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Sustainable Forest Management for Hiriyur Taluk of Karnataka State, India through Geospatial Mapping

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Abstract: Forest is one among the major resources that takes crucial role in sustaining ecological equilibrium and environmental system that earned great importance in national and international level policies implementations. Forests are the large area dominated by medicinal plants, timber, agricultural implements, carts & accessories, aromatic, oil yielding, fodder, dye, resin, flavoring agents, vegetables, pulses, fruits, and others products. Hiriyur forest lands are classified into dense & open deciduous, forest plantations and scrub forests zones that are mapped and digitized by Survey of India topomaps (1975 & 2009); IRS LISS-III (2001 & 2005) and Sentineal-2A satellite images (2019) in ArcGIS software. Satellite images portray meaningful and valuable data in identifying the changes and real factors of forest degradation. Supervised classification techniques using maximum likelihood algorithm are considered to achieve best results as final output maps. Geospatial approach is a powerful tool in adding immense value for governance policies, empower sustainable development goals, serve in better business-action plans by timely observation of forest resources and its sustainability.

Keywords: Forest management; Change Detection Analysis; Hiriyur; Geospatial mapping.

I. INTRODUCTION

Forests green blankets are naturally protecting the hill environment and preserving the natural resources. About 30% of land in India was covered with forests at the beginning of the 20th century, but it was reduced to 21.34% by the end of 2015. In 2015, of the existing forests, about 2.61% are very dense forests (canopy cover 70% or more), 9.59% moderately dense forests (canopy cover 40% or more but less than 70%), 9.14% open forests (canopy cover 10% or more but less than 40%), and 1.26% scrub forests (canopy cover less than 10%) (FSI 2015). An average of 1,200 acres of forest lands are being degraded for every twenty minutes worldwide (Conservation International, 2000) and analyzing the real factors are much necessary task for forest conservation. Assessing the types of forest covers and its change detection is a difficult task and time-consuming process for manual survey due to its rugged topography. High spatial, spectral and temporal capabilities of Remote Sensing satellite data allow superimpose of two period maps effectively in mapping of human forces that impacting the forest degradation (Jessica et al., 2001). Any changes on forest cover can be precisely calculated in GIS environment. Increase in thick vegetation forested lands had contributed to high rainfall conditions; whereas the decrease in vegetation cover has direct impact on socio-economic status of any country and gradually depletes the earth's oxygen supply (Murali, 2002).

Hiriyur taluk is characterized by huge undulating plains and is part of Eastern Ghats runs from the west of Hiriyur continue upto Chitradurga. Eastern Ghats Prominent hill ranges are Uttare chain of hills with an altitude of 3,675 ft near Marikanive and the other one is Hiduskatte chain of hills with an altitude of 2,904 ft. Vanivilas Sagar or Marikanive Reservoir is located in the Western part of the taluk and built across Vedavathi River that drains major parts of the taluk. It is the oldest dam in Karnataka built by Sir M.Vishweshvaraiah. It irrigates more than 100 km^2 area through right and left bank canals and also being the source of domestic water within the taluk. Extensive soil erosion, landslides, overgrazing, deforestation, overexploitation of forest resources, road constructions within the forest boundaries, forest fires and others are the major threats of forest degradation recorded throughout the world (Dobhal 1987, NRSA 1998, Congalton et al. 1983). Deforestation has many ecological, social and economic consequences, one of which is the loss

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of biological diversity and has affected a number of species worldwide (Ciesla 1989). Conservation priority has given most to certain habitats of tropical evergreen forests, but other such as scrub, deciduous forests and rocky outcrops are usually neglected. Protection and management of degraded forests through community participation is a major thrust area of the State Forest Department besides bio-diversity conservation and eco-tourism.

II. METHODOLOGY

2.1 Study Area: It lies in between $13^0$40' to $14^0$12' N latitude and $76^0$26' to $76^0$57' E longitude with an aerial extent of 1705.63 km^2 (Fig.1). The taluk enjoys arid climate of hot weather falling under Central Dry agro-climatic zone (CGWB, 2017). It's a part of drought zone with temperature ranging from 21^0 to 32^0C (CGWB, 2017) with an average elevation of 630m above MSL (CGEB, 2017). Most of the rainfall is received during SW monsoon (June to Oct) of 593mm (CGWB, 2017). 80% of the population is depending upon rainfall as a source for their agricultural practices. The principal crops grown are Jowar, Sunflower and Groundnut and major crops of cereals, pulses and oil seeds grown during Rabi season (CGWB, 2017).

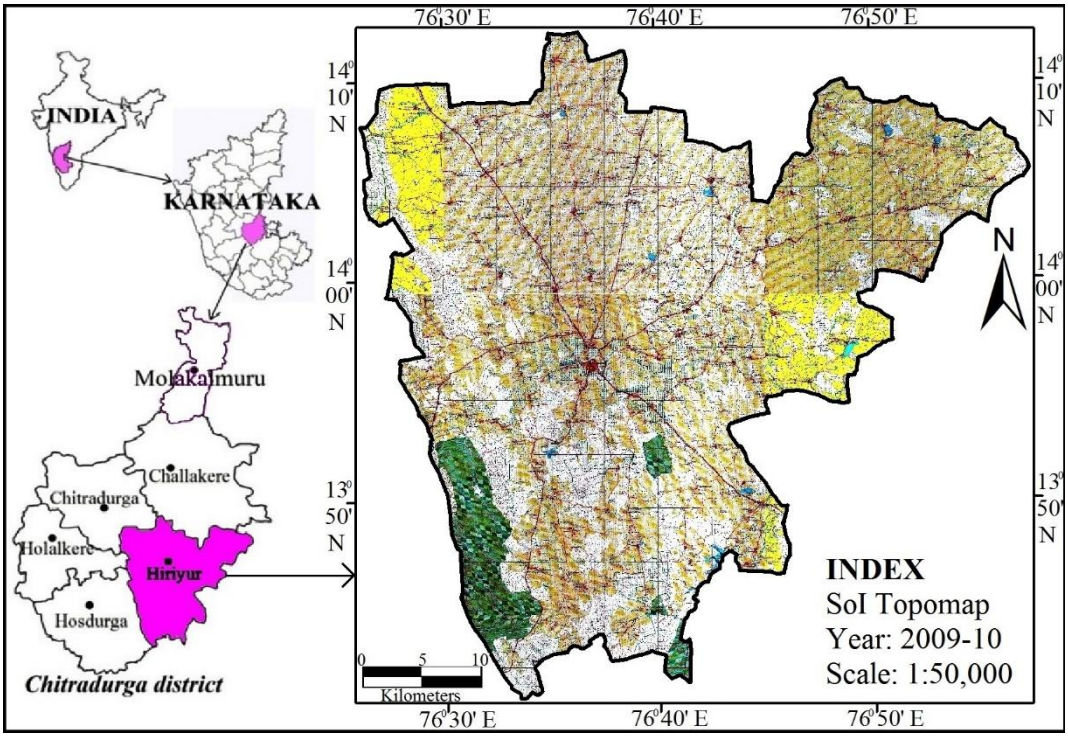

Fig.1. Location and Topomap of Hiriyur taluk

2.2 Methods: An attempt has been made to assess the forest cover of the study area in 1:50000 scale of SoI toposheet in conjunction with IRS-LISS-III satellite data and carried out Change Detection Analysis (CDA). The digital data of LISS-III+PAN (5.8m) and Sentinel-2A (10m) were corrected geometrically by considering limited GCPs (Ground Control Points) from SoI maps. All the data were geometrically corrected with least RMS error in ERDAS IMAGINE software. The supervised classification technique Maximum Likelihood Classification (MLC) was applied to classify the different types of forests from the multispectral imagery based on spectral signature characteristics. The forest areas were delineated from their red tone and contiguous pattern. Each forest boundaries were mapped and extracted from SoI topomap and overlaid on satellite data to analyze the change detection and identifying the real human factors that impacting on degradation. The scrubs were identified from their brownish yellow tone, coarse texture and scattered pattern. The agriculture and human habitations were identified from the light reddish-brown tone and regular pattern. The rocky outcrops /slopes were identified from their brighter tone, absence of vegetal cover and their association to the steeper slopes.

2.3 Materials used:

a. **Topomaps:** 57C/5, 9, 10, 13; 57B/5, 8, 12, 16 of the year 1975 & 2009, Survey of India (SoI) of 1:50,000 scale, Bengaluru.

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b. **Satellite Data:** IRS-1C & 1D; PAN+LISS-III of 5.8m Resolution (D43E12, D43K09, 10, 13, 14) [Year of Pass: 2000-01 & 2005-06], ISRO-NRSA, Hyderabad.

c. **Software's:** Arc GIS v10 and Erdas Imagine v2013.

d. **GPS:** Garmin-etrex 10 GPS is used to demark the exact boundaries of each forest covers during GTC (Ground Truth Check) with 3m accuracy.

III. RESULTS AND ANALYSIS

3.1 Mapping of Forest Cover: Forests exert influence on climate, water regime and provide shelter for wildlife and livestock (FAO, 1963). The forests of study area are distributed in fragmented blocks with natural deciduous forests as well as plantations (Kayet et al, 2019; CFD, 2012). Satellite data come in handy in mapping of forest types and density classes with reliable accuracy through visual as well as digital techniques (Madhavanunni, 1992; Roy et al., 1990; Sudhakar et al., 1992). Digital image interpretation technique is applied on the LISS-III+PAN and Sentinel-2A acquired imagery to identify the location and spatial distribution of forests types with the help of handheld GPS. Dense/ closed deciduous forest cover were identified with 40% or more vegetation density (crown cover); whereas scrub forest were with 10-40% of vegetation density and <10% are as degraded forest (Basavarajappa et al, 2014). The taluk includes 7 State Reserved Forest namely, Bagganadu, Gaudanahalli-1, Gaudanahalli-2, Jogimatti, Lakkihalli, Marikanive and Suvarnamukhi with an approximate land of 140.45 km^2 (1975) and being degraded by various factors of human forces (Manjunatha and Basavarajappa, 2022) (Fig.2a).

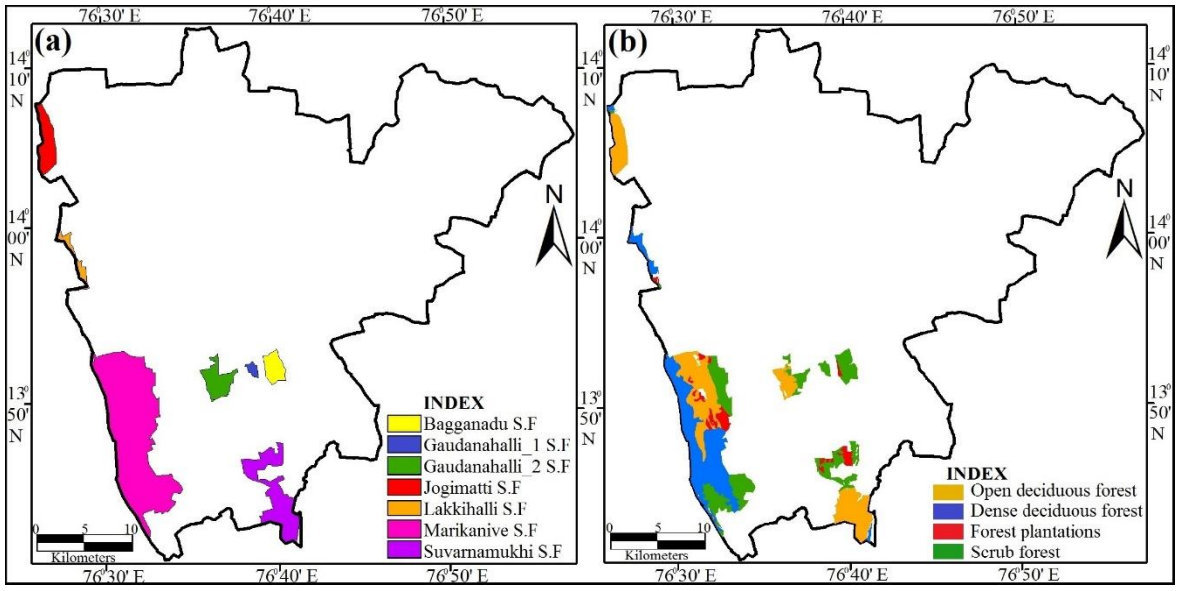

Fig.2. (a) Reserved State Forests and (b) Forest Classification map of Hiriyur taluk

3.2 Forest Classification: Forests are categorized into open deciduous; dense/closed deciduous; forest plantations and scrub forest supported by the crown cover/ density/ location and structure from two periods of time (Fig.2b). The larger imagery scale or higher sensor resolution helps in differentiating forest types more accurately (Roy et al. 2002). Generally, supervised classification techniques using maximum likelihood algorithm are considered adequate (Roy et al, 2002). However, both supervised and unsupervised method i.e., hybrid technique produces best outcome (Kushwaha and Madhavan Unni, 1989). Satellite data acquisition of a particular time period in a year, once most variations occur by phenological changes such as date of emergence of flowers and leaves, leaf fall, species phase change enhance the satellite image potentiality in delineating the forest types.

3.2.i Deciduous Forest: Represented as the forest land that chiefly contains deciduous species and wherever the trees shed their leaves once in every year (Basavarajappa et al, 2014). Vegetation density, type, structure and its composition of forest lands along with deteriorating phases assist to explore the deciduous type under sustainable limits of precision (Pant et al, 1992). Multi-temporal data, particularly of October and March/April seasons help in their discrimination from other forest types (Basavarajappa et al, 2014). It represents dark red to red tone, mainly rich in timber trees on Standard

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False Color Composite (FCC). Dense/ closed deciduous forest are noticed all along the medium relief of hill slopes occupy the major parts of Marikanive State Forest (S.F), Lakkihalli S.F, Northern parts of Joggimatti S.F and Southern parts of Suvarnmukhi S.F (Fig.2b).

3.2.ii Forest Plantation: These are artificially planted with the trees of economic importance within the forest boundaries (Basavarajappa et al, 2014). The common indigenous and exotic trees of forest plantations are teak, sal, deodar and others (Manjunatha et al, 2018).

Full grown plantations are normally difficult to differentiate from natural forests; however, new and young plantations can be readily separated from the contiguous forested areas (Basavarajappa and Dinakar, 2005). It depicts light red to red tone on Standard False Color Composite (Dinakar, 2005). A huge mass of forest plantations was noticed in Northern parts of Suvarnamukhi S.F and Marikanive S.F (Fig.2b).

3.2.iii Scrub Forest: In satellite imagery, dark brown colored features with coarse textures indicate the rocky exposures. Scrub forest is associated with barren rocky/stony waste and scrub formed due to inadequate and erratic rainfall (Basavarajappa et al. 2014).

The condition is drought and extreme heat in summer season precludes hardly any profitable forest (Manjunatha and Basavarajappa 2017). On Standard False Color Composite, it represents light red tone to brown tone relying on canopy shelter (Dinakar 2005) (Fig. 17.3b). These were encountered in Eastern and Southern parts of Marikanive S.F, Northern parts of Suvarnmukhi S.F, major parts of Bagganadu S.F, Gaudanahalli-1 S.F and Gaudanahalli-2 (Fig.2b).

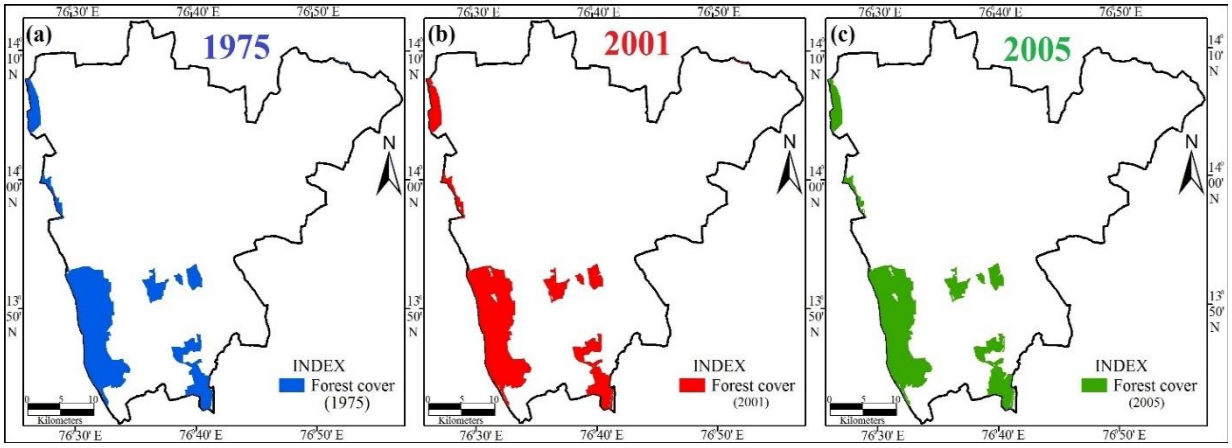

Fig.3. Temporal Mapping of Forest Covers during (a) 1975; (b) 2001 and (c) 2005

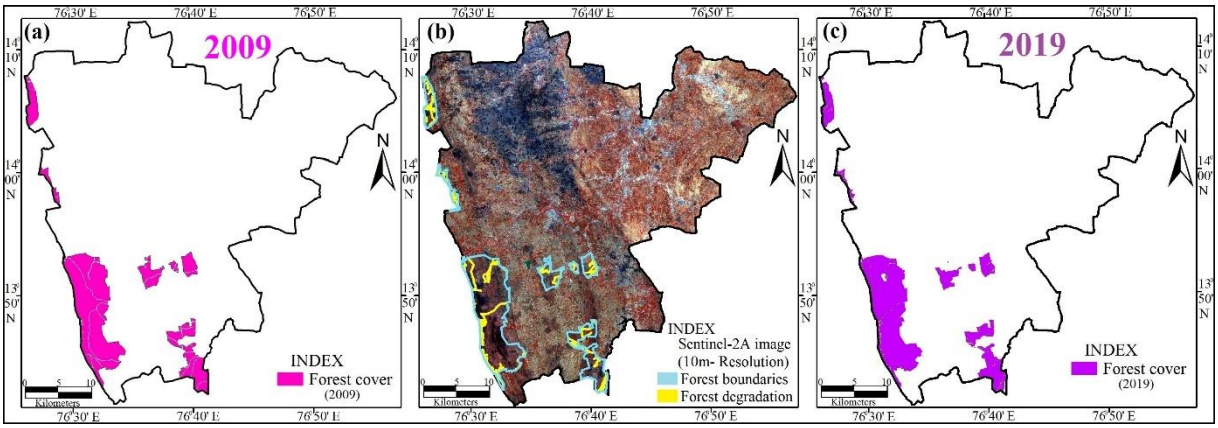

Fig.4. Temporal Mapping of Forest Covers during (a) 2009; (b) Sentinel-2A and (c) 2019

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Table.1. Temporal Mapping of State Forest lands (in Km^2) for Hiriyur taluk

Sl. No	Name of the State Forests	Area (1978) SoI	Area (2001) LISS-III	Area (2005) LISS-III	Area (2009) SoI	Area (2019) Sentinel-2A
1.	Bagganadu S.F	5.8890	5.6254	5.7035	5.8960	5.3532
2.	Gaudanahalli-1 S.F	1.3411	1.2825	1.2820	1.3353	1.0033
3.	Gaudanahalli-2 S.F	8.7466	8.2597	7.9438	8.5678	6.2311
4.	Jogimatti S.F	9.9425	9.6668	9.0781	8.9471	8.7644
5.	Lakkihalli S.F	4.2245	4.2171	3.4889	3.8409	3.1966
6.	Marikanive S.F	86.4622	85.6213	84.5616	85.1224	83.2211
7.	Suvarnamukhi S.F	23.5975	23.0728	25.2733	25.0307	22.5479
	Total	**140.4510**	**138.0938**	**137.3459**	**138.7402**	**130.3176**

a. **Change Detection Analysis (CDA):** Identifying the changes of land surface features may be extracted effectively using multi-temporal satellite data (Singh, 1989). The vector layers of forest covers mapped during various time period were overlaid one above the other for detection analysis in area coverage statistics using ArcGIS v10 software. The total State Reserved Forest cover was 140.45 km^2 in 1975 had been degraded to 130.31 km^2 due to human forces noticed in all forest lands.

Agricultural encroachment, grazing of animals, constructions of major roads, illegal mining & its dumping area and illegal cut of trees were the threats observed during limited field visits. Iron mining was identified as operating in Northern part of Lakkihalli State Forest (S.F); while gradual increase in agricultural encroachments were observed NE part of Marikanive S.F, Southern part of Gaudanahalli-1 S.F; Northern part of Gaudanahalli-2 S.F; Northern part of Jogimatti S.F and Central part of Lakkihalli S.F (Manjunatha and Basavarajappa, 2017). Metaled roads were identified passing through the Southern parts of Bagganadu S.F; major parts of Gaudanahalli-1 S.F and Northern parts of Suvarnamukhi S.F. Settlements of few houses (less than 20 number of houses) were observed within the Central part of Marikanive S.F due to the availability of major Uttare lake that provide sufficient amount of water supply for irrigation practices. Numerous wind turbines were recorded on all along the higher elevations in the Western parts of Marikanive S.F. Pilali Govt. high school was observed at the verge in the southern part of Suvarnamukhi S.F.

Table.2. Change Detection Analysis (CDA) of State Forest lands (in Km^2) for Hiriyur taluk

Sl. No	Forest Covers	1978 to 2001	2001 to 2005	2005 to 2010	2010 to 2019
1.	Bagganadu S.F	-0.2636	+0.0781	+0.1925	-0.5428
2.	Gaudanahalli-1 S.F	-0.0586	-0.0005	+0.0533	-0.3320
3.	Gaudanahalli-2 S.F	-0.4869	-0.3159	+0.6240	-2.3367
4.	Jogimatti S.F	-0.2757	-0.5887	-0.1310	-0.1827
5.	Lakkihalli S.F	-0.0074	-0.7282	+0.3520	-0.6443
6.	Marikanive S.F	-0.8409	-1.0597	+0.5608	-1.9013
7.	Suvarnamukhi S.F	-0.5247	+2.2005	-0.2426	-2.4828

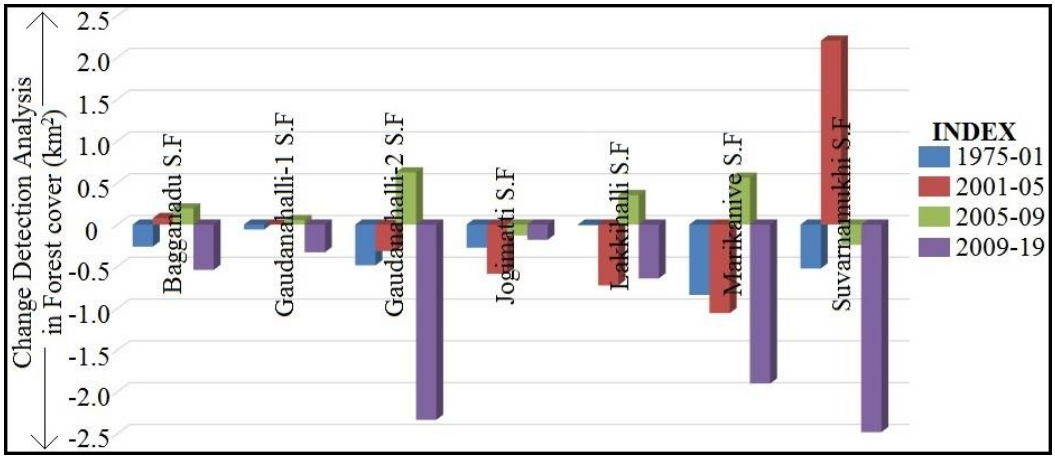

Fig.5. 3-D Column graph depicting the CDA for Hiriyur State Forest lands

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IV. DISCUSSION

The lack of appropriate data collected, analyzed and presented in a scientific manner has been a major weakness in the forestry planning process in India. (Singh, 1986). It has become obligatory to know the past forest condition and regulations of that period to correlate it with the present condition and regulations of the forests. (Akhlaq, 2008).

Degraded forest pastures on steep slopes and poorly managed forest covers were identified during limited field visits. Forest covers an area of 140.45 km^2 in 1978 has been gradually degraded to 130.31 km^2 (2019) due to various human intrusions. Over-grazing, illegal cut of trees, agricultural encroachments, pressure on economic mineral deposits through illegal mining & dumping areas, roads within the reserved forest boundaries are the major threats for Hiriyur State Forests analyzed using time-series data. Such high human disturbances can often lead to human-wildlife conflict situations.

The wind farms in the area contribute to the disturbance of these natural habitats and increases the soil erosion which in turn causes loss of greenery. Barren rocky exposures are increasing due to lack of rainfall, continuous soil erosion, deforestation and improper management. Artificial regeneration work was organized on a scale during 2008-09 that aimed at increasing productivity of all forest sites and thus maximizing the resources of timber, fire wood, industrial wood and others (Anonymous 1961).

The gradual rise in population living at the verge of forest boundaries has increased the constructions of major roads, agricultural encroachment, mining within the state forests that contributing to human-wildlife conflicts which may rise more number by coming years. Leopard attacks were reported in various places across Karnataka state over the past few years leading to concern among environmentalists and wildlife experts (Table.3).

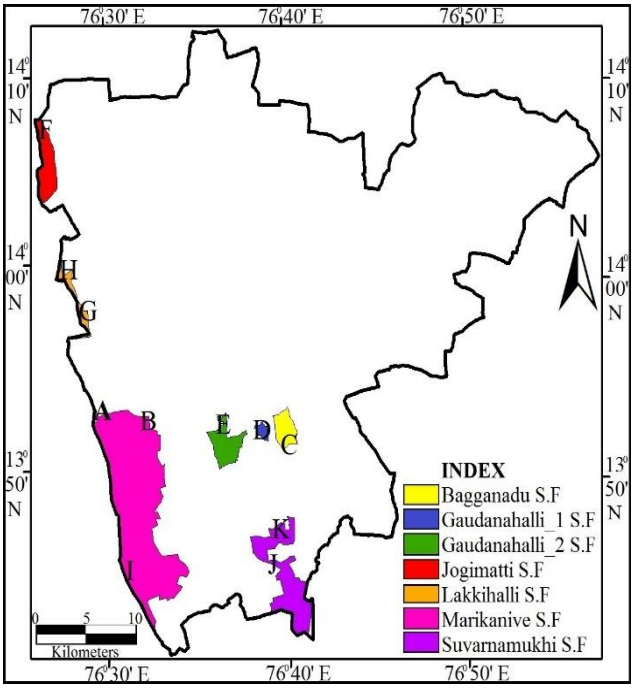

Fig.6. A-K are the locations of Field photos and Google Earth Images depicting the real human forces impacting the degradation of Hiriyur State Forests that shown in Fig.7 from A-K

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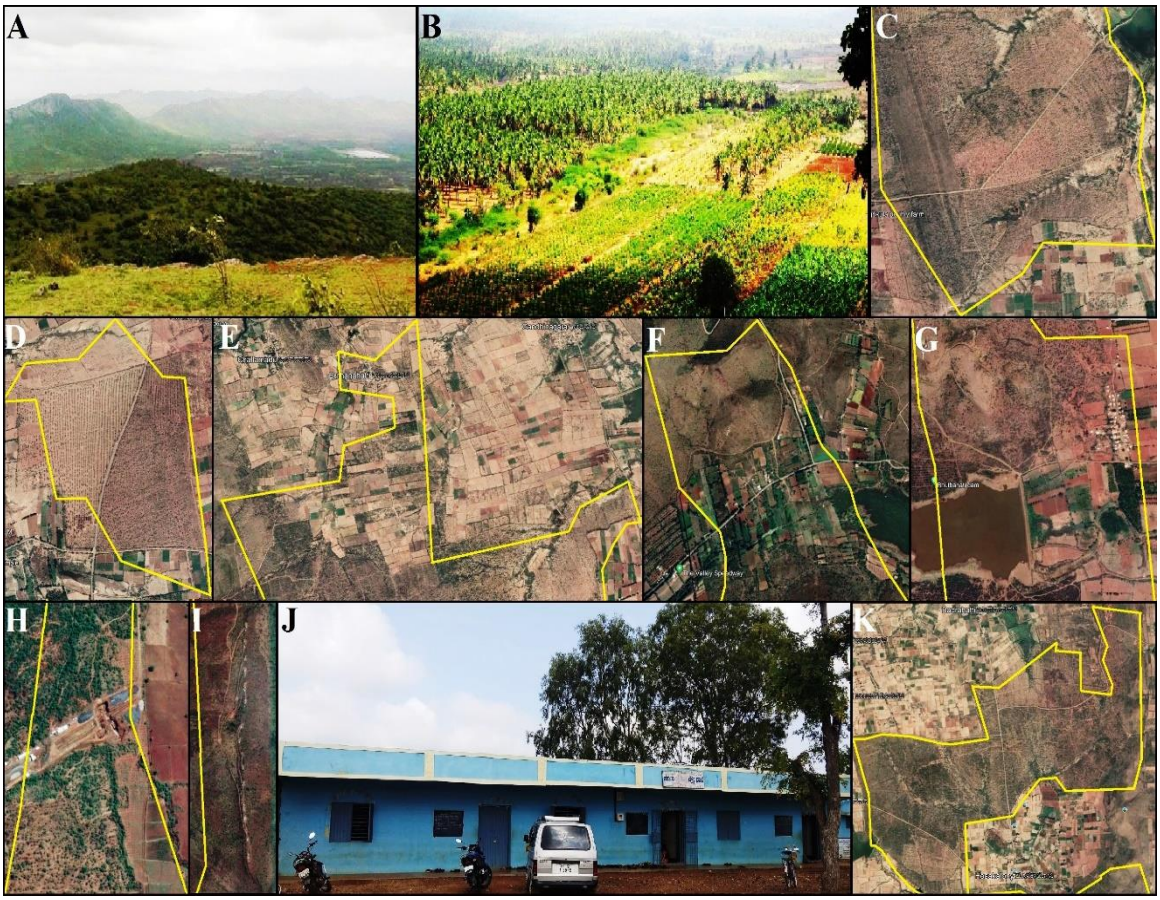

Fig.7. A: Deciduous forest of Marikanive S.F;
B: Agricultural encroachment at NE part of Marikanive;
C: Major road constructed in Southern part of Bagganadu;
D: Major road constructed and agricultural encroachment in Southern parts of Gaudanahalli-1;
E: Agriculture & Settlement encroachment noticed in Northern parts of Gaudanahalli-2;
F: Agriculture encroachment in Northern parts of Jogimatti;
G: Agriculture & Settlement encroachment in Northern parts of Lakkihalli;
H: Mining activities in Southern parts of Lakkihalli;
I: Wind Turbines installed all along the Western parts of Marikanive;
J: Govt. School, Pilali noticed at the Eastern verge of Suvarnmukhi;
K: Major roads constructed in Northern parts of Suvarnamukhi S.F

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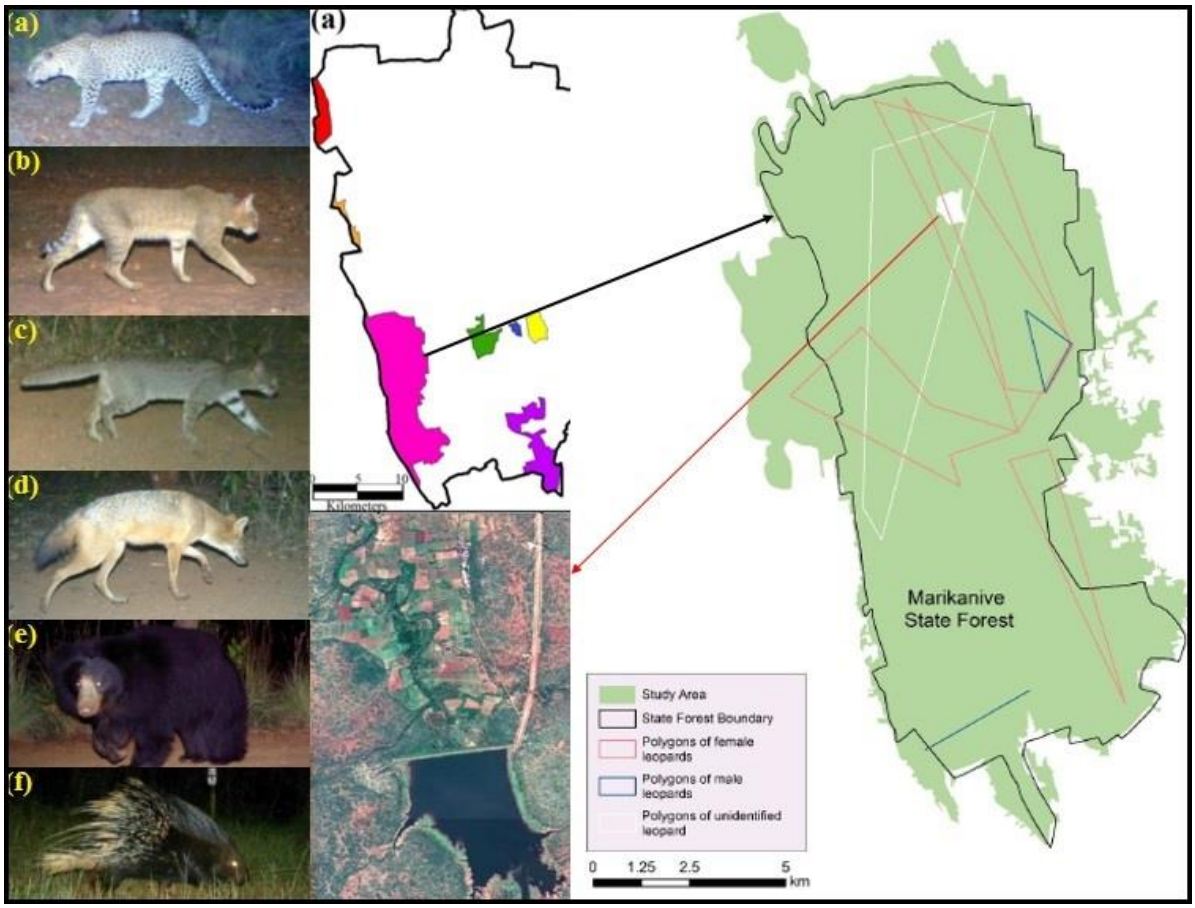

Fig.8. Settlement and agricultural encroachment identified nearby Uttare lake at the Northern Central part of Marikanive State Forest where the movement of male (blue polygon) and female Leopards were mapped by NCF during March 2011 along with other [a. Leopard; b. Jungle Cat; c. Rusty-spotted Cat; d. Jackal; e. Sloth Bear; f. Porcupine**] wildlife's (Source: NCF, 2011)**

4.1 Marikanive S.F: Marikanive is one such State Forest (S.F) of smaller patches that facilitates the wildlife movements such as Leopard, Jungle Cat, Rusty-spotted Cat, Jackal, Sloth Bear, Porcupine, Four-horned Antelope, Wild Pig, Indian Pangolin, Black-naped Hare, Small Indian Civet, Mangoose and other important species notified throughout Marikanive forest zone (Gubbi et al, 2021). Wind turbines were extensively observed all along the Western part of higher elevations (1112m above MSL) extending along the entire length (Gubbi et al, 2021). Marikanive S.F is characterized by a mixture of southern tropical dry deciduous forests and woodland savannah comprising of open grassland patches and scrub forests on the Eastern part of the S.F; and forest plantations occupying the higher elevations on the Central and Eastern part (Singh 2012). In moist and favorable areas of the forest, the lower canopy is well defined and tends to be evergreen (Singh 2012). The open woodland savannah habitat covering the Eastern part of Marikanive S.F is where most of the leopard individuals were photo-captured (Gubbi et al, 2021). The distribution patterns of leopards within this habitat could possibly be due to more human intrusion in one specific area of the state forest. Earlier, leopard movements and attacks were reported from forest regions, but at present my attacks are reported within rural and urban places across Karnataka State (Table.3). Unfortunately, human beings are encroaching the wildlife territory and complaining about being attacked; on the other hand, carnivores develops a taste of human blood especially the very young and old who cannot fight back.

V. CONCLUSION

Degraded lands were noted and mapped in all forest covers using geospatial techniques which is a cost-effective and time saving method. More than 10 km^2 of forest cover had degraded during the year 2019 noticed through CDA, when compared to 1975 (Time period: 44 years data). This may reduce further in future due to reduced rainfall by global warming, human forces (mining, agricultural encroachment, grazing) and soil erosion. Collection of fuelwood, grazing animals and illegal felling of trees were observed in high levels within Marikanive S.F, Lakkihalli S.F and Suvarnamukhi

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S.F. This also severely impacts the regeneration capacity of forest greenery. Species habitats should be mapped before constructing any major roads within any State Reserved Forest to reduce the man-wildlife conflicts and domestic animals as easy prey.

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