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Use Of Remote Sensing For Urban Impervious Surfaces: A Case Study Of Lahore

Muhammad Asad, Sajid Rashid Ahmad, Farhan Ali, Rashid Mehmood, Muhammd Atif Butt, Sana Rathore

Abstract— **Impervious surfaces are manmade surfaces which are highly resistant to infiltration of water. Accurate and rapid classification of impervious surfaces would help in emergency management after extreme events like flooding, earthquakes and hurricanes, by providing quick estimates and updated maps for emergency response. The advances on remote sensing technology provide easier, faster and cost effective method to do adamage assessment. In this study, three different remote sensing techniques (Normalized difference built up index, Supervised Classification and Object based image analysis) was used to assess the current status of impervious surfaces in district Lahore. As Increasing population, new development in open lands and recreation areas, and growing towns all translate into increasing impervious surface areas across Lahore. Therefore, estimating and mapping impervious surface is significant to a range of issues and themes in environmental science central to global environmental change and human environment interactions. The datasets of impervious surfaces are valuable not only for environmental management, e.g., water quality assessment and storm water taxation but also for urban planning, e.g., building infrastructure and sustainable urban development.**

Index Terms— **Impervious Surfaces, Normalized difference built up index, Supervised Classification, Object based image analysis**

I. INTRODUCTION

Economic development, in most of the world, is measured by (GDP) is presently amassed in urban communities. From a superior perspective, most urban development hopes to be made out of impervious surfaces. Impervious surfaces incorporate roads, garages, walkways, structures, housetops, parking garages, runways, and other falsely developed surfaces which stop water from the penetration in the soil. Impervious surfaces are the most critical and overwhelming Land use and land cover (LULC) sort in the urban and rural settings, and are rising ecological indicators for not only terrestrial but also for the aquatic life [1]

Impervious surfaces are those anthropogenic components through which water can't penetrate into the soil, for example, highways, streets, carports, walkways, parking garages, housetops, etc through which water can't penetrate and stay on the top of the surface. From past few decades, impervious surface has developed not just as a marker of the level of urbanization additionally a significant marker of ecological quality [2]. The extent, area, geometry and spatial example of impervious surfaces, and the ratio of the pervious–impervious surfaces have hydrological impact in a watershed.

Impervious surfaces have another vital impact of urban ecosystem by eliminating all the vegetation which may be the habitat of many species. In this way, assessing and mapping impervious surface is noteworthy to a scope of issues and subjects in ecological science integral to worldwide natural change and human environment cooperation. The datasets of impervious surfaces are important not just for natural administration, e.g., water quality evaluation and water tax assessment additionally for urban arranging, e.g., building foundation and economical urban improvement. Numerous strategies have been connected to portray and evaluate impervious surfaces utilizing either ground estimations or remotely detected information. Given expanding significance in the field of remote detecting, it turns into a dire need to methodically inspect the flow condition of the examination and to follow its future patterns. This audit starts with analyzing information necessities for remote detecting of impervious surfaces, with a specific enthusiasm for the effects of remotely detected information qualities (i.e., spatial, ghastly, and worldly resolutions, and LiDAR information). Next, different computerized techniques for removing and evaluating impervious surfaces are surveyed.

1.1 Pixel based Classification

Image classification for pattern reorganization in remote sensing has a place with an extremely dynamic field in computational research. Picture pixels can be characterized either by their multivariable factual properties, for example, the instance of multispectral grouping, or by division in view of both measurements and spatial associations with neighboring pixels. For each class in the supervised classification required training samples. These training points are collection of sample points of the known area of same class. Thus this classification is established based on the closeness of an unknown pixel to its training sample. Height, shape, size and location must favor convenient identification both on the image and on the ground.

1.2 Normalized Difference Built Up Index (NDBI)

Conventional classification methods are mostly pixel based classification; pixel of every image characterizes one land cover. Because of the complex structure of urban areas, spectral reflectance is the blend of numerous land covers known as mixed pixel. More over supervised order is relentless and has a high likelihood of misclassification between uncovered soil and urban area, since both area

Muhammad Asad, College Of Earth and Environmentl Science, University of The Punjab, Lahore, Pakistan

Sajid Rashid Ahmad, College Of Earth and Environmentl Science, University of The Punjab, Lahore, Pakistan

Farhan Ali , College Of Earth and Environmentl Science, University of The Punjab, Lahore, Pakistan

Rashid Mehmood , Department of Space Science, University of The Punjab, Lahore, Pakistan

Muhammad Atif Butt , Department of Space Science, University of The Punjab, Lahore, Pakistan**Sana Rathore**, College Of Earth and Environmentl Science, University of The Punjab, Lahore, Pakistan

spreads can have comparable otherworldly marks at a few spots. In this study, analyst propose a technique in light of Normalized Difference Built-up Index (NDBI) to mechanize the way toward mapping developed ranges. It exploits the distinctive spectral response of impervious surfaces and vegetation. Built-up areas or impervious surfaces are excellently recorded through arithmetic control of re-coded Normalized Difference Vegetation Index (NDVI) and NDBI raster derived from satellite imagery. The conceived NDBI technique was connected to delineate area in the city of Lahore. Contrasted and the most extreme probability order strategy, the proposed NDBI can serve as a beneficial option for rapidly and unbiased mapping developed ranges.

1.3 Object-Based Image Analysis (OBIA)

The object-based Analysis is more reliable and less troublesome for the extraction of impervious surfaces, for example, roads, street, building, parks which are objects in a satellite imagery [3] [4].OBIA has a great ability to separate different objects in a high resolution image specially confusion in shadow verse water and open land verses impervious surfaces. In certain urban scenes of impervious surfaces, it is likely that numerous characterization methodologies would work sufficiently, however in divided urban surfaces; OBIA has the unmistakable favorable position of enhanced recognizable proof of unpredictable objects. Blaschke (2010) expressed that high spatial resolution tends to support OBIA for order in light of the fact that the pixels are fundamentally littler than the picture objects, and the pixels should be joined for investigation.

II. Study Area

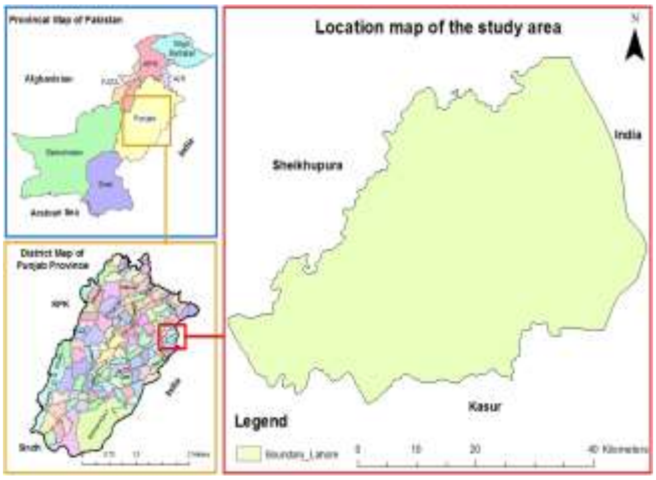


***Figure 1.1**. Map of the Study Area*

Lahore is the capital city of the Punjab province of Pakistan, as shown in Figure. Coordinates of Lahore are 31°25'0" N and 74°19'60" E in Degrees Minutes Seconds separately. There is nine towns and one hundred and forty nine union councils (UC) in Lahore including all urban and rural zones. Lahore is the second largest metropolitan city of the Pakistan. Lahore is the central oint in terms of economy, socially, politically, transportation and other recreational activities. So most of the people from the nearby areas come here to start a new or groom their lives. As a result of it every year there is a visible expansion is seen in this city. According to a survey, in January 2015 population of the Lahore is around ten million. It is situated twenty four in the most populated urban regions on the planet and the eighth greatest city within the Organization of Islamic Cooperation. The population in Lahore has verging on multiplied in the last 12 to 14 years. Lahore, once known as the city of garden is now changed into city of concrete. There is only three percent green area, which is persistently being cleared to start new projects. Lahore is experiencing an extreme environmental crisis. An overpopulated, urban city like Lahore can't survive fast and unsustainable advancement, which applies tremendous weight on existing normal assets, prompting water issues, contamination, and changes in the city's temperatures.

The growing rate and increasing trend of urbanization is solving many problems at one hand but at the other it is also becoming the cause of some major issues. Anthropogenic activities are causing the increase in impervious surfaces. Impervious surfaces are those through which the water cannot seep down; hence it can cause the depletion of underground water reserves. Hence, the mapping of these impervious surfaces is very important in order to calculate the net recharge of groundwater tables.

2.1 Impact of Impervious Surfaces

The anthropogenic activities are altering the pervious-impervious surface ratio which is at one hand disturbing the hydrological cycle and at the other hand it is one of the major cause in the drastic climate change. Impervious surfaces include buildings, houses, parks, road networks, pavements etc. The growing rate of impervious surfaces not only shows the trend of urbanization but also indicates towards the changing environment which is causing climatic changes globally [5].

2.2 Remote Sensing of Impervious Surfaces

There are many techniques for the mapping and quantification of urban surfaces ranging from in situ measurements to the analysis based on remotely sensed satellite imagery. One of the accurate yet expensive methods is through GPS or DGPS (Differential GPS). Manual digitization from the maps is also another way of mapping the impervious surfaces. This is very time consuming task and it is now almost replaced by scanning and then applying feature extraction algorithms. In 1970's to 1980's with the launching of Landsat 1 and the availability of medium resolution imagery, the satellite imagery was being used for many environmental purposes [6]. He considered papers from 1991 till 2000 and found out that there is enormous and sharp increase in the publications on the remote sensing of impervious surfaces from 2003 onwards.

2.3 Geometric Characteristics of Impervious Surfaces

It may happen that the urban streets are misclassified as vegetation which can lead to 30% error that will result in under estimation of the impervious surfaces areas. In contrast, Hodgson *et al*. (2003) [7] found that shadow can cause misclassification of urban surfaces as water. High resolution imagery result in displaced buildings which causes the occlusion of the other impervious surfaces.

2.3.1 Building extraction

Building extraction can be considered as a composite of feature classification and pattern recognition methods. Although aerial photography provides very fine resolution imageries it is very expensive and its data is very heavy and difficult to store. Hence, the best option is the satellite imagery as nowadays free images can be acquired for medium resolution imageries such as that of Landsat. Also, IKONOS and Quickbird etc provide high resolution data in various spectral bands with additional capabilities of generating stereo pairs and short revisit time.

2.3.2 Required spatial resolution:

According to Jensen and Cowen (1999) the required spatial resolution should be at least one half the diameter of the smallest object of interest. In other words the pixel should be four times less than the object to be identified in the satellite image. For example if our objective is to count the houses which have minimum dimensions of 100 m then the spatial resolution used should be at least 50m or more.

For the impervious surfaces such as roads, buildings, parks, pavements etc. the minimum spatial resolution in which these features can easily be extracted range from 0.25 to 0.5m, whereas lower resolution of 1 till 30m is required for marking of road centers only [8]

2.3.3 High resolution imagery

As the literature survey from Scopus also shows an increase in the publications, it is all due to the availability of high resolution imagery such as IKONOS (launched 1999), QuickBird (2001), and OrbView (2003) and many more. Even SPOT 5 has a resolution of 5m in multispectral bands and 2.5m in panchromatic band.

Impervious surface mapping is also done using high resolution [9],[10][11].

2.4 Mapping Impervious Surfaces through Vegetation Distribution

Vegetation distribution can provide information about the urban surfaces because almost inverse correlation exists between the two [12].

There are several methods to represent vegetation distribution. One is NDVI (Normalized Difference Vegetation Index). Other options include TCap (Tasseled Cap) and PCA (Principal Component Analysis). NDVI can then be used to compute vegetation fractional coverage [13]. The impervious surfaces can be computed from the complement of vegetation and this method is mostly used in medium and coarse resolution imageries.

2.5 Object based image analysis (OBIA)

Object based image analysis (OBIA) demands high resolution imagery and due to the commercialization of different programs and software, the accessibility of high spatial resolution imagery Object based Image Analysis (OBIA) is widely used as a basic part of remote sensing base researches. It is based on the understanding that pixel is not the finest spatial element for mapping. Best results of classification can be achieved by using both spatial as well as spectral characteristics [4]. OBIA works just like a human eye. The OBIA method is not only focus spectral characteristics also consider the shape, size, texture, hue, compactness, neighborhood topology, and sub pixels [14].

2.6 Objective

The purpose of this research is to estimation and mapping Impervious Surfaces in Lahore district using different remote sensing techniques.

III. Research Methodology

This research is based on the classification comparison technique for selected geological region and OLI Landsat-8 satellite imagery is used for this purpose. This methodology is composed of four steps as shown in the figure.

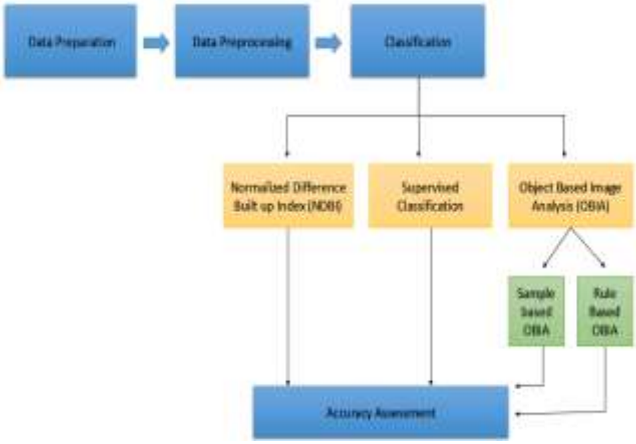


Figure 3.1. Flow chart of methods used in this study

First Step describes the procedure for the data preparation. Step two deals with the pre possessing of data. In step three, different techniques of remote sensing for the extraction of the impervious surface, includes Normalized difference build up Index, Pixel Based Supervised Classification and Object based Image Analysis. Last step includes accuracy assessment of output and Compare different classification results to evaluate the best technique to map impervious surfaces. Further explanation of each step is as under.

3.1 Data Preparation

As first step is about data so researcher has discussed those datasets which are used in the study and the preliminary steps for the data preparation as below:

3.1.1. Remote sensing Data

Landsat-8 cloud free satellite image of thirty meter resolution was used for the analysis of the study area .Earth explorer site (http://earthexplorer.usgs.gov/) is used to download the full long scene of the study area. The downloaded imagery was radiometrically corrected and geometrically resampled.

There are nine spectral bands in Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Also there is a new band 1 (ultra-blue) is present that is particularly used for coastal and aerosol studies. For cloud detection band 9 is most suitable. Thermal bands 10 and 11, which are very useful in providing precise surface temperatures, are captured at 100 meters but resampled to 30 meter.

3.2. Data Preprocessing

One of the major step in date pre-processing is layer stacking. There are eight spectral bands of operational land imager (OLI) which were stacked together by using ERDAS Imagine 9.2. Final stacked image contains medium resolution of 30 meters with high resolution merging. Lastly, by using vector shapefile of the study area, clip study area from the prepared data.

3.2.1. High resolution merging

As thirty meter resolution image is not enough for detailed study so this medium spatial resolution imagery of 30 meters is merge with the panchromatic image of fifteen meter resolution. The most suitable method to achieve this goal was multiplicative method with nearest neighbor technique for resample data. Thus spectral properties were preserved while data was fused to a better spatial resolution of 15 meters.

3.2.2. Data Truncation

Study area was extracted by researcher from truncation of full scene imagery. it was done by using subset technique in Erdas Imagine 9.2 with the help of shape file. This shape files was created from geological surveyed map.

3.3. Techniques for impervious surface extraction

3.3.1. Normalized Difference Built Up Index (NDBI)

The built-up land raster is produced using the formula of NDBI with the following equation:

This formula is emerged from the Normalized difference vegetation index by using unique spectral response of buildup areas. As built up areas have higher reflectance in medium inferred wavelength rangers rather than the Near Infrared wavelength range. But In every case, this is not generally the situation. The drier vegetation can even have higher reflectance in MIR wavelength range rather in NIR range, bringing about positive qualities in NDBI symbolism for these plants. Moreover, in a few conditions, water with high suspended matter concentration (SMC) can likewise reflect MIR more grounded than NIR in light of the fact that the reflectance crests movement to longer wavelength locales as the suspended matter increment. Along these lines, the drier vegetation and water with high SMC will have positive NDBI values when processed utilizing above mentioned Equation.

3.3.2. Pixel based Supervised Classification

To analysis data spectrally, supervised classification is best technique which is based on the training samples. In image analysis, Pixel is the building Block of the imagery. There are number of methods for image classification and several fields existed in which these classification methods are used. Image analysis and pattern recognition results which are used in this research is based on the classification. Researches use classification as a single entity. In this case, the classification served to analyzed impervious surfaces of the study area.. As a result, supervised image classification has appeared as an important tool for reconnoitering digital images. The choice of these training points is very critical and accuracy of the result is grealty depend upon these training points. The major steps of the supervised classification are described below:

1. Defining of the Training Sites.
2. Extraction of Signatures.
3. Classification of the Image.

$$NDBI = \frac{MIR - NIR}{MIR + NIR}.$$

The training sites are vector data which researcher selected after prior knowledge of the area and identification of the texture and other characteristics of the elements in the imagery. Researcher selected training sites (Water bodies, impervious surfaces and vegetation). Once the shape file of training site is prepared then the statistical classifications of the information are generated by using ERDAS Imagine software. This shape file is known as signatures. Finally the supervised classification methods are applied [15].

3.3.2.1. Accuracy Assessment

The accuracy assessment was done by visual interpretation of water, vegetation and impervious surface objects. The ERDAS Imagine softwareprovides a tool for accuracy assessment of supervised Images on samples called Reference Points. Random samples were collected for three classes: water; vegetation and impervious surface. Researcher checked thirty samples to determine the producer and useraccuracies.

3.3.3. Object-Based Classification

Object-based classification was done, using eCognition developer 8.7 software. First requirement for the object based classification is the availability of the high resolution imagery but as researcher have 30 meter resolution imagery so researcher stack this image layer with high resolution of panchromatic image of 15 meter for better results. OBIA Technique is based on the two major step which are described below:

(i) Segmentation
(ii) Classification based on Image Objects

3.3.3.1. Segmentation

Segmentation is very useful in middle resolution imagery as it enhanced every detailed of the object existed in the raster. Researcher used a segmentation algorithm available in eCognition. There are number of segmentation methods but according to the literature researcher choose the multi Threshold segmentation. Multi-Threshold Segmentation, algorithm is based on the defined global threshold values which make group out of the same pixels into sections and classes instantaneously. In the object-based model, there are three vital components of segmentation; shape, compactness, and scale, which help to segment objects or pixels which have same spectral or spatial characteristics in the raster. Researcher decided appropriate weights for each of the bands which are participating in the segmentation.

3.3.3.2. Classification

There are two type of classification in the OBIA; Rule-based classifier approach of OBIA and the nearest neighbor (NN) sample-based classifier approach.

3.3.3.2.1. Nearest neighbor (NN) sample-based classifier

The principal approach, the nearest neighbor sample based classifier, utilize spectral information which is shown in an image is for taking samples. First step in this classification is segmentation which is described above. If segmentation is not done then image object could not be discriminate during classification while using eCognition. The highest segmented level is used for sample based classification. At this level all the object should be easily differentiate from other objects in the image. As the study area of the researcher is very vast so suitablelevel with 10000 scale parameter was used in this study. Samples are taken on the base of color and texture of the object. Three classes (Impervious surface, Vegetation and water bodies) were used by researcher and all the samples were collected against them from the objects in the raster. It is very important to select the samples with great care for better accuracy of the results. Sample based classification is purely based on the visual interpretation.

3.3.3.2.2. Rule based classifier

The second approach of classification in OBIA is the rule-based approach. It is relatively automatic approach as compare to sample based OBIA. In this method, there are set hierarchical rule and defined threshold values for every individual objects based on every object in the image. These rules or default algorithms can be instantly tested in feature view mode. If any rule or threshold value cause any ambiguity in the understanding of any object (Impervious surface, vegetation, water bodies)or alter the accuracy of result can be changed immediately and those rule could apply which create less confusion.

3.3.3.3 Accuracy Assessment

Once the segmentation of the object is done the accuracy assessment was performed by visual interpretation of water, vegetation and impervious surfaces. The e-Cognition software offers a tool for accuracy assessment of objects. It is based on samples which are collected for assessment of accuracy. Random samples were collected for three classes: water; vegetation and impervious surface. A minimum of fifty samples was used to determine accuracies. The overall accuracy is influenced by all three classes.

IV. Results and Discussion

The resulting output thematic maps for all classification schemes are going to be analyzed below.

4.1. Results

4.1.1. Normalized difference Build up Index (NDBI)

Figures (4.1) show the result of the application of the NDBI on the image; built-up spaces appear in blue shade and agricultural spaces appear in green shades.

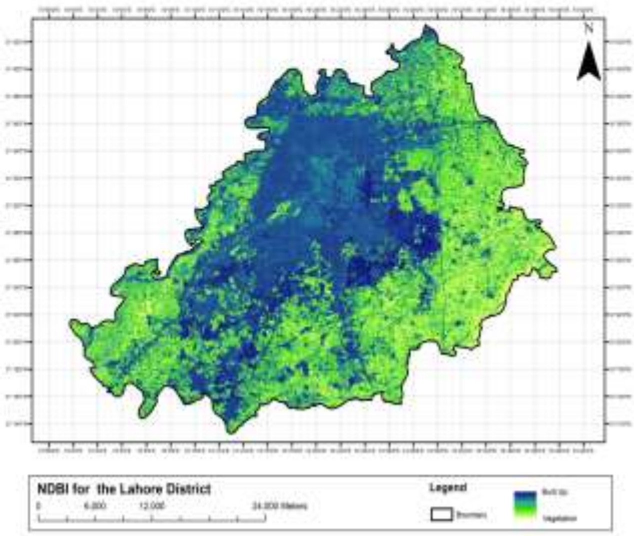


Figure 4.1. Normalized Difference Build Index for the Lahore District

Raster has different cell values as shown in figure 1 so for the analysis, it is necessary to standardize all the data to a common scale. For this purpose, reclassification technique has been applied which changed the value of input raster into new values based on the new information provided as shown in figure 4.2. Then group together same values to form a new class. Reclassification technique is used for all the data to standardize to a common scale. Vegetation and Non Vegetation datasets are reclassified on the base of their cell values. Quintile technique is used to make five classes of these datasets. Because in GIS, quintile classification gives data classes same number of values, which is effective for ordinal data as all the classes are easily computed.

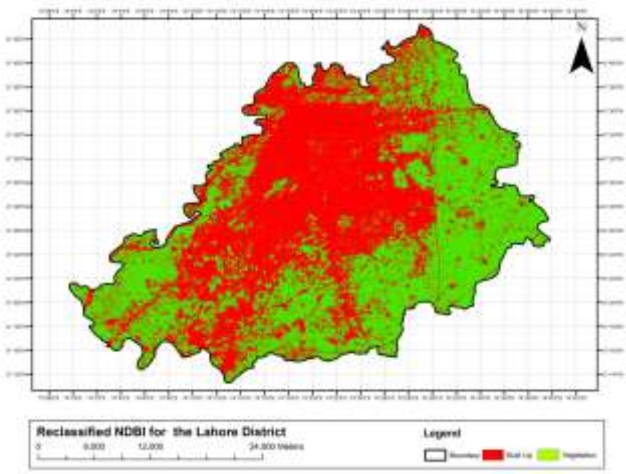


Figure 4.2. Reclassified NDBI MAP for the Lahore District

Figure 4.3. Accuracy assessment for NDBI

Normalized difference Build up Index method, utilized spectral patterns. Results are not fully satisfactory to differentiate impervious surfaces from barren or open land as spectral response of both of these object are same. Thus confusion among them is shown in Figure 4.3. Also, the results show that water is also mixed with built-up area.

4.1.2. Supervised Classification

Figures (4.4) illustrate the result of the application of the Supervised Classification on the image; built-up spaces appeared by mustard color, water bodies by blue color and agricultural spaces by green shades.

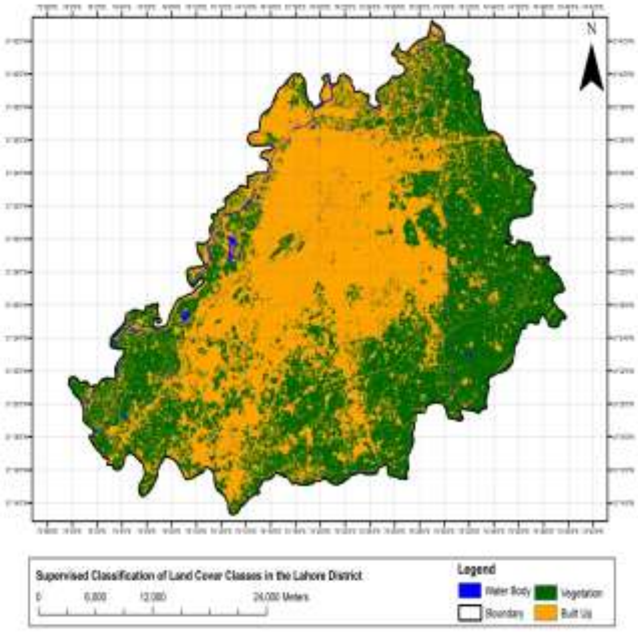


Figure 4.4. Supervised Classification of land cover class in the Lahore District

Supervised classification is much more accurate for mapping classes as compare to NDBI as shown in figure 5. Three classes are shown in the map that is impervious surfaces, vegetation and water bodies. But accuracy of this classification is challengeable because of the selection of sample points. As shown in figure 4.5. samples are collected accurately as a result of the it the results of classification shows exactly same feature of the real world image.

Figure 4.5. Accuracy Assessment For Supervised Classification

4.1.3. Object Based Image Analysis (OBIA)

4.1.3.1. Segmentation

Image segmentation was conducted within eCognition Developer 8.7. Multi-threshold segmentation was then first performed to extract the object features, with parameters of scale=10000, shape=0.3 and compactness=0.7 with equal weights to each RGB layers but 2 times weight to NIR layer.

4.1.3.2. Classification

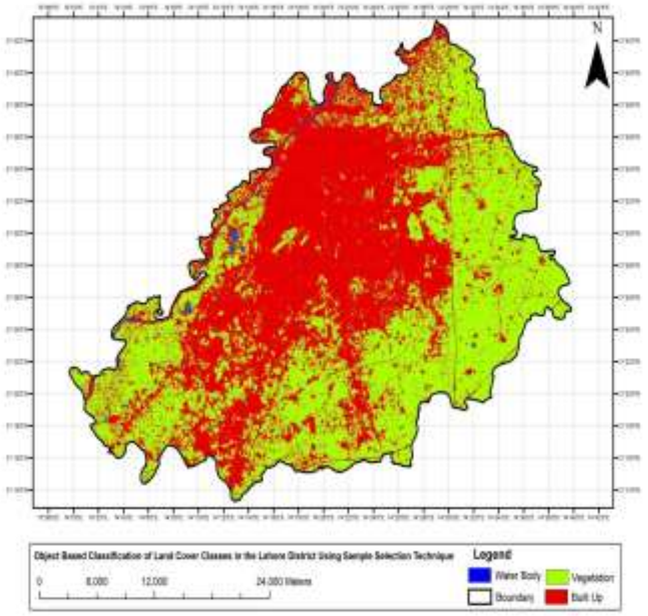


Figure 4.6 Buildup area

4.1.3.2.1. Nearest neighbor (NN) sample based

Nearest neighbor sample based classification is like supervised classification. Object based image analysis is shown in the map. Accuracy assessment is done using Cognition software. Figure (4.6) shows build up area with red color, vegetation with green color and water bodies with blue color.

4.1.3.2.2. Rule based

Rule-based classification was then performed for the land use extraction. Results are shown in the map below (figure 4.7.)

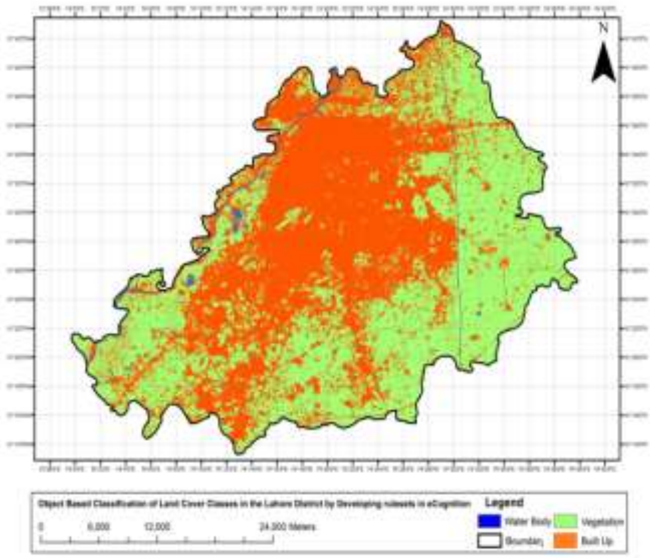


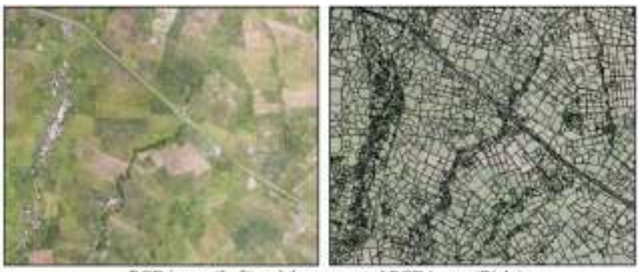
Figure 4.7 rule based OBIA technique for extraction of impervious surfaces

The result of the classification was good. Impervious surfaces and vegetation land covers were classified correctly. All water bodies were classified correctly methods. As shown in the figure 4.8, the land cover is correctly shown by using object based Image analysis.

Figure 4.8. Accuracy Assessment of Object based Image Analysis

4.1.4. Segmentation parameters

In OBIA, before the classification the same procedure of segmentation is followed. Multi-resolution segmentation was done. To elaborate the importance of these parameters, researcher selected a small portion from the study area. Figure 4.9 show satellite imagery on the left side and segmented technique of the same area on the right hand side.



RGB image (Left) and the segmented RGB image (Right).

Figure 4.9. Process of Segmentation is shown in the figure

V. Conclusion

Automatic identification of urban impervious surfaces stays a standout amongst the most difficult issues in remote sensing. This thesis concentrated how impervious surfaces in urban zone of Lahore can be efficiently classified by using different techniques and methods. These impervious surfaces in District Lahore are result of the anthropological activities. Such activities often play a role of catalyst in flood vulnerability; there is quick need of estimation for all these impervious surfaces in order to do any pre disaster management for flood estimation or degradation of the environment. This research inspected the utilization of different techniques to map the impervious surfaces.

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