Monitoring Urban Changes during the Past Decade along the Margin of Ambikapur City, Sarguja District, Chhattisgarh State Using Remote Sensing and GIS Techniques: A Case Study

Anil Kumar Sinha[1], Rishitosh Kumar Sinha[2] and Rajib Jana[3] *

[1] *Assistant Professor (Geography), at present NSS Programme Co-ordinator, Sant Gahira Guru Vishwavidyalaya , Sarguja Ambikapur (Chhattisgarh State), India..*

[2] *Scientist, Physical Research Laboratory, Ahmadabad ,Gujarat State, India.*

[3] *Research Scholar (Geography), Sant Gahira Guru Vishwavidyalaya, Sarguja Ambikapur (Chhattisgarh State), India.*

Abstract: *Given the spatial and temporal scale at which urban changes are occurring in many parts of the nation, it has become increasingly important to monitor these changes as they play an important role in deciphering the status of agriculture. Remote sensing and GIS emerges as an important tool for monitoring the rates, patterns, and consequences of urban expansion. To deal with this aspect of urban expansion at the cost of agricultural land within a region, we have carried out satellite image based investigation of the marginal areas around the Ambikapur City of Sarguja district in Chhattisgarh state. We have utilized the TERRA - ASTER imagery of 2004 and 2016 to conduct preliminary survey of the study region, following which portions around the marginal areas of study region have been selected for detailed investigation. The selected areas have been analyzed using the Google Earth data products of 2007 and 2014 for assessing the extent of urban changes during the different periods of data acquisition. This has lead to identify the specific urban classes that have undergone change and/or modification during 2007-2014 while influencing the spatial extent of agricultural lands. The observations and findings of this case study implicates that urbanization in the marginal areas of Ambikapur city has considerably affected the agricultural lands in the respective areas. Taken together, in this study we present an additional new example of urban expansion in the nation that suggests urban planners to immediately embrace new plans for urbanization; otherwise, it may eventually drown the extent of agriculture throughout the nation.*

Key Words: Ambikapur City, Sarguja District, Chhattisgarh State, Remote Sensing and GIS, Agricultural Land, Monitoring urban change.

Corresponding Author:

Rajib Jana, Research Scholar (Department of Geography), Sant Gahira Guru Vishwavidyalaya Sarguja Ambikapur (Chhattisgarh State) India,

INTRODUCTION

Urban development and /or modification is an unavoidable event taking place in every habited areas of the world, irrespective of whether they are occurring in the country/state/city that is already developed or developing. In general, urban change within a city is defined as movement of residential/commercial/industrial/religious areas to the rural areas lying at the margin of the city. The changes in the land use and cover are often visualized as land degradation and often transformation of agricultural land to a type of urban development eventually resulting in enormous loss to the prevailing environment. These changes have been monitored in the previous studies by remotely observing them at different times by satellite and mapping the changes in the land use and cover in a Geographic Information System (GIS) environment after inferring them from the multi-temporal Georefrenced satellite images [**1**]. This application of remote sensing and GIS has transformed it as a valuable source for sustainable development. The focus of present study is to utilize remote sensing and GIS as a tool to

monitor land use and cover change occurring at a variety of spatial scales around the margin of a city in the Chhattisgarh state of India.

I. STUDY AREA

Chhattisgarh state (also known as the power and mineral hub) is the 10th largest state in terms of area (135,361 km^2) and 16th most populated (27,928,015 as of census 2015) state in central India [**2**]. It is recognized as one of the fastest developing states in India (India 2010- A Reference Annual). The state is well renowned as a source for electricity, steel in India, as nearly 38% of the total steel produced comes from this state, and nearly 17% of nation's coal comes from this state. In addition, the state is world renowned for having one of the best qualities of iron ore deposits and varieties of minerals [**3**]. The status of climate and soil in the state is such that it is helping the agricultural community to enhance further from being the symbol of "**Rice Bowl**" of India to eventually make an impact in the world. In the same line, the state has been honored with a national award of "**Krishi Karman Award**" for the maximum production of rice in the year 2010-11.

The prime challenge of the present-day is to assess the status of problems affecting the agricultural growth in the Chhattisgarh state. This involves understanding of the pitfalls and caveats that may eventually slow down the rate of agricultural growth in the state. This is essential to address as among the state's total working population (Combining both rural and urban), ~70% comprises of agriculture labors and cultivators [**4**].

In this study, we address the issue of agriculture within the Chhattisgarh state by making an example case study from remote sensing and GIS survey of Ambikapur city (23.13° N, 83.18° E), Sarguja district. Sarguja district has been chosen in this study because it is one of those districts (among 27 districts of state) in which about 90% of the working population are found to depend on agriculture. Within the total geographical area of 3.75 lakh hectares, the net cultivated area is 1.72 lakh hectares and the net forest area is 1.15 lakh hectares [**5**].

Ambikapur city is the district headquarters; therefore, it is equipped with improved irrigation facilities. Therefore, assessment of ongoing urban development since the past decade may provide us with more insights on how it is affecting the growth of agriculture and agricultural lands around the margin of the city.

II. CONCEPT OF URBAN LAND USE

Before we outline the methods adopted for carrying out the urban change detection, it is essential that the definition of urban land is made clear in context of this study. In this study, we define an ‘urban land’ as a place that is dominated by the settlement environment. The settlement includes several types of built areas such as roads, buildings, bridges/dams etc. An area within a given region that is

dominated by vegetation/agriculture/forest is not considered as urban land. With such a definition in our mind, we have carried out this case study of monitoring the urban changes around the margin of Ambikapur city, Sarguja (Chhattisgarh state).

III. OBJECTIVES OF THE PRESENT STUDY

The focus of present study is to show the various urban changes occurred around the margin of Ambikapur city during the past decade that has considerably affected the status of agriculture lands in the region. For this purpose, we utilize the satellite images of the Ambikapur city acquired during the past decade (i.e. from 2004-2016). Our observations are primarily focused on identifying the zones that have undergone major urban development and/or modification in the city at the cost of comprising with the land/field that was initially used for agricultural purposes. It is important to mention here that our interpretations made from analysis of satellite images regarding the status of urban development hindering the agricultural land around the city margin does not implicate that the same may be happening in throughout the Chhattisgarh state. Instead, we aim to propose from our study that urban development should not happen in a manner that it affects the growth and continuity of agriculture. For the present study, we have chosen to provide examples from the urban classes such as commercial, residential, educational, recreational, government offices as well as buildings and religious [**6**].

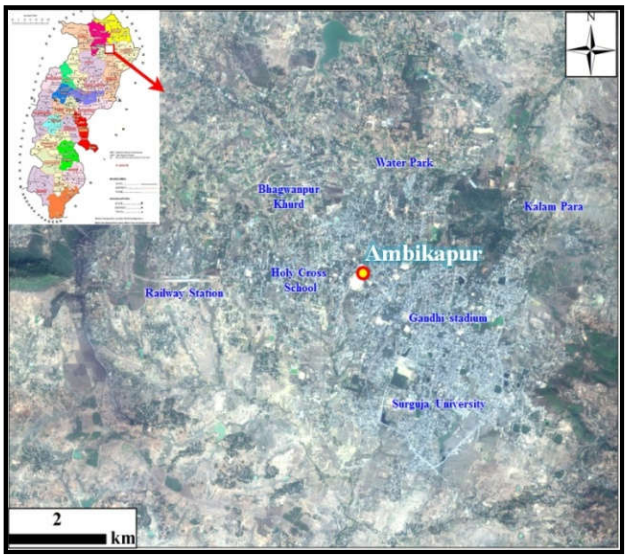

Figure no. 1: *Spatial location of the study area had shown using the district map of Chhattisgarh state. The Sentinel-2 based image of study area is displayed here to provide an overview of the salient features within the region. The key locations are illustrated to provide a context to the imagery.*

IV. DATA AND METHODOLOGY

The study region is presented using the Sentinel-2 image acquired at 10 m/pixel spatial resolution and spectral resolution varying as blue (490 nm), green (560 nm), red (665 nm), and near-infrared (842 nm) (ESA, 2011) (table no.1) [**7**]. The primary survey of the study region is conducted using the TERRA-ASTER (Advanced Space borne Thermal Emission and Reflection radiometer; https://lpdaac.usgs.gov)

satellite images acquired at a spatial resolution of 15 m/pixel in the visible and near infrared wavelength region (VNIR) of the electromagnetic spectrum. The wavelength range varies as: Band 1 (0.52-0.60 µm), Band 2 (0.63-0.69µm), and Band 3 (0.78-0.86 µm) [**8,9,10**]. The ASTER data chosen for the study comprise of registered radiance at the sensor- precision terrain corrected products. Georefrenced ASTER images obtained from USGS Earth Explorer are examined using ESRI's Arc Map 10.0 Geographic Information System (GIS). Subsequently, the satellite images are compared to decipher the spatial changes occurred around the margin of study region during the periods of image acquisition (table no.1). The locations identified within the study region to have undergone Spatio-temporal changes are then monitored using the high-resolution data products of Google Earth (table no.1) (https://www.google.com/earth/) to infer the specific changes in terms of modification/development going under the respective urban classes chosen for this study. In this way, we plan to develop a framework on which to assess whether the land/field on which Spatio-temporal changes have been noticed were initially a part of the city's agriculture or not [**11,12**].

Table no. 1
Specifications of the data used for the study area

<table>
<tr><th>Satellite/Instrument</th><th>Date of Acquisition</th><th>Spatial Resolution</th><th>Wave Length</th><th>Image Id</th></tr>
<tr><td>Sentinel-2; Multi Spectral Instrument (MSI)</td><td>January 1st, 2017</td><td>10 meter/pixel</td><td>Blue (490 nm), Green (560 nm), Red (665 nm) and Near-infrared (842 nm)</td><td>L1C_T44QQL_A007981_20170101T050737</td></tr>
<tr><td rowspan="2">TERRA- ASTER</td><td>December 4th, 2016</td><td rowspan="2">15 meter/pixel</td><td rowspan="2">Band -1 (0.52-0.60 µm) Band -2 (0.63-0.69µm) Band -3 (0.78-0.86 µm)</td><td>AST_L1T_003120420160507 16_20161205095043_3065</td></tr>
<tr><td>October 23rd, 2004</td><td>AST_L1T_003102320040512 07_20150506192153_49640</td></tr>
<tr><td>Google Earth</td><td colspan="4">Imagery of Ambikapur city stored in Google Earth database for the years 2007 and 2014 (https://www.google.com/earth/)</td></tr>
</table>

V. OBSERVATIONS

Change Detection: - In the present study, we utilize the change detection analyses to describe the difference between satellite images of study region acquired at different times (2004 and 2016). Around the margin of the city, we have conducted observations in all the directions varying from north to south, and east to west. Different spatial extents of portions from study region (total 11) are selected to

decipher the nature of changes in land use and cover. The primary type of land degradation observed in the investigated areas is human induced urbanization.

This is mainly observed in form of significant changes in the settlement around the city margin. We refer to this settlement as a human induced development and/or modification. It can be seen in Figure no.2a and 2b that within all the selected inset boxes, there is a significant change in terms of gray to magenta tone pixels. The gray to magenta tone pixels are referred as settlement class in the ASTER satellite images. These settlements can be referred as a combination of urban classes such as commercial, residential, educational, recreational, government offices and buildings, and religious. In a difference of 12 years, the settlement area along the margin of Ambikapur city is dramatically increased. This increase can be observed in form of pixels that are mainly represented in the images in form of small size clusters of square and/or rectangular shape. In the satellite images, the additional pixels with blue tone are referred as water bodies and pixels with green tone are referred as agriculture or forest cover. The agriculture and forest cover pixels can be differentiated on the basis that agriculture land is mainly represented in the images in form of square and/or rectangular patch of green pixels. Whereas, the forest cover is represented in the images as green pixels spread in irregular patches.

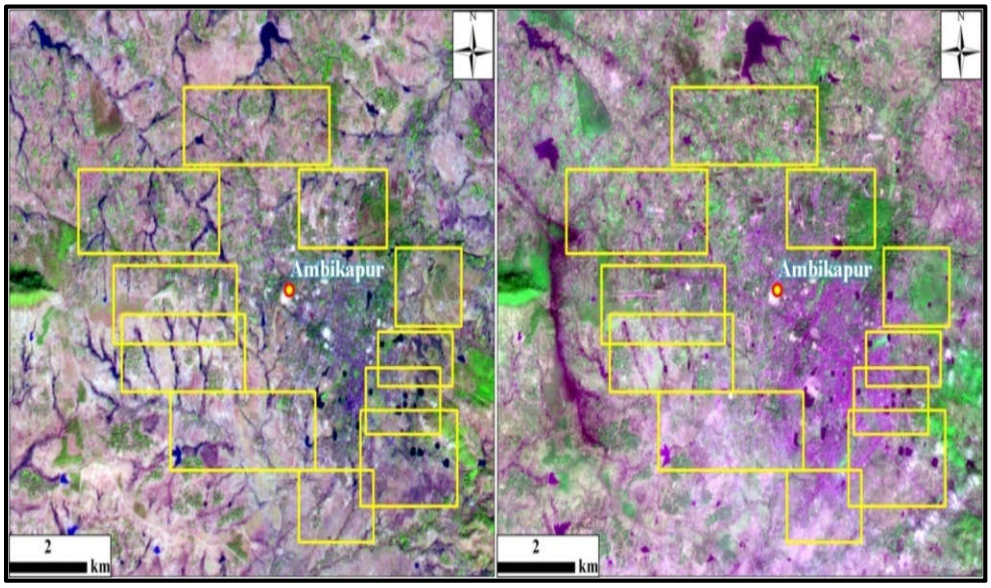

Figure no. 2: *TERRA-ASTER imagery of Ambikapur city. Left panel: 2004; Right panel. 2016. Yellow box corresponds to spatial extents of portions from study region (total 11) that are selected to decipher the nature of changes in land use and cover. These regions are shown in Figure no.3 and Figure no.4*

In the next level of change detection, for all the 11 portions selected from the study region, we utilize the high-resolution Google Earth images to conduct zoomed-in observations (Figure no.3 and 4). As a matter of fact, from our initial survey of these zoomed-in images, we observed that there is an unprecedented decline in area under agriculture due to an increase in urban area. We noticed that the high density residential areas (either public or private) increased to nearly two folds in the last 7 years

(from 2007 to 2014). Most important in these observations is that all this is occurring at the cost of agricultural fields in the region. Significant land transformations have taken place (as indicated by red arrows in Figure no. 3 and 4) around the marginal areas of the city. This can be directly inferred as significant growth in population of Ambikapur city in the period of 7 years. However, it is important to mention that though physical and population growth within a city has a close rational, it does not implicate that the city has a regular development scheme.

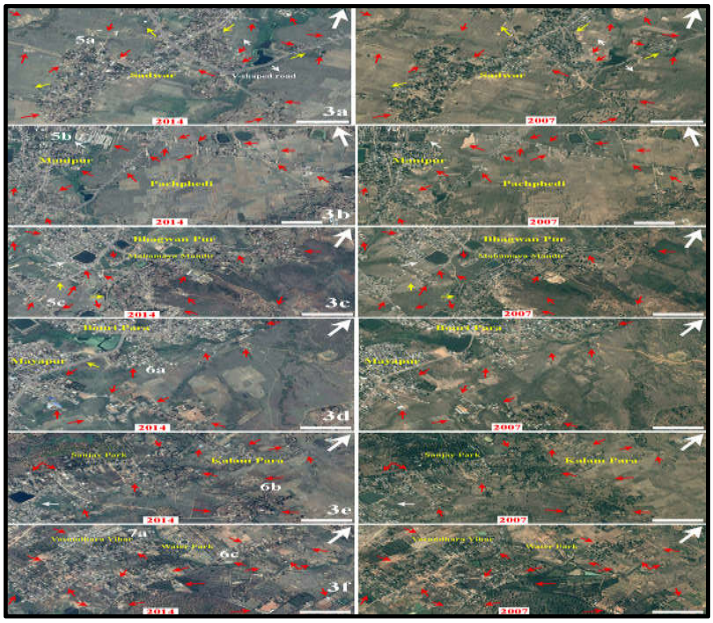

Figure no. (3a - 3f): *Google Earth based view of the selected portions in Figure no. 2. Imagery of 2014 (left) and 2007 (right) are displayed side by side to illustrate the changes observed in both the imagery. Red arrow shows the location where changes are observed predominantly from 2007-2014. Scale bar is of 200 meter in all the images.*

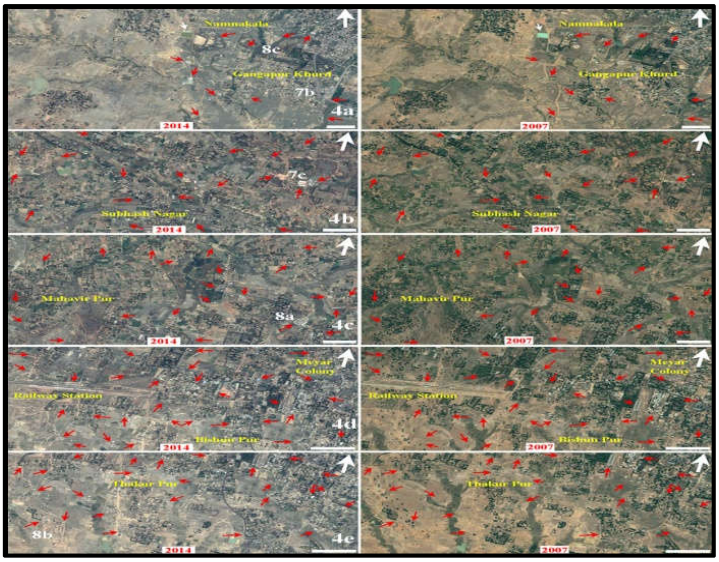

Figure no. (4a - 4e): *Google Earth based view of the selected portions in Figure no. 2. Imagery of 2014 (left) and 2007 (right) are displayed side by side to illustrate the changes observed in both the imagery. Red arrow shows the location where changes are observed predominantly from 2007-2014. Scale bar is of 200 meter in all the images.*

It can be seen in Figure no. 3 and 4 that the city has been growing along the major/minor road networks and along the water bodies. However, we found that the spread of growth is not systematic as indicated by unequal, non-directional expansions. It can be clearly seen that the spread of urbanization on going away from the roads and along the margin of water bodies is happening in an unorganized manner. For example, in Figure no.3a, the extent of urbanization along the major V-shaped road (indicated by yellow arrows) oriented towards northwest and northeast is inconsistent. Similarly,

inconsistency in urbanization is observed along the minor road network as well that is oriented south to north (indicated by yellow arrow) (Figure no.3a). Another example of inconsistent urbanization is evident from Figure no. 3c. It can be seen that urbanization is prominent only along one side of the pair of roads (indicated by yellow arrow), whereas, on the other sides, urbanization has only happened in form of small irregular patches of settlement (red arrows). This observation is supported by growth in settlement observed in the Mayapur area (Figure no. 3d) located over one side of the road (indicated by yellow arrow), whereas, on the other side, growth in settlement is negligible.

From Figure no. 4, it can be seen that within the Gangapur Khurd area (Figure no. 4a) we did not find any specific change occurring along the major/minor road network. However, it can be seen that the region surrounding the Gangapur Khurd area has undergone significant urbanization (as indicated by red arrows). Similar pattern of urbanization is apparent in (1) Figure no. 4b, over the entire region north of Subhash Nagar area, (2) Figure no. 4c, region surrounding Mahavir Pur area, and in east of it, (3) Figure no. 4d, region between Railways station, Meyar Colony and Bishun Pur areas, and (4) Figure no. 4e, over the entire region surrounding the Thakur Pur area. It is important to mention here that in Figure no. 4, we did not observe multiple major/minor road networks. Accordingly, most of the urbanization observed by us in Figure no. 4 is irrespective of the availability of road network and seem to have mostly occurred as per the availability and access to the land.

Along the water bodies apparent over the city marginal areas, we found several examples of inconsistent growth in urbanization. They are: (1) Figure no.3a, urbanization is observed in the northeast and southwest areas of the water body; however, it is not observed in the northwest and southeast areas(white arrow), (2) Figure no.3b, significant urbanization has occurred in the east of the water body(white arrow), (3) Figure no.3c, significant urbanization is noticed along the south of the water body located southwest of Mahamaya Mandir (white arrow), (3) Figure no. 3e, along the east of water body located south of Sanjay Park (white arrow), and (4) Figure no. 4a, along the northern margin of water body located west of Namnakala (white arrow).

VI. RESULTS & FINDINGS

This study thoroughly displays the application of remote sensing and GIS methods to evaluate the urban land mapping and perceive changes of urban land use and cover through different years. Our satellite image based observations comprising of change detection around the city margin have clearly shown that there are significant changes in the land use and cover during the past decade.

Overall, the key observations can be summarized as:- **(1)** inconsistent urbanization along major/minor road networks and water bodies, **(2)** urbanization in irregular patches irrespective of presence of roads and water bodies, and **(3)** significant urbanization around the periphery of some of the areas around the margin of study region.

As stated in the study objectives, our next task is to combine the observations to assess whether these urban changes have impacted the status of agriculture in the study area. To address this, we develop an end member scenario in which the changes in urban land and its agricultural impact have been analyzed based on: *Determine whether the new settlements detected in the 2014 data product retrieved from Google Earth have developed over a pre-existing agriculture land*. To do this, we have analyzed several zoomed-in examples from Figures no. 3 and 4 for which changes have been inferred. The examples of results obtained from our analysis are described below.

Example.1:- In the first example, we have noticed that there has been urbanization in form of new constructions, residential and commercial developments (Figure no.5). A new construction site is under development in the north of Sadwar area (Figure no. 3a) in the Google Earth image of 2014. The square/rectangular patches with varying green tone in the figure is a representation of an agricultural land. It can be seen in the 2007 Google Earth image that the location where construction was ongoing in 2014 is dominated by agricultural lands.

Even in the 2014 image, it can be clearly seen that the construction site is surrounded by agricultural lands. This makes it evident that urbanization has taken place in this region while affecting the land that was initially used for agriculture purpose. Similar context can be observed in Figure no. 5b, wherein, a large residential/commercial building has been constructed over a large portion of agricultural land within a difference of 7 years, i.e. from 2007-2014. This has been constructed in the Manipur area (Figure no.3b). Additionally, in Figure no.5c, it can be clearly seen that new commercial developments have taken place over the pre-existing agricultural lands in the areas south of Mahamaya Mandir.

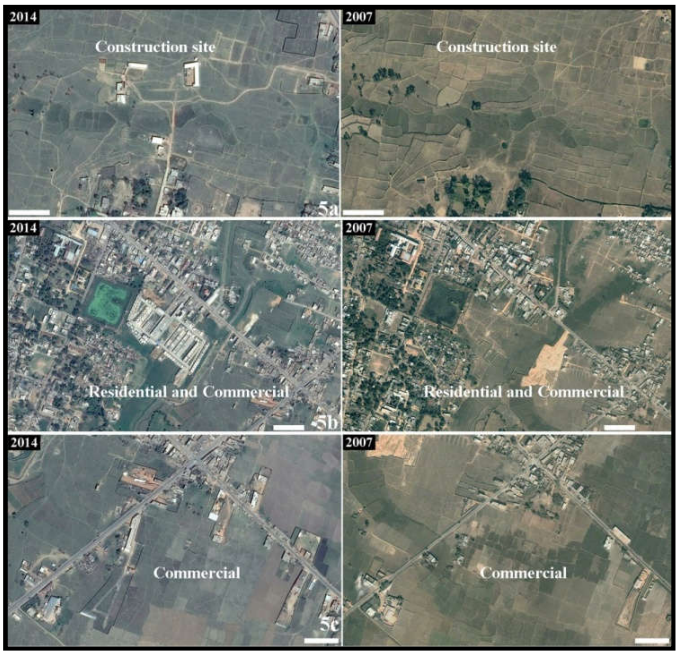

Figure no. (5a - 5c): *Zoomed-in details of the sites where urbanization is inferred from Figures no. 3 and 4. Left panel is Google Earth product of 2014 and right panel is of 2007. The type of urbanization is inferred from the figures and mentioned for clarity. Scale bar is of 50 meter in all the images. The spatial locations of these figures are displayed in Figures no.3 and 4 for reference.*

Example.2:- In the second example, urbanization has been noted mainly in form of residential developments in Figures no. 6a and 6b. These developments have taken place in the east of Mayapur and south of Kalam Para areas (Figures no.3d and 3e). Typically, the urbanization is in form of development of small houses in these areas. It can be clearly seen in the 2007 image that these land portions were initially an agricultural land. In fact, the entire areas wherein developments have been noticed were under agriculture cover. Adding to these observations, in Figure no. 6c, we have noted that new constructions have been ongoing in the 2014 image over the pre-existing agricultural lands in the east of Water Park (Figure no.3f).

Figure no. (6a - 6c): *Zoomed-in details of the sites where urbanization is inferred from Figures no. 3 and 4. Left panel is Google Earth product of 2014 and right panel is of 2007. The type of urbanization is inferred from the figures and mentioned for clarity. Scale bar is of 50 meter in all the images. The spatial locations of these figures are displayed in Figures no.3 and 4 for reference.*

Example.3:- In this example, urban changes have been noticed in three forms namely residential, public transport, and industrial/commercial (Figures no. 7a, 7b and 7c). It is apparent from the image pair that these urban changes have undoubtedly occurred over the land that was initially used for agriculture. These areas are located west of Water Park (Figure no. 3f), south of Gangapur Khurd (Figure no.4a), and northeast of Subhash Nagar (Figure no. 4b) respectively. In addition, it is important to mention that such types of urbanization has eventually resulted in destruction of large portions agriculture areas.

Figure no. (7a - 7c): *Zoomed-in details of the sites where urbanization is inferred from Figures no. 3 and 4. Left panel is Google Earth product of 2014 and right panel is of 2007. The type of urbanization is inferred from the figures and mentioned for clarity. Scale bar is of 50 meter in all the images. The spatial locations of these figures are displayed in Figures no.3 and 4 for reference.*

Example.4:- This final example (Figures no. 8a, 8b and 8c) presents urbanization mainly occurring in form of residential developments in the east of Mahavir Pur area (Figure no. 4c), southwest of Thakur Pur area (Figure no.4e), and between Namnakala and Gangapur Khurd areas (Figure no.4a). It is evident from the image pair that the residential developments have occurred over the pre-existing agricultural lands.

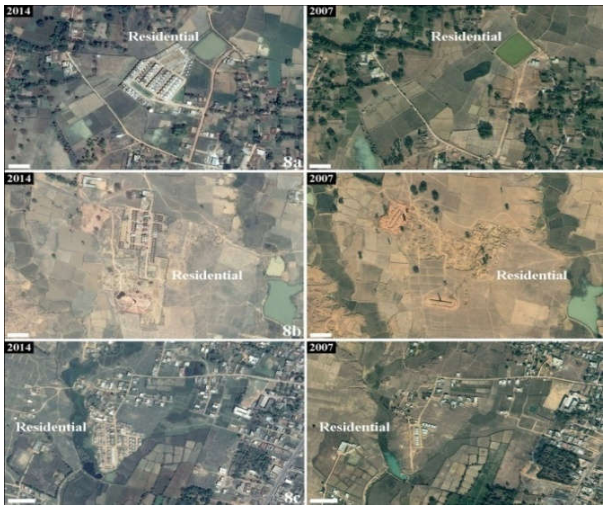

Figure no. (8a - 8c): *Zoomed-in details of the sites where urbanization is inferred from Figures no.3 and 4. Left panel is Google Earth product of 2014 and right panel is of 2007. The type of urbanization is inferred from the figures and mentioned for clarity. Scale bar is of 50 meter in all the images. The spatial locations of these figures are displayed in Figures no.3 and 4 for reference.*

Taken together, these remote sensing and GIS based examples presented above ultimately drive us to stamp that urbanization over multiple areas around the margin of Ambikapur city has significantly affected the extent of agricultural land during the past decade.

VII. SUMMARY AND CONCLUSIONS

In summary, this research has illustrated that urbanizing regions have resulted in conversion from agriculture to urban land, which can be realized in form of reduction in year-to-year greenness. Being more critical, this work has highlighted the utility of multi-date, multi-season remote sensing imagery

for change detection analysis, especially in the regions that are dominated by urban landscapes. To this end, we leave it for the readers and experts to decide on the pattern of urbanization going around the margin of Ambikapur city and think what would be happening in and around the other cities of the Chhattisgarh state, mainly for the urbanization at the cost of agricultural land. Our observations and results leave the readers at a point from where to rethink and develop plans for urbanization that is going to take place in future around the margin of Ambikapur city. It is important to ask that if the urbanization keeps on happening in this form, will it eventually drown the name of Chhattisgarh state as the nation's 'rice bowl'. We clearly understand that urban expansion is essential for any city that is aiming for development; however, we recommend that it should not be practiced at the cost of agricultural land. There should be a strict amendment in the law and regulations that the agricultural lands should be classified under 'no urbanization zone' and any type of changes occurring in the future over the agricultural lands should be scrutinized.

ACKNOWLEDGEMENTS

ESA and the USGS are thanked for the public access and redistribution of global acquisitions of ESA's Sentinel-2 data at no cost. The ASTER L1T data product was retrieved from the online Data Pool. Courtesy of the NASA Land Processes Distributed Active Archive Center (LP DAAC). USGS / Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://lpdaac.usgs.gov/data_access/data_pool Google Earth imagery is utilized in this research paper as per the guidelines/permissions documented at the website: https. The Department of Space is also thankful for the financial support for the present study.

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