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Full Length Research Article

Landuse/Landcover Change Detection Using Remote Sensing and GIS Based on NDVI Approach: A Case Study in Puliyeru River Basin, Anantapur District, Andhra Pradesh, India

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Abstract

Vegetation loss has been an ongoing practice since the dawn of human space exploration. For both upper and lower catchment, it has an impact. Vegetation Index (VI) and Remote Sensing (RS) and Geographical Information System (GIS) techniques may be used to investigate this disruption. In terms of determining vegetation cover, the Normalized Difference Vegetation Index (NDVI) is a useful tool. Visual and near infrared electromagnetic spectrum is used to generate a numerical indication. NDVI differencing was used to detect changes in the environment. In various NDVI threshold values, such as 0, 1, 2, 5, 10, 15, 20, 25, 30, 35, and 40, the NDVI technique is used based on its characteristic like vegetation. For policy makers, the simulation results show that the NDVI is very accurate in estimating surface properties of the viewable region. Over the entire study period, agriculture land was the predominant land use type (46.56%) during 2012, although it declined at an annual rate of 2%, and reached to only 7.13% in 2021. Forest showed the slight decrease (20.21% to 19.39%) since 2012–2021 with an annual increase rate of -0.82% and such growing trend does exist mainly in the peripheral rural transition of the urban centre. Within urban area, vegetation coverage has declined rapidly. Water body declined slightly at an annual rate of 2.81%, with around 4.17% to 1.36% since 2012-2021. Within main urban heartland, most of the water bodies are reclaimed and undergone into edifices. Large part of water bodies majorly captured by water hyacinth. Vegetation trend enhanced the growth of vegetation area and in between 2012 and 2021 recorded areal expansion was 29.06% to 25.56% with a decreasing rate of 3.50%. The primary goal of this article is to use the NDVI approach to spot changes in plant patterns and the disappearance of green cover.

Key words: NDVI, Landuse /landcover, GIS, Remote sensing, Change detection

Nowadays advanced remote sensing has become a powerful monitoring tool for many aspects of global monitoring for its convenience and high efficiency. This technology has widely employed for descriptive and statistical studies between satellite derived vegetation conditions and various climatological variables over different regions with spatial and temporal scales [1-2]. Vegetation change plays a crucial role in the environmental process. Vegetation indices can serve as a sensitive indicator of climate and anthropogenic influences by altering energy balance, climate, hydrologic and biological cycles [3-5]. The Normalized Difference Vegetation Index (NDVI) is one of the most important and commonly used satellite-based vegetation indexes for monitoring vegetation changes and its interaction with various climatic variables to interpret its impact on biosphere [6] NDVI is associated with a variety of vegetative parameters. The index is calculated from the following relation:

$$NDVI = (NIR – RED) / (NIR + RED)$$

Where NIR is the reflectance in the near-infrared channel and RED is the reflectance in the red channel. More than 90% of vegetation information is contained in these RED and NIR band. The underlying principle of the above formula is that the radiation from visible red light is considerably absorbed (or poorly reflected) by chlorophyll in green plants, while the radiation from near infrared light is strongly reflected by the spongy mesophyll leaf stricter. Environmental variations often alter the vegetation pattern [7-9]. Precipitation is one of the most important parameters for vegetation growth. Soil moisture is the crucial parameter for investigation of vegetation condition over a region. But over large geographical areas in situ information about soil moisture is difficult to obtain, where remote sensing precipitation information is a useful way at this circumstance as precipitation is the major natural source of soil moisture. Evapotranspiration (ET) is another essential component for assessing vegetation dynamics as it plays crucial role in energy and water budget of grassland and agricultural

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ecosystem [10-13]. Many studies have conducted to assess the vegetation patterns over the world. Among the studies, has showed a description of vegetation dynamics on a global scale; carried out the spatial patterns of NDVI in response to precipitation and temperature in the Central Great Plains and investigated interannual NDVI and its correlation to ET over northern Asia and relevant positive correlations were obtained between NDVI and interannual ET variation over vegetated regions [14-15].

NDVI and vegetation patterns exhibit large interannual variability over Andhra Pradesh and preliminary studies suggest a correlation with rainfall fluctuations, particularly in the Sahel [16-17]. This conclusion is not surprising, since rainfall (that is, moisture availability) is a limiting factor in vegetation growth at most locations on the continent. However, the NDVI- rainfall relationship has not yet been investigated in great depth. For example, it remains to be established whether and under what conditions NDVI is a sensitive indicator of the interannual variability of rainfall and what hydrological variables, such as soil moisture, are most closely linked with NDVI. Similarly, little is known about the timing of NDVI response to rainfall [18-21]. Vegetation growth might reflect the near contemporaneous occurrence of rainfall in biomes with a large population of ephemerals, but in other cases growth might lag rainfall fluctuations or respond to a multi-month or multi-year time-integral of rainfall. The purpose of this study is to investigate the relationship between NDVI and rainfall: in particular, to analyze the spatio-temporal variability of NDVI for various vegetation types and its relationship to rainfall variability.

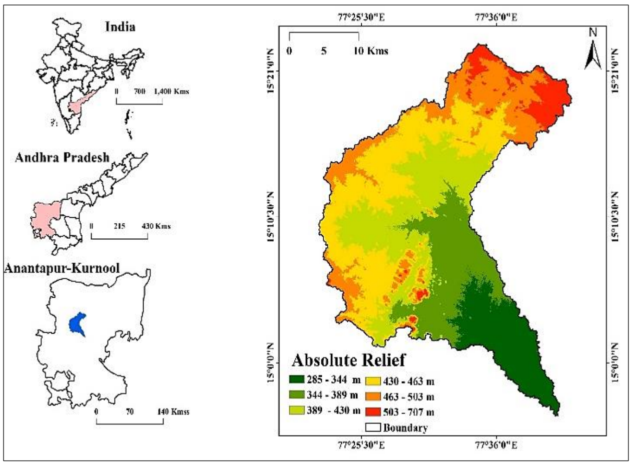

Fig 1 Location map of the Puliyeru River Basin, Andhra Pradesh, India

Study area

For the present study Puliyeru river basin is selected in Andhra Pradesh, India having different physiographic areas. The Puliyeru river basin originates from Pattikonda hill area from Kurnool district and it merges in Penna River at Anantapur district in Andhra Pradesh.

Puliyeru River basin a sub tributary of Penna River originates from Anantapur district in Gooty. Puliyeru River is located between 77° 21' 40 E to 77° 41'40 E longitudes and 14°55' 50 N to 15°24'50 N latitudes covering an area of 834.18 sq.km. The study area is included in the Survey of India (SOI) Toposheet No 57F/5, 57F/9, 57E/7, 57E/8, 57E/11 and 57E/12 at a scale of 1: 50,000. Physiography of the study area consists of mountains, ridges and hills forming gentle rolling topography. Alluvial plains are along the river courses where mainly alluvial deposits are found. The area has undulating topography and meandering streams.

Villages in the study area are well connected by metaled and unmetalled roads. Gooty, Pamidi and Pattikonda are the major townships located in the study area. A major part of the located in Anantapur District and some minor located in Kurnool District.

MATERIALS AND METHODS

In the present study we have used mainly two types of data. These are topographic map and remote sensing data. The remote sensing data of georeferenced and merged data of Landsat 8 OLI+ in the digital mode are obtained from the Earth Explorer website. The spatial resolutions 30 meters, and spectral resolutions are 30 meters, respectively. The topographic maps 57F/5, 57F/9, 57E/7, 57E/8, 57E/11 and 57E/12 (1:50,000 scale) is obtained from the Survey of India, Hyderabad, which was surveyed and prepared in 1976; it is converted to digital mode using scanning. The topographic map is georeferenced with longitude and latitudes using the ArcGIS software and spatial analyst tools and demarcated the boundary of study area. In this Section, the Normalized Difference Vegetation Index (NDVI) technique is used for extracting the various features presented in the 2-band Satellite image of Puliyeru river basin. Vegetation Cover is the one of most important biophysical indicators to soil erosion, which can be estimated using vegetation indices derived from the Satellite images [22-25].

Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The NDVI is a simple numerical indicator that can be used to analyze the remote sensing measurements, from a remote platform and assess whether the target or object being observed contains live green vegetation or not. From the equation (1), NDVI is calculated as:

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED}$$

where RED denotes reflectance in the visible red range and NIR denotes reflectance in the near infrared range. It is within the (750-1300 nm) range of the NIR band, (600-700 nm) for the red band, and (550 nm). It is the difference between the NIR and red bands that determines how much chlorophyll is present in the observed plant. As a result, it normalizes the (NIR - red) differential in order to compensate for shadows cast by clouds or hills [26-29].

For many features, (Table 1), which lists the wavelength range and characteristic values. That is to say, on a pixel-by-pixel basis, subtract the red band value from the NIR band value and divide by their total. Low NDVI values (0.1 and lower) indicate regions of rock, sand, or snow that lack vegetation. Moderate levels imply shrub and grassland (0.2 to 0.3), whereas high values indicate temperate and tropical rainforests (0.6 to 0.8). NDVI values closest to 0 are used to represent bare soil, whereas NDVI values opposite to 0 are used to depict water bodies [30-34].

In other words, the chlorophyll concentration is directly proportional to the greenness of the plant. Red light absorption by plant chlorophyll and infrared radiation reflection by water-filled leaf cells affect NDVI values. The Satellite camera gathers all visible ranges in the form of NDVI bands, from which various properties may be obtained after utilising the NDVI technique. Using wavelengths of about 1 m, each band is depicted [35]. These visible ranges (visible blue, thermal infrared and mid-IR) may all be used to extract various properties, but just three visible bands (visible red and visible green) are used in this work for feature extraction.

Table 1 Thematic bands of LANDSAT 8 Satellite Image

S. No	Name of the band	Wavelength	Characteristics and usage
1	Visible Blue	0.45-0.52	Maximum Water Penetration
2	Visible Green	0.52-0.60	Good for measuring plant vigour
3	Visible Red	0.63-0.69	Vegetation Discrimination
4	Near Infrared	0.76-0.90	Biomass and shoreline mapping
5	Middle Infrared	1.55-1.76	Moisture Content of Soil
6	Thermal Infrared	10.4-12.5	Soil moisture and Thermal Mapping
7	Middle Infrared	2.08-2.35	Mineral mapping

To determine the vegetation index from a Multi Spectral Remote Sensing picture included in a satellite image, the NDVI process necessitates the separation of each band. A series of NDVI threshold values, such as 0.1, 0, 15, 0, 25, 0, 30, 35, 0, 4, 5, 6, and 8, are used to differentiate between the various bands once the discrete bands have been separated. Satellite images of Puliyeru river basin, Andhra Pradesh, India are analyzed using a variety of NDVI threshold settings [36]. The methodology followed in this research shown in (Fig 2).

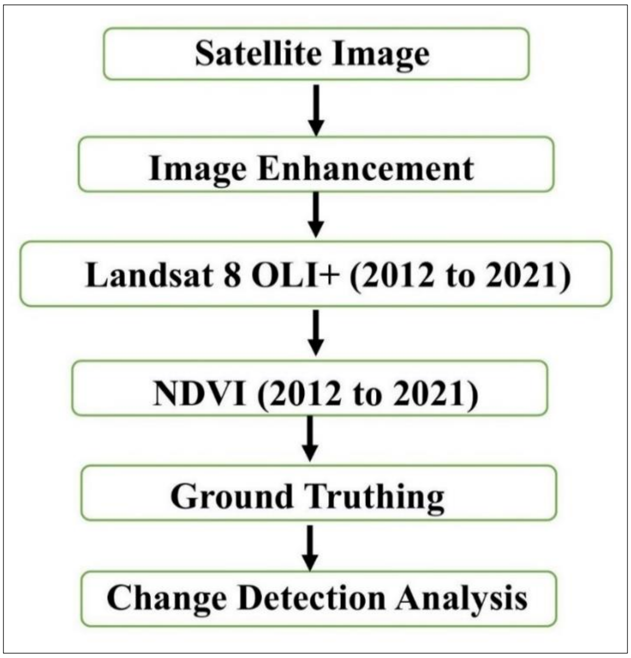

Fig 2 Methodology to change detection analysis through NDVI in the study area

RESULTS AND DISCUSSION

The annual variability of vegetation covers as reflected by the changes in maximum NDVI images were studied. Reclassified images of yearly NDVI derived for the study period of 10 years from 2012 to 2021. The differences were observed in the vegetation cover across different parts of the Puliyeru river basin, during the study period and reflected by these NDVI images. Theoretically, NDVI values vary in the range of-1 to +1. According to the data obtained in the present study, the NDVI values for all land cover categories within the selected sample sites showed variations within the range of 0.01 to 0.58. This observed range lies within the range that was reported for the natural vegetations over Puliyeru river basin for the period of 2012 to 2021 [10]. Since the used spectral data covers the land cover information at low spatial resolution (1.1km), it basically provides the information of land cover over Puliyeru river basin which is predominantly the natural vegetation.

In the Puliyeru river basin is the highest NDVI values were observed during the years from 2015, 2017, 2020 and 2021 (Fig 3-4) while the lowest values were reported for the period from 2002, 2014, 2013, 2016, and 2018 and 2019 (Fig 5-6). The Puliyeru generally experiences a marked wet season from October to February and a dry season from May to September in the Dry zone. In the observed pattern of changes in NDVI, a clear reduction in NDVI during this dry season and relatively higher values of NDVI during the wet season was observed in both Dry and Intermediate zones. The lowest values of NDVI were reported for the dry zone during the months from July to October which is the late end of dry season. Hence there is a possibility for using NDVI values to monitor the occurrences of dry and wet spells over the year within the Dry zone.

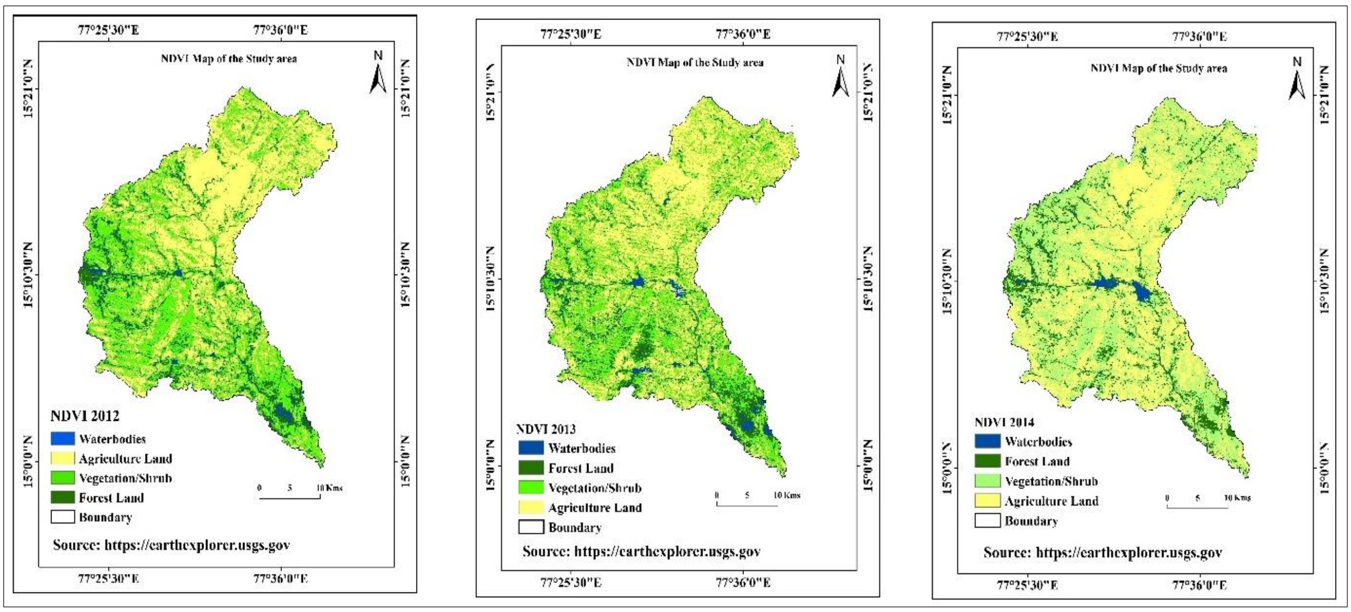

Fig 3 NDVI from 2012, 2013 and 2014 years of the study area

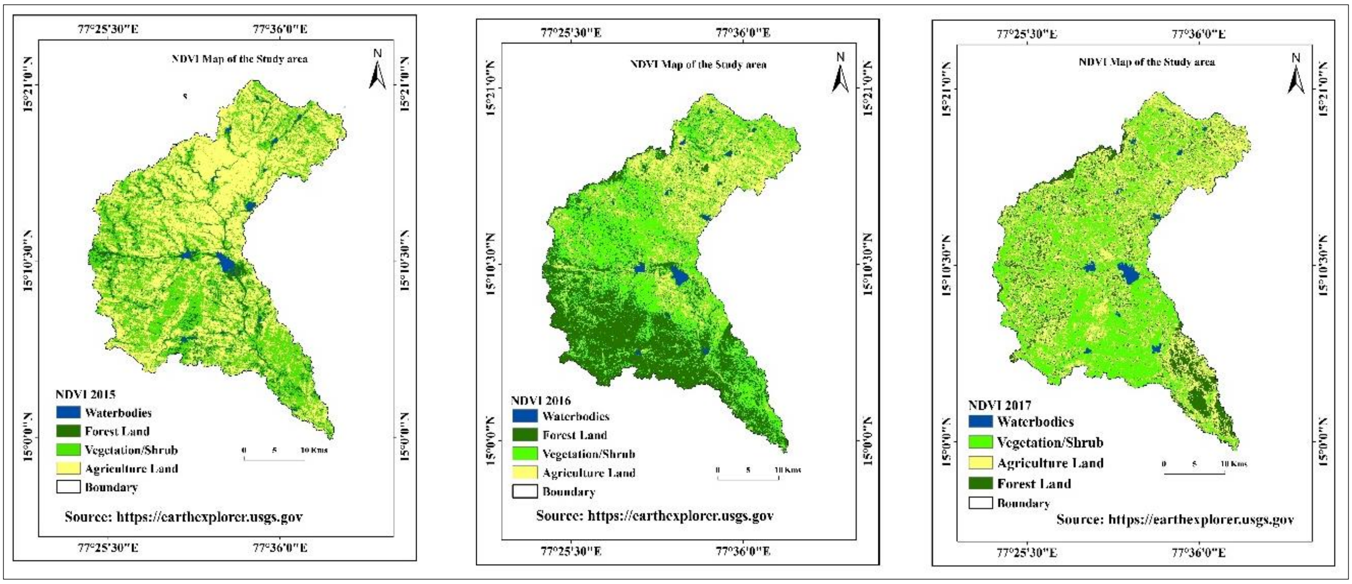

Fig 4 NDVI from 2015, 2016 and 2017 years of the study area

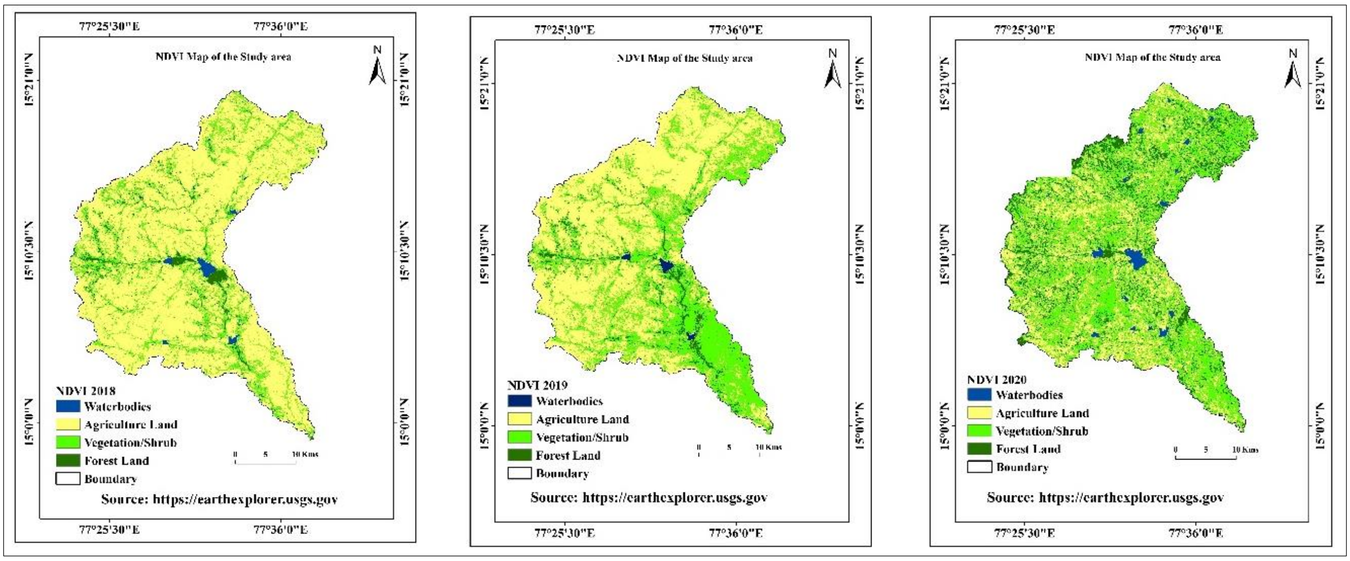

Fig 5 NDVI from 2018, 2019 and 2020 years of the study area

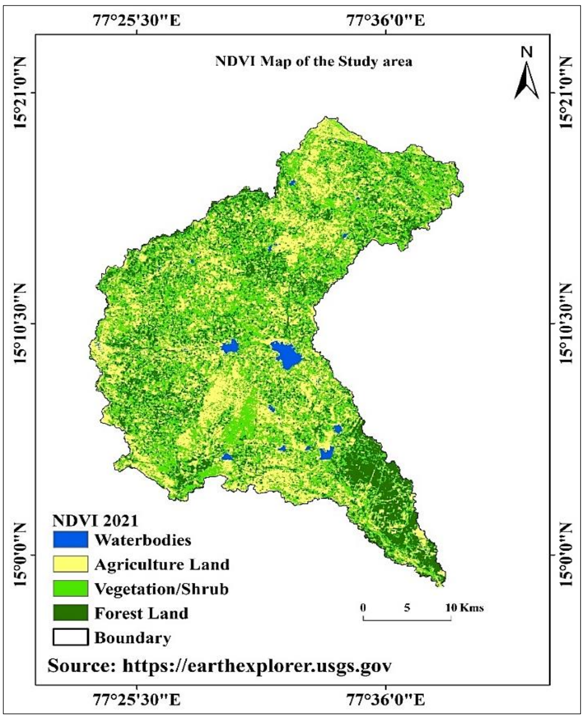

Fig 6 NDVI 2021 year of the study area

Hence, the derived values could be reflecting the general pattern of changes for a combination of different types of vegetations, crops or other land cover categories over the ground surface. The uniqueness of the temporal pattern of variations of different land cover classes is determined by their unique properties. Hence, it is necessary to study the different land cover classes separately in order to make general inferences on the patterns of seasonal changes of vegetation cover over the Puliyeru river basin. Such detailed studies demand satellite data at higher spatial resolutions which is much expensive. Hence, this seems to be the major limitation in such kinds of studies.

Change detection NDVI analysis

Over the entire study period, agriculture land was the predominant land use type (46.56%) during 2012, although it declined at an annual rate of 2%, and reached to only 7.13% in 2021. (Fig 7-8, Table 2). Forest showed the slight decrease (20.21% to 19.39%) since 2012–2021 with an annual increase rate of -0.82% and such growing trend does exist mainly in the peripheral rural transition of the urban centre. Within urban area, vegetation coverage has declined rapidly. Water body declined slightly at an annual rate of 2.81%, with around 4.17% to 1.36% since 2012-2021. Within main urban heartland, most of the water bodies are reclaimed and undergone into edifices.

Large part of water bodies majorly captured by water hyacinth. Vegetation trend enhanced the growth of vegetation area and in between 2012 and 2021 recorded areal expansion was 29.06% to 25.56% with a decreasing rate of 3.50%. (Fig 7-8) also clearly presents the land under change of different intensities (Table 2-3). Values wise indicate percentage of area under change of different category. Within main agriculture area positive change of land in between 2012 and 2021 is highly detected indicating increasing intensity of built-up area and extension of the same (Table 2-3).

These differences indicate not only dis- tinct computation procedures for deriving NDVI, but also their relationship to their vegetation density or vegetation abundance. It is also noticed that the relationship between these two vegetation indicators is not linear for different land use/land cover categories as established by other scholars also like Mallick *et al*. [37]. However, this work is not so far interested to channelize it toward investigating the same, rather importance is provided on how different categories of vegetation intensity regulates temperature.

Table 2 Percentage of area under different LULC 2012 to 2016 of Puliyeru River Basin, Andhra Pradesh, India

Landuse/Landcover classes	2012		2013		2014		2015		2016	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Waterbodies	34.97	4.17	24.96	2.98	15.28	1.82	13.08	1.56	9.46	1.13
Agriculture Land	390.26	46.56	373.49	44.56	359.33	42.87	350.86	41.86	347.84	41.50
Vegetation/Shrub	243.58	29.06	239.38	28.56	222.62	26.56	244.75	29.20	245.17	29.25
Forest	169.40	20.21	200.33	23.90	240.98	28.75	229.49	27.38	235.70	28.12

Table 3 Percentage of area under different LULC 2017 to 2021 of Puliyeru River Basin, Andhra Pradesh, India

Landuse/Landcover classes	2017		2018		2019		2020		2021	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Waterbodies	8.72	1.04	8.80	1.05	12.66	1.51	14.22	1.70	11.43	1.36
Agriculture Land	359.16	42.85	394.45	47.06	418.17	49.89	432.17	51.56	450.02	53.69
Vegetation/Shrub	245.25	29.26	235.28	28.07	239.38	28.56	205.86	24.56	214.24	25.56
Forest	225.05	26.85	199.65	23.82	167.97	20.04	185.91	22.18	162.52	19.39

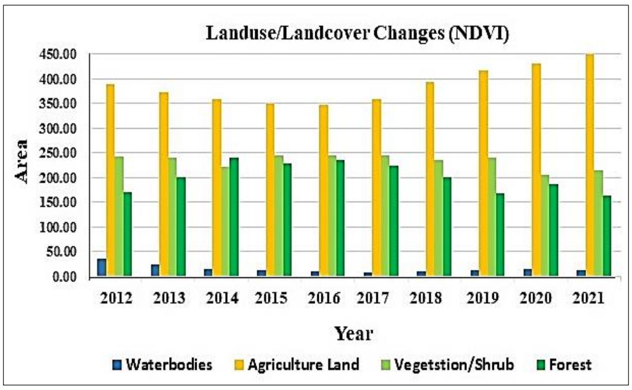

Fig 7 Area based landuse/landcover trends (2012-2021) of Puliyeru river Basin, Andhra Pradesh, India

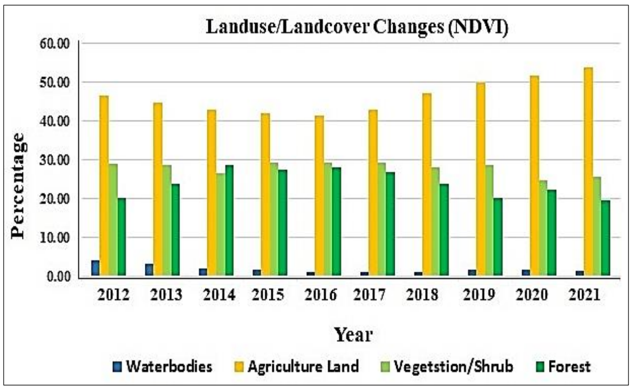

Fig 8 Percentage based landuse/landcover trends (2012-2021) of Puliyeru river Basin, Andhra Pradesh, India

CONCLUSION

Change detection analysis is an efficient way to summarize the changes discovered in each land use category. Agricultural area, mountainous terrain with flora, and dry farming all changed dramatically over the course of a decade. Ground truth traverse and supervised Landsat image classification have both improved the overall accuracy of image interpretation classes. The classification of land use might benefit greatly from the use of high-resolution satellite data. We used the normalized difference vegetation index with varied thresholds for feature extraction. According to this, vegetation coverage at different cut off points is almost identical. Vegetation analysis may be used to predict natural disasters, provide humanitarian aid, evaluate damage, and develop new defense methods. agriculture land was the predominant land use type (46.56%) during 2012, although it declined at an annual rate of 2%, and reached to only 7.13% in 2021. Forest showed the slight decrease (20.21 % to 19.39%) since 2012–2021 with an annual increase rate of -0.82% and such growing trend does exist mainly in the peripheral rural transition of the urban centre. Within urban area, vegetation coverage has declined rapidly. Water body declined slightly at an annual rate of 2.81%, with around 4.17% to 1.36% since 2012-2021. Vegetation trend enhanced the growth of vegetation area and in between 2012 and 2021 recorded areal expansion was 29.06% to 25.56% with a decreasing rate of 3.50%. Multispectral remote sensing imagery provides better findings for Normalized Difference Vegetation Index (NDVI) analysis of variable plant densities and for scattered vegetation.

LITERATURE CITED

1. Mallupattu PK, Reddy J, Reddy S. 2013. Analysis of land use / land cover changes using remote sensing data and GIS at an Urban area, Tirupati , India. 2013: 1-7.
2. Gandhi GM, Parthiban S, Thummalu N, Christy A. 2015. Ndvi: Vegetation change detection using remote sensing and GIS - A case study of Vellore district. *Procedia Computer Science* 57: 1199-1210.

3. Fathian F, Prasad AD, Dehghan Z, Eslamian S. 2015. Influence of land use/land cover change on land surface temperature using RS and GIS techniques. *International Journal of Hydrology Science and Technology* 5: 195-207.
4. Pal S, Ziaul S. 2017 Detection of land use and land cover change and land surface temperature in English Bazar urban centre. *Egyptian Journal of Remote Sensing and Space Science* 20: 125-145. https://doi.org/10.1016/j.ejrs.2016.11.003
5. Kaiser EA, Rolim SBA, Grondona AEB. 2022. Spatiotemporal Influences of LULC changes on land surface temperature in rapid urbanization area by using landsat-TM and TIRS Images. *Atmosphere* 13:. https://doi.org/10.3390/atmos13030460
6. Keerthi N, Nehru TJ Urban expansion impact on agriculture: A case study on Hyderabad, India
7. Harika M, Yamini S, Balakrishna K. 2012. Land use / land cover changes detection and urban sprawl analysis. *International Journal of Advanced Scientific Research and Technology* 2: 383-396.
8. Madhuri HVJ, Sridhar P. 2017. Application of remote sensing and GIS in land use / land cover mapping and change detection in Hyderabad , India. pp 90-98.
9. Gandhi GM, Parthiban S, Thummalu N, Christy A. 2015. Ndvi: vegetation change detection using remote sensing and GIS - A case study of Vellore district. *Procedia Computer Science* 57: 1199-1210. https://doi.org/10.1016/j.procs.2015.07.415
10. Suneela T, Mamatha G. 2016. Detection of land use and land cover changes using remote sensing and geographical information system (GIS) techniques. *International Journal of Electrical, Electronics and Data Communication* pp 2320-2084.
11. Akbar TA, Hassan QK, Ishaq S. 2019. Investigative spatial distribution and modelling of existing and future urban land changes and its impact on urbanization and economy. *Remote Sensing* 11:. https://doi.org/10.3390/rs11020105
13. Wang H, Li Z, Cao L. 2021. Response of ndvi of natural vegetation to climate changes and drought in china. *Land* 10.
14. Mustafa AA, Singh M, Sahoo RN. 2011. Land suitability analysis for different crops: A multi criteria decision making approach using remote sensing and GIS. *Water Technology* 3: 61-84
15. Bid S, Bengal W. 2016. Change detection of vegetation cover by NDVI technique on catchment area of the Panchet Hill Dam, India. *International Journal of Research in Geography* 2: 11-20. https://doi.org/10.20431/2454-8685.0203002
16. Pradesh A. 2018. Landuse and landcover analysis using remote sensing and GIS : A case study in parts of Kadapa District. 9: 1-7.
17. Raju GS, Raju RS, Basha UI. 2017. Landuse and landcover analysis using remote sensing and GIS : A case study in Uravakonda, Anantapur District, Andhra Pradesh, India.
18. Survey USG, Land-use F, Map L. 1981. Comparison of sampling procedures and data analysis for a land-use and land-cover map. *Photogrammetric engineering and Remote Sensing* 47(3): 343-351.
19. Dewan AM, Yamaguchi Y. 2020. Land use and land cover change in Greater Dhaka , Bangladesh : Using remote sensing to promote sustainable urbanization. *Applied Geography* 29: 390-401. https://doi.org/10.1016/j.apgeog.2008.12.005
20. Fahad KH, Hussein S, Dibs H. 2020. Spatial-temporal analysis of land use and land cover change detection using remote sensing and GIS techniques. IOP Conference Series: Materials Science and Engineering 671.
21. Hao S, Zhu F, Cui Y. 2021. Land use and land cover change detection and spatial distribution on the Tibetan Plateau. *Scientific Reports* 11: https://doi.org/10.1038/s41598-021-87215-w
22. Sano EE, Rosa R, Brito JLS, Ferreira LG. 2010. Land cover mapping of the tropical savanna region in Brazil. 113–124. https://doi.org/10.1007/s10661-009-0988-4
23. Poyatos AR, Latron J, Llorens P. 2019. Land use and land cover change after agricultural abandonment land use and land cover change after agricultural abandonment. 23: 362-368.
24. Bengal W, Ferdosh J. 2021. Elucidation of change detection techniques for land use and land cover mapping using the geospatial approach : A case study in Berhampore Block. 7: 219-232.
25. Sun H, Wang J, Xiong J. 2021. Vegetation change and its response to climate change in Yunnan Province, China. *Advances in Meteorology* 2021: https://doi.org/10.1155/2021/8857589
26. Petit CC, Lambin EF. 2002. Impact of data integration technique on historical land-use / land-cover change : Comparing historical maps with remote sensing data in the Belgian Ardennes. pp 117-132.
27. Sangawongse S, Sun CH, Tsai BW. 2005. Urban growth and land cover change in Chiang Mai and Taipei : Results from the SLEUTH Model. pp 2622-2628.
28. Thakur RR. 2018. Dynamics of land form features in coastal tract of Odisha from Mahanadi to Dhamra River Estuary using Remote Sensing and Geospatial Technology. 6: 370-377.
29. Munahar S, Purnomo BC, Ferdiansyah N. 2022. Risk-based leak analysis of an LPG storage tank : A Case Study. *Indonesian Journal of Science and Technology* 7: 37-64.
30. Jaiswal RK, Saxena R, Mukherjee S. 1999. Application of remote sensing technology for land use / land cover change analysis. 27: 23-128.
31. Herold M, Liu X, Clarke KC. 2003. Spatial metrics and image texture for mapping urban land use. 69 :991-1001.
32. Pattanaik C, Reddy CS, Reddy PM. 2011. Assessment of spatial and temporal dynamics of tropical forest cover: A case study in Malkangiri district of Orissa, India. *Journal of Geographical Sciences* 21: 176-192.
33. Reddy KR, Devaraj S, Biradar S. 2019. Spatial distribution of land use/ land cover analysis in Hanamkonda taluk, Telangana - A case study. *Indian Journal of Geo-Marine Sciences* 48: 1761-1768.
34. Twisa S, Buchroithner MF. 2019. Land-use and land-cover (LULC) change detection in Wami river basin, Tanzania. Land 8:. https://doi.org/10.3390/land8090136
35. Hussain S, Mubeen M, Karuppannan S. 2022. Land use and land cover (LULC) change analysis using TM, ETM+ and OLI Landsat images in district of Okara, Punjab, Pakistan. *Physics and Chemistry of the Earth, Parts* A/B/C 103117. https://doi.org/10.1016/j.pce.2022.103117
36. Aneesha Satya B, Shashi M, Deva P. 2020. Future land use land cover scenario simulation using open source GIS for the city of Warangal, Telangana, India. *Applied Geomatics* 12: 281-290.
37. Mallick J, Kant Y, Bharath BD. 2008. Estimation of land surface temperature over Delhi using Landsat-7 ETM+. *Jr. Ind. Geophys. Union* 12(3): 131-140.