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STUDY ON EVALUATING THE IMPACTS OF SPATIAL RESOLUTION ON LAND COVER AND LAND USE CLASSIFICATION ACCURACY USING REMOTE SENSING AND GIS

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Abstract: -The current need for data refinement has been increasing over the years as more and more data is being produced at an uncontrolled and unrestricted rate. Whether this data be of numbers or images, the productive use and output obtained from the data should be of the highest quality possible, with it having undergone as much fine-tuning as feasibly possible. It is imperative that produced LULCs (Land Use Land Cover) display as much of an accurate scenario of a location as possible. This can be done through the improvement of datasets used while performing the classification. The study attempts to present an optimal solution to the current landscape, while also reducing the amount of information loss that occurs when creating an LULC. For the study, the area of Jog River Watershed (265.902 km^2) in Ratnagiri district of western Maharashtra was used. The delineated watershed and False Colour Composites created for both the resolutions in QGIS were used to perform a Supervised Image Classification in SAGA GIS. The method used was Maximum Likelihood. Once the classification was obtained, a third party was requested to perform the accuracy assessment and a satisfactory Kappa coefficient was obtained. Using the final LULC maps, a comparison was made. The comparison showed that the change in area for each class was; Water (0.08%), Scrub (5.26%), Built-Up (0.78%), Wasteland (2.04%), Plantation (0.48%), Open Soil (1.46%). From the different analyses made, it was evident that the 5m (LISS IV) resolution LULC was superior in all aspects. It had greater clarity, finer edges, and even managed to provide greater detail about the area as compared to the 10m (Sentinel 2A) resolution watershed. As a result, it was concluded that the 5m (LISS IV) resolution data should be used for further studies to improve and refine the data obtained through its use.

***Key Words* -- LULC, Maximum Likelihood, Spatial Resolution, Remote Sensing**

1. INTRODUCTION

The phenomenon of land use/land cover (LULC) is the outcome of a synergy between natural and artificial forces, encompassing both the inherent characteristics of land and the impact of human activities. The spatial distribution pattern and dynamic changes in LULC not only impact the regional economic-social development but also the regional environmental and climate change. The utilization of satellite remote sensing technology provides a robust technical foundation for the rapid and extensive acquisition of LULC data (Ghayour et al. 2021). Remote sensing is used for a wide array of purposes in conservation science (Fisher et al. 2018). LULC maps play a significant and important role in planning, management, and monitoring programs at local, regional, and national levels (Gaur and Singh 2023). They serve to enhance comprehension of land utilization aspects, while simultaneously playing a significant role in the formulation of policies and programs essential for development planning (Wang et al. 2022). To ensure sustainable development, it is necessary to monitor the ongoing process on land use/land cover patterns over a period of time. The spatial resolution of the sensor plays a very important part in the accuracy and clarity of the final output LULC. It is important to note that more spectral bands should be considered, as they will also be very helpful for identifying land use/land cover. The higher resolution image greatly reduces the mixed-pixel problem, and it is possible to extract much more detailed information on land use/land cover structures (Suwanprasit and Srichai 2012).

2. STUDY AREA

Jog River Watershed is located in the Ratnagiri District of Maharashtra. In the district, the watershed mostly spans across the northern regions of Dapoli Tehsil, with its extreme fringes extending into Mandangad Tehsil. The watershed spans from 73.091E, 17.739N to 73.372E to 17.924N. The area covered by the watershed is 265.902 km^2 and its perimeter is 144.958 km. The main river of the watershed is the Jog River. Its source is located at 73.366E, 17.877N, and it meets the Arabian Sea via estuary at 73.106E, 17.841N. The Jog river has a length of approximately 45 km. The major cities located in the watershed are Dapoli and Palgad, with

Anjarle and Harnai located just outside its western borders, as visible in Figure 1. In the watershed, there as three major water reservoirs: Tanghar Lake, Sondeghar Dam and Pat Dam. The watershed experiences a lot of tourist traffic, owing to the pristine beaches along the coastline, as well as the famous seafood cuisine of the Konkan area in which it is located. Its topography is relatively flat in nature, with only a relief variation of roughly 400m, with the eastern confines of the watershed exhibiting more rugged terrain.

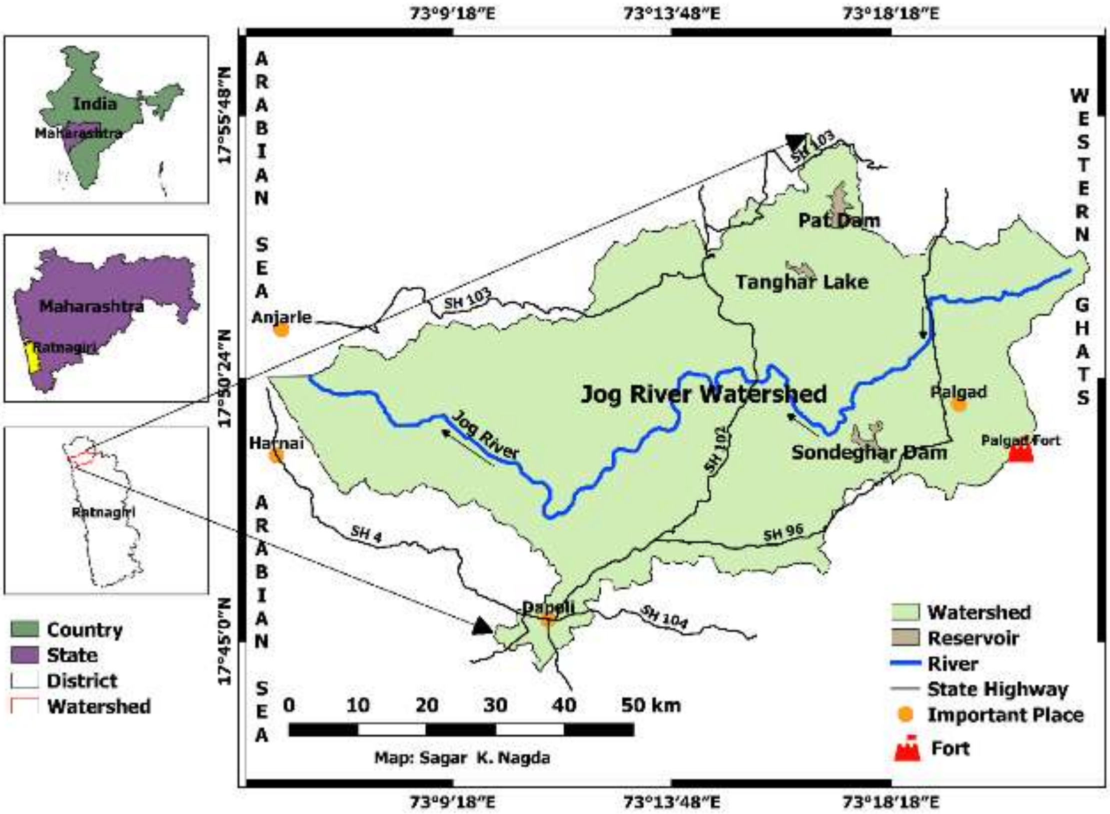


Figure 1: Jog River Watershed

3. METHODOLOGY

To identify the study area, the CartoDEM v3.1 Digital Elevation Model (DEM) obtained from the Bhuvan portal was used. The Coordinate Reference System of the DEM was adjusted and used as input for the Fill Sinks tool to remove any outlier values throughout the DEM. The filled DEM obtained as output was used in the Strahler Order tool to determine the streams in the DEM. The tool allows the determination of an outlet point that was used in the Upslope Area tool. Using the coordinates of the outlet, the area upstream of the river was obtained, which is the total watershed. This area was in a raster form and must be converted to a vector, which was done using the Vectorize tool.

For performing a Land Use/Land Cover classification, a False Colour Composite of the study area was required. To obtain this, raster image data from the EOS Landviewer Global Database Portal (Sentinel 2A data) and Bhoonidhi Database Portal (LISS IV data) were obtained. The downloaded individual band data was merged to form a composite image. The composite was clipped to the watershed shape and assigned proper bands in the proper component selections to generate a False Colour Composite of the watershed area.

LULC Classification was done in SAGA GIS, while all other tasks were performed in QGIS. Using the obtained False Colour Composite, a supervised classification was performed. The classification required training sets (AoIs), which needed to be manually created. A new shapefile layer was created where the necessary sets were created by identifying the relevant pixels and reflectance values for each class (John et al. 2020). To get a clear picture of what class each pixel falls into, the watershed was constantly compared with the 2015-2016 Indian National LULC prepared by NRSC and verified by ISRO (Kumar and Agrawal 2019). The number of AoIs required depended on the density, clarity, and dispersion of the class in question across the watershed. Classes with more variability were given 75 to 100 polygons, whereas classes with little to no variance were given about 50 polygons as their AoIs. Once the AoIs were ready, the shapefile was used to run a Supervised Image Classification using a Maximum Likelihood Classification Method (Ahmad and Quegan 2012).

To perform the assessment, another shapefile layer was created where sample AoI polygons were added to verify the trueness of the performed classification (B R and S V 2018). Since only a few samples were required, about 5 to 10 polygons were used instead of the 50 to 100 which were required for the actual classification process. This process was entirely performed by a third party to ensure truthful and accurate assessment. Once the polygons were prepared, the new AoI layer was used to create a Confusion Matrix (Alam, Bhat, and Maheen 2020). Aiming for a Kappa coefficient of at least 0.85, the AoI polygons were refined multiple times over to ensure that the accuracy was up to terms with what was expected. After a satisfactory Kappa coefficient was obtained, the final LULC was compared with the 2015-2016 Indian National LULC prepared by NRSC and verified by ISRO to ensure that the LULC was consistent with the ground-truthing of the particular area. After the final LULC of both the spatial resolutions (5m (LISS IV) and 10m (Sentinel 2A)) were obtained, they were studied with a heavy emphasis on scrutiny of the differences between them.

In the analysis of the final LULC, the main pointers considered were the number of classes created during classification, the areas under each class both in hectares and square kilometres, the number of pixels covered by each class, the correctness of the represented pixel on each map, as well as the overall representation of the LULC.

4. RESULTS

In the section, the findings of the case study have been discussed, as well as a detailed explanation on the results and outcomes have been mentioned.

Table 1: Kappa Coefficient and Overall Accuracy of performed LULCs

Factor	10m (Sentinel 2A)	5m (LISS IV)
Kappa Coefficient	0.959	0.925
Overall Accuracy	0.974	0.952

Table 1 represents the Kappa Coefficient and Overall Accuracies of the performed LULCs. The high values were attained after rigorous and meticulous re-adjustment and extensive understanding of the different parameters required to perform an accurate LULC. All the intricacies of reflectance values and type of class of signature were kept in mind while assigning the polygons for each class to ensure that the accuracy was as high as feasibly possible within the stipulated timespan.

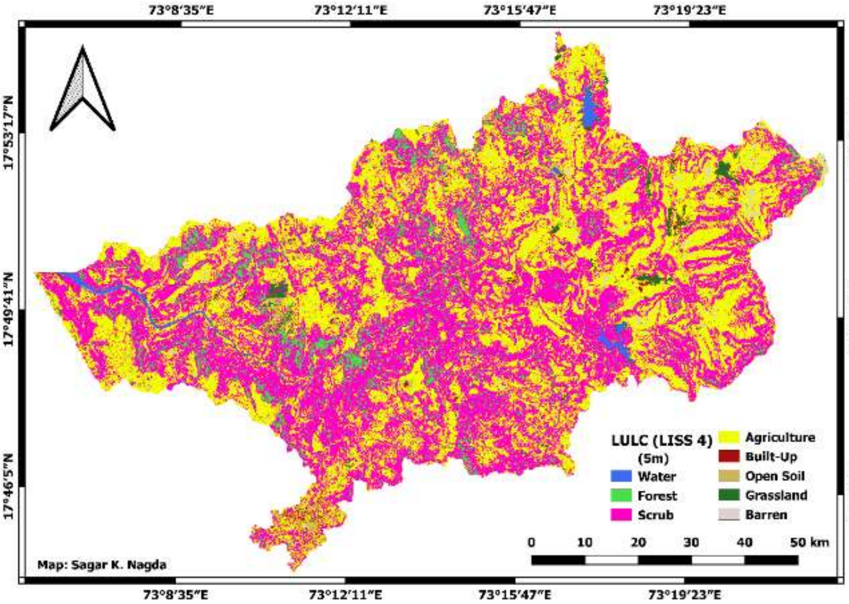


Figure 1: 5m (LISS IV) Resolution LULC of Jog River Watershed dated 19 February 2023

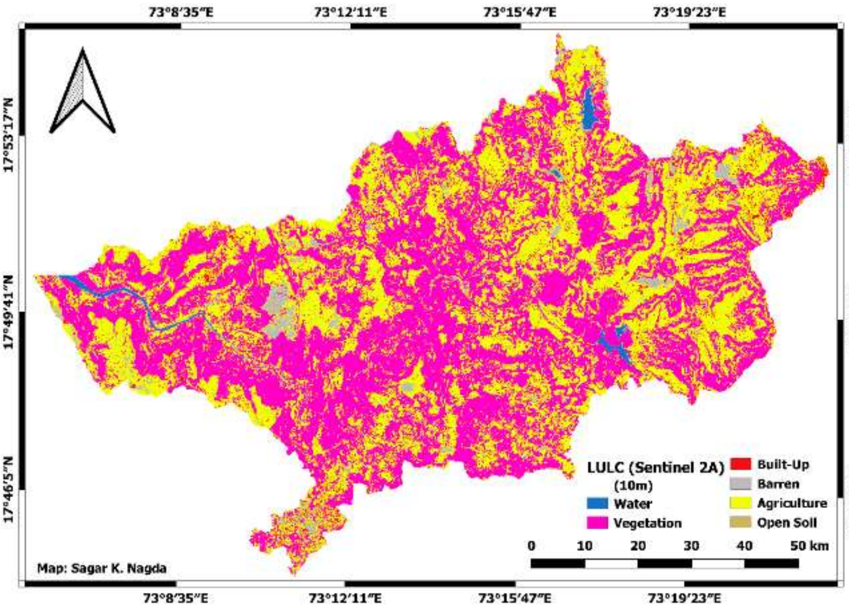


Figure 2: 10m (Sentinel 2A) Resolution LULC of Jog River Watershed dated 18 February 2023

In Figure 2, the 5m (LISS IV) resolution of the Jog River watershed is predominantly composed of scrubland, with agricultural land making up a good chunk of the areal cover as well. Waterbodies are sparse, with the major river and two dams being the main constituents. Towards the south-western quarter, the city of Dapoli is visible, where there is a greater density of built-up parcels. In the 10m (Sentinel 2A) LULC displayed in Figure 3, there is a clear dominance of scrubland, with a greater part of the remainder under agricultural cropland. The LULC also details the fact that the watershed has a decent amount of barren land.

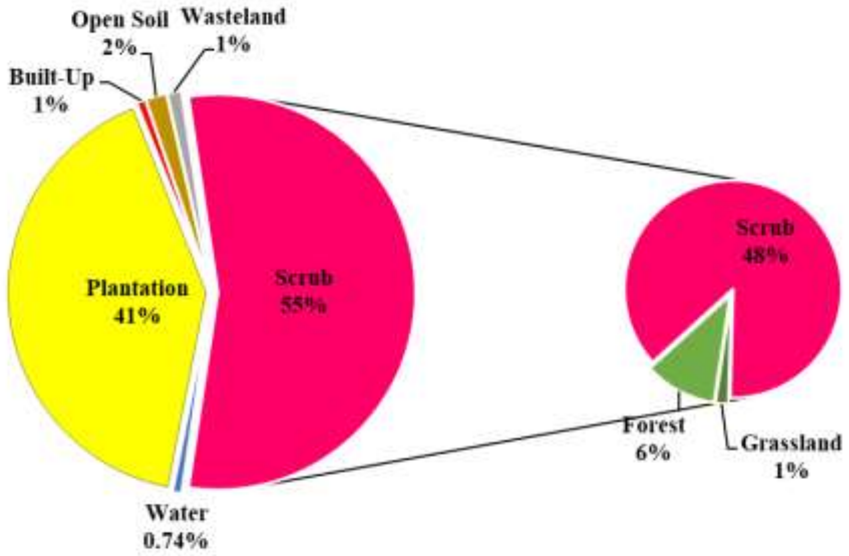
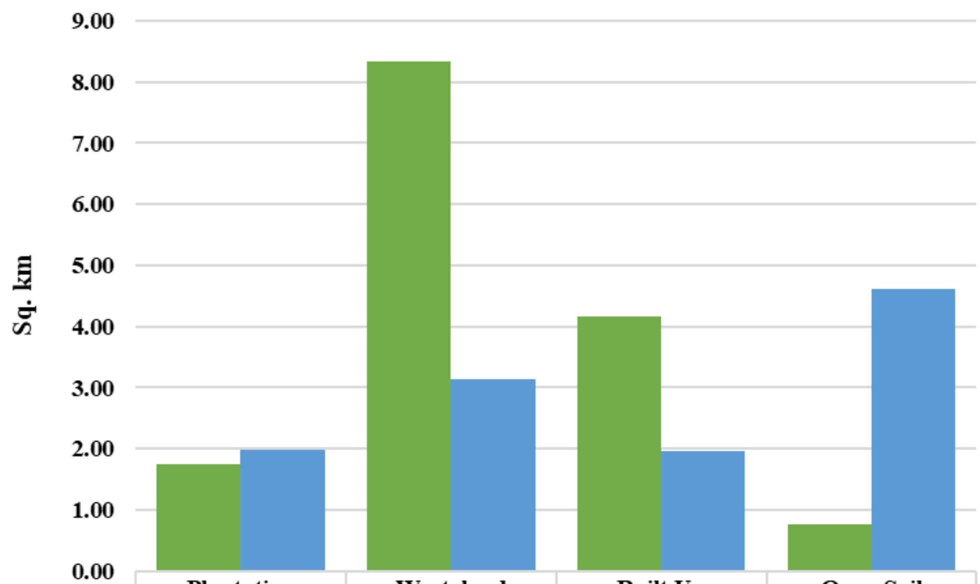


Figure 3: Increase in Classes due to Clarity of Resolution

Figure 4 elaborates on the main reason why the 5m resolution image is superior to the 10m image. The scrub class in the 10m LULC has been split into two more classes in the 5m LULC: Forest and Grassland. This was possible because the greater quality image provided more contextual information as well as better inference and differentiation of tone and texture, resulting in more precise signatures and the chance to create an improved result. This was the major change observed when comparing the two LULCs and was also the most prominent in terms of increase in accuracy.



	Plantation	Wasteland	Built Up	Open Soil
10m (Sentinel 2A)	1.75	8.34	4.15	0.76
5m (LISS 4)	1.98	3.13	1.97	4.62

Figure 4: Comparison of Common Classes between 5m (LISS IV) and 10m (Sentinel 2A) LULC

In the graph of Figure 5, the most important point of note is the sharp drop in the area of wasteland (8.34 km^2 to 3.13 km^2) when transitioning resolutions. This is most likely due to the fact that the coarse resolution gave incorrect information to the assigned signatures. The other difference of note is the increase in the area of Open Soil in 5m (LISS IV) (0.76 km^2 to 4.62 km^2). This can be explained by the fact that the size of the individual patches was so minuscule, outside a few select areas, that it was hard to pick them up in the 10m (Sentinel 2A) image. The improvement in resolution meant that the patches could be discerned more easily, leading to an increase in their area.

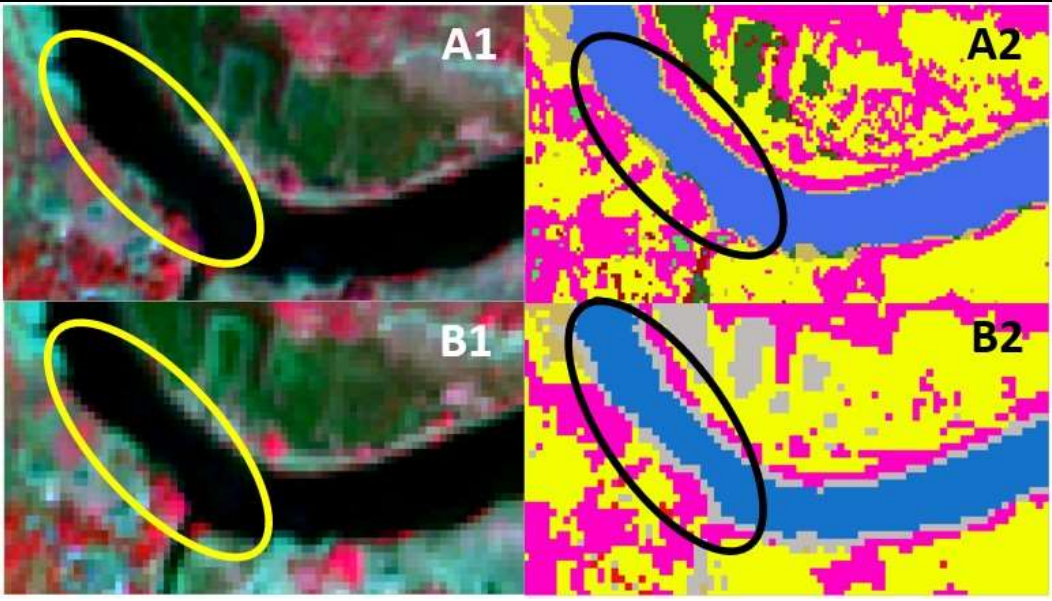


Figure 5: Comparison of Fineness of Resolution on river borders (A1 – 5m LISS IV, A2 – 5m LULC, B1 – 10m Sentinel 2A, B2 – 10m LULC)

In the Figure 6, the river boundary can be seen in higher definition in the 5m (LISS IV) FCC (A1) in the highlighted area when compared to the 10m (Sentinel 2A) FCC (B1). The same can be noticed in the LULCs, with the 5m (LISS IV) (A2) example illustrating a much more detailed boundary. The 10m (Sentinel 2A) LULC (B2) fails to recognise the curvature of the river to a satisfactory level since the edges are not as refined as required.

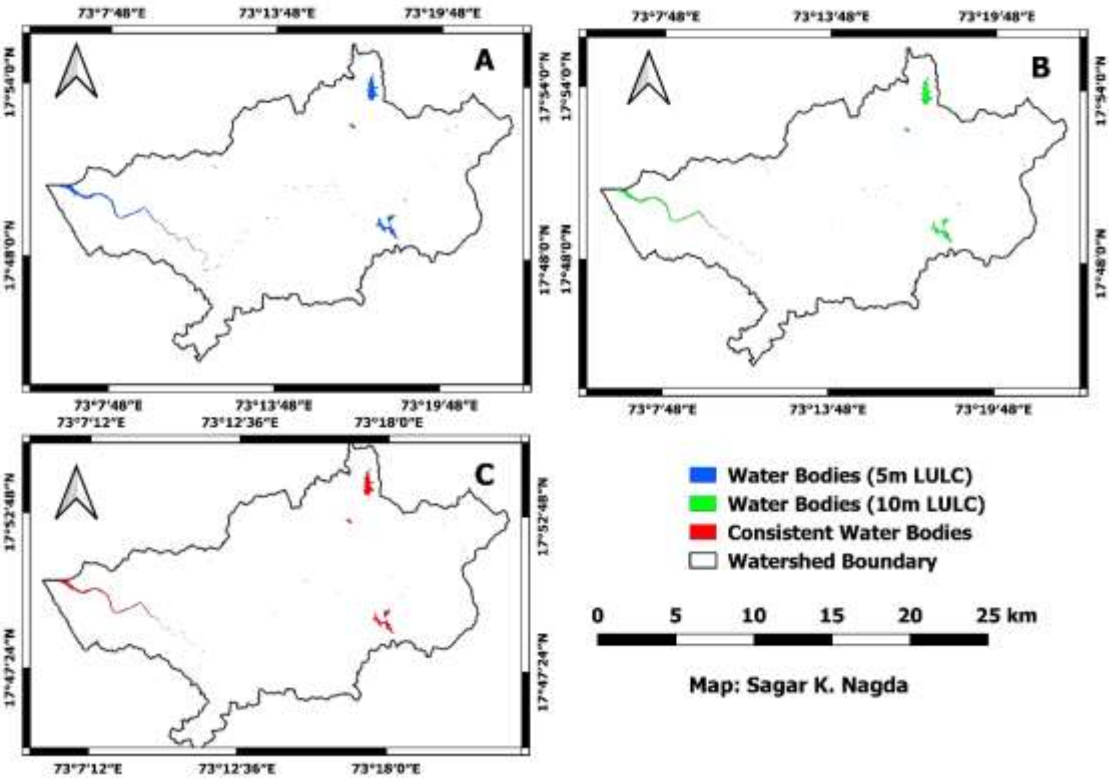


Figure 7: 5m (LISS IV) resolution (A) and 10m (Sentinel 2A) resolution (B) Water bodies and their Consistency (C)

The waterbodies in Figure 7 show a relatively consistent trend across both LULCs, but in the centre of the 5m (LISS IV) LULC (A) watershed, more parcels of water have been detected, which were not detected in the 10m (Sentinel 2A) LULC (B) due to the increased size of the pixels. Many more smaller water bodies have also been detected in the 5m (LISS IV) LULC (A) because of the resolution allowing more clarity while assigning the signatures. This was not the case in the 10m (Sentinel 2A) LULC (B) because the larger size and overall blurred information feedback of the image made it difficult to distinguish the various different features of the watershed.

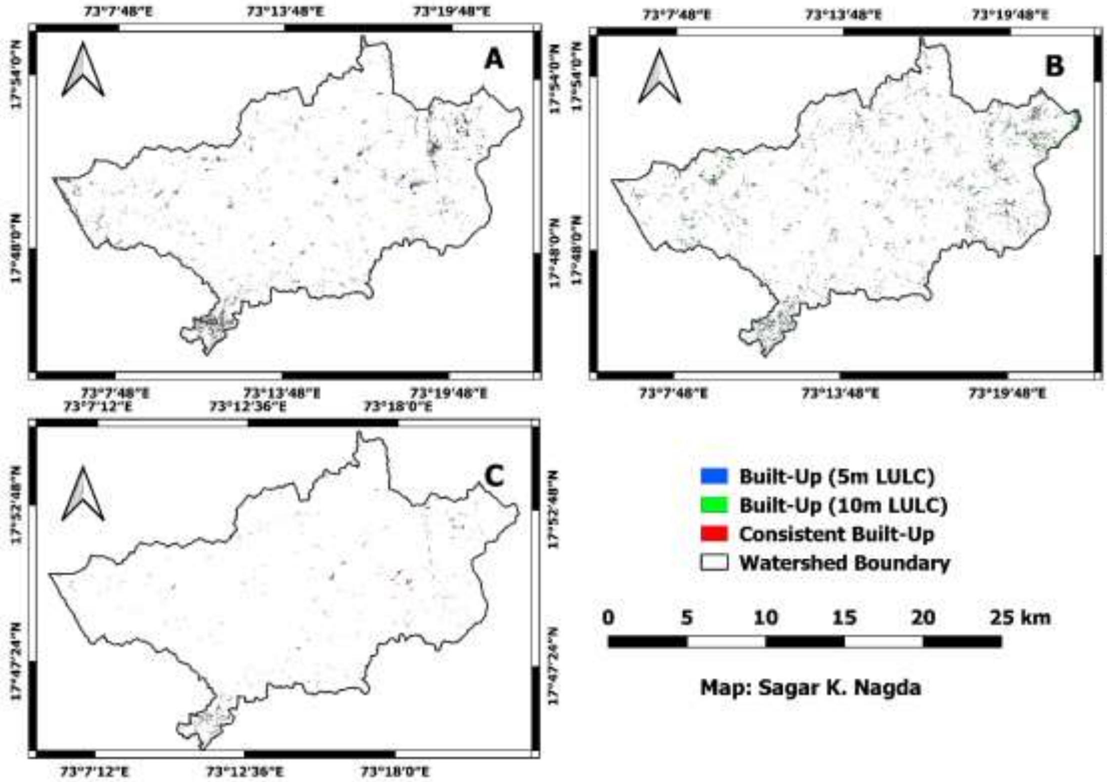


Figure 8: 5m (LISS IV) resolution (A) and 10m (Sentinel 2A) resolution (B) Built-Up areas and their Consistency (C)

Comparing the built-up areas of each LULC in Figure 8, it is inferred that the greatest amount of consistency occurs in Dapoli, whereas the scatterings of other built-up areas throughout the watershed suggest that there are smaller villages and hamlets that could not be equally understood by both LULCs. Even then, the high density on the eastern end of the watershed represents major construction work in the area.

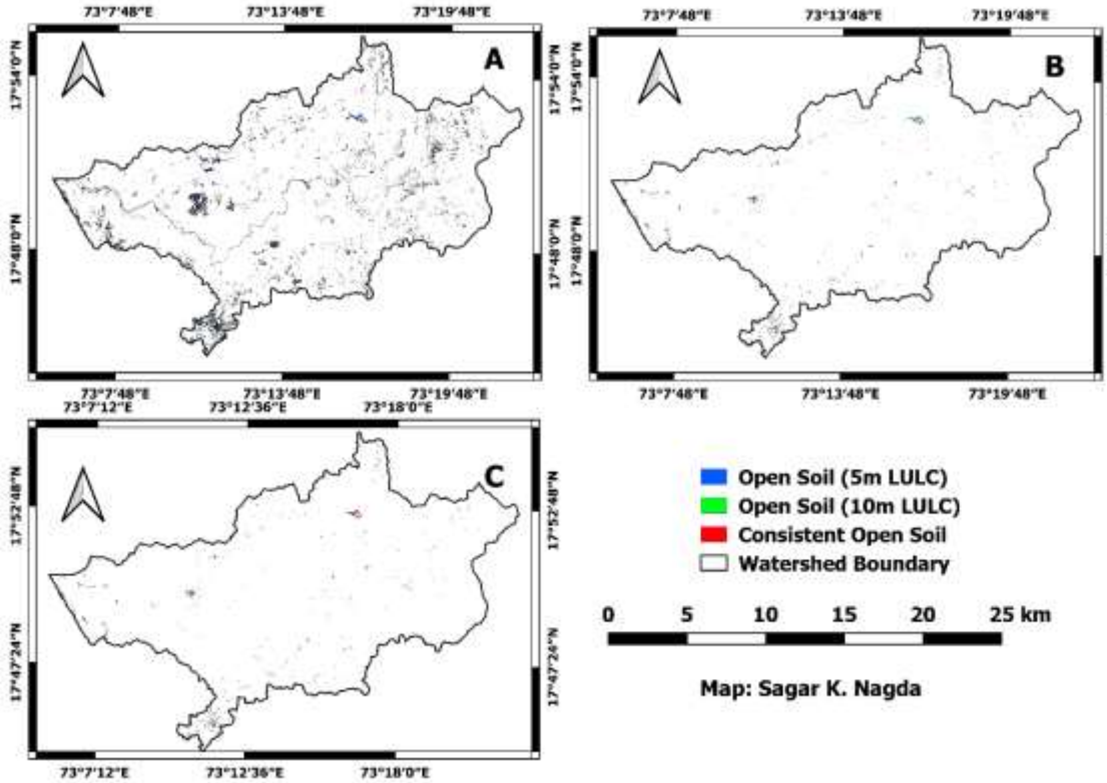


Figure 9: 5m (LISS IV) resolution (A) and 10m (Sentinel 2A) resolution (B) Open Soil patches and their Consistency (C)

The distribution of open soil across the watershed in Figure 5.8 can be seen clearly in the 5m (LISS IV) LULC because of the fact that the patches themselves are very small on an individual scale. As a result, there was more visibility of the patches in the 5m (LISS IV) resolution (A) as compared to the 10m (Sentinel 2A) resolution (B) where they are more localised to larger areas around dry riverbeds and barren lands. The consistency fails to show the riverbed around the Jog River for the same reason, that being, the 10m (Sentinel 2A) resolution fails to provide enough contextual data to be able to assign separate polygons for the class.

5. CONCLUSIONS

- The differences in the two LULCs was immediately apparent, and was a direct result of the increased clarity in the 5m (LISS IV) LULC over the 10m (Sentinel 2A) LULC.
- The increased number of classes in the 5m (LISS IV) resolution LULC depicts the increased clarity provided by the image.
- The classes that increased were Forest and Grassland. They were formed from the Scrub class due to the enhanced tone and texture recognition that the 5m (LISS IV) resolution provided.
- In both the LULCs, the greatest area was covered by the Scrub class (47.74% in 5m and 53% in 10m), while the least area was covered by Water and Built-Up (0.74%) in 5m (LISS IV) and Open Soil (0.26%) in 10m (Sentinel 2A).
- The increase in edge fineness and accuracy in 5m (LISS IV) image makes it a prime candidate for more precise work, as compared to the 10m (Sentinel 2A) image.
- With regards to the consistency between the two LULCs, Water showed the greatest common areas, whereas Open Soil had the greatest difference, owing to their inherently small patch size not being noticed in the 10m (Sentinel 2A) image LULC.
- Considering all the improvements provided by utilising the 5m (LISS IV), it is suggested that for further studies pertaining to subjects related to Land Use/Land Cover, it be used over the conventional 10m (Sentinel 2A) resolution that is preferred.

6. ACKNOWLEDGMENTS

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