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THE ROLE AND IMPACT OF VEGETATION ON THE URBAN FABRIC. CASE OF GUELMA CITY

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ABSTRACT

In cities, land use changes caused by various human activities can affect how natural ecosystems function. In this context, it is increasingly important for cities to consider the role of vegetation in preserving a sustainable environment. A diachronic analysis of landscape changes was applied to assess the presence and distribution of vegetation to determine whether it was evolving or regressing. This phenomenon was studied within the current administrative boundaries of the city of Guelma (Algeria). For this purpose, as an approach based on landscape metrics, several Landsat TM and ETM+ remote sensing satellite images were used throughout the period 1987-2019. A set of landscape indices, including NP, AREA_MN, LPI, PLAND, AI and LSI, were calculated to map land cover, the mechanism of land cover and vegetation change, and their impact on the urban ecosystem. The geo-statistical procedure was carried out using a geographic information system Qgis combined by statistical software using Fragstats to calculate various landscape metrics at class level for the analysis of fragmentation. The results of the landscape metric analysis show that the decrease in average area and the increase in the number of green patches are important indicators of land degradation, meaning that the mechanism of landscape degradation and transformation is progressive. This underlines the need to give particular attention to land use and land cover in the region to ensure the sustainable allocation of natural resources.

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Introduction.

Vegetated areas within the city are often described as ecological lungs for ventilation or irrigation of the urban matrix (Belmeziti, A., et al. 2018). Many authors also assert that vegetated spaces are an integral part of every city (Gupta, Kumara., Pathan., & Sharma., 2012) or are an essential component of the city (Peschardt., Schipperijn., & Stigsdotter., 2012). Furthermore, several studies on dynamic vegetal formation indicate that the evolutionary approach to vegetal ecosystems is in retreat (Thomas., 2014; Toko Mouhamadou et al., 2013; Kadiri., 2012; Arouna et al., 2011). The adoption of protected areas is presented as a real solution to urban limits and other means of influencing natural ecosystems (Soufouyane Z., Ismaïla TI., et al., 2018). More than 60 years after their adoption, classified forests have unfortunately not fulfilled all their commitments in terms of conserving vegetation cover (Toko et al., 2010), leading to a change in the spatial structure of the landscape (S.K. COLLINGE, 1998). Models based on landscape metrics seem useful for taking account of these changes in landscape ecology (Brahim J., 2020).

The study of the “vegetation-urbanization” dynamic over time is an important factor in understanding the immoderate consumption of natural resources influenced by accelerated urbanization, which is characterized by rapid population growth and urban sprawl in varying degrees and forms (DJEDI Toufik., 2011). As they evolve, urban areas have a major impact on their environment, particularly through the extensive use of green spaces. (Xiao et al., 2006; Deng et al. 2009). In this context, it is necessary to elaborate maps of built areas and green spaces, which can be used to assess urban development and its environmental quality. Guelma city is a typical case in point, where rapid population growth has put pressure on forests and agricultural land. The changes in land use throughout the urban area are diverse, and the need for housing has intensified the requirement for suitable land. The city is now part of an excellent agricultural zone, following its successive seizures of its agricultural land, where it is extremely important to determine what land can be built on without damaging green land (Boubaker K., 2020).

This research involves mapping and assessing the spatial growth of one of the Mediterranean ecosystems, Guelma, using a quantitative method based on the movement of multi-date satellite images and the application of landscape metrics (Assoule D., Alkama D., 2020). This latter has been applied in several areas of environmental research, including water resource management and assessment (Amiri., Nakane., 2009), protected area identification (McGarigal et al., 2005), environmental impacts of urban growth processes (Mitsova et al., 2009), and landscape rehabilitation strategies (Herzog et al., 2001). This shows that the landscape metric has significant potential for (Asgarien A., Bahman JA., et al., 2015) enhancing data on vegetation distribution and evolution (Choisnet G., Bellenfant S., et al., 2017).

The geographical reference frame of the study and the methods used to assess vegetation development and its indicators will be developed in the following section(Soufouyane Z., Ismaïla TI., et al., 2018). Landscape metrics is a very broad concept that can be grouped into seven principal categories (Evelin E., Marc A., et al., 2009):

- Use and misuse/metric selection; - Biodiversity and habitat analysis;
- Estimation of water quality; - Urban landscape model, road network;
- Landscape design; - Management, planning and monitoring;
- Assessment of landscape patterns and changes.

The research idea is to observe the vegetation situation through diachronic images, in order to observe if there is an evolution or a retreat, if there is an urban sprawl to the detriment of the vegetation cover, if there is a densification of the latter and in what direction. The final aim of this study is to represent the landscape units in cartographic form. Landscape units are defined by the human activities carried out in the area, combined with elements of the natural environment, in particular vegetation (Choisnet G., Bellenfant S., et al., 2017).

Materials And Methods.

Case study.

The study area is located in the north-eastern part of Algeria (fig01), and is delimited by the following geographical coordinates: Latitude from 36°28' 12.12 "N to 36°26'9.36 'N, Longitude from 7°28'10.72 'E to 7°23'46.44 "E. The city of Guelma resides at the heart of a vast agricultural zone renowned for its excellence. Surrounded by the Mahouna, Debagh and Houara mountains, Guelma is bordered by the Oued Seybouse to the north, the Oued El Maiz and the commune of Belkebir to the east, the Mahouna mountain range to the south and the Ben Tabouche plains to the west. This strategic location is a key transit point in the northeastern part of Algeria, linking it to the coastal wilayas (El Taref, Annaba and Skikda) as well as the inland wilayas (Constantine, Souk Ahras and Oum El Bouaghi) (Boubaker K., 2020).

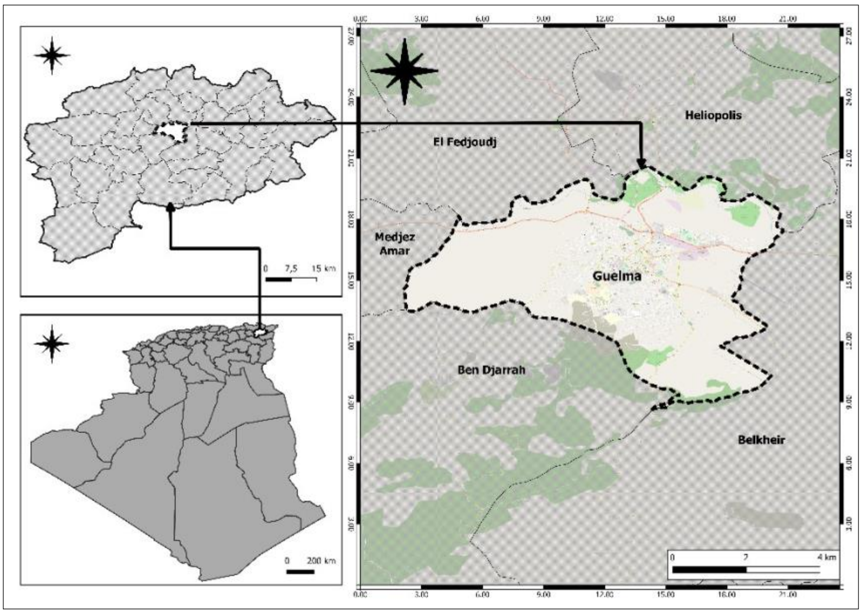

Figure. 1. The study area Guelma, Algeria.

Like all medium-sized cities in Algeria, Guelma seems to have been influenced by rapid, large-scale urban growth, which has greatly disrupted space and produced a profound spatial transformation.

Methodology.

The methodology presented in the diagram in figure 2 corresponds to the aims assigned to this work. This flowchart shows the steps from data collection to the achievement of the objective.

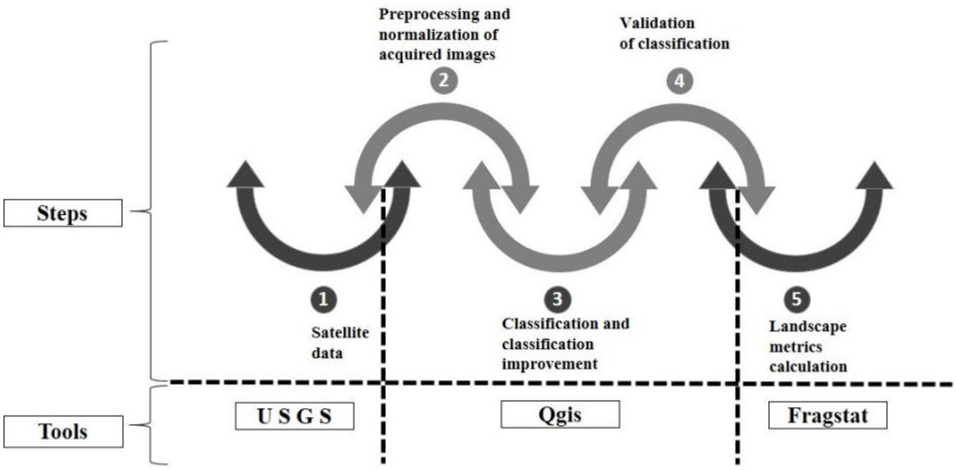

Figure. 2. Diagram of the steps involved.

Spatial Data.

As a prerequisite to the study of landscape value and change, the application of cartography is required to measure landscape composition (McGarigal., Marks., 1994). In this context, satellite images from the TM and ETM+ sensors were used to create land-use maps and detect any transformations that may have occurred. Before being made available by the USGS (https:/earthexplorer.usgs.gov), the satellite images selected for this work were geometrically self-certified and geodiffused according to the WGS 84, North 32 geographic reference system. The study area is established by means of clips containing the perimeter of the current city.

In this study, a dynamic process for detecting transformations from multiple Landsat image spatio-temporal data between 1987 and 2019. Consequently, auxiliary plans are used as reference media. Three aerial photos from 1986, 2001 and 2014 from INCT (National Institute of Cartography and Remote Sensing), and three natural color “Geotif” images from USGS (United States Geological Survey), corresponding to 1987, 2003 and 2019 successively, were used.

Three months have been selected (March, April and May) to explore how vegetation consumes over the Spring season, from 1987 to 2019. In order to make the climatic and physiological conditions more homogeneous. The following table shows the properties of the images obtained (Table 1).

Table. 1. The properties of Landsat images adopted.

Images	Sensor	Year	Bands	Cloud cover	Spatial Resolution
Image 01	Landsat 4-5TM	28-03-1987	1-2-3-4-5-7	0.00	30
Image 02	Landsat 7 ETM+	19-05-2003	1-2-3-4-5-7	0.00	30
Image 03	Landsat 8 OLI TIRS	07-05-2019	1-2-3-4-5-6-7	0.02	30

Source: USGS (United States Geological Survey).

Preparation techniques for the images were carried out using Qgis software, notably for extracting, improving geometric consistency or georeferencing, correcting atmospheric variations, rectifying topography, and superimposing layers. The study area is set up using clips containing the current city perimeter. In addition, spatial metrics are measured using FRAGSTAT software.

Picture pre-processing.

A series of pre-processing operations was carried out on each picture, making it possible to compare data obtained from different sensors, at different dates and in different contexts. Before release by the USGS, the acquired images (L1TP level collection) are geometrically autorectified and geocoded according to the WGS 84 Zone 32 North geographic reference system.

The first step was to clip these images by means of a cutting window including the perimeter of the Guelma commune. Spatial resolution is then improved by a TOA (Top Of Atmospheric) correction, followed by the subtraction of unaffected features using the DOS1 (Dark Object Subtraction) model.After this, an enhancement process is carried out on the images in order to better interpret them visually and raise their quality.

Classification and classification improvement.

The methodology adopted includes a supervised classification procedure, and the FAO (2016) nomenclature was used to define the five land-use classes:

1- Built land; 2- Vegetation+ cultivated farmland; 5- Forest.

3- fallow land; 4- Bare land ;

The images were analyzed using the supervised maximum likelihood classification method, combined with manual post-processing, and isolated pixels were excluded using a 3x3 pixel filter. This step is followed by a reclassification of the three maps to make them consistent and assimilable.

Validation of the classification.

Confusion matrices and Cohen's Kappa coefficient (K) were used to measure the quality of the maps produced by the classification. When the Khat variable has a value superior or equal to 0.8, this classification has a very strong statistical significance. To assess the accuracy of the classification, 250 verification points were established and randomly distributed throughout the study area.

Landscape metrics calculation.

Spatio-temporal change in the city of Guelma is generally assessed on the basis of land-use maps. For this purpose, the previous classifications were adopted to measure landscape metrics according to class level. To avoid generating unnecessary data, a set of class- and landscape-level metrics was chosen for the present study, based on a review of scientific resources (Wang et al. 2012; Wu and Lin 2007; Herold et al. 2005), as well as expert knowledge, the suitability of the metrics for the purpose of the study and attention to the correlation between their concepts. Table 2 describes the metrics used in the research, as well as the formulation and its units. In this study, FRAGSTATS software was used to calculate landscape metrics.

Table. 2. Presentation of the method used to calculate the selected indicators.

Metrics	the formula	Range
PLAND (%)	$PLAND = Pi \frac{\sum_{j=i}^{n} ai}{A} 100$ Pi = proportion of the landscape occupied by patch type i. aij = area (m2) of patch ij. A = total landscape area (m2)	$0 < PLAND \leq 100$
NP (unit)	NP=ni ni = number of patches in the landscape of patch type (class) i.	NP ≥1 without limit.
AREA_AM (ha)	$AREA\_AM = \frac{\sum_{j=1}^{n} Xij}{ni}$ X_{ij}: total surface area of fragments in the same class i. n_i: number of spots in class i.	AREA_AM >0
LPI (%)	$LPI = \frac{\max_{j=i}^{n} aij}{A} 100$ aij = area (m2) of patch ij. A = total landscape area (m2).	$0 < LPI \leq 100$
AI (%)	$AI = \left[\frac{gii}{\max \rightarrow gii}\right] 100$ gii = number of like adjacencies (joins) between pixels of patch type (class) i based on the single count method. max-gii = maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the single-count method.	$0 \leq AI \leq 100$
LSI (unit)	$LSI = \frac{\sum_{k=1}^{m} .25 \quad eik^*}{\sqrt{A}}$ e * ik = total length (m) of edge in landscape between patch types (classes) i and k; includes the entire landscape boundary and some or all background edge segments involving class i. A = total landscape area (m2)	LSI ≥ 1, without limit.

Source: FRAGSTATS: spatial pattern analysis program for categorical maps (Samuel Cushman., Maile Catherine Neel., 2015).

In order to calculate landscape metrics based on FRAGSTATS software, the land-use maps produced were used. So that landscape indicators can be analyzed and understood at class level, it is recommended not to analyze a single indicator, but to analyze a set of indicators in order to better highlight and characterize ecosystem dynamics and landscape structure.

Results and Discussion.

Validation of classification.

The picture classification produces three thematic maps, shown in Figure 3, 4, 5 corresponding successively to the years 1987, 2003 and 2019. Table 2 below shows the results of the classification evaluation.

Table 3. Accuracy of the three image classification 1987, 2003, 2019.

Type of assessment	1987	2003	2019
Overall accuracy (%)	93.73%	95.45%	94.30%
User Accuracy (UA) Class Built land	98.40%	94.21%	97.42%
User Accuracy (UA) Class cultivated land and vegetation	91.48%	93.36%	94.86%
User Accuracy (UA) Class Forest	100%	100%	87.54%
Khappa index (k_{hat})	0.87	0.90	0.93

Source: Corresponding author work in Qgis.

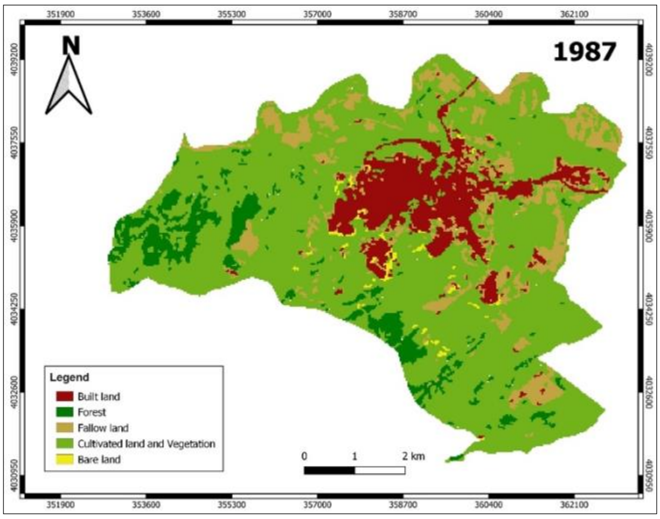

Figure 3. Chronological distribution of land use classes in 1987.

The accuracy of the confusion matrices obtained for these three maps is relatively satisfactory, particularly for urbanized areas, forests and “cultivated farmland and vegetation”, both in terms of overall accuracy and accuracy by class. As a result, the Kappa index (Khat) reached an acceptable level of accuracy, with values of 0.87, 0.90 and 0.93. A synthesis of this assessment is presented in Table 3. As part of this process of assessing map accuracy, the principal objective is to provide indications of the confidence that users can place in maps, and how planners and managers use them in their decision-making process.

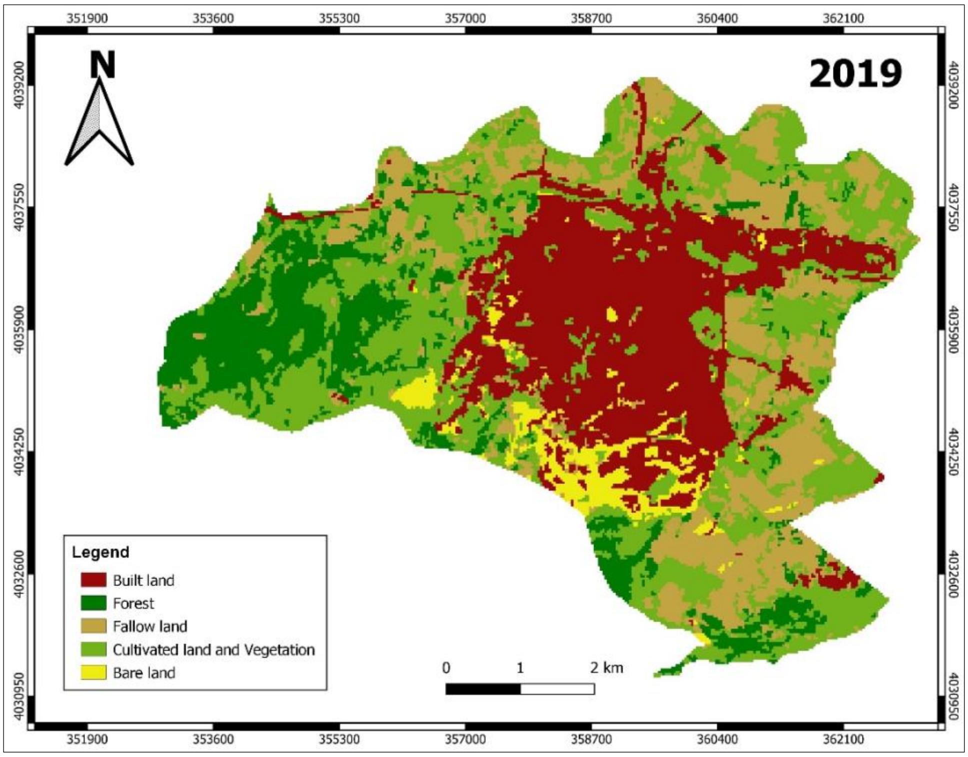

Figure 4. Chronological distribution of land use classes in 2003.

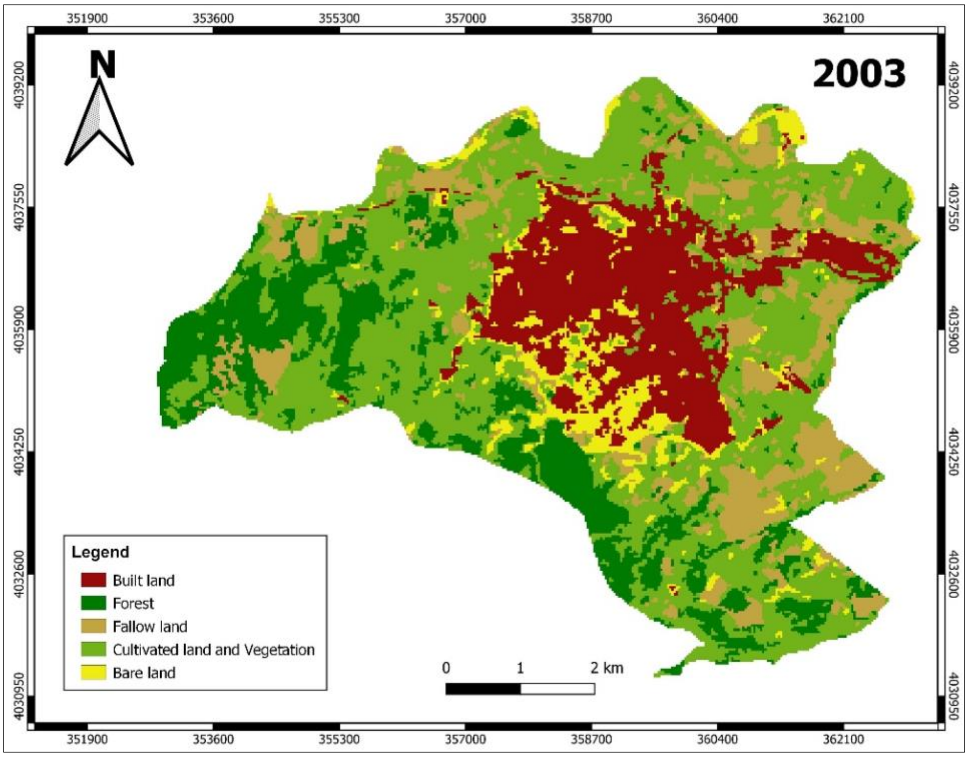

Figure 5. Chronological distribution of land use classes in 2019.

Cartographic visualization of spatio-temporal changes: The dynamics of vegetation cover between 1987 and 2019.

The supervised classification produced three thematic maps, presented in the following figure 3.4.5 to assess the consumption of vegetation on the three dates at the city scale.

From a diachronic point of view, these maps reveal a clear proliferation of built-up areas over the period studied, as opposed to a significant decline in vegetation over the last 32 years. In Algeria, Guelma is considered one of the cities with the most important urban functions. These influence adjacent communes and even the rest of the province's communes. As specified in the (PDAU 2013). A supervised classification of the base image for this study was carried out to confirm this initial analysis. Figure 3,4,5 illustrates the various land use units in the city of Guelma.

The spatial growth of Guelma city was marked by two trends throughout the first period. On the one side, continuous extensions to the south and northeast, through cultivated cropland and vegetation, were the result of a fragmentation process, which intensified during the second period (2003 -2019). On the other side, a sharp increase in forest cover in two directions: from northwest to south.

From 2003 to 2019, this second period is also characterised by strong spatial growth in urban sprawl. Fragmentation of cultivated cropland and vegetation has continued, with encroachment on these areas, particularly in the south where urban sprawl has reached the forest cover. The latter is also being nibbled away in its southern part by urban sprawl, but at the same time is becoming denser in its north-western part.

The surface areas of the different land covers and their changes were calculated to better explain urbanization over the period studied in the classification of Guelma city, and are presented in Table 4 and Figure 6.

Table.4. Distribution of land use classes by area and percentage.

Land use class	Area	1987	2003	2019	1987-2003	2003-2019
Built Land	Area (ha)	662.72	819.68	1319.72	156.96	500.04
	Area (%)	7.6	9.4	15.2	1.8	5.8
Bare Land	Area (ha)	65.25	555.57	307.05	490.32	-248.52
	Area (%)	0.8	6.4	3.5	5.6	-2.9
Unicultivated Land	Area (ha)	1312.79	1511.39	2043.74	198.60	532.35
	Area (%)	15.1	17.4	23.5	2.3	6.1
Vegetation & cultivated Land	Area (ha)	5729.65	3524.17	3635.72	-2205.48	111.55
	Area (%)	65.8	40.5	41.8	-25.3	1.3
Forest	Area (ha)	931.59	2291.53	1395.04	1359.94	-896.49
	Area (%)	10.7	26.3	16	15.6	-10.3

Source: Corresponding author work in Qgis.

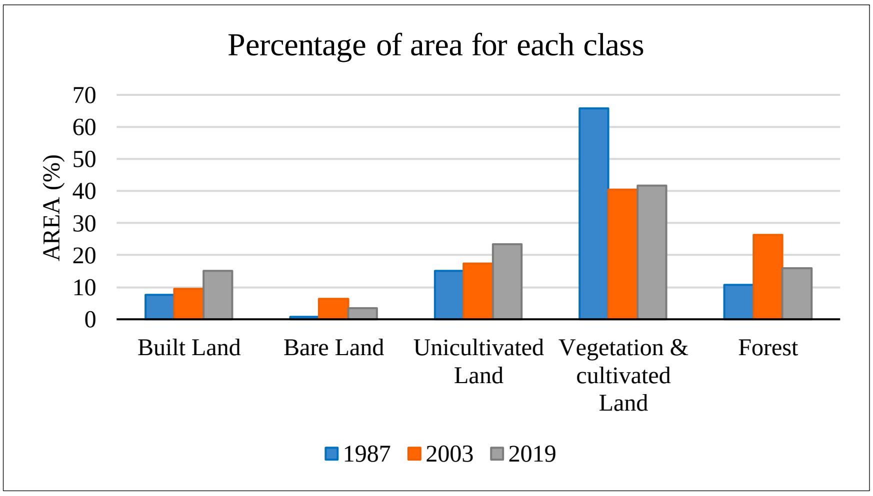

Figure 6. Percentage of area for each class.

The figure 6 above also shows the percentage change in area. According to these results, green land area decreased from 65.8% in 1987 to 40.5% in 2003, then increased slightly to 41.8% in 2019 (Fig. 4). On the other side, forest cover increased remarkably over the period 1987-2003, before declining sharply between 2003 and 2019. Conversely, the urban area grew steadily over the period studied. Its surface area increased from 7.6% in 1987 to 9.4% in 2003, and will reach 15.2% in 2019.

A synthesis of data relating to changes in land use and land cover over the study period is presented in Table 4, while Figure 6 accurately illustrates the different spatial affectation of land use in the study area. The remarkable proportion of agricultural land, vegetation cover and forests means that the city of Guelma has an important ecological character.

These results revealed that green land and forests were the dominant landscape types in the study area. In fact, cultivated land and vegetation have declined and been converted mainly to forest land and urban areas.

Assessing change in natural landscapes: emergence of contrasting spatial models.

This spatio-temporal map of changes in land use illustrates two clearly opposed spatial dynamics: the massive urbanisation of built land and the similarly considerable retreat of vegetation cover and forests. A comparison between the thematic maps generated by the supervised classification and the descriptive landscape factors is intended to highlight the impact of the evolution of built land on cultivated cropland and forests.

Performance analysis of area indicators

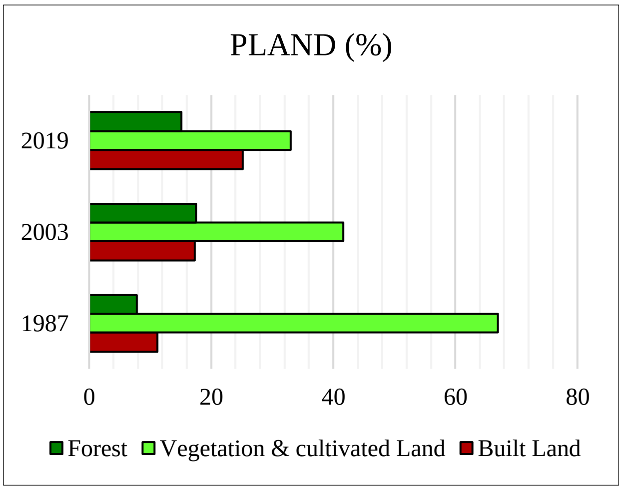

Figure.7. PLAND indicator over the period 1987 – 2019.

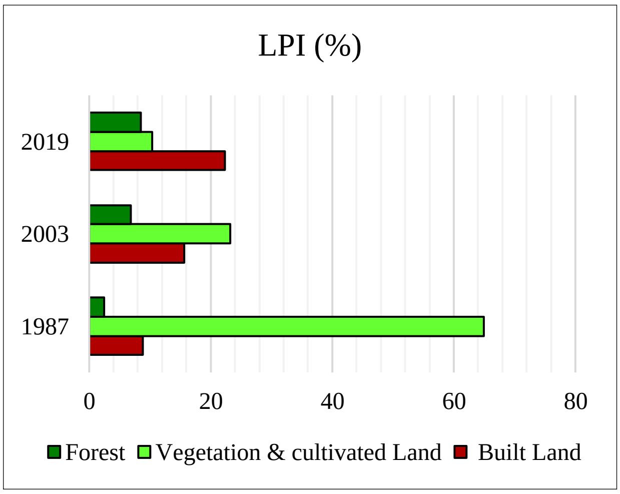

Figure.8. LPI indicator over the period 1987 – 2019.

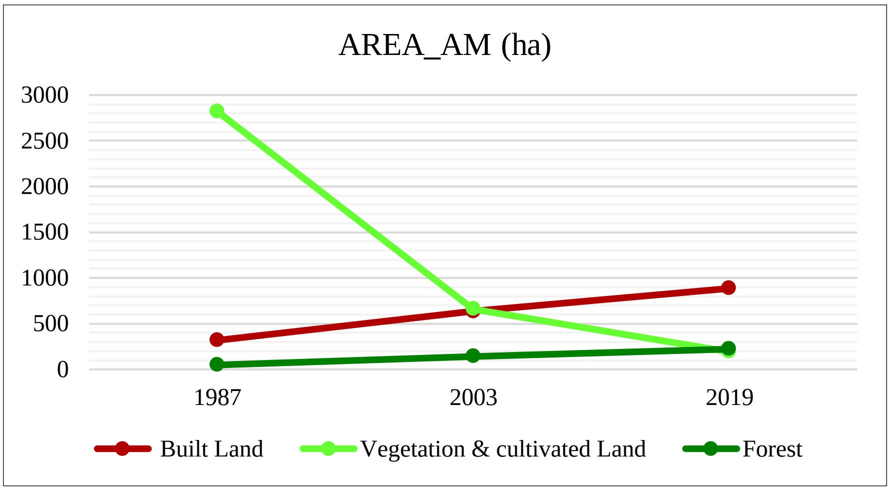

Figure 9. AREA_AM indicator over the period 1987 – 2019.

The PLAND (Percentage of landscape) metric (Figure 7) corresponds to the percentage of the class in the total landscape. In 1987, the value of this metric in the built land class was 11.16, in 2003 it reached 17.26, and in 2019 it has increased to 25.12. Consequently, the ratio of growth in the number and density of built plots and the total area of this type represent the reduction in fragmentation of the built land class and the emergence of future built-up areas. In fact, the imbalance in the region is due to this reduction, and the growth pattern does not match that of the other classes, and is considered a disruptive element.

The percentage of the landscape covered by the green land class decreased and, throughout the years studied, it was successively 66.92%, 41.62% and 33.04% for green land. In contrast, the forest class showed an increase between 1987 and 2003 (7.75% and 17.47%) and a slight decrease between 2003 and 2019 (17.48% and 15.17%). This confirms that forest is being consumed between 2003 and 2019.

In addition, the LPI (Largest patch index) (Figure 8) is an indicator of the total size of the largest plot. According to this index, a reduction in the size of the largest plot in the green land class can be a factor in reducing the area of green land. In 1987, the level of this indicator in the cultivated land class was 64.93%, in 2003 23.21% and in 2019 10.42%. In the urban and forest class, an increase in the value of this index indicates the merging of plots into a larger one, with the ratio of this index from 1987 to 2003 rising from 8.86% to 15.63% and reaching 22.28% for the urban class, with an identical ratio for the forest class: 2.46% in 1987, 6.81% in 2003, and 8.53% in 2019.

This decline in the green land class corresponds to the degradation and transformation of land in important ecosystems, and the fact that open land is being converted into built land.

AREA-MN (Mean patch size) represents the average area size (Figure 9). This reduction corresponds to the level of interspersion classes. In particular, this metric has increased in the urban and forest class and decreased in the cultivated land class. So the value of the metric for built land in 1987 is 317.62 ha, in 2003 it is 634.51 ha, and in 2019 it is 885.41 ha. On a positive note, there has been a steady increase in forest class throughout the study period from 1987 through 2003 to 2019 (48,2208 ha, 143,1729 ha and 222,0972 ha). The decline in the average size of green land islands therefore reinforces the permeability and sensitivity of this land to degradation, and intensifies ecological pressure in these areas. In 1987, the average size of green land islands was 2821.32 ha, 660.1472 ha in 2003 and 191.7051 ha in 2019.

Performance analysis of distance indicators.

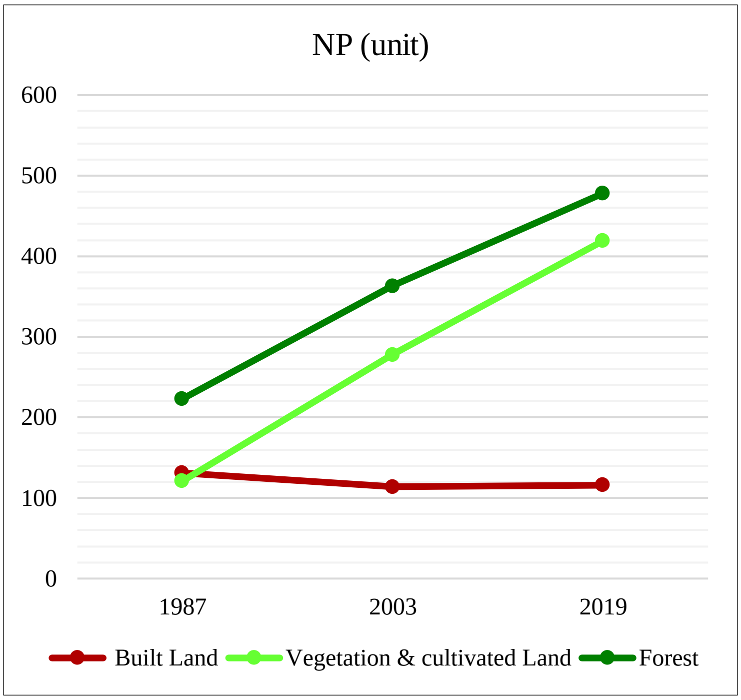

Figure 10. NP indicator over the period 1987 – 2019.

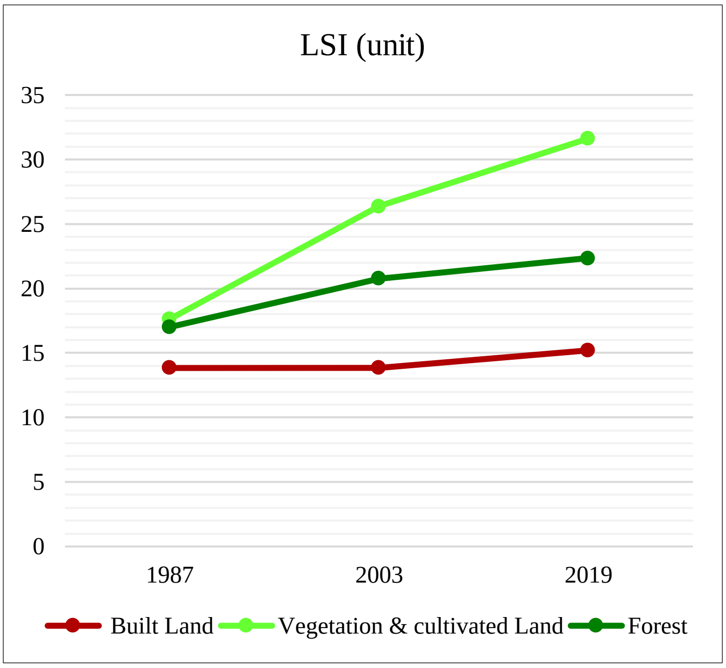

Figure 11. LSI indicator over the period 1987 – 2019.

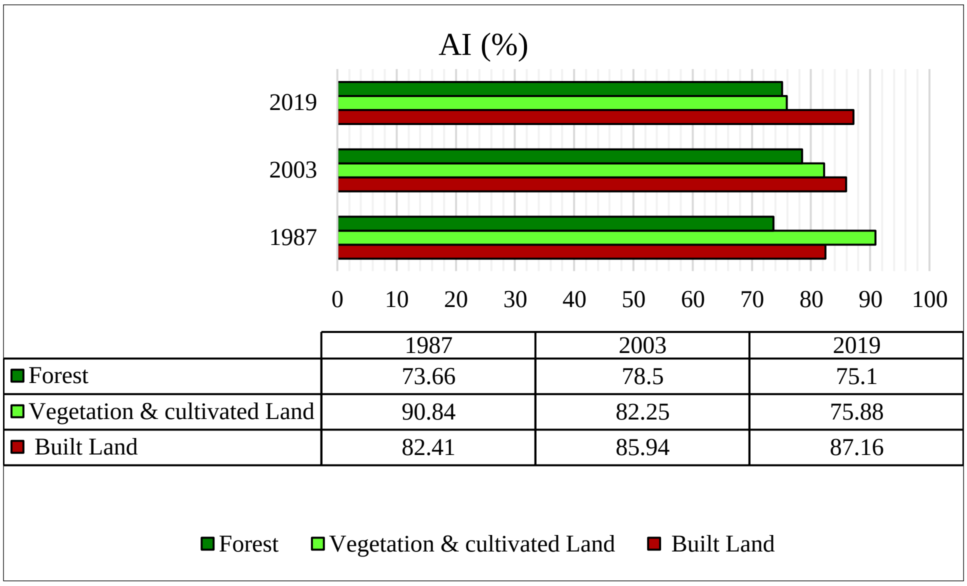

Figure 12. AI indicator over the period 1987 – 2019.

Throughout the period under review, NP (Number of patches) metric (Figure 10) values increased in green land and forests in a continuous growth pattern, from 121/223 in 1987 to 287/363 in 2003 and 419/478 in 2019. The NP metric decreased in built land, from 131 in 1987 to 114 in 2003 and 116 in 2019. The portion occupied by green cover and forests represented by the index of the largest fragment LSI (Landscape Shape Index) (Figure 11) also showed a continuous increase in its values. Two modes of variation characterize the AI (Aggregation Index) (Figure 12) for the “green land” and “forest” classes. From 1987 to 2003, there is an increasing mode, as opposed to a decreasing mode in the period from 2003 to 2019.

The combination of spatial metrics reveals an increasing number of green areas and a decrease in built areas, signifying a shift from residential space to urban sprawl and land use, including green and open spaces, as well as the integration of the urban structure and the fragmentation and inversion of forests. Indeed, the dynamics of the evolution of this measure can indicate the trend towards a change in land use.

In the context of several studies and the analysis of appropriate parameters, it is clear that landscape fragmentation is often explained by landscape measures (Stenhouse 2004., Carvalho., et al. 2009). Moreover, fragmentation is an anthropogenic mechanism that involves the degradation of a habitat, a type of land use, a continuous ecosystem (Asgarian et al. 2013), (Saeedeh Nasehi1, Aysan Imanpour namin., 2020) (Boubaker Khallef.,2019). Many attempts have shown (Dechaicha A, Alkama Dj. 2020), (Keyghobadi et al. 2005) that average plot area (AREA MN), PLAND, LPI, AI, NP are generally basic parameters.

Generally speaking, much research has also identified planning as the main factor contributing to the creation of a heterogeneous, intergenerational environment, which is certainly the most complex type of vegetation cover (Anderson., 2006). With this in view, the present study, irrespective of the impact of the spatial configuration of urban growth on landscape modification, has therefore been specifically designed to investigate the impact of the composition, configuration and structure of green cover plots on the urban landscape of the city of Guelma.

Conclusion.

Progress in remote sensing and landscape ecology has allowed us to perceive and quantify the spatio-temporal transformations resulting from the urban evolution of the town of Guelma. From this point of view, the cartography shows that the town, whose extensive vegetation cover has preserved its green identity over time, even though urbanization has grown steadily over the period studied.

Moreover, the results we have obtained are sufficiently convincing to support the process of metric change implemented in this study, which is consistent with the findings of previous studies by other researchers. The model proposed in this study therefore serves as a useful indicator of urban green space fragmentation. As such, these metrics can effectively demonstrate the degree of fragmentation of these areas.

In general, to effectively control and stop this process, it is important to prioritise management and planning. In this context, the implementation of measures to protect and restore these structural elements is paramount. In addition, it is imperative to establish a harmonious interaction between the city and its natural environment. A sustainable city can be achieved through appropriate management strategies.

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