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Change in the Urban Landscape of the Drakensberg Mountain Region, South Africa: A Case Study of Phuthaditjhaba

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The settled landscape in the Drakensberg Mountain region of South Africa is characterized by increasing urbanization. Some of the supposedly rural settlements in the region have experienced increasing change in their landscapes over the last 3 decades, resulting in significant land use and land cover (LULC) changes. Among such settlements, Phuthaditjhaba and its environs are slowly becoming a metropolitan area. Based on conceptual considerations regarding sustainable urban development, we assessed LULC change using 4 Landsat images from 1989, 1999, 2009, and 2019 and a combination of unsupervised and supervised classification methods. The images were classified into 4 LULC classes. Between 1989 and 2019, the urban built-up area in Phuthaditjhaba increased from about 5% to 19%, representing a total increase of 270%. However, the greatest increase in land cover was in bare surface at the expense of vegetated areas, including farmland, which decreased from about 45% to 15%. The increase in bare surface could be due to fires. Built-up areas also increased due to a consistent increase in population density in the study area. We further described spatial patterns in LULC using selected landscape metrics. A decrease in patch density (PD) and cohesion, coupled with constant edge density (ED) and an increase in the fractal dimensional index (FDI), indicates fragmentation and less connectivity between 1989 and 1999; we interpret this as a sign of unsustainability. An increase in PD and cohesion and fluctuations in ED and FDI show that land patterns were more aggregated between 2009 and 2019. At the class level, an increase in PD, cohesion, and ED also showed more aggregated land patterns, which was confirmed by the mean patch size. The FDI revealed greater connectivity, which we also interpreted as unsustainable because of the increase in bare surface and built-up areas. Integrative coplanning and comanagement of land use and allocation are needed to ensure sustainable development.

Keywords: *urbanization; remote sensing; land use and land cover (LULC) change; landscape metrics; settlement development; South Africa.*

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Introduction

Mountains support the livelihoods of 12% of the global population in terms of water supply, shelter, tourism, economy, food, and energy sources, among others. Furthermore, mountains provide between 60% and 80% of the world's freshwater, which is used for agricultural, industrial, and domestic purposes (Romeo et al 2021). Currently, the world is experiencing rapid population growth, urbanization, climate change, and severe and extensive degradation of ecosystems (IPBES 2018). This is also observed in mountain regions, where settlements have often changed at a thought-provoking rate (Goodall 2004; UN-Habitat 2013). The United Nations 2030 Agenda, through Sustainable Development Goals Targets 6.6, 15.1, and 15.4, focuses on the conservation of freshwater and ending the degradation of mountain ecosystems (Manuelli et al 2017). However, this vision of the international community is broad. It aims to eradicate poverty, produce sustainable food, energy, and forests, and conserve ecosystems and biodiversity (Kulonen et al 2019), but it does not focus specifically on urbanized areas in mountains.

Accordingly, settlements and urban development should also be considered significant issues of sustainable development in mountains: Unplanned or uncontrolled development can cause havoc on the entire population and the environment (Jarah et al 2019). Therefore, the analysis of land use and land cover (LULC) changes and their consequences is critical to providing a basis for sustainable development visions. Both natural and anthropogenic forces, such as infrastructure development, tourism, and climate change, drive LULC changes. Most of the changes are associated with loss of farmland and an increase in bare surfaces, as well as informal and illegal structures, especially along major roads in peripheral urban areas (Foroozesh et al 2022).

As the Drakensberg mountain range is one of the highest in Southern Africa, its sustainable development is pertinent for many communities and ecosystems. It is highly valued for its economic and natural resources but also as a tourist

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destination (Linde and Grab 2008; Blignaut et al 2010). Phuthaditjhaba and some other settlements in the Drakensberg region are experiencing highly dynamic changes due to the history and the social, cultural, and political situation of the region (Delves et al 2021). As in other regions around the world, this seems to be happening at the cost of social–ecological sustainability (Grêt-Regamey and Weibel 2020).

Phuthaditjhaba is the largest settlement in Maluti-A-Phofung Local Municipality and the headquarters of the Thabo Mofutsanyane District in the Free State Province of South Africa. It has experienced noticeable physical and socioeconomic development and demographic change, especially over the last 3 decades, negating the narrative that Thabo Mofutsanyane municipality is rural (Haack 2009; Tiwari et al 2018; Brand and Drewes 2020). It has undergone numerous changes that have led to unplanned development and created adverse impacts on natural resources. Other effects include environmental pollution, low water supply to households, loss of agricultural land, and increases in bare surfaces. These are problems faced by many developing countries (Thapa and Murayama 2009; Ishtiaque et al 2017; Foroozesh et al 2022). All are evidence of unsustainable development.

Monitoring LULC changes and population growth in the mountain region is a meaningful way to identify and measure the extent of urbanization. Particularly for settlements like Phuthaditjhaba with substantial rapid urbanization, identification and measurement of these changes are very necessary (Onaolapo et al 2020). Also, the traditional land use allocation for residential and agricultural purposes is causing land fragmentation and stressing mountain biodiversity and ecosystems (Makino et al 2020). It is imperative to understand such changes to prevent future environmental hazards and exorbitant infrastructural costs, and to achieve sustainable mountain development (Song et al 2016; Pathiranage et al 2018).

Therefore, this research examined the changes in LULC of a significant settlement in the mountainous region of the Drakensberg between 1989 to 2019. We used remote-sensing methods to analyze urbanization dynamics, and we discuss the likely factors behind the selected settlement changes. The use of the random forest (RF) method of supervised classification and calculation of various spatial metrics helped to describe landscape pattern dynamics accurately.

Conceptual framework

Few studies on sustainable urban development have considered urbanization, which is a major driver of environmental changes and a threat to balanced ecosystems, biodiversity (Kowarik et al 2020), and human health and wellbeing (Tonne et al 2021). To achieve sustainable urban development, there is a need to address the stress and pressures caused by urbanization. There is also a need to develop pathways to a balanced and sustainable biodiverse environment that are understood, accepted, supported, and comanaged by residents (Kowarik et al 2020).

Sustainable urban development is one approach to providing solutions to some environmental problems, such as unplanned and illegal development, which have negative impacts on natural resources and threaten lives and infrastructure (Foroozesh et al 2022). Abubakar et al (2020) explained that sustainable urban development could be achieved through top-down urban governance; they emphasized the use of implementable policies to control undesirable development. These included policy frameworks, legislation, and administrative processes to integrate strategic environmental assessments into sustainable development plans (Abubakar et al 2020).

The emergence of a sustainable settlement depends significantly on the development and stability of a locality's socioeconomic and political system. These, in turn, are components of regional and national planning (Harbiankova and Scherbina 2021). The theory of settlement formation can best explain the sustainable settlement development model (De Wee 2020). The approach shows the relationships among the main aspects of the settlement, namely, population, function, and form. The "population" is the basis of human settlement, while the "function" of the settlement explains the commercial roles and service delivery in so-called central place theory. The role can also be economic, facilitated by road accessibility, industrialization, and the availability of infrastructure, depending on the potential and natural resources available in the settlement (Murphy 2017). The "form" of the settlement comes about because of competition for "desirable" locations among different land uses, which eventually becomes a crucial determinant of spatial development (Musvoto 2014).

The theory of "central place" postulated in 1933 (Christaller 1966) and modified in 1940 (Lösch 1954) assumes that settlement development happens for economic reasons (Almeida et al 2021). Central place theory is based on spatial equilibrium; it emphasizes the relationship between city development and economic activity, and it also explains how the city spreads based on the utilities and services it provides (Vilajosana et al 2013). Temin (2016) defined economic development to mean a change in people's livelihoods, especially in the areas of health and education, which results in increased productivity and a rise in per capita income. It, therefore, indicates transformation and distributions of inputs. An all-inclusive approach is necessary to achieve and promote economic development (Alam et al 2016). Ajaero and Madu (2014) elucidated the importance of developing rural and semi-urban areas to enrich the social, economic, and spatial environment, which leads to an improvement in individuals' abilities to manage and sustain their livelihoods.

Harnessing the potential and natural resources of a settlement and promoting freedom, rights, and ethics lead to cultural, social, and environmental transformation; hence, development is usually due to economic, cultural, political, historical, educational, and environmental factors (Moberg 2018). In his extensive study of urban development in Natal, Musvoto (2011) highlighted some of the shortcomings of central place theory, as it fails to consider convenience, household income and status, communication modes, and the fact that settlements do not usually follow a narrow plan (Sogoni et al 2018).

The theory of urban form and the concept of sustainability provide a background for the present study. Based on the study by Musvoto (2011), we conceptualized urban development using a schematic representation or "bowl model" (Figure 1) that shows how the study is embedded in a larger understanding of the components that

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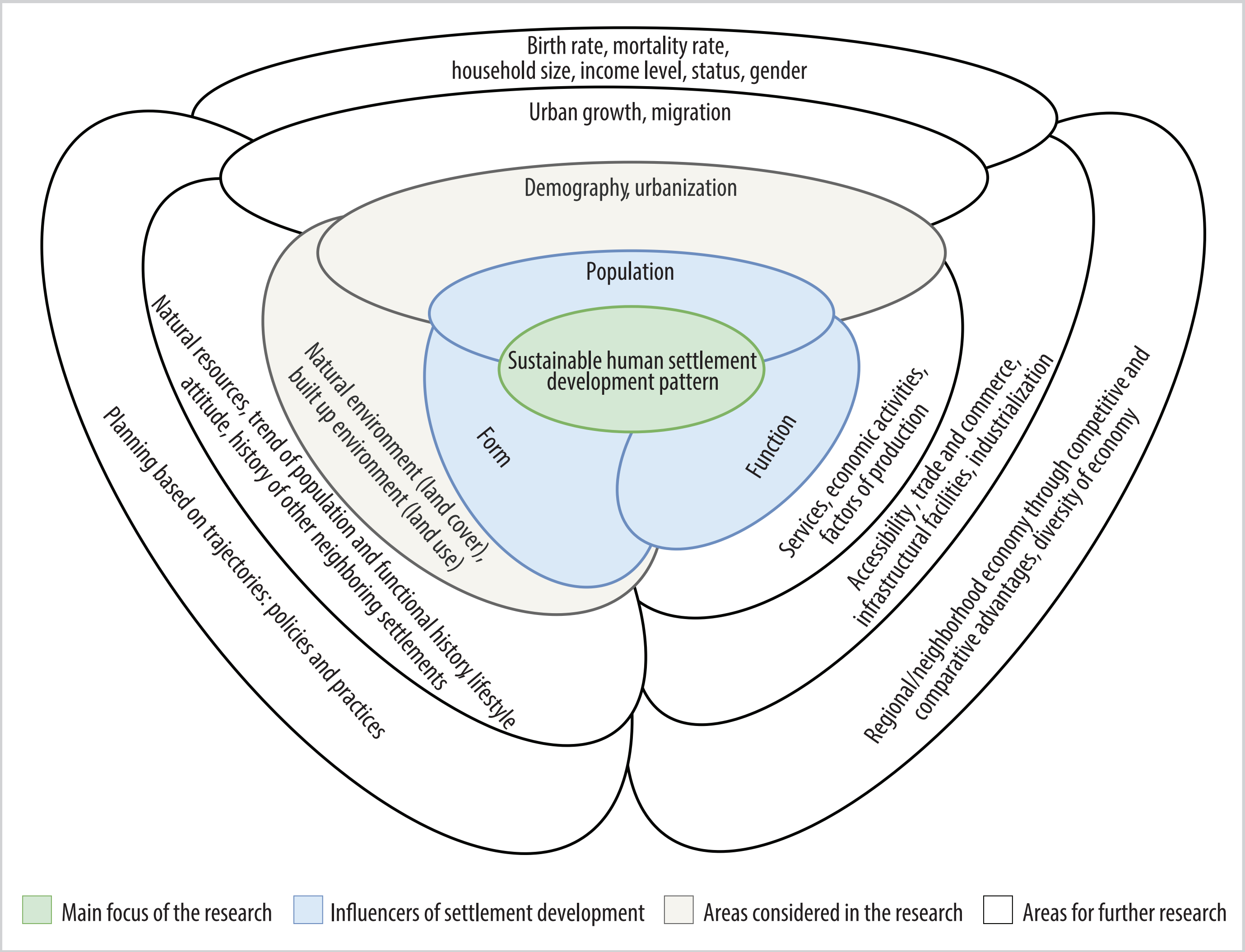
FIGURE 1 Proposed model of a sustainable human settlement development pattern, based on research conducted by Musvoto (2011).



need to be taken into account for sustainable urban development.

Study area

Phuthaditjhaba (28.5530°S; 28.8247°E), at an elevation of about 1600 masl and with a population of 54,661 people and a population density of 2294 people/km^2, is the largest settlement in Maluti-A-Phofung Local Municipality within Thabo Mofutsanyane District in the Free State Province of South Africa (Stats SA 2011). Based on its central function and status as one of the most important settlements within the Drakensberg mountains in Southern Africa (Figure 2), it was selected as a case study site to investigate landscape changes and the urbanization process. These were used to reflect on sustainability options. The Drakensberg mountain range stretches more than 1000 km southwest to northeast from the Eastern Cape Province in the south. It ranges between 200 and 3482 masl. It comprises both urban and rural areas across the region (Bishop et al 2014) and has some of the most fertile land in the Free State Province. It also has considerable potential for tourism development because of its scenic beauty and cultural heritage.

Phuthaditjhaba, the homeland of QwaQwa, became the capital of Bantustan in 1974 until the end of minority rule in 1994, when it became a part of the Free State Province and the headquarters of the Maluti-A-Phofung Local Municipality (Mocwagae 2020). The area has been through sociopolitical changes, which are reflected in land allocation, ownership, and the spatial pattern of the settlement (Delves et al 2021). After 1994, when governance changed from minority to majority rule, and various policies that encouraged land and homeownership were promulgated, built-up land use expanded further along significant roads and peripheral areas of the settlement, mainly where land allocations in such regions were traditionally controlled. The area also hosts the Basotho cultural village, which produces traditional meals and handmade crafts for tourists.

In 2016, South Africa's Council for Scientific Industrial Research (CSIR) characterized Phuthaditjhaba as a service town, where economic and social services dominate the locality. It is among 16 other service towns in the Free State Province (Van et al 2016). Nevertheless, this settlement within the rural municipality of Thabo Mofutsanyane is becoming increasingly urbanized and is referred to as a "rural conurbation" (Chingombe and Taru 2018). This region has a hot midsummer and freezing winter, low

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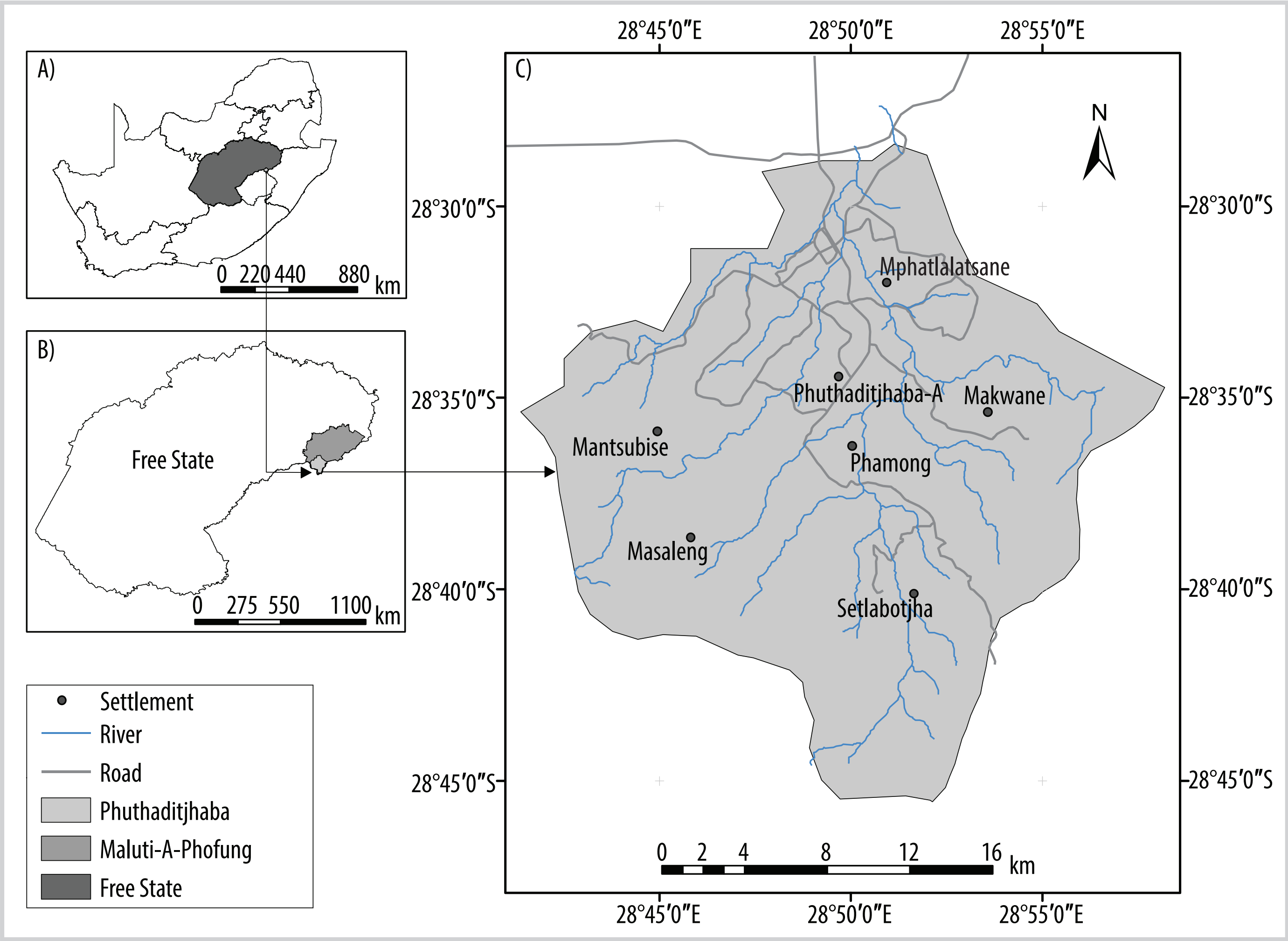
FIGURE 2 Study area location in South Africa showing the Free State Province (A), the Maluti-A-Phofung Local Municipality (B), and Phuthaditjhaba (C).



precipitation, and distinct seasons, with daily mean maximum temperatures fluctuating between 22 and 24°C for the hottest month of January.

Methodology

To monitor LULC changes in the study area, the following years were selected: 1989, 1999, 2009, and 2019. Remote sensing was used, and a pixel-based hybrid method was applied (Tewkesbury et al 2015). Postclassification techniques were then employed to provide a comprehensive matrix for change analysis techniques (Hussain et al 2013; Gómez et al 2016). The following landscape and class metrics were selected for this study: patch density (PD), edge density (ED), fractal dimensional index (FDI), largest patch index (LPI), Shannon diversity index (SHDI), Simpson diversity index (SIDI), percentage of landscape (PLAND), mean patch size (MPS), and cohesion (Aguilera et al 2011; McGarigal 2017).

This method was chosen to analyze the nature and trend of change in the Phuthaditjhaba area, after which the accuracy was assessed based on 2019 images, which provide the latest classification dates. Based on the accuracy assessment of the recent images, the results for the spectra were used to classify the older images. The accuracy analyses of the images of the study area and neighboring settlements by Adepoju and Adelabu (2020) gave overall accuracy and kappa statistics of 0.846 and 0.775, respectively, which validates the results of the accuracy assessment. Figure 3 shows the research methodology flowchart.

Data sources

Three Landsat 4-5 Thermal Mapper (TM) images of the study area from 1989, 1999, and 2009, and one Landsat-8 Operational Land Imager (OLI) image of the study area (190/55) from 2019 were used. The images were obtained from the US Geological Survey retrieved from the Google Earth Engine (GEE) code editor. This was used to sort Landsat image collections to select the best scene with lowest cloud cover from January to March for 1989, 1999, 2009, and 2019 (Table 1). The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model from National Aeronautics and Space Administration Earth data, also accessible on GEE, was used as ancillary data to take care of any misclassification caused by the different illumination effects usually found in mountainous regions (Adagbasa et al 2020).

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FIGURE 3 Research methodology flowchart.

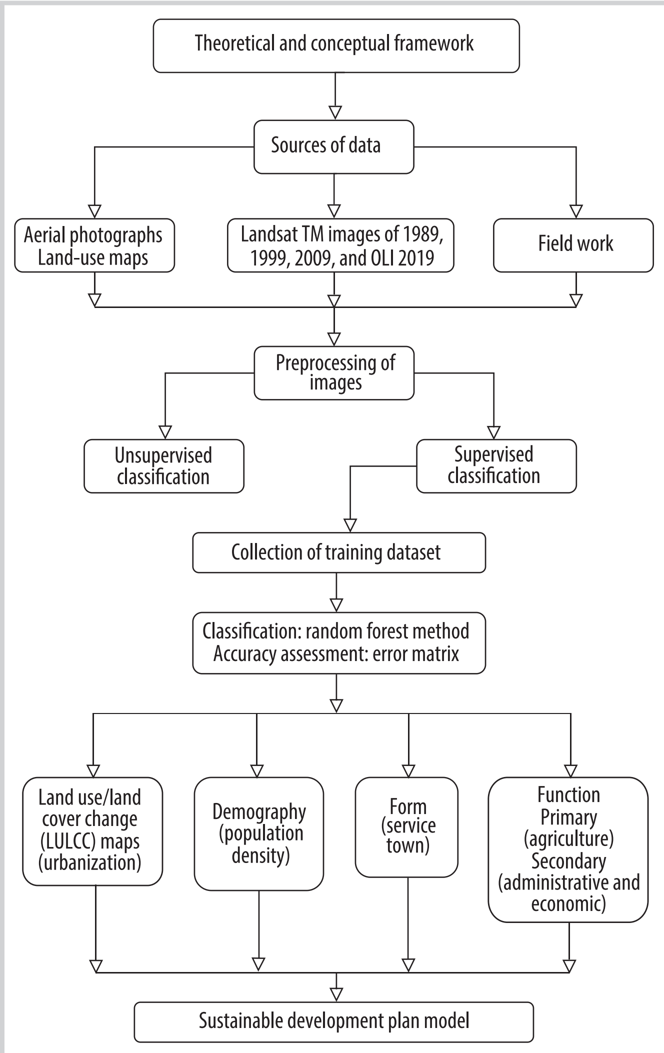

Image processing and classification procedure

Unsupervised classification of images was conducted using ee.Clusterer, an algorithm with enormous computational ability (Xing et al 2021).

Subsequently, supervised classification was done on the unsupervised classified images with the widely used random forest (RF) machine learning classifier on the GEE platform to achieve a higher accuracy (Table 2) (Rodriguez-Galiano et al 2012; Kulkarni and Lowe 2016).

Bands 1, 2, 3, 4, 5, and 7 (TM) and bands 2, 3, 4, 5, 6, and 7 (OLI) of the preprocessed images generated the highest classification accuracy with 10 trees in the RF classifier (Fashae et al 2020). A linear mapping function in the resample module was used for the corrections and validation. The corrected images with a root mean square error range of 0.0095 to 0.010 were uploaded back to the GEE platform for image classification.

Fieldwork

In total, 160 training sites 30 m × 30 m in size were established using stratified random sampling. Forty training sites each were created within the perimeter of 4 prominent clusters produced from the unsupervised classification. These clusters were identified during the fieldwork as 4 major land use classes common to the study area (Table 2).

Cross-validation and accuracy assessment

Clusters with similar land use categories were combined, and the set of 160 samples of spectral signatures was used as a training dataset. The data were randomly split into a training set (70%) to train the RF classifiers and a test set (30%) for cross-validation purposes (Adagbasa et al 2019). The test data were used to validate the classified maps, producing the error matrix accuracy assessment (Tilahun and Teferie 2015). Overall, producer accuracy and user accuracy were obtained from the error matrix in Table 3. The landscape metrics were later computed using FRAGSTATS QGIS 2:18:9 software to generate spatial analysis.

The landscape-level metric was calculated based on the entire landscape, which included all the LULC classes and determined the heterogeneity of the landscape, while the class-level metric was computed based on the patches of each of the 4 land use classes. The level of fragmentation explains the process of contiguous settlement divided into smaller and geometrically more complex units. The PD metric was selected to quantify the features in terms of the density, area, and diversity of each land use class; the percentage of land (PLAND) equals the percentage of landscape composed of the corresponding class patches. Both FDI and ED were selected to analyze the configuration of landscape patterns. At the same time, MPS measured the relative size of urban patches, and, in addition to cohesion, both were selected to estimate characteristics of the size, shape, distribution, fragmentation, aggregation, and connectivity of the landscape in the study area (Dadashpoor et al 2019; Onaolapo et al 2020). The combinations of PLAND, PD, ED, and MPS helped to analyze the landscape fragmentation, while FDI and cohesion helped to determine the landscape's spatial aggregation.

TABLE 1 Sources of data used.

Year of acquisition	Date of acquisition	Sensor	Resolution (m)	Cloud cover (%)
1989	08 March	Landsat 4 TM	30	8.14
1999	26 March	Landsat 5 TM	30	12.55
2009	27 February	Landsat 5 TM	30	0.25
2019	25 February	Landsat 8 OLI	30	0.42

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TABLE 2 Land use and land cover classes.

Class	Class description
1 Built-up	Settlements, anthropogenic structures, and roads
2 Bare surface	Undeveloped, rocks, and grazed land
3 Vegetation	Green spaces, agriculture, forest (trees, bushes, shrubs, and grasses)
4 Water	Streams and rivers, etc

Results

Land use and land cover change

Table 4 reveals the changes in the LULC of Phuthaditjhaba between 1989 and 2019. The built area experienced a notable increase of 270.83% in this period, increasing from 24 km^2 to 89 km^2. This result is evident in the clustering of buildings in and around the town, as revealed in Figure 4. This corresponds to a population density of 2294 people/km^2 in 2011 (Stats SA 2011).

The vegetation decreased from 44.68% to 15.11%, representing a decrease of 66.18% in 30 years (Table 4). Bare surface and water bodies experienced fluctuations within the years under study.

Spatiotemporal pattern analysis

The analysis of the landscape patterns indicated that the PD, ED, FDI, and cohesion metrics significantly changed during the years under study in the whole landscape (Figure 5).

FDI increased from 4.17 to 4.18; this indicates a landscape with no definite topographical dimension. It also indicates that the heterogeneity of the landscape patterns of Phuthaditjhaba tended toward fragmentation more than aggregation, and there was less connectivity between the years 1989 and 1999. With an increase in PD from 15.50 to 21.00 and cohesion from 38.75 to 38.94, and slight fluctuations in ED and FDI in the years after, results show more aggregation in 2009 and 2019 than in the former years under study.

The class-level results of the PD, ED, FDI, cohesion, PLAND, and MPS metrics are shown in Figure 6. At class level, built-up land use reveals an inverse pattern from the landscape level. The PD, cohesion, and ED values increased from 0.92 to 1.09, from 9.79 to 9.84, and from 0.0044 to 0.0072, respectively, between 1989 and 1999. These results mean that built-up land aggregated from 1989 to 1999, while the increase in FDI and increase in cohesion reveal more connectivity in the years after 1999. The additional metrics of PLAND and MPS in the class-level analysis indicate that the percentage of built-up land development continued to increase over the years.

Discussion

Interpretation of LULC change

Findings show an exponential increase in the built-up areas, a decrease in the vegetation, and variations in the results of bare surface and water bodies in the 30 years between 1989 and 2019. Phuthaditjhaba shows urban traits in population growth but is rural in subsistence agriculture and has a low level of basic infrastructural facilities and service delivery (Mashiri et al 2016). Some vegetation (with fertile soil) is being converted to built-up areas, which continue to expand with little control. Most farmers in the local municipality, Maluti-A-Phofung, are older and have low levels of education (Myeni et al 2019). Because of their low levels of income, farmers have limited access to credit facilities. They cannot invest sufficiently in their farming projects, which ultimately results in low crop yields. Production costs are too high to

TABLE 3 Error matrix for accuracy assessment of the study area, Phuthaditjhaba.

Phuthaditjhaba	Settlement				
	Built up	Vegetation	Bare surface	Water	Total
Built up	21	1	1	0	23
Vegetation	0	9	0	0	9
Bare surface	0	0	2	0	2
Water	0	0	0	6	6
Total	21	10	3	6	40
Omission	0	0.11	0.50	0	53
Commission	0.09	0	0	0	
Producer accuracy	1	0.90	0.67	1	
User accuracy	0.91	1	1	1	
Total accuracy	**95%**				

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TABLE 4 Land use and land cover of Phuthaditjhaba between 1989 and 2019.

Class	1989		1999		2009		2019	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Built up	24	5.11	62	13.19	70	14.89	89	18.94
Vegetation	210	44.68	227	48.30	165	35.11	71	15.11
Bare surface	233	49.58	177	37.70	225	47.87	302	64.26
Water	3	0.64	4	0.85	10	2.13	8	1.70
Total	470	100	470	100	470	100	470	100

FIGURE 4 Land use and land cover (LULC) maps of Phuthaditjhaba for the years 1989, 1999, 2009, and 2019.

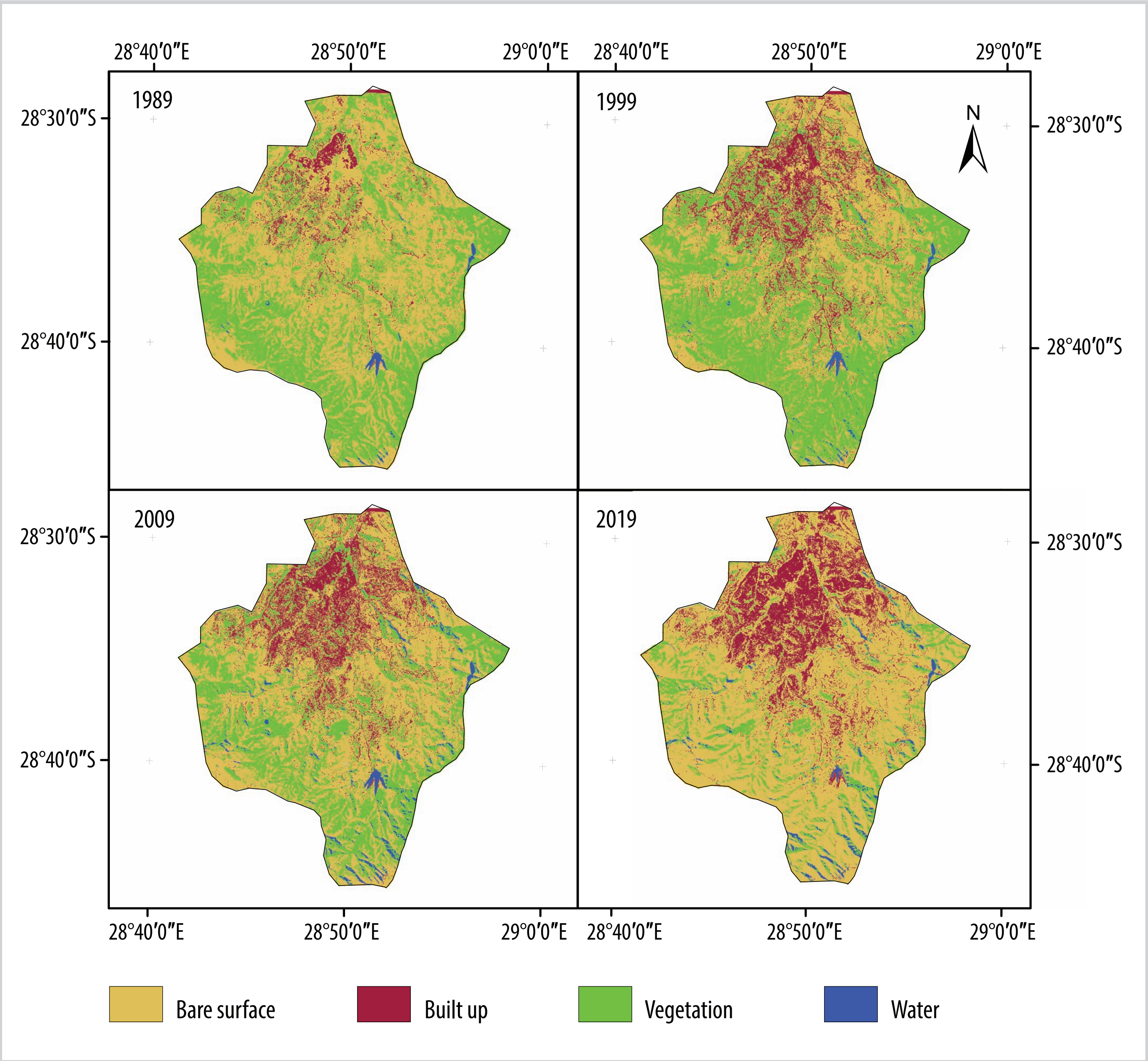

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FIGURE 5 Landscape metrics for Phuthaditjhaba.

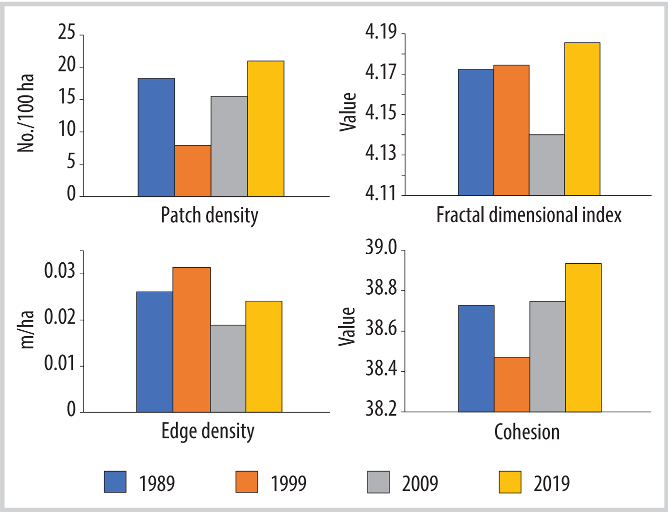
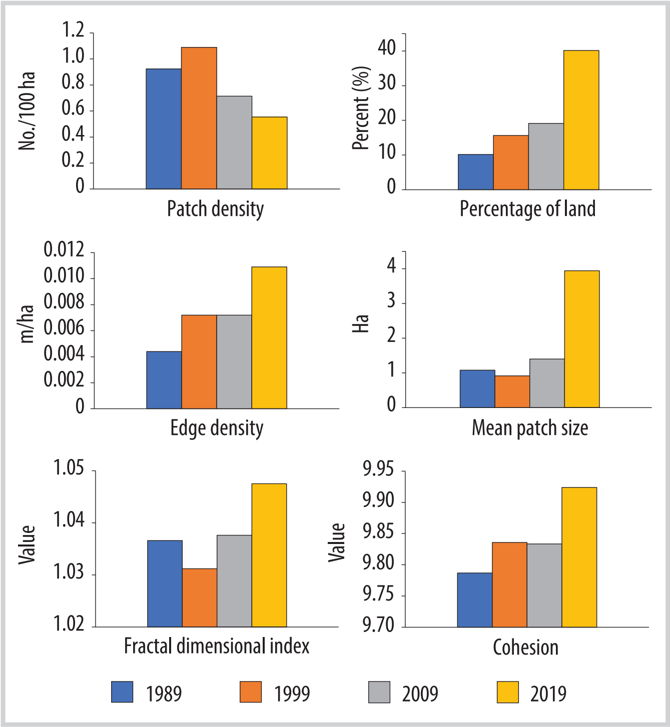


FIGURE 6 Class-level metrics for Phuthaditjhaba.



bear and are exacerbated by poor road networks within the settlement and natural disasters such as fires and drought (Hlongwane 2015; Strydom et al 2015).

Water bodies usually depend on precipitation. As the Free State is an area of low precipitation (Brand et al 2008; Adeola et al 2021), the eastern Free State usually experiences drought, which at times leads to naturally occurring wildfires, especially during summer. These spread without control, burning bush, which takes several years to regenerate (it takes 20 years on average for vegetation to recover to its prefire state). Burned vegetation can be reduced to bare surface before the soil nutrients can return the land to its original stage (Adagbasa et al 2018; Belle et al 2018).

Spatiotemporal patterns

The results of the spatiotemporal analysis reveal that the landscape of Phuthaditjhaba experienced consistent urbanization in the years under study.

The LULC changes in Phuthaditjhaba, a local government headquarters and a center of economic activity in the Drakensberg mountain range in South Africa, show similar urbanization trends as other places in developing mountainous regions in Africa and around the world (Rounsevell et al 2006; Deng et al 2010; Boori et al 2015). These places are usually the seats of government authorities that control economic and other significant activities in the region (Williams and Pradhan 2008).

This trend is in line with the United Nations' assertion that the 21st century is the "urban century." By 2030, half of the global population will be dwelling in urban settlements (Taubenböck et al 2019). One of the major transformations has occurred over the past 30 years, during which areas formerly dominated by agriculture are now being taken over by built-up areas in the form of residential, commercial, and public buildings. The gradual disappearance of vegetation represents an alteration in the ecosystem of the study area, which could become a threat to sustainable development (Nhlapo et al 2011; Delves et al 2021).

Environmental professionals have used landscape metrics extensively in monitoring, planning, and managing land development, as the land use intensity and level of fragmentation are crucial to formulating spatial planning and sustainable development policies (Cervelli et al 2020). A decrease in PD value between 1989 and 1999 revealed that the land use pattern became more fragmented and coarser, and a later increase after 1999 showed less fragmentation toward heterogeneity of landscape and more aggregation again between 2009 and 2019 in the study area. This usually happens because of anthropogenic impact through intense farming or urban sprawl (Frank and Walz 2017).

At the same time, at the land use class level, the values of the PD, cohesion, and ED metrics indicate an increase in aggregation and connectivity in the years under study. As in most developing countries, especially in Africa, where urban development in less urban areas occurred with little government knowledge and management, most of this development happened at the expense of the green spaces (Useni et al 2018).

This study agrees with similar research conducted by Estoque and Murayama (2017) on selected cities of Asia and Africa, where built-up patterns were fragmented between 1990 and 2014, with a prediction that these cities would become aggregated in the years between 2020 and 2030. They discovered the same trend in Lubumbashi, Democratic Republic of the Congo, where increases in the number of patches and percentage of urban growth were directly proportional to the degree of urbanization. There, existing green spaces were eventually replaced by built infrastructures for sociopolitical reasons.

Drivers of change

Some of the main driving forces of urban change dynamics are population increase, change in policy, and biophysical factors. These forces are usually associated with the demand for land for various uses, which in turn have effects on the

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natural environment (Cheruto et al 2016; Bufebo and Elias 2021). The challenges of these forces are felt in land and nature conservation, land use planning and management, and creating a sustainable environment (Ayele et al 2014). The connections between urban dynamics and the aforementioned driving forces are not easily explained, but most literature emphasizes demographic factors as a major contributor (Bufebo and Elias 2021).

In addition, Phuthaditjhaba is the headquarters of Maluti-A-Phofung Local Municipality and performs an administrative function for Thabo Mofutsanyane District. It is midway between 2 important cities in South Africa. These factors have triggered many economic activities, in terms of housing, commercial prospects, transportation, fast food, hotels, and so forth, and led to migration from the rural area. Phuthaditjhaba is the most urbanized area in Maluti-A-Phofung. Maluti-A-Phofung had a population density of 77 people/km^2, while the population of Phuthaditjhaba increased by 1.7% to a population density of about 2294 people/km^2 in 2011 (Lehohla 2015; Denoon-Stevens and Mocwagae 2019). However, population densities of 2102 people/km^2 and 3428 people/km^2 in 2001 and 2021, respectively, reflect rapid population growth (Stats SA 2011, 2021). The presence of government and higher learning institutions could explain the increase in the population (Williams and Pradhan 2008; Barbero-Sierra et al 2013). The impact of the urban growth of Phuthaditjhaba is not just on the physical landscape but also on socioeconomic status and service delivery in the settlement, confirming the central place theory. Maluti-A-Phofung, the local municipality, consistently has a deficit in its budget, with an increase of 10.47% in household number, 11.3% in house ownership, and 4% in electricity usage from 2011 to 2016 (Stats SA 2019).

Though the local municipality should boost the agricultural sector, creating a national target for job creation, of late, the sector has suffered a setback (Stats SA 2019). The department of Rural Development and Land Reform in South Africa has established a few programs (Khan 2021), such as the National Rural Youth Service Corps, that aim to empower youth and combat poverty: The Comprehensive Rural Development Programme (CRDP) aims to acquire and distribute land all over the country, as well as ensure sustained agricultural production and support for small-scale farmers through different initiatives, and the Land Reform Programme restores land rights to the rightful claimants.

Nhlapo (2020) showed that despite the benefits embedded in the policy of the CRDP, delivery of social infrastructure and rural development were still slow among rural dwellers of the eastern Free State. Poverty levels were also high. However, he reiterated the success stories recorded in housing and physical infrastructure delivery by the Reconstruction and Development Programme (RDP) and suggested constant monitoring of the program at a lower level of government (Nhlapo 2020).

Economic factors are a major driver of LULC dynamics (Mansour et al 2020). The University of Free State in Phuthaditjhaba, since its inception in 2003, has continued to draw people from various places. It has both on- and off-campus residences providing different accommodation ranges to students, staff members, and visitors in general, real estate, insurance, finance, and other business services. These have significantly contributed to the local economy of Phuthaditjhaba. The university is one of several drivers of the transformation in Phuthaditjhaba, as shown by various studies (Nhlapo et al 2011; Denoon-Stevens and Mocwagae 2019; Onaolapo et al 2020; Oranje et al 2020). Many government policies, such as the Development Facilitation Act of 1995, permitted all rightful citizens to own land and properties in any part of the country (Bapela and Stoop 2016). The Housing Act of 1997 (GoSa 1997) aimed to enable sustainable housing development, by which people could more easily own land and houses. These policies and others have permitted land and house ownership to an extent and made it easier for land speculators to invest more in housing. One of the shortcomings of this policy is where traditional rulers possess the authority to allocate land at will; field studies show the allocation is not sustainable. Schraven et al (2021) have suggested that different actors such as environmental experts, governments, and citizens need to be involved in urban governance to achieve sustainable urban development.

Having discussed some major driving forces, demographic changes, policy changes, and economics, an in-depth study on urban dynamics from the perspective of LULC, demography, and economics is vital for land use planning, management, and sustainable development.

Model of a sustainable settlement development plan

The "bowl model" (Figure 1) adopted in this research from the study by Musvoto (2011) was used to develop sustainable development plans for urban settlement. With its focus on LULC changes and their driving forces (Bufebo and Elias 2021), the present study provides insights into aspects of population, function, and form proposed by the model. These could be relevant for promoting sustainable development in Phuthaditjhaba.

It is also essential to link these factors to interactions within and outside the territory and at regional scale, that is, to harness the potentials that may not occur within the settlement but are available in other settlements within the region. Finally, the model suggests the need to prepare sustainable settlement development plans based on analytical studies and to promote local economic development (Abrahams 2018). Such strategies must be supported by governmental planning and policies aimed at the less privileged and consider the nature and number of natural resources available. Likewise, local economic development projects should be attached to economic potential and involve relevant stakeholders at the national, provincial, local district, ward, and private-sector international level to achieve progress toward the sustainable development goals.

The government has undertaken efforts in spatial planning to promote local economic development, for example, through the Spatial Planning and Land Use Management Act (GoSA 2013). This enables recognized traditional rulers to allocate land at their discretion within their jurisdiction. However, this gives little or no room for development control (Ogunronbi 2014), and it faces criticism because of the future consequences of indiscriminate and haphazard development, which may cause social problems, environmental damage, and high reconstruction costs (Watermeyer and Phillips 2020). These

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problems could be averted if sustainable settlement development plans are put in place, which will improve residents' quality of life and create affluence for this part of the province, producing wealth through tourism, energy generation, and other potentials.

This plan should include stakeholders in environmental development such as traditional rulers, councilors, government at the local and municipal levels, residents' representatives, and relevant private sector parties. Furthermore, stakeholders like government and community leaders can influence the function performed by a settlement.

The bowl model has been able to explain the function of the study area as both primary (agriculture) and secondary (administrative) forms of a service town, with a population density of 3428 people/km^2 in 2021 (Stats SA 2011, 2021). Further research should explore the demographic data on income level, household status, birth and death rates, immigration, and other data needed to establish the proposed model.

Conclusions

This study analyzed the change in the landscape of Phuthaditjhaba in the Drakensberg mountain range in South Africa based on the 10 year intervals between 1989 and 2019, using remote-sensing data. The study provides insights into settlement development in a mountainous region of South Africa. However, we recommend further studies into the demography and socioeconomic activities of the settlement, especially after the release of the results of the national census of 2022. These are needed in order to better understand the dynamics that lead to changes in this mountain area and reflect on options to prevent increasing bare land cover and loss of fertile land to uncontrolled urbanization. Mountainous regions with fertile land for agriculture have great potential and benefits that could contribute greatly to regional economic growth and sustainable development if adequately harnessed. Monitoring the effectiveness of the Rural Development and Land Reform policy and more in-depth research considering the various aspects of the bowl model of sustainable settlement development are vital in planning, developing, and managing such areas. This can also offer practical solutions and opportunities to manage green spaces, which would be beneficial to human health and environmental wellbeing.

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