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URBAN GROWTH ANALYSIS USING REMOTE SENSING AND GIS TECHNIQUES TO SUPPORT DECISION-MAKING IN ALGERIA—THE CASE OF THE CITY OF SETIF

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Abstract: Rapid urbanization in Algeria is causing significant problems, such as the emergence of unplanned neighborhoods, and local authorities need to apply modern tools like geomatics to monitor and update spatial planning databases to support sustainable development. More to the point, these tools—geographic information systems (GIS) and remote sensing (RS) are of assistance to update the spatial planning and development database so as to support the decision-making. In fact, for understanding the purpose of the process of urban growth in the region of the interior high plateaus, we chose the city of Setif as it represents an urban and economic pole in the region. Besides, economic activities exacerbate the phenomenon of rapid and unplanned urban growth alongside the environmental impact thereof. In the light of the obtained results, there exists a significant increase in urban lands and a significant decline in forests and agricultural lands, as the urban area has tripled from 10.4% in 1985 to 20.3 in 2003 and to 29.7% in 2021. At the same time, the agricultural area has then shrunk from 76.4% in 1985 to 65.8 in 2003 and to 55.5% in 2021, while the forest areas have decreased from 5.04% in 1985 to 4.4 in 2003 and to 2.3% in 2021.

Keywords: urban growth; remote sensing; GIS; land use land cover (LULC) change; support decision-making

1. Introduction

The world's population is increasingly concentrated in urban areas, with more than 55% living in cities in 2018, and this is expected to increase to 68% by 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2018). Besides, urbanization refers to the growth of urban areas at the expense of rural areas, reflecting the reality of this complex change in lifestyles and societal impacts (Kisamba & Li, 2023). In addition, urbanization has shown a rapid increase in the number of people living in urban areas, which can lead to the growth of the existing urban centers (Deribew, 2020). However, urban growth occurs through new residential areas or the regeneration of the old ones (Bhatta, 2010). More importantly, factors such as increasing agricultural productivity and technological change concentrate economic resources in

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urban areas leading to increased migration from rural areas (Cao et al., 2012). Also, many natural and human factors contribute to the complex and dynamic process of urban transformation, which leads to the expansion of urban centers and neighboring suburbs where job opportunities, benefits and educational services are available, and thus amplifies the degree of urbanization (D. Dutta et al., 2020). Moreover, urbanization occurs through strip sprawl, extended wastage, and low-density sprawl, which results in an intermittent pattern of urbanization (Falah et al., 2020).

There is a need to study urban growth and its sustainability. Urban growth and sustainability are important areas in supporting decision-making, particularly in urban planning, poverty reduction, disaster prevention, and environmental protection (Bhatta, 2010). However, rapid urbanization can affect energy consumption, resource use, and water demand, which could cause problems such as water scarcity, environmental pollution, and infrastructure degradation (Koç et al., 2020). Moreover, unplanned urban growth can lead to serious problems, including pollution, epidemic diseases, natural hazards, social inequality, and political instability (Netzband et al., 2007; Songsore, 2017). On the other hand, rapid urban growth can also exceed the capacity of governments, and lead to slum crisis and urban poverty (Liu et al., 2021).

Indeed, remote sensing (RS) techniques and geographic information systems (GIS) are useful tools for studying urban growth and land use, and they can provide accurate data for urban planning and decision-making (S. Dutta & Guchhait, 2022). However, the land use land cover (LULC) change scenario method is one way of analyzing and understanding how human activity affects the physical properties of the land surface over time (Das & Angadi, 2022). These tools can also help identify violations of laws and regulations and support the development of appropriate plans for sustainable urban growth (Geymen & Baz, 2008).

In this regard, RS techniques with GIS can provide powerful tools for analyzing the spatio-temporal and spectral phenomena of land use and changes in land cover at various local, national and international levels (Hassan & Nazem, 2016). Landsat satellite data are often used to monitor changes in land cover. To build a remote sensing application, however, researchers need information about the properties of the data, the region of interest, and the desired outcomes (Fonseca et al., 2009). In addition, the study of LULC change is important for understanding ecosystem interaction and human activities (Kisamba & Li, 2023). On the other hand, it can be analyzed using satellite imagery in a GIS environment (Khan et al., 2021).

In fact, the provision of accurate data for urban planning and decision-making relies on the systems called Spatial Decision Support Systems (SDSS), which are computer-based tools, to provide spatial assistance and advice to support decision-making (Wagner & de Vries, 2019). The SDSS are flexible tools for solving spatial problems through functions for storing, managing, retrieving, analyzing, and presenting spatial data that they provide to decision makers (Armstrong & Densham, 1990). In addition, the PPS Planning Support System relies on a combination of methods and computer models in order to support planning functions, and provides tools, models, and information used for planning (Yeh, 2006).

The problem of urbanization in Algeria (Dechaicha & Alkama, 2021; Dridi et al., 2015), as well as in the city of Setif (S. Belguidoum, 1995; Diafat et al., 2017), include issues such as encroachment on agricultural lands (Boudjenouia et al., 2006, 2008), housing shortage (Diafat & Madani, 2016; Madani & Tacherift, 2010), urban poverty, environmental degradation, pollution, waste management (A. Belguidoum et al., 2022; Harkat et al., 2022; Koucim et al., 2021; Sellami et al., 2022), and traffic jams (Djouani et al., 2022). In addition, urbanization contributes to climate change by increasing temperatures and reducing carbon uptake (Bounoua et al., 2009).

The study's main objective is to analyze and evaluate urban growth and its impact on the environment in the city of Setif from 1985 to 2021, i.e., the period of 36 years, through the use of geomatics techniques (RS and GIS) in particular. Thus, we can make a contribution to support decision-making in the city of Setif, by creating assistance systems to support decision-making. Besides, it could provide urban planners and policymakers with accurate and detailed information to design better urban plans and policies for sustainable development and governance. It should be noted here that it was planned to establish a GIS for the city of Setif several years ago (Ministry of Territorial Planning and the Environment Ministry, Delegate in Charge of the City, 2007; Slimani & Raham, 2009). However, the project has not been implemented yet due to financial and technical difficulties. Based on the above, the following question can be asked: Can modern technologies (RS and GIS) support officials and planners in the Setif region to improve decision-making processes? Can it provide a clear vision of the problems of urbanization and its impact on the environment in the city of Setif?

2. Study area

Setif is located between longitudes 5.34° and 5.51° east of Greenwich, and between latitudes 36.13° and 36.25° north of Equator (National Institute of Maps and Remote Sensing [INCT], 2021), in the High Plateau region in eastern Algeria, as shown in Figure 1. Setif is the administrative center of the Province of Setif, consisting of 60 municipalities.

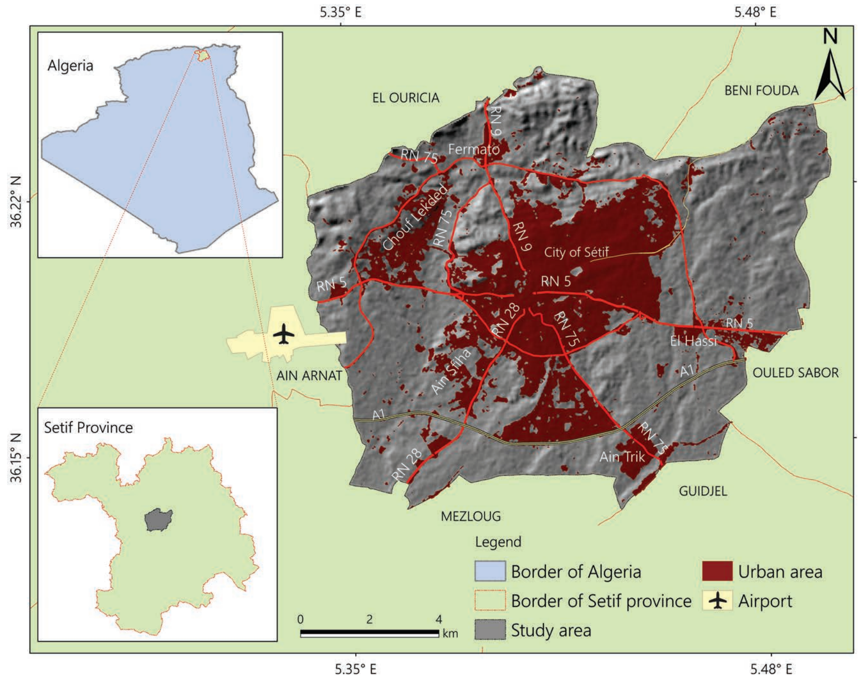

Figure 1. The geographical location of the study area.

Based on the digital data (INCT, 2021) and using the ArcGIS and QGIS it is calculated that the city of Setif area is about 130.99 km^2 (13,098.6 ha). The city of Setif has great geographical and economic importance. It is the economic hub of the province of Setif, and it is considered one of the most important economic centers in eastern Algeria. It is close to the three largest metropolitan cities in Algeria, given that it is located about 267 km from the capital Algiers, 127 km from Constantine, and 285 km from Annaba. Its geographical location is taken as an advantage to make the city a future center for urban growth in Algeria.

It is generally characterized by its flat terrain. There are numerous hills that surround the city from the north and south sides. The city of Setif represents a meeting point for a number of important roads, including: Highway A1 and National Road No. 5 (RN 5) which connect the capital with east and west Algeria, RN 75, RN 9, and RN 28, the national roads that link Setif with the neighboring regions—Bejaia, Jijel, Batna, and M'sila. Moreover, there is a railway which links Setif with the capital and the eastern part of the country. There is also an international airport in the municipality of Ain Arnat, 11 km from the city of Setif. More than 393,966 people live in Setif, according to 2021 estimates, and at the last population census in 2008, it was 287,574 and in 1987 there were 186,642 inhabitants (Office National of Statistics [ONS], 2021).

3. Materials and methods

In this study, the urban expansion in the city of Setif was tracked during a period of 36 years from 1985 to 2021, using the methodology of LULC change, with the aim of studying urban growth, determining the pattern and its environmental impact in the region of Setif.

To reach the results, this process was carried out through stages:

- Collecting data, satellite images, maps and censuses for the study area, i.e., the city of Setif;
- Processing of data and satellite images;
- Classification of satellite images using MLC and classification verification;
- Using two indicators to measure urban growth patterns, the urban direction, and the Shannon entropy, in order to examine if the urban growth is sustainable or urban sprawl (not sustainable). It is sustainable if urban growth is equal in all directions and clustered; and
- Finally, the results were discussed.

3.1. Data and image processing

This study used three Landsat satellite images—1985, 2003, and 2021, obtained from the USGS website archive for the selected area (U.S. Geological Survey, 2021), that is, the city of Setif. For this purpose, images were selected in a time period from February to May, to improve the detection of vegetation and agricultural cover. These satellite images have a spatial resolution of 30 m for the elements used and they are shown in Table 1. The remaining elements, such as clouds and temperature, were excluded. Land use maps in the Setif region were extracted at three different times. The pre-processing and processing of satellite images were carried out through stages. These phases include spatial, spectral, and radiative corrections.

Table 1. Characteristics of used Landsat satellite images

Image	Sensor type	Acquisition Date	Path/raw	Band	Spatial resolution (m)
Landsat 5	TM	30-04-1985	194/35	1-2-3-4-5-7	30
Landsat 7	ETM+	08-04-2003	194/35	1-2-3-4-5-7	30
Landsat 8	OLI/TIRS	01-04-2021	194/35	2-3-4-5-6-7	30

Using QGIS and ArcGIS, the projection was corrected using ground control points, while UTM 31 projection was used for all images. The study area was cropped from satellite images, using the administrative boundaries of the city of Setif obtained from the INCT (2021) of Algiers and all of them were matched against the administrative boundaries available online. For the purpose of verification, the projection of the satellite images was corrected using the ground control points from the field, the Global Positioning System (GPS), and the administrative boundaries of the concerned area. The images were classified using the MLC-supervised classification method to extract land use categories. In addition, the collected ground control points were used to evaluate the classification accuracy of satellite images in this study. Accordingly, the classification accuracy values were acceptable because it was greater than 0.85 (Anderson et al., 1976). In general, the maps that we obtained after the classification of land uses are accurate because we verified them by obtaining land use points from the field and after comparing them with the maps of the National Cartographic Institute, a producer of maps and satellite images in Algeria, which are used in urban planning and environmental management.

After estimating the accuracy of the land use maps of the Setif region for the years 1985, 2003, and 2021, we compared these maps with high-resolution images from different sources, including Google, to see if there was any agreement or disagreement between them and the actual use of the land in reality. The Kappa coefficient values were 0.905, 0.880, and 0.903, respectively, which means that the accuracy of land use classification meets the criteria for the study requirements.

3.2. Supervised classification MLC

Landsat 5, 7, 8 image was used to extract Landsat images for the years 1985, 2003, 2021 in the city of Setif using different variables derived from the images to classify and group different types of land cover. For image processing, QGIS, ArcGIS, and the SCP plug-in (Congedo, 2021) were used to perform image corrections and classification. Administrative boundaries were used to crop the study area from the images. Radiometric correction was used through photo-radiometric calibration by applying a Top of Atmosphere (TOA) type of atmospheric correction (Dechaicha & Alkama, 2021). In addition, the categories of land uses used in the classification were identified. They were used to classify the Landsat images of the study area, i.e. the city of Setif, using the maximum likelihood classification method (Strahler, 1980), which is presented according to the logarithm shown in the Equation 1:

$$\mathrm{gk}(x) = \mathrm{lnp}(c_k) - \ln\left|\Sigma_k\right| - \frac{1}{2}(x - yk)^2 \sum_k^{-1}(x - yk) \tag{1}$$

where c_k is the land cover class *k; x* is the spectral signature vector of a image pixel; p(c_k) is the probability that the correct class c_k ; $|\sum_k|$ is the determinant of the covariance matrix of the data in class c_k ; $|\sum_k^{-1}|$ is the inverse of the covariance matrix; and *yk* is the spectral signature vector of class *k* (Prantl et al., 2017).

Many variables were used in the classification, and thermal ranges, clouds, and spatial resolution were excluded from the spectral variables, and different spectral channels were used to extract information about land cover types as shown in Table 1. True color and false color composite were used. These two tools help highlight and increase the clarity of the phenomena that represent the land cover (Das & Angadi, 2022). In addition, more information about land cover types was extracted using spatial variables such as texture, object analysis, and image-derived indices. Temporal variables have also been used to analyze changes in vegetation cover or to identify the types of land cover that have changed over time.

Classification of these images was done by selecting accurate polygons as training areas (ROI). Five categories were examined: agriculture, forestry, urban land, wasteland, and surface water. Training points are supported by collecting points from the field. Between 25 and 30 field samples were collected for each category of land use during spring of 2020 and 2021. For comparison, high-resolution imagery and Google Maps combined with field data using GPS were used to perform the accuracy assessment. The accuracy of the total classification of images for the years 1985, 2003, and 2021 was 93.68, 91.13, and 93.92%, respectively, which is an acceptable accuracy.

Additional data for the city of Setif, including socio-economic data, were collected from the ONS (2021). Several maps and data were collected for the study area, including: a plan for the city in 2006 at a scale of 1:5,000 consisting of two parts, and a topographical map at a scale of 1:50,000, an aerial image of the city of Setif in the year 2000 (INCT, 2021), and a satellite image of the Algerian satellite Alsat-2A in the year 2011 with a resolution of 2.5 m (Algerian Space Agency, 2018).

3.3. Spatial analysis of urban growth

In this study, spatial and quantitative analysis were used to estimate and evaluate the urban growth patterns of the city of Setif, in order to calculate the urban direction and Shannon entropy. The urban land area analysis (urban area) was carried out using the circle and concentric circles approach, based on the fact that the city expands from the center towards the periphery in a circular manner according to Burgess's theory (Aburas et al., 2018). The urban land cover map was converted into a binary map representing urban and non-urban areas. Urban areas were categorized according to four directions (northeast, southeast, southwest, northwest).

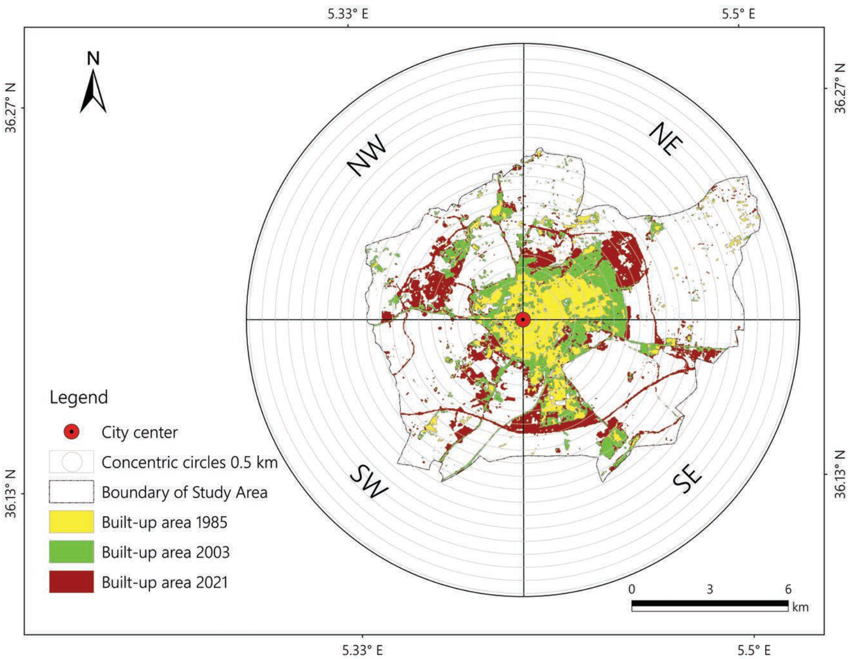

Figure 2. Urban growth by direction and Shannon entropy in the Study area.

To calculate the Shannon entropy (Shannon, 1948), the urban land cover map was transformed into a probability map, where each value represents the probability of being urban or non-urban. The probability map is divided into a grid of equicentric circles with the center in the city. We calculate the Shannon entropy using the following formula (Shannon, 1948):

$$H_n = -\sum_{i=1}^{n} p_i \ln(p_i) \quad (2)$$

where p_i is a percentage of the variable which is the urbanization of i circle (i.e., the percentage of urbanization in each circle/the percentage of urbanization in all circles) and n is the number of circles (i.e., n = 21). Then, based on the results using maps and graphs, we compared urban direction and Shannon entropy to determine patterns of urban growth and change over time.

4. Results and discussion

4.1. Validating classification

In the light of the results extracted from the analysis of satellite images taken during the years of 1985, 2003, and 2021, and through applying the Kappa coefficient and the Confusion Matrix obtained from the classification of the three images, the accuracy level is considered acceptable (Anderson et al., 1976; Sun et al., 2009) as the values were 0.905, 0.880, and 0.903 for the years of 1985, 2003, and 2021, respectively. The confusion matrices have also shown accuracy in the classification of land uses extracted from the images, urbanization, vegetation, agriculture, forests and water, as demonstrated by Table 2.

Table 2. Accuracy of the classification of the three images taken during 1985, 2003 and 2021

Kind of evaluation	1985	2003	2021
Overall accuracy (%)	93.68	91.13	93.92
Urbanized area class precision (%)	91.79	96.28	87.32
Vegetation class accuracy (%)	96.98	91.28	99.16
Bareland class accuracy (%)	92.70	79.60	88.11
Forest class accuracy (%)	90.18	96.96	99.88
Water class accuracy (%)	96.79	92.16	96.88
Kappa coefficient	0.905	0.881	0.903

4.2. Study of changes in LULC 1985–2021

Through the process of classifying the land using the LULC method, results were drawn for the time period extending from 1985 to 2021, whereat maps show a significant growth of the urban area at the expense of vegetation cover and agricultural land, along with a significant deterioration in the environment and the absence of surface water in the studied area, as the city has crawled, particularly in the northeast, southeast, and the northwest regions, as well, through Table 3 and Figure 3 relating to changes in the land cover between 1985 and 2021.

In the period 1985–2003, the spatial expansion of the urban area was conducted in all directions, but not in an even way, as the city grew in the first period at the vicinity of the old fabric, especially the Al-Hidhab neighborhood and the industrial area, with the emergence of nuclei for secondary agglomeration in the suburbs, in respect of Al-Hassi and Ain Trik in the southeast, Chouf Lekdad and Fermato (Cheikh Laifa) in the northwest, and Ain Sfiha in the southwest, whereat it is based along the main roads, National Roads—RN 5, RN 75, RN 9, and RN 28.

Table 3. Changes in the land cover in the city of Setif, between 1985 and 2021

Land	Urban area		Vegetation		Forest		Bareland		Water		Total	
Year	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1985	1,359.58	10.38	10,008.52	76.39	660.42	5.04	1,051.82	8.03	21.29	0.16	13,101.63	100
2003	2,654.26	20.26	8,625.35	65.84	570.31	4.35	1,243.65	9.49	7.6	0.06	13,101.17	100
2021	3,890.73	29.70	7,268.95	55.49	297.56	2.27	1,642.26	12.54	1.68	0.01	13,101.18	100

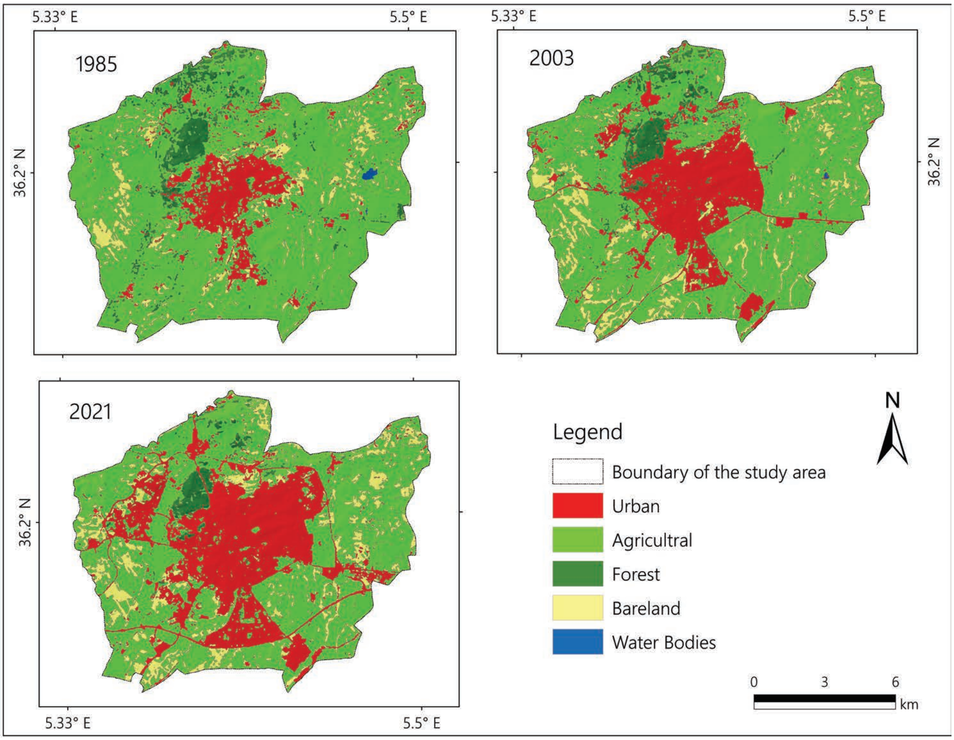

Figure 3. Changes in the land cover in the study area between 1985 and 2021.

In reality, during the second period extending from 2003 to 2021, there was a significant expansion of the built-up area in all directions, with the expansion of the road network and urban secondary agglomeration (suburbs), whereat the urbanization next to the agglomeration Ain Trik exceeded the administrative boundaries of the city, within the administrative ones of the municipality of Guidjel on the southern side. During this period, the urban space increased, the expansion had been carried out at the expense of agricultural land and water sources, and most suburban neighborhoods were unplanned. Besides, we can track the growth in the urban area and changes in the land cover through Table 4.

Table 4. Percentage of changes in LULC in the city of Setif 1985–2021

Period	1985–2003		2003–2021		1985–2021	
Land Use	ha	%	ha	%	ha	%
Urban area	+1,294.68	+9.88	+1,236.47	+9.44	+2,531.15	+19.32
Vegetation	−1,383.17	−10.56	−1,356.4	−10.35	−2,739.57	−20.91
Forest	−90.11	−0.69	−272.75	−2.08	-362.86	−2.77
Bareland	+191.83	+1.46	+398.61	+3.04	+590.44	+4.5
Water	−13.69	−0.1	−7.6	−0.06	−21.29	−0.16

Additionally, there is a great variation in the land cover changes, as the built-up area has significantly increased at the expense of the vegetation cover and agriculture during the periods extending from 1985 to 2003 and from 2003 to 2021. During the period 1985–2003, the urban area increased from 1,359.58 ha to 2,654.26 ha, with an increase of 1,294.68 ha, or 9.88% of the total area, the fact of which represents an annual increase of 71.88 ha. However, with regards to the vegetation cover and agriculture, they witnessed a significant decrease from 10,008.52 ha in 1985 to 8,625.35 ha in 2003, with a loss assessed to 1,383.17 ha, hence representing 10.56% of the total area, with an annual loss assessed to 76.83 ha. More to the point, in terms of the area of small forests, it decreased from 660.42 ha in 1985 to 570.31 ha in 2003, whilst the surface water decreased from 21.29 ha in 1985 to 7.6 ha in 2003.

During the second period extending from 2003 to 2021, the changes in the land cover continued at almost the same pace, as the built-up area increased from 2,654.26 ha in 2003 to 3,890.73 ha in 2021, with an increase of 1,236.47 ha, or 9.45% of the total area, the fact of which represents an annual increase of 68.69 ha. Nonetheless, barelands increased by 398.61 ha with an annual increase of 22.15 ha, whilst the agricultural land, vegetation cover, and water continued to decrease. With regards to the agricultural land as the largest share, it decreased from 8,625 ha in 2003 to 7268.95 ha in 2021, with a decrease of −1,356.4 ha, at a rate of –10.35% with an annual loss of 75.35 ha. More to the point, in terms of the forest area, it decreased from 570.31 ha in 2003 to 297.56 ha in 2021, with a decrease of 272.75 ha, the fact of which represents a loss of 47.8% of the forest area in 2003, whilst the surface water has dramatically shrunk as a result of the drought and excessive consumption.

Undeniably, urban growth has shown to be characterized by two advantages. The first represents the continued urban growth of the main agglomeration of the city of Setif in all directions, but at a stronger pace on the eastern side than on the western side, due to the presence of the valley of Bousselem along with the location obstacles. Secondly, there has been a growth on the road axes and some secondary agglomerations that appeared outside the main urban fabric, whereat the expansion continued in Ain Tarik, Bouaouadja in the southern side on the axis of RN 75, Fermato (Cheikh Laifa), Chouf Lekdad in the northwest side on the axis of RN 09, Al-Hassi in the southeast side on the axis of RN 5, and the university in the western side. As for the remaining area of agricultural land, forests, and water, it is constantly under pressure, as agricultural land is being cut up by continuous expansions and preparation for development. In addition, random construction, principally in secondary agglomeration, constitutes an important part of not planned construction (Belmahdi & Djemili, 2022). Above and beyond, that area is considered arid and lacks water resources, as there is an earthen dam on the eastern side, and it has become semi-arid, in recent years, as a result of drought and indiscriminating exploitation.

Definitely, by use of techniques of geomatics (RS and GIS), along with the LULC method, we were able to extract the changes that occurred in the land cover of the city of Setif over a period of 36 years. During the period extending from 1985 to 2021, the urban expansion that occurred at the expense of vegetation cover, agriculture, and water, was a doubled urbanization from 10% in 1985 to nearly 30% in 2021, as urbanization spread in all directions and secondary agglomeration appeared. Likewise, it has alike begun to expand and surpassed the administrative boundaries in the south, whilst it was crawling toward the administrative boundaries in the west to approach the urban settlement of Ain Arnat. At this place, the expansions extended on the major road axes, RN 5, RN 75, and RN 9, whereat this phenomenon increased the contraction of vegetation cover and agricultural area. The agricultural area decreased by 20% of the total area during 36 years due to the shortage of surface water sources, and these facts are obtainable on the ground. With this pace, the sustainable development of the region, especially with the emergence of many neighborhoods and slums, threatens the enforcement of building and construction laws. More to the point, it also demonstrates the need to implement new planning and management systems based on the use of modern technologies, such as (RS and GIS), so as to monitor and understand the rapid spread of urban lands, and evaluate the effects thereof on the ecosystem, to support the decision-making with regards to the phenomena of urbanization, urban sprawl, and the environmental impact thereof. Thus, it could be concluded that it is not only the city of Setif suffers from this phenomenon, but the same applies for many other regions facing such a problem.

4.3. Urbanization direction

For assessing the purpose of the sustainability of urbanization and the construction areas growth in equal way, we extracted the urban area from the rest of the land uses, and divided the same into four directions, namely NE, SE, SW, and NW, as illustrated in Figure 2. Using GIS and extracting the urban area from the analysis and classification of the three satellite images of the area, we quantitatively estimated the urban dynamism of the city of Setif during the periods of 1985–2003 and 2003–2021, along with measuring urban sprawl across different periods for the same area, and creating a thematic map, which is presented in Figure 2 and 6, and Table 5.

Table 5. Distribution of urban growth by direction in the city of Setif, between 1985 and 2021

Direction	Urban Area (ha)			Change of Urban Area (ha)		
	1985	2003	2021	1985–2003	2003–2021	1985–2021
NE	552.47	955.27	1270.66	402.80	315.39	718.19
NW	185.57	513.34	768.74	327.77	255.40	583.17
SE	452.66	895.15	1270.66	442.50	375.51	818.01
SW	168.89	290.49	555.10	121.60	264.60	386.2

The period extending from 1985 to 2003, as illustrated in Figure 4, shows that the city was more expanded in the SE with 442.50 ha, then in the NW with 402.80 ha, whereat the area represents a natural extension of the city, and there are no major natural obstacles to expansion, as in the Western side of the valley of Bousselem and the forest of Zenadia. Nonetheless, although the urbanization crossed the natural obstacle with an expansion area of

327.77 ha in the NW outside the urban fabric of the city, forming a secondary agglomeration, the lowest rate of expansion was recorded in the southwest side with an area of 121.60 ha, as a result of the presence of the valley of Bousselem as a natural obstacle.

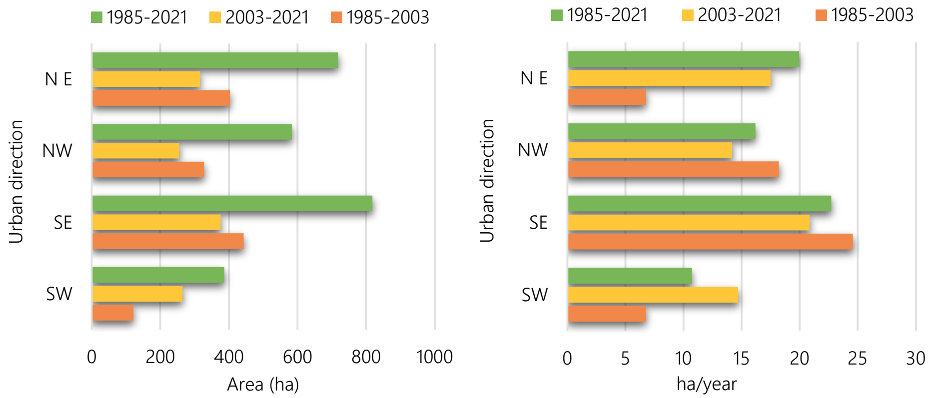

Figure 4. Urban growth rate by direction in the Study area, between the periods of 1985–2021.

In the period extending from 2003 to 2021, the expansion continued in the SE side, but at a rate slower than the one from the previous period, with 375.51 ha, and in the NE side with 315.39 ha. However, the consumed area in the NW side decreased from the previous period, whereat records refer to 255.40 ha, in the presence of site obstacles, whilst it rose in the SW and reached 264.60 ha, as construction took place in the area separating the industrial area from the valley of Bousselem. In general, the first period was more consuming real estate, as a result of rural encroachment in that period to benefit from the services provided by the city, along with the poor infrastructure in the countryside.

4.4. Shannon entropy and urban areas (concentration–dispersion)

The Shannon entropy method was applied in the study area, the city of Setif, as an effective tool for measuring and evaluating the quality of urban growth in terms of concentration or dispersion. The relative and absolute Shannon values were calculated. The absolute Shannon entropy is calculated by Equation (2), while the relative Shannon entropy is calculated by dividing the absolute Shannon entropy by $\ln(n)$, $n = 21$ being the number of regions (concentric circles). The study area, i.e., the city of Setif, was divided into concentric circles representing the regions $n = 21$, the circles start from the city center, and the distance between two circles is 0.5 km as shown in Figure 2.

Shannon's absolute entropy values range between 0 and $\ln(n)$ (i.e., 3.04). If the entropy value approaches zero, it means that urban areas are highly concentrated, that is, compact, when the entropy value approaches $\ln(n)$, urban areas are highly dispersed. When the relative Shannon entropy ranges from 0 to 1, the value of 0 means agglomerated urbanization, while values around 1 mean dispersed urbanization (Al-Sharif et al., 2013; Bhatta, 2010).

The analysis results show that the entropy values are higher than the middle point of $\ln(n)$, i.e., 1.54. The value decreased from 2.39 in 1985 to 2.21 in 2003 and rose again in 2021 to 2.52. While the relative Shannon entropy values were 0.79 in 1985 and decreased to 0.73 in 2003, they increased to 0.83 in 2021.

The results show that the city of Setif is always a sprawling city, and here the middle of ln(*n*) is the threshold in our case, the number 1.54. If the value exceeds the mean, it is considered a sprawling city. In addition, regular and non-regulated urbanization is taking place in the main center of Setif with the secondary centers of El-Hassi, Chouf Lekded, Fermato (Cheikh Laifa), and Ain Sfiha. In fact, unplanned urban expansion increases urban dispersion. As a result, Shannon's entropy indicates the occurrence of urban sprawl, and this phenomenon increases the excessive consumption of land and the heterogeneity of land use.

Our results are consistent with several previous studies that explored the impact of urban growth on the environment using RS, GIS, and LULC methods. For example, Hassan and Nazem (2016) used GIS and LULC to study the urbanization of Chittagong, Bangladesh, from 1977 to 2013. The results indicated that the built-up area increased by 618%, and the annual rate of increase was 17.5%. The agricultural area has shrunk by 2,178 ha, and the remaining agricultural hills close to the built-up area face serious threats of further encroachment and deterioration. Additionally, Deribew (2020) used GIS, RS, Shannon entropy, and LULC to follow urban growth trends and their effects on vegetation and agricultural land in Sebeta-Awas, Ethiopia. From 1986–2019, the study area experienced intense urban sprawl. Annual urban growth rates of 1.2% in 1986, 5.5% in 2002, and 15% in 2019 were recorded. The expansion was in agricultural land (25.48%) and forest land (16.6%). This led to the acceleration of deforestation and the reduction of rural agricultural land. The entropy index increased from 0.02 in 1986 to 0.996 in 2019, indicating that the urban growth is more dispersed to the periphery. Also, Dridi et al. (2015) concluded that the city of Batna significantly increased in the urban area between 1972 and 2013. Dechaicha and Alkama (2021) confirm the increase in the urban area of Bou-Saada from 1984–2020 by more than 470 ha and the loss of 47 ha of palm oases. Finally, the results of the study carried out by Al-Sharif et al. (2013), showed that urban growth in Tripoli increased significantly from 1984 to 2010 with the dispersion of urban expansion.

5. Conclusion

In the light of this study in which RS and GIS systems were used, changes in the land cover in the city of Setif were determined using the LULC methodology according to the supervised classification. Comparisons were also made between land uses during the analysis of images for three different years—1985, 2003, and 2021. Through studying the changes in the land cover of the city of Setif, the continuous and rapid expansion of the urban area emerged at the expense of vegetation, agriculture, and forests. However, in 1985, the results indicated that urban lands accounted for 10.4%, agricultural lands accounted for 76.4%, forests accounted for 5.04%, barren lands accounted for 8.03%, whilst water accounted for 0.16%. In 2002, the proportion of urban lands rose to 20.26%, which almost doubled, and the barren land increased to 9.5%, whilst the remaining uses witnessed a decrease, as agricultural land reached 65.8%, forests 4.4%, and water 0.06%. Nevertheless, the urbanization rate increased in 2021 to 29.7%, and the barren lands reached 12.53%, whilst the decline continued in the remaining uses, as the percentage of the agricultural lands recorded 55.5% and forests attained 2.3%; as for water, it was almost non-existent. Moreover, statistical records show that the population of Setif doubled in 34 years, from 211,859 in 1987 to 393,966 in 2021.

In addition, the urbanization direction shows that the city of Setif is not growing evenly in all directions. While the Shannon entropy index showed that the city of Setif is experiencing urban sprawl significantly, at a rate of 0.83 out of 1 in 2021, which means a dispersion of the built-up area and a waste of land consumption.

In conclusion, the use of RS and GIS for a clearer understanding of this phenomenon helps in making appropriate planning decisions. Similarly, the use of multiple time-lapse satellite images is of great help in monitoring changes in land cover, along with analyzing the spatial dynamics of urban environments and their impact on the environment. However, several significant limitations exist in using RS and GIS for tracking urban growth and making decisions. Some of these include availability, quality, accuracy and interpretation of the data, and how to use it. Additionally, urban systems are very complex. To avoid these limitations, other sources, such as census data and field outputs, should be used to provide a comprehensive understanding of urban growth.

Nevertheless, remote sensing and GIS provide valuable information and insights for tracking urban growth and making decisions. Geomatics also allows to follow the spatial evolution and identify the current and future trends of land uses in cities, including the city of Setif, as effective tools in the urban management of such cities. Based on the results obtained using LULC to understand the size and trends of any urban development clearly, this study can make a future projection for using a model based on a simulation of the urban growth of the city of Setif in the medium and long term.

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