Original Research Article

Land Use-Land Cover Change Detection in East Godavari District, India (2002-2020)

ABSTRACT

Land use-land cover (LULC) exerts a strong influence on the structure, functions, and dynamics of landscapes. Monitoring and mapping of LULC dynamics are important as changes over a land reflects the status of environment and provide a clear picture of optimum natural resources and their utilization. This study assessed the LULC changes in the East Godavari district of Andhra Pradesh over the years between 2002 and 2020. This study evaluates the status of land use land cover change over the past 20 years with the help of ArcGIS 10.1 software. Supervised classification method with the help of band combination of Landsat 7 and Landsat 8 were used to classify the LULC types or classes. Six major LULC types (agricultural land, built-up area, barren land, forest and sediment) from the Landsat images of 2002 and 2020 were mapped. The result reveals that the district has experienced quite visible LULC changes that seem to be continuous in the future. The major changes were detected in the built-up area and barren land.Built-up area increased from 8.15% to 10.8%, Barren land increase from 7.54% to 12.96%. Accuracy Assessment test was also performed with the classes. The overall efficiency of the years 2002 and 2020 were 77.61% and 73% respectively. The kappa coefficient of the years 2002 and 2020 were 0.67 and 0.66 respectively. This study concludes that there was a rapid reductionin rural areas that resulted from increasing construction of buildings and roads or some form of industrial development. Farmers in the study area have neglected to farm and reserved their lands for other businesses, which is one of the reasonsbehind decreasing agricultural land and increasing barren land.

Keywords: *LULC, supervised classification, kappa coefficient, change detection,India.*

INTRODUCTION

Land use-land cover (LULC) change is a tenacious issue experienced on global scale. Half of the world progress is indirectly connected to LULC. Land use refers to how land is used for agricultural, residential, or industrial purposes(Riebsame*et al.*, 1994). Land use/cover change detection is beneficial for a better understanding of landscape dynamics over time with sustainable management(Basha *et al.*, 2018). Land use/cover change is a large and growing process that is mainly driven by natural and anthropogenic processes, resulting in changes that have an impact on natural ecosystems (Ruiz-Luna *et al.*,2003;Turner and Ruscher 2004).Land use classification is important because it provides data that may be used as input for modelling,

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particularly modelling that interacts with the environment, such as models that deal with climate change and policy changes.

East Godavari is a district in the coastal Andhra region of Andhra Pradesh. Agriculture and its federal activities are the mainstay of East Godavari district's economy.The undivided state of Andhra Pradesh in India was popularly known as the “rice bowl” of India. East Godavari district carries the same status.Land use and land cover data, evolving patterns, and the best use of land resources have all become predetermined criteria for land use planning and effective natural resource management in a given area. Due to the convergence of numerous industrial interests, various parts of East Godavari have seen extensive LULC modifications in recent years. The Godavari River basin is home to a substantial amount of industrial development, agricultural growth, and accompanying LULC changes in this district.

Land cover and land use changes in dry, semi-arid, and agriculturally productive land have been the subject of several studies.Sophia *et al.,* (2017) did the classification of LULC and accuracy assessment test using Nonparametric rule. The overall classification accuracy of the study was 81.7%, with a kappa coefficient (K) of 0.722.With MODIS and Landsat satellite data, Spruce et al. (2018) created Land Use Land Cover maps for the lower Mekong basinto improve hydrologic modelling and basin planning. Unfortunately, effective mapping of certain LULC types in the Lower Mekong Basin (LMB) can necessitate more than one data set of remote sensing data per year, particularly for LULC classes with distinct foliar greenness phenology, such as agricultural and forest kinds.(Sudhakar *et al.*,2018) used digital change detection techniques based on multi-temporal and multispectral remotely sensed data, which have shown a lot of promise as a way to understand landscape dynamics- detect, identify, map, and monitor differences in land use and land cover patterns over time, regardless of the causal factors. In the ERDAS Imagine Software, he used a supervised classification method with a maximum likelihood algorithm.(Twisa*et al.*,2019) investigated the upstream and downstream Wami River Basin's LULC patterns during a 16-year period. The Landsat series' multitemporal satellite imagery was used to map LULC changes, which were separated into three stages (2000–2006, 2006–2011, and 2011–2016). The results of the change-detection analysis and the change matrix table from 2000 to 2016 show the magnitude of LULC changes in various LULC classes, with the majority of grassland, bushland, and woodland being intensively converted to cultivated land both upstream and downstream.The Geospatial Assessment of Land Use and Land Cover Patterns in the Black Volta Basin, Ghana,was completed by Amprochee*et al.* (2020). Satellite images were taken from the US Geological Survey's (USGS) Landsat archives and the Earth Observation database. Four separate Landsat scene pictures of 30 m resolution from the years 2000, 2015, and 2018 were used as the spatial dataset. ArcGIS 10.5, ENVI 5.3, MS Excel software, and Google Earth were used to examine the Landsat images.Ramanamurthy*et al.* (2020) used RS and GIS to investigate change detection in the LULC of the upstream Thandava reservoir. Toposheets of 65K5, 65K6, 65K9, and 65K10 (scale: 1:50000, first edition) were collected, and geo rectification and mosaicing

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Comment [JB15]: Reconcile with "Lower Mekong Basin" below and choose the correct one.

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were performed on all of them. For the years 1995, 2008, and 2020, supervised classification was applied by picking every pixel of the image.

- **Before proceeding further, we need to see your research questions or hypotheses listed here.**
- **Provide a section on (a) Conceptual Framework & (b) Literature Review (separate or combined). These are needed to solidify the theoretical underpinnings of your paper.**

Comment [JB19]: Attend to these comments.

MATERIALS AND METHODS

Study area description

The study area, East Godavari district is situated in Godavari River basin, Andhra Pradesh, India. It lies on the East coast of India with Bay of Bengal one side and Eastern Ghats on the other side as boundaries and having the Coastal Plains in between with fertile alluvium soils. It is located between latitude 16°30'00" N and 18°00'00" N and longitude 81°30'00" E and 82°30'00" E. The total geographical area of the study area is 10,807 sq.km. The district is divided into five revenuedivisions viz., Kakinada, Peddapuram, Amalapuram, Rajahmundry and Rampachodavaram. The capital of the district is Kakinada. The district is traversed by many water courses, like River Godavari, River Pampa, Yeleru, Tandava etc.

Comment [JB20]: Justify or clarify your reference to revenue divisions, when your paper is not about revenue generation.

Spatial data collection and sources

Satellite images were gathered from the US Geological Survey's (USGS) Landsat archives and the Earth Observation database. Four separate Landsat scene images with a resolution of 30 m were used, as well as the Digital Elevation Model (DEM) for the years 2002 and 2020.The Landsat data of year 2020 is from Landsat 8 and the data of year 2002 is Landsat 7.The research entails ground-truthing processes that use ground observations taken from Google Earth photos to verify the resulting spatial information. These images were chosen based on the USGS website's data availability for download. To eliminate bias in the picture analysis, photographs from the dry season were chosen, which were cloud-free and had the same discernible features. The photos from the dry season were more accurate and unambiguous in identifying the various LULC kinds in the basin. The radiometric and spectral features of the downloaded photos were also consistent.Certain steps arefollowed before classifying the datasets, which also refer topre-processing of the datasets. Although tough remotely sensed data is important in LULC change investigations, it cannot provide complete answers to topics such as why and how changes occur. (Fisher 2011; Sohl and Sleeter 2012).

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Data Pre-processing

This includes data operations, which normally precede further manipulation and analysis of the image data to extract specific information. The Landsat data were processed in ArcGIS10.1 software. The satellite imagery was overlaid in one file by using the layer stacking. Due to this process, a False Color Composite (FCC) was developed. The study area had four data sets for respective years which covers all parts of the study area. All these four datasets were combined together by mosaicking. The required portion of the study area was mask out by the operation called extracted by mask in ArcGIS software. The methodology of the process is as shown in Fig.1.

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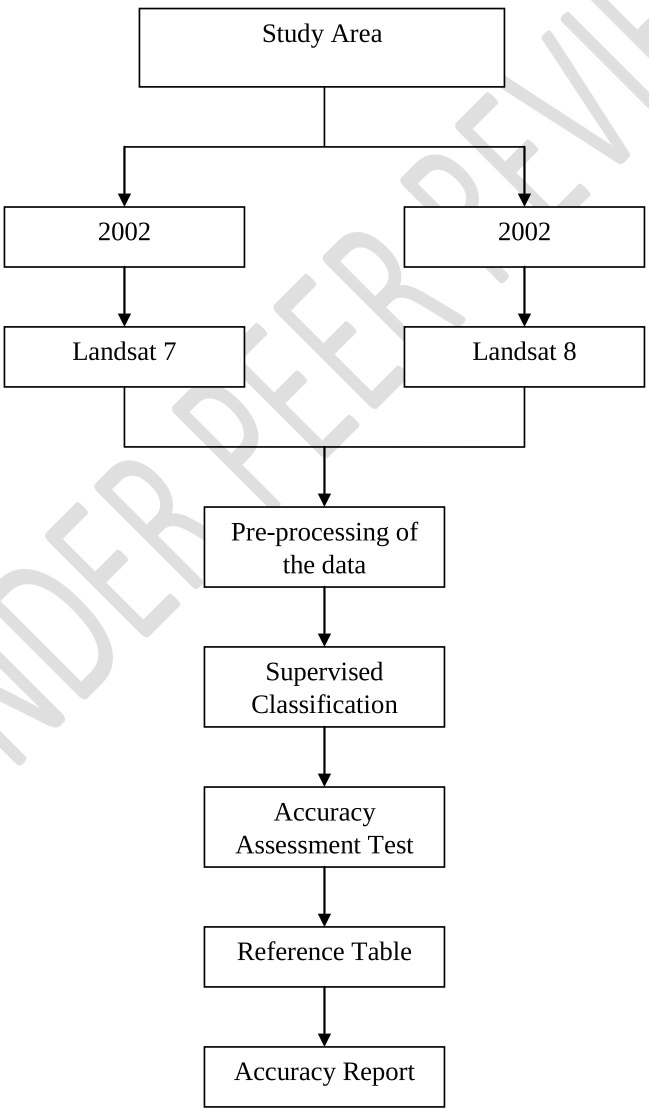

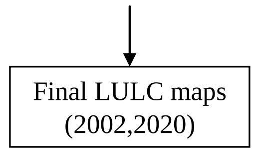

Fig.1. MethodologyFlowchart

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Image classification process

Five unique categories were used to divide the study area. Table 1 has a detailed description of the classes. Texture, tone, and colour were used to create each class (Radhakrishnan *et al.*, 2014). In image categorization, these classes were allocated to pixels.

Comment [JB24]: Replace "thorough" with "detailed" and use nuances instead of words that can introduce bias into the paper.

Table 1. Description of LULC classes

S.no.	Class	Description
1.	Built-up area	Low-, medium-, and high-density road networks; residential, industrial, and commercial buildings; transportation; open-roof concrete structures; educational institutes; other human-made structures; and solid waste landfills are all examples of land covered by concrete.
2.	Forest	Land with a high percentage of forest vegetation
3.	Agricultural land	Parks and regularly tilled, planted croplands are examples of areas with a high density of grasses, herbs, and crops.
4.	Barren and/other lands	Areas with minimal vegetation that may alter or be converted to other uses in the future. Land without crops, land with barren rock, and sand sections along river/stream beaches all fall into this category.
5.	Water Body	Rivers, reservoirs, ponds, lakes, and streams, as well as aquaculture land, are all covered by water.

Comment [JB25]: This error has been repeated too many times. Please check this out and amend.

Selecting of training data samples(Supervised classification)

Data sets have been skilled using different band combinations of the satellite images, field survey data, and Google Earth Maps. The satellite image of the study area and Landsat data were connected together through(Ground control points) GCPs in Google earth.This progression empowered the interesting elements in the study area to be perceived.Different band combinations were utilizedto decide the pixel group of a predetermined class. Band combinations are mentioned in the Table. 2for both Landsat 8 and Landsat 7. Data sets were prepared by thecolor of pixel.Preparing sites were made in the symbolism by drawing polygons, which were set in an AOI (Area of Interest) layer. To prepare each particular class, 20 polygons or more than that were drawn and placed in the signature editor. These polygons were combined and given a unique class name. Following that, the signature editor file was saved as a signature file (.sig format). In this work, two signature files were created to train the two data sets (2002 and 2020).

Table 2. Band combination of Landsat 8 and Landsat 7

S.no	Composite Name	Band combination (RGB)		Data source
		Landsat 8	Landsat 7	
1.	Natural Color	7 6 4	3 2 1	
2.	False Color (Urban)	5 4 3	-	
3.	Color Infrared (Vegetation)	6 5 2	4 3 2	
4.	Agriculture	5 6 2	-	
5.	Healthy Vegetation	5 6 4	1 4 7	www.esri.com
6.	Land/ Water	7 5 4	4 5 1	
7.	Natural with ATM removal	7 5 4	-	
8.	Shortage Infrared	6 5 4	-	
9.	Vegetation Analysis	7 6 4	-	

Image classification

Through supervised classification, the different LULC of the East Godavari district were identified and mapped from Digital Landsat images. In this study, the supervised classification method Maximum Likelihood classifier (MLC) was applied. The primary goal of the image categorization process was to find pixel clusters.

In the classification process, some LULC units were misclassified withdifferent classes. For example, bare lands were misclassified to the farmland/settlements class. This happens due to the reason that some bare land’s spectral properties or pixel color were almost similar to the harvested crop lands which creates the difficulties in separating them during image classification operation. To further develop arrangement exactness and lessen misclassifications, incline toward Google Earth. The last step on this classification was the maximum likelihood operation to be performed in the ArcGIS software.

Accuracy Assessment Test

The accuracy assessment or validation of the LULC data is a key step in the processing. It determines the user's information value of the resultant data.All the same color pixels were organized into a particular class by supervised classification. To verify the accuracy of the classification by the software, the accuracy assessment is a key step. All the landsat image classification accuracy were checked using error matrix rule. In this rule the kappa coefficient, overall accuracy, the producer's and user's accuracy were evaluated.The overall accuracy of the categorized image refers to how each pixel compares to the exact land cover conditions acquired from the ground truth point. The errors of omission, which are a measure of how accurately real-world land cover types are classified, are defined by the accuracy of the producers. The errors of commission are defined by the user's accuracy, which is the likelihood that a classified pixel would match the land cover type of its corresponding location. The kappa coefficient and error matrix have become common methods for evaluating image classification accuracy. Furthermore, error matrices have been employed in a variety of land categorization studies and were an important part of this study(Rwanga*et al.*, 2017). This analysis was done with 67 verifying points which was also the Total Sample(TS) in the study area. These points were created as a shape file in study area. Google Earth was used as a reference source to verify the points. For this step the point shapefile was converted in KML file. The error matrix rule table format was presented below. User points were represented by the software and producer points were identified by the operator with the reference of the Google Earth. The diagonal of the error matrix table represented the Total Corrected Sample(TCS).

Before moving further in this paper, please operationalize the Total Corrected Sample (TCS). What is its significance and relevance to your paper? In what way is it relevant to your research questions?

Comment [JB26]: You need to attend to these comments.

Table 3. Layout of error matrix table for accuracy assessment test

	Agricultural Land	Barren land	Build up area	Forest	Sediment	Water body	Total user
Agricultural Land							
Barren Land							
Build up area							
Forest							
Sediment							
Water Body							
Total Producer							

$$User\ accuracy = \frac{Number\ of\ correctly\ classified\ pixels\ in\ each\ category}{Total\ number\ of\ classified\ pixels\ in\ that\ category\ (The\ Row\ Total)} \times 100$$

$$Producer\ accuracy = \frac{Number\ of\ correctly\ classified\ pixels\ in\ each\ category}{Total\ number\ of\ reference\ pixels\ in\ that\ category\ (The\ column\ total)} \times 100$$

$$Overall\ accuracy = \frac{Total\ number\ of\ correctly\ classified\ pixel\ (Diagonal)}{Total\ number\ of\ reference\ pixels} \times 100$$

$$Kappa\ coefficient = \frac{(TS \times TCS) - \sum(column\ total \times row\ total)}{TS^2 - \sum(column\ total \times row\ total)}$$

(Note: TS- total sample; TCS- total corrected sample)

RESULTS AND DISCUSSION

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The area under the LULC classes and its changes from 2002 to 2020 are presented in Table 4. In 2002, the area covered by built-up area was insignificant and predominantly situated in the centre part of the study area. Some big changes were observed over the period in the study area. It can be inferred from the Table 4., that positive changes were observed in water bodies, build-up area and barren land whereas negative changes were observed in forest, agricultural land and sediment. The waterbodies category slightly increased from 2.49% to 3.81% and the forest category slightly decreased from 58.7% to 52.82%. The agricultural lands decreased from 21.83% to 18.53%. The barren land increased from 7.58% to 12.96%. The build-up area increased from 8.15% to 10.8%. The sediment decreased from 1.22% to 1.05%.

Change in classification

1. Water bodies

According to Table 4, the area under water bodies rose from 268.67 km^2 in 2002 to 409.20 km^2 in 2020, representing a net gain of 140.3 km^2. This rise in area under water bodies was caused by an increase in aquacultural operations in the district's southeast side throughout time.

2. Build-up area

It can be inferred from the Table 4., that the area under build-up area increased from 876.823 km^2 in 2002 to 1162.921 km^2 in 2020, which represents a net increase of 286.093 km^2. The area under built-up land increased due to the rapid increase in population, industries, and roads construction. There is rapid development in rural areas that accounted for construction of buildings, roads etc., One of the major reasons for increase in buildup area accounts for growth in industries with Kakinada being the industrial hub.

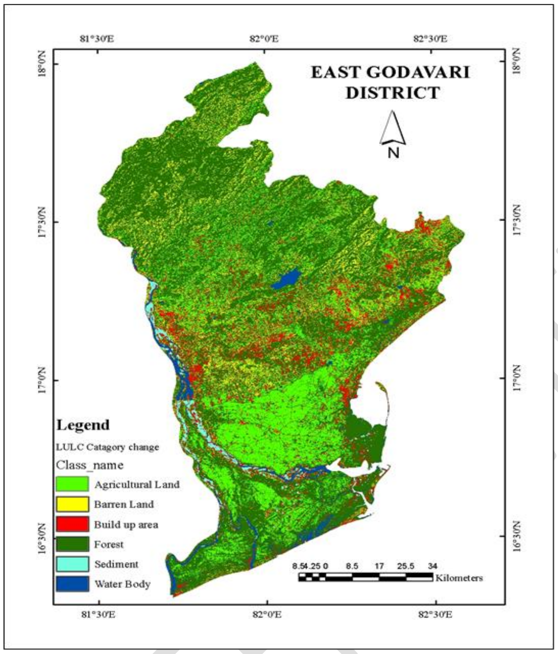

Fig.2. LULC classification of East Godavari District (2002)

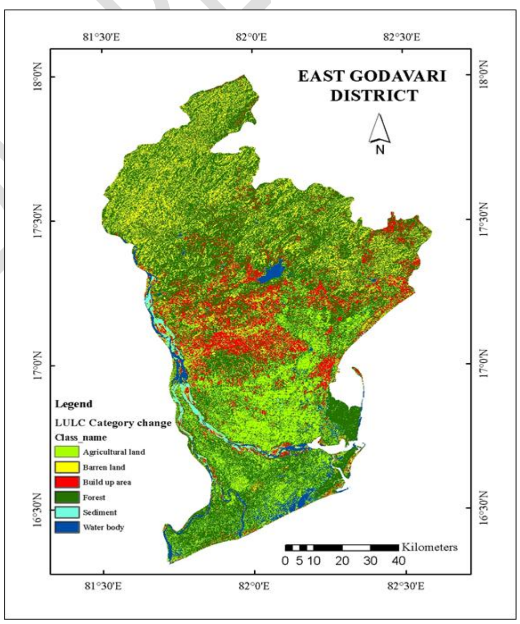

Fig.3. LULC classification of East Godavari District (2020)

3. Forest

It can be inferred from Table 4., that the area under forest decreased from 6309.459 km^2 in 2002 to 5677.78 km^2 in 2020, which represents a net decrease of 631.67 km^2. The decrease in forest area is attributed to the conversion of forest area into built-up areas, such as houses, roads, and industry places. The decrease can likewise be credited to the utilization of forest area for other formative exercises or developmental activities.

4. Agricultural Land

It can be inferred from Table 4, that the area under agricultural land decreased from 2347.371 km^2 in 2002 to 1992.61 km^2 in 2020, which representsa net decrease of 354.76 km.^{2}.During the study period, the amount of available agricultural land in the study area quickly reduced (2002-2020).The demand for urban areas and socio-economic development projects is one of the key factors for the decrease inagricultural land. Another reason is that farmers were neglecting farming and gaining interest in other businesses or industrial work.

5. Barren Land

Table 4 shows that the area covered by barren land/other land increased from 815.224 km^2 in 2002 to 41.55 km^2 in 2020, representing a net gain of 578.04 km^2. Farmers have been abandoning farming and demonstrating interest in other industries or industrial labour, which has resulted in the growth of barren land/other land even though some barren land was converted into habitation and farmland.Also, the northern part of the district, which was majorly occupied by mountains, was identified as barren land in the absence of forest. In some portions of the district, the quarrying operations were also performed frequently, which is another reason for increasing barren land.

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6. Sediment

It can be inferred from Table 4 that the area under sediment slightly decreased from 131.39 km^2 in 2002 to 113.18 km^2 in 2020, which represents a net decrease of 18.219 km.^{2}With the observation of the classified data, some portion of the sediment area was covered with vegetation in this study period.

Table 4. Area statistics of LULC in 2002 and 2020

S. no.	Class Name	LULC, Area (km^2)				Area changed (km^2) (2002-2020)	% Change in LULC
		2002		2020			
		Area (km^2)	Area (%)	Area (km^2)	Area (%)		

1.	Water bodies	268.67	2.49%	409.20	3.806%	140.3	1.316%
2.	Build up area	876.823	8.15%	1162.92	10.8%	286.097	2.65%
3.	Forest	6309.459	58.67%	5677.78	52.82%	-631.679	-5.85%
4.	Agricultural Land	2347.371	21.83%	1992.61	18.53%	-354.761	-3.3%
5.	Barren Land	815.224	7.54%	1393.27	12.96%	578.046	5.42%
6.	Sediment	131.399	1.22%	113.18	1.05%	-18.219	-0.17%

Accuracy assessment test

One of the most important final steps is accuracy assessment. The accuracy assessment result of LULC shows that for year 2002, overall accuracy was 77.81% with a kappa coefficient of 0.6. In other words, for the year 2020, overall accuracy ~~was overall accuracy~~was 73% with a kappa coefficient of 0.6. The ~~user's~~accuracy figures of all LULC classes arepresented in Table 5.

Table.5 Accuracy assessment of East Godavari District

LULC Classes	**2002**		**2020**	
	User's	**Producer's**	**User's**	**Producer's**
Agricultural Land	100	52.63	93.75	65
Barren Land	0	0	20	25
Build up area	71.48	100	55	100
Forest	82.75	88.89	70	58.33
Sediment	66.67	100	100	66.67
Water Body	100	100	100	100
Overall efficiency	**77.61**		**73**	
Kappa coefficient	**0.67**		**0.66**	

A Kappa coefficient of 1 indicates complete agreement, whereas a value near zero indicates agreement that is no better than would be predicted by chance(Rwanga*et al.*,2017).

Discussion – Where is this section in your paper? Make sure you focus on an international audience and compare your findings withprevious international findings.

Comment [JB29]: Attend to this comment.

CONCLUSION

The image classification method had made a huge impact over the past years to classify the LULC.

Based on the analysis of the result of this study, the following conclusions could be drawn:

1. Most significant changes are observed in the barren land and build-up area category. The portions of Kakinada and Rajahmundry mostly changed throughout the year. More build-up area is increased in these portions over the two decades.
2. In view of LULC analysis of Landsat data for the year 2002 and 2020, it was observed that the LULC change patterns shifted fundamentally during the periods referenced above. The results showed that most of the forest and agricultural land converted into build-up or barren land. In 2002, the forest land was 58.67% whereas in 2020, it decreased to 52.82%. Agricultural land was also decreased from 21.83% to 18.53%. In other hand the build-up area was increased from 8.15% to 10.8%.
3. Land interest for settlement area has expanded with the population development experienced in 18 years.
4. Likewise classified image should be evaluated for accuracy, before the equivalent could be utilized as contribution for any further study. The study had an overall classified accuracy of 77.61% for 2002 and 73% for 2020. The kappa coefficient is 0.67 for 2002 and 0.66 for 2020. The kappa coefficient is evaluated as generous and thus the classified image viewed as fir for additional research.

Comment [JB30]: Your Conclusion must be a standalone section of the paper. It must include a revision of your research questions and corresponding findings in a systematic fashion. This simplistic style of presenting your conclusion is not acceptable.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use productsin our area of research and country. There is ~~absolutely~~ no conflict of interest between the authors and producers of the products.~~because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.~~ Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

Comment [JB31]: Rewrite this section

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Comment [JB35]: Revise your list of references after adding a conceptual framework and literature review to your paper.

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Comment [JB36]: Use capital 's' and capital 'r'

CGWB. District Groundwater Brochure, Tiruchirappalli District, Tamil Nadu. Central Ground Water Board (CGWB), Ministry of Water Resources, Government of India, South Eastern Coastal Region, Chennai, India. 2008.