An analysis of sustainability and urban sprawl in an Algerian oasis city

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Abstract

This paper examines the state of the sustainability and the urban sprawl phenomenon of an Algerian Oasis city. Our purpose is to analyse sustainability and sprawl in M'zab valley through measuring its impact on the environment by using indicators. The work consists of three parts: firstly, analysis of the urbanization process of M'zab valley and identification of sprawl impacts through a cause-effect structure from literature investigation; secondly, a brief overview of sprawl land impact indicators in order to define the analysis framework and to chose the appropriate indicators to apply to our study case; finally, calculation of the land resource consumption indicator by measuring the land use change area amounts from 1968 to 1997 in M'zab valley using GIS.
Keywords: oasis city, sustainability, second residence, loss of oasis farmland, sprawl indicators, GIS.

1 Introduction

M'zab valley has been faced with the urbanisation process and has suffered from population growth during the last 50 years. Many studies reported the problems generated from the sprawl phenomenon, especially since the 80's; the loss of oasis farmland.

Our purpose in this paper is to analyse the sprawl and sustainability of the valley through the analysis of the urbanisation process from the literature survey and to calculate the land resource consumption indicator via the land use change area amount measurement using GIS.

1.1 Geographical features of M'zab valley

M'zab valley is situated at the entrance of the Algerian Sahara at some 600Km south of Algiers. It is a city with one hundred twenty eight thousand people. It is known for its five old towns called Ksour with their respective oasis farmlands that were established in the 11th century and classified as a world heritage by UNESCO in 1982. M'zab valley is also known for its traditional irrigation system using the "Foggara".

From the northwest to the southeast along the valley, runs a Wadi called Oued M'zab in the local language, which floods once or twice per year. Along Oued M'zab are the Ksour, settled since 1014, characterised by their compact structure of hundreds of houses made from local material such as sand, lime and dates trees wood.

1.2 Historical features of M'zab valley

According to the literature, the history of M'zab valley is divided to three periods:

- The traditional period (1014-1850): is characterised by a construction in harmony with the nature and the environment and a land use that obey the rules designated by a local social law called "Ourf", made by a old and wise M'zab people. This period is also characterised by a local seasonal migration from the Ksour to the second residence in the oasis during the hot season (Brahim [1]). In summary, this traditional life style supported the valley's sustainability.
- The colonization period (1850-1962): this period is known by the French colonization, which opened the valley to the economical development (Commandant [2]). Thus, the modernization of the valley is the main characteristic of this period.
- The independence period (since 1962): is characterised by the industrial development of the valley, the migration flow of population attracted by the new opportunities of job and investment, the housing pressure and the sprawl phenomenon (ANAT [3]).

2 Analysis of urbanization process in M'zab valley through literature investigation

In order to analyse the urbanisation process of M'zab valley and to understand the background of the sprawl phenomenon, we did a literature investigation that allowed us to identify the following factors: historical, economical, econo-demographic, socio-cultural, geographical one and a policy factor.

- The effect of the colonization as a historical factor that brought modernization to the valley fixed the migration flow of nomad people and developed lands in some areas, which were forbidden to any construction by the Ourf during the traditional period (Raymond [4]).
- The economical development due to the industrial zone near the valley from 1962-1980 (ANAT [3]).

- The housing development pressure by migration flow through the modernization and the economical development (ANAT [3]), (Raymond [4], Helmut et al [5]). The census statistics of 1954 and 1998 show that M'zab valley faced a rapid growth of population during this period, it increased from 25,541 to 128,087 people. Especially, the population grew at a noticeable pace from 1966 to 1977 by an annual growth of 4.5% and from 1987 to 1998 by 3%.
- The decrease of the custom of seasonal migration from the Ksour to the Oasis farmlands generated the sprawl through a development of low-density neighbourhoods in the oases under the housing pressure. In fact, many second residents changed their state from temporal to permanent one (ANAT [3]). According to the census of 1998, half of the houses in Ghardaia dates farmland were always occupied. Among 2990 houses, 1345 were occupied all the time that represents the percentage of 47%, in comparison to 1540 unoccupied houses (50%). It is important to note that only 15.4% of this population work in agriculture, which threatens the preservation of the dates plantations and encourages their building-up.
- The impact of the land reserve policy that was applied in M'zab valley in 1982 to provide the land for developing housing and public facilities (Brahim [1], ANAT [3]). This policy was adopted in all of Algeria by the national government from 1974 to 1990 and consists of giving each municipality the exclusive right to use and manage the land inside the build-up area or near the boundary. The pieces of land were to be reserved and then redistributed to the national organization to promote public projects and development plans. However, the land was secured by possible expropriation were needed (Mouaouia [6]). In a case of M'zab valley, most of the provided land was located inside the oasis farmlands near the urban areas (ANAT [3]).
- The impact of the land reserve policy was from three points: 1) it provided the pieces of land in low price, which encouraged the rapid urbanization in those areas (Brahim [1]); 2) it considered the farmland of the oasis as build able land (ANAT [3]); 3) it allowed the low density, since the lots of land were designated for an individual houses or public facilities (ANAT [3]). Here we present fig.1 of the Floor Area Ratio (FAR), which is the ratio of the number of square feet of built area to land area (Oliver [7]), to show the low density in the oasis farmland that increases with the distance to the centres and to the historical cores of the cities (Ksour).
- The geography of the valley dictated the development of land along the Oued M'zab in the downhill and toward the dates farms (ANAT [3]).

As a summary, we made a cause-effect structure of sprawl in M'zab valley as Driving Forces Pressure State Impact Result (DPSIR) model, fig.2. It consists of factors that played a role of first causes of sprawl problems; we call them Driving forces, which made a pressure on the environment that generated the sprawl phenomenon. We also show aspects of sprawl as well as their consequences divided into: impacts on the urban environment and reactions of different institutions to solve the sprawl problems. Let's note that because of lack

of space and time, we could not include all the impacts of the sprawl phenomenon on the society, economy and environment.

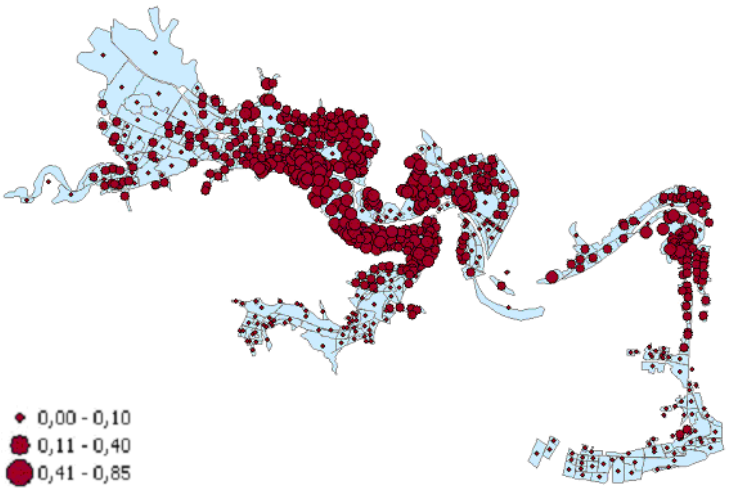

Figure 1: The density by Floor Area Ratio (FAR) in M'zab valley.

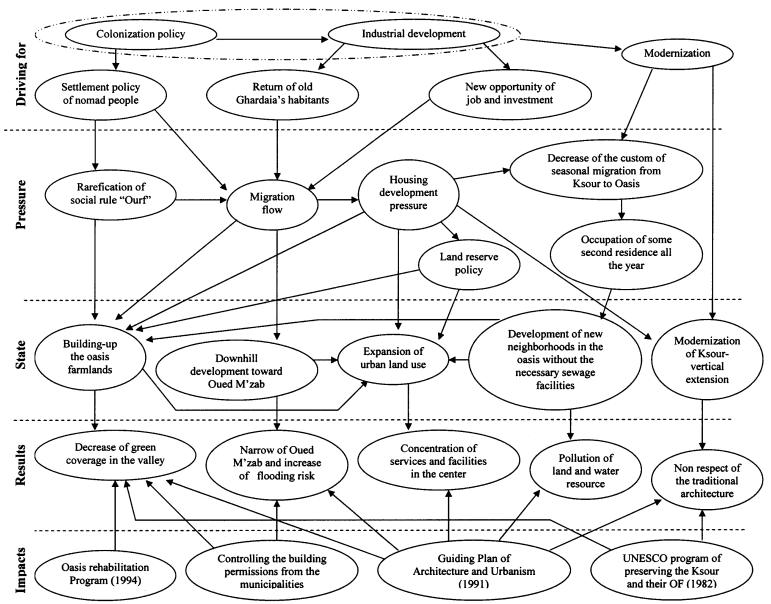

Figure 2: The cause-effect structure of sprawl showed as a DPSIR model.

In conclusion, this diagram implies that the following impacts: the decrease of green coverage; the narrow of Oued M'zab and decrease of its flooding risk; the concentration of the services and facilities in the centres; the pollution of land and water resource; and non-respect for the traditional architecture; have been mainly caused by the econo-demographic factor (Brahim [1], ANAT [3], Helmut [5]): housing development pressure by migration flow through the modernization. Also, the sprawl problem of M'zab valley is influenced by other unique factors, such as geographical features as an oasis city and historical circumstances of the colonization, social and cultural changes according to the modernization, and moreover in the independence period, policy factor such as the land reserve policy.

M'zab valley is an oasis city, so both of its water resource and oasis farmland have functioned as the critical lifelines for sustainability. However, the results from the existing literature survey suggest that the modernization and the rapid urbanization have broken the sustainability that the traditional M'zab valley achieved.

In the next sections, we are going to do analysis-based indicators to verify what the references reported about the impacts of sprawl on the environment and measure the decrease of the green cover area in M'zab valley. But before this, an overview of the sprawl indicators is needed in order to choose those, which fit the M'zab valley problematic.

3 Sprawl land impact indicators: a brief overview

Most of the sprawl researchers linked the sprawl indicators to the density, accessibility, transportation infrastructure, and land use patterns; some of them use a fiscal and socio-economic indicator (Oliver [7]). To measure the sprawl, a calculation of indicators between two time points is usually done to evaluate the change in data. For instance, the comparison of a percent population growth over a given period of time to the percent growth of a factor such as developed area; vehicle miles travelled, number of cars, of dwellings, etc. (Kent *et al* [8]).

The sprawl indicators are represented by percent and by capita, such as the per household land resource consumption (PHLC), this indicator was used by the Montgomery county in USA in 1993. It is calculated by dividing the total area of land by the number of households that resides in the developed area. The increase of PHLC indicates a low density and consequently a sprawl development (US Environmental Protection Agency [9]). The difference between the per capita indicator and the percent change indicator is that the first one "provides a measure of land use efficiently of the new urban growth", however the second one "measures the impact on the selected geographic unit's remaining land resources" (John and Richard [10]). Although both representations give different kind of data, their combination is strongly recommended.

In addition to the land use pattern and transportation infrastructure, sprawl is measured through its impacts. In reference to the sustainability goals promoted by the European Union (Elena and Nancy [11]), the indicators of impacts are

classified to environmental such as land resource consumption, energy consumption and atmospheric pollution; economic such as costs on housing and transportation; and social such as degree of spatial segregation between households (Oliver [7]).

Let explain more about the indicators of impact on the environment, especially the land resource consumption, which was pointed out by the references as the most noticeable impact of sprawl on M'zab valley, as an oasis city.

John and Richard [10] propose five groups of land resource consumption indicators called the Land Resource Impact indicators (LRI) as following: 1) density of new urbanisation; 2) farmland loss; 3) forest core habitat loss; 4) natural wetlands loss and 5) impervious surface increase.

In further work, John [12] used more indictors to calculate the environmental impact indices to measure new development tracts for characteristics of sprawl in Hunterdon County-New Jersey. The farmland loss indicator was used with the loss of wetlands and endangered habitat to calculate the loss of important land resources. In addition, the following indicators were used: the encroachment upon sensitive, preserved opened space indicator, the excessive per capita impervious surface coverage indicator and the explosive growth trajectory imposed on localities by new development indicator.

In fact, the increase of the impervious surface indicates less efficient land use that develops sprawl. For example, the urbanization of Kharga oasis in Egypt under a random method of land distribution by the local government decreased agricultural and date farmlands and raised both residential land use area and impervious area via streets land uses to equal surface (Arch et al. [13]).

It is clear that the application of these indicators depends on the locality's problematic, geographical scale, and the availability of data. The development of advanced technologies and the access to information encourage the wide use of GIS, aerial photos and remote sensing data, especially the land cover/land use data.

The use of such data and techniques has helped a lot in measuring the spatial and temporal change of land use and detecting the boundary change that are necessary for calculating land resource consumption indicator.

As an example, we quote the SCATTER project (Sprawling Cities and Transport; from Evaluating to Recommendations), which occurred to quantitative and qualitative analysis on six European cities in Belgium, Germany, the United Kingdom, Finland, France and Italy. The project used GIS to complete the statistical analysis of spatial change for each of the six cities (Elena and Nancy [11]).

Other example is Hyderabad project in USA, which used the remote sensing data to measure the urban sprawl of the city via land use/cover analysis. The combination remote sensing-GIS made the calculation of the density of land development (%) indicator, defined as the amount of land developed divided by the land area in each of the studies zones of the cities (Lata *et al* [14]).

Nevertheless the indicators using remote censing should not be limited to the physical attributes of sprawl; the population data should be taken in

consideration. Furthermore combination with socio-economical indicators, for instance the fiscal one, is strongly recommended (Kent *et al* [8]). So, the impacts of the several factors interfering in sprawl development should be involved in the indicators calculation process.

In this section, we briefly overviewed the use of sprawl indicators in order to define the framework of our analysis. So in the next section, we are going to:

1. Use only the land resource consumption indicators to measure the sprawl impacts on the environment, because of the limitation of data;
2. Make a spatial analysis of land development of M'zab valley by using GIS in four time points from 1968 to 1997 in order to measure the land use change;
3. Use the GIS database, made by a group of Algerian and German academic researchers (Helmut *et al* [5]), and aerial photos at different scales and dates.

4 Land resource consumption indicator: measurement of land use change in M'zab valley from 1968 to 1997

In section 2, we analysed the urbanisation process of M'zab valley through the literature investigation and identified the sprawl problems. In this section we are going to measure its impacts on the environment via the land resource consumption indicators, which can be listed in reference to the literature to: density of new urbanization, loss of farmland, loss of wetland, loss of farmland core habitats or endangered habitat and increase of impervious surface.

According to the problematic of M'zab valley explained in section 2, which is focused on the decrease of green coverage, and because of the limitation of the data to population, socio-economic and history of land development, neither the wetland loss indicator, nor the loss of the farmland core habitat, nor the decrease of impervious surface are considered by our analysis.

So, in order to analyse the land resource consumption, we are going to use the density of new urbanization indicator, calculated by dividing the land development growth by the population growth for the same period, and the loss of farmland indictor, expressed by the difference of the land area amount of Oasis farmland between tow time points. For this, we are going to measure the land use change area amount of M'zab valley from 1968 to 1997.

Firstly we will make a classification of the land use into different categories, secondly will map the land use of the valley in 1968, 1982, 1991 and 1997, thirdly will measure the land use change area amount of each category in each time point, fourthly will calculate the difference in the area amount during the periods 1968-1982, 1982-1991, 1991-1997, and will calculate the percent of the land development density for each land use category.

4.1 Step 1

We classified the land use of M'zab valley to four categories based mainly on the Plant cover ratio PCR and the Building ratio BR as following: the Oasis

Farmland (OF) (1>) PCR (≥0.8) and (0.2 ≥) BR >0; the Mixed land use area (MX) (0.8 >) PCR> 0.2 and (0.4 ≥) BR≥ 0.2; the Build-Up area (BU) (0.2 ≥) PCR ≥ 0.05 and (0.7≥) BR> 0.4; and finally the historical cores of the cities, which we call Old Town (OT) (0.05 ≥) PCR> 0 and (0.85≥) BR>0.7, we also used other criteria, such as the building type, the construction age and the current land use. Let note that the dates farmlands in M'zab valley are divided to two types, those with only dates plantation that we classify with MX category and those with a cultivated vegetables, fruits and cereals under the dates palms (Djennane [15]) that we include in the OF category.

4.2 Step 2

We mapped the land development of the valley via four maps of land use change in 1968, 1982, 1991 and 1997, using GIS Arc View and based on the aerial photos of 1/25,000 scale in 1968, 1/60,000 in 1982 and 1/10,000 in 1991, we also used GIS data, which was produced from the aerial photomaps of 1/40,000 scale in 1997, the census of 1998 and the land use map scale of 1/25,000. In fig.3, we show the land use change in M'zab valley from 1968 to 1997.

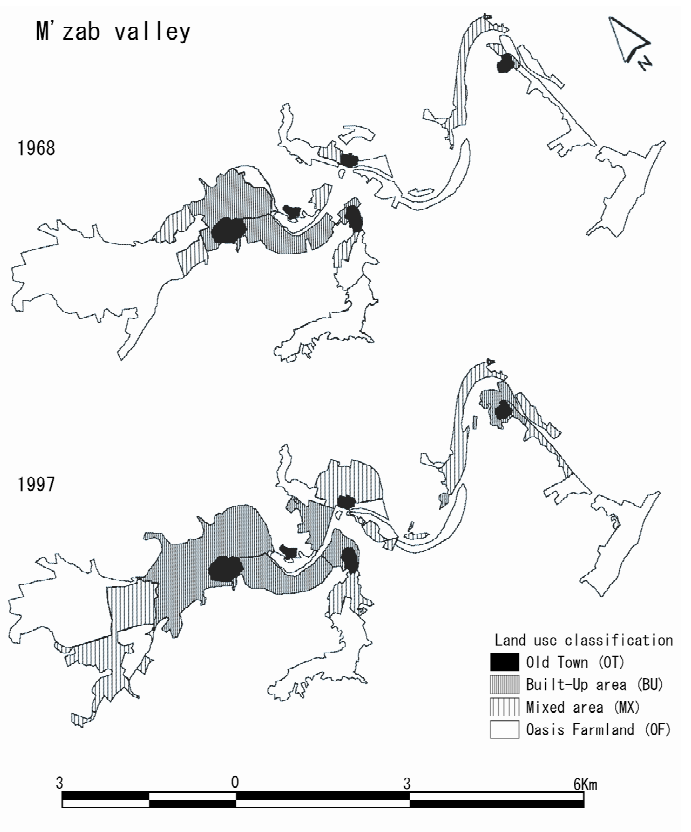

Figure 3: The land use change in M'zab valley from 1968 to 1997.

4.3 Step 3

We calculated the land use change area amount of each category in GIS in each time point 1968, 1982, 1991 and 1997, fig.4.

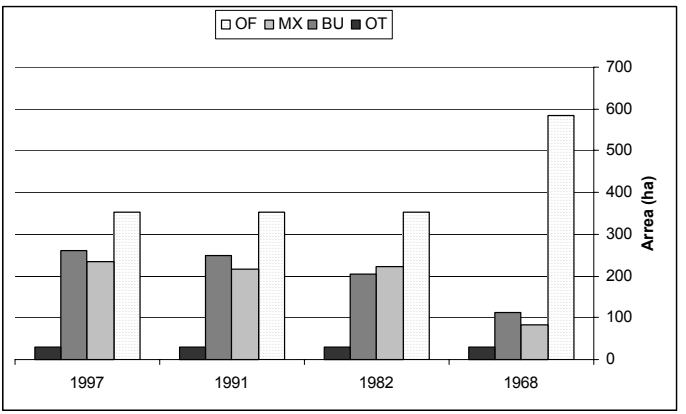

Figure 4: Change of area amount for each land use category from 1968 to 1997.

4.4 Step 4

We made table 1, in which we show the difference in land use change area amount for each period 1968-1982, 1982-1991 and 1991-1997. Also, we represented the percent of land development density.

Table 1: The difference in the area amount and in the land development density.

	Area (Ha) 68-82	Land-Dev-DENS%	Area (Ha) 82-91	Land-Dev-DENS%	Area (Ha) 91-97	Land-Dev-DENS%
OF	-231,1	-40%	0	0%	0	0%
MX	+138,3	+165%	-4,3	-2%	+16,8	+8%
BU+ OT	+93,5	+66%	+42,7	+18%	+248,6	+89%
Total	+0,7	+0%	+38,4	+5%	+29,9	+4%

4.5 Results analysis

The results show: 1) the decrease of OF area amount from 1968 to 1982 then halted because of some countermeasures, such as the Oasis rehabilitation program (Messar [16]), the control of building permissions from the municipalities (ANAT [3]), the Guiding plan of architecture and urbanism (CNERU [17]), and the UNISCO program of preserving the Ksour and their OF

(Pietro [18]); 2) the increase of MX area amount, especially from 1968 to 1982 by building-up OF and developing a new land; 3) the expansion of BU in all periods, mainly by building up the MX through decreasing its green cover areas; 4) the area amount of OT did not change during the period of analysis.

It is important to note here that more accurate results about the change of land use and decrease of green cover area would be obtained if the use of remote sensing data could be possible.

The land development density indicated that Build up area reached the highest percent 89% during 1991-1997 and the lowest percent 18% in 1982-1991. From 1982 to 1991, the MX decreased a lot (-2%). However, it reached the percent of 165 from 1968 to 1982.At the opposite, OF decreased a lot (-40%) during 1968-1982.

These results show the decrease of the green cover area in the valley via dates farmland consumption due to the expansion of the build-up, mainly by developing the oasis farmland. So, by calculating these indicators, we verified the land resource consumption in M'zab valley during the period 1968-1997. Consequently, we confirmed one impact of the sprawl on the environment.

4.6 Considerations

Because of the availability of the socio-economic data only from the census of 1998, we could not include the land use change area amount measured from 1968 to 1997 in calculating other land resource consumption indicators, such as PHLC.

However, we consider the number of occupied and unoccupied houses in the oasis farmland, explained in section 2, as an indicator of urban density and by consequence an indicator of urban sprawl in the oasis city; in addition, we consider the percent of the population living in the oasis farmlands, that does not work in the agricultural activity, as an indicator of farmland loss.

5 Conclusion

This paper has analysed the state of sustainability and sprawl in an Algerian oasis city, M'zab valley through analysis of urbanisation process and land resource consumption. The worked consisted of literature survey and land use change area amount calculation from 1968 to 1997 using GIS, in order to measure the indicators of land development density and oasis farmland loss.

The results of our work show:

1) The sustainability that was achieved during the traditional period of M'zab valley has been interrupted mainly because of the modernization, brought by the colonization, and the rapid urbanization; nevertheless the geographical features, the historical circumstance, the traditional society and the policy factor have generated the sprawl, which has been stressed since the independence;
2) The necessity to use the oasis farmland loss indicator to measure the sprawl impact in an oasis city; so, we could verify the decrease of green coverage due to the building-up of oasis farmland in M'zab valley;

3) The consideration of socio-economic data and socio-cultural factor such as the custom of "second residence" in analyzing the sprawl in M'zab valley;
4) The importance of using GIS in studying the spatial and temporal patterns of sprawl phenomenon in general.

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