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Forest mapping and its Change Detection Analysis in Molkalmuru taluk of Karnataka state, India using Geospatial Technology

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Abstract: Geospatial approaches address cost-beneficial, convenient and genuine data moreover by temporal domain for natural resource management and developmental planning. Forest conservancy and its impact on environment have gained importance in national and international program. Extreme changes on forest cover around the globe had recorded by fast jump up in population, varying in land use activities, forest fires, pressure on economic mineral deposits, reduced rain conditions and climate change. Forest degradation is a matter of grave concern and prime focus that immensely required for forest sustainable management through systematic planning. According to 1999 assessment of the Karnataka Forest Department, Molakalmuru taluk holds 21% spread of forest cover which includes open deciduous; dense/closed deciduous; forest plantations and scrub forest. The study focuses on timely designing & management of forest lands to satisfy future desires. Mapping of forest lands and its detection is explored using topographic maps of 1:50,000 scale; geo-rectified satellite data of IRS-LISS-III and Sentinel-2A through GIS software's. The ultimate output outlines the forest land exploitation using geospatial tools for its sustainability.

Keywords: Forests; Change Detection Analysis (CDA); Molkalmuru; Geospatial Technology.

I. INTRODUCTION

Forest is one among the major resources that take crucial role in sustaining the ecological equilibrium and environmental system continuously disappearing at an alarming rate (Roy et al, 2002). Forests are the large area dominated by medicinal plants, timber, construction purposes, agricultural implements, carts & accessories, firewood & charcoal, aromatic, oil yielding, fodder, dye, detergents & soap, resin & gum, flavoring agents, vegetables, cereals & millets, pulses, pickles, fruits, fibre, green manure, other commercial crops, sacred trees, basket making, mat weaving, roof thatching (FAO, 2001). India would need 300 million tons of food grain to feed its projected population of 1.3 billion by 2020 (Roy et al, 2009). Deforestation will increase region greenhouse emission and different trace gases; presumably influencing the climatic conditions, as a result of the absorption of carbon is higher in forests regions than within the agricultural lands (Fearnside, 2000). Satellite based mapping of vegetation cover is also a major demand for numerous planning and designing schemes at the topographic extent (Singh et al., 2002). Moreover, depicting the exact locations of vegetation varieties and human land activities carry valuable data for regular monitoring of terrains and sustain their multifariousness, human interruptions and varying environmental conditions (NLULC, 2006; Tiwari and Singh, 1984; Tiwari, 1994).

The development, maintaining and management of forest assets require comprehensive understanding of the forests concerning their standard and location overtime, so as to achieve the balance between the implementation and restoration strategies (Kushwaha, 2005). The extent of information depends greatly on the spatial and spectral resolution of the satellite imagery acquired. Four regular characteristic features derived from satellite Remote Sensing (RS) data are canopy shape, tree size categories, percent of crown and vegetation structure (Roy et al, 2002). Geospatial approach is a powerful tool with decision making will successfully uplift governance, empower sustainable development, serve in better business action plans to bring people for location based information. Technology is employed comprehensively in India for forest identification, exploring groundwater zones, ocean productivity, environmental impact analysis, land and water sustainability, and natural disaster monitoring (Geospatial Today, 2013). Geospatial methods offers immense role in collection, analysis and storing all kinds of geospatial data particularly prerequisite for forest appraisal (Roy et al, 2002). Geospatial tools show tremendous approach in fast spatial and temporal monitoring of tropical forest resources as support system for decision makers (Prabhat Kumar Rai, 2013).

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II. METHODOLOGY

A. Study area

The study area located in $14^0$34' to $15^0$02' Northing and $76^0$35' to $76^0$52' Easting measuring an area of 738.23 km^2 (Fig.1) (Manjunatha and Basavarajappa, 2015b). Study area enjoys moderate climate throughout the year with temperature ranging from 20^0 to 31^0C (CGWB, 2013). Most of the rain is recorded throughout SW monsoon of 541.5mm in 28 rainy days. 90% of the population is depending on agricultural practices. The major crops grown are bajra, groundnut, horsegram, small millets and jowar (CGWB, 2013). Molakalmuru is the heart for silk textiles having immense values. The net sown area of the taluk is only 43.81% due to low, erratic and undependable rainfall (CGWB, 2013). Undulating topography, interspersed with patchy ranges, detached clusters & isolated low ranges of rocky hills, barren hills are noticed all along the northern parts (Manjunatha and Basavarajappa, 2015b; CGWB, 2013).Two important hill streams flow towards Northwestern direction in the taluk, flow into Janagahalla, a few miles on the far side of taluk boundary (Hema Thakur, 2016). Several other minor streams also find their way into the Janagahalla. Several anicuts have been constructed all along the basin to impound water (Fig.2b) (Sathyan, 1967). Granites, granitic-gneisses and amphibolite gneisses are the most water bearing formations within the study area (Ravikumar et al, 2014; CGWB, 2013).

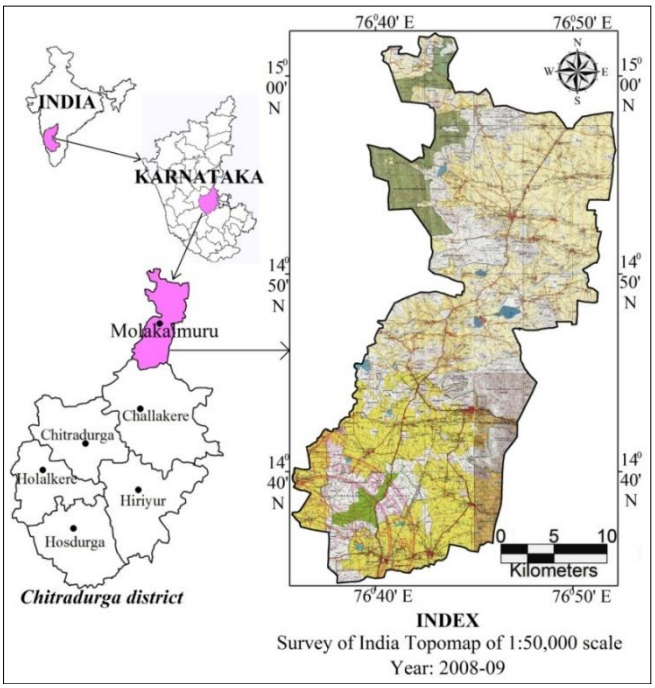

Fig.1. Location and Topomap of Molakalmuru taluk

B. Database and Methods

The study involved Indian Remote Sensing (IRS-1C/1D), PAN + LISS-III (Fig.2a) and Sentinel-2A (Fig.6a) satellite data to achieve the spatial and temporal changes of forest area. Satellite data are digital mosaic information of earth's land features which have immense value in forest study and monitoring (Prabhat Kumar Rai., 2013). Geospatial technology enables upgraded drawing and timely observing of forest resources for better results (Franklin, 2001). Forest lands with its categories are digitized supported the quality schemes given by National Remote Sensing Agency (NRSC, 2007; Manjunatha, 2017). Limited field visits were carried out to map Ground Control Points (GCP) of each forest boundary using Garmin GPS of 3m resolution which was later overlaid on SoI Topo map.

Satellite images are geo-rectified by adopting the permanent earth surface features of major roads, power-lines, settlements, co-ordinates and forests boundaries derived from SoI topomaps (Basavarajappa et al, 2016). Forest maps are first digitized by SoI topographic sheets during the year 1975-78 and 2008-09 (Manjunatha, 2017) (Fig.4a; 5a). The contrast in the satellite data in the form of Size, Texture, Shape, Pattern, Association and Shadow are involved to measure types of forest cover using ArcGIS and Erdas Imagine software's (Manjunatha et al., 2015a). Supervised classification investigations are executed on multispectral and multi-temporal satellite data in GIS environment (Manjunatha and Basavarajappa, 2015b; Manjunatha, 2017).

C. Data Used

a. Topomaps: 57A/12; 57B/9, 10, 13, 14 during 1975-78 & 2009-10, Survey of India (SoI) of 1:50,000 scale, Bengaluru.

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b. Satellite Data used: IRS-1C/1D; LISS-III of 23.5m Resolution (D43E12, D43K09, 10, 13, 14) [Acquisition year: 2000-01] and Panchromatic data of 5.8m resolution [Acquisition year: 2005-06] (Manjunatha, 2017); Sentinel-2A Image of 10m Resolution [6th April 2021](Fig.6a).
c. Software's: Erdas Imagine v2013 and Arc GIS v10 (Manjunatha, 2017).
d. Thematic maps: Rivers & Tanks; Reserved Forest Classification and its change detection analyzed maps.
e. GPS: Exact forest boundaries are recorded during extensive field visits using Garmin-etrex 10 (Manjunatha, 2017).

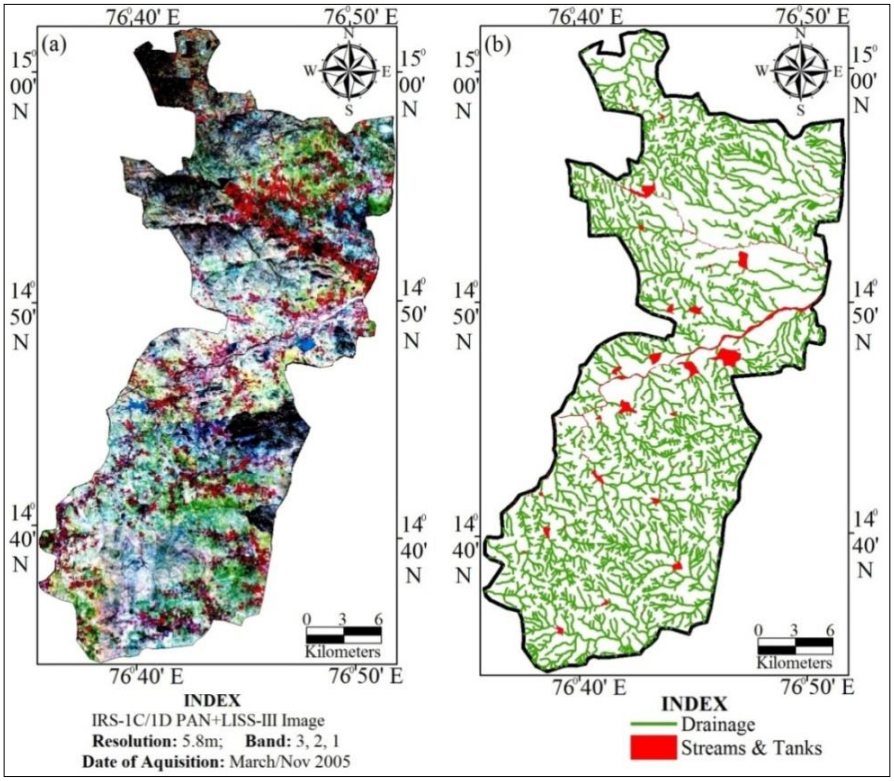

Fig.2. (a) IRS-PAN+LISS-III image and (b) Drainage and tanks of Molakalmuru taluk

III. RESULTS AND ANALYSIS

A. Mapping of Forest Cover

Visual Image Interpretation Technique (VIIT) been globally utilized for forest survey (Anonymous, 1983) and monitoring satisfactorily by Remote Sensing (RS) data with high spatial resolution. Horizontal plantation measuring 7-8 m in width and pack of 3-4 trees are effectively recognizable (Roy et al, 2002). Acquiring the temporal data provides information regarding phenological conditions such as, deciduous or evergreen forests. The multispectral satellite data in digital form can be analyzed through computers using digital image processing software and categorized into different forest cover types (Roy et al, 2002).

Forests are mostly outlined as a plant community chiefly of trees and alternative woody vegetation cover with a tree cluster beyond 10 percent and area greater than 0.5 ha (FAO, 2001; Singh et al., 2006). Forest lands are primarily consisting of dense vegetation cover, medicinal plants & variety of large vegetation types able to yield timber and forest materials (Saxena et al, 1993; Basavarajappa et al., 2014; Manjunatha, 2017). In Molkalamuru taluk, reserved forest lands are dispersed as fragmented blocks and include both natural forests and man-made forests (plantations) (Narayan et al, 2019; CFD., 2012). The study area includes 7 State Reserved Forest namely, Bandravi, Hire Adavi, Kamarakaval, Konasagara, Krishnarajapura, Sanjivarayana kote and Santegudda State forests (Fig.3a) with an approximately area of 155.04 km^2 (1978) being reduced by numerous major and minor factors (Manjunatha, 2017) (Fig.4a & b; 5a & b; 6b; Table.1).

B. Mapping of Forest Classification

Classification studies of LU/LC portray numerous perspectives of natural resources which keep changes due to its demand (Roy et al, 2002). Multiple land uses on a single land parcel with respect to standardize the LULC information is very much required to analyze land classification system. Forests are categorized into open deciduous; dense/closed

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deciduous; forest plantations and scrub forest supported by the crown cover/ density/ location and structure for two periods of time (Fig.3b). 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 produce best outcome (Kushwaha and Madhavan Unni, 1989). Satellite data acquisition of a particular time period in a year, once most variations occur by phonological changes such as date of emergence of flowers & leaves, leaf fall, species phase change etc, enhances the satellite image potentiality in delineating the forest types.

1) 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 like teak wood, rose wood, honne, bamboo on Standard False Color Composite (FCC) (Fig.3b). Dense/ closed deciduous forest are noticed all along the medium relief of hill slopes occupy the major parts of Sanjivarayana Kote State Forest (S.F), Vaderahalli, SW parts of Chinivaladagudda and Southern parts of Jalipente villages (CFD., 2012). Open deciduous forests are noticed in Northern parts of Chikkanahalli, SW parts of Hire Adavi S.F, major parts in Konasagara S.F, Adavimallapura village, SW parts of Nerlahalli village, major parts of Kamarakaval S.F and Eastern parts of Harvinadoddi village.

2) Forest Plantation: These are forest areas artificially planted with trees economic importance of forest resources (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) (Fig.3b). A huge mass of forest plantations were noticed on foot hills in the northern parts of Hire Adavi S.F cover with elevations.

3) Scrub Forest: 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.3b). These were encountered in major parts of Bandravi S.F; Krishnarajapura S.F & Hire Adavi S.F, Southern parts of Kamarakaval S.F, Northern parts of Sanjivarayana Kote S.F and few patches in Eastern parts of Santegudda S.F.

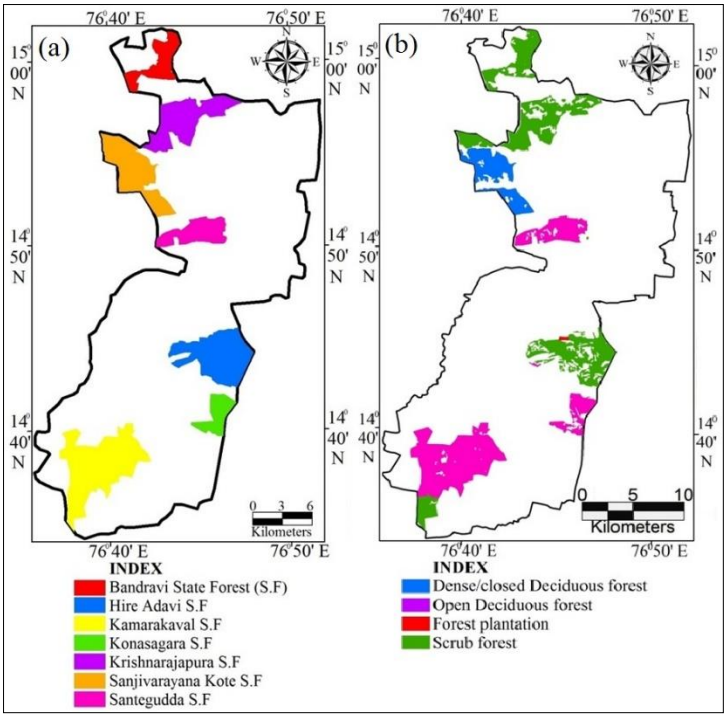

Fig.3. (a) Reserved Forest and (b) Forest Classification map of Molakalmuru taluk

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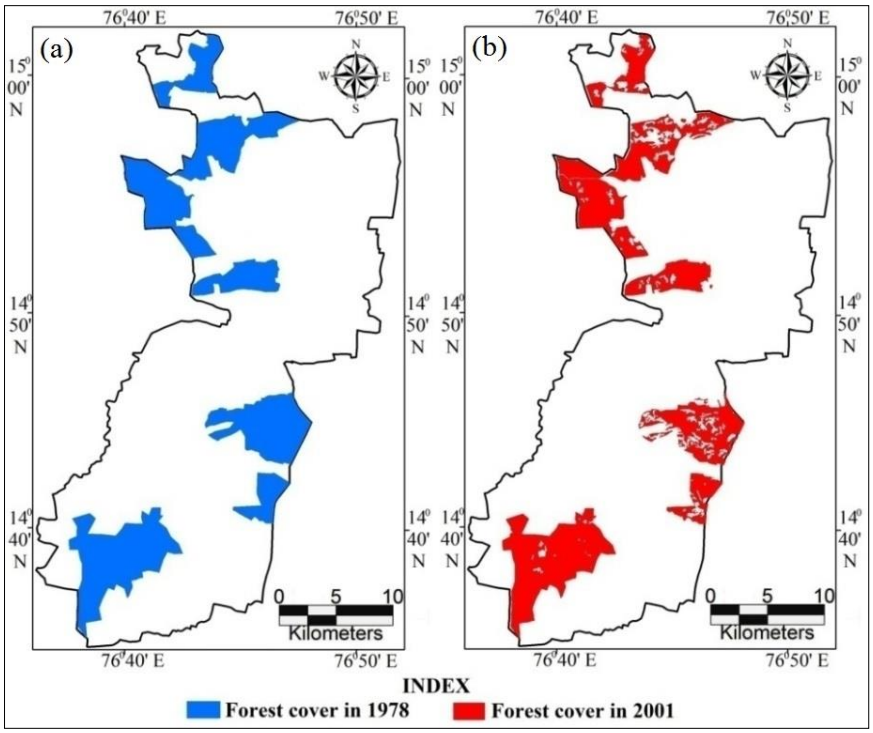

Fig.4. Temporal Mapping of Forest Covers during (a) 1978 and (b) 2001

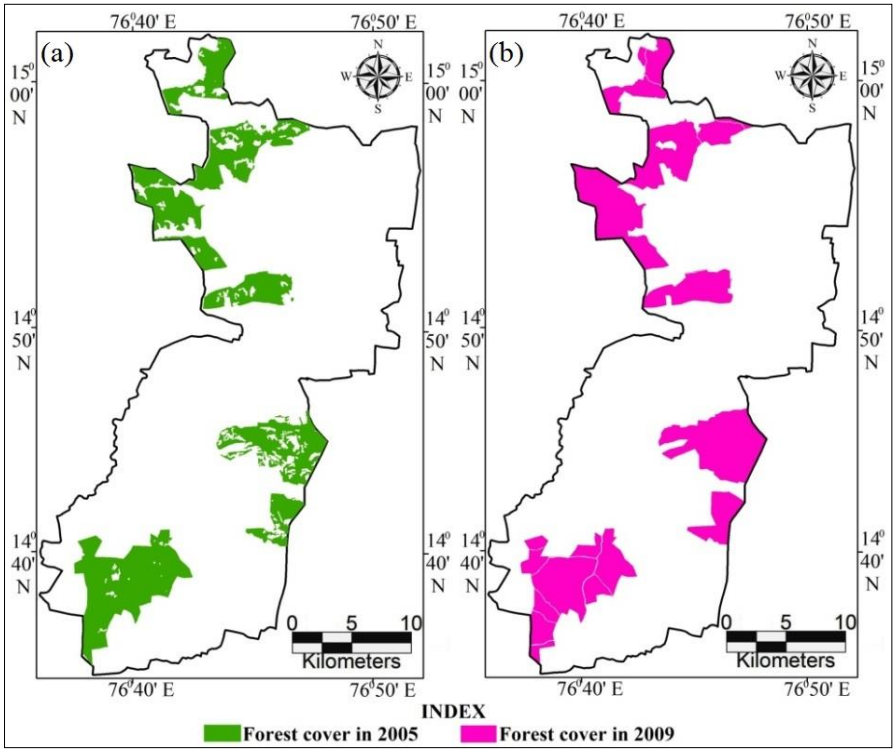

Fig.5 Temporal Mapping of Forest Covers during (a) 2005 to (b) 2009

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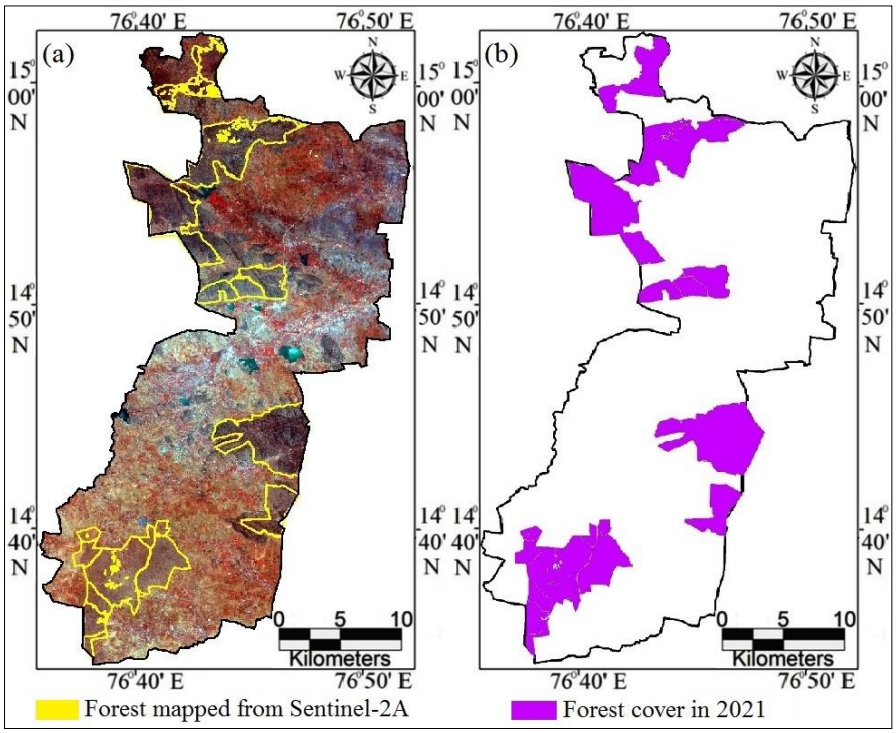

Fig.6 (a) Sentinel-2A image and (b) Forest cover map in 2021

Table 1. Temporal Mapping of Forest covers in Molakalmuru taluk

Sl. No	Name of the Forest	Area in Km^2 (1978)	Area in Km^2 (2001)	Area in Km^2 (2005)	Area in Km^2 (2009)	Area in Km^2 (2021)
1.	Bandravi S.F	12.1229	10.1699	11.1589	12.1644	11.3919
2.	Hire Adavi S.F	29.0800	20.9275	19.8554	29.2613	29.0062
3.	Kamarakaval S.F	43.2716	42.2774	42.1890	42.6838	42.3479
4.	Konasagara S.F	8.7105	7.0458	6.7978	8.7816	8.5668
5.	Krishnarajapura S.F	24.0071	18.7014	19.2166	23.3181	23.515
6.	Sanjivarayana kote S.F	24.2959	22.6714	19.5859	24.4314	24.1894
7.	Santegudda S.F	13.5518	11.6456	11.3378	13.5756	13.3267
	Total	***155.0400***	***133.4390***	***130.1414***	***154.2162***	***152.3439***

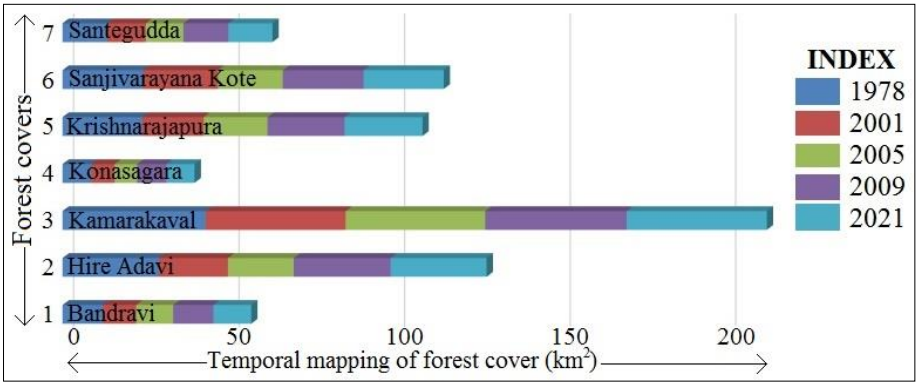

Fig.7 Bar chart representing the Temporal Mapping of Forest covers

C. Change Detection Analysis (CDA)

Forest covers an area of 155.04 km^2 in 1975-78 has been degraded to 133.43 km^2 (2001) because of human encroachment at all forest border limits by agricultural overlap (Manjunatha, 2017), grazing animals, illegal cut of trees and illegal quarrying activities (Manjunatha et al, 2018) (Fig.4a & 4b). Approximately 21 km^2 of the forest land been reduced from 1975 to 2001 observed by Change Detection Analysis (CDA) (Manjunatha, 2017) (Fig.7; Table.2). Illegal granitic-gneiss

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quarry was observed along the northern parts of Bandravi S.F, Krishnarajapura S.F, and NE parts of Kamarakaval S.F. Gradual increase in population increased the agricultural activities noticed all along the State Forest boundaries of Bandravi, Hire Adavi, Konasagara, Krishnarajapura and Santegudda (Manjunatha and Basavarajappa, 2017). Metalled and Unmetalled roads were identified to be passing through Bandravi S.F, Krishnarajapura S.F, Santegudda S.F, Hire Adavi S.F, Kamarakaval S.F; while only unmetalled roads were observed in Sanjivarayana Kote S.F and Konasagara S.F which later may lead into more illegal granite/ gneiss quarrying activities, illegal cut of trees, agricultural sprawl, grazing domestic animals and other impacts (Manjunatha et al, 2018).

Table.2 Change Detection Analysis (CDA) of Forest Covers in Molakalmuru taluk

Sl. No	Forest Covers	1978 to 2001	2001 to 2005	2005 to 2009	2009-2021
1.	Bandravi S.F	-1.9530	+0.9890	+1.0055	-0.7725
2.	Hire Adavi S.F	-8.1525	-1.0721	+9.4059	-0.2551
3.	Kamarakaval S.F	-0.9942	-0.0884	+0.4948	-0.3359
4.	Konasagara S.F	-1.6647	-0.2480	+1.9838	-0.2148
5.	Krishnarajapura S.F	-5.3057	+0.5152	+4.1015	+0.1969
6.	Sanjivarayana kote S.F	-1.6245	-3.0855	+4.8455	-0.2420
7.	Santegudda S.F	-1.9062	-0.3078	+2.2378	-0.2489

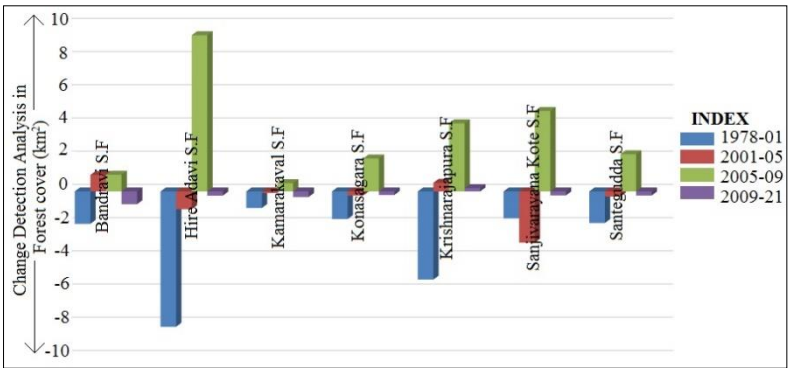

Fig.8 Column graph showing Change Detection Analysis (CDA) of Forest covers

VI. DISCUSSION

The forest cover and its patterns are digitized based on the standard schemes developed by National Remote Sensing Agency to extract the change occurred over a period of 4 decades. The northern parts of Molakalmuru are considered predominantly as central hilly forest zone; whereas southern parts are considered as eastern Vedavathi plains (Ganesh Babu, 2013). Molakalmuru chiefly consists of crystalline schists, granitic gneisses with younger granites and hardly older basic intrusives (Radhakrishna and Vaidyanathan, 2011). Ample parts of soils are exposed and few places are noticed with thin cover of grasses (Ganesh Babu, 2013). These cover larger parts of forests in the study area with complete barrenness of various massive rocky hills of irreversible phases are recorded (Sathyan, 1967). About 75% of the taluk covers granite hillocks and dying State Reserved Forests and the remaining 25% is partly dry land cultivated (CGWB, 2013). The taluk is one of the most backward taluk facing lack of basic infrastructure, unemployment, poverty, lack of skills, illiteracy, health care centers (Nagesha and Ajeya, 2018). The Forests of Molakalmuru vary from dry mixed deciduous type occur in patches in certain blocks with primarily scrub forests tending to thorny bushes in the driest localities (Ganesh Babu, 2013).

The taluk holds 98.28 hectares of permanent pastures and other grazing lands within the notified State Forest cover (CGWB, 2013). These pastures may face scarcity of fodder for the domestic animals which need feeding during extreme summer conditions. Deforestation was noticed recently due to the intensity of over-grazing, forest fires and other anthropogenic factors (Manjunatha and Basavarajappa, 2017). A variety of assorted massive rocky hills of irreversible phases are observed in Hire Adavi S. F covering large portion of forest barrenness (Ganesh Babu, 2013). Extreme edaphic condition is one of the types of degraded forests occurs in poor and shallow soil associated with vast area of bare and rocky localities (Ganesh Babu, 2013). Illicit cutting of trees were commonly observed by the vicinity of village peoples to fulfill their needs of fuel, small timbers for huts & houses and agricultural implementations (CFD, 2012). Over-grazing was observed by the large population of cattle, goat & sheep especially in Hire Advai forest premises which affecting the natural regeneration status causing deterioration of wild life habitat (CFD, 2012). Geospatial approach by forest

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authorities has regularly increased, encouraged in vast part which suits the information require for forest regeneration practices (Wulder and Franklin, 2003).

A. Reclamation Strategies: In India, forest covers an area of 21.54% (ISFR, 2017) but the total expected is 33% as per India's forest policy (Geospatial Today, 2013). Forest Survey of India (FSI) has taken up various implemental strategies to reclaim reserved forest cover in many states of the Country (Geospatial Today, 2013). Karnataka Forest Department Authority came up with many regeneration programs along with local village peoples to retain the forest resources during recent years (Manjunatha and Basavarajappa, 2017). Rotational grazing, controlling fire hazards combined with rigid protection avoiding soil erosion and enriching moisture regime were practiced periodically by the Forest Department Authorities (CFD, 2012), but still it need more regeneration programs to reclaim natural forest resources in the study area. Illegal quarrying lands were demarcated and maintained to enlarge the forest covers in the study area. Artificial mode of sowing seeds in the bushes also helps in regeneration (CFD, 2012). Plantations in large areal extent of encroachments of agricultural activities, grazing lands and mining area should be implemented.

IV. CONCLUSION

SoI topomap & IRS LISS-III and Sentinel-2A satellite images were effectively utilized to bring out temporal changes of Forest covers through GIS software's. More than 24 km^2 area of forest cover has been restored and reclaimed through periodic implementation programs by Forest Authorities (2008-09). An accurate mapping of forest cover and its classification analyses are the meaningful data for natural resources sustainability. Geospatial technologies come in handy for effective management & add immense value to planning & development analysis for forest regeneration and acts as support system to achieve sustainable goals.

Conflict of Interest

There is no conflict of interest between authors.

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