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Remote Sensing for Land Use Mapping, Case of The Study Area: Urban Commune of Saada, Morocco

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ABSTRACT

The phenomenon of urban planning in favor of agricultural land on the outskirts of the city of Marrakech is in full expansion. The study of land use changes is of pivotal interest for the knowledge, management, monitoring, surveillance, and evaluation of our environment. Indeed, the city of Marrakech has been experiencing exponential population growth for several decades. This phenomenon has led to a dynamic urban characterized by the increase and densification of urbanized areas (e.g. buildings and infrastructures) which leads to the occupation of natural spaces. To this end, this study aims at highlighting the mapping and evolution of land use in the city of Marrakech from Landsat satellite image data (1989, 2005 and 2020) through the application of the Image classification using Machine Learning algorithms with the QGis Orfeo Toolbox, which facilitate the production of land use maps at three dates as well as an evolution map of the conurbation and also to quantify the obtained results. The directions of extension of the urban area were defined and thus demonstrate its impact on the agricultural land located in the peri-urban area.

1. Introduction

Since 1950, world urban population and urban infrastructure has grown rapidly (United Nations Population Division). And in the late 1990s, the outskirts of Marrakech experienced an unprecedented development. This urban sprawl is mainly due to the development of the more diverse and important tourism sector. The tourism sector then became an agent of economic development as well as an engine of development and new urban dynamicsAs a result, the city is facing several dysfunctions such as peripheral extensions, a lack of global cohesion and significant urbanization. All this tends to become a direct menace to local agricultural development. Areas open to urbanization do not always respond to real needs and often follow a speculative logic. (Abouhani, 2001). This extension cannot be done without consequences. When a city develops, it transforms land use. This urbanization is therefore essentially detrimental to the natural environment in which it is located (Burel and Baudry, 1999). Today, despite measures and regulations such as Planning Act 12-90, which advocates the preservation of land with high agricultural potential from urbanization and non-agricultural uses, agricultural land on the urban periphery is threatened and the sustainability of urban agriculture is compromised. During this transformation, the region experienced a change in land use. Monitoring spatial-temporal evolution and analyzing land use dynamics is the focus of this study. Land-use and land-cover change studies are of great importance as they provide an overview of current trends in the processes of urban sprawl and biodiversity loss in a given region. (Lambin and al. 2001). The objective of our study is to detect changes in land use in the city of Marrakech Saada from multi-date satellite data and to estimate the overall impact of these changes on agricultural and urban activity. The method of diachronic comparison of classifications was used. The Image classification using Machine Learning algorithms with the QGis Orfeo Toolbox was used. These results identified the temporal and spatial evolution of land use in the city of Marrakech over a period of thirty-two years (1989 to 2020). Such work requires the use of new technologies of information and communication combined with image processing in land use planning. In other words, the use of geographic information systems (GIS) and remote sensing, even if the methods (acquisition and processing of images) used to understand this spatial phenomenon are cumbersome to implement and sometimes very expensive. GIS are very good analytical tools because they allow the collection and analysis of information from several sources.

2. Geographical location

Marrakech is located in south-central Morocco. It is the capital of the Haouz plain, and by far its main city.It is bounded to the north by the former low-lying Jbilets range, to the south by the High Atlas Range which rises to 4,165 m (Mount Toubkal), to the west by the Essaouira-Chichaoua plateau that separates it from the Atlantic Ocean, and to the east by the first reliefs of the Middle Atlas.Its longitude lies between the meridians 8-14 and 7-47 West, and its latitude between parallels 31-30 and 31-45 North.Its area is 230 Km2.La medina was built on the left bank of the Waed Issil, five kilometers south of its confluence with the Oued Tensift.Built at an average altitude of 450 meters above sea level, Marrakech Saada is a city with essentially flat terrain.The city is under the jurisdiction of the Marrakech Prefecture.Capital of the region Marrakech-Safi.La city is divided into 5 districts: Annakhil Guéliz Medina Menara Sidi Youssef Ben Ali (SYBA). In order to better study the evolution of the city of Marrakech, we considered it useful to work only in the urban space as well as in a neighboring commune SAADA as shown in the figure above. The exclusion of the other communes of the study area is due to the strong resemblance of the spectral signature between the buildings and the bare ground on the one hand and between the vegetation on the other hand. This leads to a great deal of confusion. The quantification of these classes (buildings, vegetation and bare soil) will be overestimated when introducing these parts.

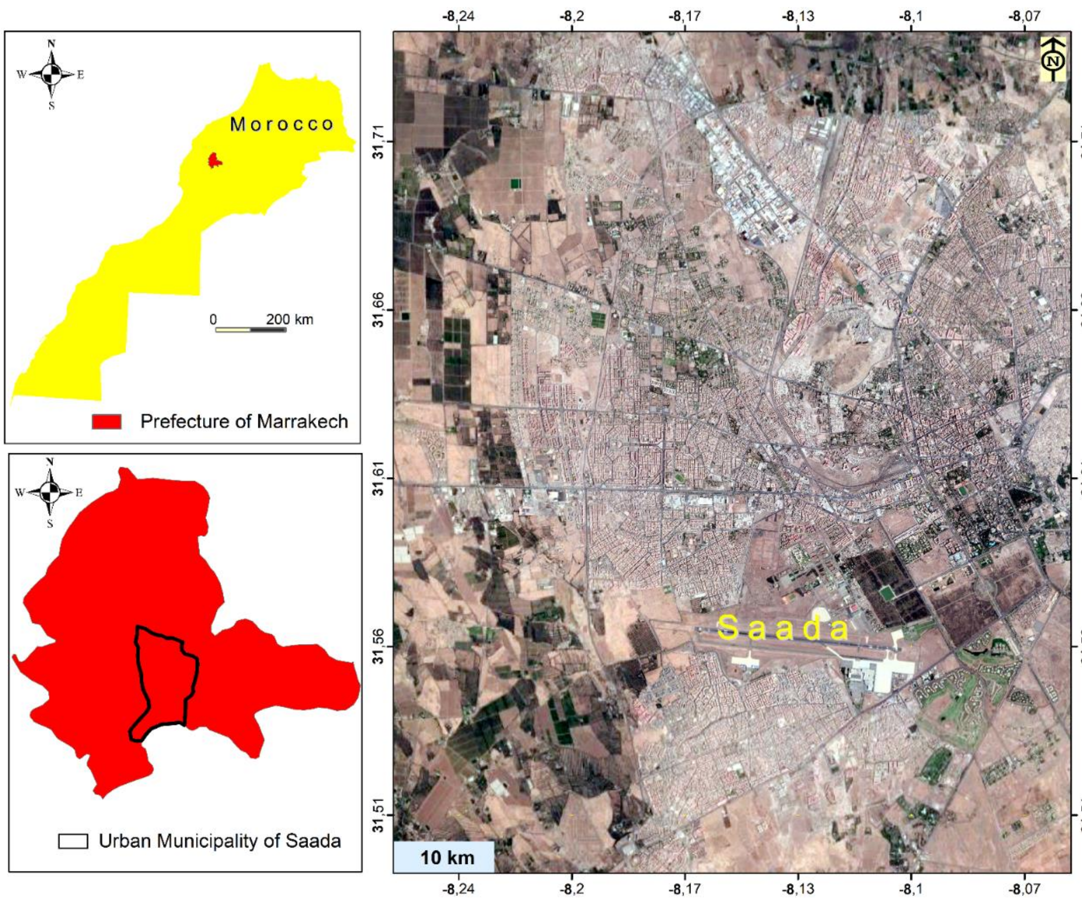

Figure 1: Geographical location of the study area.

3. Socio-economic characteristics

The Prefecture of Marrakech has a Population of 1 330 468 inhabitants according to the last population and housing census of 2014, against 1070838 inhabitants in 2004. The distribution of the population of Marrakech shows the dominant character of the urban population with 980548 inhabitants against 349920 inhabitants in rural areas. The population of Marrakech occupies the first place, at the level of the region of Marrakech Safi, with 29.3% of the total population and 50.60% of the urban population, against 13.55% of the rural population. The population growth of Marrakech, has recorded an average annual growth rate of 2.2% between 2004 and 2014 (1.5% in urban areas against 4.4% in rural areas). At the 2004 census, the prefecture of Marrakech had 1 063 415 inhabitants. The five districts of Marrakech had 795,000 inhabitants. Marrakech is surrounded by the following rural municipalities: Tassoultante, Sidi Abdellah, Al Ouidane, Saada, Oulad Hassoun, Harbil.

Since the 1960 census, Marrakech has maintained a steady pace of growth but with a significant downward trend since 1994. Thus, the average annual growth rate was 2.7% between 1960 and 1971 and between 1982 and 1994.This growth declined between 1994 and 2004 with 2.2%. This decline is an important indicator of the demographic transition that characterizes the country as a whole. Occupying just 21 km2 in 1945, the urban area of the city of Marrakech increased to 37 km2 in 1989 to 181 km2 when the agglomeration was relimited in 1992 and then to 230 km2 in 2020.

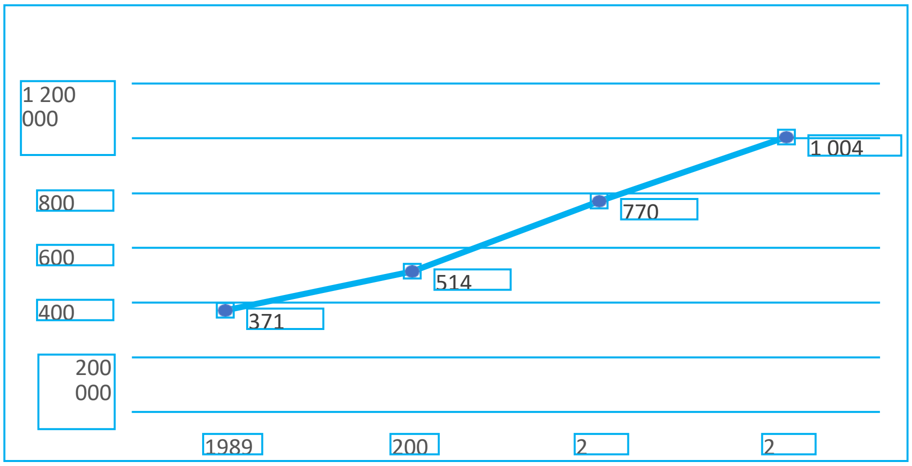

Figure 2: Evolution of the urban population in Marrakech.

3. Data

In this study, we used multi-temporal Landsat products acquired from the U.S. Geological Survey (USGS) from 1989 to 2020 (Table 1). Three Landsat products were used in this study to compare land cover changes: the Landsat-5 Thematic Mapper (TM), the Landsat-7 Enhanced Thematic Mapper (ETM+) and the Landsat-8 Operational Land Imager (OLI).

Table 1: Landsat TM/ETM+/OLI imagery used in this study

Years	Path & Row	Types
1989	202/038	Landsat 5 TM (only one image scene) acquired on 06-Mar-1989 ID : LT51930511985065XXX01
2005	202/038	Landsat 7 ETM+ (single image scene) acquired on March 31, 2005 ID : LT51930511994090MPS00
2020	202/038	Landsat 8 OLI (single image scene) acquired on May 24, 2020 ID : LO81930512003075EDC00

Only area-wide Landsat image scenes without cloud cover have been selected. OLI/TIRS has been developed in relation to the rest of Landsat sensor technology. Indeed, the OLI/TIRS was developed compared to the rest of Landsat sensors technology. Indeed, at the level of TIRS sensors and unlike for TM and ETM+ products, which have thermal infrared bands acquired in a single wavelength interval that ranges from 10.40 to 12.50 µm, the Landsat 8 contains two thermal infrared bands similar to those of the MODIS thermal bands (Roy and al, 2014. Irons and al, 2012). A Topographic Map of the city of Marrakech at the scale 1/50000 (1990,2004), and Google Earth imagery were used to confirm the choice of the different land use classes. Source : https://jemecasseausoleil.blogspot.com

4. Methodology

Two methodological approaches were adopted to carry out this work, it is the method of land use mapping of the urban municipality of Saada by diachronic study from 1989 to 2020, as well as the extraction of the built environment and the temporal evolution of the urban space on 3 dates 1989, 2005 and 2020. As mentioned above, the images acquired by the sensors on board the satellites contain radiometric and atmospheric errors related to the characteristics of the instrument and the presence of the atmosphere, hence the need for this data pre-processing approach. Before starting our work, we have to apply the necessary modifications for each image so as not to affect the value of each digital nambre and keep the original information, we limited ourselves to three types of pre-treatments, namely radiometric calibration, radiometric enhancement and geometric correction. Figure 3 summarizes the methodology adopted in this document.

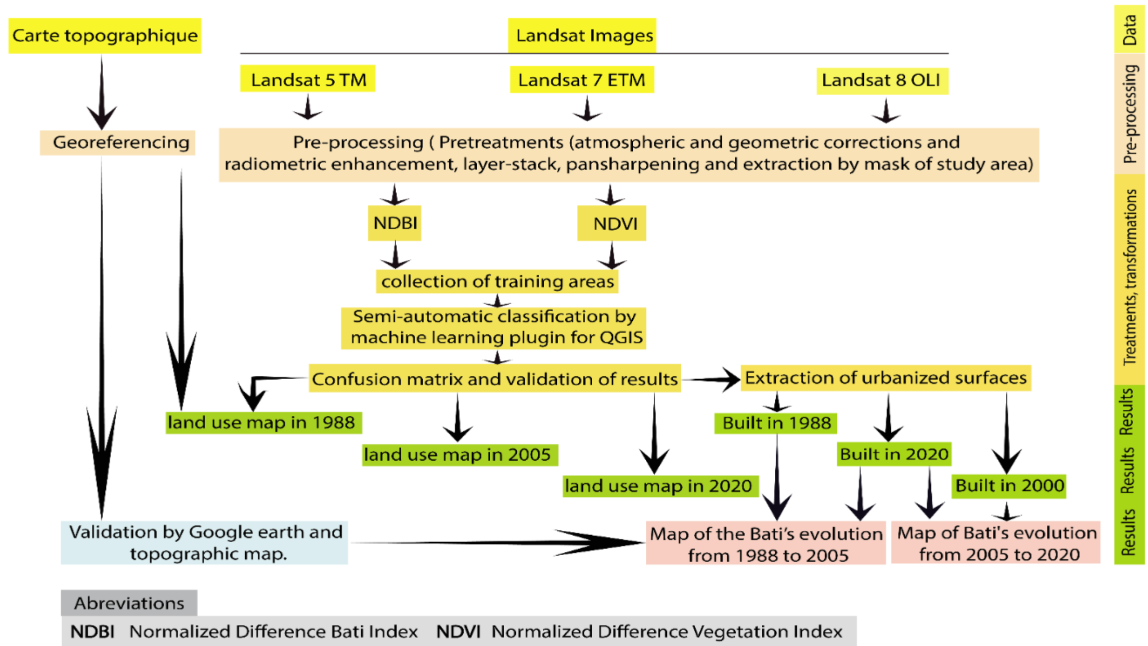

Figure 3: Methodology of work

The methods adopted for the realization of this end-of-study project are modest and flexible methods of use. Many authors have used these methods in their research work. They are (Mas, 2000 ; Bouziani and al, 2010).

5. Results and discussion

The 1989, 2005 and 2020 land use maps of the Study Area are shown in Figure 4 and the respective areas of each land use class in Table 2. These mapping results were validated using a confusion matrix that allowed us to arrive at good classifications with respect to the Kappa indexes with 0.74 for the 1989 classification, 0.70 for 2005 and finally 0.80 for 2020.

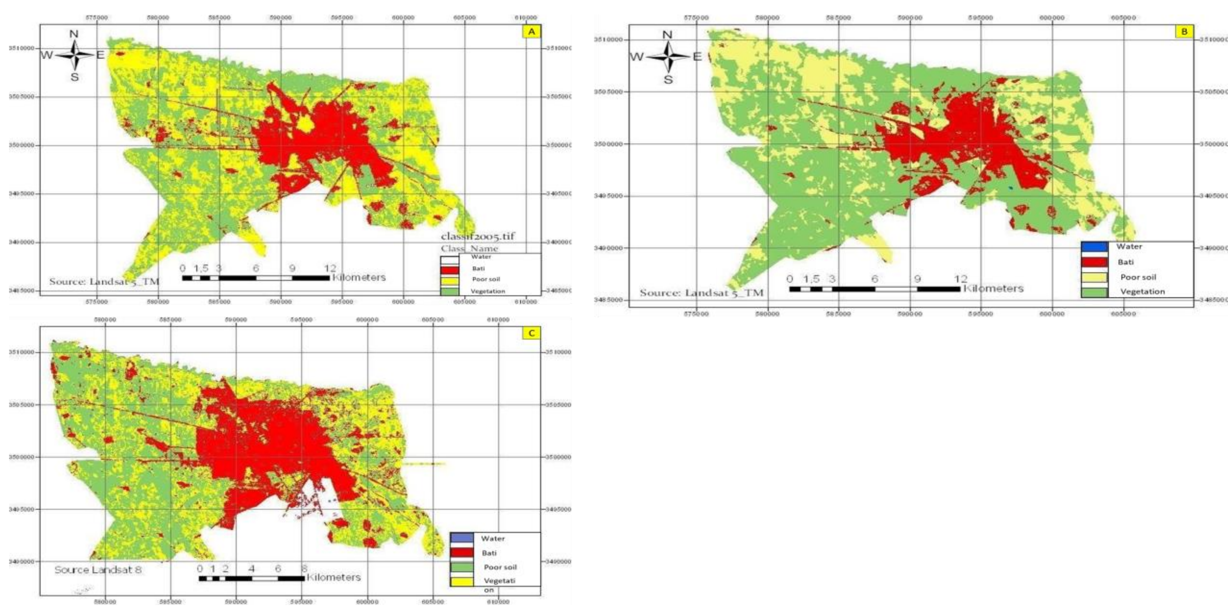

Figure 4: Land use map of the study area, A in 1987, B in 2005 and C in 2020.

Table 2: Area in hectares and percentages of land use classes

Land use classes	**Area in hectares**			**Area in percentages**		
	1989	**2005**	**2020**	**1989**	**2005**	**2020**
WATER	5,76	7,11	756,00	0,02	0,02	0,66
Urbanized space	5112,71	6103,44	10587,40	12,39	17,51	27,34
Vegetation	25068,12	17001,36	17492,51	60,73	40,16	45,37
Bare ground	11093,34	18170,64	10322,62	26,87	43,31	26,63
Total	41279,93	41282,55	25476,35	100,00	100,00	100,00

5.1 Analysis of the evolution of land use from 1989 to 2020

The purpose of this analysis is to quantify the proportion of each land-use class and its spatio-temporal evolution and then a comparison between the different dates (1989- 2005,2005-2020) in order to show the evolution of the different classes. According to Robin M, (2002) Each geographical entity (plot of land, forest, town, sandy beach, etc.) evolves at its own pace over time. Thus, after calculating the areas of the different land use classes, we determined the rate of evolution of each class during the time interval considered (1989-2005, 2005-2020) (table 3). Positive values represent an increase in the area of the class during the analyzed period, negative values a loss and values close to or equal to zero (0), relative stability (Cristina and al, 2010).

Table 3: Rate of change in percentage and in hectares of the land use classes in the city of Marrakech from 1989 to 2020

Land use classes	**1989 - 2005**		**2005 - 2020**	
	Ha	%	Ha	%
Water	1,35	0,005	748,89	0,64
Urbanized space	990,73	5,12	4483,96	10,83
Vegetation	-8066,76	-19,565	491,15	4,21
Bare ground	7077,3	17,44	-7848,11	-17,68

The analysis of the cartographic and statistical results (figures 21, 22, 23, table 6), shows, on the one hand, a progressive dynamic of bare soil, urbanized space, water and, on the other hand, a regressive dynamic of vegetation (table 6). In 1989 the built area occupied 5112.71 hectares (12.39%), this increased to 6103.44 hectares (17.51%) in 2005, an evolution rate of 990.73 hectares (5.12%) during this period. This overall urban expansion is proceeding without regression, by the establishment of new urban cores, by spreading out on the margins and by filling in interstitial urban spaces. (Lagabrielle and al, 2007). The bare soil also experienced a strong increase between the two dates: an evolution rate of 17.44% (11093.34 hectares in 1989 against 18170.64 hectares in 2005). This strong growth of bare soil is explained by the disappearance of areas of vegetation (agricultural land and others). This evolution is justified by the waves of drought that affected Morocco. According to the heatwave and drought review, in general, since the 20th century there has been a decrease in precipitation that highlights the overall decrease in humidity and the regular installation of a drought that is coupled with rising temperatures.

5.2 Change in land use from 2005 to 2020

The occupancy of bare land is 18170.64 hectares in 2005 and 10322.62 hectares in 2020 or a rate of change of -17.68%, the decrease in the area of bare soil of -7848.11 hectares can be justified simply because of the strong expansion of urban space. We note that bare soils have steadily declined since 2005 in favour of urban spaces. The expansion of urban spaces continues until 2020, which is quite normal.Indeed, for some time now, the population of the city of Marrakech continues to climb. On the other hand, there has been a small increase in vegetation from 17001.36 hectares in 2005 to 17492.51 hectares, a rate of change of 4.21%.

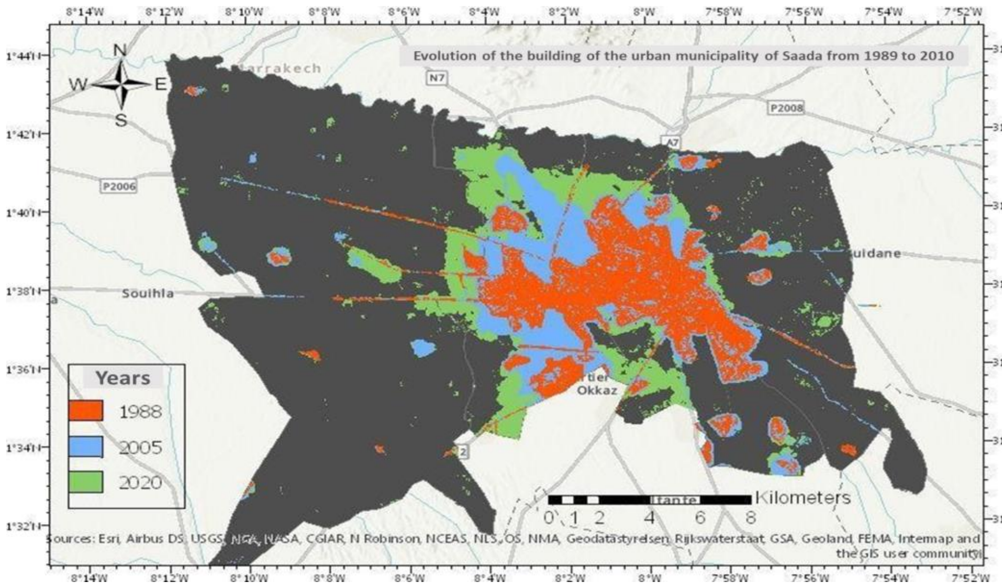

Figure 5: Evolution of the Urban Cummune Building from 1989 to 2020.

5.3 Analysis of the evolution of the Building from 1989 to 2020

The analysis of Figure 5 above allows us to observe the trend of urban space extension. We then observe an extension in almost all directions (North, North-West, West, South-West, South and South-East). The extension of the urbanized spaces of the city of Marrakech results from the combination of several factors including, among others, we can cite in terms of demographic movement, high natural population growth and the mass exodus of rural populations to the cityThe urban structure of the city of Marrakech is characterized by the persistence of mono-centrality and the absence of polarities susceptible to create other places of animation. Indeed, the Jamâa El Fna square and Mohamed V avenue constitute the central heart of the city. After a detailed analysis of urban sprawl, we made a synthesis of the evolution in these directions:

Northern extension: urbanization has crossed the limits previously defined by the Oued Tensift and the palm grove, considered until recently as the green belt of Marrakech, to reach today the surroundings of the Olympic stadium. Various residential and tourist projects are emerging to the detriment of the banks of the Oued Tensift, on either side of the road to Casablanca, the case of Parc de l'Atlas, River Palm.

Northwest extensions: the extensions are in line with the linearity of the Safi road.The district and the new Sidi Ghanem Industrial Zone, testifies to this urban thrust which is stretching more and more towards Tamansourt. The Targa road is now a linear development axis that is not very coherent with new villa zones on either side.

Extensions West: A very sustained spread and densification make cohabit activities and various housing programs, in particular the social and medium standing. The site along the road to Agadir, initially intended for an industrial zone, was to be reinforced to serve as a central location. Various monofunctional residential projects such as Portes de Marrakech on 300 ha on irrigated area.

Southwestern extensions: extensions are manifested by large housing projects in the form of juxtaposed housing estates and are developing particularly along the road to Agadir. The Agadir road alone remains the backbone of the adjoining districts in continuous expansion.

South and Southeast Extension: the developments are located in the area between the roads leading to Tamesloht and Ourika.

Marrakech stretches more and more towards the West with a more compact urbanization development towards the North-West and West (Essaouira and Targa road). The asymmetry is significant with the eastern part of the territory of the Urban Municipality of Marrakech. So, with this considerable urban sprawl to the detriment in particular of wadis and irrigated perimeters. This extension has a considerable impact on agricultural land in the peri-urban area where there is a strong regression and loss of agricultural land around the city consumed by this urban sprawl despite its significant agricultural potential. For example, the construction of the industrial district of Sidi ghanem was to the detriment of an area of better palm trees, spread over about 36 ha, and of strong natural interest. This also concerns the hundreds of hectares of irrigated land invaded by large public housing estates to the west of Marrakech.

6. Conclusion

The present study is part of the mapping of the spatio-temporal evolution of the city of Marrakech in order to characterize the dynamics of land use between 1989 and 2020 with Landsat images and subsequently assess the trend of the evolution of urban extension. All the objectives set were achieved in Savoi, the detection of land use changes in the city of Marrakech from 1989 to 2020, mapping the evolution of urban sprawl in the study area during the same period. The application of the Image classification using Machine Learning algorithms with the QGis Orfeo Toolbox of Landsat images allowed us to meet our objectives. Topographic maps and visual interpretation as well as ancillary work were used for the validation of the produced maps. By comparing the land use statistics generated from the maps produced, we were able to highlight the changes that took place in the city of Marrakech between the periods 1989-2005 and 2005-2020.

From these cartographic and statistical results, a regressive then progressive dynamic of vegetation emerges despite the loss of agricultural land in the peri-urban area noted in the analysis of the evolution of the built environment (-19.56% in 2005 and 4.21% in 2020), and a strong increase in urbanized areas (5.12% in 2005 and 10.83% in 2020), water has seen a slight increase (0.005% in 1988 and 0.64% in 2020) and bare land has seen an increase and then a decrease of the same value (17.44% in 2005 and -17.68% in 2020). As regards the most remarkable directions concerning the evolution of the urbanized space, a predominantly westerly evolution has been noted. In fact, from 1989 to 2020, the conversion of a large part of the bare soil and agricultural land into urbanized space has favored a strong urbanization of the city. The use of intelligent remote sensing data offers a lot of perspective in the study, management, monitoring and evaluation of our environment.

The interest of this work is to have carried out a diachronic study which shows, thanks to cartography, the dynamics of land use in the urban municipality of Saada from 1989 to 2020, 32 years. However, the maps drawn up can serve as very useful tools for decision-makers and all those involved in planning for territorial management and monitoring of urban environments.

On the other hand, numerous research studies have shown that this phenomenon of urban concentration leads to significant climatological and meteorological problems (Collier, 2006) which weigh heavily on the quality of water and the health of the environment, and which are accompanied by a significant increase in pollution and air temperature (Taha, 1997. Cui and Shi, 2012). The urban action in Marrakech also affects the microclimate, the urban heat island (UHI), which is considered as a temperature difference between urban and rural areas (Zhang, 2009). This is the result of several factors such as the intensity of construction [8], the size of the city (Streutker, 2002), the low albedo (Boukhabl and Alkam, 2012) and greenhouse gas emissions (Rhinane,2012). Its aggravation is based on synoptic conditions that can be summarized as anticyclonic weather, cloudiness and low wind (Sakhy,2011). In addition to the adverse effects of heat islands on the local climate, they affect human health (Tan and al, 2010; Gong and al, 2012) and contribute to excess mortality and morbidity (Gong and al, 2012; Patz and al, 2005)

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