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Assessment of Land Use/Cover Change and Urban Expansion Using Remote Sensing and GIS: A Case Study in Phuentsholing Municipality, Chukha, Bhutan

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Abstract: The rapid phase of urbanization and infrastructure development in Bhutan has been observed recently. This leads to causing of decrease in vegetation cover and growth in urban sprawl undergoing rapid land use/land cover change (LULC). This paper attempts to analyze the temporal and spatial patterns of LULC change and detects the urbanization processes of Phuentsholing city over a period of three decades (1996-2016) using multi temporal remotely sensed data. For this, the satellite images of Landsat 5, 7 and 8 were used to assess the changes of vegetation cover, built form and water bodies. This study has found that urban built area was increased from 6.7% in 1996 to 17% in 2016 and similarly vegetation cover was declined from 48.4% in 1996 to 49.9% in 2016. This urban expansion causes loss of vegetation cover that hinders the country's regulation of retaining 60% forest according to The Constitution of the Kingdom of Bhutan. These finding can provide city planners and decision makers with information about the past and current spatial dynamics of LULC change to investigate, plan and monitor the urban development and management of Phuentsholing municipality.

Keywords: Land Use Land Cover (LULC), Geographic Information System (GIS), Remote Sensing (RS), Images Classification, Phuentsholing

1. Introduction

LULC change is a main factor for environment transformation because it can affect ecosystem, hydrology, climate, flora and fauna, energy balance and human activities. [16] [29]. According to nation's vision, Bhutan 2020 [17] a vision of peace, prosperity and happiness, all the development activities should be carried out based on the concept of four pillars of the Gross

National Happiness that are: Equitable and Scio-economic Development, Environmental conservation, Preservation and promotion of culture and good governance. Moreover, The Constitution of the Kingdom of Bhutan states that a minimum of 60% of Bhutan's total land shall be maintained under forest cover for all the time [22]. These two-important statement urges all the planners and decision makers to monitor the LULC changes on regular basis in the country. This will maintain balance land related need of the inhabitants, urbanization, development activities with environmental conservation.

The importance of GIS and RS for studying LULC patterns and their dynamics are well recognized and practiced in numerous researches and projects. The literature studies below have been carried out to analyze the importance of mapping and classifying the land use classes/themes to monitor their changes over a period of time using different spatial satellite data and adopt the best practiced procedure for this study. This change detection techniques using GIS and RS are useful in various application which has utilized to recognize changes in different land use patterns [1]. These techniques range from post classification comparison to simple image differencing of principle components analysis [3]. This method is also used in identifying the urban expansion in many of the studies.

Urban growth is a universal phenomenon taking place all around the globe due the better job opportunities and comfortable life leading people to migrate from rural to urban areas [27].

Therefore, much more attention have been given on urban land use pattern change by the policy makers and professionals in last decades because the change in LULC pattern has immensely disturb the ecosystem and micro climate of the urban settlements by various activities carried out by city dwellers. [1] [29].

According to Sebastian, Jayaraman and Chandrasekhar (1998), the urbanization process has been characterized by increase in built up areas due to industrial expansion, economic and social development activities, consuming much of the natural resources. This has been visibly seen in the most of the Bhutanese towns in last two decades. As stated before Phuentsholing city have experienced rapid urbanization over the last two decades due to high natural growth rate and higher rural-urban migration as Phuentsholing being the economic hub of the country. Many studies have point out that urban expansion has direct impact natural resources and community character, however proper study has been not carried out for sustainable management and monitoring of urban development of the Phuentsholing city.

Decision makers of the urban development authorities are constantly in need of present geospatial information on patterns and trends in land cover and land use changes. LULC changes can be monitored by traditional inventories like survey, however remotely sensed satellite images have more potential to provide accurate and timely geospatial information describing changes in LULC patterns along with advantages of cost and time savings [7] [31].

This study describes the methodologies and process, result of classification and post classification of change detection of Landsat images of three decades. It was carried out with following aims and objectives to develop the procedures to map and monitor the change detection, assess the accuracy of classification and change detection and analyze the urban growth patterns and its impacts on land cover especially the green vegetation. Therefore, to achieve the objective of the study, the remotely sensed spatial data with time series of three decade were analyses using ENVI, ERDAS and GIS.

2. Materials and Methodology

2.1. Location and Study Area

The study area is located at the foothills of Himalayan mountains adjacent to Indian border town Jaigon of West Bengal. It lies 165km south from the capital city Thimphu. As shown in Figure 1a, 1b, and 1c, the Phuentsholing city covers an area of about 15.6 km^2 according to structure plan 2013 and is located at 26’49’’N to 26’54’’N Latitude and 89’20’’E to 89’28’’E Longitude according to United States Geological Survey 2017 and at an altitude of 293m above the sea level.

Due to its suitable location on Indo-Bhutan border, it has gained the fame as the pivotal center for economic activities and also referred as Economic gateway to Bhutan. As busiest business hub of Bhutan, Phuentsholing is the second largest city in the country after Thimphu, with total population of 20537 in 2005 census and approximately 23925 according to structural survey held in 2013 according to Phuentsholing thromde.

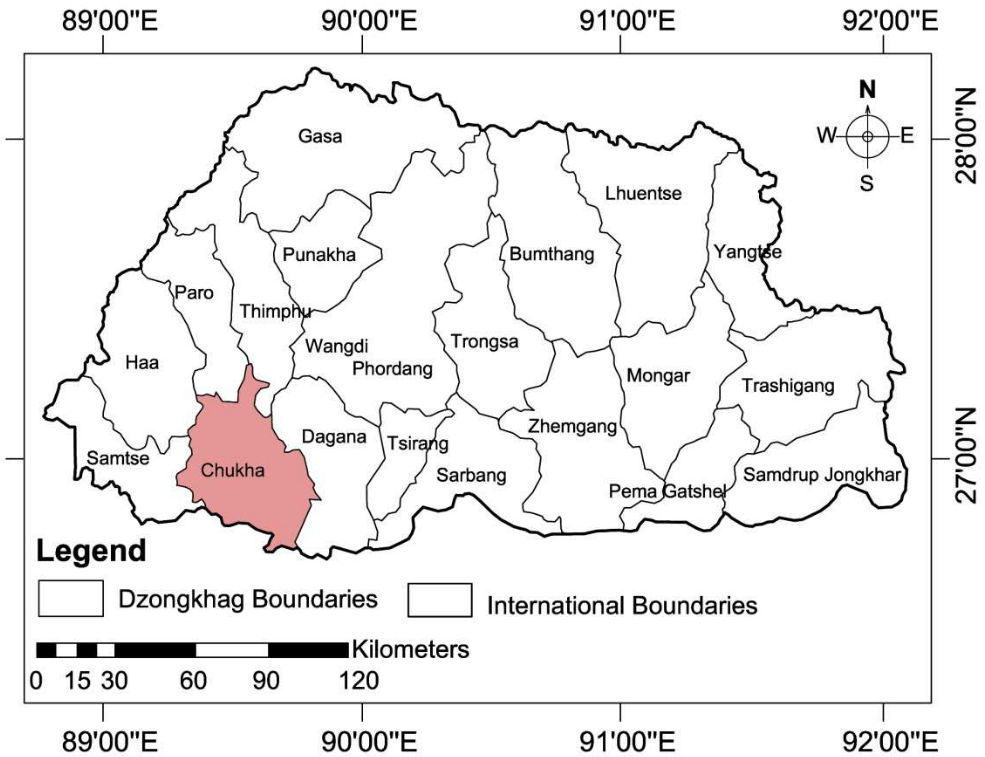

Figure 1a. *Map of Bhutan.*

Figure 1b. *Map of Chukha District.*

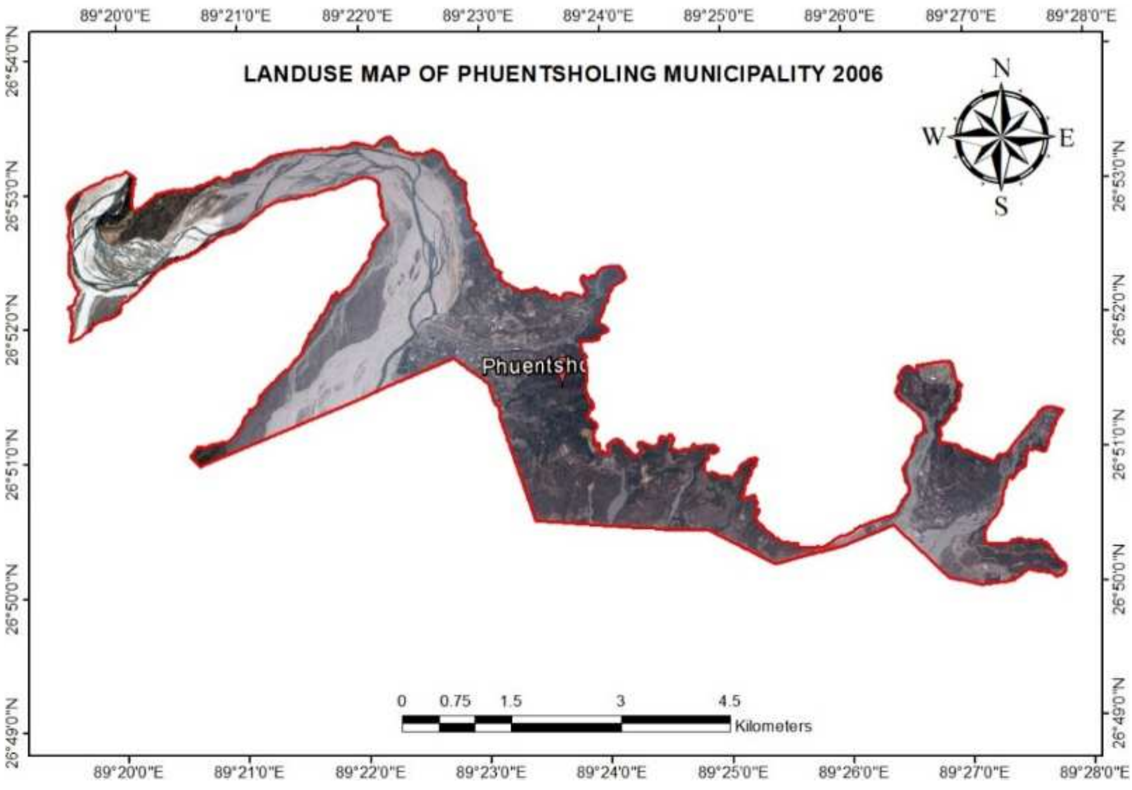

Figure 1c. *Map of Phuentsholing city.*

From a small hamlet with hardly any human settlement in 1950s, Phuentsholing, facilitated and accelerated its development after launching the first Five Year Plan in 1961. and simultaneous commencement of the construction of Phuentsholing-Thimphu National Highway, has grown at an unprecedented rate leading to the preparation of First Development Plan in 1987 [18]. Currently, Phuentsholing has been experiencing tremendous pressure on development due to rapid commercialization and industrialization. To guide such unprecedented growth, there is an urgent need to update the past Development Plan which was prepared 20 years ago.

2.2. Data Acquisition

The multispectral and multitemporal raster images of 1996, 2006 and 2016 were acquired from USGS Earth Explorer [25]. An interval of one decade was desirable for property detecting the land use changes in a country like Bhutan where a large area of the land is covered by vegetation and the pace of infrastructure development is comparatively slow in the world.

As stated before the time span of the study has been about three decades; therefore, the data used covers different sensors of different Landsat series like Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) of Landsat 5, Landsat 7, and Landsat 8 respectively [13] as shown in Table 1.

Table 1. *Satellite data used in this study.*

Sl. No	Date	Satellite	Sensor	Path	Row	Could Coverage	Resolution
1	11/09/1996	L5	TM	138	41	32%	30
2	17/10/2006	L7	ETM+	138	41	10%	30
3	10/10/2016	L8	OLI-TRIS	138	41	11%	30

Numerous researchers have demonstrated the value of multitemporal image for classification of land cover. However, for this particular study the images are collected for Autumn month because the cloud cover in minimal at this time of year and could distinctly differentiate between green area, barren land and buildup area. [11] [28] [30] [31]

The population data for year 1996, 2006 and 2016 are 18089, 20825, 23931 respectively, based on the Population and Housing Census of Bhutan (PHCB 2005). The population figures are computed based on the 1.4% population growth annually based on the 2005 population where the population of Phuentsholing was 20537 in 2005. This was validated after comparing to computed values of 2013 is almost equal to 23925, which was observed during structural survey conducted in 2013.

2.3. Digital Image Processing

The first step in pre-processing is to examine all images free from defects such as striping. Then, these images were clipped, in order to focus only on study are using ERDAS imagine 14. After that, the images were corrected geometrically and radiometrically. Finally, all three images are stacked and classified. All these were performed using ENVI 4.8.

2.3.1. Image Correction

D. A Stow (1999) stated that geometric correction of the satellite images is important for change detection of LULC as there are more possibilities of registration errors which leads to the over overestimation of actual change. Using ENVI, the Google earth images was used as a base map to georeferenced the Landsat image acquired in 2016 through image to map referencing. Then, the Landsat 8 image of 2016 was used as master image to register the other images through image-to-image registration. To accurately register each image, about 35 ground control points (GCP) was examined and matched with all images [31]. The calculated route means square error (RMS) was found about 0.33 pixels, which confirms a good geo-referencing of the images.

The radiometric correction is used using tools in ENVI which combines the sun and view angle effect by calibrating senor with atmospheric correction. This correction is used to correct images that has defects dues to atmospheric scattering caused by haze, dust or fog/cloud. as stated by A. Masria and team in 2015.

Six bands which are closely matching and common, i. e. bands 2, 3, 4, 5, 6, 7 for Landsat 8 and bands 1, 2, 3, 4, 5, 7 of Landsat 5 and 7 are selected, composed and stacked together using ENVI, however, the band with wavelength 0.43m-0.45micro meters [23] [24] in Landsat 8 is excluded as this band is missing in Landsat 7 and Landsat 5.

2.3.2. Image Classification

In unclassified image, features like vegetation, built up areas and waterbodies, etc. cannot be differentiated from each other, as most features inside the images are combined by different bands without proper attribute table [9]. Therefore, Land cover categories/classes are usually mapped from digital remotely sensed data like satellite images through the method of supervised image classification [4] [20].

Table 2. *Image Classification schema.*

Class ID	Class Name	Class Description
1	Water bodies	Permanent open water, lakes, streams, rivers and estuaries
2	Barren Land	Degraded areas, bare soil on river banks and side flood plain areas, Quarries, sand and gravel pits
3	Built up area	Residential, commercial services, industrial, transportation, communications, industrial and commercial, mixed urban and sub urban areas
4	Vegetation	Broad leave forest, parks, gardens, bushes and orchards.

The main purpose of image classification process is to automatically classify all pixels in an image into land cover classes. [9]. To convert images to their respective features/themes, the extracted three spatial images of the Phuentsholing municipality are classified to four classes as stated below in Table 2 using supervised classification tool of ERDAS Imagine.

According to Shalaby & Tateishi (2007), the maximum likelihood classification methods quantitatively evaluates both the variance and covariance of the categorized spectral responded patterns when classifying an unknown pixel values. Thus, it is considered to be one of the most accurate classifier because it is based on statistical parameters.

Since the spatial resolution of the Landsat images are approximately 30m, it was very difficult to distinguish between some classes having similar optical characteristics. Therefore, post-classification refinements are used by referring to high resolution images on ArcGIS online, Google Earth [30], digital topographic maps (Bhutan LCA, 2010) and physical inspection for 2016 images to minimize the errors during the process.

2.4. Accuracy Assessment

The accuracy assessments are necessary to validate the result generated from image classification. Numerous validation method has been developed for this type of classification procedure. [2] [26] The accuracy assessment was carried out using 160 points/pixel. This sample size was derived based on thumb rule that, at least ten times the number of class are required for each class. [30] The four classes are computed as 4X10X4=160 points. The number of points in each class are based on the ratio calculation of the sizes of the class as shown in table 3.

The location of these points is chosen using random stratified method which represent different land cover of the study area [20]. And to increase the accuracy of the classification, the ancillary data and the result of visual interpretation were integrated to the classification result of classified imaged in Arc GIS.

Furthermore, for the overall accuracy, users and producer's accuracy, the Kappa statistic were then derived from the classification error matrices. The Kappa statistic integrates the off-diagonal elements of the error matrices and represents common value obtained after omitting the proportion of common values that were occurred by chance.

Table 3. *Sample size for accuracy assessment.*

Sl. No	Class	Ratio	Sample size
1	Water bodies	1	1/10X (160) =16
2	Barren Land	3	3/10X (160) =48
3	Built up	2	2/10X (160) =32
4	Vegetation	4	4/10X (160) =64
Total		10	160

3. Result and Discussion

3.1. LULC: Area Change Detection

Table 4. *Phuentsholing City: LULC area-1996, 2006 and 2016.*

Sl. no	Class	1996		2006		2016	
1	Water bodies	245 acres	4.7%	245.6 acre	4.7%	228 acres	4.4%
2	Barren land	2097 acre	40.2%	2007 acre	38.5%	2021 acre	38.7%
3	Built up	350 acres	6.7%	552 acres	10.6%	887 acres	17%
4	Vegetation	2524 acre	48.4%	2411.4 acre	46.2%	2080 acre	39.9%

Note: Total area of Phuentsholing city is 5216 acres approximately.

Classified maps were created for three years as shown in Figure 2a, 2b and 2c with individual class area and their change statistic as shown in table 4. From 1996 to 2016, major changes are occurred to increase in urban built up (6.7% to 17%) of the total area, i. e. 350 acres to 887 acre.

The area of water bodies remains almost same (4.7% to 4.4%). Most rapid changed in land use was observed in urban built from 552 acre (10.6%) in 2006 to 887 acre (17%) in 2016. It was occurred due sudden increase of economic development of the country during last decade after the government system has shifted from Monarchy to Constitutional Monarchy. This transition in governance system has brought up the rapid increase in infrastructure development in the country booming the construction activities in the urban center and country sides.

On other hand due to higher urban development activities, nature/vegetation has been adversely damaged, reducing the vegetation cover from 2422.4 acre (46%) in 2006 to 2080 acre (39.9%) in 2016. This may disturb the balanced ecosystem in the urban green areas leading to various health, environmental and social issues.

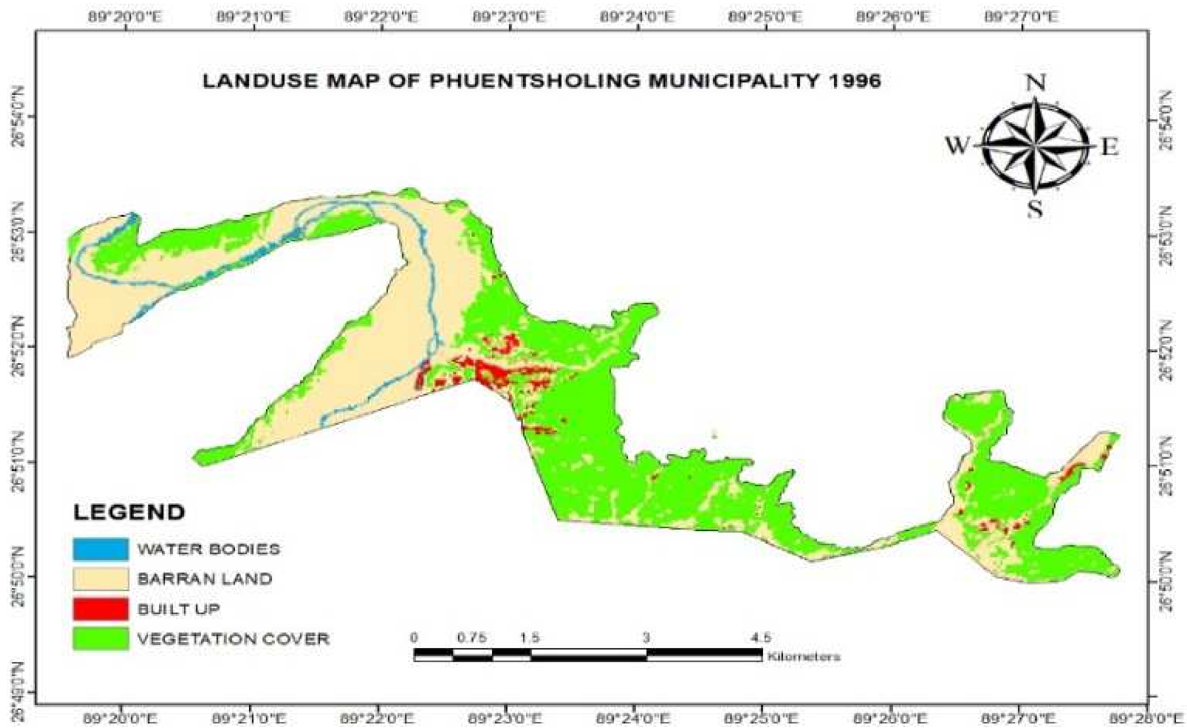

Figure 2a. *Land use map of Phuentsholing city-1996.*

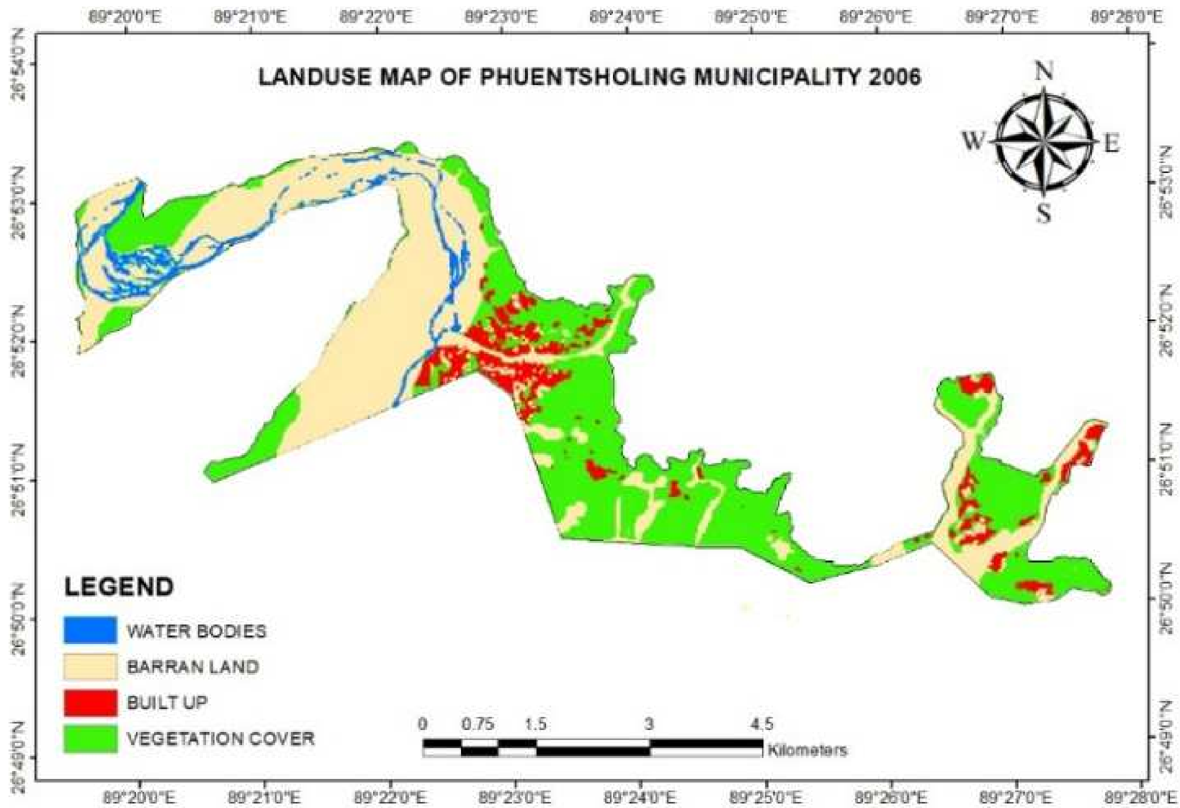

Figure 2b. *Land use map of Phuentsholing city 2006.*

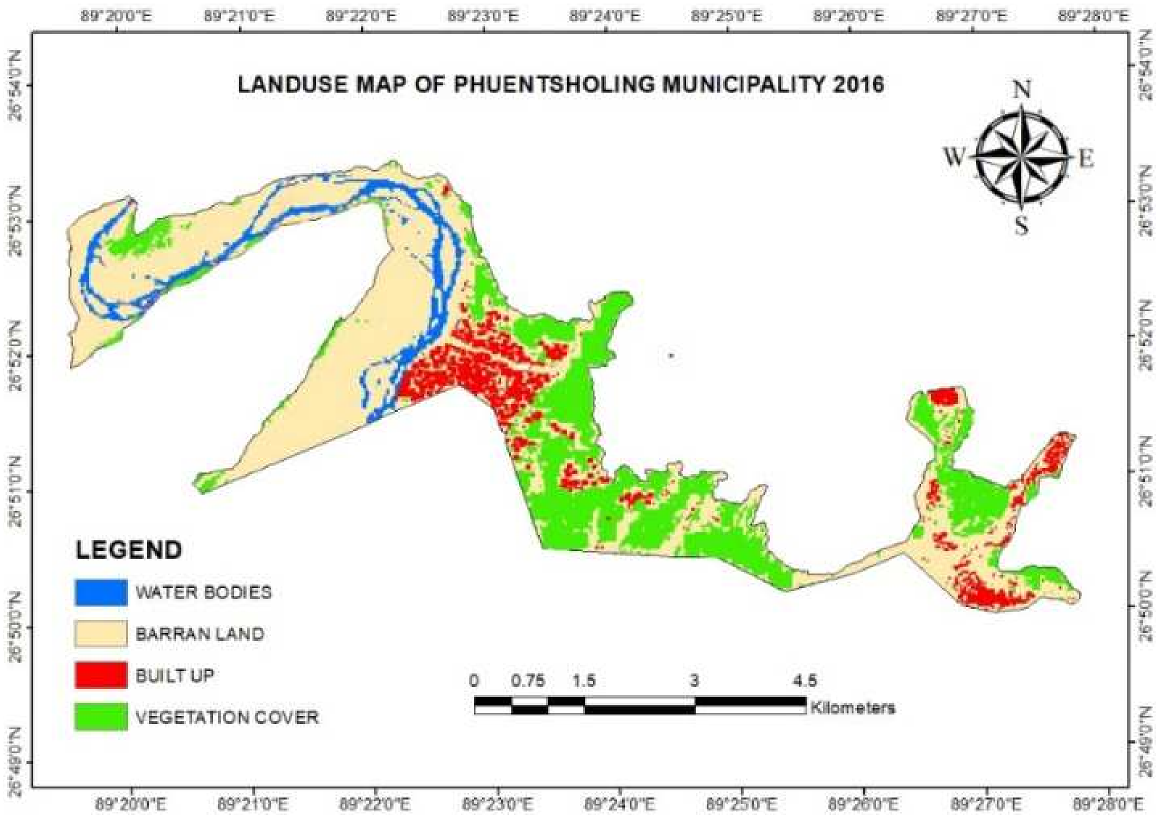

Figure 2c. Land use map of Phuentsholing city-2016.

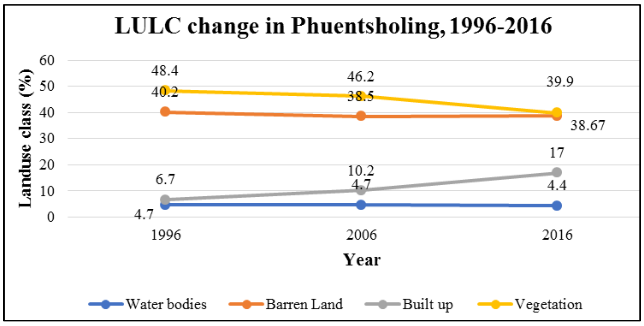

Figure 3. LULC change in Phuentsholing, 1996-2016.

3.2. LULC: Accuracy Assessment

As discussed before, Error matrices were used to assess classification accuracy. The overall accuracies were 70%, 67% and 72% for 1996, 2006 and 2016 images respectively. These percentage of accuracy are considered to be threshold of good classification [10], as the resolution of images captured from USGS explorer are of poor spectral quality which has become difficult to distinguish between buildup and barren land.

3.3. Urban Density

As discussed earlier, the population data for year 1996, 2006 and 2016 are 18089, 20825, 23931 respectively, computed based on the Population and Housing Census of Bhutan (PHCB 2005) with the annual increase of 1.4%. Based on the current LULUC change ratio, the expected urban built up and production density is as shown in table 5. The status of urban built area and urban density also justify the extent of urban sprawl.

Table 5. Urban density of Phuentsholing city.

Year	1996	2006	2016	2016 (forecasted)
Urban built up (acre)	350	552	887	1356
Population	18089	20825	23931	27500
Population density (M^2/capita)	78.3	107.3	150	199.5

4. Conclusion

In this study, it was demonstrated that supervised classification of multi-temporal satellite images is one of the effective methods to quantify the current land use and detect and estimate the changes over the last three decades in the short span of time. The analysis of Landsat images of 1996, 2006 and 2016 using ENVI, ERDAS and ArcGIS can also forecast the expected change in land use in the future (2026), if the growth rate of population is constant.

This study also advocates that remotely sensed satellite data are very useful to distinguished and detect the changes in LULC very comprehensively. It also reveals that the LULC pattern and its distribution are the major fundamental requirement for the decision makers/ planners to plan and carryout the sustainable and efficient development activities of any given area.

It was also observed that the changes varied from one LULC class over the two analysis periods (1996-2006 and 2006-2016). Some classes like barren land and waterbodies underwent fluctuates due to the natural disaster like foods and landslide because of climatic change and heavy rainfall.

It was found that within last 10 years, 6.3% forest cover was removed due to considerable increase in urban built up area by 7%. If it is not taken serious consideration at this very point of time, the huge change of land use pattern between green areas will be decreased to 32% and urban settlement is expected increased to 26% by year 2026. Therefore, the management of the municipality office should emphasize to study on LULC changes before preparing various strategies in urban development in Phuentsholing thromde/city.

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