LAND USE AND URBAN SPRAWL IN THE CASE OF THE CITY OF RABAT IN MOROCCO: AN INTEGRATED APPROACH USING REMOTE SENSING, GEOSPATIAL MODELING, AND MACHINE LEARNING.

Soufiane BOULMANI[1*], *Abderrahme SAADANE*[1]

[1]CERNEDD, GEOSCIENCES, WATER AND ENVIRONMENT LABORATORY (L-G2E), Geology Department, Mohammed V University Faculty of Sciences, Rabat

Abstract. This document is produced as part of a project of mapping, monitoring and prediction of urban sprawl in the city of Rabat, using algorithms of machine Learning, remote sensing and geographic information system. It therefore aims to determine and monitor the urban sprawl of the city of Rabat, using new Geo-spatial technologies, this socio-economic mechanism is theoretically based on the increase in the horizontal area of the city, and a decrease in population density. On the contrary, the city of Rabat is characterized by a negative growth rate between the years 2004-2014 at about -0.79% different from 1.2% at the national level, and defined by a higher population density of 255 inhabitants per km2, these statistics were directed to a hypothesis that indicates a horizontal confinement of the city of Rabat and reverse immigration to per-urban territories. In addition, this project is mainly aimed at the implementation of a computerized simulation model for the characterization and prediction of the urban expansion of the city of Rabat for 40 years (1990, 2000, 2010, 2020, 2030). To conclude, the city of Rabat has experienced a very slow urban sprawl, thanks to the green belt put in 1971, and the modernization strategy that has been adapted in recent years to eliminate informal housing, in addition to the development of roads and the new TGV railway line, and also to the lack of land use, of which many large villas of several hectares were built. Although this mechanism is moving very slowly, the city of Rabat has had negative consequences on the territory and the environment. So, local authorities need a creative, innovative and intelligent urban planning programme to both eliminate the effects of this mechanism, and build the pillars of the functional city (smart city).

Keywords: Mapping, urban sprawl, machine learning, remote sensing, geographic information system, urban planning, smart city.

1 Introduction:

Urban sprawl is the process of expanding cities that extend beyond their original boundaries to meet the needs of their growing population. This phenomenon can be caused by rural migration to cities, an increase in the birth rate or simply by the attraction of economic and cultural opportunities offered by urban life.

In Africa, and particularly Morocco has experienced in recent years a rapid growth of their urban population and a remarkable economic development of cities, these territories offer more opportunities for work, quality educational follow-up and health care, which leads to a migration of the population from rural areas to seek work in the cities. This urban growth has negative consequences for the environment and the quality of life of citizens. Of which, it leads to strong pressure on soils and natural resources such as water, agricultural land and green spaces and a negative impact on air and water quality, as well as transport problems and an increase in inequalities.

Moreover, the rapid pace of urban growth in Morocco often results in inefficient urban planning and poor regulatory policies, as well as urban services are often not equitably distributed across wider urban areas, which can lead to significant disparities in quality of life. In addition, governance problems due to mismanagement, corruption and conflicts of interest.

Finally, the study of urban sprawl therefore represents an important challenge to understand the effects of urbanization in African cities.

1.1 Issue:

Although the city of Rabat is a special territory, with his strategic location, disrupted characteristics, and their administrative character, it knows a lot of suffering in the different levels and sectors of life.

Currently, the city has been taken an important place in international discourse, so that it emerges from their classical identity, and this has stripped of several defects, especially in the processes of exploitation of natural resources and transformation or creation of wealth.

This work therefore aims to determine and monitor the urban sprawl of the city of Rabat, using new Geo-spatial technologies, this socio-economic mechanism is theoretically based on the increase in the horizontal area of the city, and a decrease in population density. On the contrary, the city of Rabat is characterized by a negative growth rate between the years 2004-2014 at about -0.79% different from 1.2% at the national level, and

*boulmanisoufiane@email.com

defined by a higher population density of 255 inhabitants per km², these statistics were directed to us to a more important question, is the city of Rabat to really exercise this phenomenon of urban sprawl, and if so, how can we explain the horizontal confinement of the city and the reverse immigration of the population to peri-urban territories (Temara, Salé, Romani, Ain Aouda, Zhiliga, Tamesna).

1.2 Project Objectives

This project aims to solve this problem and to carry out a Geospatial modelling of urban sprawl to detect the changes and progress of buildings in the city of Rabat, both by comparing the results of supervised classification and that of Machine Learning algorithms, and to make a prediction in the future of this phenomenon thanks to the most valid approach.

Moreover, this work is mainly based on the implementation of a computerized model for the characterization and monitoring of the urban expansion of the city of Rabat for 30 years (1990, 2000, 2010, 2020), this modelling must be confused with the public policies and strategies provided in the city. So, the expected results of this project is a model of automatic land use mapping that offers the opportunity to determine the environmental and spatial effects of the urban advancement of the city of Rabat, and also to adopt better planning to land management. This is a modelling approach that has the following features:

- Automatic mapping: creation of thematic maps of land use in the city of Rabat in the various years of this study (1990, 2000, 2010, 2020);
- Multi-temporal analysis: Identify and evaluate the dynamics of the territory, and extract the rate and statistics of urban development over 30 years;
- Multi-criteria analysis: determine the relationship between urban acceleration and cultivated areas;
- Urban prediction and simulation: determine the evolution of urban sprawl in the future from 1990 to 2030, and understand the socio-economic trends of the city;
- Object-oriented solution: propose a smarter space management strategy based on the institutions of the sustainable development plan;

2 Presentation of the Study Area

The city of Rabat covers an area of 118 km², constituting 1.23% of the total area of the region, and has 577,827 inhabitants (RGPH2014) or a significant density of 255 inhabitants in km². It is bordered to the north by the province of Salé, to the east southeast by the provinces of Salé and Temara-Skhirate, and to the west by the Atlantic Ocean.

The prefecture of Rabat is known for its historic old town, its ancient monuments and its distinctive architecture, as well as their tourist character, this territory is benefiting from several investments thanks to its strategic position, so that industrial zones, green spaces, parks, forests and hotel entities are installed. Rabat is part of the Atlantic domain, it extends over the coastal plateau which consists of alluvial plains and low plateaus at the edge of the Atlantic Ocean, this coastal plateau is bounded by the Sidi Mohammed Ben Abdellah dam to the east, and the Atlantic coast.

The province is subject to a temperate climate due to its position in the humid to semi-humid bioclimatic scale, it is mild and humid in winter and hot and dry in summer, The intensity of humidity increases as one moves from east to west and from south to north.

Table 1. Rainfall distribution in the province of rabat between (2008 and 2018).

Year	2008-2009	2009-2010	2010-2011	2011-2012	2015-2016	2016-2017	2017-2018
Precipitation in mm	812,4	881,7	672,8	302,7	485	664,8	1 129,2

Source: Statistical Yearbook of Morocco.

Table 1. Below shows that the rainfall of the province is irregular from one year to the next, it is concentrated during the month October to December with an average of 485mm in 2016, and an average temperature of 17.9 ° C. As well as the temperature differentiations remain less varied, which brings an annual temperature range that does not exceed 20 ° C. but with regard to the rainfall measured in the Rabat-Salé station during the agricultural years 2016-2017 and 2017-2018, it increases successively to 664 mm and 1129mm.

The soils of the province are mostly sandy in the littoral zone, it is the soils of iron sesquioxides based on limestone, it has a high capacity of water retention and moisture brought by the ocean mass. The province also has groundwater resources stretching from Oued Akrach in the east and Oued Ikem in the west that allow it to meet irrigation needs and potentially constitute an important asset for its socio-economic development.

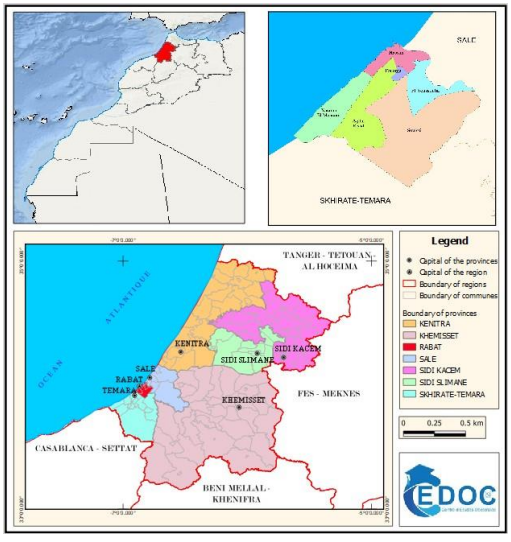

Fig. 1. The geographical location of the Province of Rabat.

Administratively, Rabat is the administrative capital of Morocco, created in 1955, it has two urban communes: the commune of Touarga and the commune of Rabat, the latter consists of five arrondissements,

Hassane, Agdal Hay-Riad, El Youssoufia, Souissi and the arrondissement of Yaecoub-ElMansour.

Table 2. The distribution of the population of the province of rabat (1994, 2004 and 2014).

Province	circle	Urban communities	arrondissement	Pop_1994	Pop_2004	Pop_2014
Rabat		Rabat	Hassane	146488	128425	108179
			Agdal-Hay Riad	74006	90568	77257
			El Youssoufia	170138	172863	170561
			Souissi	25070	27323	23366
			Yaecoub El Mansour	199675	202301	194532
		Touarga	Touarga	8080	6452	3932
			Total	623457	627932	577827

Source: Official Bulletin 2-08-520 published on 28 October 2008 of the administrative boundaries of Morocco and the statistical yearbook of Morocco.

The Table 2 shows that the population is concentrated in the district of Yaecoub El Mansour, at about 194532 inhabitants, given 30% of the population of the province in 2014, and then El Youssoufia with 29.5%, although the districts of Hassane, Agdal-Hay Riad, Souissi and Touarga successively bring 18.7%, 13.4%, 4.1% and 0.1%. We also observed a decrease in population between 1994-2014 which also affects the weight of the province in the total population of region, it is ranked third with a share of 12.6%, after the province of Kenitra 23.2% and the province of Salé 21.4% during the year 2014.

First of all, the region of Rabat-Salé-Kenitra experienced between 2004 and 2014, an increase in the rate of urbanization, this mechanism is expressed by several factors, among the most important the phenomenon of immigration of the rural population to urban centers, and the transformation of some rural territories into urban centers. In addition, the expansion of cities in per-urban areas, and the continuous growth of new urban centers, but the province of Rabat no longer contains a rural population which may explain the rate of urbanization stable for 20 years. Here is a table that expresses in figures this development of the urbanization rate over time:

Table 3. The development of the urbanization rate (%) by province (1994, 2004 and 2014).

Province or prefecture	1994	2004	2014
Rabat	100	100	100
Salé	92,8	94,4	93,2
Skhirate-Témara	71,8	90,0	90,1
Khémisset	36,0	44,8	51,8
Kenitra	45,8	52,7	57,2
Sidi Kacem	27,1	30.2	32,3
Sidi Slimane	-	38.0	40.9
Region	60.4	67.4	69.8

Source: General Statistical Yearbook of Morocco 1994, 2004 and 2014.

3 Materials and work method:

In order to carry out the study entrusted to us well, it seemed necessary to follow the following methodology in order to achieve the assigned objective and the expected results of the project. This methodology was based on a consistent approach composed of three distinct but chronological parts that are illustrated in the figure below:

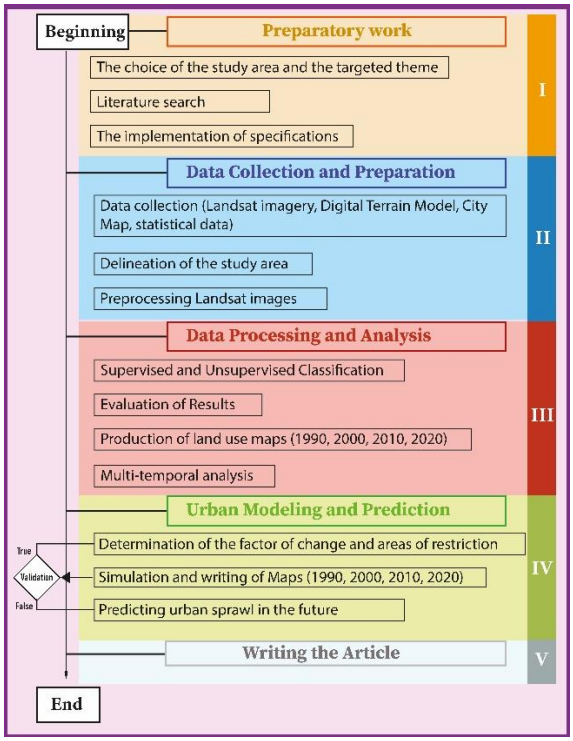

Fig. 2. The methodology of the work.

3.1 Preparatory work

In this phase, we sought to know and understand more about the scope of the subject. It is a question of collecting the necessary documents and information (Articles, Dissertations, Books, Theses and monographs), in order to constitute a clear idea on the theme to be adapted in the form of a project specification.

3.2 Data collection and preparation

After describing a clear and objective idea of this work in a specification, we collect the geospatial data that covers the city of Rabat from the different data providers, and that are necessary for the validation of the adapter approach. This data is acquired in various ways, depending on its type and method of acquisition:

- Geometric data: these are Open Street Map data and the municipal inventory;
- Attribute data: it corresponds to the statistical data of the statistical yearbooks and provincial monographs produced by the High Commission-Au-Plan;
- Satellite images: these are open source Landsat images download Geospatial data from the USGS platform, these Landsat images are a valuable source of data for environmental monitoring, they have 04:
  - A Landsat TM (Thematic Mapper) image from 07-06-1990

- A Landsat ETM+ (EnhancedThematic Mapper Plus) image from 2000-07-28;
- A Landsat ETM+ image from 2010-06-06;
- A Landsat OLI_TIRS image (Operational Land Imager/TIRS, Thermal Infrared Sensor) of 21/10/2018;

In particular, other literature searches were conducted on the Internet to supplement the literature (Google Scholar).

Finally, we implemented the pre-processing of Landsat images under spatial analysis software (ENVI, ArcGis), and this involved several steps necessary to make these images compatible with the objectives of the project. In addition, we checked the quality of the open source data by eliminating typology errors and duplicates, and then we also reorganized this data in a geodatabase, so as to facilitate its use in later phases.

3.3 Data processing and analysis

This work proposes an automatic and semi-automatic mapping approach to land use, through the application of GIS tools under the ArcGis 10.5 program, and artificial intelligence machine and deep learning algorithms, it is a question of exploiting spatially referenced data in all stages of research. Here we have an integration of Landsat images on the image processing software (ENVI 5.3), and then we define the characteristics of the classes for supervised pixel classification, and then we extract pixel samples for each defined class to create a training set. These formation pixels are then used to classify the pixels of the entire data set.

Once we had completed the data processing, we carried out an evaluation of the classification under the IDRISSI17 software, thanks to Accuracy Indicators such as overall accuracy, kappa and producer and user accuracy.

Then, we wrote land use maps for the years 1990, 2000, 2010 and 2020, which allowed us to make a multi-date comparison of these thematic maps, to extract and follow the evolution of buildings and other land use classes in the city of Rabat.

3.4 Urban modeling and prediction

Generally, modeling and prediction can help us better understand the different aspects of the city of Rabat such as traffic, energy consumption and lifestyles, they also allow us to predict the changes that occur in the city and plan accordingly. So, it is thanks to the coupling of GIS and machine learning algorithms, that it is possible to find solutions to improve the quality of life of citizens, make the city of Rabat more sustainable and resilient, and anticipate future changes.

In this phase, we performed modeling with supervised learning under the IDRISSI17 platform, taking into account Landsat images classified under ENVI, whose objective is to make an assessment of the classification, in order to choose the best possible outcomes and execute the prediction of future outcomes using historical data.

4 Results and discussion

4.1 Empirical observation (Multi-date analysis)

As part of this project, we carried out a naked-eye observation of the Landsat images that are illustrated below, and with their processing under the ENVI image processing environment, they visually showed the spatial variation of different geographical objects (Buildings, Bare soils, vegetation, and Water), and concretely translated the socio-economic activities of the inhabitants through their needs (housing, agriculture).

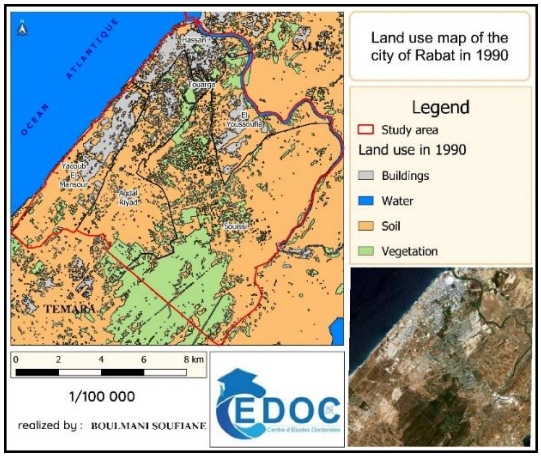

Fig. 3. Land use map of the city of Rabat in 1990.

In 1990, the urban extension of the city of Rabat occupy a smaller space compared to the surfaces intended for agriculture, forests and green spaces, it is characterized by a circular structure, it was built on the coastal part of the full in accordance with the ideology of the inhabitants who seek to settle always as close as possible to natural resources, thus the city of Rabat begins its spread from the mouth of Oued Bouregreg and follow its flow, moreover to what appears clearer in the image, we observed that there is a significant area of unused soils at the edge of the coast, and this due to the unexpected natural risks that characterize the coastal line (erosion, alteration and advancement of the ocean).

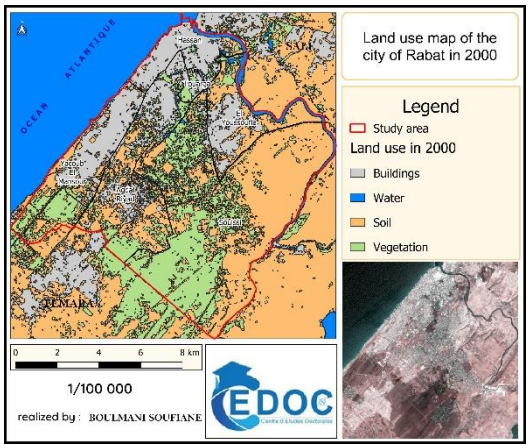

Fig. 4. Land use map of the city of Rabat in 2000.

In 2000, the urban evolution begins in the edges and centers of the city of Rabat, with a slower urban advancement, of which more than going west northwest towards the ocean, we found changes about medium to low degree, with a restructuring of the shape of the city that takes the shape of a wand. In particular, economic activities that develop in parallel with the needs of the inhabitants.

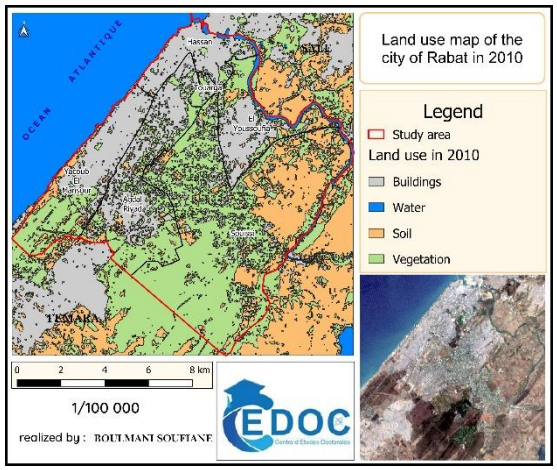

Fig. 5. Land use map of the city of Rabat in 2010.

In 2010, the city of Rabat to follow its urban evolution, it knows a succession of events of opening of new subdivisions in places or surface of bare ground. Of which, it appears new neighborhoods and urban areas, then the sector of buildings and public works become a more interesting field of activity, on the one hand to meet the housing needs of the inhabitants, and on the other hand to create wealth and job offers.

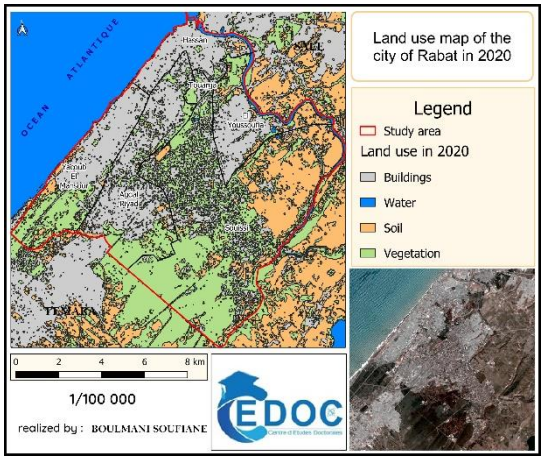

Fig. 6. Land use map of the city of Rabat in 2020.

In 2020, with a simple comparison of the urban extension of the city of Rabat between 1990 and 2020, we saw that the city of Rabat had a slower urban advance, in the direction North-North-West South-South-East, especially on the edges of the ocean towards the city of Temara and towards the East closest to the Moulay Mohamed ben Abdellah dam. In addition, among the geographical objects that have no change in the ecosystem of the city of Rabat, it is the forest areas, or what is called the green line. The latter is an important element of the city, it supports the image or ecological character of the city of Rabat, although it makes the horizontal sprawl of the city more difficult and prohibited on these surfaces.

According to the results obtained (Figure 6) and what emerges from the observation of satellite images of Landsat, we interpreted in accordance with the hypothesis that was made at the beginning of this study, that the city of Rabat is located in a limited area between the territory of the cities of Temara and Salé, even if it knows an improvement of the population between 1994 and 2015 according to the statistics of the High Commission for Planning, but the current urban extension of the city of Rabat no longer meets this improvement and the housing needs of this population, and in parallel the new neighbourhoods created are the fruits of territorial planning policies, either with regard to the fight against illegal occupation of housing, or by the change in the nature and destination of the land posed by the old development plans.

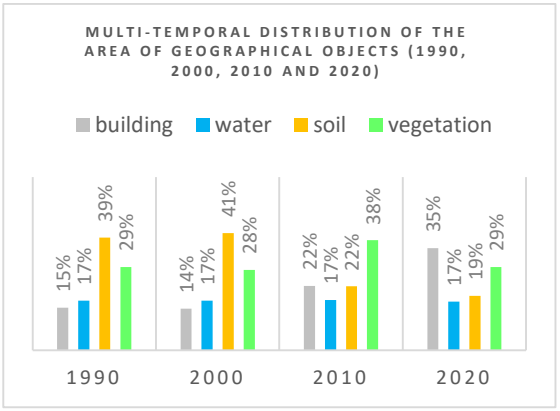

Fig. 7. Multi-temporal distribution of the area of geographical objects (1990, 2000, 2010 and 2020).

4.2 Real urban dynamics of the city of Rabat

This period of our study, which spans more than 30 years, is considered the most important in the history of urbanization in the city of Rabat. During this course of the present city, the main components of the present city will be formed in all their forms and appearances.

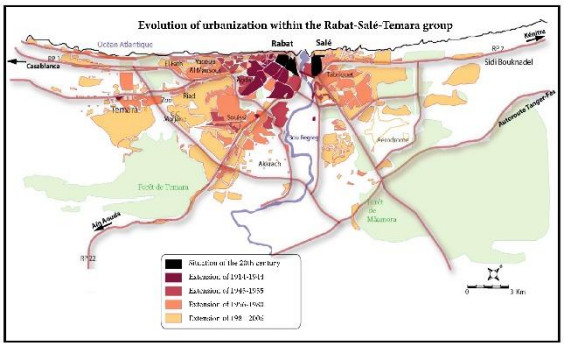

Fig. 8. Map of urbanization evolution within the Rabat-Salé-Temara conurbation.

Before the year 1990, the city of Rabat experienced a more complex period, which is reflected in a strong and rapid demographic dynamic that was expressed by immigration from rural territories to urban centers, in addition to their administrative location and strategic position. Indeed, during this period, the city of Rabat is forming an urban core. Moreover, it knows the

predominance of tin houses (Douar ElKoora, Douar Rjaf Allah, etc.).

Between 1990 and 2010, a new urban development strategy was applied in the city of Rabat. This vision focuses on a new form of housing intended mainly for the resettlement of households living in tin houses, the latter will be set up as part of major projects in the Yaecoub AlMansours district such as Diar AlMansours Residence, Assabah, and Oum Kaltoum. In addition, this strategy proposes new sectors for urbanization at the local level, such as Akrach, El Boustane, and El Kournich.

From 2010 until 2020, this period was also distinguished by a slow urban expansion in the east-southeast direction and west at the edges of the Atlantic Ocean, especially after the saturation of the urban core of the city, the depletion of available land use, and the dominance of villa areas (Enahda District, Hay Riad). Then, the city of Rabat is currently experiencing almost total saturation of his urban territory.

In general, the different sectors of urbanization and development of the city of Rabat have experienced a slow dynamic, whether in terms of origin or development, although the sectors of the East South-East and West (Yaecoub al Mansour and Taquadoum district) have experienced rapid territorial and demographic transformations since they attract more immigrants and welcome informal housing in addition to organized housing such as the Dyar al Mansour residences, Oum Kaltoum, and Hay Riad.

4.3 The future urban evolution of the city of Rabat

Currently, the city of Rabat is a real jewel in Morocco, it is growing, with a negative population growth rate and an expanding economy. The local authorities have implemented several urban development projects aimed at improving transport infrastructure, developing residual and commercial areas, and promoting tourism. In this part of the study, we will show the results of an urban sprawl projection of the city of Rabat in the future. These results are obtained from the coupling of remote sensing, GIS and machine learning algorithms.

4.3.1 The evolution of land cover predicted by the Markov Model

The predictive calculation of land cover is carried out using an analysis of Markov chains. This prediction is based on an estimate of the probabilities of transition between different types of land cover, as a function of time, based on transitions observed in the past. The result is presented in the form of a matrix that encodes the probabilities of change for each land cover category, as well as the number of pixels affected between the last reference date and the projected date.

The map below **Fig. 8.** shows the different changes in land use between the various categories between 1990 and 2000, based on the resulting probability matrix.

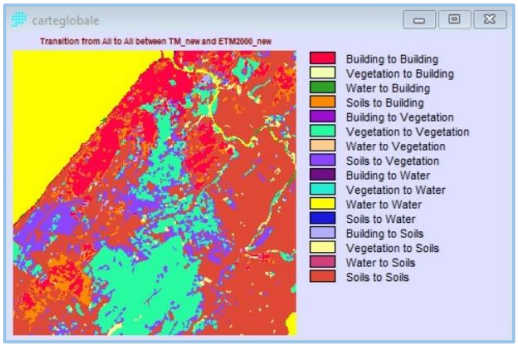

Fig. 9. Land use map extracted from the transition matrix between 1990 and 2000.

Between 1990 and 2000, the area of agricultural and bare land decreased due to the increase in buildings, while green space gave way to bare and built-up land. Using the resulting probability matrix, the map **(Fig. 9.)** shows changes in land use categories between 2000 and 2010.

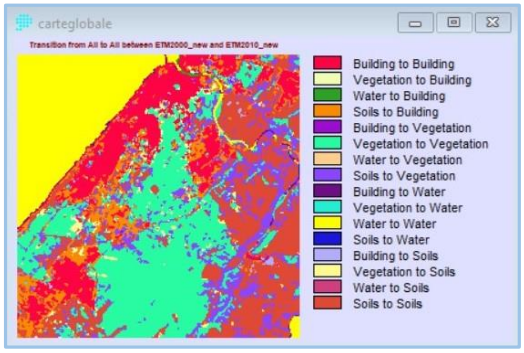

Fig. 10. Land use map extracted from the transition matrix between 2000 and 2010.

The same trend was observed for the period 2000–2010, with an apparent increase in the area built to the detriment of all other types of land use, especially bare land and agricultural land.

The map in question (**Fig. 10.**) is a visual representation of the changes that took place in the different land use categories between 2010 and 2020, using data from the probability matrix. It shows how these categories have changed over time, such as buildings, vegetation, soil, or other types of land use.

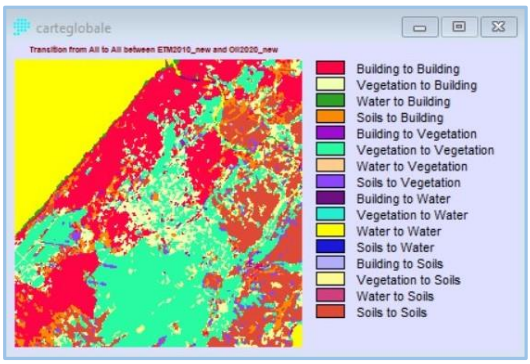

Fig. 11. Land use map extracted from the transition matrix between 2010 and 2020.

During the period 2010–2020, built-up land increased at the expense of all other land cover categories, including bare land and agricultural land.

4.3.2 Validation of results obtained

In order to evaluate the quality of a model, a quantitative and visual comparison of the grids representing the observed situation with those resulting from the simulation of the Markov model should be carried out. The validation results show that the differences between the surfaces of the different land cover classes obtained by classification in 2010 and 2020, and those simulated by the Markov model, are relatively small. This observation testifies to the model's ability to accurately reproduce the spatio-temporal dynamics of land use. These results can be useful in building confidence in the model and guiding decisions related to land use planning and management.

The figures below (Fig. 11.) illustrate the land use dynamics of the city of Rabat over a period of 30 years, from 1990 to 2020. They represent the actual state of the city in 2010 and 2020, as well as a simulation of this land cover for these same years.

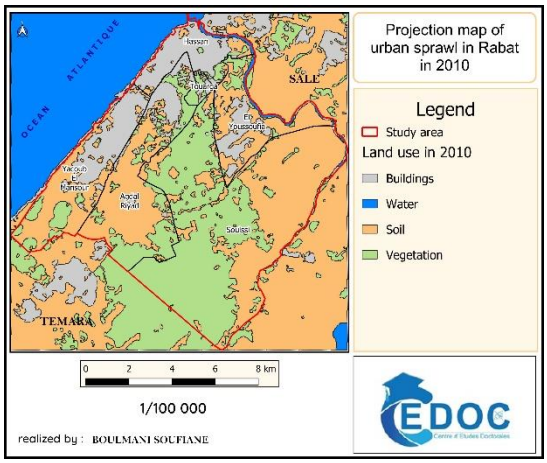

Fig. 12. Projection map of urban sprawl in Rabat in 2010.

A comparison between the land use map of the city of Rabat in 2010 (Fig.4.) and the projected map (Fig.12.) of the same date reveals minimal changes. Indeed, the area of vegetated areas has remained virtually unchanged, while the class of buildings has undergone a significant evolution in reality compared to the projected map.

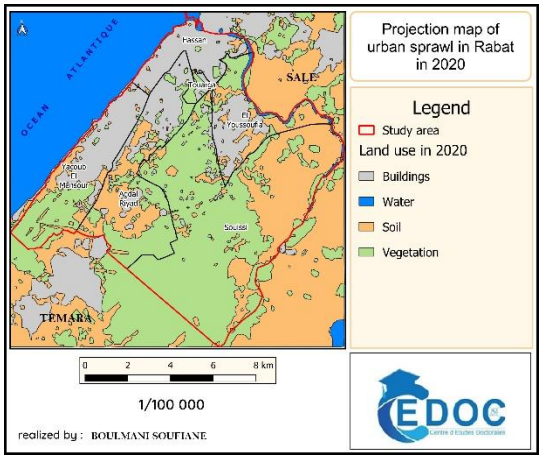

Fig. 13. Projection map of urban sprawl in Rabat in 2020.

In 2020, we note that the land cover classes remain broadly similar between the map of reality (Fig.5.) and that of the projection of urban sprawl in Rabat 2020 (Fig.13.). This demonstrates once again the effectiveness of this projection model for the city of Rabat.

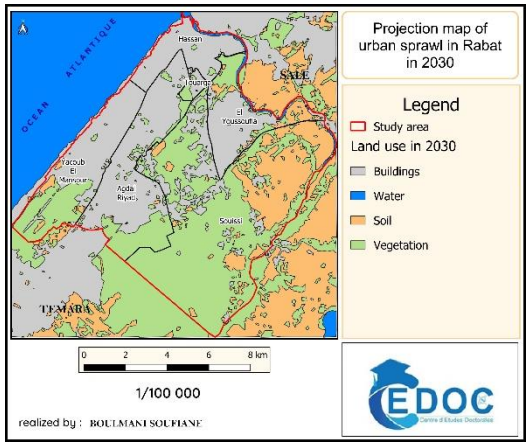

Fig. 14. Projection map of urban sprawl in Rabat in 2030.

The projection of urban sprawl in Rabat highlights a significant dynamic of reality, which is in line with the directives of the local authority. At the base of the map projection of urban sprawl projected for 2030 (Fig.14.), it can be seen that it extends north-north-east and south-south-west, along the coastal line towards the cities of Temara and Salé. This trend suggests that the city of Rabat can truly become the link between the city of Salé and the city of Temara, thus forming a complete urban ensemble.

4.4 The Environmental and Spatial Impact of Urban Expansion

In the city of Rabat The urban development observed in the four territorial communities located on the periphery of the metropolitan region of Rabat has led to several changes, the latter taking place in two main periods, either during the period of urban advancement, when the city of Rabat has a consumption of agricultural land and increased risk of flooding due to the change of shorelines, or during the period of reverse immigration, which gives rise to the reformulation of other negative effects on the city in general, such as pressure on public transport, congestion, air pollution and increased water needs.

4.4.1 Consumption of agricultural land

On the one hand, the city of Rabat experienced an important urbanization mechanism that led to a strong penetration of the urban population by the rich and middle classes in the rural communities located on the outskirts of the city. This has directly affected the rural landscape of these communities, which have experienced an increase in the number of luxurious houses surrounded by high walls. And on the other hand, it has led to an increase in the price of farmland, which becomes more expensive for local farmers.

4.4.2 Increased risk of flooding due to shoreline change

There are several measures to reduce the risk of flooding caused by shoreline changes, and in relation to our study, the city of Rabat is characterized by significant urban sprawl along the Atlantic Ocean, which leads us to say that land use planning must take into account the risk of flooding and limit human activities in high-risk areas.

4.4.3 Transport issues

Moreover, urban transport is a major problem in many major cities in Morocco, and the city of Rabat is no exception. Of which, the main transport difficulties in the city of Rabat include traffic jams, a lack of efficient transport infrastructure, high public transport costs, and air pollution. The public transport network in Rabat consists mainly of buses operated by the Rabat Public Transport Company (STRS). However, buses are often overcrowded, and their schedules can be unpredictable, making it difficult for locals to plan their trip.

In addition, the high cost of public transport in Rabat makes it difficult for many residents to travel regularly, especially for low-income families. As a result, many Rabat residents use private cars to get around, exacerbating the city's congestion and air pollution problems.

To address these issues, Rabat authorities have undertaken several initiatives, including the construction of tram lines and the expansion of the bus network. However, these projects faced delays and funding difficulties, which slowed down their implementation. Ultimately, solving Rabat's transportation problems requires a comprehensive approach that includes initiatives to reduce congestion, improve public transport infrastructure, and encourage the use of more sustainable modes of transport such as cycling and walking.

5 Conclusion

The future development of the city of Rabat is an ongoing process. Public policies, urban planning, renewal, and mobility are key elements that shape the evolution of the city. By working together, the people of Rabat can create a more vibrant and sustainable city for future generations.

The use of GIS, remote sensing, and artificial intelligence algorithms can help better understand and manage urban sprawl. By combining these technologies, it is possible to collect accurate data on land use, soil characteristics, and urban growth patterns. AI algorithms can then be used to analyze this data and provide forecasts and recommendations for more efficient urban planning. This can help reduce the negative impacts of urban sprawl, such as natural habitat loss and traffic congestion, while promoting sustainable and balanced urban development. However, it is important to note that the use of these technologies must be accompanied by appropriate urban planning and regulation to ensure their responsible and ethical use.

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