kudhremukh Division during 1976 to 2009

Kudhremukh Division				
Types of fragmentation	1976	1991	2000	2009
Patch	1.81	4.40	4.18	4.73
Transitional	9.44	13.62	12.88	13.44
Edge	41.63	46.41	46.53	42.88
Perforated	4.33	3.35	2.91	3.90
Interior	42.79	32.22	33.51	35.05



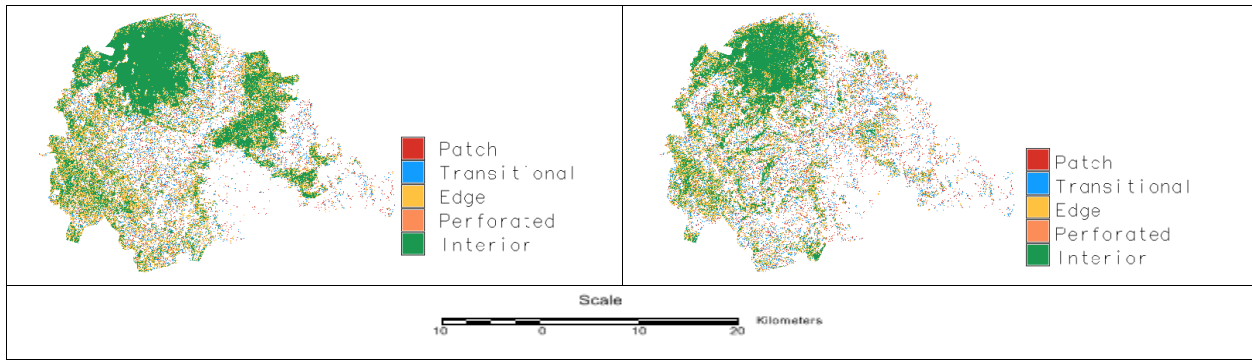


Figure 12: Spatial extent of forest fragmentation in Chikmagalur Taluk

Table 12: Extent of forest fragmentation in Chikmagalur Taluk during 1976 to 2009

Chikmagalur Taluk				
Types of fragmentation	1976	1991	2000	2009
Patch	3.59	4.56	5.21	9.03
Transitional	9.04	10.24	10.54	14.64
Edge	26.87	35.21	33.82	34.88
Perforated	4.77	2.10	2.10	2.78
Interior	55.74	47.90	48.34	38.68

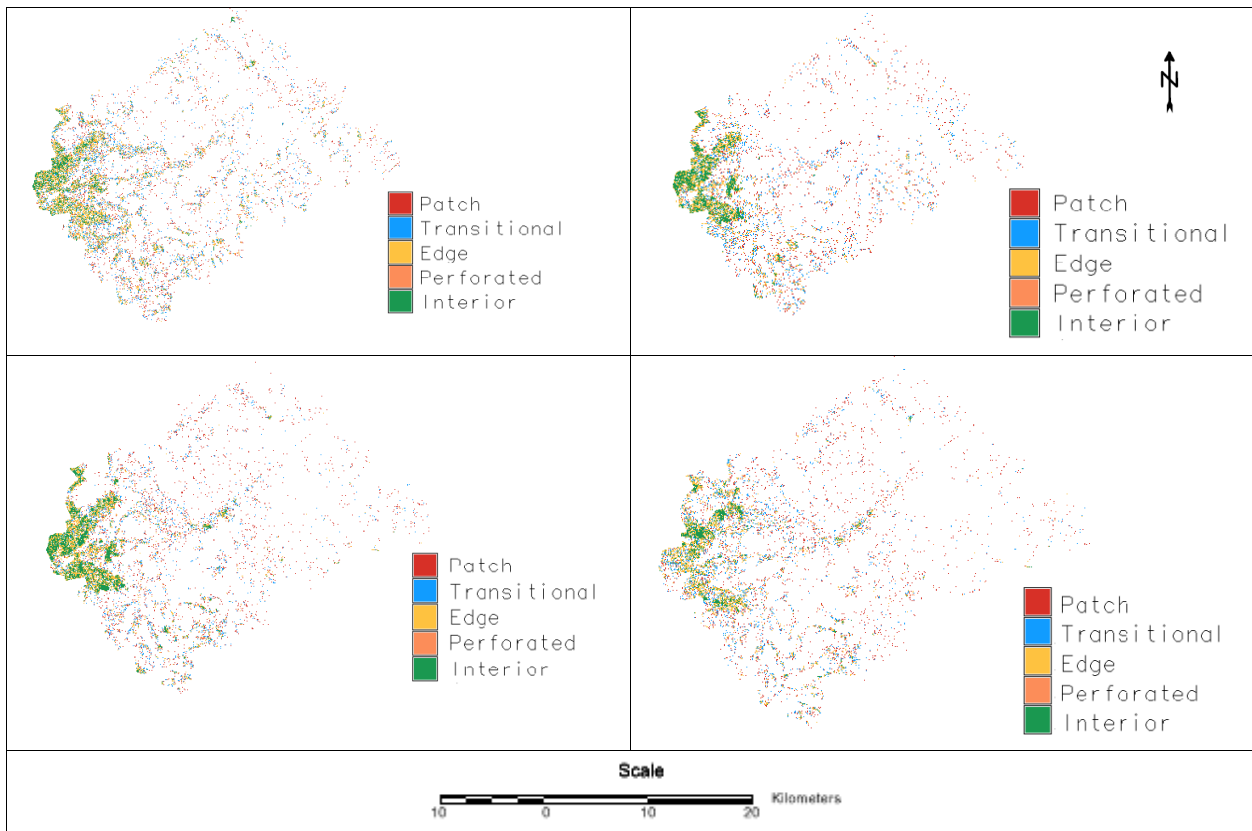


Figure 13: Spatial extent of forest fragmentation in Kadur Taluk

Table 13: Extent of forest fragmentation in Kadur taluk during 1976 to 2009

KadurTaluk				
Types of fragmentation	1976	1991	2000	2009
Patch	19.76	23.83	22.92	27.43
Transitional	23.04	20.12	18.03	23.87
Edge	33.65	31.88	31.20	31.10
Perforated	7.81	2.54	3.31	4.22
Interior	15.74	21.64	24.55	13.37

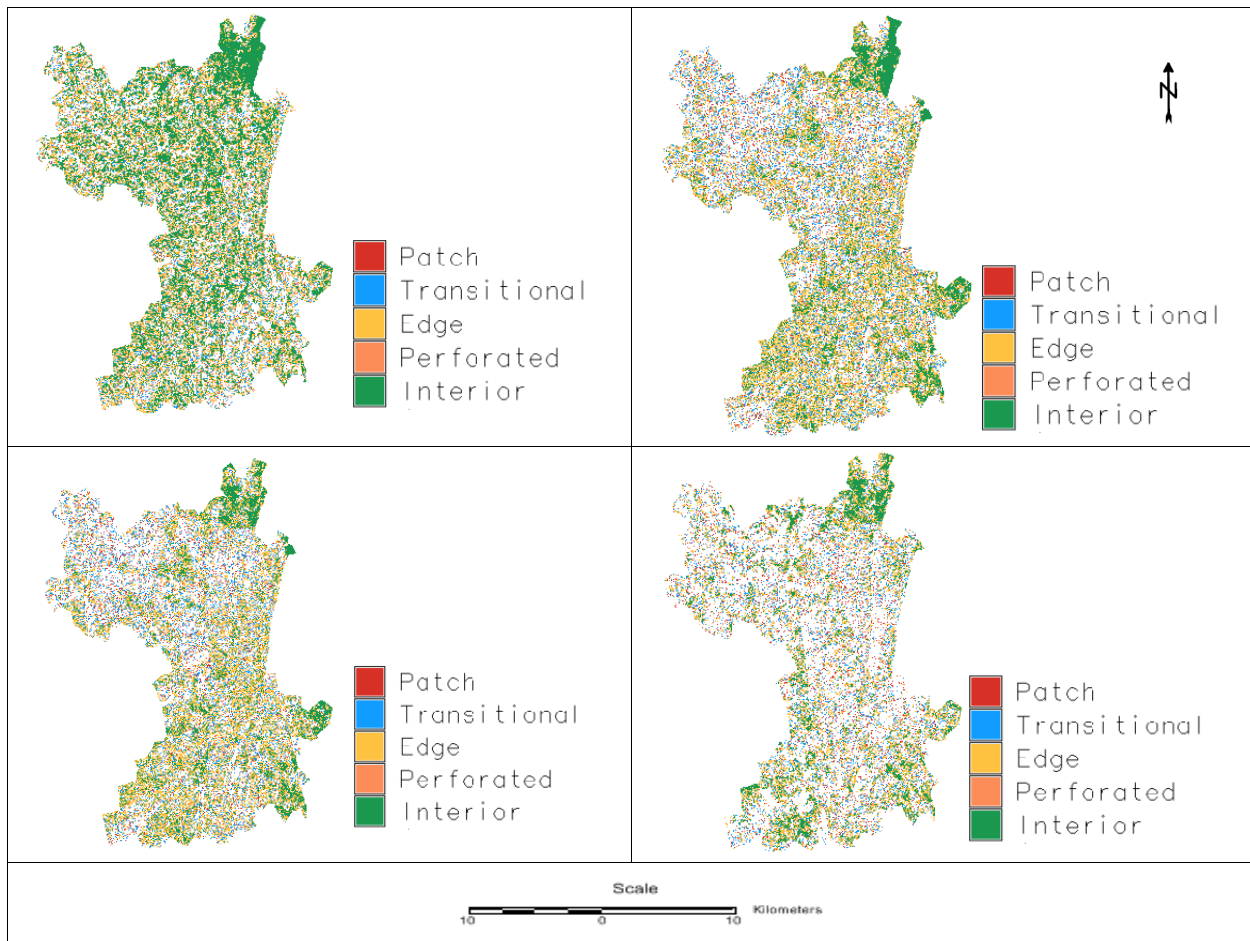


Figure 14: Spatial extent of forest fragmentation in Koppa Taluk

Table 14: Extent of forest fragmentation in Koppa taluk during 1976 to 2009

KoppaTaluk				
Types of fragmentation	1976	1991	2000	2009
Patch	1.31	7.15	8.13	10.46
Transitional	9.79	19.66	20.25	20.92

Edge	34.31	48.68	48.19	39.69
Perforated	9.51	2.90	2.97	6.10
Interior	45.09	21.61	20.46	22.83

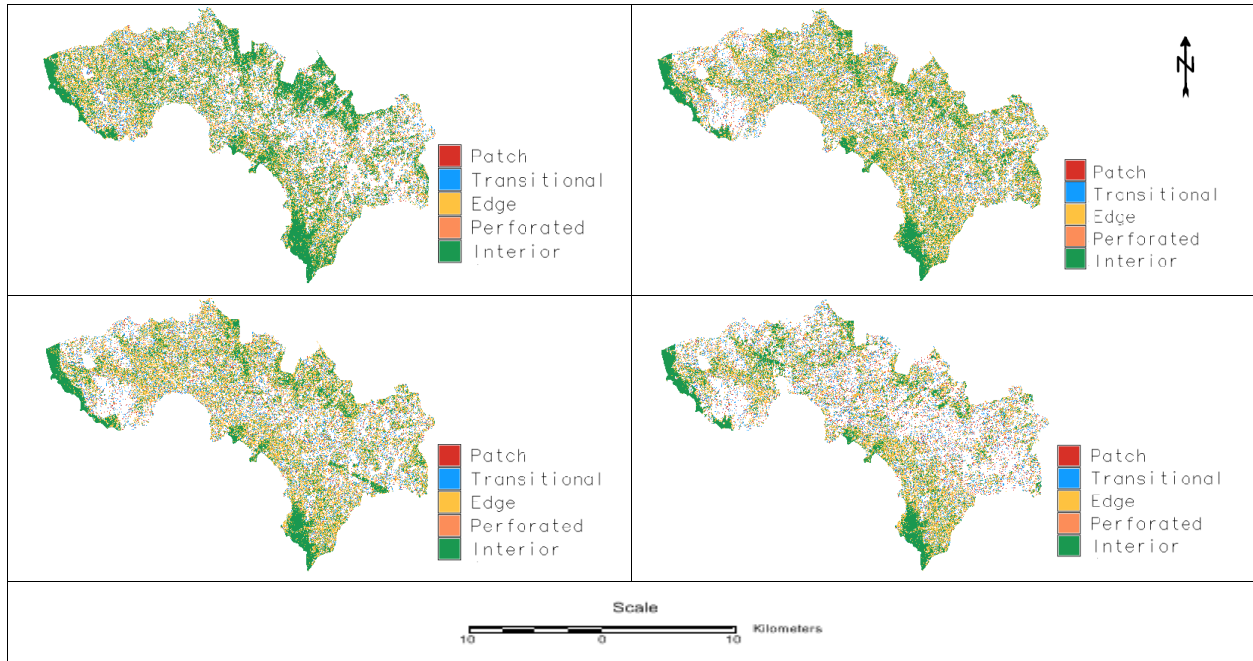


Figure 15: Spatial extent of forest fragmentation in Mudigere Taluk

Table 15: Extent of forest fragmentation in Mudigere taluk during 1976 to 2009

Mudigere Taluk				
Types of fragmentation	1976	1991	2000	2009
Patch	2.87	4.28	5.20	8.68
Transitional	11.82	14.29	15.55	17.86
Edge	38.03	48.95	47.96	42.45
Perforated	6.56	2.92	3.04	3.54
Interior	40.72	29.55	28.25	27.48

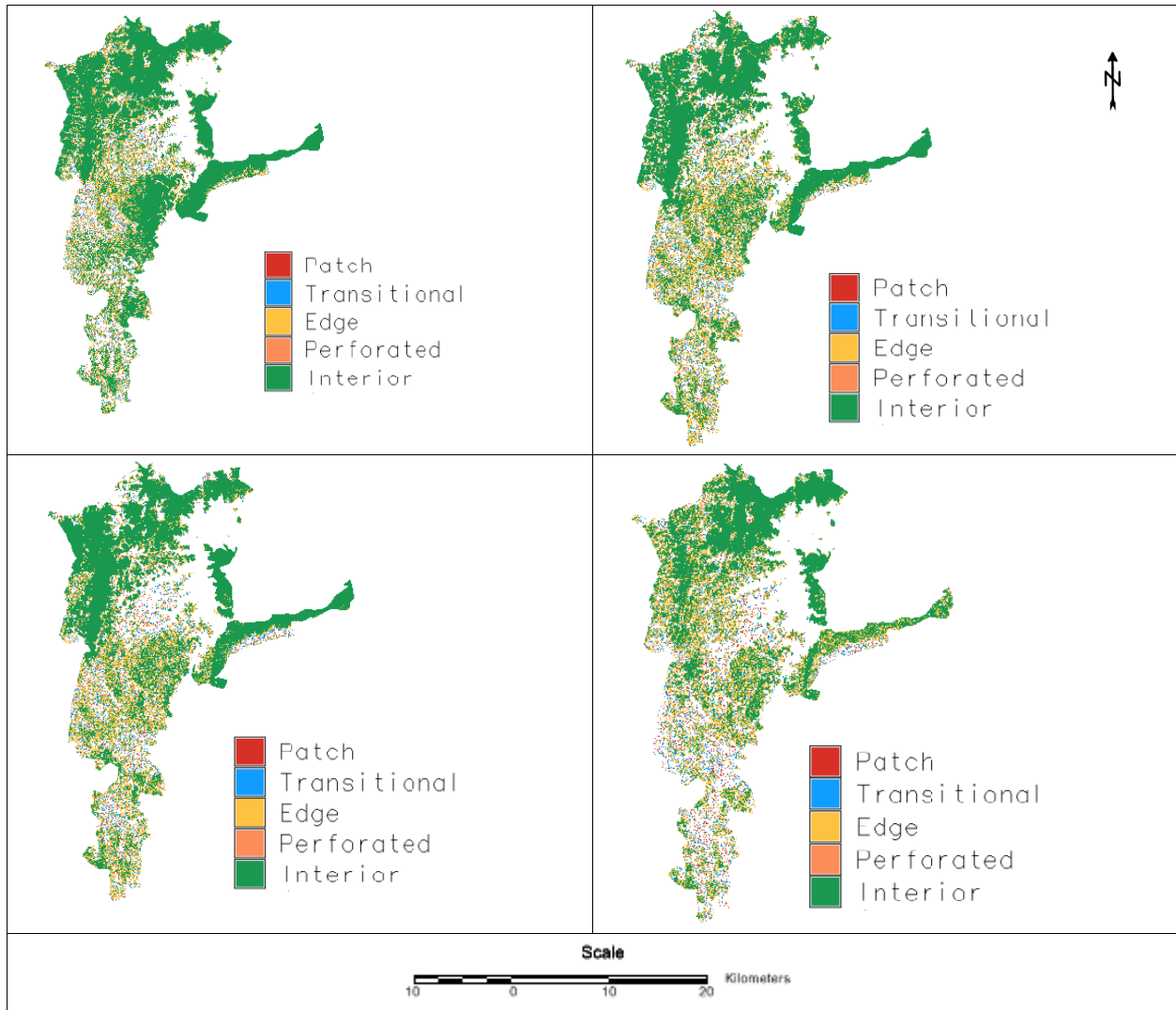


Figure 16: Spatial extent of forest fragmentation in Narasimharajapura Taluk

Table 16: Extent of forest fragmentation in Narasimharajapura taluk during 1976 to 2009

Narasimharajapura Taluk				
Types of fragmentation	1976	1991	2000	2009
Patch	1.05	1.64	1.93	3.08
Transitional	4.66	6.23	6.39	7.98
Edge	20.70	27.91	27.29	32.77
Perforated	2.55	1.96	1.60	1.91
Interior	71.03	62.27	62.78	54.27

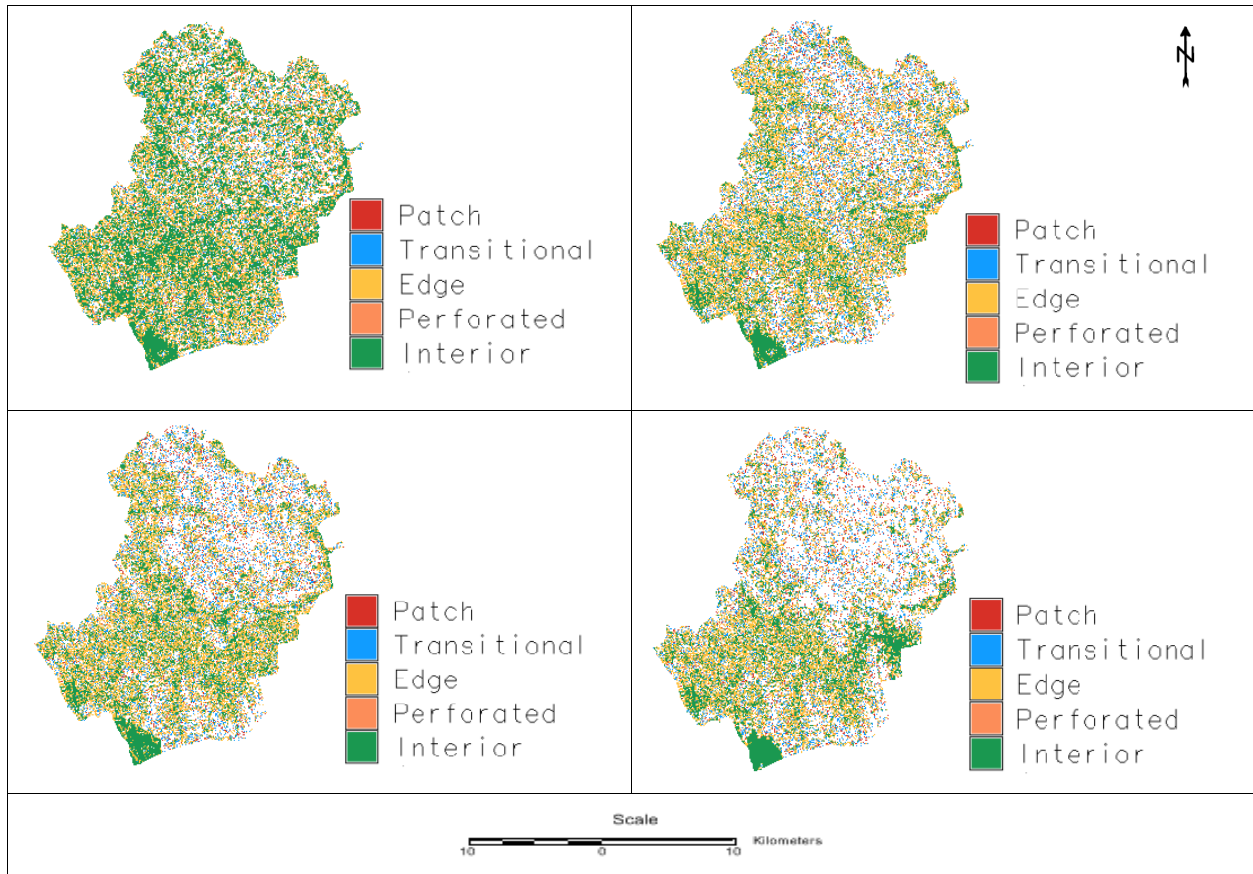
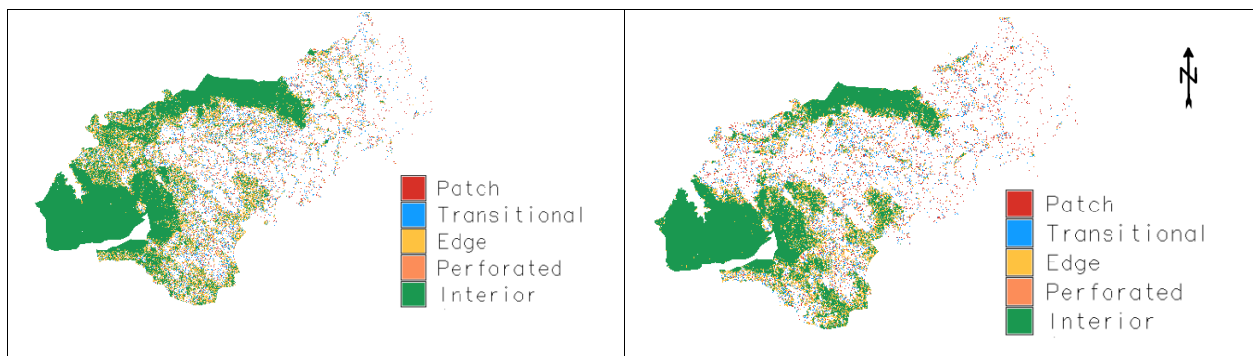


Figure 17: Spatial extent of forest fragmentation in Sringeri Taluk

Table 17: Extent of forest fragmentation in Sringeri Taluk during 1976 to 2009

Sringeri Taluk				
Types of fragmentation	1976	1991	2000	2009
Patch	0.88	5.17	5.56	6.45
Transitional	7.70	16.54	15.41	15.90
Edge	37.28	50.77	50.10	43.90
Perforated	7.28	3.33	2.91	5.21
Interior	46.87	24.20	26.02	28.55



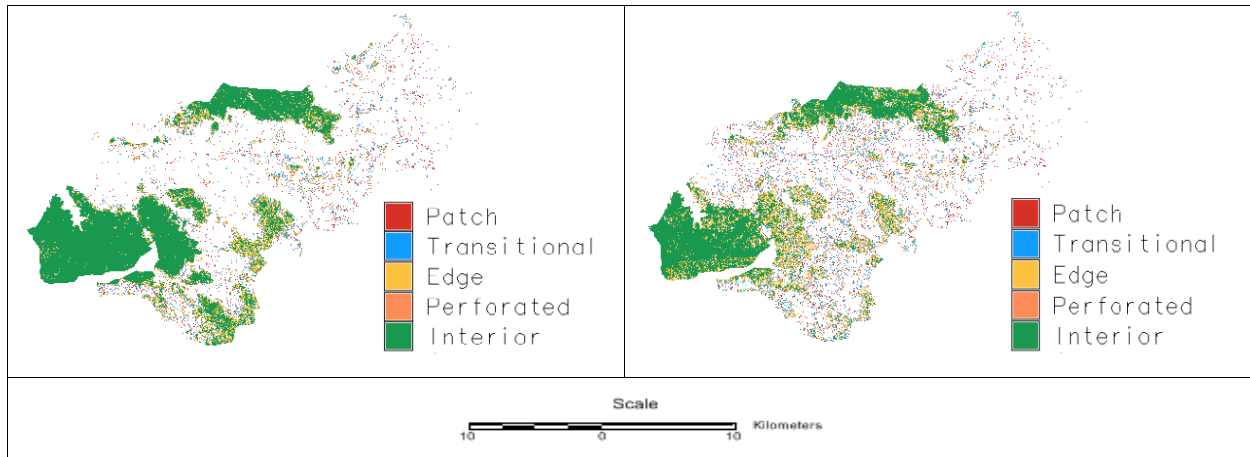


Figure 18: Spatial extent of forest fragmentation in Tarikere Taluk

Table 18: Extent of forest fragmentation in Tarikere taluk during 1976 to 2009

Tarikere Taluk				
Types of fragmentation	1976	1991	2000	2009
Patch	4.66	7.91	6.29	9.95
Transitional	8.73	9.30	6.63	12.36
Edge	22.73	21.66	16.87	27.16
Perforated	3.29	1.49	1.31	2.01
Interior	60.60	59.64	68.89	48.51

Temporal Land cover analysis emphasized the decline of forest cover from 96.62 (1976) to 93.60% (2009). Spatio-temporal land use analysis indicated the increase of built-up patches from 0.05 to 0.25% (2009). The results also showed the conversion of forest areas for agricultural and development activities which reflects the fragmentation of forest patches.

Forest fragmentation analysis showed the decline in interior forests from 1976 to 2009 and domination of edge and patch forest in all division. Land use changes from forests to non-forests with intensified human interference had been very high especially in Bhadravati and Chikmagalur division. Koppa showed more fragmented forest patches with increased edge and patch forest. The extent of interior forest declined in last few years in Kudhremukh National Park due to mining/ quarrying activities. Bhadra wild life Sanctuary also showed decline in forest cover.

Forest fragmentation analysis at taluk level showed increased decline in forests in Chikmagalur, Kadur, Sringeri taluk. Koppa and Narasimharajapura taluk with increased Transitional and Patch forests due to human alterations in between the forest areas. Decline of interior forest in Mudigere is due to mining activities. Tarikere taluk also showed degraded forests with time.

The Chikmagalur district forest consists of evergreen and semi-evergreen climax forests and their degradation types and deciduous climax forests and their degradation types (Pascal et.al, 1982). The evergreen and semi-evergreen climax forests and degradation type consists following categories: *Dipterocarpus indicus-Humboldia brunonis-Poeciloneuron indicum* type, *Dipterocarpus indicus-Diospyrus candolleana-Diospyros oocarpa* type, *Dipterocarpus indicus-Persea macrantha* type, *Persea macrantha-Diospyros spp.- Holigarna spp.* type, *Diospyros spp.-Dysoxylum malabaricum-Persea macrantha* Kan forest type of low elevation (0-850m) *Mesua ferrea-Palaquium ellipticum* type, *Palaquium ellipticum Poeciloneuron indicum-Hopea canarensis* type of medium elevation (800-1400 m) and *Schefflera spp.-Gordonia obtusa-Meliosma arnotiana* type. The secondary or degraded type contains secondary Evergreen, Semi-evergreen and moist deciduous forests. The Deciduous climax forests consist of moist deciduous type-*Lagerstoemia microcarpa-Tectona grandis Dillenia pentagyne* type and dry deciduous-*Anogeissus latifolia-Tectona grandis-Terminalia tomentosa* type (Figure 2). The areas of different types of forests are given in Table 19 and spatial distribution is given in Figure 19.

Table 19: Spatial extent of different classes of forests (Pascal et.al, 1982)

Forest Type	Area in Hectares
Evergreen Forest	3138.66
Semi-Evergreen Forest	3747.03
Evergreen and Semi-Evergreen Degraded Forest	42839.96
Moist Deciduous Forest	88723.98
Dry Deciduous Forest	52022.39
Dry Deciduous Shrubs	34185.53
Degraded Shrubs	57211.47
Total	281869.02

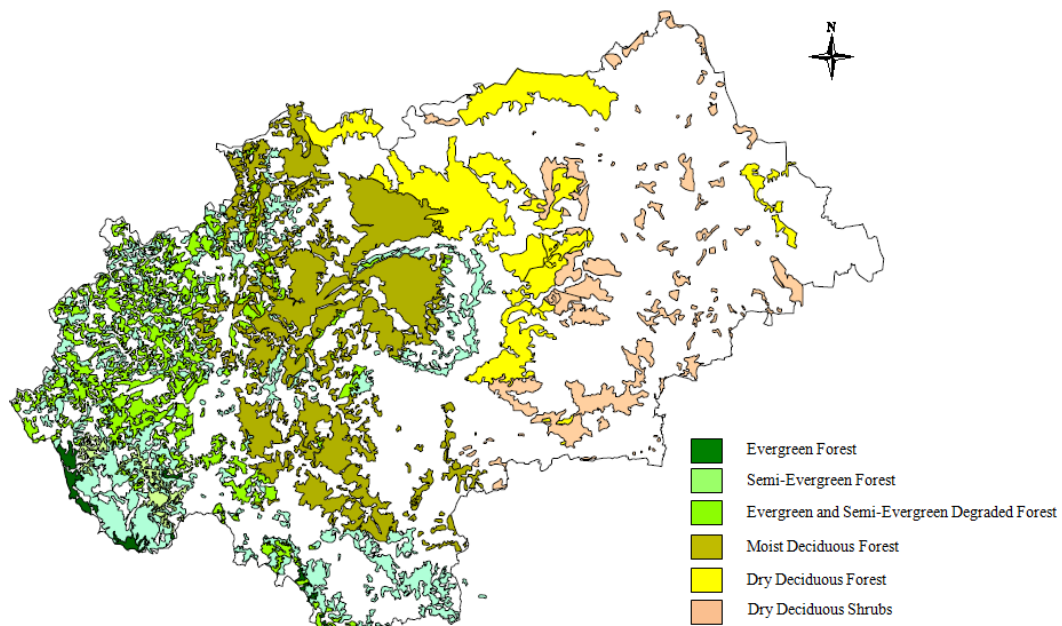


Figure 19: Forest types in the district (Source: Pascal et.al, 1982)

According to Champion (1936), the area falls under the category “Western tropical evergreen”.

The vegetation broadly falls into 4 types (Figure 20):

- Dry deciduous hill type
- Moist deciduous type
- The Evergreen type and
- The Sholas and Grassland type

Dry deciduous hill type: This type of forests is characteristic around hills of lower elevations (below 750 m) where the annual rainfall ranges from 160-200 cm. It is seen around some parts of forests of Charmadi Ghats, Muthodi, Mudigere, Hebbegiri, Kigga, Narasimharajapura and Bhadra Sanctuary. The tree species of this type of forests are *Albizia lebeck*, *Anogeissus latifolia*, *Bridelia retusa*, *Cassia fistula*, *Diospyros montana*, *Grewia tiliifolia*, *Mitragyna parviflora*, *Terminalia arjuna*, *Terminalia bellirica*, *Terminalia paniculata*. The shrubs of this region are *Flacourtia indica*, *Maytenus heyneana*, *Ziziphus oenoplia* and *Ziziphus xylopyrus*.

Moist deciduous type: These are found in regions where the altitude ranges from 600-1200 m and rainfall from 200 to 300 cm. They are seen in certain parts of forests of Charmadi Ghats, Muthodi, Bhadra Sanctuary, Sringeri, Aldur, Balehonnur, Mudigere and Kigga. Trees like *Anogeissus latifolia*, *Dalbergia*, *Pterocarpus marsupium*, *Antidesma diandrum*, *Erinocarpus nimmonii*, *Grewia hirsuta*, *Kydia calycina*, *Nothapodytes foetida*, *Oroxylum indicum*, *Sterculia guttata* and *Stereospermum personatum* occur here.

Evergreen type: These forests are common around the hills and valleys of Charmadi Ghat, Bhyrapura, Samse, Gagamula, Bhagavathi and Kemmangundi where the altitude ranges from 500 to 1500m and the rainfall ranges from 250-450cm. The layers or tiers of vegetation, each with its characteristic floral composition can be recognized depending upon the height attained by mature trees:

a) *Top layer or the emergent layer (30-40 m tall):* Trees like *Artocarpus hirsutus*, *Chukrasia tabularis*, *Elaeocarpus tuberculatus*, , *Hopea parviflora*, *Mesua nagassarium*, *Mimusops elengi* and *Vateria indica* are found here usually covered with epiphytic orchids, aroids and ferns.

b) *Canopy layer (15 to 25 m tall)*: This layer comprises of medium sized trees which adapt themselves to the more shady condition forming a second storey. Some of the important trees include *Abarema bigemina*, *Bischofia javanica*, *Garcinia morella*, *Humboldtia brunonis*, *Meliosma simplifolia*, *Microtropis latifolia*, *Myristica dactyloides* and *Sapindus laurifolia*.

c) *Sub-canopy layer or third layer (3-10 m tall)*: Innumerable woody shrubs and small trees form this layer such as *Agrostistachys indica*, *Allophylus serratus*, *Antidesma menasu*, *Apodytes dimidiata*, *Beilschmiedia wightii*, *Callicarpa tomentosa*, *Celastrus paniculatus*, *Cinnamomum zeylanicum*, *Euonymous angulatus*, *Macaranga indica*, *Madhuca neriifolia*, *Mallotus tetracoccus*, and *Microcos paniculata*.

d) *Ground layer*: The vegetation where the light can enter is thick formed by a dense carpet of herbs and shrubs including ferns. The herbs are *Adenosma capitatum*, *Aeginetia indica*, *Apama siliquosa*, *Asystasia chelonoides*, *Begonia malabarica*, *Curcuma aromatica*, *Elatostemma lineolatum*, *Rauvolfia serpentina* etc.

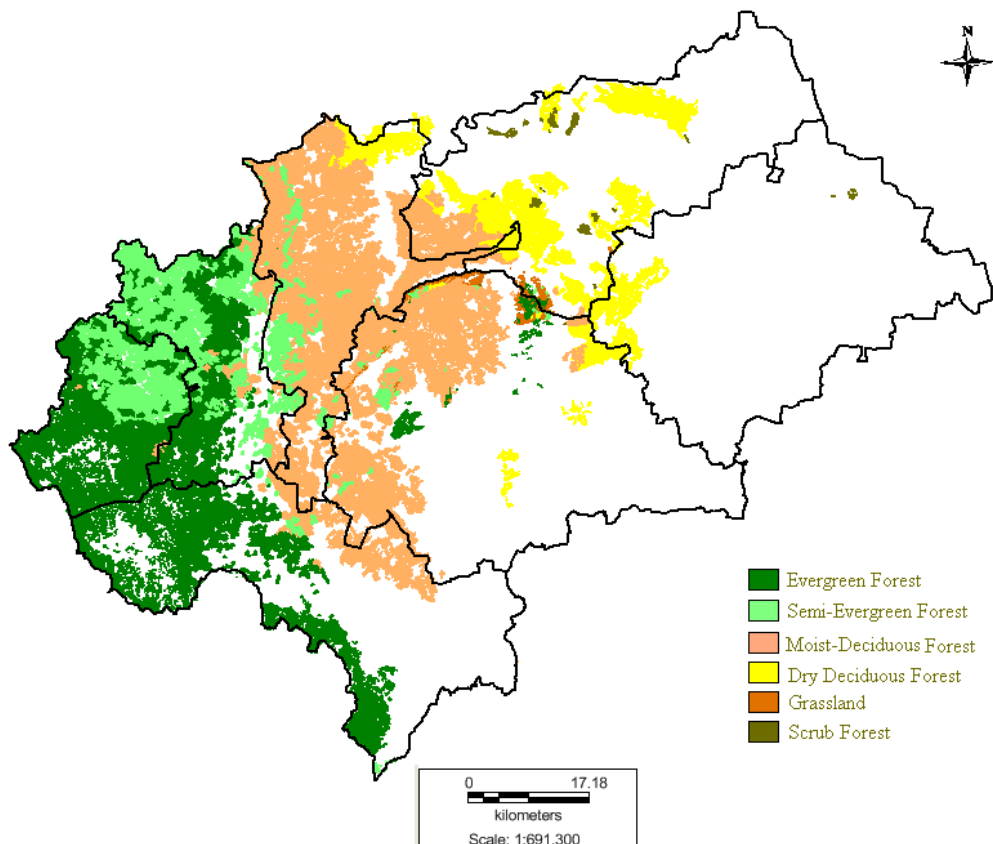


Figure 20: Vegetation distribution of Chikmagalur district (classification as per Champion and Seth, 1968)

Chikmagalur hosts a high degree of evergreen to semi-evergreen forests in malnad part and deciduous forests on the lower rainfall eastern plains. Field surveys and secondary literature of forest flora revealed presence of 710 species of plants from 125 families. Trees had total of 244 species, shrubs with 158, herbs 248 and climbers with 60 species (Figure 21).

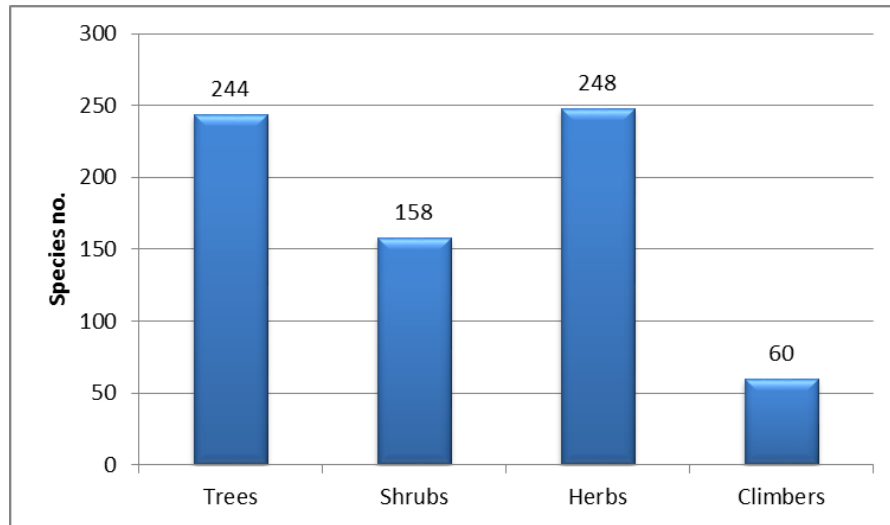


Figure 21: Habit wise distribution of species number

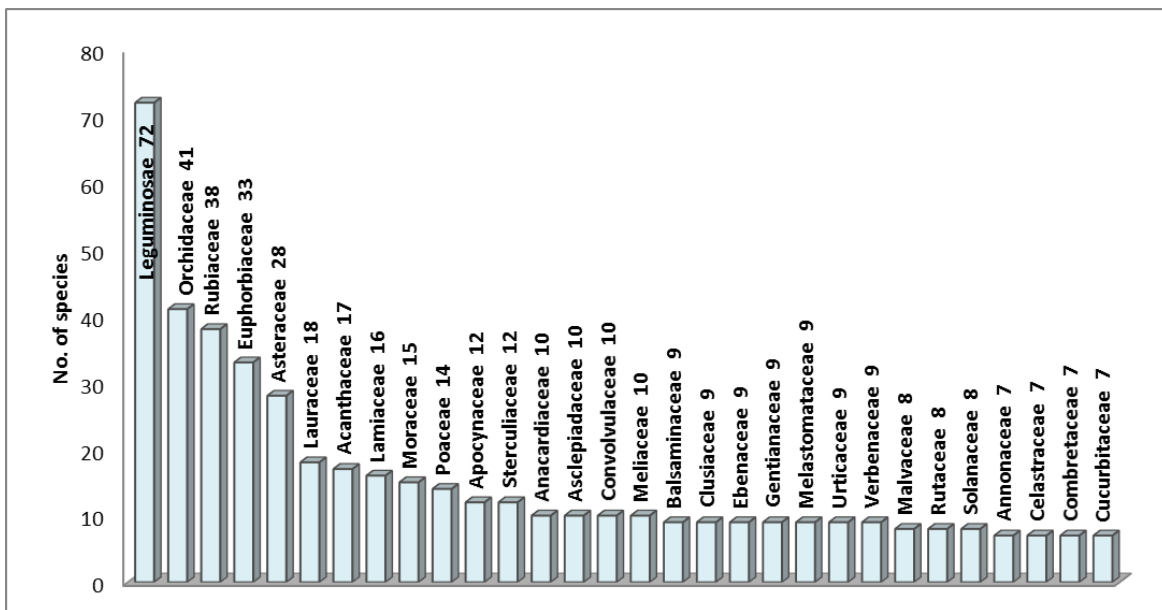


Figure 22: Family wise species richness of first highest 30 families.

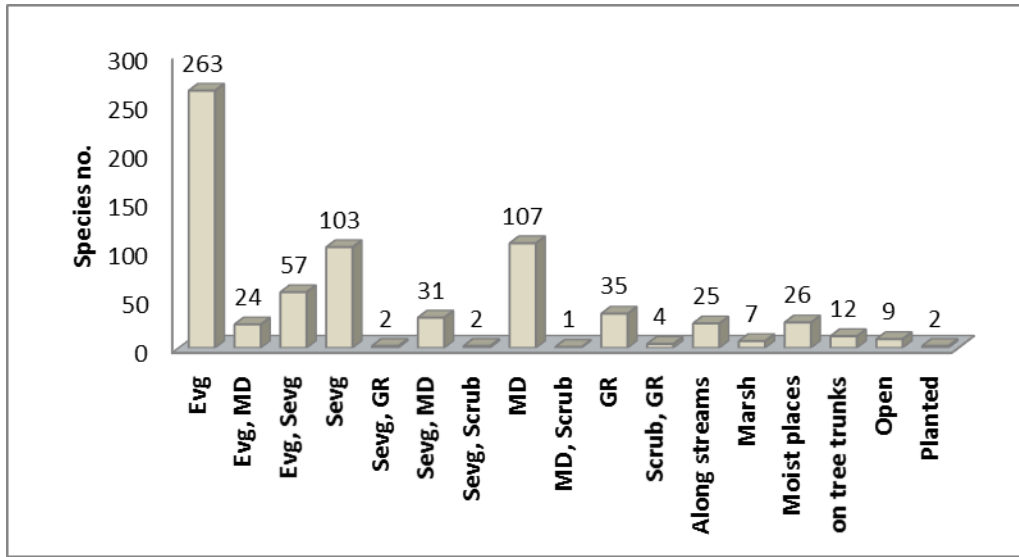


Figure 23: Habitat wise species distribution (Evg-Evergreen, Sevg-Semi-evergreen, MD-Moist deciduous, GR-Grassland).

Champion and Seth (1968) classified the vegetation of the Upper Plains (above 1700 m) in the Western Ghats covers numerous, isolated, sharply defined and small woods of stunted evergreen trees as ‘Southern Montane Wet Temperate Forests.’ (Known as sholas) surrounded by ‘montane wet grasslands’. The shola forests actually represent continuation of the evergreen forests in response to elevational gradient, the sequence being: Wet Evergreen Forests - Subtropical Hill Forests - Montane Wet Temperate Forests (Meher-Homji, 1986; Ranganathan, 1938). The sholas simply are natural patches of evergreens confined to valleys, hollows and depressions of the mountains, separated by rolling grasslands (Davidar et al., 2007). ‘Shola’ might have come from ‘chola’ which signifies the dark shades of the thick stunted forest or a small or large stream that emerges from the floor of the forest, flowing down to the valleys (Kunchikrishnan, personal communication).

The montane habitats that occur on hill ranges between 1,400 and 2,400 m are generally accepted as Shola habitats by many. These are a natural mosaic of grasslands and forest patches in an undulating terrain, with forests in the valleys. These authors characterize sholas as found only on ‘sky island’ mountain-tops, isolated at a large geographical scale (Robin and Nandini, 2012). Within each one of these ‘islands’ the habitat is a natural complex of grasslands and forests (Suresh and Sukumar, 1999). The Anamalais, Nilgiris and Palnis are considered main strongholds of

genuine sholas by many. The Anamalais rise sharply as a vertical rock wall from the south of Palghat Gap and expands from the Nelliampathis to the Anamudi peak, which stands at 2695 m above msl forming the highest peak in the Indian peninsula. The Palani Hills are a mountain range in Tamil Nadu, an eastward extension of the Western Ghats ranges. The Palani Hills adjoin the high Anamalai range on the west, and extend east into the plains of Tamil Nadu, covering an area of 2,068 sq.km). The highest part of the range is in the southwest, and reaches 1,800-2,500 metres, which are the main locations of the shola-grassland ecosystems. The Nilgiri or blue mountains in the Tamil Nadu state, are a range of mountains rising abruptly from the north of the Palghat Gap with at least 24 peaks above 2,000 metres.

In Karnataka Sholas occur at medium elevation (1400-1800 m) mainly in Chikmagalur and Coorg districts. The highest point in Chikmagalur district, and for the whole of Karnataka is Mullayanagiri, part of Bababudan ranges at 1926 m. Kudremukh National Park in Chikmagalur can be considered as Karnataka's largest sholagrasslands. Highest point in Kudremukh is 1894 m. The rolling hills of Kudremukh and Bababudan ranges are covered with grasslands alternating with shola woods. The shola woods are rich in mosses, orchids and many other epiphytes. They are found mainly around Bababudangiri, Kudremukh, Gangamula, Kimmangundi and patches of Charmadi ghats.

The sholas may be considered as a dual climax of forests and grasslands. The shola forests of Western Ghats are dense and floristically rich with many endemic and rare species. The trees in the sholas form a continuous canopy usually not exceeding 10-15m. There is no marked differentiation into canopy layers. The tree bark is covered with lichens, orchids, mosses and climbers. The crowns are generally rounded and dense. As elevation increases, tree height in TMF reduces and leaf thickness and complexity in tree architecture increases. These forests are characterized by high levels of endemism driven by the limited availability of habitat (Bubb et al., 2004; Bunyan et al., 2012).

The tree vegetation in the true shola forests is dominated by members of Lauraceae and Symplocaceae (Robin and Nandini, 2012). Karnataka's sholas do have some domination by members of these families. At the generic/species level we find good number of shola specific trees of Lauraceae in the Chikmagalur sholas: eg. *Cinnammoum* spp. (mainly *C. malabathrum* and *C. sulphuratum*), *Litsea* spp (*L. glabrata* and *L. floribunda* – both present in Nilgiris and

Anamalais) and *Neolitsea* sp. *Symplocos gardneriana* of Symplocaceae, characteristic of Nilgiris and Anamalais has been reported from Bababudan shola forests. *S. villosa* has been reported for first time from Karnataka from Kerkeatte of Chikmagalur.

Some other typical high altitude shola trees of southern Western Ghats present in Chikmagalur are *Microtropis latifolia* and *M. stocksii* of Celastraceae, *Mastixia arborea*, a streamside tree of Cornaceae, *Elaeocarpus munronii* of Elaeocarpaceae, *Schefflera rostrata* of Araliaceae, *Glochidion neilgherrense* of Euphorbiaceae, *Hydnocarpus alpina* of Flacourtiaceae, *Noothapodytes nimmoniana* of Icacinaceae, *Michelia nilagirica* of Magnoliaceae, *Memecylon malabaricum* of melastomaceae, *Prunus ceylanica* of Rosaceae, *Meliosma pinnnata* and *M. simplicifolia* of Sabiaceae, *Salix tetrasperma* of Salicaceae, *Gordonia obtusa* of Theaceae etc. Among the true shola trees what seems to be strikingly absent in the Chikmagalur-coorg sholas are *Rhododendron arboreum* var. *nilagiricum*, *Mahonia leschenaultii* (Berberidaceae), *Rhodomyrtus tomentosa* of Myrtaceae etc.

Compared to the plains the sholas of Chikmagalur have several shrubs of Rosaceae which are also present in the cooler high altitude sholas of southern Western Ghats. These are notably *Rosa leschenaultiana*, *Rubus ellipticii* and *R. fockei*. Other typical shola shrubs are *Strobilanthus sessilis* of Acanthaceae, *Indigofera cassioides* and *Sophora wightii* of Fabaceae, *Hypericum mysorensense* of Hypericaceae, *Solanum denticulatum* and *S. indicum* of Solanaceae, *Vaccinium neilgherrense* of Vacciniaceae. Notable absence shrub level is *Berberis tinctoria*. Numerous herbs are common to the sholas of Karnataka and high altitude sholas-grasslands. These include *Heracleum candolleana* of Apiaceae, *Cardamine africana*, *C. trichocapra* of Brassicaceae, *Drosera bumanni* and *D. peltata* of Droseraceae, *Desmodium repandum* of Fabaceae, *Gentiana quadrifaria* of Gentianaceae, *Leucas marrubioides* and *teuucrium tomentosum* of Lamiaceae, *Lobelia nicotianifolia* of Lobeliaceae etc.

Vegetation succession in shola grasslands of Western Ghats is poorly understood, because of the short-term nature of most studies. Human activities have historically influenced these grasslands and will continue to do so in more intensive manner. Threats to these grasslands include habitat loss, fragmentation, fires, and invasive species (Thomas and Palmer, 2007). Many of Karnataka's sholas have more tropical forest elements than temperate/Himalayan elements unlike sholas of Nilgiris and Anamalais. *Rhododendron*, which can be considered the remains of a glacial age

surviving in the coolness of the high altitudes of southern Western Ghats. Nilgiri tahr (mountain goat) is yet another remarkable species whose close relatives are in the Himalayas. Members from some of the predominantly evergreen families of Western Ghats like Ebenaceae, found mainly in the plains and lower altitudes, are absent in the Nilgiri Anamalai sholas, but occur in the lesser altitude sholas of Karnataka, including Chikmagalur.

Diospyros saldanhae and *D. Montana* are instances of the same (Yoganarasimhan et al., 1981). Interestingly the pan-tropical genus *Diospyros* with 600 species is hardly represented in Europe and higher altitudes of Himalayas. Gradual isolation of the ancestral Ebenaceae is considered to have given rise to mainly high altitude shola families Theaceae, Symplocaceae, Ternstroemiaceae, Ericaceae etc. (Singh, 2005). Notably *Symplocos gradneriana* of Symplocaceae, reported from Bababudan sholas also occurs in Nilgiris and Anamalais. The high altitude sholas of Nilgiris and Anamalais have exclusive species such as *S. gardneriana*, *S. foliosa*, *S. microphylla*, *S. anamallayana*, *S. pendula* etc. (Gamble, 1921). *Gordonia obtusa* is the lone Theaceae species from Chikmagalur, a connecting link between still more higher altitude species (*Ternstroemia japonica* and the tea plant *Thea sinensis*). A comparative account of species of common occurrence in the sholas of Chikmagalur, Nilgiris and Anamalais is given in Table 4.1.

Table 4.1: Flowering plant taxa shared between sholas of Chikmagalur with those of Nilgiris and Anamalais

CHIKMAGALUR SHOLA/ GRASSLAND SPECIES	FAMILY	HABIT/HABITAT	PRESENCE (P) NILGIRI SHOLAS	PRESENCE (P) ANAMALAI SHOLAS
<i>Justicia simplex</i>	Acanthaceae	Herb; open places	P	P
<i>Strobilanthus sessilis-Bababudan</i>	Acanthaceae	Shrubs	P	P
<i>Heracleum candolleianum</i>	Apiaceae	Herb, in open	P	P
<i>Pimpinella</i>	Apiaceae	Herb, in open	P	P
<i>Schefflera rostrata</i>	Araliaceae	Tree; shola	P	P
<i>Ceropegia</i>	Asclepiadaceae	Herb	P (genus only)	P (genus only)
<i>Centrantherum</i>	Asteraceae	Herb	P (genus only)	P (genus only)
<i>Dichrocephala integrifolia</i>	Asteraceae	Herb; in the open	P, in downs	P, in downs
<i>Emilia sonchifolia</i>	Asteraceae	Herb; in open	P	P
<i>Erigeron</i>	Asteraceae	Herb	P (genus only)	P (genus only)
<i>Galinsongaparviflora</i>	Asteraceae	Herb	P, weed	
<i>Gnaphalium</i>	Asteraceae	Herb, open	P (genus only)	P (genus only)
<i>Launaea acaulis</i>	Asteraceae	Herb	P	-
<i>Vernonia</i>	Asteraceae	Shrub/tree	P (genus only)	P (genus only)
<i>Impatiens chinensis</i>	Balsaminaceae	Herb; moist slopes	P	P

<i>Cardamineafricana</i>	Brassicaceae	Succulent herb, marshy places >1200m	P	P
<i>Cardaminetrichocarpa</i>	Brassicaceae	Herb in high alti. rocky places	P	P
<i>Celastruspaniculatus</i>	Celastraceae	Woody climber	P (low alt)	P (low alt)
<i>Microtropislatifolia</i>	Celastraceae	Shrub/small tree	P	P
<i>Microtropisstocksii</i>	Celastraceae	Tree	P	P
<i>Cassia mimosoides</i>	Caesalpiniaceae	Amidst grasses, shaded roadsides	-	P
<i>Commelina</i>	Commelinaceae	Herb	P (genus only)	P (genus only)
<i>Mastixiaarborea</i>	Cornaceae	Tree	P	P
<i>Zehneriamaysorensis</i>	Cucurbitaceae	Climbibg herb	P	P
<i>Fimbristylis</i>	Cyperaceae	Herb	P (genus only)	P (genus only)
<i>Kyllinga</i>	Cyperaceae	Herb	P (genus only)	P (genus only)
<i>Droseraburmanni</i>	Droseraceae	Herb	P	P
<i>Droserapeltata</i>	Droseraceae	Herb	P	P
<i>Elaeocarpusserratus</i>	Elaeocarpaceae	Tree	P (low alt)	P (low alt)
<i>Elaeocarpusmunronii</i>	Elaeocarpaceae	Tree	P	P
<i>Elaegnuskologa</i>	Elaegnaceae	Straggler, in sholas	P	P
<i>Eriocaulon</i>	Eriocaulaceae	Herb, wet places	P (genus only)	P (genus only)
<i>Euphorbia laeta</i>	Euphorbiaceae	Herb	P	P
<i>Glochidioneilgherrense</i>	Euphorbiaceae	Tree	P	P
<i>Glochidionvelutinum</i>	Euphorbiaceae	Tree	P (low alt)	P (low alt)
<i>Phyllanthus simplex</i>	Euphorbiaceae	Herb	P	P
<i>Crotalaria albida</i>	Fabaceae	Herb	-	P
<i>Crotalaria calycina</i>	Fabaceae	Herb	-	P
<i>Crotalaria leischenaultii</i>	Fabaceae	Herb	P	P
<i>Desmodiumrepandum</i>	Fabaceae	Herb; moist slopes	P	P
<i>Flemingea</i>	Fabaceae	Herb	P (genus only)	P (genus only)
<i>Indigoferacassiooides</i>	Fabaceae	Shrub, open places	P	P
<i>Sophorawightii</i>	Fabaceae	Shrub/tree	P	P (low alt)
<i>Hydnocarpusalpina</i>	Flacourtiaceae	Tree	P	P
<i>Gentianaquadrifaria</i>	Gentianaceae	Herb, grassland	P	-
<i>Aeschynanthusperottetii</i>	Gesneriaceae	Epiphyte, shrub	P	P
<i>Ophiopogonintermedius</i>	Haemodoraceae	Herb	P	P
<i>Hydrocotylenepalensis</i>	Hydrocotylaceae	Herb; moist places	P	P
<i>Hpericummysureense</i>	Hypericaceae	Shrub; open areas	P	P
<i>Nothapodytesfoetida</i>	Icacinaceae	Tree; sholas	P	P
<i>Juncus</i>	Juncaceae	Herb	P (genus only)	P (genus only)
<i>Leucasmarrubioides</i>	Lamiaceae	Herb	P	P
<i>Plectranthus</i>	Lamiaceae	Herb	P (genus only)	P (genus only)
<i>Pogostemon</i>	Lamiaceae	Herb	P (genus only)	P (genus only)
<i>Teucriumtomentosum</i>	Lamiaceae	Herb	P	P
<i>Cinnamomum spp.</i>	Lauraceae	Tree	P (genus only)	P (genus only)
<i>Cinnamomummalabathrum</i>	Lauraceae	Tree		
<i>Litsea floribunda</i>	Lauraceae	Tree	P	P

<i>Litsea glabrata</i>	Lauraceae	Tree	P	P
<i>Neolitsea</i>	Lauraceae	Tree	P (genus only)	P (genus only)
<i>Chlorophytum</i>	Liliaceae	Herb	P (genus only)	P (genus only)
<i>Curculigo orchiooides</i>	Liliaceae	Herb; damp places	P	P
<i>Lobelia nicotianifolia</i>	Lobeliaceae	Herb	P	P
<i>Gardneria ovata</i>	Loganiaceae	Shrub, scandant; shola	P	-
<i>Macrosolen parasiticus</i>	Loranthaceae	Shrub; parasite	P	P
<i>Michelia nilagirica</i>	Magnoliaceae	Tree	P	P
<i>Abelmoschus angulosus</i>	Malvaceae	Herb; moist rocky slopes, shola edges	P	P
<i>Memecylon malabaricum</i>	Melastomaceae	Shrub/small tree	P	P
<i>Osbeckia</i>	Melastomaceae	Herb	P (genus only)	P (genus only)
<i>Maesa indica</i>	Myrsinaceae	Tree; lower sholas	P	P
<i>Jasminum</i>	Oleaceae	Climber	P (genus only)	P (genus only)
<i>Linociera</i>	Oleaceae	Tree	P (genus only)	P (genus only)
<i>Bulbophyllum proudlockii</i>	Orchidaceae	Epiphytic herb	P	-
<i>Coelogyne breviscapa</i>	Orchidaceae	Epiphytic herb	P	-
<i>Disperis zeylanica</i>	Orchidaceae	Herb, terrestrial	P	-
<i>Eulophia</i>	Orchidaceae	Herb	P (genus only)	P (genus only)
<i>Habenaria heyneana</i>	Orchidaceae	Herb, grassland	P	P
<i>Habenaria longicorniculata</i>	Orchidaceae	Herb, terrestrial	P (low alt)	P (low alt)
<i>Malaxis versicolor</i>	Orchidaceae	Herb; terrestrial/epiphytic	P	P
<i>Oberonia brunoniana</i>	Orchidaceae	Epiphytic herb	P	P
<i>Passiflora calcarata</i>	Passifloraceae	Slender climber	P (garden escape)	P (garden escape)
<i>Peperomia</i>	Piperaceae	Herb	P (genus only)	P (genus only)
<i>Piper</i>	Piperaceae	Climber	P	P
<i>Pittosporum neelgherrense</i>	Pittosporaceae	Tree	P (low alt)	P (low alt)
<i>Plantago asiatica</i>	Plantaginaceae	Herb, weedy sp	P	P
<i>Chrysopogon</i>	Poaceae	Herb, grass	P (genus only)	P (genus only)
<i>Eragrostis unioloides</i>	Poaceae	Herb, open areas	P	
<i>Heteropogon contortus</i>	Poaceae	Herb, grassland	P	P
<i>Polygala</i>	Polygalaceae	Herb	P (genus only)	P (genus only)
<i>Polygonum chinense</i>	Polygonaceae	Herb	P (genus only)	P (genus only)
<i>Clematis</i>	Ranunculaceae	Climber	P (genus only)	P (genus only)
<i>Prunus ceylanica</i>	Rosaceae	Tree	P	P
<i>Rosa leschenaultiana</i>	Rosaceae	Shrub	P	P
<i>Rubus ellipticus</i>	Rosaceae	Shrub	P	P
<i>Rubus fockei</i>	Rosaceae	Shrub	P	P
<i>Knoxia wightiana</i>	Rubiaceae	Herb	P	P
<i>Lasianthus</i>	Rubiaceae	Herb	P	P
<i>Ophiorrhiza brunonis</i>	Rubiaceae	Herb	P	
<i>Pavetta</i>	Rubiaceae	Shrub	P (genus only)	P (genus only)
<i>Acronychia laurifolia</i>	Rutaceae	Tree	P (shola outskirts)	P
<i>Meliosma pinnata</i>	Sabiaceae	Tree	P	P

<i>Meliosmasimplicifolia</i>	Sabiaceae	Tree	P	P
<i>Salix tetrasperma</i>	Salicaceae	Tree	P	P
<i>Allophyluscobbe</i>	Sapindaceae	Shrub		
<i>Parnassiamysorensis-</i>	Saxifragaceae	Herb	P	P
<i>Datura</i>	Solanaceae	Shrub	P (genus only)	P (genus only)
<i>Solanumdenticulatum</i>	Solanaceae	Shrub	P	P
<i>Solanumindicum</i>	Solanaceae	Shrub	P	P
<i>Symplocosgardneriana-bababudan</i>	Symplocaceae	Tree	P	P
<i>Symplocosvillosa-</i>	Symplocaceae			
<i>Gordonia obtuse</i>	Theaceae	Tree	P	P
<i>Gnidiaglauca</i>	Thymeliaceae	Tree; in lower sholas	P	P
<i>Celtiscinnamomea</i>	Ulmaceae	Tree	P (low alt)	-
<i>Elatostemmalineolatum</i>	Urticaceae	Herb; damp, shaded	P	P
<i>Elatostemmasurculosum</i>	Urticaceae	Herb, damp, shaded	P	P
<i>Vacciniumneilgherrense</i>	Vacciniaceae	Shrub	P	P
<i>Curcuma neilgherrensis</i>	Zingiberaceae	Herb; grasslands; near river	P	-

Shola forests are of high ecological significance in protecting head waters of rivers. Every shola gives rise to a spring; such springs are main contributors for Karnataka's rivers like Tunga, Bhadra, Nethravathi, Kumaradhara and Kaveri. Shola forests have high percentage of endemism of Western Ghats. About 30% of the species in the Palani hills are endemic to Western Ghats (Somasundaram and Vijayan, 2010). There is also high percentage of bird endemism (20-23%) in the shola forests, as bird endemism of the Western Ghats as such is much lower (Nameer, 2001). Sholas have also high amount of amphibian diversity (Inger et al., 1987).

Shola fragments contain species of both tropical and temperate affinities. The grasslands of the Western Ghats, according to Karunakaran et al. (1998), show more biogeographic similarity with Western Himalayan species than TMF in Sri Lanka. Typically temperate genera of sholas are *Eurya*, *Daphiphyllum* and *Rubus*. Sub-tropical elements are: *Rhododendron*, *Berberis* and *Mahonia* of Himalayan origin. Of Indo-Malayan origin are families of flowering plants Lauraceae, Rubiaceae, Symplocaceae, Myrtaceae, Myrsinaceae and Oleaceae while dicotyledonous understorey species are dominated by Asteraceae, Fabaceae and Acanthaceae

Conservation: Sholas and grasslands of Karnataka have been subjected to relentless developmental pressures. Mining in Kudremukh and Kemmangundi created severe havoc on this mountain top ecosystem. Coffee and tea cultivation had already taken heavy toll on shola vegetation. Mining areas are afflicted with severe forms of soil erosion and siltation of water bodies. Continuity of the shola forests is at stake as an estimated 50% of such forests have been lost from the Western Ghats since 1850 (Sukumar et al. 1995). Acacias, Eucalyptus and pines were introduced in the South Indian sholas over a century ago creating substantial replacement of native flora of shola-grassland

complexes. The non-regenerating and fast receding shola community is called 'living fossil' community (Vishnu-Mittre and Gupta, 1968).

Kumara and Sinha (2009) encountered 24 groups of the endangered primate Lion-tailed Macaque having total population of 378 individuals inhabiting Kudremukh NP and Someshwara WLS.

Praveen and Kuriakose (2006) sighted the Near Threatened Black and Orange Flycatcher *Ficedula nigrorufa*, endemic to the shola forests of southern Western Ghats, a range extension of the bird to Kudremukh and Bababudangiri ranges in Chikmagalur.

Rhacophorus lateralis, an endangered tree frog reported from isolated pockets of southern Western Ghats was reported as occurring in the vicinity of Kudremukh NPP (Dinesh et al., 2010).

Dinesh et al. (2008) discovered a new species of endemic frog called wrinkled night frog *Nyctobatrachus dattatreyaensis* from shola streams of Bababudan range. It is one among the 16 nominal species from the world. Dinesh et al (2007) discovered a new species of frog *Nyctibatrachus karnatakensis* from a torrential stream in Kudremukh NP.

Sholas are in urgent need of conservation. Shola recovery into their potential zones, if they are degraded by anthropogenic activities, except perhaps farming, is essential. Corridors between shola patches should be carefully re-established through selection of appropriate species. Fire control in the adjoining grasslands is essential until the shola species establish successfully.

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