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AGRICULTURAL OASIS EXPANSION AND URBAN GROWTH IN TOLGA SOUTHEASTERN ALGERIA: A GEOSPATIAL STUDY

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ABSTRACT

The assessment of land use and land cover (LULC) changes is crucial to understanding its impacts on the natural environment and resources. The dynamics of LULC might be a result of national legislation or unplanned development. This study utilizes remote sensing data to evaluate the LULC in Tolga Oasis resulting from the promulgation of agricultural development law in 1983. Four Landsat images from 1985, 2000, 2015, and 2023 were classified using the Support Vector Machine (SVM) and ArcGIS Pro software. The findings showed a continuous change in the built-up area and vegetation area. The increase in built-up area was in conjunction with the rise in vegetation area. A spatial direction approach and concentric circle approach were used to assess the change in each direction and to identify the zone experiencing the most change in the built-up and agricultural oasis expansion. Shannon's entropy model was used to measure the dispersion and the compactness of urban growth. The overall outcomes revealed that all directions showed an increase in built-up and vegetation area. Total Shannon's entropy values showed compact urban growth in 1985, while, a dispersed development was recorded in 2000, 2015, and 2023. Statistical analysis demonstrated a high correlation between date palm plantations and vegetation area by 0,928%, as well as a significant correlation between built-up areas and population growth by 0,926%. These results can be helpful for the local authorities and planners in order to make a sustainable urban development and protect the fragile oasis ecosystem.

KEYWORDS

Agricultural Oasis Expansion, Urban Growth, Landsat Images, Support Vector Machine, Quantitative Analysis, Statistical Analysis

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Introduction.

The arid and semi-arid lands cover more than 80% of the Middle East and North Africa (MENA) region. It extends from the Arabian Gulf to the Atlantic Ocean. Since the discovery of oil, in 1950, this region has experienced a radical economic transformation. Oil and gas have become the primary financial resources. These resources have improved living conditions and increased per-capita income. Because these resources are non-renewable (Chevalier & Geoffron, 2016), these countries are compelled to find other alternatives to ensure their economic stability and food security. Agricultural development is one of the biggest challenges in the MENA region. The reclamation of arid lands requires access to water resources. Most of these countries suffer from precipitation scarcity and thus lack surface water. Groundwater has become the primary and almost the only resource of irrigation and the growing population needs. In developing countries, the economy and food security depend on small-scale rural agriculture (Anandajayasekeram, 2008). To meet the needs of the growing population, China reclaimed arid and semi-arid lands from natural vegetation to agricultural oasis by using fertilizers and groundwater resources (Bai et al., 2014).

The expansion of oasis agriculture is known as oasification. This process is a result of human activities, political policies, and climate change (Song & Zhang, 2015; Xie et al., 2015). Agricultural oasis is related to irrigated cultivated lands in arid and semi-arid lands utilizing surface or groundwater (Bai et al., 2014). This phenomenon is observed globally, particularly in China. Oasification is the decrease or increase of the oasis boundaries over time, influenced by natural or human factors, or both (Martínez-Valderrama et al., 2023; Xue et al., 2019). Usually, oasification is associated with the opposite process, which is desertification. The latter results from several causes: natural factors such as climate change, water scarcity, soil salinization, and anthropogenic causes like urban expansion, wastewater, and industrial activities (Rubio *et al.*, 2007).

The presence of water resources, fertile soil, and human effort are the main factors contributed to the emergence of an oasis (Knight et al., 2023). An oasis is defined as an area that is completely different from its dry outer surroundings (Charles Riou, 1990; Hong et al., 2003). In North Africa, Oases cover around 4,124.82 Km² (FAOSATA 2022). However, this area can vary according to climate conditions and human activities. These oases are located in arid and hyper-arid areas of the Sahara. Oases are the core of Saharan urbanization; they were essential nodes in caravan routes and landmarks for crossings of the Sahara (Alkama, 2005). The existence of the Saharan oasis and its agro-system is conditioned by the presence of water which is the main factor that determines its size (Ait Khandouch, 2000; Dubost, 1992; Lasram, 1990). (Abou Zaki et al., 2022) used the water consumption rate and agricultural expansion water demand index to categorize MENA and Asian countries according to their sustainability in water use. The results have shown that Algeria is among the 12 countries that may achieve sustainability in agricultural expansion, but this does not negate that it is not among the areas most vulnerable to water scarcity.

In Algeria, the oasis is the fundamental ecosystem of the Sahara, defined by a balanced relationship among three elements: water, palm grove, and built-up area (Ahriz et al., 2019). The date palm is the cornerstone of this ecosystem (Bouzaher & Alkama, 2013).

In the early 1980s, Algeria witnessed the issuance of Law (APFA- 83), related to access to agricultural land ownership. Citizens were granted previously uncultivated plots of land to reclaim and cultivate (Bedrani, 1987; Hamamouche et al., 2018), with the aim of organizing rural areas and reducing rural exodus on one hand, and promoting commercial export production on the other hand (Hamamouche et al., 2015; Khiari, 2018).

The oases' entry into the market economy was one of the reasons they became strategic areas in arid and semi-arid zones. The oases have witnessed many changes depending on their location and types. (Knight et al., 2023) have summarised the causes of oases changes as follows: political changes such as the cultural revolution in China, economic changes which are related to the expansion of irrigated lands such as seen in Algerian and Tunisian oases, that rely on pumping groundwater, social changes relevant to emigration and arrival of investors, cultural changes concerning the promotion of oases heritage to encourage oasian tourism, and environmental changes, which may be caused by urban growth.

Date palms are the primary economic source for people living in oases across the Middle East and North Africa. They are considered among the oldest fruits cultivated in this region. In North Africa, particularly in Algeria and Tunisia, the oases produce Daglet Noor (DN) dates, recognized globally as one of the finest varieties. The demand for these high-quality dates continues to grow annually. In Algeria, the plantation of date palms increases each year to meet the local and global demand. In this context, local authorities have decided to increase productivity by planting one million palms, bringing the total number of palm trees to more than 20 million (MADR, 2021).

Algeria is ranked third in date production in the world after Egypt and the Kingdom of Saudi Arabia (FAO, 2023). In the arid lands of the MENA region, date palms play a crucial role in the economic and social stability of Oasian society (Bouzaher & Alkama, 2013).

Globally, based on previous studies (Song & Zhang, 2015) have classified the oasis changes into four aspects: assessment of land use in oasis agricultural region, highlighting the relationship between agricultural oasis change and water resources, measuring of the ecological effect of oasis agricultural change, and examining the appropriate scale for oasis agriculture.

Currently, regional and local oases are undergoing changes caused by climate change, with a significant temperature rise was recorded and a decrease in rainfall, which may affect agricultural lands and water resources, threatening the food security of these countries (Amouzay et al., 2023; Hamed et al., 2024).

Simultaneously, uncontrolled urban growth is a serious challenge facing the Oases cities (Dechaicha & Alkama, 2020; Hadji & Petrişor, 2024; Yagoub et al., 2023). This phenomenon has many impacts, including the potential loss of agricultural lands, deforestation, loss of vegetation especially palm trees, and the increase in desertification. According to the (UN, 2018) by 2050, 83 % of the world's population is expected to live in less developed countries. This is due to the high rate of population growth, with Africa ranking first in urban population growth at 3.44% (UN-Habitat, 2022).

Oasis cities are not exempt from this phenomenon. In the Algerian Sahara, more than 70% of the population lives in urban areas (Kouzmine & Fontaine, 2018). As the Saharan population grows, oasis cities expand to accommodate the increase, leading to urban growth that surpasses their established boundaries.

Oases are fragile and more vulnerable due to the surrounding dry and harsh environment, and the scarcity of natural resources. Urban growth may lead to irreversible changes and negative repercussions in these areas. In this regard, it became necessary to periodically assess and monitor LULC in these areas, especially since traditional mapping techniques are time-consuming and uneconomical (Mohabey et al., 2023). Therefore, understanding the dynamics of LULC and its driving forces is essential. This will help decision-makers to create appropriate policies to manage LULC in these fragile areas, as well as the preservation of its palm groves.

Remote sensing and GIS (RS and GIS) have become increasingly used in several fields. RS and GIS are highly efficient in urban studies: assessment and monitoring LULC, infrastructure development, predicting urban sprawl, and understanding urban growth patterns (Al-sharif & Pradhan, 2016; Din & Yamamoto, 2024; Kyriou et al., 2023; Sahana et al., 2018). In environmental and ecological studies, RS and GIS play an important role in assessing land degradation, air quality, habitat loss, desertification, and oasification as well as the impact of urbanization on natural resources (Al-Alola et al., 2022; Amrouni et al., 2022).). In addition, RS and GIS are important in managing socio-economic data: demographic distribution, service accessibility, and economic activities (Bendib, 2024; Huang et al., 2024; Luqman & Khan, 2021). Urban growth can be measured according to its concentration or dispersion. Shannon's entropy which is a mathematic equation is widely used with RS and GIS techniques to measure the intensity of urban growth.

Numerous studies have used Landsat images to assess the LULC in oases environments. (Rodríguez-Caballero et al., 2017) highlighted the correlation between access to groundwater and the development of agricultural oases. The results of the study showed a gradual expansion of irrigated agricultural oases and built-up areas. (Al-Kindi et al., 2023; Karmaoui et al., 2023) found that the decrease in oases vegetation is the result of groundwater depletion, caused by its previous overuse. (Chouari, 2024; Mansour et al., 2022) and the studies mentioned previously emphasized that population growth and the rising demand for housing and services have consistently been among the primary causes of agricultural land loss, degradation of the oasis ecosystem, and the acceleration of desertification in these fragile areas.

The incorporation of GIS techniques such as the spatial direction approach and the concentric circle approach with remote sensing data are more valuable in monitoring and assessing the changes in LULC.

The present study aims to assess, quantify, and identify the LULC changes in the Tolga Oasis over the period, from 1985 to 2023. The starting date was chosen to understand the impact of the (APFA- 83) law promulgated in 1983 on LULC dynamics accurately. Landsat images were used to generate land use maps and assess LULC change. A quantitative method was adopted, using the spatial direction approach and concentric circles approach to understand in-depth agricultural oasis expansion and urban growth. This study is the first to use these techniques in the study area. The findings are effective in the management, monitoring, and controlling of urban growth, as well as the protection of the oasis.

Materials and Methods.

Figure 2 represents a flowchart of the research method used in this study.

Study Area.

The Study area, Tolga (34° 20′ 00″ N to 35° 00′ 00″N and 5° 50′ 00″ E to 5° 30′ 00″ E) is one of the greatest oases in the Algerian Sahara and North Africa. Geographically, it is located in the western part of the Ziban region in the southeast of Algeria, along the national road N46 leading to the capital, Algiers. It is known as the *gateway of the desert* because of its location under Sharan Atlas Mountain. The study area is divided into five administrative districts: Tolga city, Borj Ben Azzouz (BBA), Lichana, Bouchagroune and Foughala. It is characterized by a hot and dry climate with scarcity of rainfall, averaging 126mm annually (Matallah et al., 2021). The region benefits from an important groundwater reservoir, which has enabled it to develop its agricultural sector (Masmoudi et al., 2024), especially date palm plantation.

The study area consists of a series of neighbouring oases whose origins date back to the Numidian period. Date palm cultivation and trade are the region's inhabitants' oldest activity, with the high quality of its dates being a defining characteristic.

The region has transformed with the promulgation of the law on access to agricultural land ownership (APFA-1983). This law aims to enhance the agricultural sector in the Saharan and steppe regions by granting private plots of uncultivated land with access to groundwater, provided that the land is used for agricultural purposes. As a result, the area has attracted investors and workers from nearby cities and even further wilayas. Remarkable growth has been recorded due to the region's economic appeal and the development of the secondary and tertiary sectors. Currently, the study area has become a leader in date production, particularly the Daglet Noor (DN) variety. This agricultural oasis expansion has been accompanied by population growth and a notable urban growth.

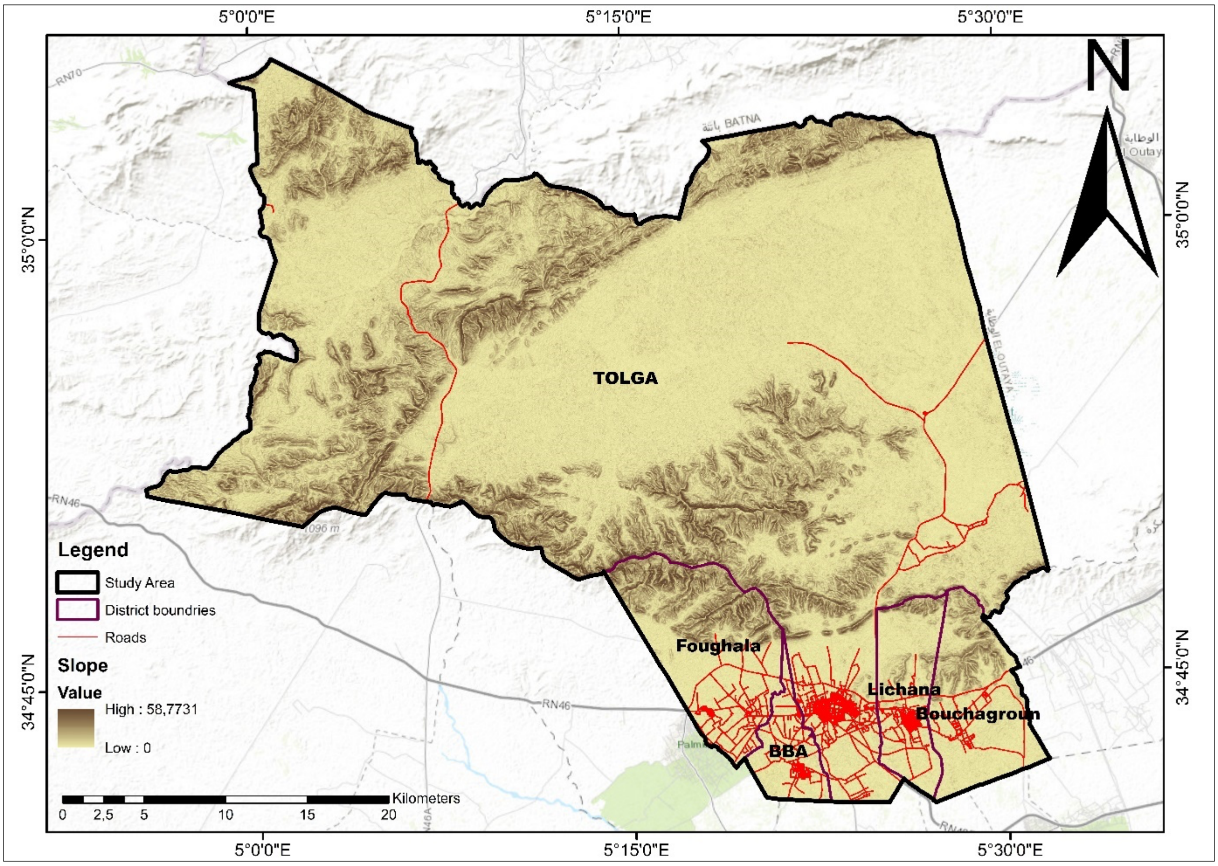

Fig.1 Overview of the study area

Data Acquisition.

Four Satellite images from the USGS Earth Explorer were used to analyse the LULC dynamics in the study area: (1) Landsat 5 TM acquired in1985, (2) Landsat 7 ETM+ acquired in 2000, (3) Landsat 8 OLI acquired in 2015, and (4) Landsat 8 OLI acquired in 2023. All images have less than 1% cloud cover (CC), and a spatial resolution of 30 m.

Socioeconomic data (Population data and date palm data) were collected from various local sources, such as census centres, monographs, and the Ministry of Agriculture and Rural Development.

Pre-processing Data.

The pre-processing of Landsat images aims to get a reliable output that helps decision-makers in analysing and monitoring the LULC. The acquired images are pre-georeferenced and were projected to the UTM zone 31 North using the datum of WGS 1984. A radiometric correction was applied to standardise the spectral characteristics of the images. We used a radiometric calibration to remove atmospheric aerosols, calibrating the images to the top of atmosphere TOA reflectance and converting the pixel digital number of the images to normalize the spectral signature. Finally, we selected appropriate multispectral bands to generate a comprehensive dataset suitable for LULC dynamics analysis.

Image Classification and Accuracy Assessment.

Commonly, there are two types of satellite image classification: the unsupervised method, and the supervised method. In the first method, image classification is done automatically without the need for prior knowledge or training data. It depends on the spectral signature of the pixels, and the identification of the number of classes. This method is considered easy and useful when there is a piece of limited information about the study area. In the second method, supervised classification depends on prior knowledge of the study area. It is based on training data, where the users select representative samples for each class. These samples are then grouped and identified as a single class and used to learn the classification algorithm for the spectral characteristics of each class. As a result, in supervised classification, the outputs are more accurate and reliable.

There are many methods used in supervised classification: Maximum Likelihood Classification (MLC), Support Vector Machine (SVM), and Random Forest (RF). In this research, we have employed (SVM). Compared to other popular methods, the support vector machine is considered a reliable technique in supervised classification, thanks to its ability to provide more accurate outputs from highly spectral data (Tamirat et al., 2023; Yousefi et al., 2022). We used ArcGIS Pro to classify the images into four classes: built-up (urban area, roads, habitation...), Vegetation (date palm, and seasonal yields), Water Body (Sabkha and surplus of oasis irrigation), and bare land (bare soil, reliefs, and barren area). Post-processing was applied to eliminate the isolated pixels by using smoothing and filtering tools. For the accuracy assessment, 250 random ground points were used to calculate the producer accuracy, overall accuracy, and kappa coefficient by using referenced dataset and historical Google Earth images (Hasnine & Rukhsana, 2023; Wilson & Wilson, 2016).

Urban Growth and Oasis Agricultural Expansion Based on The Spatial Direction Approach.

The spatial direction approach is a useful method for understanding the patterns and dynamics of LULC. This method is widely used in urban studies to assess how built-up areas develop over time and space .It helps planners, geographers, and policymakers in identifying urban growth trends by dividing the case study into several directions according to the needs of the study (Badapalli et al., 2024). Before dividing the direction, it is crucial to identify the Central Business District (CBD) which is the historical and important centre business hub. In this regard, and to understand the impact of agricultural policy in the development of built-up areas and palm groves in Tolga Oasis, we used the spatial direction approach to assess the development of both of them (figure 3). Tolga Oasis was divided into eight directions: North (N), Northeast (NE), east (E), southeast (SE), south (S), southwestern (SW), western (W), and Northwestern (NW). The agricultural oasis expansion (date palm plantation and seasonal yields) was quantified in each of these eight directions. For more understanding of agricultural oasis expansion dynamics, we combined the agricultural oasis growth values with date palm statistical data to extract the relationship between them. A quantification of the built-up area in the eight selected directions was calculated to measure the urban growth and to understand where the urban areas are expanding uniformly.

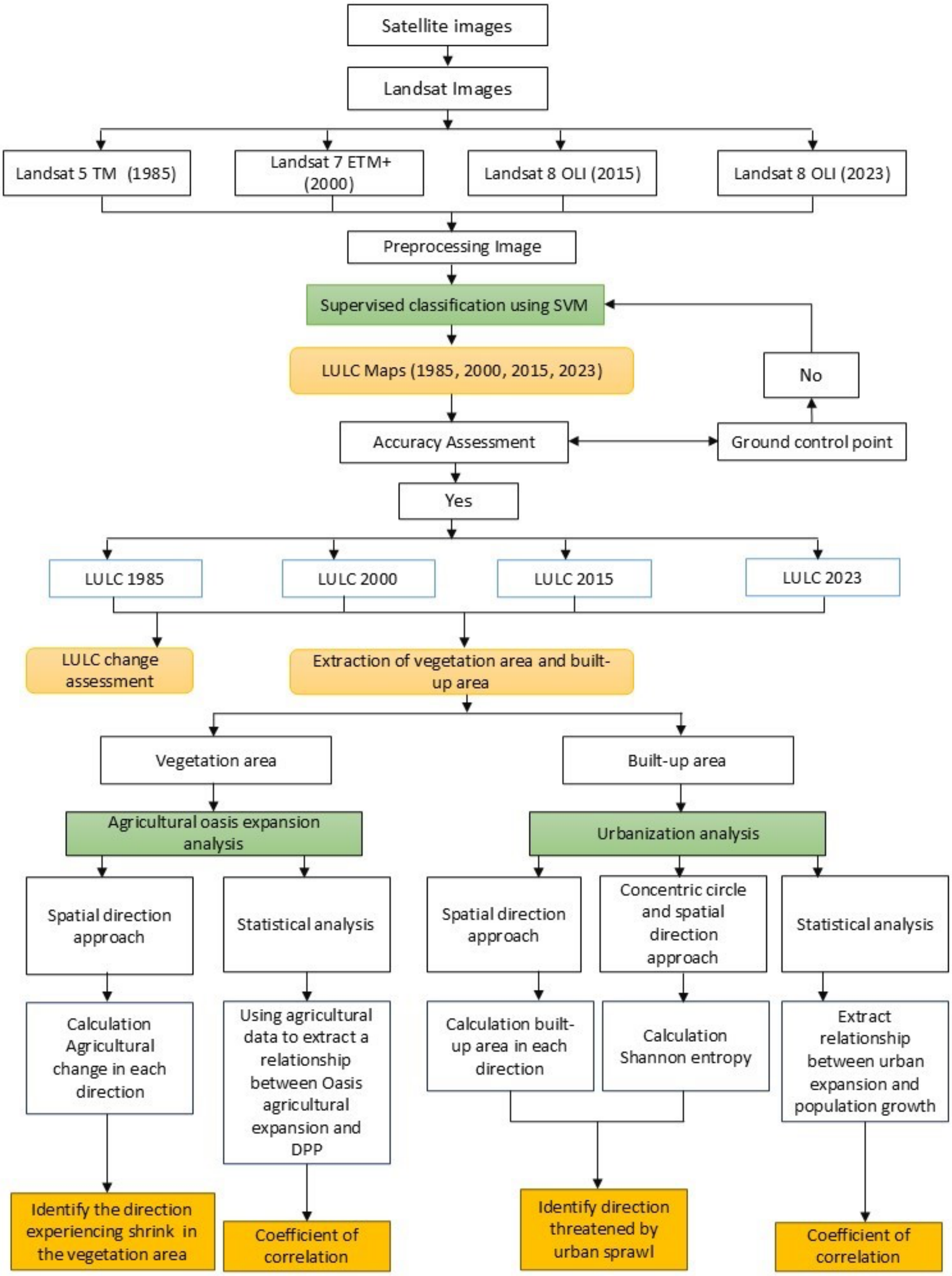

Fig.2. Flowchart representing the research method

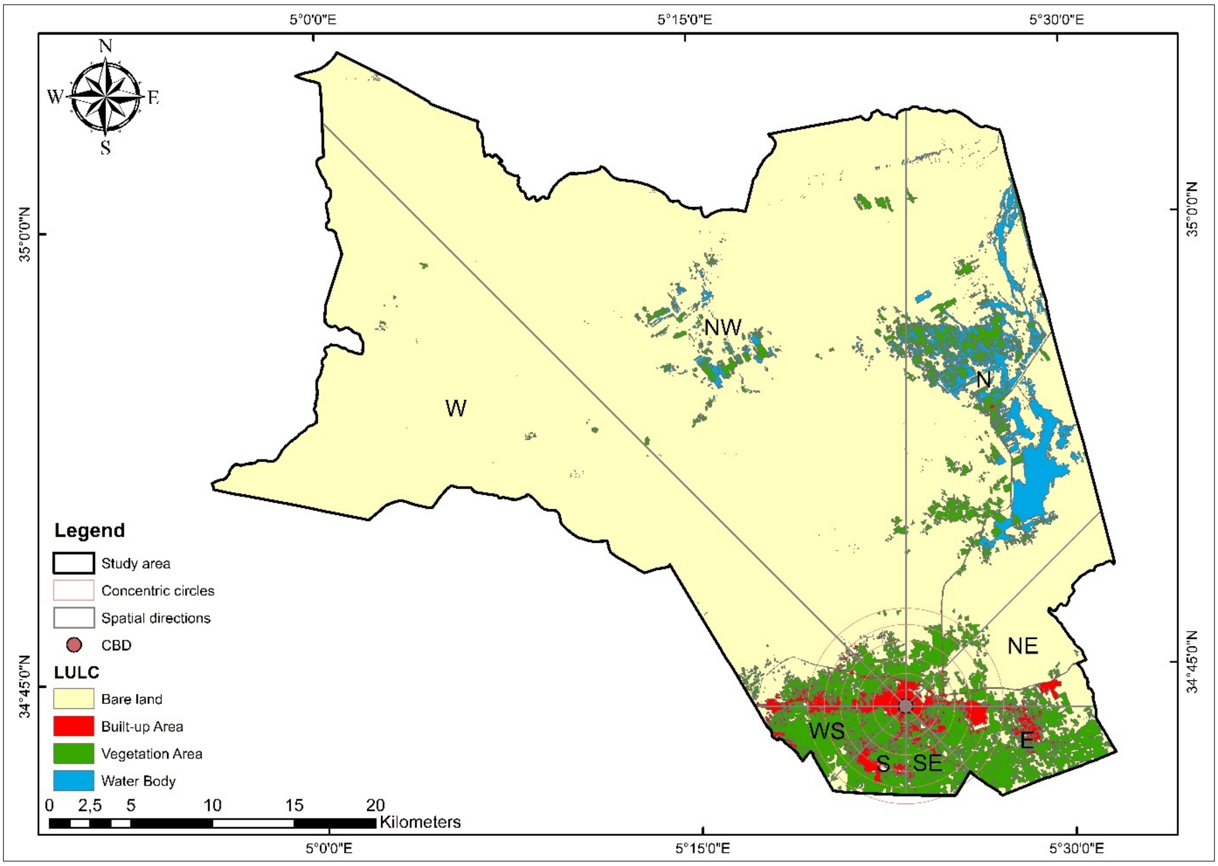

Fig.3 Diagram of the division of the study area according to the spatial direction approach and concentric circle approach

Shannon's Entropy Model.

The shannon's entropy is a mathematical method developed by Claude Shannon in 1948 to quantify the uncertainty of a dataset. It is prevalent and used in urban studies to measure the spatial dispersion or compactness of urban growth. The values of the absolute and relative Shannon's entropy are calculated according to the following equation (1):

$$Hn = \sum_{i=1}^{n} Pi \ln(Pi)$$

where:

- n is the number of all circles,
- Pi is the rate of built-up area in each zone

The values of absolute entropy Shannon range between 0 and ln(n). Values near to 0 refer to a compactness of built-up area, while values near to ln (n) refer to a high degree of dispersion of urban growth.

For relative Shannon, the values near to 0 denote a high degree of compactness of the urban growth, in contrast, near values to 1 refer to urban sprawl and dispersion of urban growth (Barman et al., 2024). The threshold value of the relative entropy is 0,5. Values that exceed the thresholds refer to haphazard and Widespread built-up areas (Das & Angadi, 2021; Patra et al., 2022). In the present research, the relative and absolute Shannon's entropy were calculated according to concentric circle approach. Buffer circles were created from the (CBD) with a distance of 1 km between two successive circles. The urban areas are concentrated in the southern part of the study area, while the northern part appears largely undeveloped. To have more accurate results about the dispersity or compactness of urban growth, the circles were created only up to 6 km from the CBD, because the urban sprawl was visually observed within this range (figure 3).

Results and Discussion.

The Spatiotemporal LULC in Tolga Oasis.

Similar to the Algerian Saharan regions, the study area has experienced radical changes with the promulgation of (APFA- 1983) law about the reclamation of Saharan and steppe regions. To assess the LULC dynamics, the four satellite images (1985, 2000, 2015, 2023) were classified using the (SVM) and ArcGIS Pro software. The classified maps were compared to reference dataset and historical Google Earth images to validate them for LULC assessment. The overall accuracy values of classified images (1985, 2000, 2015, and 2023) were: 0.88, 0.90, 0.93, and 0.92%, meanwhile the kappa coefficient values were: 0.85, 0.87, 0.91, and 0.90%, respectively, indicating a high alignment between the classified images and the referenced data.

Table.1 LULC changes of different classes over time

LULC	Year				Change in area Km²		
	1985	2000	2015	2023	1985-2000	2000-2015	2015-2023
Vegetation (date palm and seasonal yields)	38,75	48,73	85,97	121,23	9,98	37,24	35,26
Built-up area	4,89	8,13	14	26,94	3,24	5,87	12.94
Water bodies	80,26	37,89	33,6	43,58	-42,37	-4,29	9,98
Bare lands	1291,47	1320,62	1281,80	1223,62	29,15	-38,82	-58,18

The results of LULC change are presented in Table 1, and the LULC maps for 1985, 200, 2015 and 2023 are shown in Figures 4, 5, 6, and 7 respectively. The vegetation area (date palm and seasonal yields) shows a gradual development from 38.75 km² to 121.23 km² over the 38 years. This was the result of state policies that aimed to develop its agricultural sector and achieve food security. Over the first 15 years, between 1985 –2000, we observed an increase of 9.98 km² in the vegetation class. Over the second 15 years, from 2000 to 2015, a leap in vegetation class, estimated at 37.24 km², was recorded**.** From 2015 and 2023, the agricultural oasis expanded by 35,26 km². Simultaneously, the change in built-up areas showed a gradual development over the 38 years. An increase of 3.24 km² was recorded between 1985 and 2000, while between 2000-2015 the increase in built-up area was 5.87 km², followed by a jump of 12.94 km² between 2015 and 2023. This growth resulted from the natural increase in population, and the attractiveness of Tolga oases for residents of neighbouring cities to benefit from agricultural land, particularly as land ownership is transferred to individuals after reclamation (Khiari, 2018). As for water bodies, the study area has a synclinal depression in the north and northeast zones. This depression is shaped like a splayed basin, where the edges form accumulation zones filled by run-off from the relief during rainfall. In the south part of the case study lies *Sabkha,* which is formed by the drainage of irrigation water from date palms. The decrease in the water body class between 1985-2015 resulted of the construction of drainage canals that drain excess irrigation water, dry out the *sabkhas*, and avoid the phenomenon of water rise to allow the oasis extension. However, the increase observed between 2015-2023 is because of the humidity in the synclinal depression caused by rainfall or water rise.

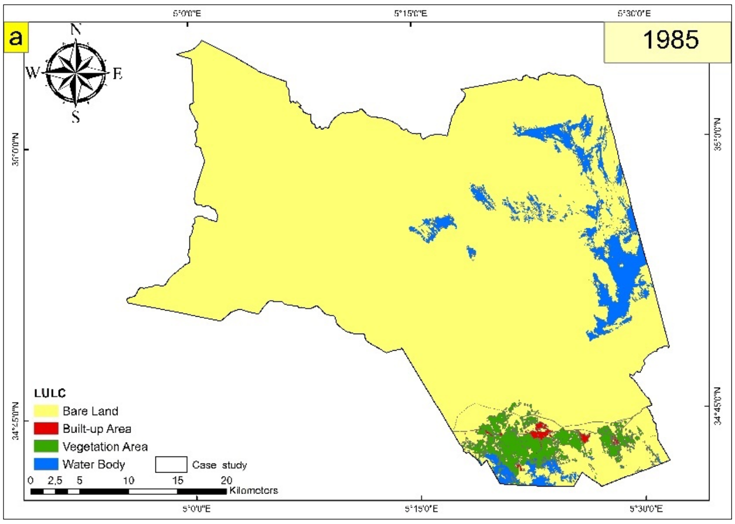

Fig. 4. LULC map in 1985

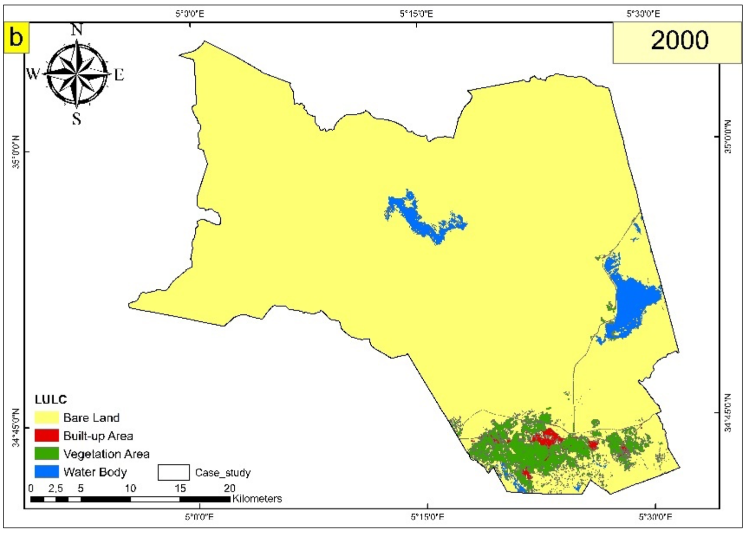

Fig.5. LULC map in 2000

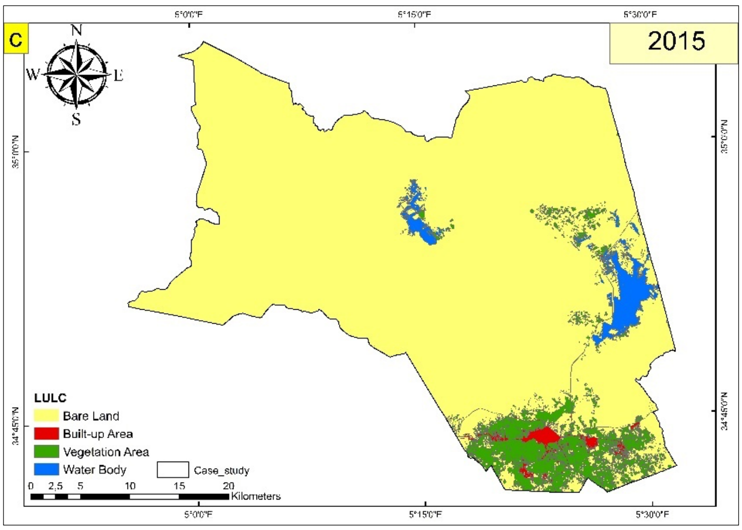

Fig. 6. LULC map in 2015

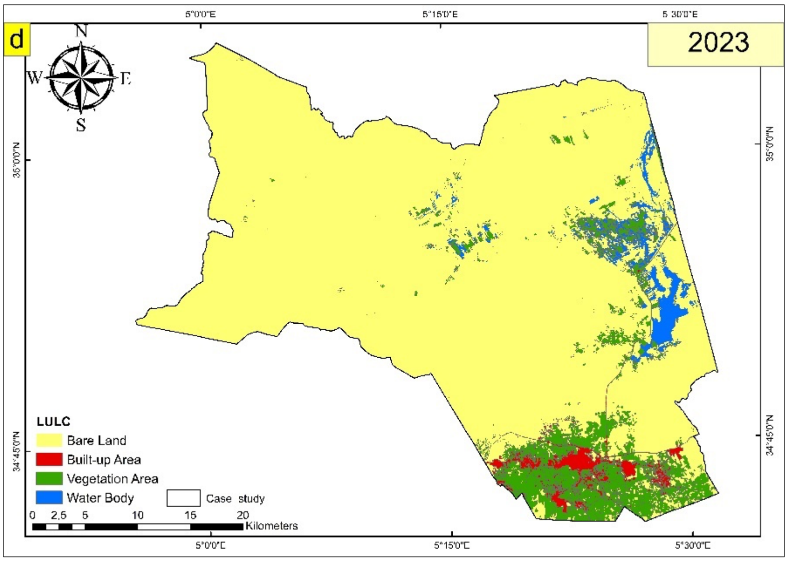

Fig. 7. Land use maps in 2023

Agricultural Oasis Expansion Based on Spatial Direction Approach.

The agricultural oasis expansion is a crucial element influencing LULC dynamics in arid lands. Under the process of oasification or agricultural oasis expansion in arid and semi-arid regions, the land changes from yellow to green (Zhu et al., 2023). Traditional methods are often used to assess and quantify the global agricultural expansion or land cover change. However, these methods may neglect the spatial direction of agricultural expansion, which is an important factor in land management. The spatial direction approach is a common method used to measure and assess urban growth. Using this method in agricultural oasis expansion may be useful in understanding the landscape dynamics over time. This allows planners and decision-makers to grasp the impact of socio-economic factors influencing the expansion on the one hand, and the guarantee of balanced expansion especially in fragile areas on the other hand.

The study area is composed of neighbouring oases, *intra palm grove* as (Cote, 2005) describes it. It is crucial to understand the direction of agricultural oasis expansion as well as the identification of zones that may be affected by urbanization.

After image classification and the assessment of the global LULC change, the vegetation class from all land use maps was extracted. Then, the intersect tool was used to find the Vegetation area in the eight spatial directions. The results of the change in vegetation area are shown in Table 2 and figure 8.

During all the time periods, the region has witnessed a consistent upward trend in vegetation area resulting from the creation of new private farms. From 1985 to 2000 all spatial directions had identical growth in vegetation area, with the highest expansion recorded in the (SW) direction at 1.88km², while the lowest value was recorded in the (SE) direction at 0.65km². In the second period, between 2000- 2015 a rapid rise in vegetation area was estimated at 9.82km² and 12. 32km² in (N) and (E) directions respectively. In the (N) direction, the increase in vegetation area was due to the establishment of new farms behind the mountains north of urban agglomerations, as well as the establishment of farms with seasonal products along the synclinal depression *Sabkha.* As for the (E) direction, the expansion of the oasis was through date palm plantation. Concerning the other directions, the highest value was recorded in the (SE) direction with 4.6 5km², while the lowest value was observed in the (SW) direction with 1.03 km². The increase of vegetation area in these zones was primarily the result of date palm plantations. In the last time period 2015-2023, a sudden peak of 17.82 km² in vegetation area was noted in the (N) direction resulting from the continued creation of new investments in the large bare land behind the mountains. Followed by the (NW) direction with an increase of 7.21 km² as a result of the same previous causes. In terms of other directions, varying values were detected ranging from 1 km² to more than 5 km², except in the (NE) which witnessed a stabilization in the value of vegetation area estimated at 0.06 km² due to the expansion of the cities of Tolga and Lichana at the expense of existing palm grove along National Road N46. Additionally, the expansion of the outlying district Amirouche contributed to this shift. Some palm plantations were established towards the mountains in the northern part of this zone. Therefore, we can conclude that there was no net increase in oasis agricultural land, but rather a compensation for what was lost due to urban sprawl .Considering the land use maps, we noted that all cities in the study area are enclosed by palm groves especially (BBA) district in the (S) direction which appears with a saturated urban fabric. Currently, the future growth of this city is a challenge for the local authorities, as on the one hand the palm grove must be preserved, and on the other hand growth must be achieved with lower costs. The change in vegetation area in the (S) direction ranged approximately from 0.7 to 2 km² in all time periods. This is a consequence of the aging of palm trees and contrived human causes. The land use maps showed the expansion of the city at the expense of the palm groves, especially in the last time period 2015-2023. However, this decrease was not reflected in the overall values because it was compensated by the reclamation of bare lands in the south and the establishment of new palm farms. As for the same reasons the change in vegetation area in the (SW) was less than 1.9 km². As a general summary, all the directions witnessed an agricultural oasis expansion. A drastic increase was observed in (N) and (E) directions valued at 28.64 km² and 18.87 km² respectively. Concerning the other directions, the values of agricultural oasis expansion were ranging approximately from 3 km² to 10 km².

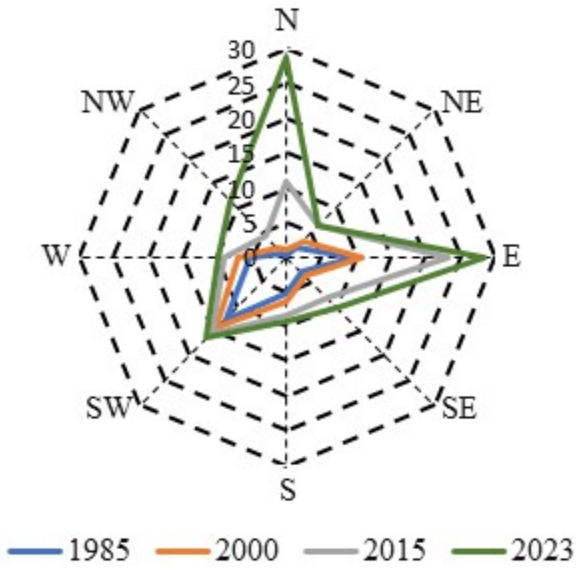

Fig. 8. A radar chart representing the vegetation area development in different directions and times

Table 2. Vegetation area changes in different directions and times

Vegetation	N	NE	E	SE	S	SW	W	NW
1985-2000	1	1,34	1,27	0,65	1,01	1,88	1,56	1,09
2000-2015	9,82	2,92	12,32	4,65	2,17	1,03	2,03	2,31
2015-2023	17,82	0,06	5,28	2,03	0,74	1,05	1,07	7,21
Total	28,64	4,32	18,87	7,33	3,92	3,96	4,66	10,61

Agricultural Oasis Expansion and Date Palm Plantation.

Tolga Oasis is recognized for the excellent quality of its date palm. This sweet fruit is considered as a fundamental food security crop in arid lands, especially during years of poor harvest (Al-khayri et al., 2015). Dates contribute to local food self-sufficiency, especially since date palm is a perennial plant that can live and produce fruit for several decades depending on care and surrounding factors. Given the (APFA-83) law and then the National Agricultural Development Program (NADP-2000), new date palm farms, and irrigated perimeters have been created in Tolga after providing electricity and allowing groundwater accessibility. The availability of water was important for enabling agricultural expansion and boosting productivity. Pumped groundwater is the main and only resource used in agricultural irrigation. To encourage investment in the agricultural sector, hundreds of wells have been constructed in the region, including four Albian drilling with depths ranging from 1200 m to more than 2000 m.

Table 3. Number of date palm trees, Daglet Nour palm trees, and vegetation area over time

	Total Date palm Trees	Daglet Nour	Other varieties	Percentage of Daglet Nour	Vegetation area km²
1985	450 978	202 940	248 038	45	38.75
2000	622 154	491 270	130 884	78,96	48,73
2015	813 790	642 000	171 790	78,92	85,97
2023	863 598	692 108	171 490	80,15	121,23

As reported by (Hamamouche et al., 2018; Khiari, 2018; Mihi et al., 2017) the new palm farms are oriented towards the monoculture of (DN) because of its economic profitability compared to other varieties. According to (MADR, 2021), (DN) occupies 46,40 % of total date palms in Algeria and continues to expand at the detriment of other varieties. In the study area, between 1985-2000 the (DN) plantation experienced an immediate jump, the percentage of (DN) was estimated at 45% in 1985, while by 2000 it had grown to 78,96 %. This percentage remained stable until 2015 and grew slightly between 2015-2023 to reach 80,15 % in 2023 (Table 3).

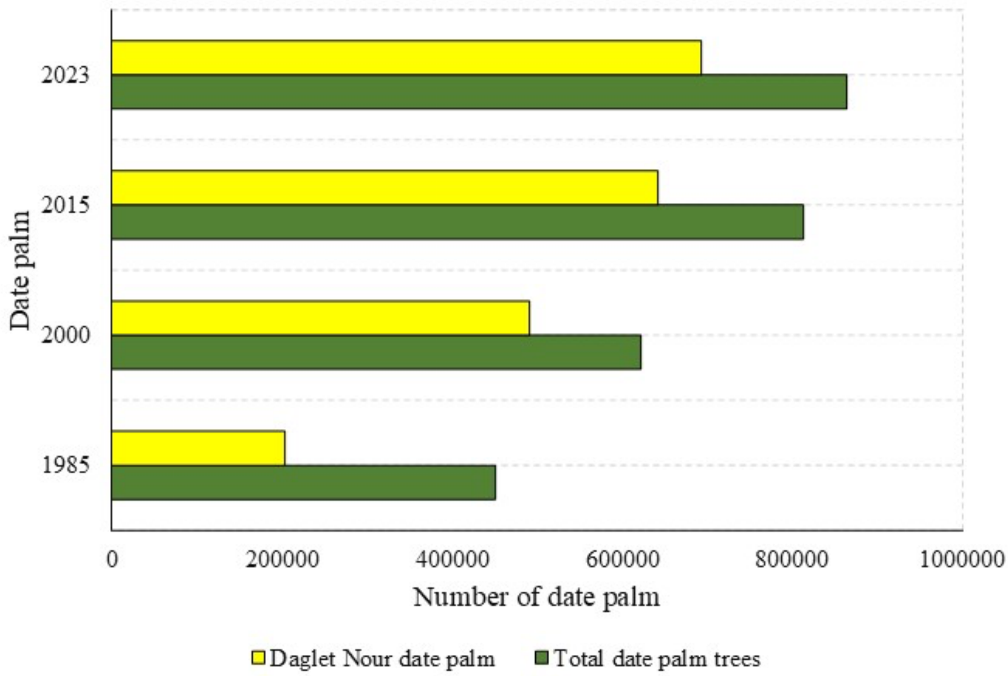

Fig.9. Number of Daglet Nour palm and total palm trees

The growth in vegetation area was mainly due to the date palm plantation (DPP). The correlation between (DPP) and development in vegetation areas is shown in Fig 10. The correlation value is approximately R=0.928% and R^2= 0.8613 which indicates a strong correlation between the (DPP) and the growing vegetation area (Schober & Schwarte, 2018). Currently, the production of (DN) in the study area (Tolga, Lichana, Bouchagroune, BBA, and Foughala) is 880 225 Qx which represents 80% of the total date production, estimated at 1 089 707 Qx. This production is oriented toward local and international markets.

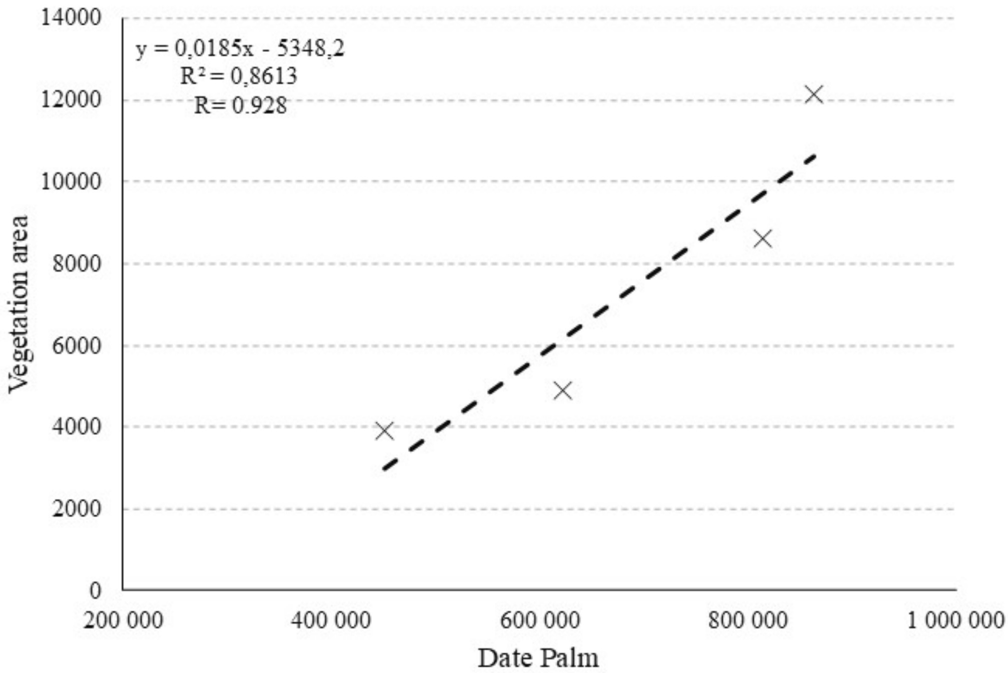

Fig.10. Relationship between palm trees plantation and vegetation area

Urban Growth Analysis Based on Spatial Direction.

The outcome of the built-up area offers a strong representation of urban growth in Tolga oases (Table 4, Figure 11, and Table 5). The spatial direction approach provides a thorough understanding of how urban expansion occurs in each direction over time. The findings show an important expansion in the built-up area in the (E, W, and SW) directions, with 4,96 km²and 4,34 Km², and 3.26 km², respectively in all time period. The (E) direction contains part of Tolga, Lichana, and Bouchagroune. The growth in this zone was gradual over three time periods and was due to population growth. The maps showed an expansion of three cities with trends of urban conurbation between Tolga and Lichana, and Lichana and Bouchagroune. The linear organization of the districts along the National Road N46 and province roads encourages the phenomenon of conurbation, especially with the absence of strict oversight. For the same reasons, a trend of urban conurbation was detected between Tolga and Foughala in the (SW) direction. The rise in the built-up area in this zone was almost entirely at the expense of palm groves. This explains the low values in vegetation area change in this zone previously cited in Table 2. An important urban expansion at the detriment of palm groves has been recorded in the (W) direction due to population growth with the increased demand for lands and housing. The (S) zone includes (BBA) and a part of the old oasis of Tolga. The rise in built-up area in this direction is 2.55 km² for the three time periods. (BBA) appears totally surrounded by palm groves, which is a challenge for its future growth. Resembling other zones, a trend of urban conurbation between (BBA) and old Tolga at the expense of palm grove was detected. As for the other zones, the values of growth range approximately from 1 km² to 2,6 km² in bare lands and palm groves.

Table 4. Built-up area in different directions and times

	N	NE	E	SE	S	SW	W	NW	Total
1985	0,21	0,77	1,3	0,11	0,58	0,86	0,66	0,4	4,89
2000	1,09	1,01	1,74	0,23	0,99	1,06	1,46	0,55	8,13
2015	1,1	1,54	3,34	0,91	1,82	1,95	2,7	0,64	14
2023	1,81	3,45	6,26	1,81	3,13	4,12	5	1,36	26,94

Due to Algerian legislation that safeguards palm trees by prohibiting their removal or destruction, some landowners may resort to intentional neglect or arson as a means to eliminate these trees. This strategy allows them to clear the land and subsequently sell it at a premium for construction purposes. The state must put in place strict measures to protect this wealth, especially as its destruction threatens the oasis ecosystem and could lead to irreversible repercussions.

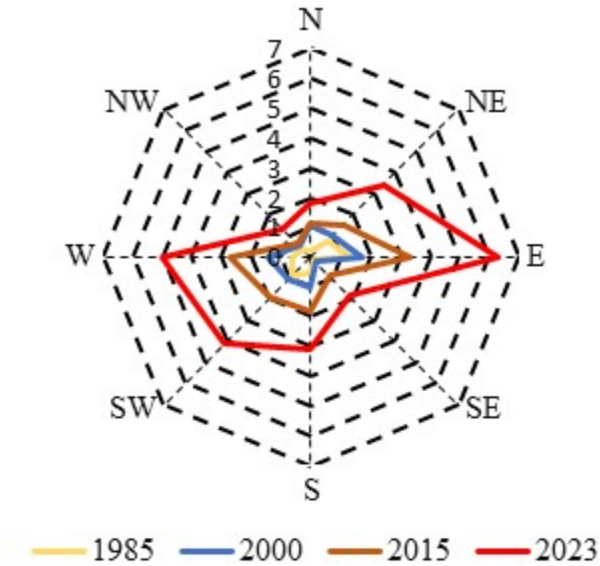

Fig.11. A radar chart of built-up area in different directions and times

Table 5. Built-up area changes in each direction over time

	N	NE	E	SE	S	SW	W	NW	Total
1985-2000	0,88	0,24	0,44	0,12	0,41	0,2	0,8	0,15	3,24
2000-2015	0,01	0,53	1,6	0,68	0,83	0,89	1,24	0,09	5,87
2015-2023	0,71	1,91	2,92	0,9	1,31	2,17	2,3	0,72	12,94
Total	1,6	2,68	4,96	1,7	2,55	3,26	4,34	0,96	22,05

Population Growth and Expansion of Built-Up Area.

Without a doubt, human population growth is the primary driver of urbanization and urban sprawl. The steady increase in population places pressure on natural lands and resources. Several studies have shown a high correlation between population and urban growth (Jamal & Ali, 2023; Patra et al., 2022). The regression linear model was used to measure the relationship between population and built-up area. The results indicated a high relationship between population growth and built-up area expansion, measuring R= 0.926, while the R^2= 0.857 (Figure 12). The rates of population growth and built-up area expansion are presented in Table 6. The rise in population growth rate was due to the development of facilities and the agricultural sector's attractiveness for investors and workers. Simultaneously, the increase in built-up area was due to these same reasons, along with the expansion of the road network to enhance connectivity to various farms.

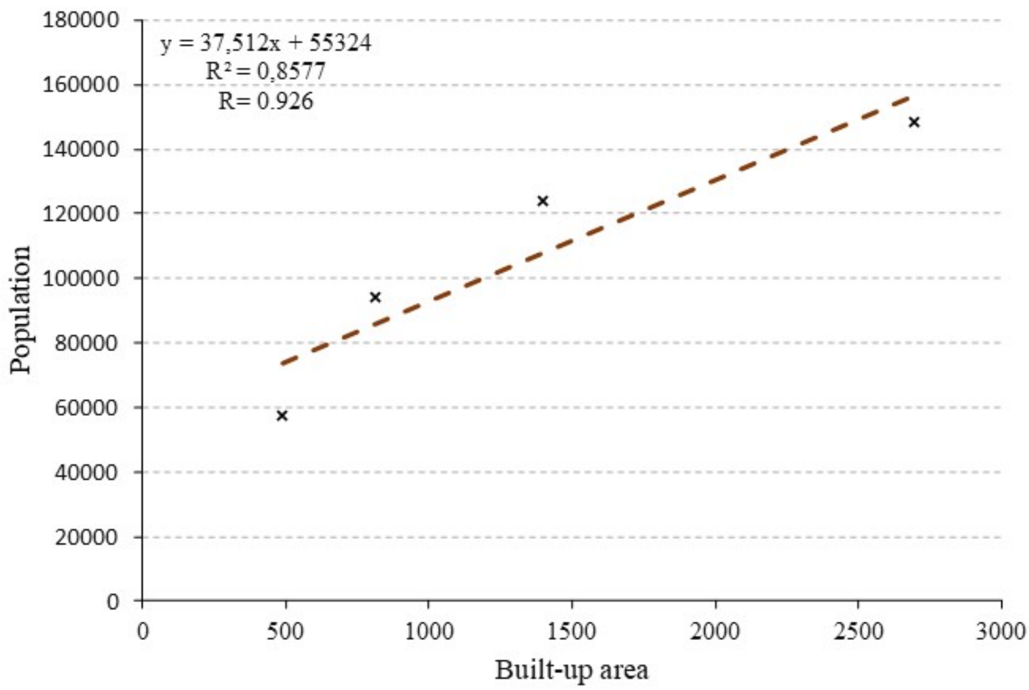

Fig.12. Relationship between population growth and Built-up Area

Table 6. population growth and built-up areas with their growth rate

Year	Built-up Area	Growth rate	Population	Growth rate
1985	489		57097	
2000	813	3.45%	94246	3.3975%
2015	1400	3.69%	123832	1.8368%
2023	2694	8.53%	148538	2.3%

Shannon Entropy and Urban Sprawl Assessment.

Several scholars have adopted the Shannon entropy model to measure the growth of urban sprawl. The severity of urban sprawl is determined based on the dispersion value, where the larger the dispersion value, the higher the sprawl, while smaller values indicate more concentrated growth. Shannon entropy is calculated based on administrative boundaries or arbitrary zones (Cho et al., 2021). It is mandatory to divide the study area into zones in order to compute the entropy value. According to (Aburas et al., 2018; Mohabey et al., 2023) the circle is a suitable shape used in understanding urban growth because it maintains equal distance in all directions. To characterize urban growth and identify urban sprawl, we calculated the absolute and the relative Shannon entropy according to the number of zones using the previously mentioned equations (Eq 1).

Overall, the values of absolute and relative Shannon's entropy are presented in Table 7. The findings of entropy value show values below to ln (n). Shannon entropy in 1985 indicates a compact urban growth with a value estimated at 0.78. In 2000, the value exceeds ln (n)/2 which indicates a trend of dispersed growth. This value continues to rise to reach 1,52 by 2023. This value is near to ln (n) which denotes a high dispersion and urban sprawl.

Table 7. Values of absolute Shannon and relative Shannon

Year	1985	2000	2015	2023	Ln (n)	Ln (n) / 2
Absolute values	0,78	0.95	1.18	1.52	1.79	0,89
Relative values	0.43	0.53	0.66	0.85		

The values of the relative Shannon in 1985 indicate a compact built-up area by 0.43. By 2000, the relative Shannon exceeded the threshold of 0.5 which indicates an urban sprawl. The values continue to grow to reach 0.85 in 2023. This value near to1 indicates a high dispersion of built-up area. These findings indicate the phenomenon of urban conurbation and urban sprawl at the detriment of palm groves previously cited.

Conclusions.

This paper highlights the relationship between local policies and the changes in LULC. The study area has witnessed changes resulting from desert land reclamation and agricultural development laws. GIS techniques and remote sensing have been effective in monitoring, identifying, and assessing LULC. Landsat images were classified by using SVM to generate the land use maps in the three time periods. The built-up area and vegetation area demonstrated a gradual rise over these periods, while, the water body showed a decrease because of the construction of drains in the southern part of the study area to evacuate excess irrigation water and to dry the existing sabkhas. Among different districts, Tolga ranked first in built-up area growth, followed by Foughala, Bouchagroune , Borj Ben Azzouz, and then Lichana. To achieve a deeper understanding of the built-up and agricultural oasis expansion, a quantitative analysis method utilizing a spatial direction approach and concentric circle approach was used to assess and identify the urban growth and agricultural expansion in each zone and each direction. The agricultural expansion increased in all directions over all periods. The findings of the quantitative analysis of the agricultural development were combined with a statistical analysis of agricultural data. The findings revealed a strong correlation between date palm plantations and the rise in vegetation area emphasizing that the agricultural oasis expansion was due to date palm cultivation. Urban growth was also identified using the spatial direction approach, and then Shannon entropy values were calculated by using concentric circle approach. The outcomes of the spatial direction approach illustrated a continued rise in built-up areas from 1985 to 2015. By 2023, a jump was recorded, notably in the southern part of the study area, in the (E, SE, S, and SW) directions which are the most urbanized areas. Shannon's entropy was calculated to explore the dispersity and compactness of urban growth, as well as, to identify areas subject to urban sprawl. The overall outcome showed a compactness of urban growth in 1985, while, the outcome in 2000, 2015, and 2023 revealed a dispersed urban growth. Conversely, the results of statistical analysis for urban growth indicated a high correlation between built-up area expansion and population growth.

The land use maps revealed saturation in the urban fabric of different districts in the study area. Agricultural oasis expansion occurred in areas for future urban expansion in the northern part, while the urban growth was at the detriment of palm groves in the southern part of the study area. This indicates unplanned growth and randomness in the management of the urban fabric.

The findings of this study provide useful graphic and statistical support for local administrative authorities and urban planners to make sustainable development in the Tolga Oases, and to address the ecological problems caused by human activities.

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