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Evaluation of Land Use/Cover Change and Urban Sprawling Pattern Using Remote Sensing and GIS: A Case Study in Thimphu, Bhutan

Leki Dorji[1], Sangay Kumar Shukla[1], Dorji Wangchuk[1], Karma Tandin Dorji[1], Kencho Gyeltshen[1], Nimesh Chettri[1,2,*], Komal Raj Aryal[3], Khameis Mohamed Al Abdouli[3]

[1]Department of Civil Engineering and Geology, College of Science and Technology, Royal University of Bhutan, Bhutan
[2]Centre of Disaster Risk Reduction and Community Development Studies, Bhutan
[3]Faculty of Resilience, Rabdan Academy, Abu Dhabi, United Arab Emirates

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Abstract The urbanisation and multifarious upsurge of infrastructures in Bhutan have caused intense alteration of land cover topographies. These rapid changes undergoing are predominately snow cover, vegetation, water bodies, built-up, barren land, and agricultural land which are commonly called land use/land cover (LULC) change. The current research attempts to analyse concerning temporal and spatial frameworks features to observe the nature of development sprawling processes of Thimphu over 30 years (1990-2020), by using multi-temporal remote sensing data. Landsat 5, 7 and sentinel 2B imageries have been adopted for estimating land use/cover change in Thimphu for the past 30 years. The confusion matrix and Kappa coefficient methods were adopted for the classification accuracy assessment. This is further validated by field visit essentially on water bodies and barren land which were quite perplexing. The paper concludes that the largest proportion of the area (65.97%) in 1990 was under vegetation cover, followed by barren land (31.63%) and the third biggest (1.39%) was under snow cover. The current research will provide significant aid to the planners and architects to understand the pattern of development sprawling in the past and facilitate futuristic mapping the developmental activities.

Keywords Land Use Land Cover Change, Maximum Likelihood Supervised Classification, Landsat Image, Confusion Matrix, Kappa Coefficient

1. Introduction

Change detection as land use/cover created on remotely sensed data forms the significant basis of information for planning future developmental activities [1]. Assessment of LULC change is imperative in evaluating the land protection, justifiable development and management of water bodies [2]. The current research attempts to analyze the change in land features in the case of land use over the years in three gewogs (sub district), (Mewang, Chang, and Kawang) in Thimphu dzongkhag (district). Land use and land cover alteration need to comprehend especially the dynamics of development activities critically for the monitoring of forest ecosystems [3]. Development activities and urbanization are one of the key driving factors of global warming and environmental change that alters the ecosystem, climatic condition, hydrological dynamics, flora/fauna, and energy equilibrium with human actions [4]. The rapid pace of urbanization and the development activities is an indication of reducing the area of forest cover, agricultural land, and shrublands leading to an increase in the runoff coefficient. According to the Bhutan's vision, a vision of peace, any developmental activities within the country have to be aligned with Gross National Happiness to balance socio-economic development and environmental conservation. Further, this is reinforced in Bhutan's constitution which states that a minimum of sixty percent of the country's land area shall be conserved under the forest at all times. The reliable and updated information on the land use land cover maps and their dynamics can help in keeping a balance of land related to the people's need, urbanization, development activities and environmental conservation [5]. To produce a baseline in quantifying the land features alterations as land use land cover, the most suitable methodology is adopting Remote Sensing (RS) and GIS techniques [6]. Quantifying the change using RS and GIS techniques is considered to be convenient in diverse applications which are used to identify the change in land use patterns [7]. Remote sensing and geographical information system have the advantage of reducing costs and time to a large extent.

Urban sprawling is considered to be the most prevailing activity involved all over the world to create job opportunities and better amenities facilities that encourages the migration from rural to urban [8][9]. The urban growth process has been recognized due to the enhancement of built-up amenities and rapid population growth leading to competitive job opportunities. As opposed to, rural land abandonment in remote areas significantly amplified consumption of much of natural resources in urban. Therefore, Thimphu city has been experiencing an intense increase in migration in the last decades [10].

This paper emphasis on the approaches in the classifications and land change detections using Landsat and sentinel imageries of past few decades. Moreover, it focuses on the detections of the rate of change in particularly the buildup areas as to plan the developmental activities in the future appropriately.

2. Study Area

The study area lies approximately between longitude ranging from 89º30'00''E to 89º45'00''E and between latitude 27º20'00'' N to 27º40'00''N (Fig. 1).

The total geographic area of the three gewogs (Mewang, Chang, and Kawang) located within Thimphu is about 685.0917 km^2 and concentrated at an altitude of 2320 m above sea level. The whole area of Thimphu, a capital city is around 1681.8 km^2 consisting of eight gewogs (sub-district). The general climatic conditions of Thimphu are wet humid summer and dry winter, having a small area under a glacier and perpetual snow in higher ranges [11][12]. According to the census of Bhutan 2017, the total population in Thimphu was 1, 50,404 in-person [13].

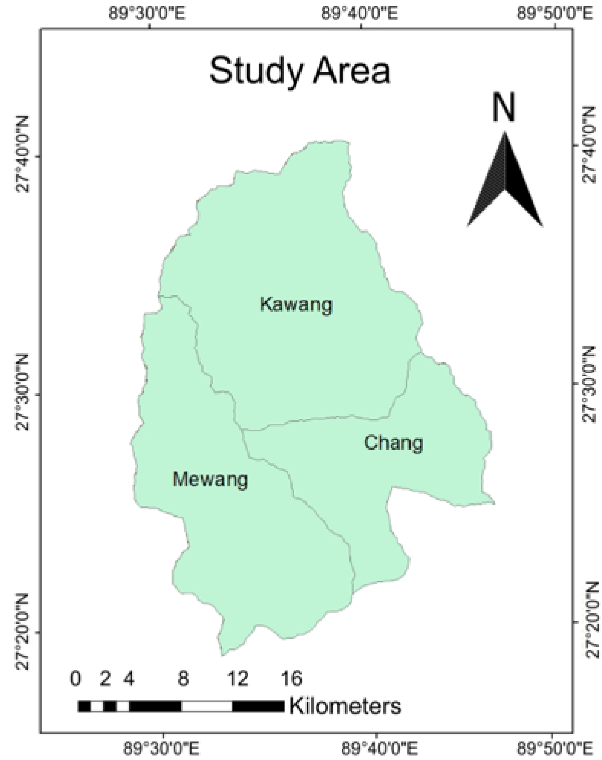

Figure 1. Study area of three regions (gewogs)

3. Materials and Methodology

The methodology used in research is showed in Fig. 2. Extensive literatures are explored in the form of published journals, reports prepared by Royal Government of Bhutan (RGoB) to demystify the rainfall data, remote sensing satellite imagery (1990, 2000, 2020), and Toposheet 78F05 (1:50000). These serve as an input to ArcGIS software to extract the areal deviation adopting the digitalization process. Further, the Digital Elevation Model (DEM) has been extracted from the USGS Web site of required resolutions. Those results obtained have been put to the accuracy assessment process. Hence, the land-use/cover maps were being generated to observe the areal alteration within 30 years of selected important parameters (vegetation, water bodies, barren land, snow cover, and agriculture land).

3.1. Data Acquisition

The multispectral images of Landsat 5 for the year 1990, Landsat 7 for the year 2000, and Sentinel-2B for the year 2020 were obtained from USGS Earth Explorer as indicated in Table 1. Many researchers have illustrated the value of multi-temporal images of classification for land use/cover. The low cloud cover during autumn season facilitated the clear distinction among green area, barren land and built-up area [14].

Table 1. Satellite data used in the study

Date	Satellite	Path and Row
30 October 2020	Sentinel-2B	T45RYL
30 September 2000	LS7	P – 138, R – 41
14 November 1990	LS5	P – 138, R – 41

Bands 2, 3, 4, and 8 of Sentinel 2B (table 2), having the highest resolution among the other bands i.e., 10 m were selected for 2020. The Bands 1, 2, 3, 4, 5, and 7 of Landsat 5 and 7 (as shown in table 3 & 4) having a resolution of 30 m were selected for the years 1990 and 2000, respectively. The selected bands of each image were composited in ESRI Software ArcGIS. To examine all the images, pre-processing was performed and the images were clipped to the study area using ArcGIS version 14. The images were further corrected geometrically and radiometrically before to extract the classification.

3.2. Image Processing and Classification

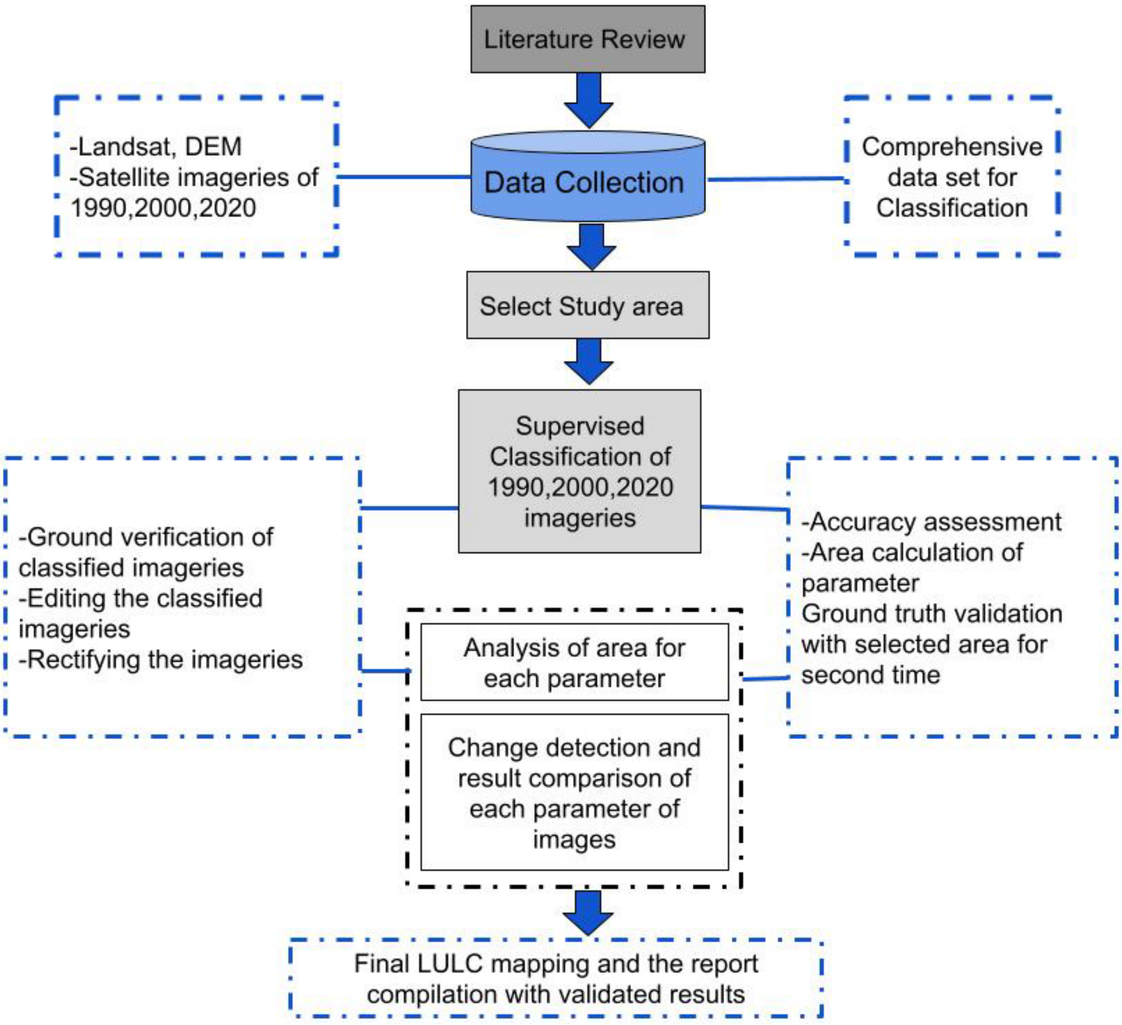

Figure 2. Process of adopted research methodology

Table 2. The bands, Wavelengths, and resolution in Sentinel-2B Satellite

Sentinel-2B Bands	Central wavelength (μm)	Resolution (m)
Band 1 - Coastal aerosol	0.44	60
Band 2 –Blue	0.49	10
Band 3 - Green	0.56	10
Band 4 – Red	0.66	10
Band 5 - Vegetation Red Edge	0.70	20
Band 6 - Vegetation Red Edge	0.74	20
Band 7 - Vegetation Red Edge	0.78	20
Band 8 – NIR	0.84	10
Band 8A - Vegetation Red Edge	0.86	20
Band 9 - Water vapor	0.94	60
Band 10 - SWIR -Cirrus	1.37	60
Band 11 - SWIR	1.61	20
Band 12 - SWIR	2.19	20

Table 3. The bands, Wavelengths, and resolution in Landsat 5 Satellite

Landsat 7	Wavelengths (μm)	Resolution (m)
Band 1 – Blue	0.48	30
Band 2 – Green	0.56	30
Band 3 – Red	0.66	30
Band 4 - Near Infrared	0.83	30
Band 5 - Infrared short wave	1.65	30
Band 6 - Infrared Thermal	11.45	60*(30)
Band 7 - Infrared short wave	2.21	30
Band 8 - Panchromatic	0.71	15

Table 4. The Bands, Wavelengths, and resolution in Landsat 7 Satellite

Landsat 5	Central Wavelengths (μm)	Resolution (m)
Band 1 - Blue	0.48	30
Band 2 - Green	0.56	30
Band 3 – Red	0.66	30
Band 4 - Near Infrared	0.83	30
Band 5 - Infrared short wave	1.65	30
Band 6 - Infrared Thermal	11.45	120
Band 7 - Infrared short wave	2.21	30

The images of the study area for each of the three years were classified using a supervised maximum likelihood classification method. This classification method was required for the training samples for each class. Six classes (table 5) namely snow cover, vegetation, water bodies, built up, barren land, and agricultural land were identified. Due to the low resolution of Landsat 5 and 7 images, it was difficult to differentiate the classes with similar optical characteristics but these were verified by field visit. Moreover, the high-resolution base map and Arc google images in Arc map were used as a reference to identify the features and minimize the errors in collecting training samples. To ascertain the classifications, the maximum number of training samples were collected for an individual category on each parameter to generate signature files. The erroneous classified pixels were then reclassified to reduce the errors in the overall classifications.

Table 5. Image classification schema

Class ID	Class Name	Class Description
1	Vegetation	Broadleaf, conifer, fir, chirping, spruce forest, shrub, meadow
2	Agriculture	Dryland, wetland
3	Snow Cover	Areas covered by snow
4	Barren land	Rocky outcrop, bare soils, degraded area
5	Water bodies	Area covered by rivers
6	Built-up	Settlements, industrial, commercial, facilities

3.4. Accuracy Assessment

It is essential to validate all the results obtained from the classification of the images through accuracy assessment approaches and used several methods that have been available in literatures [5]. Ground truthing is commonly adopted technique that relates the classified images data with the accurate source of data for the affirmation process. Ground truth data can also be derived from the high-resolution imageries or GIS data layer or else visiting the selected real ground. The values of the reference dataset should match the schema. Google Earth is the essential tool for positional data that can be used for examination and initial studies with an appropriate accuracy at minimal efforts [15]. After images were classified, more than 100 arbitrary points were created in the ArcMap. Then the values of arbitrary points were identified from Google Earth Pro and on a real ground for the adaptation of validation approaches. The Kappa coefficient, complete accuracy, and producer accuracy were estimated to check the accuracy of the classified images.

4. Result and Discussion

Based on remote sensing and GIS techniques, natural resources such as water and environment controlling approaches have been adopted in research categories extensively [16]. Table 6 shows the land use and land cover changes in the years 1990, 2000, and 2020 of Thimphu dzongkhag, particularly three gewogs. The result obtained from the map (Fig. 3, 4 & 5) shows that the vegetation occupies the maximum area in all three varying decades.

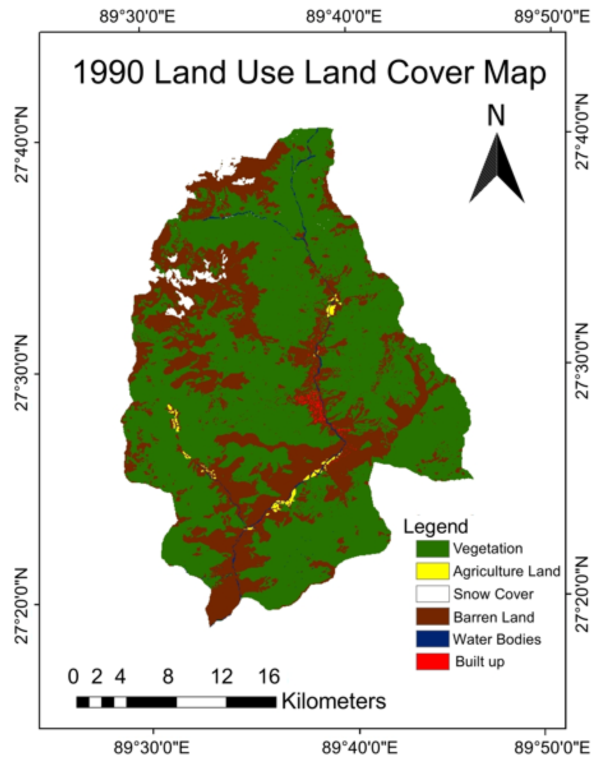

Figure 3. LULC maps of three gewogs, Thimphu - 1990

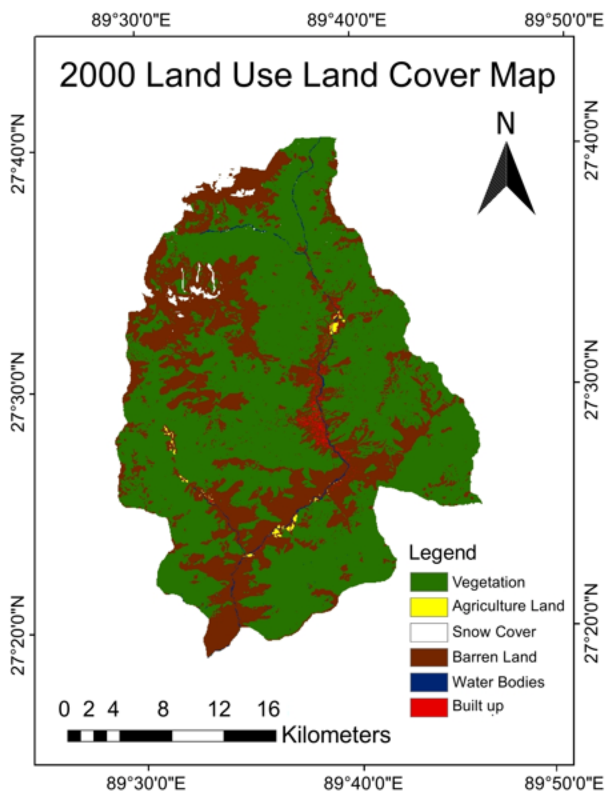

Figure 4. LULC maps of three gewogs, Thimphu - 2000

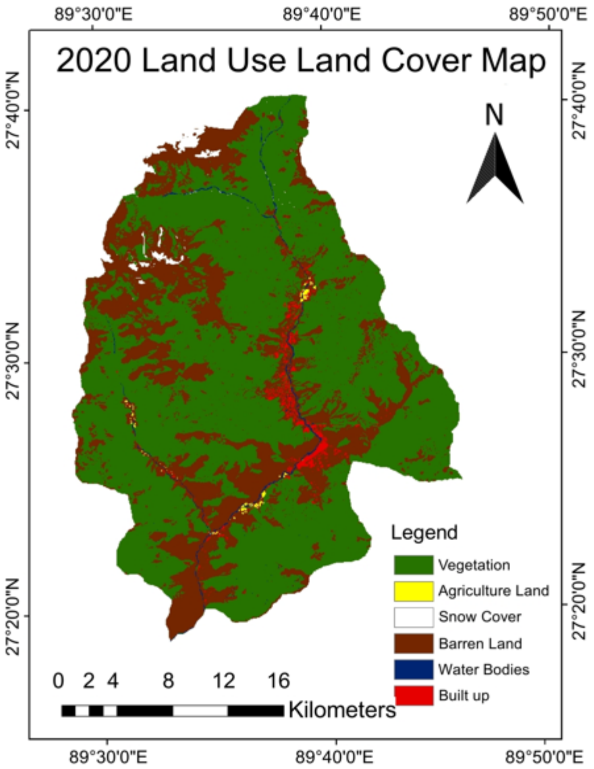

Figure 5. Land use map of three gewogs, Thimphu - 2020

The area of each gewog from the years 1990, 2000, and 2021 was determined by all the assigned land-use/landcover parameters as indicated in Table 6. The overall changes in percentage from 1990 to 2021 were also indicated. Among the six parameters, the vegetation is found to be highest in all three years, followed by barren land, snow cover, water bodies and the least was agriculture land. It has been noticed that the changes of areas are only small in every parameter except in built-up area increased by five times more than the previous area from 1.65 km^2 to 6.86 km^2.

The percentage decreasing/increasing trend of each parameter of land-use/landcover is indicated in Table 7. There is significant decrease in agricultural land as it is being replaced by built-ups and other developmental activities which had accentuated the rural-urban migration [5]. The increase in the vegetation coverage in the year 1990-2020 (by 1.05%) because the optimum temperature for plants is achieved at high altitudes due to global warming (as suggested by many government reports). This enabled vegetation growth enhancement [17] with favorable temperatures from barren land to shrubs and trees thereby, decreasing the barren land by 1.26%. The melting of snows and glaciers has added more water to the river ultimately increasing the water bodies by 0.06% leading to the retreating of glacier/snow toes.

Table 6. Showing the area changes in land-use/landcover

Landuse/landcover Category	Area in km^2 (1990)	% of the total area (1990)	Area in km^2 (2000)	% of the total area (2000)	Area in km^2 (2020)	% of the total area (2020)
Vegetation	452.55	65.97	454.09	66.19	459.75	67.02
Water bodies	4.33	0.63	4.67	0.68	4.73	0.69
Snow cover	9.54	1.39	6.47	0.94	5.69	0.83
Barren land	216.98	31.63	217.41	31.69	208.33	30.37
Built up	1.65	0.24	2.61	0.38	6.86	1.00
Agricultural	0.96	0.14	0.75	0.11	0.63	0.09
Total Value	686.00	100.00	686.00	100.00	686.00	100.00

Table 7. LULC area for three gewogs of 1990, 2000 and 2020

Landuse/ landcover Category	Change in area km^2 (2000-1990)	Change in Percent (2000-1990)	Change in area km^2 (2020-2000)	Change in Percent (2020-2000)	Change in area km^2 (2020-1990)	Change in Percent (2020-1990)
Vegetation	1.54	0.22	5.66	0.83	7.20	1.05
Water bodies	0.33	0.05	0.07	0.01	0.40	0.06
Snow cover	-3.06	-0.45	-0.78	-0.11	-3.84	-0.56
Barren land	0.43	0.06	-9.08	-1.32	-8.64	-1.26
Built up	0.96	0.14	4.25	0.62	5.21	0.76
Agricultural	-0.21	-0.03	-0.12	-0.02	-0.33	-0.05
Total Value	0.00	0.00	0.00	0.00	0.00	0.00

4.1. LULC: Accuracy Assessment

As discussed in the methodology section, a total of 100 random pixels were selected and compared with the high-resolution imageries using Google Earth Pro. The result shows that the overall accuracy of classification for the dataset for 3 years, i.e., 1990, 2000, and 2020 was 72%, 80%, and 82% respectively (Tables 8, 9, 10). The Kappa coefficients for the classification for 1990, 2000, 2020 are 64.58%, 73.93%, and 77.68% respectively and from the Kappa coefficient agreement (Table 8), the results for accuracy assessment were good for 1990 and very good for 2000 and 2020.

Table 8. Kappa coefficient

No.	Kappa coefficient	Rate
1	Less than 0.4	Poor
2	0.4<Kc<0.5	Fair
3	0.55<Kc<0.7	Good
4	0.7<Kc<0.85	Very good
5	More than 0.85	Excellent

To further define the accuracy assessment of the image developed, Kappa Analysis with confusion matrix has been performed. Hence, a discrete multivariate technique measuring agreement and the accuracy of the result is obtained by finding Kappa Coefficient (K) value in percentage as determined below for a sample of the year 2020.

$$\boldsymbol{K} = \frac{N\sum_{\substack{i=1\\j=1}}^{m}\sum D_{ij} - \sum_{\substack{i=1\\j=1}}^{m} R_i C_j}{N^2 - \sum_{\substack{i=1\\j=1}}^{m} R_i C_j} \tag{1}$$

Where N=total no. of pixels

m = number of classes

D_{ij} = sum of correctly classified pixels for all classes diagonally.

R_i = Total number of pixels in row

Total no. of correctly classified pixel=82

Total no of classified pixel=100

Overall accuracy=82/100*100=82%

$$kappa\ coefficient = \frac{82*100-((26*30)+(17*14)+(10*7)+(23*23)+(15*14)+(9*12))}{100^2-((26*30)+(17*14)+(10*7)+(23*23)+(15*14)+(9*12))}$$

=0.7768=77.68%, the Kappa coefficient obtained from equation 1 i.e., 77.68% is essentially within the good range.

5. Conclusions

Three gewogs from Thimphu have a wide-ranging area coverage under vegetation i.e. more than 50%. The built-up areas are increasing due to urbanization and developmental activities which also encroach into the agricultural land and vegetation. There are no significant changes in the water bodies however, a slight change in the snow coverage was noted. It is also recorded that vegetation, water bodies, and built-up parameters were slightly increased as 7.2, 0.4, and 5.2 respectively. However, the rest of the parameters like snow cover, barren land, and agricultural land were indicated decreasing trend as -3.8, -8.6, and -0.3 respectively. Among the increasing trend, vegetation and built-up showed significantly high coverage whereas snow cover and barren land indicated a significant declining trend overall from the year 1990 to 2020.

The overall accuracy of the classification images varied between 72% to 82% and Kappa coefficient from 64.6% to 77% which is considered to be a good to very good range. If the accuracy is bad, there are profound factors that contribute to bad accuracy including the date of images, data validations, and resolutions of Landsat images. The findings depict rapid infrastructures development and decline greenery in urban Thimphu. Moreover, significant rural urban migration was noted which is responsible for such drastic changes in the land features.

Table 9. Confusion Matrix for LULC-2020

Matrix	Vegetation	Water bodies	Snow cover	Barren land	Built-up	Agri. land	Total	User (%)	Producer (%)
Vegetation	25	0	0	0	0	1	26	96.1	83.3
Water bodies	2	13	0	0	1	1	17	76.4	92.8
Snow cover	0	1	6	3	0	0	10	60.0	85.7
Barren land	3	0	1	18	0	1	23	78.3	78.2
Built up	0	0	0	0	13	2	15	86.67	92.8
Agriculture land	0	0	0	2	0	7	9	77.78	58.3
Total	30	14	7	23	14	12	100		

If the timely intervention is not taken, there arises major decline in green areas which in turn decreases the rate of infiltration. Therefore, excessive run-off shall be expected. Therefore, concerned government agencies need to take charge of the elaborated scenarios and detail exploration on LULC change before implementation of futuristic developmental activities.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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