Study of urban sprawl using the built-up area extraction map and supervised classification Case Study Wilaya of Tizi-Ouzou, Algeria *

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Abstract

The objective of our study is to evaluate the phenomenon of urbanization in the wilaya of Tizi-Ouzou through two distinct methods, the first method is to generate a map of extraction of built-up areas (BAEMOLI) from the calculation of the index of normalized difference of the built-up NDBI OLI, the index of vegetation NDVI OLI and the modified index of normalized difference of the water MNDWI OLI, and the second method is to use the supervised classification has different period 1987, 2000, 2009, 2019 and 2021, we start with the first method in order to have a visual overview of the urban growth in the different regions of the wilaya of Tizi-Ouzou, and in knowledge of the limitations of the first method which certainly allows to have an approximate and global overview of the phenomenon to study something which is primordial to have a methodical approach of the phenomenon which rages in the wilaya and these regions, but which unfortunately does not make it possible to make the distinction between the bare grounds and the urban zones, thing which pushed us has used a second complementary method, that of the supervised classification in order to add a more detailed study by quantifying this urbanization, with figures and statistics which make it possible to analyze the phenomenon of urbanization with much more precision, and end up with explanations and interpretations drawn from past studies made on the six regions of the wilaya of Tizi-Ouzou

Keywords : Urban Sprawl , BAEMOLI,TIRS, NDBI, Tizi-Ouzou , Valley Oued Sebaou

I-Introduction:

After the independence of Algeria, a strong anarchic and non-programmed urbanization was felt in the wilaya of Tizi-Ouzou and one of the main causes is the demographic weight in
particular in the valley of oued sebaou and the depression of Drâa El mizane, because according to the Census RGPH 2018 published in the statistical yearbook of the DPSB and the division into homogeneous areas of the wilaya of Tizi-Ouzou according to the geomorphology of the region by the author and an article published in the journal of the Mediterranean House of Human Sciences (the journal of the Mediterranean House of Human Sciences ), where 6 homogeneous zones could be identified in figure 1, so the phenomenon only worsens with the strong demographic growth due to the natural increase on the one hand and the immigration of the populations of the bordering wilayas on the other hand, because, Tizi-Ouzou represents a hinterland for the wilaya of Algiers by its proximity, and among the projects which are going to tighten the grip on the wilaya of Tizi-Ouzou, we have the penetrating road of the east-west highway a project of regional importance, and the railroad line connecting Algiers Tizi-Ouzou which made the access to the capital easy, thus transforming the wilaya of Tizi-Ouzou into a place of residence for the workforce of the employment basin of Algiers, moreover the wilaya of Tizi-Ouzou is endowed with equipment of regional importance such as the university pole of Tamda, the university hospital of Tizi Ouzou... etc.. (Abid & al , 2014)

The most suitable approach to study this phenomenon is remote sensing, which will be applied with two distinct methods in order to study the phenomenon that is rampant in the wilaya in more detail.

II-Study Area :

The wilaya of Tizi-Ouzou is located in the region of Greater Kabylia in the heart of the Djurdjura massif. It is divided administratively into 67 communes and 21 Daïras, it covers an area of 2,992.96 km2, the resident population as assessed in the 2018 census is 1,191753 inhabitants and the density reaches 403 inhabitants per km2 according to the direction of programming and budget monitoring of Tizi-Ouzou (DPSB Tizi-Ouzou, 2018,p21), the wilaya of Tizi-Ouzou is located in the north of Algeria, in the region of Kabylia, it is bounded on the
east by the wilaya of Boumerdes, west and south-west by the wilaya of Bejaia, north by the Mediterranean Sea, and south by the wilaya of Bouira, the wilaya of Tizi-Ouzou, figure2, has an area of 2969.03 km² and the surfaces of each region are distributed as table 1.

III-Previous study on urban sprawl in Tizi Ouzou:

Among the authors, who have treated the subject in connection with our study on the urbanization of the wilaya of Tizi-Ouzou, we have the study of Saïd Doumane, entitled history of a pass and its urbanization (Doumane, 2011), which was made with a different approach and which is limited geographically has the town of Tizi-Ouzou only. There are also two authors Mohamed Laïche and Mouloud Sadoudi with an article published on the Algerian journal of anthropology and social sciences entitled "The extension of the city of Tizi-Ouzou to its eastern and western flanks: What alternative to the land constraint? "(Laïche & Sadoudi, 2011),these two articles have recounted the evolution of urbanization through time and the direction of urban evolution for the town of Tizi-Ouzou, and which predicts the evolution of this urbanization in the entire valley of Oued-Sebaou, in addition to a study entitled "a new generation of cities: les villes/villages cas de la wilaya de Tizi-Ouzou" (Cahiers Des CERAD, 2011), where the speaker mentioned that within the urban framework of the wilaya, large villages gravitate around urban centers represented generally by the chief towns of communes and that Tizi-Ouzou alone has six villages, some of which have more than 6,000 inhabitants and even if the emergence of large cities is stopped by the large villages that are considered as urban spaces and not rural, In addition to the large number of these large villages and hamlets that house a high number of populations that classify them in the urban stratum, states that the wilaya suffers from excessive urbanization, in a doctoral thesis, entitled "Urban planning through the PDAU-POS and the problem of growth and interaction cities / villages in Algeria. Empirical reference to the wilaya of Tizi-Ouzou"(RAHMOUN Naima, 2013), the phenomenon of urbanization has been treated in depth, the difference between the approach published in
previous studies and our current study, and the use of remote sensing that has not appeared in any other publication concerning the region of Greater Kabylia. Unlike the previous studies which were based on the documents of urban planning instruments and manuscripts that deal with the phenomenon of urbanization in the region, our study aims to enrich this knowledge by using remote sensing and new technologies.

**IV-Methodology** :

To be able to study the phenomenon of urban sprawl in Kabylia, also called suburban sprawl or urban encroachment, the only method is the approach through remote sensing, we will begin by establishing a map of extraction of built areas BAEMOLI, but before we embark on the elaboration of the extraction map of built-up areas we must first perform a preprocessing to the spectral bands, downloaded from the USGS site and which have been cut to the study area, and whose characteristics are described in the table 2.

**IV.1-Image pre-processing equations (U.S. Geological Survey, 2016, 54-55):**

**IV.1.1-Conversion of the numerical values of bands 2-8 to top of atmosphere reflection (TOA reflection) for the OLI sensor:**

Equation 1 : conversion of numerical values to top of atmosphere reflectance (TOA reflectance)

\[ \rho_{\lambda'} = M_{\rho} Q_{\text{cal}} + A_{\rho} \]

Equation 2 : final conversion to TOA reflectance

\[ \rho_{\lambda} = \frac{\rho_{\lambda'}}{\sin (\theta_{\text{SE}})} \]

With :
\( \rho' \): ToA planetary reflectance, without correction for solar angle

\( M_p \): Band-specific multiplicative resizing factor from metadata

(REFLECTANCE_MULT_BAND_x, where x is the band number)

\( Q_{cal} \) : DNs of the tape being processed

\( A_p \): Band-specific additive resize factor from metadata

(REFLECTANCE_ADD_BAND_x, where x is the band number)

\( \rho \lambda \): ToA planetary reflectance, with correction for solar angle

\( \theta_{SE} \): Local sun elevation angle

(SUN_ELEVATION)

IV.1.2- Conversion of TIRS sensor data from spectral radiation to brightness temperature

Equation 3 : conversion to spectral radiation using the radiance scale

\[
L_{\lambda} = M_L Q_{cal} + A_L
\]

Equation 4 : conversion of spectral radiation into brightness temperature

\[
T = \frac{K_2}{\ln \left( \frac{K_1 L_{\lambda}}{L_{\lambda} + 1} \right)} - 273.15
\]

With :

\( L_{\lambda} \): Spectral radiation ToA (Top of atmosphere) (Watts/(m^2 x sr x \mu m))

\( M_L \): Band-specific multiplicative resizing factor from metadata

(RADIANCE_MULT_BAND_x, where x is the band number)

\( A_L \): Band-specific additive resize factor from metadata (RADIANCE_ADD_BAND_x,
where x is the band number)

T Brightness temperature at the satellite (°C)

\( K_1 \): "Band-specific thermal conversion constant from metadata" (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11)

\( K_2 \): Band-specific thermal conversion constant from metadata (K2_CONSTANT_BAND_x, where x is the band number, 10 or 11)

Data related to the parameters of the pre-processing equations for the spectral bands cut out from the study area in table 3 & 4

**IV.2- Built-up Area Extraction Map of OLI Sensor (BAEMOLI):**

After introducing the equations respectively for each spectral band through the arcmap 10.8 raster calculator, we will move to the next step to perform our various calculations to establish a built-up area extraction map, cut to the study area and which will be used for the calculation of NDVIOLI, NDBIOLI, MNDWIOLI, which will subsequently be used for the calculation and elaboration of the built-up area extraction map BAEMOLI, via the following methodology:

The proposed methodology for the built-up areas using extraction map Landsat-8 OLI imagery included four main steps (Bhatti & Tripathi, 2014, p 8, 14-18):

1-process ing, and examination of the satellite data (radiometric correction)

2-image enhancement by resolution fusion

3-development of the built-up area extraction method

4- accuracy and evaluation

Here is the formula (Bhatti & Tripathi, 2014b) that will calculate the BAEMOLI:
Equation 5 : Built-up Area Extraction Map

\[ BAEM_{OLI} = NDBI_{OLI} - NDVI_{OLI} - MNDWI_{OLI} \]

**IV.2.1 NDBI (Normalized Difference Built up Index) :**

The NDBI calculation formula for the sensor TM (Thematic Mapper(NASA)(Zha, Gao, & Ni, 2003, p583-594), has been modified, and adopted for the OLI sensor of the landsat8 project, by Saad Saleem Bhatti & Nitin Kumar Tripathi (Bhatti & Tripathi, 2014). Without going into details, which are out of the author's field of competence, the calculation of NDBI_{OLI} is done through the following equation:

Equation 6: the normalized difference index of the frame modified by S.S. Bhatti et al for the OLI sensor

\[ NDBI_{OLI} = \frac{PCA_{OLI} \text{BAND } 6,7 + PCA_{OLI} \text{BAND } 10,11 - OLI \text{BAND } 5}{PCA_{OLI} \text{BAND } 6,7 + PCA_{OLI} \text{BAND } 10,11 + PCA_{OLI} \text{BAND } 5} \]

**IV.2.2- Normalized Difference Vegetation Index (NDVI) :**

The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remotely sensed measurements (Wikipedia), for the definition proposed on the ESRI site the NDVI Index is a normalized index to generate an image displaying the vegetation cover (relative biomass).

Equation 7: Normalized Difference Vegetation Index (NDVI)

\[ NDVI_{OLI} = \frac{NIR-RED}{NIR+RED} = \frac{\text{BAND5-BAND4}}{\text{BAND5+BAND4}} \]

**IV.2.3-Modified Normalized Difference Water Index**

For the modified normalized difference water index, MNDWI (Xu, 2006, 3025-3033) the near infrared NIR band 4 for the TM sensor has been replaced by the mid infrared band 7 for the OLI sensor then:
Equation 8: MNDWI

\[
\text{MNDWI} = \frac{\text{Green} - \text{MIR}}{\text{Green} + \text{MIR}} = \frac{\text{OLI Band 3} - \text{OLI Band 7}}{\text{OLI band 3} + \text{OLI Band 7}}
\]

After generating these different indices, we introduce equation 5 in the raster calculator of arcmap 10.8 in order to obtain the built-up areas of extraction map that will be used to evaluate and detect urban areas, given the limitations of this technique that does not allow to differentiate between built-up areas and bare soil on the one hand and the spatio-temporal study of the study area in a precise way on the other hand, we will present a second complementary method to study the phenomenon that is rampant in the wilaya of Tizi-Ouzou in depth via the methodology that we will present in the paragraph that follows.

IV.3- Generate the land use map using the supervised classification technique:

From the multispectral image, we will use the technique of supervised classification, in arcmap, after cutting the multispectral band to the study area, we will choose 4 classes which are the urban area, vegetation, bare soil and seasonal crop as well as water, we will apply this process for different satellite images acquired at different periods Table 5.

We will show, the methodology to apply, for the generation of land use maps for different satellite images we will take as an example, the satellite image of 2019, to simplify we will schematize our methodology in the figure 3.

V-discussion results:

V.1- Generate the Built-up Areas Extraction Map BAEM_OLI:

V.1.1- Raster of the Normalized Difference Built-up Index (NDBI):

After the preprocessing, of the spectral bands cut to the study area of bands 5, 6, 7, 10 and 11, and the introduction of the formula of equation 6 in the raster calculator we obtain figure 5,
For the resulting NDBI\textsubscript{OLI} imagery, it is worth noting that the pixels with white and bright gray colors show the urban areas, a contrario the pixels with dark gray and black colors show the other types of ground cover for the densely vegetated areas they appear dark in this image, as for the water and the few areas with less dense vegetation we have bright tones.

The index of normalized difference of the built-up area remains rather debatable to analyze the urbanization in areas such as the wilaya of Tizi-Ouzou, with an uneven relief and a diversified land use, for example for those who know the region, they can easily detect in figure 5, that the Taksebt dam located between the two communes of Irdjen and Beni-Aissi which has a water showing a strong turbidity because of the daily erosion, as well as the pollution marked by the presence of the green algae in summer because of the fall of the water level is confused with the forest of Tagmut At Djennad which is very dense, because both are presented by a dark color, hence the need to subtract the index of vegetation NDVI\textsubscript{OLI} and the index modify water to normalized difference MNDWI\textsubscript{OLI} that we will see later, however we can detect less accurately the wadi Sebaou and some of these streams, with a luminous tone, but unfortunately can be confused with less dense vegetation, as is the case downstream from the Taksebt dam, which is why we opted for the Built-up Area extraction Map BAEM\textsubscript{OLI}, to eradicate any confusion with the different types of land use

\textbf{V.1.2- Raster of NDVI:}

For the vegetation index, pixels with white and bright gray tones show vegetation, while those with moderate to dark gray tones show other types of land use and finally black is associated with water, and as shown in the figure below the waters of Taksebt dam are represented with a black color, so in sum there is no confusion in this index except for some areas of the forest Tagmut at Djennad that appear a blackish color confusing with water, And according to figure 6, the bright gray color predominates in the mountainous regions (Coastal massif of azeffoun, Massif of Grande Kabylie and the chain of Djrudjura) while the moderate gray tones to dark
and which represents either the bare soil, or the built-up areas predominate in areas has low altitude such as the hill of Grand Kabylie, the depression of Drâa El Mizane and to finish the valley of Oued Sebaou

V.1.3- Raster of Modified Normalized Difference Water Index (MNDWI):
The water is represented by white pixels in this image, while the other types of ground cover are represented by gray and black colors, analyzing finely we see that the areas with dense vegetation are dark while the built areas are with variable shades of gray, In the same way, the Taksebt dam is represented by a white color which means that it is a body of water, as mentioned well enough in figure 7, for the urban areas they appear in light gray and these areas correspond, has the major part of the coastal Massif of Azeffoun, the Massif de Grande Kabylie and the Djurdjura mountain range, while the Oued-Sebaou valley, the Hill of Great Kabylia and the Drâa El Mizane depression have a predominantly dark gray color intermingled with light gray pixels, which means that the vegetation is intermingled with the urban areas, These results may contradict what we have seen previously and this is logical, because the MNDWI is used to identify only the water bodies in a clearer way and can be limited enough to show more clearly the urban areas, hence the need to use the BAEMOLI

V.1.4- Built-up Area Extraction Map:
The higher DN values in BAEMOLI indicate a greater possibility for these pixels to represent built-up areas, while the lower values represent land cover classes other than built-up.

Pixels with white, bright gray, and light gray colors show built-up areas, while dark gray and black tones represent other land cover types. The areas with high density of built-up areas appear with brighter tones, on the contrary the areas with low density of built-up areas appear less bright, among the limitations of this method is the fact that we are unable to detect the bare ground, in addition to the vegetation, The built-up areas and the water bodies are
detectable, but in a less precise way, globally before sinking into the details and based on the observation of Figure 8, we note that in the region of the Coastal Massif of Azeffoun we have the dark gray color which predominates what show the weak presence of the built-up area in this region, and it is the same observation for the Hill of Great Kabylie and the Djurdjura Chain, as for the two regions (valley of Oued-Sebaou and Depression of Drâa El Mizane) they appear with a light gray color, which means a priori that the built environment predominates in these regions except that it is not true, because this technique does not distinguish between bare soil (fallow agricultural land) and built-up areas, and to finish the hill of Grand Kabylie, according to the visual overview we have almost an equality between the portions of territory having taken a light gray color and dark gray, This means that the built-up areas and other types of land use are intermingled, these results remain to be discussed, because it remains simply a visual analysis that does not give more details with figures and statistics to have more precision, and it is noted that these results can be questioned, because they depend on the weaknesses of the human eye moreover this technique does not allow the distinction between bare soil (agricultural land set aside) and urban areas, and knowing that the regions (Valley Oued-Sebaou, hill of Great Kabylie and depression of Drâa el Mizane) are home to several fallow agricultural land (bare soil) especially in summer period where the confusion between the built areas and bare soil that take the same color gray and is one of the flaws of this technique, It should be noted that this method does not give more precision on the quantitative level, as would a supervised classification, but we can have a global overview of the territorial dynamics of the wilaya of Tizi-Ouzou through this empirical approach.

**V.2-Spatio-temporal study using the supervised classification technique:**

**V.2.1-Generation of the land use map of the wilaya of Tizi-Ouzou for the year 2019:**

After slicing the Landsat8 multispectral image of the OLI sensor of 09/08/2019, with a resolution of 30 to the study area, we have chosen in knowledge of the field, several points to
represent our 04 classes (Urban areas, Vegetation, Bare soil, and Water), and after engaging our supervised classification we have obtained our land use map represented in the figure 9.

**V.2.2-Accuracy assessment for our supervised classification (accuracy assement)**

We chose 21 points for urban areas and 20 points for other land use types (vegetation, water and bare soil and seasonal crops), the calculated accuracy is 91.36%, which gives an excellent reliability for our classification (ESRI) (Youtube Chanel GeoDev), we will do the same for the other years, as shown in the confusion matrix in the table 6.

Equation 9 : Matrice de confusion

\[
\text{Overall accuracy} = \frac{\text{correct predictions}}{\text{total predictions}}
\]

Calcul :

\[
\text{Overall accuracy} = \frac{(21 + 19 + 16 + 18)}{81} = 91.36\%
\]

**V.2.3-Statistical study and regional analysis of the wilaya between 1987, 2000, 2009, 2015, 2019 and 2021 :**

We will proceed with the same methodology to generate the land use maps for the different periods, starting with the land use raster of the wilaya of Tizi-Ouzou, with a division into regions instead of communes as was the case in Figure 9, Then we will make the comparison of land use for the different periods studied, starting with the year 1987, even if the resolution of the raster, was 60 meters, because the instrument or the thematic sensor mapper embedded in the Landsat 4 satellite could not capture images beyond this resolution. However, we note the opposite of what we have seen previously that urbanization is less dense in the valley of Oued-Sebaou, but still a linear urbanization along the national road No. 12 is noticeable as
shown in Figure 10 in contrast to other regions, The urbanization of the region of the valley of Oued-Sebaou has gone through several stages and has been influenced by the policies put in place by the Algerian government, the president A. Ben Bella launched the textile factory in Draa Ben Khedaa within the framework of the economic reform and which was followed by a special program established by Boumediene with the aim of developing the wilaya of Tizi-Ouzou, a rather important budgetary envelope 550 million dinars were allocated to the wilaya with the aim of realizing new residential buildings, House of the culture, psychiatric hospital, seat of the academic Inspection, high school, hotel training institute, hotel of high standing, which aim were to rehabilitate mountainous areas, to relieve the populations of rural areas and to curb the rural exodus to large cities (Oualikène, 2009, p.195-209), a spectacular extension of urban agglomerations and the establishment of industrial fabric implanted on easily accessible sites (the fertile agricultural plains located along the valley of the Sebaou: Tadmaït, Draâ-Ben-Khedda, Tizi-Ouzou, Oued-Aïssi, Tamda, Azazga, Fréha), as for the other regions the urbanization was less ferocious and represented by clusters of small grid points scattered all over the figure 9, these areas represent the traditional colonial villages and some projects elaborated by the local authorities at the independence and following the first Algerian administrative cuttings of 1985, Among the causes which was behind this weak urbanization one has the policy of centralization, which to support the development of the large cities and the core of the chief town of the wilayas while marginalizing the other communes, adding to that the absence of instrument of development at this time

If we compare the land occupations of 2000, 2009, 2015 and 2021 through figures 11,12,13,14, the first observation is the vegetation which was quite significant in the year 2000 compared to the other periods and even to the land occupation realized by the images taken on 30-06-1987 and 09-08-2019 and represented by figures 09 and 08 respectively, This can be explained by the chronological evolution of urbanization over time on the one hand and on the other hand by
the appearance of bare soil which is caused by the extreme drought for the year 2009 and 2021 in addition to the period of acquisition of the image which was in summer, a season where grass and vegetation are rare. The appearance of a more pronounced urban fabric in 2000 is mainly due to the adoption of the law of November 18, 1990 on land orientation and promote the industrial sector in the region of the valley of Oued-Sebaou. This spatial dynamic is accentuated over time by an excessive urbanization, because of the marginalization of the agricultural sector to the detriment of the industrial and tertiary sector, especially with the establishment of an industrial fabric on highly fertile land including the agricultural plains located along the valley of Sebaou and which have affected not only the agricultural land in the Sebaou region, and the plains of high altitudes, but also the mountainous areas of other regions that were once depopulated and have suffered the throes of this uncontrolled and unrestrained urbanization, the finding is an exponential urbanization in all regions of Greater Kabylia.

V.2.4- Chi-square test for the urbanization phenomenon between 2009, 2015 and 2021

Using the rasters of supervised classification for the different years 2009, 2015 and 2021, and the tool zonal statistic as table we obtain the number of pixels for urban areas for each year, using the formula in the equation below and we obtain results in table 7

Equation 8 : Calculating the area from pixels

\[ \text{AREA} = \text{number of pixels} \times \text{Resolution in meter}^2 \]

It should be noted that the resolutions of the rasters of land use, are 30 meters, as mentioned in Table 5

V.2.4.1- Observed urban growth for each region

We proceed to calculate the urban growth observed between 2009-2015 and 2015-2021 for each region by a simple subtraction and we obtain Table 8

Equation 11: Calculation of Observed Urban Growth
Observed Urban Growth

\[ = \text{Urban area of the current period} \]

\[ - \text{Urban area of the previous period} \]

V.2.4.2- Theoretical urban growth for each region :

Theoretical urban growth is calculated using the formula in the equation (الهادي, 2021)

Equation 12: Calculation of theoretical growth

\[ M_{ij}^E = \frac{M_i^s + M_j^s}{M_g} \]

An we obtain the result in the table 9

With :
\[ M_i^s \quad \text{row total} \]
\[ M_j^s \quad \text{grand total} \]
\[ M_g \quad \text{column total} \]

V.2.4.3- The difference between observed and estimated urban growth and calculation of the Chi-square :

By subtracting the observed urban growth from the theoretical urban growth, we can determine the value of urban expansion in the study area so the resulting positive values indicate a high urban growth, while the negative values indicate a low urban growth, the results in table 10

To calculate the Chi-square values (Pearson’s chi-square) we will proceed by applying the formula of equation 13, the Chi-square is used to calculate the degree of freedom for the urban growth of the Study Area for different directions and time periods, so the degree of freedom for urban growth indicates the sustainability or not of this growth, because a high degree of freedom indicates that the regional processes of urban growth are not balanced(رهير, النامي, نبهان, ص88-95, Aburas, 2016, page 7), and the results in table 11
Through the following equation (Dadras, Shafri, Ahmad, Pradhan, & Safarpour, 2015, page 43)

Equation 9: Calculation of the Chi-square \( X_i^2 \)

\[
X_i^2 = \sum_{j=1}^{m} \left( \frac{(M_j - M_j^E)^2}{M_j^E} \right) = \frac{(\text{observed value} - \text{theoretical value})^2}{\text{theoretical value}}
\]

\( M_j \) Observed value  
\( M_j^E \) Theoretical value

It can be seen that the urban growth is balanced only for the region of the hill of Grande Kabylie for the two periods 2009-2015 and 2015-2021, but this is not the case for the other regions with a lesser extent for the valley of Oued-Sebaou, whether for the period 2009-2015 or 2015-2021. Thus the high value of the degree of freedom indicates an unbalanced urban growth, which implies a totally unbalanced and anarchic urban growth and which goes in all directions, for the regions (Massif of Great Kabylie, hill of Great Kabylie, Oued Sebaou valley, Depression of Draa el Mizane, and finally the Djurdjura Mountains), The results of the table 12 indicate that the urban growth of the wilaya of Tizi-Ouzou is totally unbalanced.

V.2.5- Calculation of the urban extension density index:

To calculate this index, we will use the formula in equation 15 (Akubia & Bruns, 2019, page 7), the urbanization density index is used to analyze differences in the quantitative spatial extension of an area, the so-called Preference for urban growth phenomenon, and it can be used to determine the preference for urban growth at a certain period, but also the potential future direction and evaluate possible urban extensions, and comparing the speed or intensity of change of urban areas at different periods (الهادي, 2021)

Equation 14: Urban sprawl intensity index

\[
UEII_i = \frac{\text{UL}_i^{12} - \text{UL}_i^{11}}{\text{TL}_i \cdot \Delta t} \times 100
\]
With:

\[ ULA_{t1} \] : built-up area in km² for year t1

\[ ULA_{t2} \] : built-up area in km² for year t2

\[ TLA_i \] : Total area (entire region)

\[ \Delta t \] : Period between t1 and t2

V.2.5.1-Rhythm of urban growth for each region and wilaya

We apply the formula of equation 14 to table 8 and we obtain the results of the table 13 for each region and table 14 for the wilaya. It is to highlight that, if the value of the index is higher than 1.29, urban growth is very fast, between 1.05 and 1.92 it is fast, between 0.59 and 1.05 it is medium, between 0.28 and 0.59 it is low and if the value is lower than 0.28 it is very low [53]

so in conclusion the period of 2009-2015, this rapid growth can be explained by the projects that have been carried out by the state and the private sector, with the main purpose was to reduce the housing crisis, adding to that the illicit constructions due to the non-respect of the rules of town planning and construction, the urban police intervenes only rarely in the case of the infringements related to the wild urbanization, the absence of sanction towards those who infringe the rules of construction and town planning, For the period 2015-2021, the phenomenon has accelerated dramatically and this can be explained by the population explosion, the evolution of the purchasing power of the resident population and the emergence of the middle class

Conclusion:

The first method to obtain a map of extraction of built-up areas has certainly clarified the situation, showing the extent of damage related to this uncontrolled urbanization that has hit
hard, the regions hosting the most fertile land of the wilaya, such as the valley of Oued-Sebaou, the Depression of Drâa El Mizane and the Hill of Grand Kabylie, but visually we see that the result is exaggerated because of a flaw or a limitation of this methodology that does not allow the distinction between urban areas and bare soil, which is why we have opted for the technique of supervised classification for different period, for the year 2019 for example the values of the percentage of urbanization were very close for all regions with a maximum for the hill of Grand Kabylie that is 40.84% and a minimum value for the region of the coastal Massif of Azeffoun 27.80%, for the space-time study of the wilaya of Tizi-Ouzou for the years 2009; 2015 and 2021, we opted for the calculation of chi-square in order to establish the mode of urban growth, the results obtained show that the wilaya of Tizi-Ouzou and all these regions have a mode of urban growth unbalanced and that goes in all directions, As for the density index of urban extension, it has been noticed that the rhythm of urbanization has accelerated for the wilaya by passing through a rhythm of rapid urban growth from 2009-2015, to a very rapid urban growth, for the period of 2015-2021

Data available to be shared:

The raw data needed to reproduce the above results can be downloaded freely. The processed data necessary for the reproduction of the above results are available for download

Références bibliographiques:


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