

Geomorphologic Change in Nagavali River Basin: Geospatial Approach

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The Nagavali river basin (NRB), along east coast of India investigated for its land use and land cover changes (LULCC) in the golden spike period of Anthropocene Epoch. Attempts made to assess the vicissitudes, causes, and consequences of natural resources, and soil/water resources of the NRB in last three decades as significant changes in hydro-climatic variables occurred. The interstate basin is well developed in lower reaches (north Andhra Pradesh) whereas upper stretches, South Odisha is less organized.

GIS and remote sensing are efficient tools for an ideal study of LULCC of the area. Present work evaluates the dynamics of LULCC of NRB. LANDSAT-5, LANDSAT-8, of 1990, 2000, 2010 and 2020, respectively, were digitally classified for land use land cover mapping. The changing aspects of LULCC critically analyzed for three span, 1990–2000, 2000–2010 and 2010–2020. Through Normalized Difference Vegetation Index (NDVI) of the NRB examined carefully to assess the recent LULCC pattern.

Major changes are due to exchanges of areas are in between forest and built-up land followed by water body. The transformations are from forest to human habitation; especially built-up area that constitutes major percentage of the total landscape. The study shows that emphasis is necessary on more water consolidation projects in the upper Nagavali Basin considering the long-term LULC trend analysis.

Keywords: Geographical information system; land use and land cover changes; Nagavali river basin; normalized difference vegetation index; remote sensing.

ABBREVIATIONS

NRB	: Nagavali river basin
GSSP	: Global boundary Stratotype Sections and Points
LULCC	: Land Use and Land Cover Changes
NDVI	: Normalized Difference Vegetation Index
AP	: Andhra Pradesh
SW	: South West
ROR	: Record of Rights
RS	: Remote Sensing
GIS	: Geographical Information System
ULB	: Urban Local Body
FC	: Fecal Coliform
TKN	: Total Kjeldhal Nitrogen
BOD	: Biological Oxygen Demand
ANN	: Artificial Neural Network
SVD	: Singular Value Decomposition
BoB	: Bay of Bengal
UAV	: Unmanned Aerial Vehicles
NIR	: Near Infrared
ESCS	: Extreme Severe Cyclonic Storms
TM	: Thematic Mapper
OLI	: Operational Land Imager
TIRS	: Thermal Infrared Sensor

1. INTRODUCTION

In geological time scale, the globe is passing through golden spike period (from 1980 onwards) of the Anthropocene epoch from mid-20th century, superseding the Holocene epoch according to Global boundary Stratotype Sections and Points (GSSPs). The golden spikes, accepting that the real time that the hominids have changed the global milieu and influencing the earth systems forces through overall development in science and technology. After 1980, during the golden spike period of the Anthropocene epoch, the climate, and environment have augmented the growth of sixth extension due to the land use and land cover. Present study envisages the change detection of a under developed basin to anthropogenic stressed area of the interstate river the Nagavali [1-3].

The Nagavali River (Lat.18.10 to 19.44 deg. N and Long. 82.53 to 84.05. deg. E) is emerging from Niyamgiri Hills (Bijipur Hills), from an elevation of 1300m (near Lakhbahal village, of

Kalahandi district, Odisha) within Eastern Ghats hills range. The average annual flow is 2.853BCM. It drains the runoff of the districts from Odisha state (Kalahandi, Koraput, and Rayagada), and Srikakulam, Vijayanagaram, and Visakhapatnam of Andhra Pradesh state. The river is flowing southeasterly and is debouching in the Bay of Bengal at Kallepalli near Srikakulam. The influencing natural factors for discharge of NRB are the climate; i.e. rainfall and evapotranspiration, the hydrology of the river basins, the anastomosis of drainage network. The Anthropogenic activities like dams, barrages, the urban and industrial flow, and the canal network. All these factors decides the biodiversity and ecological status of the area. The utilization of the river flow is meagre in south Odisha, whereas over-exploited in its lower reaches. The excess mining activities, particularly the Bauxite mine and aluminum industries have made the river water polluted due to high pH value of red mud, the major industrial waste [4-7].

1.1 The Nagavali the Unclassified River in India

The Central Water Commission, India is the pioneer organisation of hydrologic data of rivers of India. They are classified, and unclassified. The classified data is provided by the CWC for specific purpose/ study only and is not transferable. The unclassified data is either available WRIS website or published in CWC hydrology books to users free without any payment. The 256km is long composing 161 Km.in Odisha and 95 Km in AP. The Nagavali river has 9510km² basin area out of which 4462km² in Odisha, and 5048Km² in AP respectively. The upper river basin is in hilly topography of EGB Hills and dwelled mainly by tribal/aboriginal people housed in Odisha. The climate is Savannah type and drenched by SW summer monsoon with average annual rainfall of 1000mm. The river flows through major districts/ Urbans Visakhapatnam, Vizianagaram, Srikakulam Amadalavalasa, Parvatipuram, Veeragattam, Palkonda, in AP, and Koraput, Rayagada, and Kalahandi in Odisha (Fig. 1) [6] https://www.indianetzone.com/70/nagavali_river.htm.

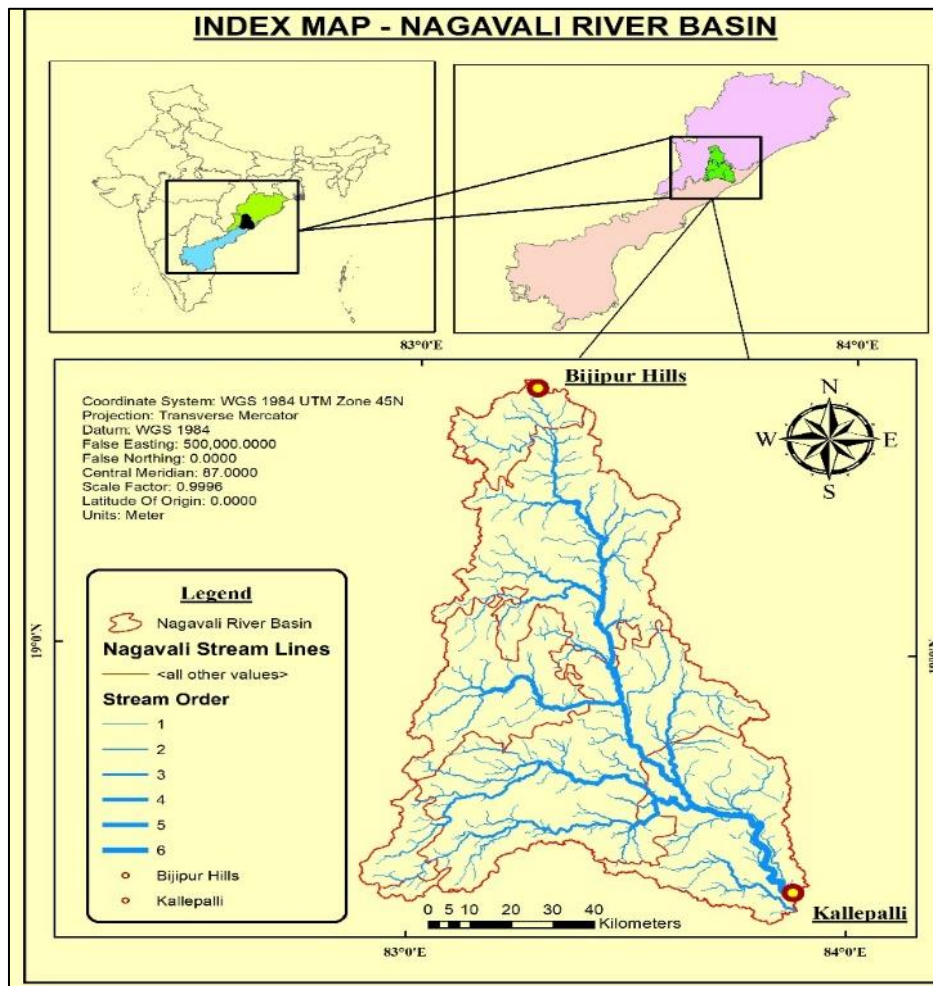


Fig. 1. The index map of the Upper Nagavali River Basin

The NRB has the Vamsadhara river in North, the Champavathi, and the Peddagedda rivers in the South, the Godavari in West and the Bay of Bengal (BoB) in East. The major tributaries of the Nagavali river are Barha, Suvarnamukhi, Vonigedda, Vegavathi, and Relligedda. The anastomosed nallahs are Pitadar, Datteibannda, Sat, Sitagura, Ghora and rivulets are Bada & sana nadi, Baldiya, Srikona, Sitaghera, Bonamarha, Errigeda, Jhanjhabati, <http://www.india mapped.com/rivers-in-india/nagavali-river/>.

1.2 The Stream Order of NRB

Allocating the links in numeric order to a river, its distributaries, and major Drainage Channels (DC's) deltaic reaches to origin chronologically called stream ordering. It is an indicator of hydraulic geometry, that identifies the classification and the anastomosis of the river

based on the drainage network and finally its relative size [7].

If the stream order rises, the discharge upsurges, the gradient drops, the velocity escalates, and the aspect ratio (full bank width to depth) surges to house the amplified discharge (Fig. 2). The stream order also specifies the discharge variations cross section wise or longitudinal gradient that determine the channel characteristics and water quality [8]. The Nagavali river is a river of sixth order (Amazon is 12th order), medium river with less drainage area (9510Km²) with an average discharge 24 cumec.

The stream order is helpful to find discharge of drainage channels of the basin as $w \propto Q^b$, $d \propto Q^f$, and $v \propto Q^m$, where w (width), d (depth), v (velocity) and m, b, f, m are numerical constants found from the flow equations. The sum of the exponents is given as $b + f + m = 1$, The basic relation $Q = wdv$ for a straight river. Prabhakaran et al. [9].

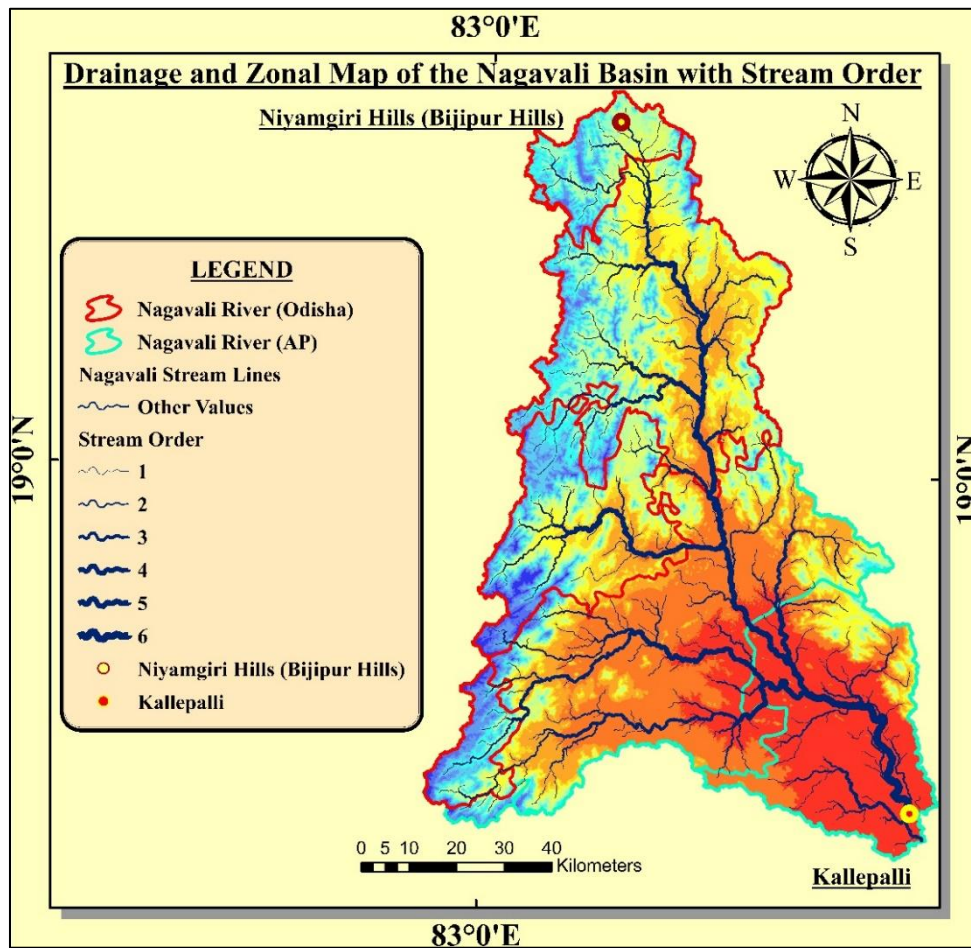


Fig. 2. The geomorphologic drainage & Stream order map of the NRB

1.3 Geospatial Technique

Remote sensing (RS) and Geographical Information System (GIS) have emerged as powerful techniques to generate the state of art of spatial inventory on natural resources and environment. GIS&RS is the process-based modelling that play pivotal role in spatial, and dynamic assessment of an area. RS methods have great advantages of synoptic views of wide area, non-destructive, and/or real time base attributes Gao et al. [10], Bogale [11].

The RS methodology can sense the reliability, accuracy, baseline information for land use and land cover (LULC), the classification of the attributes, their delineation and spatial distribution in large area synoptic reporting of large expanses, through the multi-temporal imageries and information. The modus operandi is fast/instant, economic and user friendly. The user of the tool can plan and formulate policies to decide landscape management, and the

hydraulic structures, ecosystem management and guide the project managers for their long-term optimal policy decisions of the natural resources of the area [12].

1.4 Developmental Infrastructures in Lower NRB

The upper Nagavali Basin in Odisha explored less from water resources point of view. The NRB in its lower stretch in AP is properly set-up through many Irrigation projects. The present status is in Table 1.

However, the number of WR projects have served the area and has brought changes the land use pattern of the ayacut in both AP and Odisha, mostly in 21st century. The changes in physical attributes like built up land, crop land, mountainous forest, shrub land and water bodies needs to be studied for better planning of the basin.

Table 1. Various developing infrastructures that helped in geospatial changes in LULC in NRB

Name of project	Village/district	Gist of projects in NRB	Status; Capacity in TMC
Bedant Alumina	Lanjigarh	Alumina refinery with red mud waste and	2 MTPA(million tons/ annum
J. K. Paper Industries	Rayagada	Paper Industry, two large integrated paper manufacturing units	455 TTPA (Th tones/annum
Jhanjabati; Vizianagaram; 2016	Rajyalaxmipuram, Komarada mandal; Jhanjabati R disty,	Rubber dam, 4TMC, ayacut of 24640acres ; last 20 years 0.6 tmcft reservoir storage capacity against 4 tmcft storage planned	Interstate dispute bet Odisha/AP
Madduvalasa Reservoir	Madduvalasa vil. in Vangara mandal	Maddigedda tributary; 24500acres CCA	Old project from 1977
Thotapalli Barrage; Nagavalli R.	Thotapalli Garu-gubilli Mandal, Vizianagaram	Catch. Area: 4455 sqkm – Orissa 3994 sq.km. AP.; 461 sq.km. Water (A.P. share) : 16 TMC	Old barrage: 25900 ha ayacut; 74462.1Ha irrign.
Vengalaraya Sagar (MIP)	Suvarnamukhi & Gomukhi	I.P:24700 acres; Ayacut; 6540 Ha Lakhmipuram(V) Saluru (M)	Twin reservoir; Const 1976/1998
Narayanapuram barrage	Burja mandal of Srikakulam	Across Nagavali Reservoir. The link channel shall both the bet. Nagavali & Vansadhara R. ,	30km long link
Vottigedda Reservoi	Rawada Vil., G. M.Valasa Mandal	gross capacity of 27.13 TMC; 6746 Ha irrigation;	Tribu. of Nagavali R.
Vengalaraya Sagaram Project	Lakshmipuram; Salur Mandal Vizi-anagaram Dist.	Irrigation 9996Ha; Croppin pattern; Khariff wet	Suvarnamukhi R, tributary of Nagavali R.
Peddankalam Anicut	Peddankalam;	Ayacut: : 3302Ha; Length: 23 km.; Discharge:4.0cumec	Cropping Pattern Khariff (wet)
Thatipudi Reservoir	Gosthani R., Thatipudi,vil. Gantiyada Mandal	Ayacut:5611.7 Hect ; Gross cap: at FRL : 94.15Mha;	Water supply to Visakhapatnam: 18.2Mm ³

Source: Veerabhadru et al. [13]

1.5 Water Quality in the Upper Nagavali Basin

The upper Nagavali Basin passes through Industrial towns and ULB's in areas like Rayagada, Koraput, Jay Kay Pur, Damanjodi and Lanjigarh are polluting the river water by industrial/ municipal liquid wastes and making unhealthy. IS.2296-1982 – (2nd revision), classified rivers based on the limits (tolerance) in five categories depending upon their overall water Quality. They are: **Class-A**: source for drinking water without treatment but then to undergo disinfection, **Class-B** – source for alfresco bathing; **Class-C** – Source for Drinking with treatment & disinfection; **Class-D** - Fish farming and wild life use; **Class-E** – For Irrigation, industrial use or controlled waste disposal. Water quality of the Nagavali river cannot conform to Class-C. TC is the major, as polluted from Industrial waste from Jay Kay Pur and Rayagada town ship, beyond acceptability level due to TKN and FC values. BOD data Jaykaypur to Rayagada, for a stretch of 11km the river identified under priority-V category [14].

2. LITERATURE REVIEW

The medium rivers Vansadhara and the Nagavali emerging from south Odisha are beyond the Bahuda river. The Basins are unclassified declared by Central water Commission, GoI. All the rivers along east coast directly or indirectly debouching to the Bay of Bengal (BoB) [15]. Vani et al. [16] has studied by Comparative study of NDVI & SAVI, the LULC of Anantpur district, Andhra Pradesh and has reported that the Semi-arid area; the SAVI veg. index; suitable over popular NDVI especially in medium spatial resolution. The soil factor 0.9 is useful (low vegetation cover areas). Gandhi et al., [17] similarly studied the NDVI changes of vellore dist, Tamilnadu for (2001-2006), and reported that The forest, shrub, & barren land cover decreased by 6% & 23%, where crop, built-up & water body areas increased by about 19%, 4% and 7% respectively. Ozyavuz, et al. [18] have reported that the NDVI values are high towards northern part of Tekirdag dist., Sarkoy, Turkey. The NDVI of the Jabalpur City studied by Bhandari et al. [19] and have mentioned that the % of vegetation is same and changes found to

be 32.1304% at NDVI threshold of 0.3, waterbody (6.5771%), rock & urban (23.49%) & rest 37.8%. Roy et al. [20] studied the LULCC of India from 1985-2005 and found major increase farming (47.55–49.34%), built-up (1.03–1.44%), major decrease forests (23.25–22.18%), wastelands (2.57–2.27%).

Attri et al. [21] reviewed the RS/GIS based approaches for LULCC finding and reported about differencing, image rationing or regression, post-classification contrast, multi-date direct link, ANN, SVM, GIS, decision tree, multi-sensor data fusion, Fuzzy.. Feature level change detection employ NDVI, KT/ TC change. Preferred post-classification link method. Mondal et al. [22], found LULCC of Kamrup district in Brahmaputra Basin, and mentioned changes in LULCC due to forest degradation during (1987– 1997) 68.40% and (1997–2007) 80.12%. Singh SK. [23], studied the LULC map by standard (FCC) satellite images of Samastipur dist., Bihar and reported that the 90% with the Kappa coeff. of 0.83 geo spatial approach, proved as a powerful tool to find LULCC. Gidado, et al. [24], reported that the GIS/RS tools used for LU/LC classification are supervised MLA, CD, MLC, SAR, GEE,NDVI, MCA, Hybrid, DT, Transition matrix,& unsupervised. MLA is dominant for LULCC. Setti et al. [25], Setti et al. [26], considered Nagavali river basin (1985- 2000), using GIS/RS/SWAT model for rainfall/ runoff of the Nagavali river basin (1985- 2000), reported difference in rainfall/ discharge in the basin ranging from 914 to 1319 & 82 to 246 mm respectively. From 2002–2012, there is increase in runoff 41.52%, and LU changes are causes for decreased runoff -23.54% (1990 as base year). Roy et al. [27], considered LULCC (1972-2016) of Shivna basin, a tributary of Godavari River and found LULCC (1972- 2016). Eman et al. [28], discussed the about LULC classification using RS/ GIS, ANN to find accuracy, is the best classifiers, & features. Soft classification (object-based classification (RF) is better than (MLC, SVM).

Various techniques and tools described in literature are about change detection in vegetation, and other attributes to analyse the satellite imageries like NDVI , ANN (Artificial Neural Net-work), and satellite image contrast enhancement (Table 2). They use discrete wavelet trans-form (DWT), and singular value decomposition (SVD), for increased spatial, accurate, and temporal coverages, [29-34]. The way of taking/receiving satellite imageries and

big data done by innovative methodologies by using LIDAR, GNSS, unmanned aerial vehicles, drones etc [34-36].

The major deltas of east coast of India well planned with hydraulic structures, and ample data is available pertinent to the basin for planning. The small rivers debouching Bay of Bengal (BoB) less explored, particularly in their upper basins. It is essential to study the changes in flow, sediment; land use and land cover (LULCC) that has occurred due to climatic and anthropogenic changes in those small basins. The Research Gap and present study aims at focussing on the LULCC in a small river basin, the Nagavali river basin flowing within Odisha and AP.

2.1 Justification for the Study

However, climate changes, meteorological extremes, disastrous cyclones [(super cyclones (SUCS), Extreme severe cyclonic storms (ESCS), and Very severe cyclonic storms (VSCS) in Bay of Bengal (BoB) hitting north Andhra coast have impact on LULC in NRB . They were Gulab (2021), Amphan (2020) Phethai, Titili (2018), Hudhud (2014), Lehar and Phailin (2013), Pyarr-2012, ESCS BOB-05; 1999, VSCS BOB 06; 1996, ESCS- BOB 02; 1993, and SUCS- BOB 01 in 1990 [37].

During last three to four decades, the climate change in the BoB and anthropogenic stresses, have notable alteration in the land use pattern and water management in NRB. Consequently, the quality and quantity of riverine flow have changed in the Nagavali basin. There is less study on the decadal change in the vegetation, Agriculture and land use pattern in the Nagavali basin, which has become pertinent as the manual assessment LULCC is time consuming, costly and the available ROR (Record of rights) are challenging. The use of satellite images and remote sensing tools have made the task easy, prompt and noncontroversial [38].

3. THE METHODOLOGY

The study LULCC of various areas have growing importance after innovative GIS/ RS growth, and many other software based techniques. The global climate change have reflected in regional scale. Both anthropogenic causes, extreme events, mass extinctions and climatic anomalies donate prominently to inventory and monitoring records of LULCC.

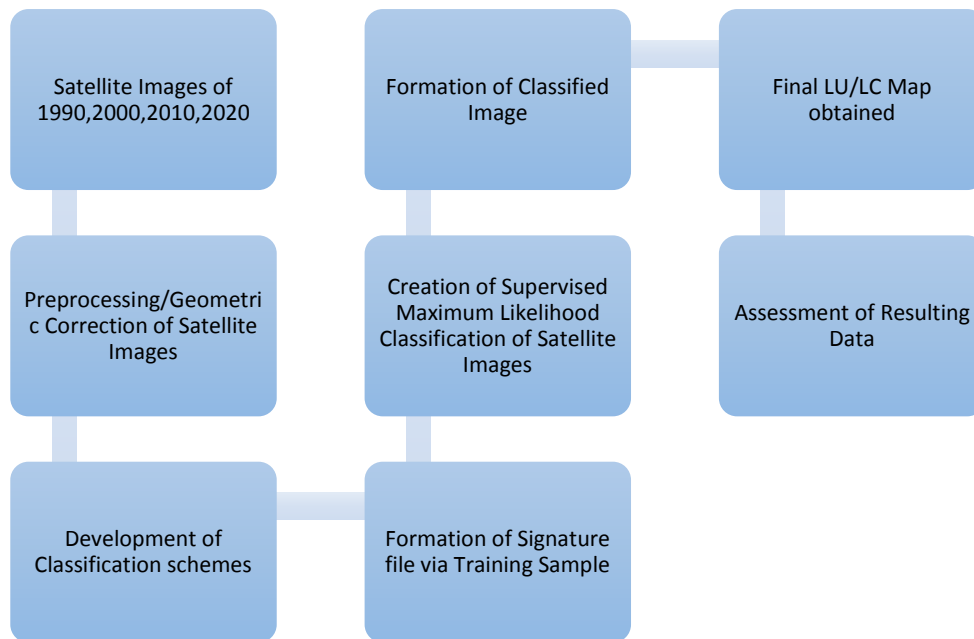


Fig. 3. The flow chart for methodology applied for making various maps in the analysis

The focussed objective is to identify the LULCC changes over the last three decades (1990-2020) in the Nagavali river Basin using Multi-temporal and multi-sensor data from satellite images of 1990, 2000, 2007 and 2020. LULC maps prepared. The analysis made by using post classification comparison methods. It is important the upper NRB developed a number of industries and urban areas where as the lower NRB have a number of irrigation projects. The whole basin has gone physical changes.

The latest sensor technologies, captures non-visible signals like near infrared, thermal-infrared and microwave band wavelength. The commanding GIS expertise can integrate big data and information. Later the data make the spatial analysis, and finally interpret them for visual presentations. The levels and LULC classes considered for classification are forest (dense or degraded), water bodies (rivers, drains or lakes), agricultural land (crop, fallow lands, and plantations), and built up land.

Attempt made through NDVI (Normalized Difference Vegetation Index) calculations. It is useful for continental- to global-scale vegetation monitoring because it can compensate for changing illumination conditions, surface slope, and viewing angle. The methodology is in the following flow chart Fig. 3.

3.1 Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) has been one of the most commonly used vegetation indices in remote sensing since its introduction from 1970s. The increased availability of remotely sensed imagery from satellites drones, and unmanned aerial vehicles (UAVs). The NDVI method for LULCC determination has become popular. Agriculture is the most popular industry present days. Leveraging advantages of satellite data due to its large area of coverage, accuracy of results, and higher rate of acquisition the entire country observed from space at a certain frequency Sharma et al. [38], Huang et al. [39].

The NDVI allows to determine how health status of vegetation. The Cell structures in plants reflect the near infrared (NIR) waves. When photosynthesis occurs, the plant develops, and grows and contains more cell structures. A healthy plant with plenty of chlorophyll and cell structures actively absorbs red light and reflects NIR and an unhealthy plant behave opposite. The NDVI index detects and quantifies the presence of live green vegetation using this reflected light in the visible and near-infrared bands [40] (Table 2).

Table 2. NDVI range and concerned objects

Range of NDVI Value Range	Name of the Objects
-1	Water Body
0	Bare Soil, Rock, Sand and Snow, Cloud
0.2- 0.3	Shrub and Grassland
0.3-0.5	Sparse and Unhealthy Forest
>0.5	Dense and Healthy Forest

3.2 Data Collection

To download the Level-1 reflective browse either the scene bundle (all bands), or individual bands it is necessary to delineate the area under interest. After selecting the area on the map, or entering an address, zip code, or by place name by using the graphical interface interface as per normal procedures in vogue. The details of land sat imageries imported and their characteristics are in (Fig. 4), Table 3.

3.3 Results of Land Use Land Cover Classification

The quantitative results and spatial distribution of LULC, based on digital classification of satellite images for four different years 1990, 2000, 2010, and 2020 displayed in Table 4 and Fig. 5. Each LULC map (1990, 2000, 2010 and 2020) contains five LULC classes, for example built up land, agricultural cropland, dense forestland, and the land with or without scrub, river/lakes/reservoirs /ponds. The LULC types derived from digital image classification validated. The overall accuracy of the LULC maps of these maps achieved with minor error percentage. Error percentage caused due to wrong color detection while creating training samples, which lead to change in area of LULCC [41,42].

The land use patterns derived from various land use maps infer that total study area is about 9044.34 km² (against 9150Km²). The LULCC variations in the basin during the period from the year 1990 to 2020 are (i) there is a continuous surge in the built up area from 2.5% to 14% and agricultural land has increased from 8% to 41.6%. The rise can be accountable for exponential population explosion, urbanization, deforestation, industrialization in the lower NRB and conversion of EGB hilly terrain to accommodate the urban population [43,44].

The increase in irrigation potential in lower NRB can be the main cause of increase in cropland. (2) The hilly forest areas has become sparse and reduced from 45.5% to 22.7% along with the shrub and other areas have decreased from

42.8% to 17.7% due to mining and industrial activities, conversion of fallow lands, and urbanization. The vigorous impact of the more numbers of cyclonic storms passing through the basin has shattered the area. The major causes of transformation is due to conversion of the forest area to newly formed towns and industries in the upper basin. The lacustrine area have augmented from 1.2% to 4% may be due to focused attention of the government for the development of watershed, formation of reservoirs and waterbodies [45].

3.4 Relative LULCC between Three Consecutive Periods

The statistics of LULC and relative changes in NRB area of two periods, *i.e.*, between 1990, 2000, 2010 and 2020. The correlations between relative changes of three periods are positive, where $R^2 = 0.3165$ (Fig. 6). It established that correlation between relative changes of three periods are relatively strong. The trends of relative changes in the LULCC pattern between the periods between 1990 and 2000 and 2000 and 2010 and 2010 and 2020 are slightly different from one period to another period. Above plot indicates that the correlation of the three periods *i.e.* 1990- 2000, 2000 – 2010 and 2010 - 2020, which infer the trend, is similar and have minor differences [46].

3.5 Normalized Difference Vegetation Index (NDVI) Result

Normalized Difference Vegetation Index (NDVI) is used to find rainfall, LULCC, vegetation trend, surface air temperature, soil moisture etc [47]. Landsat Surface Reflectance-derived Normalized Difference Vegetation Index (NDVI) products are produced from Landsat 4–5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) Collection 1 and Collection 2 scenes that have been processed to Landsat Level-2 Surface Reflectance products. NDVI classification was in use to quantify vegetation greenness and is useful in understanding vegetation density and

assessing changes in plant health. NDVI calculated as a ratio between the red (R) and near infrared (NIR) values in traditional fashion:

3.6 Calculation Used for Different Landsat Data

$$(NIR - R) / (NIR + R)$$

In Landsat 4-7, NDVI = (Band 4 – Band 3) / (Band 4 + Band 3).

In Landsat 8, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4).

This Table 5 shows the NDVI of year 1990, 2000, 2010 and 2020. It includes 4 different NDVI

classes bare soil, dense and healthy forest, shrub and grassland and water body. It shows that the percentage of vegetation is almost same for different threshold value the year 1990.

Empirical study implies the highest percentage of vegetation of bare soil found to be 66% in 2010, water bodies & river found to be 6% in 2010, dense, healthy forest found to be 46% in year 2020 and shrub, and grassland area found to be 50% in year 1990. The NDVI method gives superior results for vegetation varying in densities and for scattered vegetation from a multispectral remote sensing image (Table 5).

Table 3. The dates of Landsat data collected and used for the analysis in NRB geomorphology study

Landsat	Date of acquisition	Date of generation	Cloud covered	RMSE of Geometric model	UTM zone/datum
Landsat-5	09.04.1990	16.09.1990	No clouds	4.566	UTM 44/ WGS84
Landsat -5	09.04.1990	16.09.1990	No clouds	4.746	UTM 44/ WGS84
Landsat – 7	12.04.2000	18.09.2020	No clouds	4.468	UTM 44/ WGS84
Landsat – 7	08.12.2000	17.09.2020	No clouds	4.319	UTM 44/ WGS84
Landsat -5	27.02.2010	25.08.2020	No clouds	3.767	UTM 44/ WGS84
Landsat -5	27.02.2010	25.08.2020	No clouds	3.978	UTM 44/ WGS84
Landsat -8	07.12.2020	13.03.2021	No clouds	4.913	UTM 44/ WGS84
Landsat -8	07.12.2020	13.03.2021	No clouds	5.327	UTM 44/ WGS84

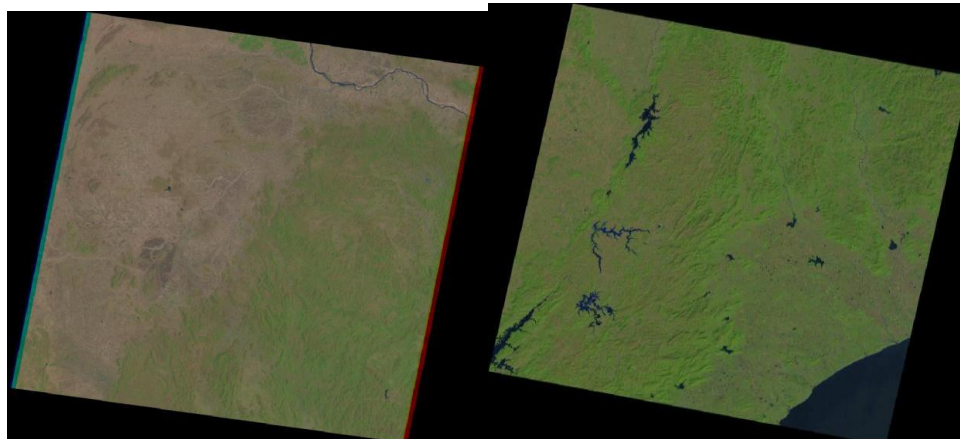


Fig. 4. Samples of Level-1 Reflective Browse on 19.9.1990 and on 7.12.2020;
<https://www.usgs.gov/core-science-systems/nli/landsat/landsat-data-access>

Table 4. The comparison of various LU areas of NRB in the years 1990, 2000, 201 and 2020.

#	LULC Classes	1990		2000		2010		2020	
		Area in Km ²	Area (%)	Area in Km ²	Area (%)	Area in Km ²	Area (%)	Area in Km ²	Area (%)
1	Built up Land	226.108	2.5	361.773	4	813.99	9	1266.207	14
2	Crop Land	723.547	8	1899.311	21	3255.96	36	3762.445	41.6
3	Hilly Forest	4115.174	45.5	4187.529	46.3	2713.302	30	2053.065	22.7
4	Other Land	3870.977	42.8	2441.971	27	1998.799	22.1	1600.848	17.7
5	Water Bodies	108.532	1.2	153.753	1.7	262.285	2.9	361.773	4
	Total	9044.34	100	9044.34	100	9044.34	100	9044.34	100

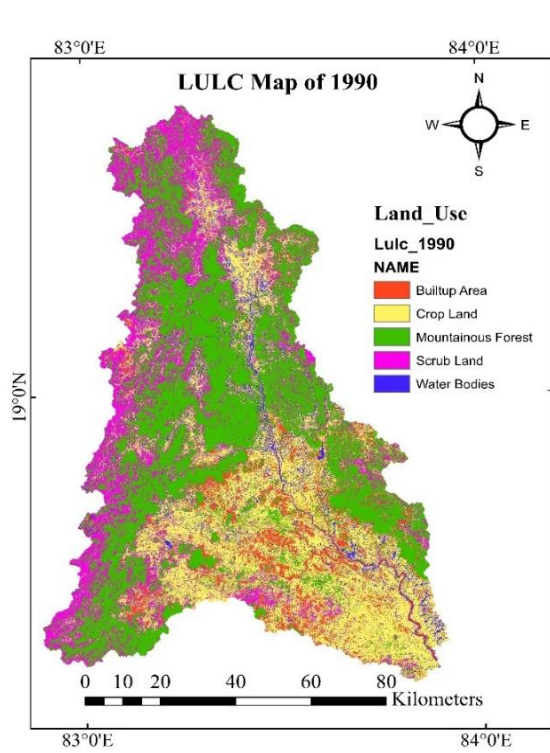


Fig. 5 (a). LULC Map of 1990;

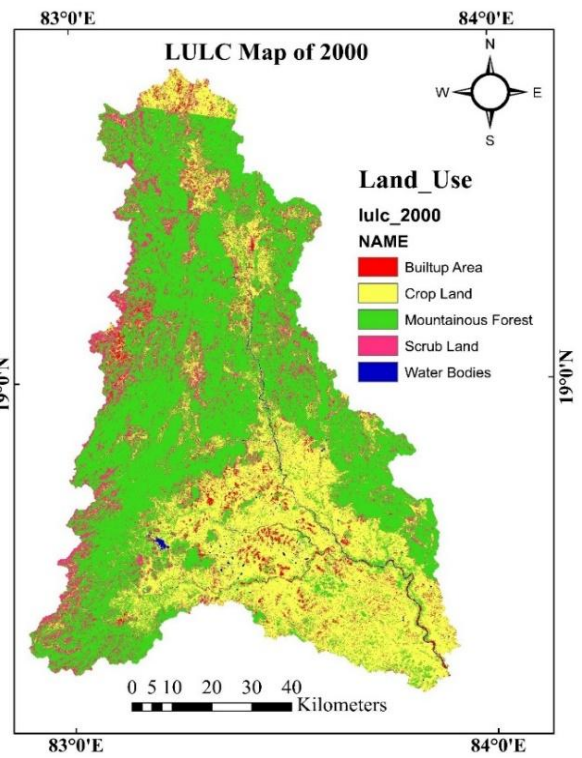


Fig. 5(b). LULC Map of 2000

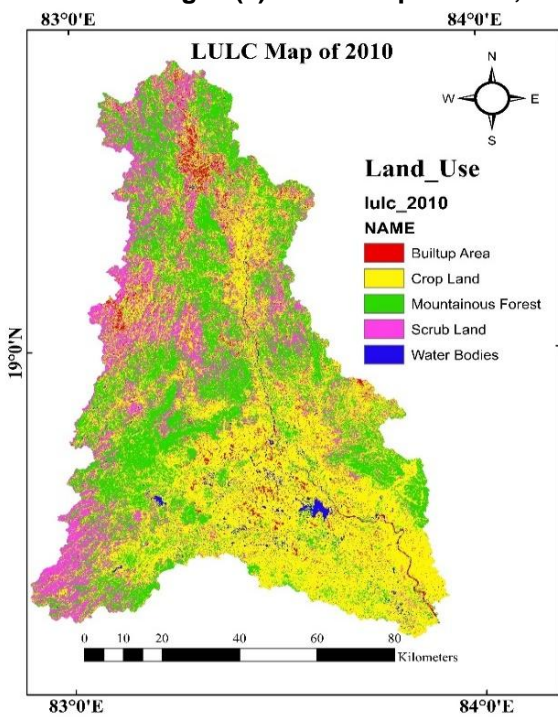


Fig. 5 (c). LULC Map of 2010;

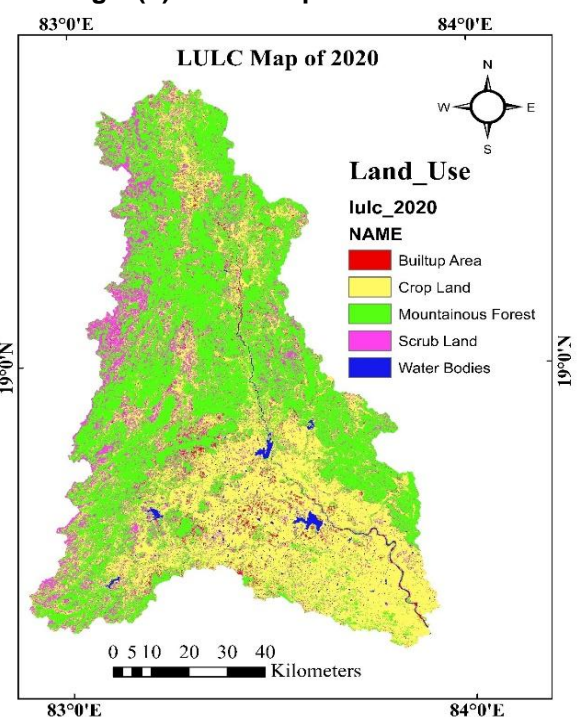


Fig. 5 (d). LULC Map of 2020

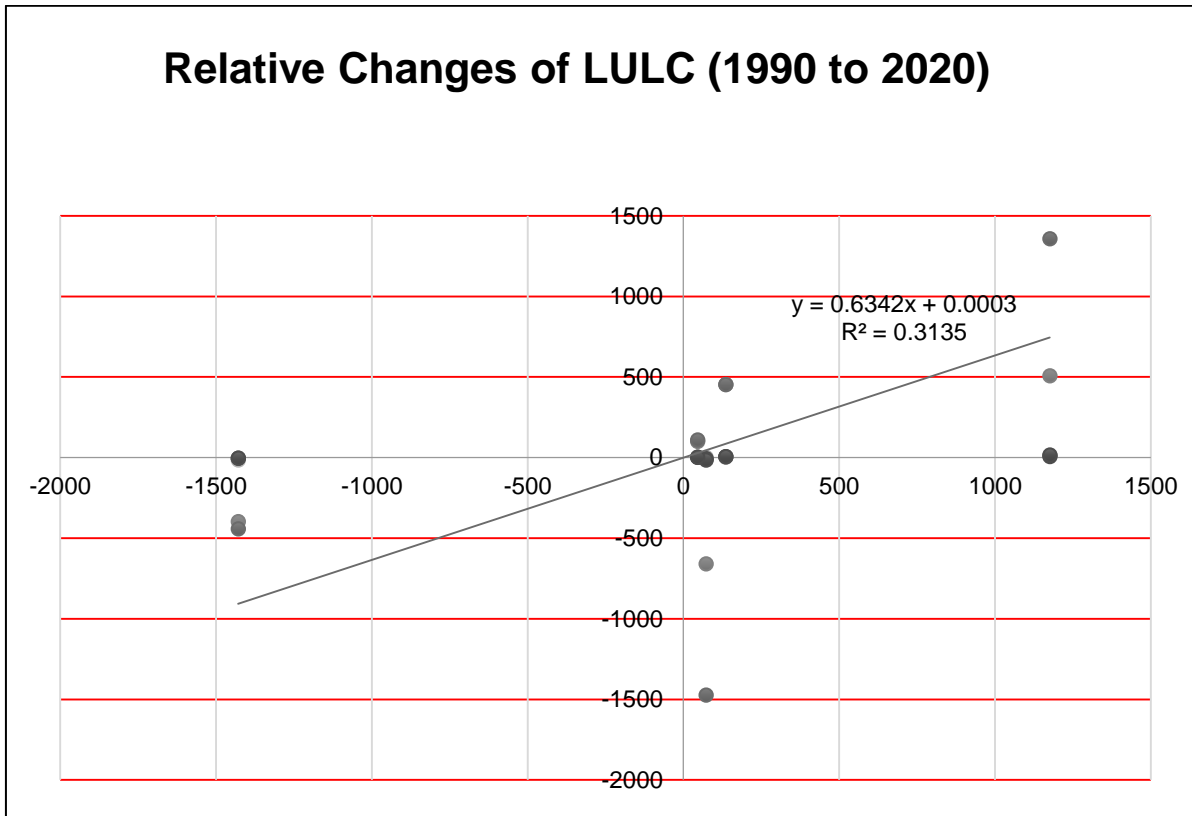


Fig. 6. Correlation of relative changes of LULC (1990–2000, 2000–2010 and 2010–2020)

Table 5. Land use/ land cover changes area statistics of NDVI in NRB (1990-2020)

Sl. no	NDVI Classes	1990		2000		2010		2020	
		Area in Km2	Area in (%)	Area in Km2	Area in (%)	Area in Km2	Area in (%)	Area in Km2	Area in (%)
1	Bare Soil	3818.52	42%	300519	34%	597532	66%	134631	15%
2	Forest	394.37	4%	207680	23%	11602.5	1%	416786	46%
3	Shrub/pastures	4533.43	50%	366037	40%	244959	27%	339262	37%
4	Water Body	298.92	4%	30286.1	3%	50427	6%	13840.2	2%
	Grand Total	904524.4	100%	904522.1	100%	904520.5	100%	904519.2	100%

4. RESULTS AND DISCUSSION

The Change Detection analysis is an efficient way of describing the changes observed in each land use category. Over a decade, there were considerable variations in agricultural land, hilly area with vegetation and in dry farming. Supervised classification of Landsat images and cross verification by ground truth traverse has results an overall accuracy of the image interpretation classes. A high-resolution satellite data would suitably improve the land use classification. The NDVI technique with different threshold values employed for features

extraction. It clearly shows that the percentage of vegetation is almost same for different threshold value. Empirical study implies the highest percentage of vegetation of bare soil found to be 66% in 2010, water bodies & river found to be 6% in 2010, dense/healthy forest found to be 46% in year 2020, shrub/grassland area found to be 50% in year 1990. The NDVI method gives superior results for vegetation varying in densities and for scattered vegetation from a multispectral remote sensing image. The following details are updated/new information for the Nagavali river basin [48].

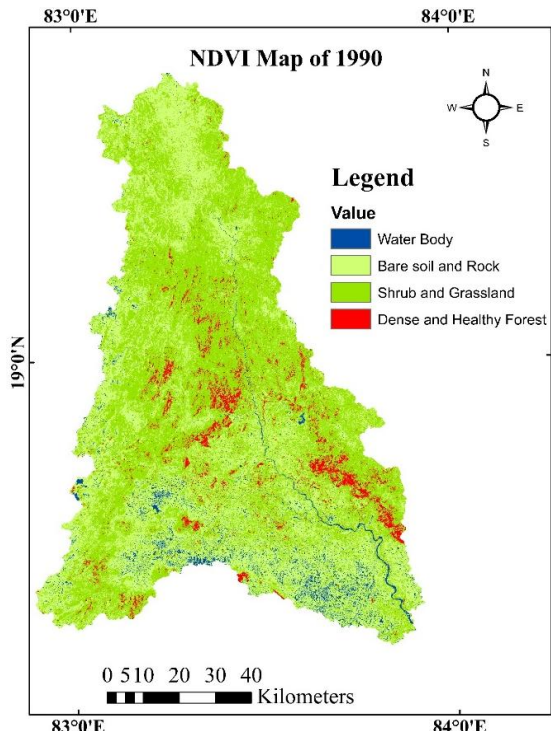


Fig. 7a. NDVI Map of 1990

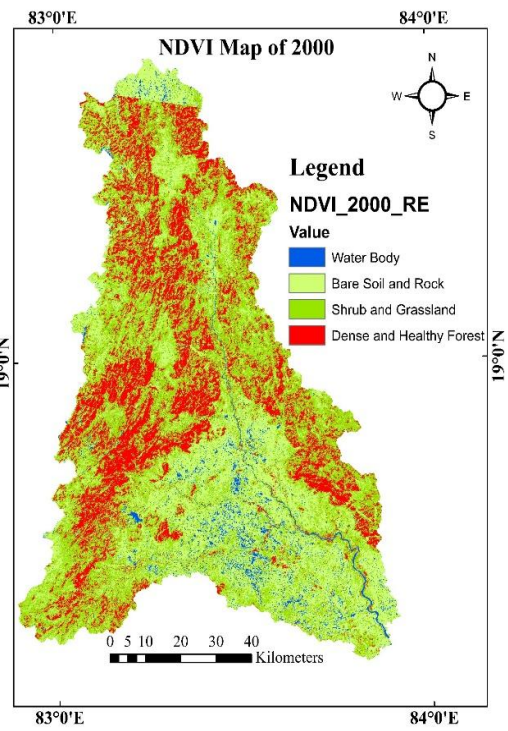


Fig. 7b. NDVI Map of 2000

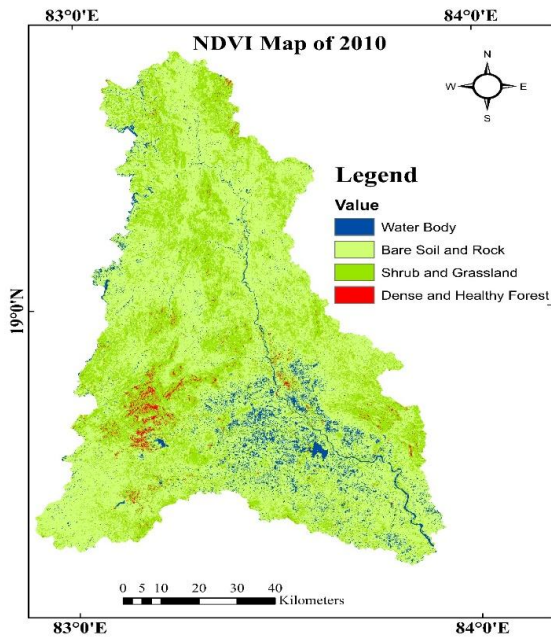
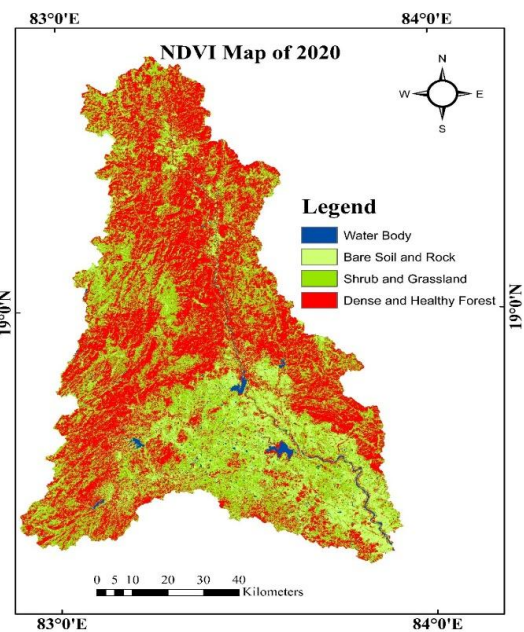


Fig. 7c. NDVI Map of 2010;



7d. NDVI Map of 2020

- Total Area as of

- 09/04/1990
 - 12/04/2000
 - 08/12/2000
 - 27/02/2010
 - 12/07/2020
- 9044.5 km²

- NDVI changes observed (1990) - minimum= -0.3 maximum= 0.44
- NDVI changes observed (2000)- minimum= -0.17 maximum= 0.51
- NDVI changes observed (2010) – minimum= -0.13 maximum= 0.45
- NDVI changes observed (2020)- minimum= -0.31 maximum= 0.53

5. CONCLUSION

This study analyses remotely sensed observations to measure and characterize the changes of the land use land cover (LULC). The dynamics of LULC analysis examined changes among several land categories between 1990–2000 to 2000–2010 and 2010–2020 in the NRB area. The results show that the annual speed of changes was slower during 1990–2000 than during 2000–2010 and 2010–2020. The total change during (1990–2000) is 15.8%, during (2000–2010) is 21.2%, and during (2010–2020) is 11.7%, which is showing a decreasing trend, confirming to the sustainable and stable LULCC. The geospatial method of change detection of LU/LC of Nagavali basin area influenced by climate change, meteorological extremes and overall anthropogenic activities. The land use and land cover changes need to be evaluated and utilised for efficient basin planning.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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