Assessment of Urban Green Cover and its Types using Threshold-based Approach

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Abstract

Providing adequate green cover in the form of trees, parks and gardens is a nature-based solution which every city must adopt to address the urbanization and its impacts, as it helps to reduce the temperature, maintain the ecology and biodiversity, provide recreational facilities for the city inhabitants and many more. Accurate mapping and monitoring of Urban Green Spaces (UGS) through satellite images is essential to check whether a city has adequate green cover or not. Studies on UGS have mostly used Landsat and Sentinel-2A satellite images for extracting the green covered areas in cities. Though it is advantageous to use these freely available images, however the accuracy of extraction is a major concern as the images are of >10m spatial resolution. Distinguishing the various green cover types, such as trees, shrubs, cropland, etc. is not an easy task in low and medium resolution satellite images. To overcome these drawbacks, one has to use high (1-10m) and very-high resolution (<1m) images for extracting the UGS accurately, however, purchasing such 'cm' resolution satellite images is a costly affair. In order to balance between the cost and resolution, the best and viable option is to use the Google earth (GE) imagery and the same was attempted in the present study by proposing a simple threshold-based approach to extract the UGS and its types from GE imagery. To illustrate the proposed method, 15 sites from the city of Vellore, India were taken and the latest cloud free GE imagery was then downloaded, projected and carefully checked for its range of pixel values in different types of UGS classes. The threshold values of each UGS type were then used to reclassify the original GE image and finally the accuracy assessment was performed on the reclassified UGS map. The results were promising as the overall accuracy (OA) was > 90% at 12 sites and only 3 out of 15 sites exhibits OA in the range of 75-86%. In order to assess the performance of the proposed approach at other locations, 5 cities across the globe [2 from India (Bangalore and Hyderabad) and 3 from abroad (Barcelona, Kuala Lumpur, New York)] were taken and the results revealed that the proposed method performs well in extracting the UGS and its types as the OA was found to be above 90% at all the 5 cities. The proposed approach can be used by civic authorities not only to check whether the city has adequate green cover or not but also can monitor whether UGS has increased or decreased over the years using the historical GE images.

Keywords: Accuracy Assessment, Google Earth Images, Threshold Value, Urban Green Space, Urbanisation

1. Introduction

Urbanisation is the process through which people move from rural areas to cities due to increased work opportunities. In order to obtain better housing environment, better facilities for recreation and better health care facilities and social life too, an increasing number of people are being forced to relocate to cities and towns from rural areas. For a developing nation like India, urbanization is unavoidable; however, unplanned, rapid, and unsystematic urban growth may have adverse effects on a variety of environmental and ecological components, particularly on land and water. The problem is more critical as 68% of the world's population, up from 55% today, is anticipated to reside in cities in 2050 [1]. Nearly 90% of this population growth would occur in Africa and Asia. Due to the country's apparent rapid urbanization, the urban landscape appears to have undergone significant changes in terms of land use and land cover, placing a substantial strain on a number of natural resources [2].

One of the major effects of urbanization is loss of beautiful green cover in a city apart from other ill effects like water scarcity, polluted air, traffic jams, etc. Loss of green cover plays a major role as it directly deals with ecology and biodiversity.

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In order to maintain the city with good environmental conditions, one need to adapt the pace of growing green within the empty spaces both indoor and outdoor [3]. Many cities across the world especially in developed nations have already realized the advantages of green spaces and thus took initiatives not only to increase the forest cover but also the green cover within cities, popularly called as urban green spaces (UGS).

Globally, the need for more UGS is a high priority on city policy agenda and it includes trees, grass, shrubs, or other types of vegetation within urban areas. The sustainable growth encourages active lifestyle and protect biodiversity. UGS also reduces the consequences of heat islands on a broader scale. The contributions they have made to lowering carbon emissions and enhancing public health have also received attention in recent years [4]. UGS promotes biodiversity, lowers summer city temperatures and reduces urban flood risk. UGS advances enhanced wellness, increased social cohesion, and ensures wellbeing of citizens. Considering the benefits associated with UGS, many countries in the world have formulated guidelines on how much green space should be available in a city on per capita or per hectare basis. For example, World Health Organization (WHO) has suggested a minimum of 9 m^2/person of UGS and in European Union, the publicly accessible UGS in core cities is found to be 18.2 m^2/inhabitant on an average, which is twice the recommended value [5]. In India, the suggested UGS per capita is 10-12 m^2 [6]. In Tamil Nadu state of India, the UGS targeted is 20 to 40% of city's geographical area or in other words, one-third of the city should be covered by green [7]. In order to check, whether the existing UGS available per capita or per hectare is adequate or as per standards, it is essential to perform an assessment of UGS in a city/town so that if there is any deficiency, steps can be taken by the city authorities to increase the same. In recent years, the advancements in remote sensing and GIS and availability of open source data such as Google earth made UGS calculation easier than before.

Existing studies on extracting UGS from satellite images have mostly used the Landsat and Sentinel-2A data [8] and [9]. Though it is advantageous to use these freely available images, however there are certain drawbacks. For example, accuracy of extraction is a major concern as the images are of ≥10m spatial resolution. Distinguishing the various green cover types, such as trees, shrubs, grassland, cropland, etc. is not an easy task in low and medium resolution satellite images. To overcome these drawbacks, one has to use high (1-10 m) and very-high resolution (<1 m) satellite images for extracting the UGS accurately [10] and [11]. However, purchasing such 'cm' resolution satellite images is a costly affair. So, the major limitations in existing studies are accuracy while classifying the low-resolution satellite images and huge cost of purchase if very high-resolution images of less than 1m are employed. In order to balance between the cost and resolution, the best and viable option is to use the Google earth (GE) images where one can clearly see the green cover and its types. There are many advantages in using GE images in remote sensing studies. The main advantage is, it is an open-source data and does not involve any purchase cost. Another advantage with GE is that it provides historical images since the year 2010. So, one can do change detection analysis with very high-resolution GE images, for example, how much UGS have increased or decreased over the years. Another major advantage with GE images is we can get latest imagery as GE often updates the satellite images especially for cities, thus one can get one image every two months on an average for cities like Chennai, Bengaluru, etc. The only drawback with GE image is we may not get the original multispectral bands i.e., Near Infrared (NIR), Red, Green, Blue with digital numbers. Hence the vegetation calculators such as normalized differenced vegetation index cannot be calculated on GE imagery to extract the green covered areas as there is no NIR or Red band available. One of the major gaps in existing studies is the GE imagery was used as a background image and onscreen manual digitisation was performed to prepare the UGS map.

However, it is a cumbersome and time-consuming task especially manual digitizing of features on a very high-resolution imagery [12] and [13]. In order to overcome the above said gap in existing studies and utilize the GE image more effectively, the present study proposed a threshold-based approach to extract the urban green cover and its types from GE image for the city of Vellore, India. The proposed approach is very easy to understand and apply and can be performed in any open-source GIS software also. The objectives of the present work are 1). To extract various UGS types, such as trees, shrubs and crop land from GE imagery using threshold-based approach and perform accuracy assessment 2). To perform universality checking of the proposed approach by extracting UGS in five cities across the globe and perform accuracy assessment. The scope of the study is limited to extraction of only green covered areas and does not include other landuse/landcover classes. All the landuse/landcover classes other than UGS are named as 'Others' while classification. Also, the scope is limited to only cities as focus is extracting only urban green spaces.

However, the study can be extended to extraction of forest cover too. The scope of the study is limited to use of only GE imagery and does not use any other satellite data for classification or accuracy assessment.

2. Materials and Methods

The study area chosen for the present work is in the city of Vellore which is the administrative headquarters of Vellore district in Tamil Nadu state of India as shown in Figure 1. Decades ago, it was just a municipality or a town with a population of only few lakhs but after it became a municipal corporation in 2008, the town has experienced massive urbanization and now it is one of the major cities in the state of Tamil Nadu. The major reasons for its tremendous urbanization are it has been selected for smart city mission by Govt. of India in 2015 and also it is one of the famous hubs for education in the country as Christian Medical College and Hospital (CMCH) and VIT University are located in Vellore. Also, the Vellore fort and Golden temple attracts huge number of tourists every year. In order to cater the housing requirements and commercial needs of the city, many new residential areas and shopping malls have come up in recent years. The urbanization has resulted in reduction in agriculture land over the years but still one can see agriculture lands on the Northern side of Palar River which bifurcates the city at its middle and runs from west to east as seen from Figure 1. A total of 15 sites within Vellore corporation were taken and their locations are shown in Figure 1. Google earth (GE) images of those 15 locations are showed in Figure 2. The 15 locations were decided based on the criteria that the selected location must have considerable amount of green cover when compared to other landuse/landcovers. As seen from Figure 2, all 15 locations are having significant green cover in terms of trees, shrubs, crop land, etc. It can also be seen from Figure 2 that each location has presence of other landuse/landcovers too such as built-up, water body, open land, etc. surrounding the green cover, so that we can cross check the performance of the proposed threshold-based approach in extracting the green cover alone accurately when compared to other land covers.

2.1 Data Collection and Processing

The satellite images from Google earth (GE) are the input data for the present work and hence the Google Earth Pro version was downloaded and installed on the computer. The GE was then checked for the availability of satellite imagery pertaining to the study area based on three criteria: (1). The images should be of recent one (2). The images should be free from clouds because even a small cloud cover may affect the results (3). The images should be from the same sensor. Sometimes the satellite images covering the study area may be from different sensors and in that case, half of the image would appear in one tone, texture and the other half would have a different tone, texture. It is not advisable to consider such imagery as it would adversely affect the classification results. In order to download the images from GE, an open-source GIS software, called 'Smart GIS' was used [14]. There is a tool called 'Connect Google Earth' in Smart GIS which can be used to visualize and preview the Google earth image for the study area chosen before it can be downloaded. The required zoom level was kept and then the latest GE images of all the 15 locations were downloaded.

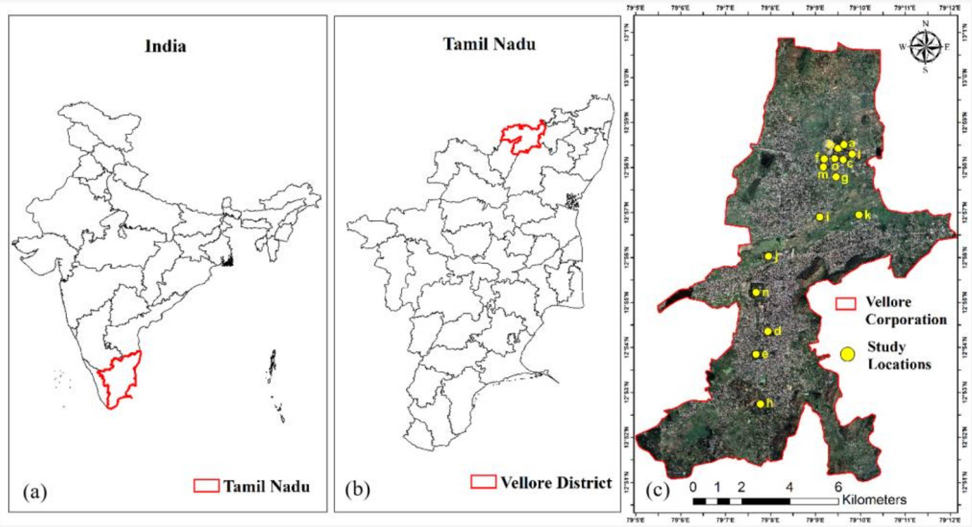

Figure 1: Study area (a) Tamil Nadu state in India (b) Vellore district in Tamil Nadu (c) Vellore corporation

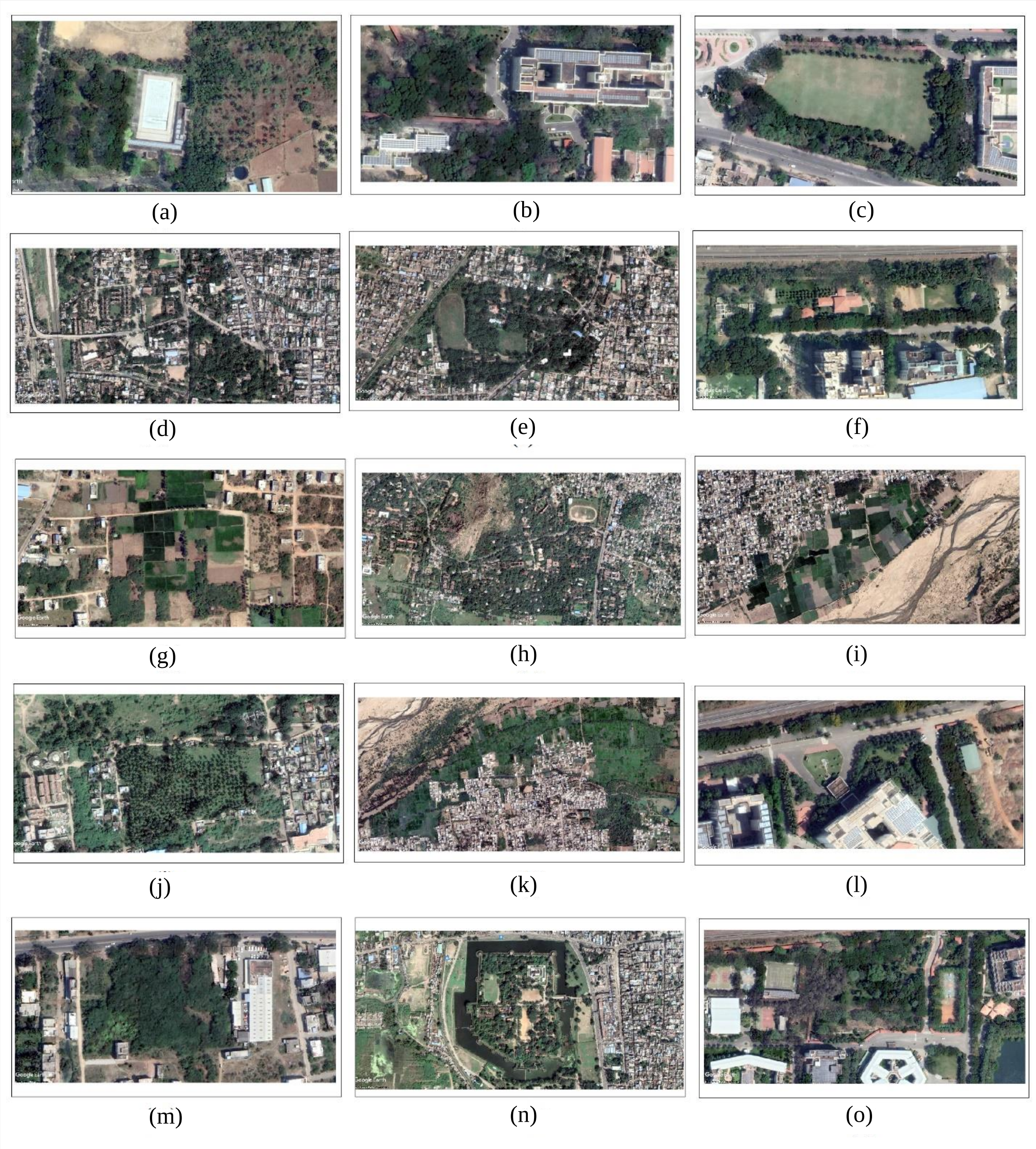

Figure 2: Google Earth (GE) images of 15 study locations in Vellore, India

Figure 2 shows the downloaded GE images of various locations within Vellore city in India. It can be seen that there is no cloud cover in any of the images. Also, one can clearly see the area covered by green. The GE images obtained from Smart GIS will usually be in geographic coordinate system, i.e., in decimal degrees. Such images cannot be used for measurement of area covered by green as they are in spherical coordinate system.

Hence the downloaded GE images were converted to projected coordinate system, i.e., rectangular or cartesian coordinate system in meters using Universal Transverse Mercator (UTM) projection in ArcGIS software. Once the input GE images are ready, the threshold-based approach can then be used to extract only the green covered areas and the same has been explained below.

2.2 *Threshold-based Approach to Assess the Urban Green Cover*

The present study proposed a threshold-based approach to extract the green cover from GE images and its step-by-step procedure is shown in Figure 3. The first step is selection of study area and identifying suitable locations for UGS extraction. The present study has selected 15 locations in the city of Vellore, India. The locations were carefully selected in such a way that the green cover is predominant at each location covering different types of UGS such as trees, shrubs, etc. Once the test locations are identified, the next step is to select the suitable GE image for analysis based on the three criteria as explained before, namely, the image should not have cloud cover, should be of recent one and must be from the same sensor. The Elshayal smart GIS software was then used to download the required GE images for the study locations selected. The downloaded GE images were then opened in ArcGIS software for projecting it into UTM projection. Before applying the threshold-based method, it is essential to first decide the number of UGS classes required. Based on visual inspection and field survey, it was found that there are three types of UGS classes that are present in the study area, namely, trees, shrubs and crop land. Trees are predominant at all the 15 locations when compared to other two classes. Once the UGS classes are decided, the threshold-based method can be applied, by carefully examining the range of pixel values for each UGS classes in each of the GE image of various locations.

Suppose if a GE image of a particular location consists of trees, shrubs and crop land, pixel ranges, i.e., minimum and maximum pixel values of each of these categories in that GE image are noted down. Likewise for all the other locations also, the range of values were noted down. Once the range is known, reclassification tool was then applied in ArcGIS software to prepare the UGS map with required number of classes. It is a trial-and-error procedure, i.e., identifying the pixel range and applying reclassification is repeated until the desired accuracy is achieved. For accuracy assessment, the random sampling method was adopted to get the testing points in the range of 20 to 40 which were randomly distributed over the resultant classified map using 'Create Accuracy Assessment Points' tool in ArcGIS software. Their ground truth information was obtained from the original/background GE image. Before running the 'Compute Confusion Matrix' tool of ArcGIS, it was ensured that the points are well distributed throughout the study area. The ground truth was then compared with the classified output to prepare the Overall accuracy (OA) and Kappa coefficient. Once the accuracy assessment results are acceptable, the universality checking of the proposed approach was then performed. It means whether the proposed approach would work well or not in other cities was verified by taking sample locations from different cities of the world. For the present work, 2 locations from Bangalore and Hyderabad cities in India and 3 locations from Barcelona, Kuala Lumpur and New York cities were taken. The threshold-based approach as explained above was then applied and finally OA and Kappa were arrived to check the performance of the proposed approach in extracting UGS from GE images.

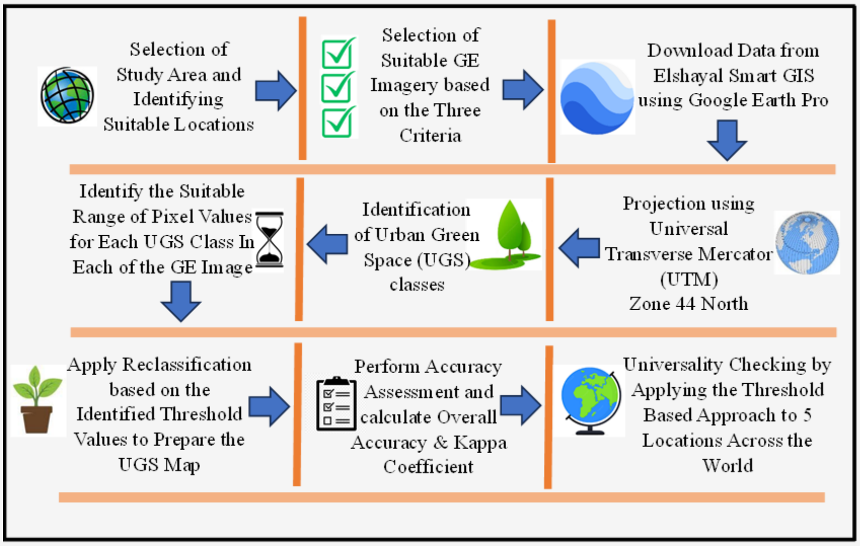

Figure 3: Methodology flowchart

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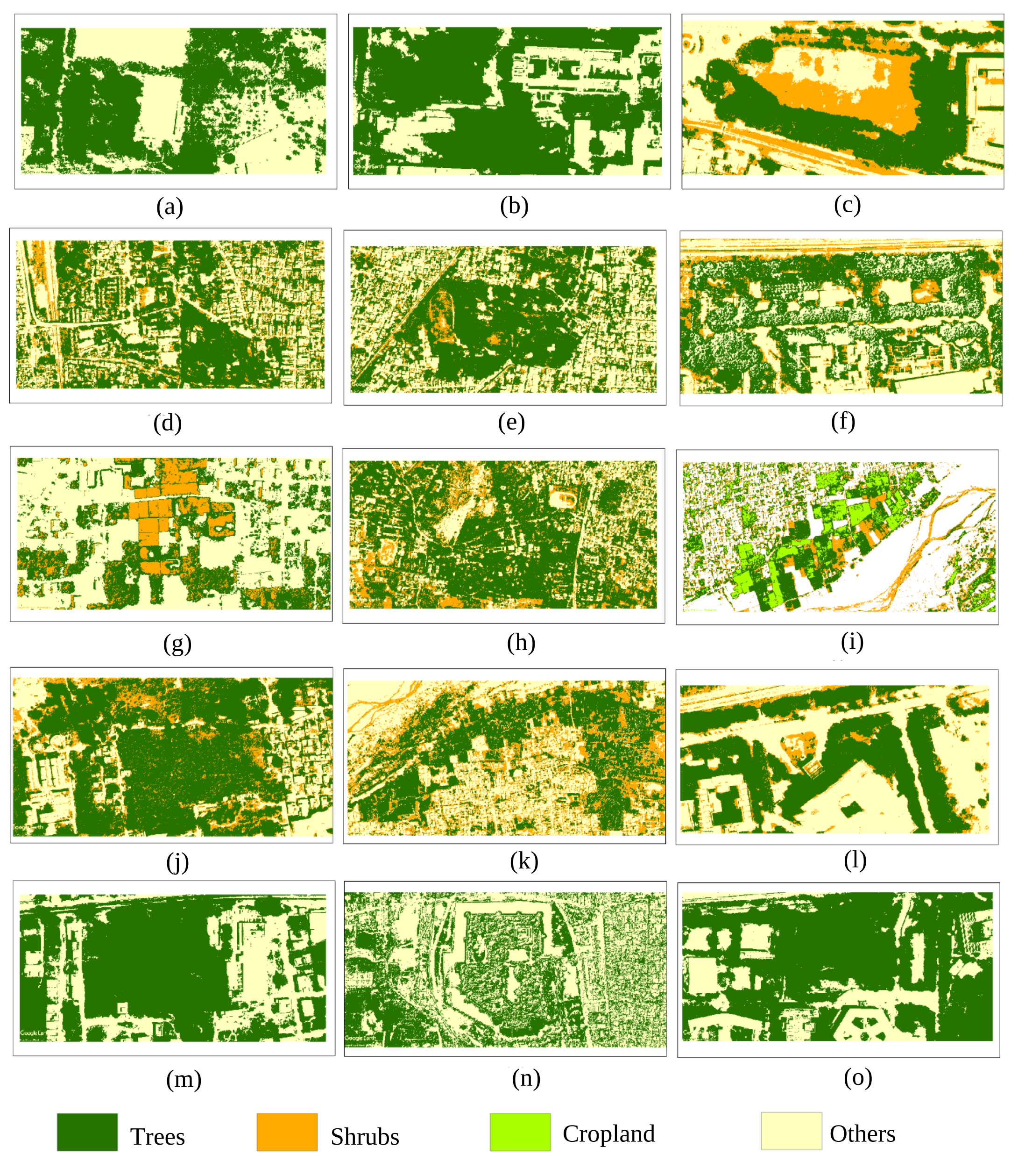


Figure 4: UGS Maps prepared using Threshold-based approach for 15 study locations in Vellore, India

3. Results and Discussion

3.1 Results of UGS Extraction from GE

The UGS map prepared for all the 15 locations in Vellore, India is shown in Figure 4. The range of values used for reclassification is shown in Table 1. It can be seen from Table 1 that the range of values for each UGS class is not same and also the values are not same for the same class in different locations. For example, in location 3, the pixel range of shrubs is 71 to 110 but whereas same shrubs exhibit pixel values of less than 35 in location 14. The results of UGS maps in Figure 4 revealed that the threshold-based approach performs well as it classifies correctly the UGS and its types and very well differentiates from other landuse/landcover classes. The results of accuracy assessment as shown in Table 2 revealed that the overall accuracy (OA) was > 90% at 12 sites and only 3 out of 15 sites exhibits OA in the range of 75-86%. The reason for less OA at three sites is, at some places, the water body is covered with algae and hence they are misclassified as green cover due to its greenish appearance in GE image though they are actually the waterbodies.

Table 1: Range of pixel values for various UGS classes for the 15 study locations from Vellore, India

No.	Locations	Tress		Shrubs		Crop land		Others	
		Min	Max	Min	Max	Min	Max	Min	Max
1	Figure 2a	0	70	N/A	N/A	N/A	N/A	71	255
2	Figure 2b	0	100	N/A	N/A	N/A	N/A	101	255
3	Figure 2c	0	70	71	110	N/A	N/A	111	255
4	Figure 2d	0	70	71	100	N/A	N/A	101	255
5	Figure 2e	0	70	71	90	N/A	N/A	91	255
6	Figure 2f	30	70	71	100	N/A	N/A	0	255
7	Figure 2g	N/A	N/A	31	70	0	30	71	255
8	Figure 2h	0	70	71	100	N/A	N/A	101	255
9	Figure 2i	31	70	71	100	0	30	101	255
10	Figure 2j	0	70	71	100	N/A	N/A	101	255
11	Figure 2k	0	50	N/A	N/A	51	99	100	255
12	Figure 2l	0	70	71	99	N/A	N/A	100	255
13	Figure 2m	0	99	N/A	N/A	N/A	N/A	N/A	255
14	Figure 2n	36	100	0	35	N/A	N/A	101	255
15	Figure 2o	0	90	N/A	N/A	N/A	N/A	N/A	255

Table 2: Results of accuracy assessment

	Overall Accuracy (OA)	Kappa
Locations in Vellore		
Figure 2a	85.7	0.714
Figure 2b	95.8	0.915
Figure 2c	90.0	0.850
Figure 2d	96.6	0.950
Figure 2e	96.6	0.950
Figure 2f	93.3	0.900
Figure 2g	93.5	0.903
Figure 2h	90.6	0.858
Figure 2i	75.0	0.660
Figure 2j	93.7	0.906
Figure 2k	76.6	0.650
Figure 2l	96.6	0.950
Figure 2m	100.0	1.000
Figure 2n	95.8	0.915
Figure 2o	90.5	0.811
Locations in the other cities		
Bangalore	95.8	0.913
Hyderabad	100.0	1.000
Barcelona	90.9	0.813
New York	100.0	1.000
Kuala Lumpur	95.5	0.909

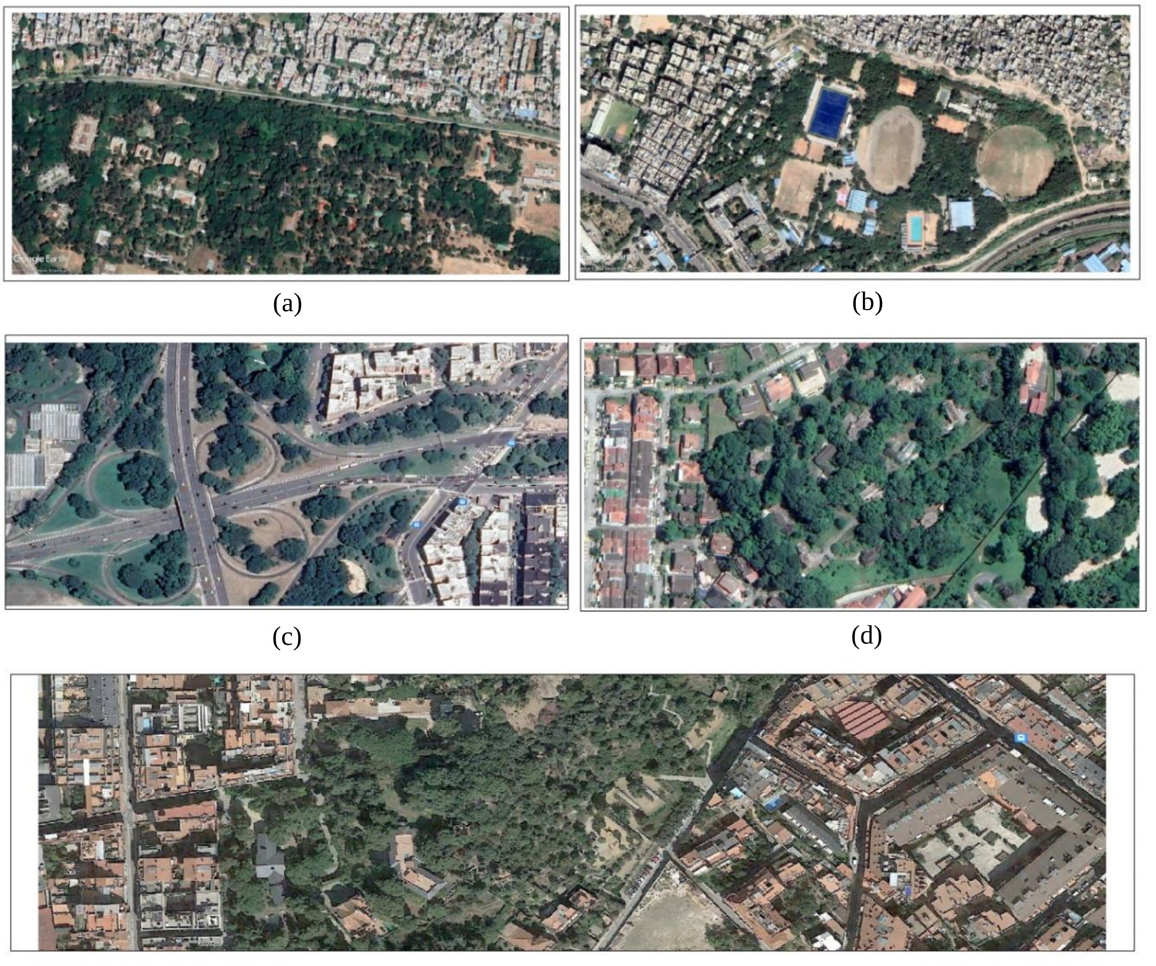
Also, in some places when the crop land is in harvesting stage, it looks darkish green and thus resembles with trees and hence they are misclassified as trees instead of crop land. In general, an OA of more than 85% is considered as the acceptable one [15]. Based on this, it can be said that in majority of the cases (13 out of 15 locations), the OA was above 85% and thus we can say that the proposed approach can be used to extract UGS from GE images. The advantage of the UGS maps shown in Figure 4 is we can calculate the areal extent of the UGS and check whether the available or existing UGS extent is as per standards. The results revealed that the % of UGS in all the 15 locations ranges between 45% to 77%, thus well above 33%, i.e., more than one-third of the area is covered by green.

In case if the UGS % is less, then civic authorities can take appropriate measures such as planting more number of trees, converting open lands to public parks, etc. to increase the green cover at that particular location.

3.2 *Universality Checking of the Proposed Method*

In order to check whether the threshold-based approach would work for other cities as well, a total of 5 cities other than Vellore were taken.

Among the five cities, two were taken from India (Bangalore and Hyderabad) and 3 were from abroad (Barcelona, Kuala Lumpur, New York). As explained in Figure 3, GE images of these 5 locations were downloaded and then the threshold-based approach was attempted. The original GE images of 5 locations and their corresponding UGS maps obtained from threshold-based method are shown in Figures 5 and 6 respectively. As mostly trees only were found from GE image, only one UGS class was taken, i.e., 'Trees' and rest all were considered as 'Others'. It can be seen from Figure 6 that the proposed method performs well in extracting green covered areas from GE image and the same can be witnessed in Table 2 also, where OA for all the 5 locations were > 90%. Thus, the results of universality checking clearly indicates that the proposed method can be used to map areas of UGS for any city in the world using the GE data. There are few limitations in the proposed method. One is it works well for areas which are covered by mostly trees and shrubs with less crop land. This may not be a major limitation because in most of the cities, the proportion of crop land would be very less or in negligible amount as they are already converted to built-up area over the years. Also, the water bodies should not be covered by algae otherwise it will be misclassified as UGS as they appear in green mostly.



(a) (b) (c) (d) (e)

Figure 5: GE images of the other cities (a) Bangalore (b) Hyderabad (d) Kuala Lumpur (e) Barcelona

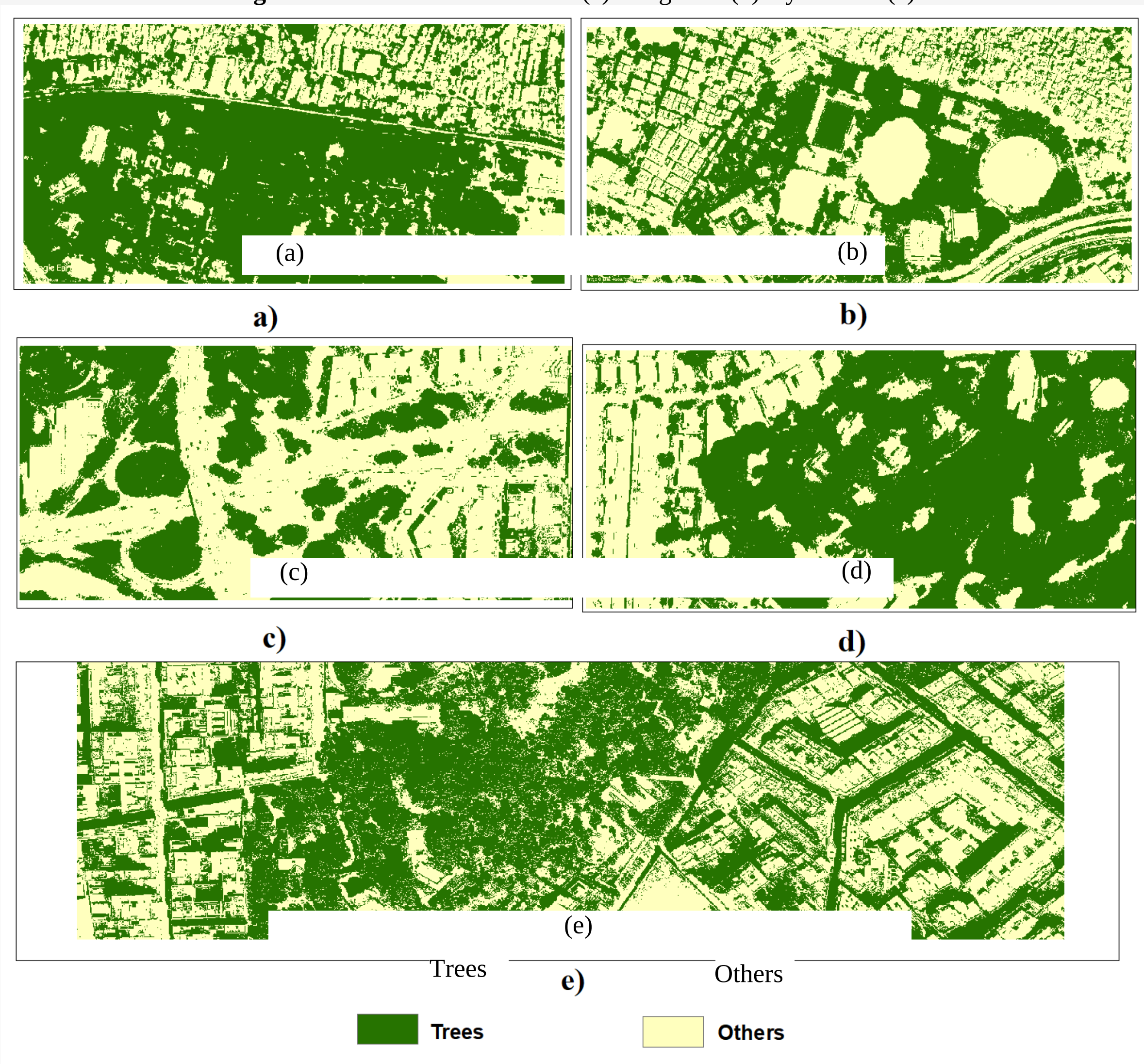


Figure 6: UGS in the other cities (a) Bangalore (b) Hyderabad (c) New York (d) Kuala lumpur (e) Barcelona

Table 3: Accuracy assessment

Class	UGS	Others	Total	User's accuracy
UGS	75	4	79	0.95
Others	6	215	221	0.97
Total	81	219	300	
Producer's accuracy	0.92	0.98	Overall accuracy = 96.6% Kappa coefficient = 0.914	

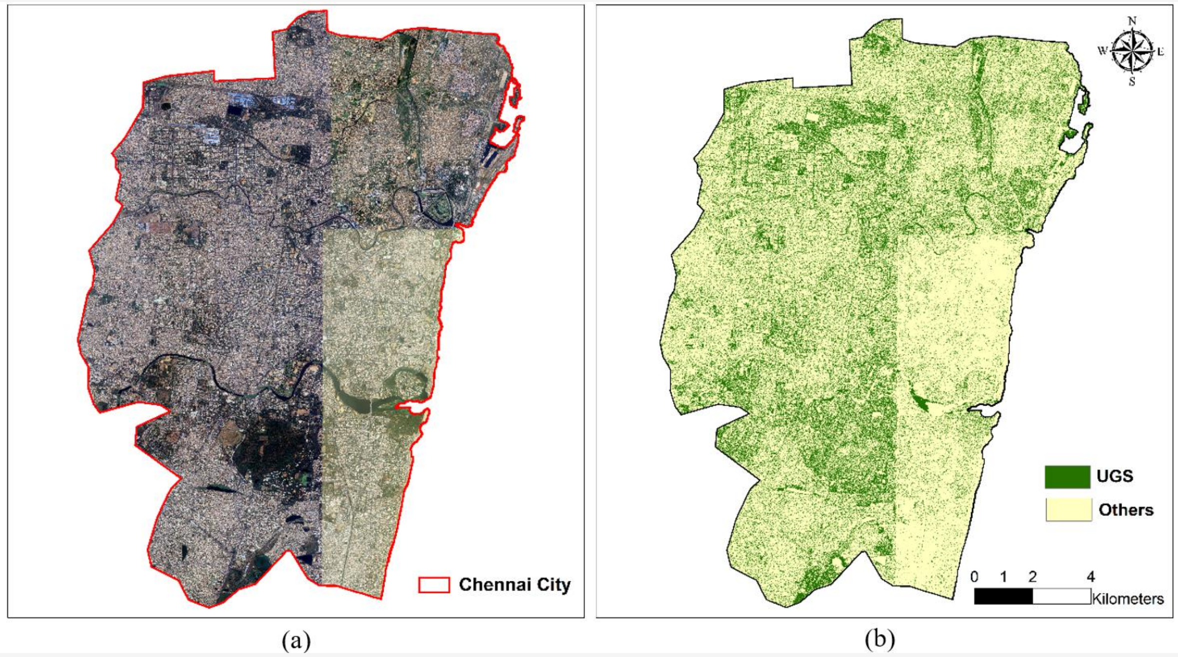


Figure 7: UGS extraction (a) GE image of Chennai, India (b) UGS threshold-based extraction

In order to check whether the proposed threshold-based approach would perform well or not over larger areas, Chennai city which spanned over an area of 196 sq.km has been taken and a total of 286 GE images of 2024 were downloaded. They were then mosaicked, clipped within the study area and projected to UTM projection as shown below in Figure 7(a). As Chennai is a metropolitan city without any crop land, only two categories were taken, namely Urban green space (UGS) and Others and the range of pixel values for these two categories were manually found by trial and error. For UGS, the pixel values were found to be in the range of 20 to 50, 60 to 70 and 90 to 100 and all the remaining pixels values were falling in 'Others' category. Based on the threshold values found, the reclassification was done and the resultant map of urban green space for the city of Chennai is shown in Figure 7(b). Comparing Figure 7(a) and 7(b), we can observe that the proposed threshold-based approach performs well for identifying the green covered area even if the area is of larger in size. In order to check its accuracy, 300 random points were considered and accuracy assessment was carried out and the results are shown in Table 3. The overall accuracy was found to be 96.6% with Kappa coefficient of 0.914 which clearly indicate that the proposed approach can be used to find the UGS of larger areas even at the city level. The major advantage of the UGS map showed in Figure 7(b) is it can be used by urban planners and policy makers to check whether the city has sufficient green space or not. For example, in Tamilnadu state of India, one of the missions is to increase the green cover to 33%, i.e., one-third of a city should be covered by green [7]. The present study can be used to check the extent of green cover in a city. For the UGS map showed in Figure 7(b), the area covered by UGS is 51.723 sq.km, which is only 26%. So, the results would be useful for the city authorities to periodically monitor the green cover and check whether the green space has reached the target UGS of 33%.

4. Conclusion

The demand for sustainable development is greater than ever because of the massive urbanization taking place in our cities. Due to the numerous ecological benefits, they offer us, UGS are important contributors to sustainable development. UGS aid in the reduction of air pollution, noise pollution, heat islands and carbon sequestration. The UGS have a significant impact on the built environment because they include public recreation areas that foster social inclusion in neighbourhoods. In recent years, all cities across the world irrespective of developed or developing nation focus on developing greener cities both indoor and outdoor. The first step in developing such greener cities is to assess the present extent of UGS and its types. The low and medium resolution open-source satellite images can be used to map UGS but they are poor in accuracy due to their low spatial resolution. On the other hand, one can use high and very high-resolution satellite images to get accurate maps of UGS but they are costly to purchase.

In order to bridge the gap and keep a balance between cost and accuracy, the GE images can be employed to extract UGS and the present work carried out the same for the city of Vellore, India. The results of the proposed threshold-based approach yielded good results as the OA is mostly above 90%. The proposed method was applied in various other cities as well and similar results with high OA was obtained, thus indicates its high potential in extracting UGS from GE image. The threshold-based technique was applied to Chennai city in India as well and an OA of 97% was obtained which indicates that the proposed method can be applied for larger areas as well irrespective of the green cover it has, that is areas with more green coverage or relatively small green spaces. The present study also showed how to calculate the current extent of UGS in a city and check whether it is as per the standards or not.

GE image was utilized for UGS extraction through manual onscreen digitization [12], which is a time consuming and cumbersome task as digitizing each and every polygon that too on very high-resolution images like GE is not an easy task. First, one has to identify where the green spaces are and this is extremely difficult especially if the study area is a larger city. Sometimes there are chances that one may miss few green covers also. Whereas the present study which is based on threshold-based approach does not involve any manual digitization, thus one can save lot of time and also does not involve any laborious work. Only range of pixel values need to be identified for the green covered areas and then reclassification can be applied to extract the UGS area. As there is no manual intervention during reclassification, there is no chance of missing of any green cover in the study area. The present threshold-based approach has been successfully demonstrated for the entire city of Chennai, India and also five locations across major cities of the world, like Bangalore, Hyderabad, Barcelona, Kuala Lumpur and New York. The results were very good which clearly shows that the threshold-based approach can be preferred for extracting UGS from GE images. The present study is simple, easy to understand and apply and thus would certainly help the civic authorities to check their city's UGS extent using GE data alone.

4. Recommendation and Future work

The proposed method is a trial-and-error method and hence it may take considerable time to arrive at the correct threshold values for various UGS classes. If machine or deep learning is used to train the pixels, then this manual trial-and-error method can be automated which is the future scope of the present work.

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