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RESEARCH ARTICLE

Monitoring urban evolution between 1975 and 2015 using GIS and remote sensing technics: case of Lâayoune City (Morocco)

Y.MAKBOUL^{1*}, M.HAKDAOUI², A.GHAFIRI³, S.ELMOUTAKI⁴

Geomatic and Environment Laboratory, Department of Geology University Hassan II/Faculty of Science Ben M'sik- Casablanca

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***Corresponding Author**

Abstract

This paper presents an integrated study of urbanization trends in Lâayoune City, Lâayoune Province of Morocco, by using Geographical Information Systems (GIS) and remote sensing technics. The study explores the temporal, spatial characteristics and annual growth rate (AGR) of urban expansion from 1975 to 2015. Temporally, urban expansion shows fast and slow growth stages, with direction of growth, generally, to the east side of the city. The spatial patterns of urban growth can be categorized into four types: demographic migration intervention type, security intervention type, socioeconomic intervention type and normal urban growth type. Lastly, the major factors influencing urban expansion change are also discussed. In general, the population, commerce, industrialization, and security are the major factors that influenced the urban expansion.

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INTRODUCTION

In the last half century, more than half of global population lives in cities, as consequence the world knows a very speed urban expansion due to the demographic and economic development (Tsutsumida et al., 2015; Xu& Li.,2014(a); Song at al., 2015(b);). Rather that the urban area only present 3% of the total land in the world, but it has a very dangerous impacts on the environment (Pandey et al.,2014; Güneralp et al., 2008;GRUMPv1; Seto et al., 2010;Seto et al., 2012; Jiang et al., 2013; Demographia.,2015). The use of Geographic Information System (GIS) for detecting dynamic Land use changes has become an important aspect in many sectors (Swetnam et al., 2011; Kulawiak&Lubniewski., 2014(c); Gagné et al., 2015; Liu et al., 2015). These technics help decision makers to protect the environment, control and drive urban sprawl to a sustainable development especially in desert parts of the world and manage the food and water resources (Nassar et al., 2014; Abdel-Galil.,2012; Kulawiak&Lubniewski., 2014(c)). Today remote Sensing coupled with GIS is an effective and successful way to detect urban sprawl (Hegazy&Kaloop., 2015; Nielsen., 2015). Remote sensing provides a very large number of data which cover a very large area of world with a high spatial resolution and high temporal frequency and it also offer a historical data (Beuchle et al., 2015; Allen et al., 2013; Poyil&Misra., 2015). Recently, many studies approve that the combination of remote sensing with GIS is a vital if not the only way to map urban expansion (Xu& Li., 2014(a); Song at al., 2015(b); Belal&Moghanm., 2011). In order to analyze the urban growth and its relation with the socio-economic factors and impacts on the environment, an important number of studies, using these aspects, are trying to extract urban expansion's indexes, such as Annual Growth Rate (AGR) (Zeng et al., 2015; Travisi et al., 2010; Arribas-Bel et al., 2011; Yue et al., 2013; Poelmans&Rompaey., 2009; Su et al., 2010). In the last decade, due to the demographic development and socio-economic, Morocco knew a very important urban development (HCP., 2013(d)). In 2004 the rate of urbanization attends 55.1%, and estimated to be at 60% today (World Bank). In order to develop its southern Cities, such as Lâayoune City, Morocco has forced the socio-economic development by many investigations which caused a very important development in many sectors, like infrastructure, sociology and

industry (Muradlithran & Zerhouni., 2009; Sahara Developpement(e)). Lâayoune, as a capital in Southern regions of Morocco, is a typical city in Morocco which reflects the efforts of the government to develop these regions (Lacroix ., 2005(f)). In this study, we use the spatial analysis function of GIS to specify the urban expansion characteristics of Lâayoune City, during the past 40 years from its reintegration by the Green Marche. In this study we will extract the temporal and spatial characteristics of urban expansion and analyze the main factors which drive the expansion in period of study.

1. Study area's description:

The study area is located in South of Morocco (Figure 1) between the range of 13°16'W-27°11'N and 13°7'W-27°5'N with an area about 100 Km². Lâayoune is limited by Smara City in the East, Boujdour by South, Atlantic Ocean in the West and Tantan in the North. It lies on the Southern riverbank of Saguia Hamra River. Its agglomerations are about 20 Km². The semiarid climate determines its precipitation, which is only about 67 mm per year making the region incompatible with any type of non-irrigated agriculture. The humidity is around 70% along the year. The Saguia Hamra River Runs through the Northern limit of Lâayoune coming from region of Smara. It is a seasonal River depends on seasonal precipitations.

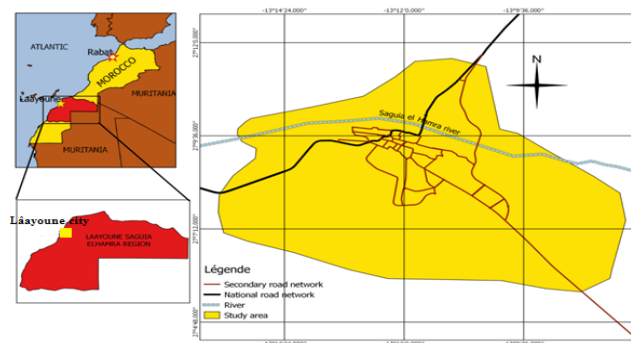


Figure 1: Spatial localization of the study area

Lâayoune is the largest city in its province; it is the most important city in South part of Moroccan territory. It is the first economic and social pole in this part. The actual population is about 253000 of people (HCP & DRL., 2013(g)). Before 1930 it was just a supplying point for caravan's passage, and before the green March in 1975 it was a military post counting 6000 person (Lacroix ., 2005(f)). This demographic development is due to its strategic localization between the Sahara and the Atlantic part of Morocco and to the return of Sahrawi peoples, who migrated to the North part of Morocco, due to the Spanish colonization, before the Green Marche in 1975 (Lacroix ., 2005(f)). The Moroccan efforts for a sustainable development in these reintegrated regions especially in Lâayoune City, where he created a very important economic and industrial zone which has encouraged the population of the North morocco to emigrate to Lâayoune in order to searching for a job Lacroix ., 2005(f)). As a result the migration is a great factor on the urbanization expansion (DRL., 2011(h)).

2. Data and Materials

a. Data:

In this study, multi-annual demographic statistical data, a city plan of 1975 downloaded from a Spanish military association's web site (MILI SÁHARA(i)), and five scenes of satellite multi-spectral image are collected in order to monitor the urban expansion of Lâayoune from 1975 to 2015 from U.S Geological survey web site (GLOVIS(j)). The materials used in this study are listed in the table (table 1).

Table 1: Data and data sources.

Data type	Year	Data provider	Process	Output
Plan of Lâayoune	1975	Spanish military (MILI SAHARA(i))	digitizing	built up area map of Lâayoune in 1975
Landsat 5 TM	1984	U.S.G.S	Supervised	built up area map of

		(GLOVIS(j))	classification	Lâayoune in 1984
Landsat 7 ETM+	1999	U.S.G.S (GLOVIS(j))	Supervised classification	built up area map of Lâayoune in 1999
Landsat 7 ETM+	2003	U.S.G.S (GLOVIS(j))	Supervised classification	built up area map of Lâayoune in 2003
Landsat 5 TM	2010	U.S.G.S (GLOVIS(j))	Supervised classification	built up area map of Lâayoune in 2010
Landsat 8 OLI/TIRS	2015	U.S.G.S (GLOVIS(j))	Supervised classification	built up area map of Lâayoune in 2015
census of population	1974, 1982, 1994, 2004	HCP (HCP.,2013 (d))		
Estimation of population	2010	HCP (HCP., 2013 (d))		

b. Map processing:

The Lâayoune plan was geo-referenced using a Google base map and projected to WGS 84/UTM Zone 28N which is the specific projection system of the study area, then it was digitized to a shape file format; all that operations was realized under Quantum GIS software. Figure 2 show the urban area of Lâayoune in 1975.

c. Satellite imagery pre-processing:

All images were pre-processed to remove radiometric, atmospheric and geometric distortions. All Landsat bands were used in layers subsequent stages, apart from the thermal and quality bands because they had a coarse spatial resolution and failed to provide useful information for land cover discrimination in the context of this study. The two TM 5 scenes were geo-referenced using OLI image, then re-registered in a WGS 84 datum/ UTM Zone 28N projection.

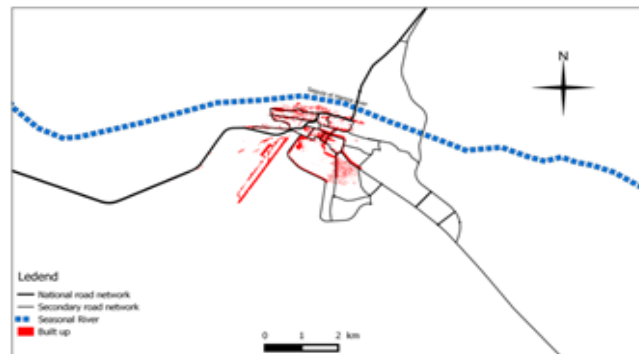


Figure 2: The urban area of Lâayoune in 1975

After stretching images using its histograms, the spatial resolution of images was reduced to 15m using pan-sharpening technics and its panchromatic bands. In the output we had multispectral images with resolution of 15m. In the end, all images were passed in sharpen filter, under the open source software GRASS GIS, in order to enhance the contrast. Then, the images were extracted by the limits of the study area.

d. Land cover classification and urban area extraction.

For displaying real objects color in images, the false color method was used selecting bands as shown in the table below to easily choose treating area for classification (table 2).

To extract the built up area, the satellite images were classified on many classes; built-up area, barred land, sandy land, vegetation, water and road. For every class, four training area were defined and verified under normalized distribution criteria.

Table 2: Bands combination

Year	Data	Bands combination (B, G, R)
1984	Landsat 5 TM	2, 3, 4
1999	Landsat 7 ETM+	2, 3, 4
2003	Landsat 7 ETM+	2, 3, 4
2010	Landsat 5 TM	2, 3, 4
2015	Landsat 8 OLI/TIRS	3, 4, 5

The maximum likelihood supervised classification method was used to discriminate the different land cover types. The images of classification were reclassified to select only built up area, then it was converted to feature form. Figure 3 shows the built up area extracted from each image and the development of the urban area from 1984 to 2015.

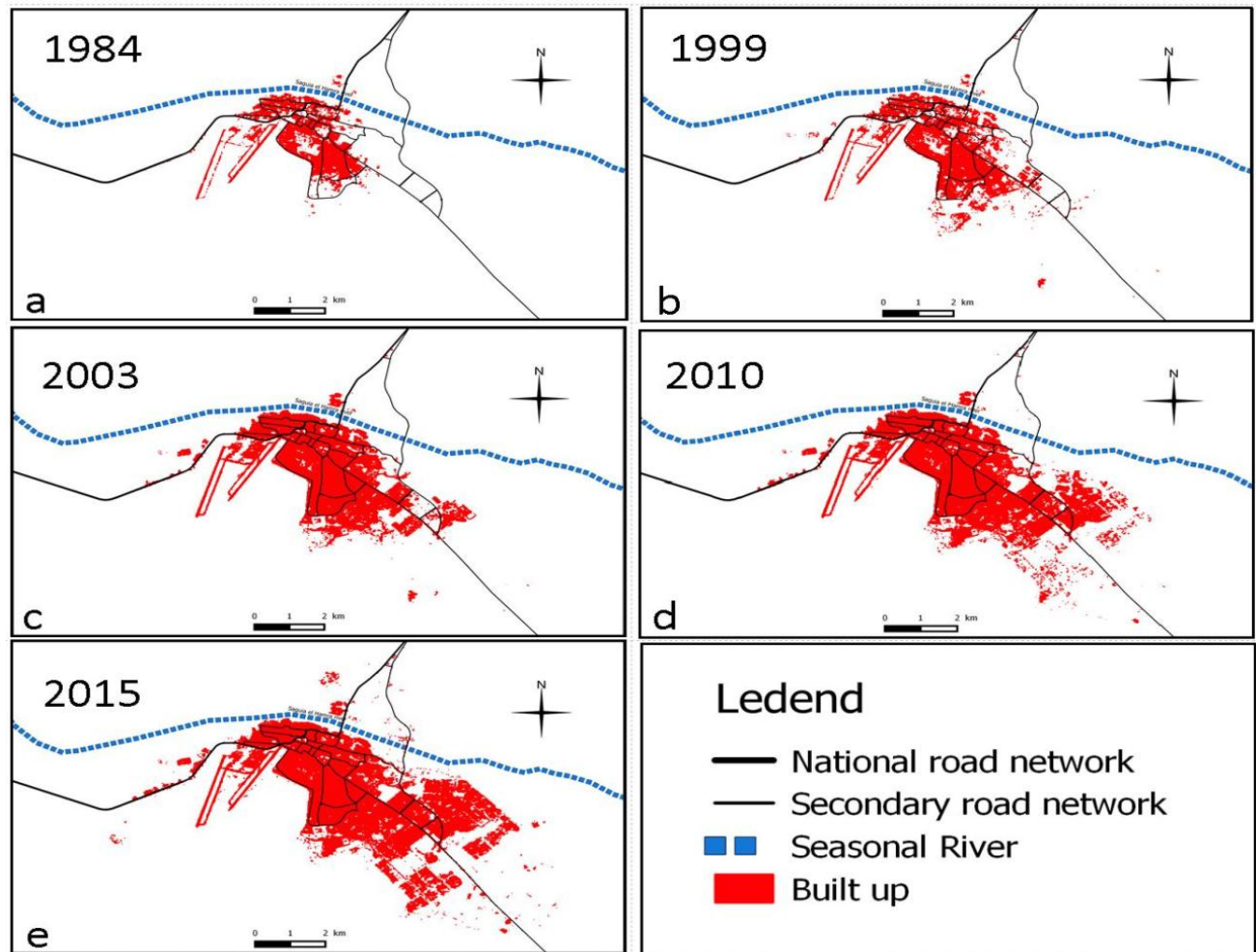


Figure 3: Serial time of built up area of Lâayoune; a: 1984, b: 1999, c: 2003, d: 2010, e: 2015.

e. Annual urban growth rate

In order to monitor the spatial distribution of urban expansion intensity, we adapted the annual urban growth rate index (AGR) for evaluating the speed of urbanization. AGR is defined as follows (Xiao et al., 2006):

$$AGR = \frac{UA_{n+i} - UA_i}{nTA_{n+i}} \times 100\%$$

With $An+i$ is the total land area of a grid and nT the number of years between the initial year and the final year; $UAn+i$ and UAi are, respectively, the urban area at the final year and, respectively, the urban area at the initial year. Generally, the grid size is set to calculate the change in each part of the study area. The maps were therefore gridded as $225\text{ m} \times 225\text{ m}$, and the annual urban growth rates of each unit were then calculated. Lastly, the grid-based annual urban growth rates were clustered by using manual break method, and mapped to evaluate the spatial features of the urban expansion.

3. Urban expansion over the 40 past years:

The urban surface of Lâayoune was expanded from 1.6 Km^2 in 1975 to 19.54 Km^2 in 2015 with a 17.4 Km^2 of change which present 1121.25 % of urban area in 1975, and mean expansion speed about 0.44 Km^2 per year and an annual growth rate about 2.29%.

4. Result and discussion:

a. Temporal proprieties of the urban expansion:

The bellow table (table 3) resumes the speed of urban expansion, and the annual urbane growth rate in each period from 1975 to 2015. The urban expansion speed was calculated using the following expression.

$$UES = \frac{UAn+i - UAi}{TAn+i}$$

With UAi the initial year, $UAn+i$ is the final year of the period and $TAn+i$ the total of the years of the period.

The table 3 resumes the results of the urban expansion of Lâayoune between each successive two years, it present the percentage of the global urban change occurred in Lâayoune in each period, the annual speed by percentage and kilometer square and the global annual urban growth rate.

Table 3: statistics of urban development.

Period	Initial Area (Km ²)	Final Area (Km ²)	Changed area (%)	Expansion speed (%/year)	Expansion speed (Km ² /year)	Global Annual urban growth rate (%)
1975-1984	1.6	4.57	185.625	20.625	0.33	7.22
1984-1999	4.57	7.28	59.3	3.95	0.18	2.48
1999-2003	7.28	13.18	81.04	20.26	1.475	11.19
2003-2010	13.18	16.13	22.38	3.19	0.42	2.61
2010-2015	16.13	19.54	21.14	4.22	0.682	3.49

b. Global analyze of spatial urban expansion's characteristics.

According to these statistics, urban expansion speed can divide the urban sprawl of Lâayoune into four stages as: 1- 1975 to 1984, 2-1984 to 1999, 3-1999 to 2003 and 4-2003 to 2015.

During the initial growth stage (1975-1984) urban area grew very fast passing from 1.6 Km^2 to 4.57 km^2 of surface with 185.625 % of total change and an annual speed of $0.33\text{ Km}^2/\text{year}$ witch present 20.625% per year. During this stage, the city was recently reintegrated to the mother part of Morocco; it was occupied by Spanish before 1975. Normally, in this period when the city is coming to be converted from a military to a civil city, the expansion may have to be slow; but the demographic explosion caused by the returning of Sahraouian people which had migrated to the North part of Morocco due to Spanish colonization between 1919 and 1975. This explosive migration was resolved by many urbanization projects between 1975 and 1984 which cause the urban development shown in following figure (figure 4).

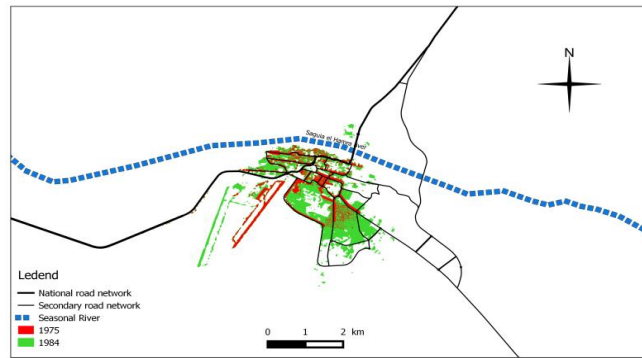


Figure 4: The urban expansion between 1975 and 1984.

Between 1984 and 1999, the urban expansion was in the slowest stage; its speed decreased to 0.18 km^2 per year due to the effects of the armed conflict in the first period. In this period the urban area passed from 4.57 Km^2 to 7.28 Km^2 which present only 59% of change in fifteen year and about 3.95% per year (figure 5).

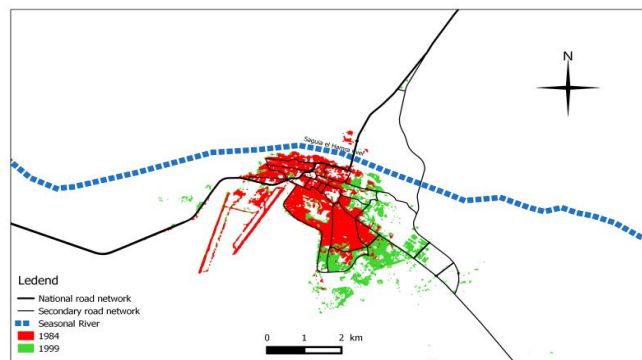


Figure 5: Urban expansion between 1984 and 1999.

In the period of 1999-2003, the urban expansion has creased to 20.26% of change per year, with a speed of urbanization of $1.475 \text{ Km}^2/\text{year}$ and the total of change was about 81% only in four year. In this period the city knew a very important investing in many sectors such as industry, infrastructure and sociology, but the major factor of the urban expansion in this period was the project of slumsreorganization (figure 6).

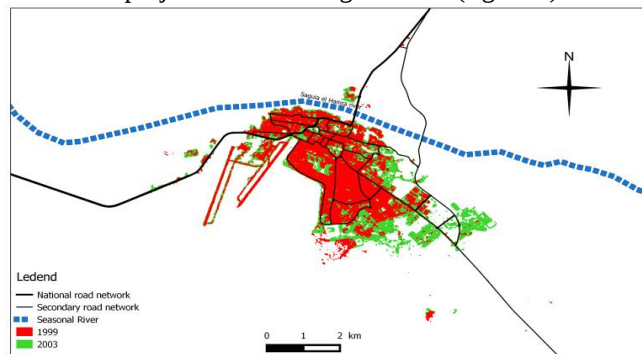


Figure 6: Urban expansion between 1999 and 2003.

During The last period, the mean urban expansion's speed was about $0.55 \text{ Km}^2/\text{year}$, with change near to 4% per year and total change is about 43.52 % of urban area in twenty year (figure 7).

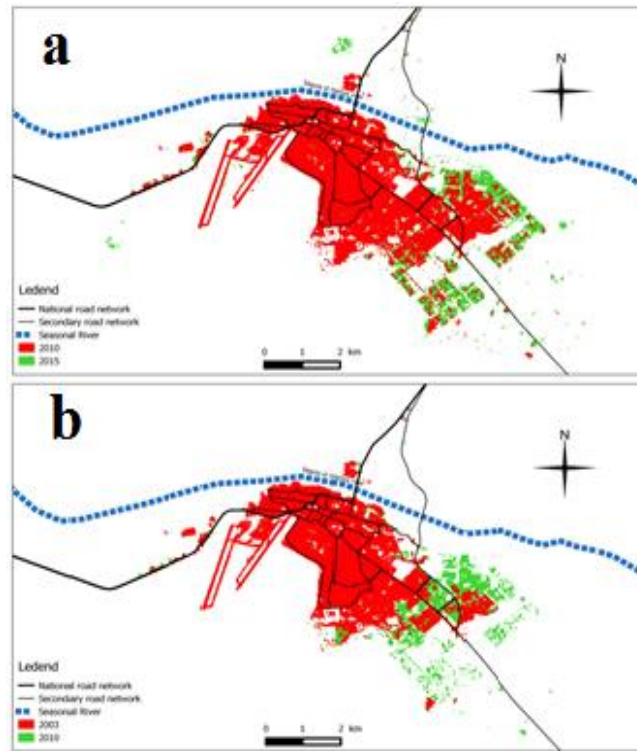


Figure 7: Urban expansion from 2003 to 2010 (a) and from 2010 to 2015(b).

As a synthesis, generally, Lâayoune know an expansion with a direction to the East following the secondary road relating it with Smara city situated in the East of the region. The expansion was stopped in the south riverbank of Saguia Hamra River. The speed of development was very fast in the first period, and slows in the second, than the city return to a fast development speed in the third period. In the last period the development was generally slow (Figure 8).

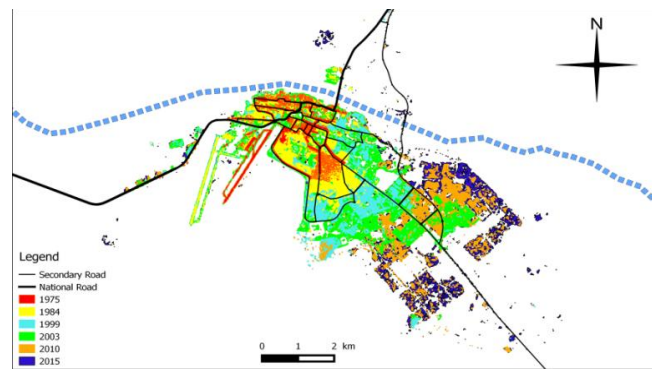


Figure 8: Urban expansion in Lâayoune between 1975 and 2015.

c. The local analysis for characteristics of spatial urban expansion

The local analysis of the urban expansion in each period are figured using the urban growth rate (AGR) using gridding technic with unit of 250m x 250m.

Between 1975 and 1984 the mean value of annual urban growth rate are about 2.8% with maximum value about 10.8%; the majority of maximum value grids are located in the South-East of the city (Figure 9).

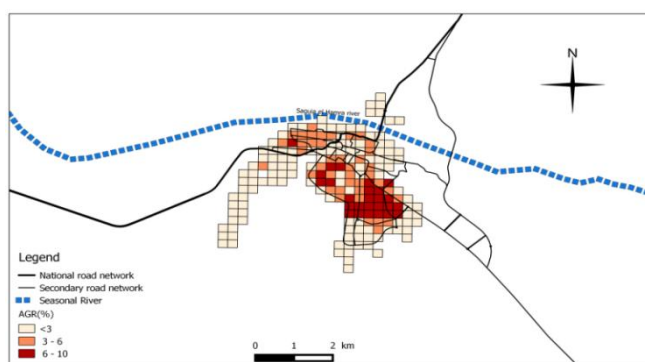


Figure 9: The AGR map of Lâayoune between 1975 and 1984.

During the period from 1984 to 1999 the mean on AGR are decreased to 0.94% and the maximum to 6.29%. The most of maximum value grids are grouped in the South- East of the city (Figure 10).

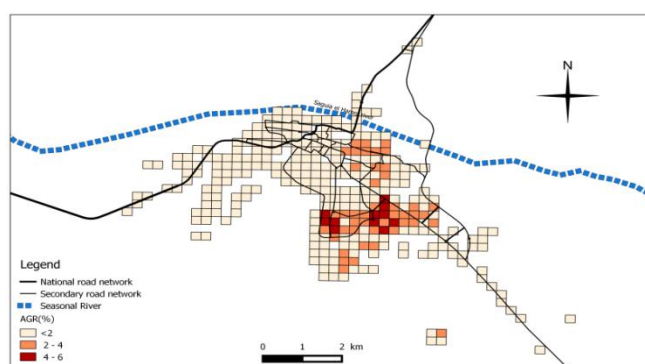


Figure 10: The AGR map of Lâayoune between 1984 and 1999.

In the period of 1999-2003, the mean AGR value are 6.06% and the maximum 21.4%, the majority of maximum grids values are gathered in the North, South and in the East of the city (Figure 11).

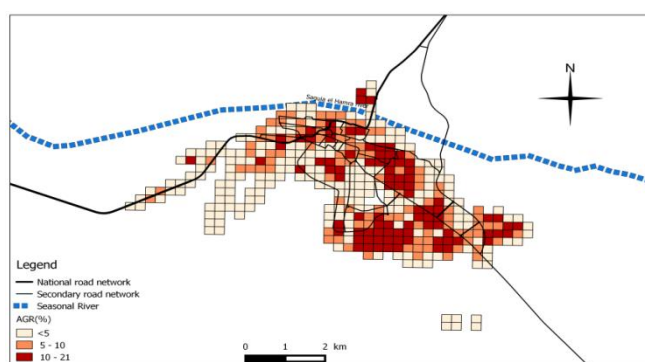


Figure 11: The AGR map of Lâayoune between 1999 and 2003.

Through the next period between 2003 and 2010, the mean value of the AGR is about 1.8% and the maximum about 13.1%. The maximum values grids are accumulated in the East of the city (Figure 12).

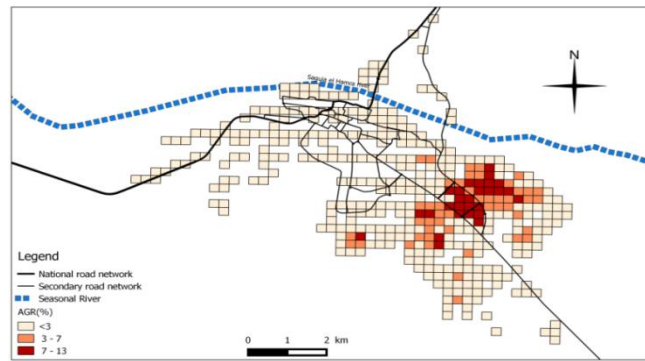


Figure 12: The AGR map of Lâayoune between 2003 and 2010.

At the five last years, last period, the maximum and mean values of AGR are, respectively, 2.37% and 15.7%. Most of the maximum values grids are located in the East and the South- East of city (Figure 13).

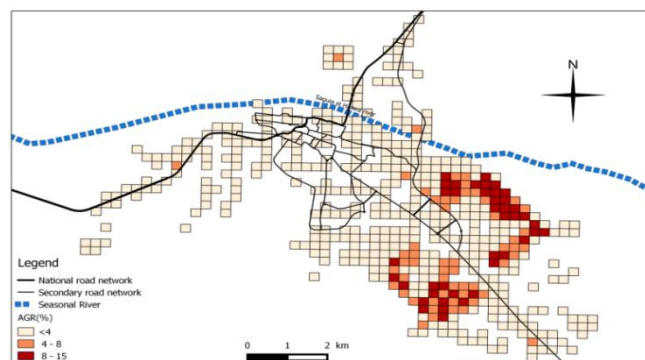


Figure 13: The AGR map of Lâayoune between 2010 and 2015.

As the figure 14 shows, the majority of maximum values are located in the South-East of the city in every period. And its direction is to the South-East.

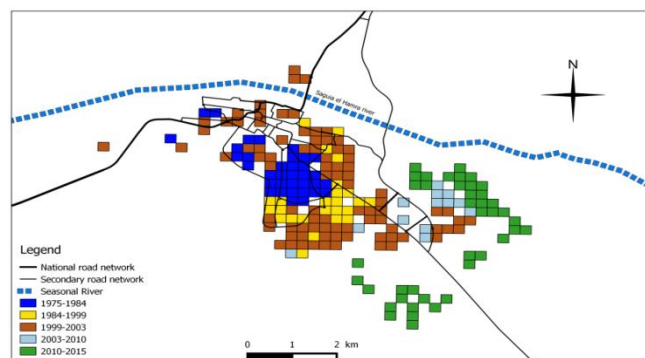


Figure 14: Map of AGR maximum values between 1984 and 1999.

d. Factors of urbanization:

For explaining the speed and direction of the urbanization, it is recommended to compare the urban expansion with the development of other socio-economic factor such as population growth, and economic development. Figures 15 show how the development of the socio-economic factors influences on the urban expansion in the period of study.



Figure 15: The socio-economic and infrastructure development in Lâayoune compared with urban expansion.

As the figure 15 shows, between 1994 and 2004 number of freezing unite (a), number of registration (b), journal water access volume (c) and the population (d) knew a significant increase accompanied with a very important growth of the urban area.

5. Conclusion:

This study has been the first to monitor the urban evolution in Lâayoune City, which was achieved using a time series of Landsat imagery to capture the key phases of development during a period of 40 years from 1975 to 2015. Indeed, without satellite remote sensing it is difficult if not impossible to document such large scale the urban expansion, as other sources of information are restricted or nonexistent for this region. A hybrid unsupervised and supervised classification method was able to provide an accurate discrimination between urban and other land cover types, even in this challenging desert environment. There was a rapid rate of development over the entire study period and this was particularly intense first period and between 1999 and 2003, making Lâayoune one of the fastest growing cities in Moroccan Southern regions during this period, but growth has slowed recently (UN., 2014(k)). The observed spatiotemporal dynamics of urban growth were closely associated with prevailing local and global economic conditions and the ambitious development strategies implemented by Moroccan government in its Southern part (Sahara Developpement(e)). Now most of the total population has occupied urban areas throughout the development period in Lâayoune province (HCP&DRL., 2013(g)). While the population growth rate has been high, this has been outpaced by the rate of increase in urban area and the declining population density is indicative

of a process of urban sprawl that has been observed generally in the country (HCP., 2013 (d); HCP & DRL., 2013(g); DRL., 2011(h); Catin et al., 2008). In this study, the spatial characteristics of urban expansion in Lâayoune, monitored in resulting maps, can be divided by four types. 1- Demographic migration intervention type where the urban expansion obeys to the immigration of Sahraouian people from north parts of Morocco to Lâayoune. 2- The armed conflicts consequences intervention type between 1984 and 1999 by the influence of the armed conflict in the end of the first period. 3- Socio-economically intervention type, whereby Lâayoune know a very important social and economic investigation of Moroccan authority in its southern part as the project of urban management of slum. 4- Normal growth type in a period known due the socio-economic stability and the food and water safety. Nevertheless, as the maps of annual urban growth rate show in the four periods, the urban expansion in Lâayoune differs from the other Moroccan cities as Casablanca which is the economic capital of the country and Marrakech the touristic capital and other cities known by its agriculture and industrial activity (UN., 2014(k)), where the urban expansion in Lâayoune is sustained by Moroccan effort for developing southern regions socio-economically.

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