

ANALYSIS OF URBAN SPRAWL PHENOMENON IN BATNA CITY (ALGERIA) BY REMOTE SENSING TECHNIQUE

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Abstract: Define Batna city, define its outlines and follow the spatio-temporal evolution is one of the complex problems. Urban sprawl, that rapid urbanization is the occupancy factor of soil changes, generally irreversible. His study in a medium-sized city is an important issue that requires monitoring and detailed analysis. Our approach includes the use of remotely sensed images to evaluate and qualify urban sprawl in Batna. For this purpose, we used a series of images in digital format for the years 1972, 1987, 2001 and 2013, acquired by multispectral sensors mounted on Landsat satellite platforms, for area which is the subject of experimentation, then supervised classification by Support Vector Machine (Radio Basis Function classifier RBFC) was utilized. The selection of the images available from Landsat archives was made so that their acquisition date is spread enough to better distinguish changes within the urban fabric. The results obtained confirm that urban area increased 173.32% between 1972 -1987, 55.62% between 1987 -2001 and 38.71% between 2001 -2013. Furthermore, Shannon's entropy index shows that the city has a high level of sprawl along its urban expansion history.

Key words: Batna, Urban Sprawl, Remote Sensing, Shannon's entropy, SVM classification.

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INTRODUCTION

In 2008, half of the world population started living in urban areas (Tewolde & Cabral, 2011). In Algeria, over the past four decades, the notable events which emerges from the general population and housing census (RGPH) is the rapid growth of the urban population representing 66.3% of the population in 2008 while it was 49% in 1987 and 31% in 1966, whereas the rural population showed a negative growth which decreased from 68% in 1966 to 33% in 2008 linked to the transformation of the relations between town and country (immigration and transferring of rural population to urban centres).

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This study presents the case of Batna city in the eastern of Algeria. Batna's resident population reached 319742 inhabitants on 2013 while it was estimated at 289504 in the latest RGPH in 2008, which correspond to a population growth, the rate of 2.06%. This latest census indicates that 26.1% of Batna province population is grouped in Batna city on 0.99% of the territory. Indeed, much of the urban expansion has occurred as sprawl around the central urban core, with many of the most affluent residents migrating to the periphery. From 1972 to 2013, the land area of the city increased by almost 7 percent, while the population only grew by 3 percent.

Today, Batna is one of the most rapidly developed urban areas of the state. The increase of the urban perimeter has generated a many problems, among other ones, related to the development of peri-urbanization, unplanned and uncontrolled spreading of urban development into areas adjoining the edge of a city, and recently enormous urban sprawl. This is the result of an urban dynamic not accompanied with an appropriate instrumentation concerning urban planning in order to control and regulate its growth.

Any form of urban growth is not necessarily synonymous with urban sprawl. However, urban sprawl, as a concept, suffers from difficulties in definition (Barnes et al., 2001; Roca et al., 2004). Peiser (2001) considers that urban sprawl term is used to mean „*greedy and ineffective use space and a monotonous, uninterrupted and discontinuous development*”. Charles et al., (2006) defines the urban sprawl as being „*a model of urban and metropolitan growth which reflects a low density, an automobile dependence and a new development of the zones to the fringe, often in the neighborhoods of the city*”. In Algeria, any public policy based on regulatory instruments, by its nature, the land is a scope and an essential means of political planning, urbanism, planning and housing. This is obviously an instrument of intervention and regulation as it is a factor of production, concentration and management of interests and wealth. Established by the law 90-29 issued in 1/12/1990, on urban and city planning, and the law 90-25 issued in 18/11/1990, carrying the land orientation, texts and tools regulating land sector in Algeria seem inadequate. Regulatory dispositions and administrative practices impose constraints which people cannot respect. These inappropriate dispositions require the majority to seek solutions to their problems in irregular and informal field, outside the guidelines of planning tools, which gives large areas with constructs a poor quality, usually not straight and they suffer lack of basic equipment and areas, which cause accumulation. Within this framework, to control the urban growth and minimize the problems caused, policymakers in the difficulty of obtaining sets of spatial data accurate enough to detect the growth of the city, need decision support tools to assist them in management and strict implementation of urban planning instruments, it is essentially through spatializing of the phenomena that they address question of urbanization.

The main goal of our contribution is to make some reflections about the urban sprawl process and to exhibit the integrated use of remote sensing and GIS together with Shannon's entropy in addressing and quantifying urban growth patterns in the studied area in the last 40 years through Shannon's entropy approach.

DESCRIPTION OF STUDY AREA

Batna, capital of the Aurès Massif (figure 1) with an area of 2852.41 Ha is located in eastern Algeria, between 6°7'59" and 6°13'31" East longitude and between 35°34'23 and 35°31'26" North latitude. Located on high plains, at the crossroads of Constantine, Biskra and Khenchela. This gave him a polarizing role. Founded in 1844 (Hogue, 2008) in the middle of a bowl surrounded by mountains with rugged relief, located on a site slightly sloping (47% of grounds do not exceed 10%), easy accessibility which makes it a useful location to build and spread. With more than 319742 residents and approximate 61100 housing units, Batna occupies a central and sensitive point. A statistical assessments show that Batna become in short time a pole of attractiveness and engine of economic growth of the province, where the majority of economic activities are focused in major sectors; the trade (45.50%), the services (38.08%) and industry (16.41%) (National Statistical Office of Algeria, 2012).

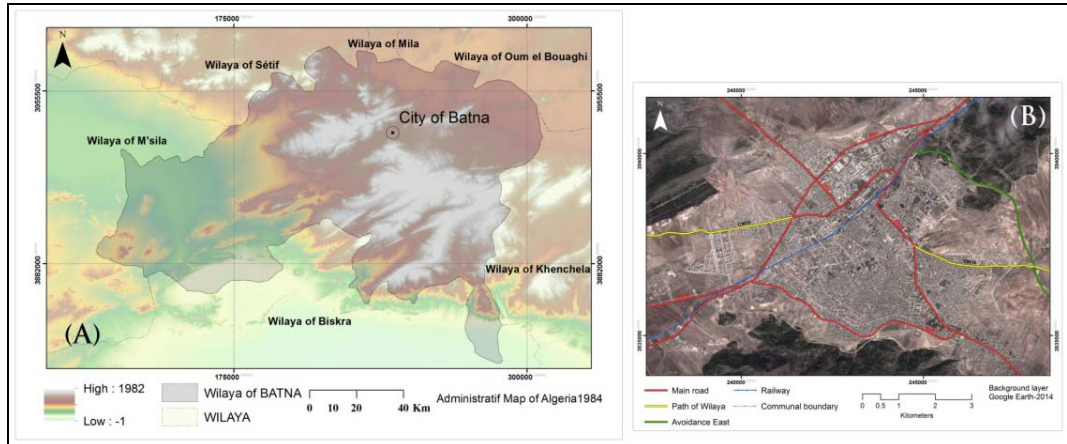


Figure 1. A map of the study area: (a) location of wilaya of Batna, (b) study area – Batna city (Background layer Google Earth-2014)

MATERIELS AND METHODS

The following multi-temporal remote sensing imageries and software have been used to extract built-up areas of Batna:

- Landsat Multispectral Scanner (MSS) image (path 209, rows 35) from 14 August 1972;
- Landsat Thematic Mapper (TM) image (path 193, row 35) from 16 June 1987;
- Landsat Enhanced Thematic Mapper Plus (ETM+) image (path 194, rows 35) from 02 April 2001;
- Landsat Enhanced Thematic Mapper Plus (ETM+) image (path 193, rows 35) from 06 January 2013;
- Topographic map of Batna East, West, Arris East, West (at 1:50 000 scale, 1995, NI 32 XIX 3).

ENVI4.7 and ArcGIS10.1 (ESRI) software are used for digital images processing because they support the file formats of one another.

PRELIMINARY TREATMENT

This work will be based on the raw images that have distortion and degradation and preliminary treatments are designed to eliminate to get a map reference to its users.

Filling gaps in Landsat ETM (Filling Gaps)

May 31, 2003, Landsat 7 Enhanced Thematic Mapper (ETM) sensor had a failure of the Scan Line Corrector (SLC). Since that time, all Landsat ETM had wedge-shaped gaps on both sides of each scene, which results in data loss of about 22% (Wulder et al., 2008). Scaramuzza et al., (2004) have developed a technique that can be used to fill gaps in a scene with data from another scene Landsat. A linear transform is applied to the „filling” image to adjust, it based on the standard deviation and mean values of each band, of each scene. In this work we used a TM image obtained by the Landsat 5 Jan. 2, 2011, this image intended to fill a more recent ETM + image (L7 SLC- off) obtained by the Landsat 7 January 6, 2013 satellite.

Image registration (geo-referencing)

The images that we have not exactly represent the same area of land. There is a gap between them. To remedy this problem and adopt the same standards (provide a common scale to all data), we conducted a registration of images using ArcGis10.1 software. To do this, a Universal Traverse Mercator (UTM WGS84) has been selected as the projection system, then a ground control points have been selected from topographic map (1:50 000), for more precision our procedure of geo-referencing is to move each point of raster (satellite images) to the same point of the target map using Geo-referencing tools.

Pan-Sharpening

Generally, the Pan-sharpening is defined as a combination of two or more different images to form using an algorithm a new image (Pohl & Van Genderen, 1998). The aim of image fusion is to integrate complementary data in order to obtain more and better information about an object or a study area than can be derived from single sensor data alone (Singhai & Sarup, 2011).

In our work the pan- sharpening is to merge a panchromatic image (band 8) at high spatial resolution (15 m) obtained by the ETM + sensor with a multispectral image of medium spatial resolution (30 m) also obtained by the same sensor and the result produced a multi- spectral image with the same resolution as the panchromatic image.

Application of Supervised Classification (SVM)

Our work has focused on an approach of mapping the urban sprawl by Support Vector Machine classification method from Landsat satellite imagery. It is, in the absence of measures on land and in the absence of available data, to apply SVM classification method. In terms of definition, the support vector machines (SVMs) is a supervised non-parametric statistical learning technique (Mountrakis et al., 2011). Indeed, the machines with vectors of support or separators with vast margin area set of techniques of supervised training in tended to solve problems of discrimination and regression, i.e. to decide to which class a sample belongs. In this regard, The SVM approach consists in finding the optimal hyperplane that maximizes the distance between the closest training sample and the separating hyperplane (Melgani & Bruzzone, 2004).

By their strong connection to the underlying statistical learning theory, where they implement the structural risk minimizing for solving two class classification problems (Vapnik, 1995), and their effective in automatic estimation of impervious surfaces (Esch et al., 2009), the SVMs are quickly adopted in our work for their capacity to work with large-sized data, limited quantity and quality of training samples (Ghogkali et al., 2009; Gidudu et al., 2007), their theoretical warranties, and their good performances in practice.

RESULTS AND DISCUSSION

After extraction the study area, colorful composition; (band4, 3 and 2) suitable for urban themes were made from MSS, TM and ETM + images of 14 August 1972, 16 June 1987, 02 April 2001 and 6 January 2013 successively. Indeed, Support Vector Machines (SVMs) are typically a supervised classifier, which requires training samples (Mountrakis et al., 2011). Moreover, as we know perfectly the study area, we classified our area into three major classes; a class of Covered Plants (CP), a class of career, Sol Naked and Rocky Outcrops (CSN) and a class of urban frame (UF). This choice is made in a way to allow better identification of the city, and its extension in reference space-time.

The images provided by the Landsat satellite since 1972, are successfully utilized to quantify and mapping the urban space, and follow the evolution of the city (figure 2).

The combination of these maps will allow to elaborate the final map of urban sprawl which can be used to guide the development of Batna city, and extraction of the various axes of extension. Either, for lack of an optimal spatial resolution and maybe, by not adequate weather conditions at the data acquisition time, we can conclude that there are some pixels badly classified in this classification. Development of confusion matrix is a key element in this present work, it is for objective to evaluate the performance of classifications and validate the results, by evaluating the number of pixels correctly classified inside each piece of training.

By analyzing the table 1, the matrix of confusion shows that the various classifications carried out by SVM (Support Vector Machine) method have a very high performance (table 2), of which total precision given equal to 96% and the Kappa coefficient equal to 93%. By works of Landis and Koch, (1977) and Rupali and Karbhari, (2015), when $0.81 < Kc < 0.99$, it means that our results are statistically perfect, which means that the map of urban sprawl classified for different dates is compatible with ground realities.

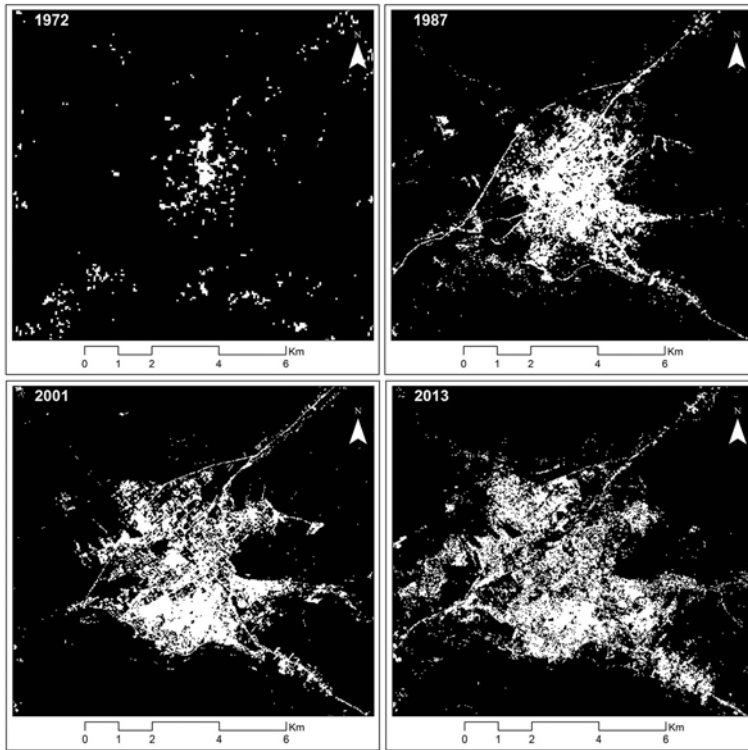


Figure 2. Classified images from different dates showing built-up areas in white

Table 1. Confusion Matrix of the supervised classification SVM_1972, 1987, 2001 and 2013

Class	1972				1987			
	UF	CSN	CP	Total	UF	CSN	CP	Total
UF	52	3	0	55	414	6	1	421
CSN	5	1408	0	1413	41	2386	7	2434
CP	0	0	22	22	0	0	119	119
Total	57	1411	22	1490	455	2392	127	2974
Class	2001				2013			
	UF	CSN	CP	Total	UF	CSN	CP	Total
UF	265	1	0	266	900	10	3	913
CSN	16	3280	2	3298	38	925	14	985
CP	0	1	50	51	0	12	374	396
Total	281	3282	52	3615	938	961	403	3330

Table 2. Validation the results of classification by good values of GP and KC

Matrix of Confusion	Global Precision (GP)	Kappa Coefficient (KC)
Confusion Matrix 1972	0.952	0.890
Confusion Matrix 1987	0.966	0.948
Confusion Matrix 2001	0.960	0.936
Confusion Matrix 2013	0.963	0.950
Average (%)	96.06	93.12

Quantification of growth rate

Visual comparison of changes, limit their real appreciation and encourages misjudgement (Tonyé et al., 1999). Therefore, in addition to the visual method, it was confirmed using two other relative approaches. It is important to mention that most of the sprawl measurement techniques, in general, are relative measures, and can be used as indicators of sprawl by the analyst (Bhatta, 2012).

The next table (table 3) shows the results of two quantitative methods for estimating the area of urban fabric. The first method is to estimate the surface by manual delineation, this method was carried out under ArcGis 10.1 (ESRI) software, a polygon can trace our study area and then measuring and calculating perimeters and surfaces. The area by the second method obtained by automatic extraction of pixels, then multiple the number by spatial resolution of the scene pixels, this is the most reliable and most accurate method because it neglects all undeveloped areas within the urban fabric. Statistically, the surface of the city increased from 483.43 ha in 1972 to more than 1321.32 ha in 1987, either rate of evolution of 173.32%, and from 2056.30 ha in 2001 to more than 2852.41 ha in 2013, or a rate of 38.71%. That is to say that, on average, Batna city needs 57 ha every year for its extension. Results reveal that land development on global (7.87%) is more than two times the population growth (3.86%). Indeed, urban growth before 1990 is a logical response of a demographic growth marked the first two decades of independence (from 55017 inhabitants in 1966, to more than 184000 in 1987). It was accompanied by national policy based on the principle of „*Economy planned*” and „*industrializing industry*” which involved a considerable increase in urban system of the city.

After 1990, by displacement of the rural population to the city, because of security conditions that Algeria has known in the 90s (whether a population growth rate of 2.3%), and the release of land market, characterized by the appearance of new actors in land management (private owners), a major redistribution of human workforce operates in the city, causing an extensive consumption of peripheral grounds, situation since a few years began to present signs of urban saturation under the influence of urban sprawl.

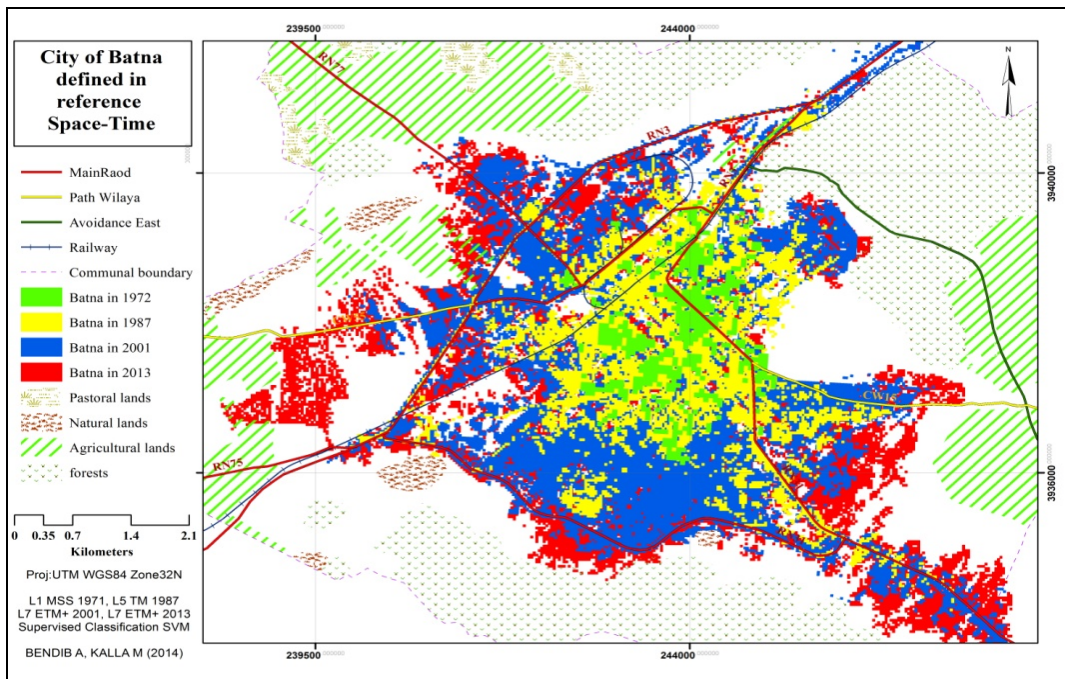


Figure 3. Map synthesis of urban sprawl in Batna (combination with other geographic entities by a GIS)

Table 3. Evolution of the area of Batna city in 1972, 1987, 2001 and 2013.

Year/ Sensor	Nbr of Pixels	Area by manual delineation (ha)	Area auto-extraction method (ha)	Percentage of built-up (%)
1972 MSS	1 482 344	483.43	121,32	25.09
1987 TM	11 116 875	1321.32	909,86	68.86
2001 ETM+	23 537 094	2056.30	1926,40	93.68
2013 ETM+	33 192 750	2852.41	2716.68	95.24

Analysis of Urban sprawl by Shannon’s Entropy method

The Shannon’s entropy was computed in this study to detect the urban sprawl phenomenon (Yeh and Li, 2001). Entropy is calculated according to:

$$H_n = - \sum P_i \log_e(P_i) \dots\dots\dots (1)$$

Where; P_i is the proportion of the variable (built-up) in the i th zone and n is the total number of zones.

This value ranges from 0 to $\log(n)$, if the distribution is very compact then the entropy value would be closer to 0 and when the value closer to $\log(n)$ the distribution is more dispersed. In order to calculate Shannon’s Entropy, the study area was divided into five zones using multiple concentric circles created around the city center at 1000 meters interval (figure 4).Table 4 shows the Shannon’s entropy results for 1972, 1987, 2001 and 2013.

Table 4. Shannon’s Entropy Value for the study area

Years	1972	1987	2001	2013	Log(n)
Value of Shannon’s entropy H_n	0.486	0.911	0.962	1.135	1.60

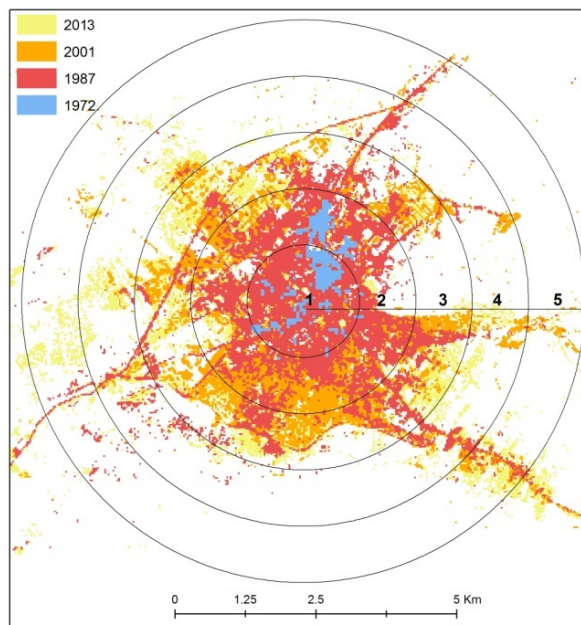


Figure 4. Buffer Zones around the study site

The entropy used for detect and measure the sprawl of the city and was calculated for each individual zone (n is the total number of zones. i.e., n= 5), the results show that Batna city was always sprawled. However, relatively lower value of Shannon’s entropy (0.486) was marked in the year of 1972 and largest values 0.911, 0.962 and 1.135 for 1987, 2001 and 2013 respectively. It indicates that at the time of 1972 the built-up area was distributed compact and homogeneous around the city center. Also, it should be noted that the entropy values have continuously increased during 1987, 2001 and 2013 to be close to the upper limit of log (n), 1.60 i.e. which means that the city has experienced sprawl.

Axes of this urban sprawl

Visual examination of satellite images acquired shows that the occupation of soil changes are identified mostly in the city, previous map (figure 3) can help detect changes of the city since 1972.

We are located in the city of Batna in few 900 - 1200 meters altitude. Eastward, more than 1954.61 ha of agricultural and plain land remained in continuous decline that due to the existence of a national road (NR # 31) connecting the city of Batna with the province of Khenchela which gives to the places adjacent a commercial importance translates rapidly by modifications on ground (from 56.26 ha in 2005 to 105.77 ha in 2013). Modifications operated in this zone; the replacement of the agricultural lands and open green spaces by built surfaces of commercial and individual habitat type, such the road of Tazoult and sector of Parc à Fourrage which does not cease to spread out inside agricultural lands (in average, Batna lose 2522.2m², of the best agricultural lands every year for illegal growth). As you move south more changes and spreads operated the last 40 years, among these changes is Bouakal, Tamchit and Douar Eddis sectors, this trend is now almost blocked by the relief (slopes DJ Ich Ali 1400m), but here we notice the gradual filling of the inbuilt space especially by individual houses.

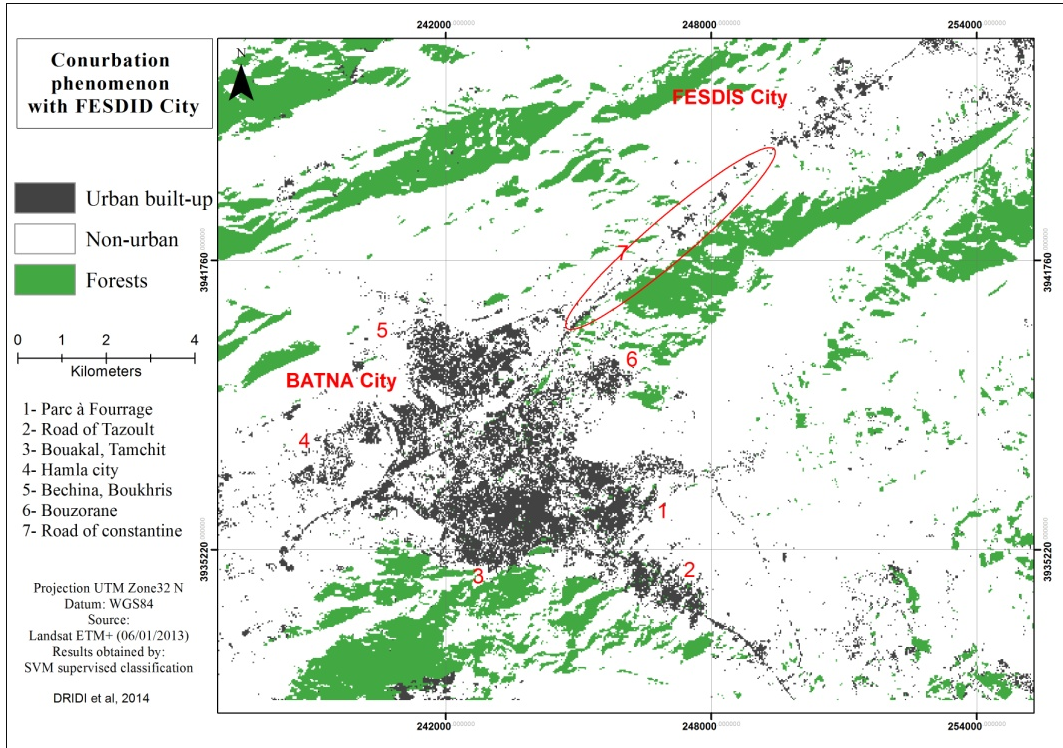


Figure 5. Linear dynamics and conurbation phenomena

We are located west of the city; the changes made here are clearly on large and fairly ground. The installation of Hamla city (over 120 000 inhabitants), multi- functional city (university residences, public buildings...) with a total area of 105.62 hectares, this area is completely installed on a plain platform very fertile, in similar, we add the considerable evolution of the road of Hamla, B'china and Boukhris sectors, where informal habitat (individual) is the most spectacular. It should be noted that the continued growth of B'china and Boukhris (46.23 ha in 2005 to 87.23 ha in 2013) is currently almost faced by relief of Dj Boumerzoug (1700m). Finally, we headed North where we could distinguish and report some modifications and changes on the territory, among these changes we quote Bouzorane sector, which is completely stopped by the relief (Koudiet Bouzorane 1150m), on the other hand, the side of the road of Constantine, sprawl continues to increase to Fesdis city at 6 Km; conurbation phenomenon with the municipality (figure 5).

Patterns of sprawl can take place either in radial direction, around a well-established city or linearly along the highways (Theobald, 2001). As shown in the following figure 6, the history of Batna city is characterized by two distinct forms of extension either in radial direction from the core coincides perfectly with the concentric model of Burgess, characterized by excessive consumption of open space and agricultural land, or linearly along the highways started after exhaustion and saturation of grounds by spreading, where the lines of communication have a structuring role.

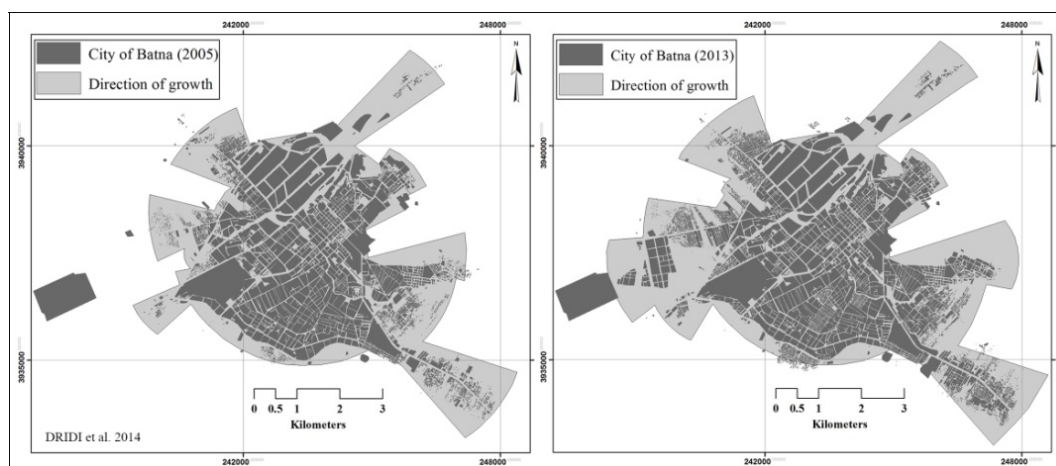


Figure 6. Forms of growth of Batna city in 2005 and 2013

CONCLUSION

Batna constitutes a fertile environment of a fabulous wealth with the big advantage to be just a step from France (...) from then on, few years Batna will become too small to maintain the mass of its inhabitants, believe it! (Pérès, 1875) The attractiveness of Batna city is a very old phenomenon, whose consequences on the current space constitute a real field of studies and experimentation through to the syndromes of the bad development and recently to urban sprawl.

The main objective of this paper was to verify the ability of this type of multi-dates images provided by the satellite Landsat to identify the contours of the urban fabric, what led us to evaluate the spatiotemporal spreading of the city. Furthermore, Shannon's entropy is a good method to detect and measure the spatial pattern of urban growth. The entropy value indicates an increase in the degree of dispersion of urban sprawl (from 0.486 in 1972 to 1.135 in 2013). This study presents an exhaustive assessment of urban sprawl status for the city which can be used by decision makers for ensuring sustainable urban development. Finally, the study demonstrates that remote sensing technique in combination with Geographic information system (GIS) is very useful for urban monitoring and future planning at local or global level.

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