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Impact of Climate change on the Bouregreg Watershed Vegetation and Forest of Morocco

El Houssaine OUHARBA[1], Zine el Abidine TRIQUI [2] and Rachid MOUSSADEK [3]

[1]FSR, Mohammed V University -Rabat, Ibn Battouta Avenue, Rabat-Agdal, PO Box 1014 RP- Morocco.

[2] FSR, Mohammed V University -Rabat, Ibn Battouta Avenue, Rabat-Agdal, PO Box 1014 RP- Morocco.

[3]Scientific Division, Environment and Natural Resources Department (INRA), Avenue Hassan II, BP 415 – Rabat R.P - Morocco.

ABSTRACT

This study aims to describe the meteorological conditions of the Bouregreg watershed, in order to answer the problematic dealing with the effect of climatic fluctuations on the forest resources, and also to describe the meteorological conditions of the sites favorable to the development of the forests, in order to address the issue dealing with the effect of climate fluctuations and climate change on the forest in the Bouregreg watershed, using climatological characterization, remote sensing and modeling in the study area. The work done is likely to further contribute to forest research, planning and integrated natural resource management. The adoption of modeling could help alert and drought and quantify areas at risk of desertification and fire in advance by forest management. Assessing the potential impacts of climate change on the forest and assessing the vulnerability of this sector is essential.

The purpose of this work is to assess vulnerability in order to identify current impacts and threats and to identify strategies, policies and actions to address climate variability and change as well as to reduce the impacts and future vulnerability of these changes.

***Key Words:** Agro-climatology, Modeling, Vegetation- Forest, Climate, Watershed- Morocco.*

1. INTRODUCTION

The catchment area of Bouregreg is a rainfed agriculture area. This agricultural feature of the basin is part of the agricultural policy put in place after independence. Certain areas of Morocco have indeed benefited from the irrigation policy to the detriment of other areas, such as the one to which the Bouregreg watershed belongs. Although rainfed farming areas have not had significant investments in irrigation, they remain today the main agricultural producers in Morocco.

However, rainfall dynamics since the 1970s have made this rainfed agriculture more and more uncertain. Strategies are put in place by farmers to mitigate the effects of climate hazards. But these strategies often lead to degradations of vegetation and soils.

1.1 Goal of the study

Analyze the dynamics of plant productivity (natural vegetation and cultivated vegetation) in relation to climatic variations from 1980 to 2009 Biomass is influenced by two main factors: human activities and climate. The latter is at the origin of the geographical distribution of the plant species at the terrestrial surface. Plant phenology is thus correlated with seasonal and interannual variations in climate, in this case the rainfall and temperature variability of terrestrial areas (Lambin, 1996). It is through this specific objective to analyze the spatio-temporal variations of the vegetation of the basin, according to the biogeographic sets, and this in relation to the rainfall variability. -Analyze the impact of agro-pastoral activities on the degradation of vegetation and soils The Bouregreg catchment area is characterized by predominantly rain-fed agriculture dominated by cereals. This agriculture is strongly correlated with the seasonal distribution of rainfall. This dependence on precipitation has been a problem since the 1970s and 1980s when the growing seasons are subject to climatic hazards, in this case frequent agricultural droughts. [1] et[13]

2. OBJECTIVE AIMS TO STUDY

.• On the one hand the risks of future degradation of the physical environment related to the climate and to the current pressures on the agricultural and pastoral spaces;

• On the other hand, it is a question of using different reduced climate models on the Bouregreg watershed to analyze the future climate scenarios and their potential impacts on the agricultural level [1] et [7].

2. METHODOLOGY

From the perspective of global analysis and analysis of details (localized analyzes), the main methodological tools used were remote sensing, statistics and GIS. Thus, on a global scale were used images of NOAA and MODIS (NDVI and surface temperature) for understanding the evolution of vegetation from 1980 to 2009. At the local level, agricultural and population statistics as well as the exploitation of LANDSAT and SPOT 5 images have made it possible to understand the correlation between the evolution of vegetation, climate dynamics and anthropogenic pressures.[10], [11] et [13]

2.1. Study zone

The Bouregreg catchment is located in the north-west center of Morocco. It belongs to the favorable rain-fed agro-ecological zone of the Kingdom. 78% of the Moroccan territory is made up of arid and Saharan zones, and only 15% of the country presents semi-arid features **(Figure n° 1).** This bioclimatic spatial distribution forms the basis of all the issues related to the agro-sylvo-pastoral dynamics of the country. [3]

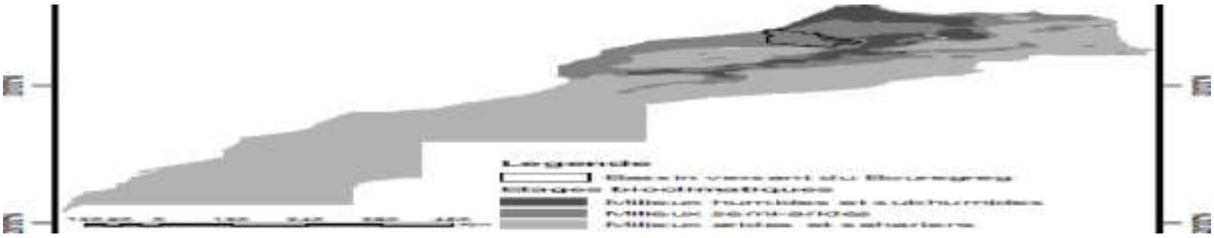

Figure 1: Location of the Bouregreg watershed.

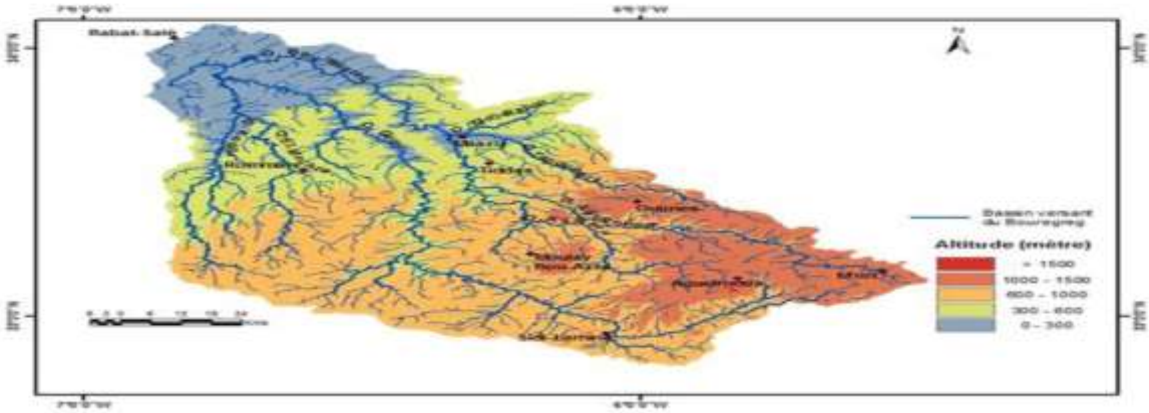

Figure 2: Hypsometric map of the Bouregreg watershed.

2.2. Data used

2.2.1. Vegetation

Identification and description of the main occupations

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Figure 3: Agropastoral and Land Degradation (Shoul)

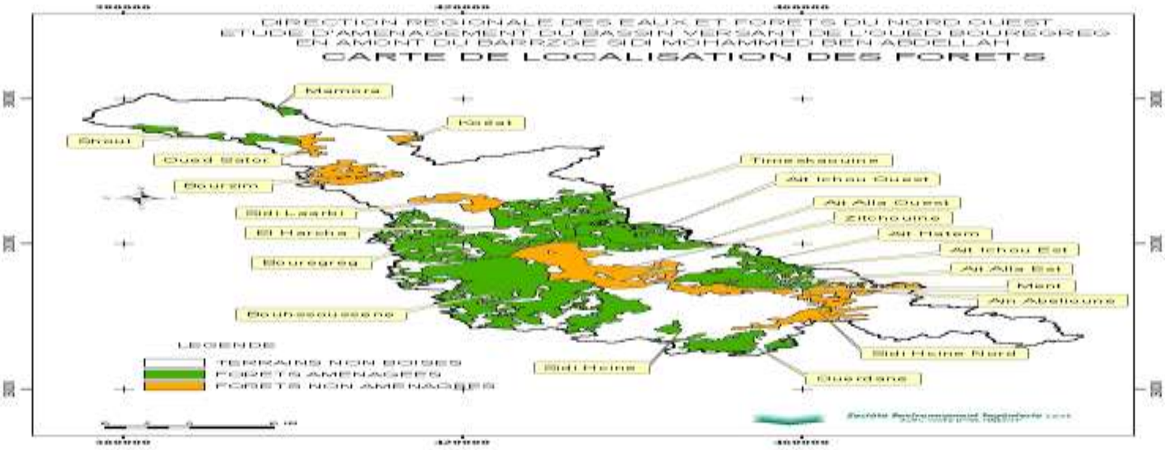

Figure 4: Location map of the Bouregreg watershed forests.

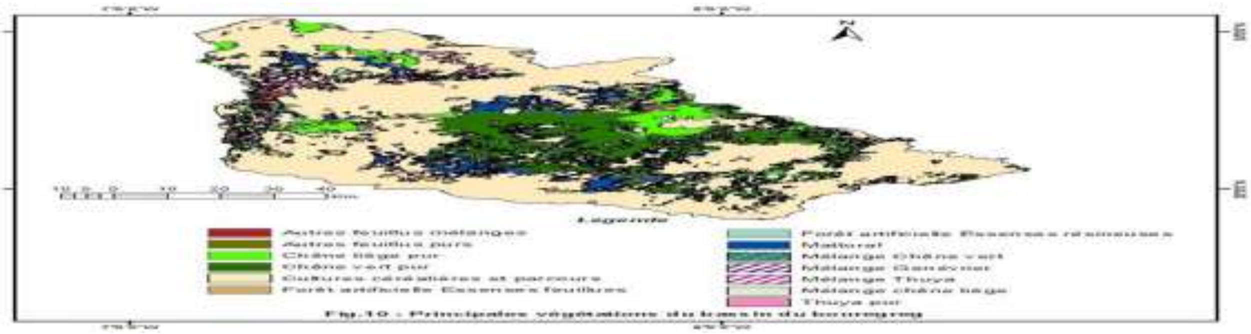

Figure 5: Main vegetations of the Bouregreg Basin (Source: CERGEO).

- The vegetation cover of the Bouregreg watershed (Berkat and Tazi, 2004, Ministry of Agriculture and Agrarian Reform, 1992).

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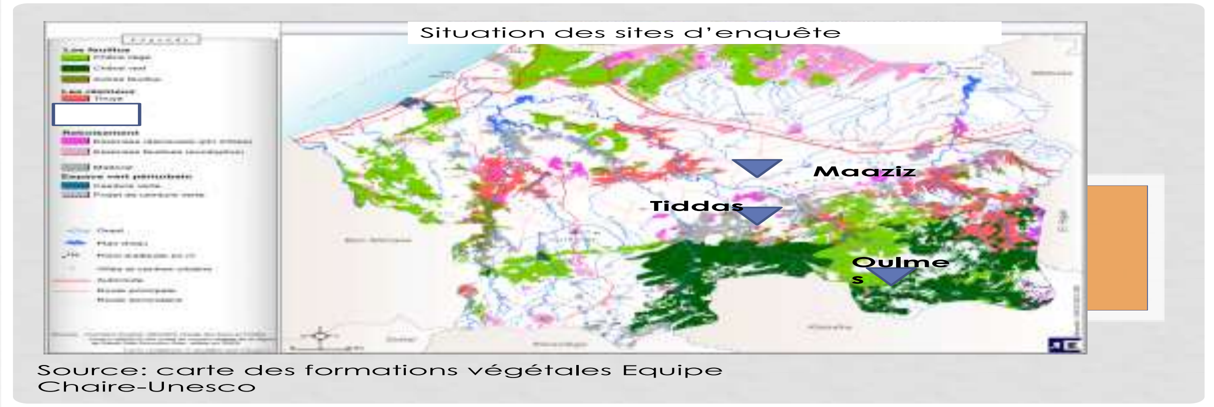

Figure 6: Vegetation formation of the Bouregreg basin (Source: Chair - Unesco)

Six main occupations are identified at the basin level:

Fields of crops
Arboriculture
Courses
Matorrals
Reforestation

Forest :

- **Oak cork**
- **Holm oak**
- **Thuja**
- **Juniper**

Figure 7: Intensive arboreal production farm located next to Tiddas

Figure 8: Matorral based on very degraded green oak used as rangeland (SBV3)

Matorrals : They represent small areas at the basin scale. They concern land covered by an association of secondary species, usually shrubs. This is a consequence of a state of very advanced degradation of the existing natural environment. Overgrazing and the action of man are the main factors of degradation of its environments. Matorrals cover an area of 13 972 ha.

Forests : The forest covers 147325 ha, or about 37% of the catchment area. Its description and characterization is based mainly on the composition and type of stands and the rate of soil cover by vegetation. The stratification criteria adopted and the name of the stratum in case of mixed stands are inspired by those used in forest management studies. However, the determination of the overall recovery rate takes into consideration all the species that make up the stratum. The main species identified are Cork Oak, Green Oak, Thuya, Juniper and other secondary species of varying economic, ecological and pastoral importance.[10] , [11]

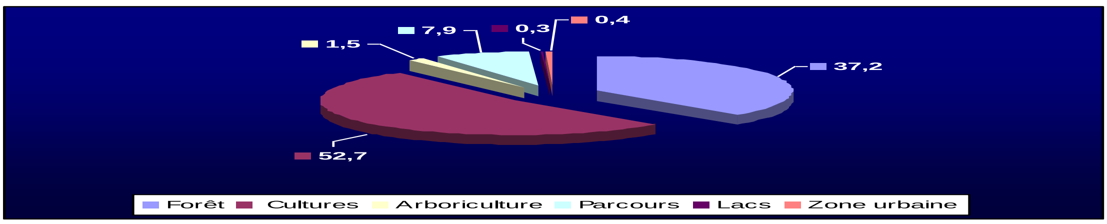

Figure 9: Importance and distribution of land use in the watershed

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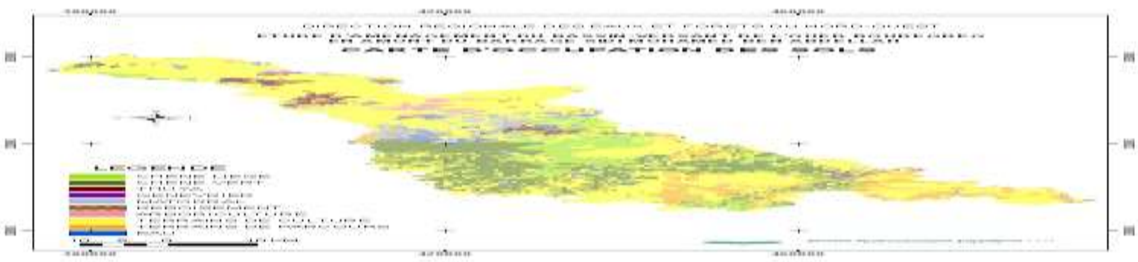

Figure 10: Map of land occupation

__Description of forest stands__

The study of natural vegetation has revealed the existence of a diversity of natural forest species in the watershed from the Littoral to the high altitudes of the Middle Atlas. The area of distribution of the species encountered responds to the combined influence of a multitude of ecological parameters and in particular climate, soil types, altitude and exposure. The coolness of the North and West exposures favors the installation and the development of a dense plant cover with a large undergrowth, whereas the slopes with South and East exposures generally carry a sparse cover. This variation of the microclimate as a function of exposure is governed by insolation, which leads to greater evapotranspiration on south and east facing slopes.

The main forest species found in the basin are in order of importance (capacity), holm oak, cork oak, cedar and juniper. The relative distribution of this area by species is given by (**Figure 11**). [13]

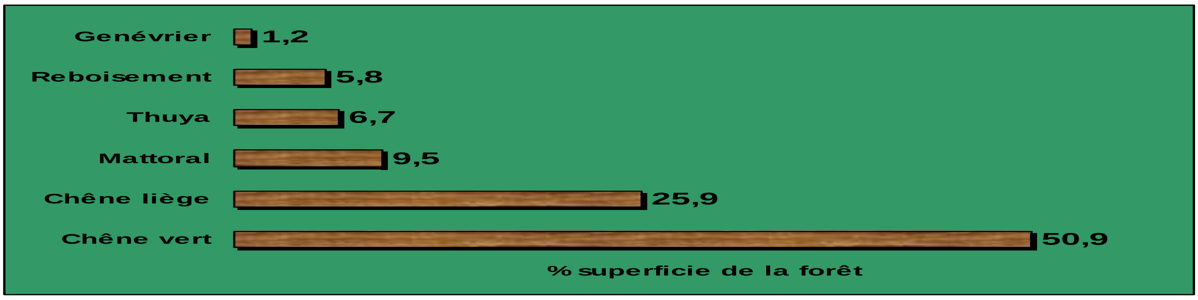

Figure 11: Importance and distribution of forest stands in the basin.

Figure 12: El Harcha cork oak forest with very dense cover (Oulmes)

Thuya de Berbérie, a thermophilic species, is found in the hottest and most degraded areas of the basin. It is usually in a state of unsatisfactory development. It occupies an approximate area of 9,907 ha.

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Figure 13: Thuya degraded population in the Shoul region (SBV5)

2.2.2. Climatology

2.2.2.1. Temperatures

2.2.2.1.1. Monthly Temperatures

Thermal factors combined with precipitation influence the growth of plant species. It is useful to consider the extremes of temperature that condition the development of plants. In general, the average temperature oscillates between 15 and 18 ° C for stations.

However the average minimum reached 3.2 ° C in Oulmes, Sidi Ahsine and Moulay Bouazza and less than 2 ° C in Khénifra for the coldest month. It is 4.5 ° C at Tiddas.
The highest values of the hottest months are recorded in June, July and August and reach between 30 and 40 ° C.
Based on the values of the aforementioned indicators, it appears that the thermal regime at the watershed level is mainly characterized by a semi continental climate of moderate type .[3] et [4]

2.2.2.2. Rainfall

Precipitation at the watershed level is subject to three main influences: latitude at the country level, distance from the sea, and altitude. The latter is the determining factor in observing differences in water heights received. [1]

2.2.2.2.1. Annual precipitation

Annual average rainfall data are often indicative. Indeed they allow to characterize the climate as a whole (rainy year or drought ...). The analysis shows that the average annual rainfall at the watershed level is generally between 400 mm and 800 mm / year. They are very variable from one area to another. Thus, average annual precipitation is 387 mm / year in Sidi Amar and reaches 773 mm / year at Oulmes and 797 mm / year at El Harcha which is located at 890 m altitude. The map of isohyets elaborated in the framework of the study carried out by the RFRE in 2000, represented by the **(Figure n°14),** illustrates this spatial distribution at the scale of the basin. However, the areas considered as watered in the basin are El Harcha, Oulmes, Moulay Bouazza, Mâaziz, Dar Lâaroussi, Bir Ameur, Tifoughaline, Timeskaouine and Sidi Ahssine where average rainfall annual exceeds 500 mm / year. Areas of low rainfall are represented by, Ain Harrak, Ain Harcha, Lalla Chafia and Sidi Amar where the average annual rainfall is less than 400 mm / year. The origin of this difference observed in the average annual rainfall between the zones is due mainly to the altitude. [1], [3], [4] et [5]

2.2.2.2.2. Monthly average rainfall

The majority of the stations, the precipitation is more concentrated in period going from December to the end of May with maximum recorded in the month of December. Indeed, the months of December to February record a monthly average precipitation ranging from 71 to 79 mm, against 30 to 60 mm for the months of March to May. June, July, August and September are the months that correspond to low rainfall that does not exceed 14 mm / month.

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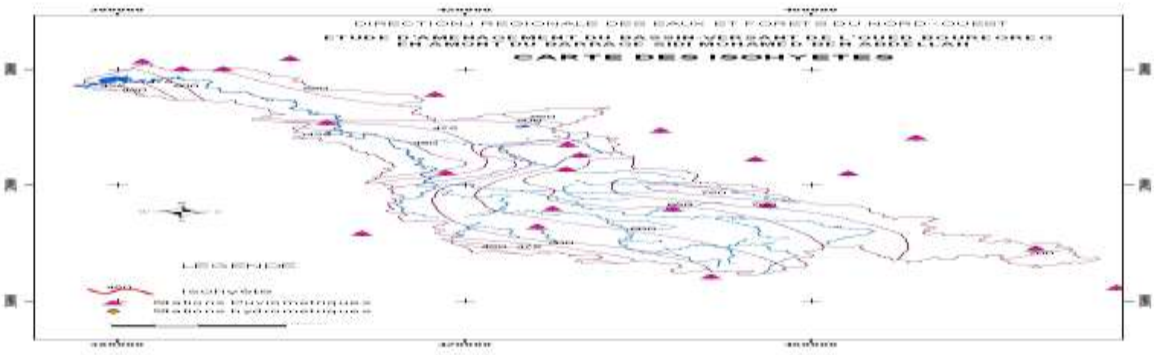

Figure 14: Map of Isohyets

Maximum mean rainfall is characterized by a main peak in winter and a secondary peak in spring. Thus, for the winter period, it reaches between 226 to 233 mm / month. It varies between 110 to 175 mm / month for the spring season. The minimum average rainfall shows that the period from June to September can be considered as a period where the risk of rainfall deficit is more pronounced. Ain Labiod, Tsalat, Aguibat Ezziar, Tamedrouss and Sidi Amar are the regions with a higher rainfall deficit where the minimum rainfall is less than 5 mm / year. The discrepancy or amplitude found between the minimum and maximum precipitation of the same month is illustrated by **(Figure 15**). The latter shows that this difference records the most important values during the rainy season and in particular the month of December. This difference is around 200 mm / month. Summer remains the season in which these differences are relatively small and approach a variable average amplitude of 20 to 40 mm / month. [3] et [9]

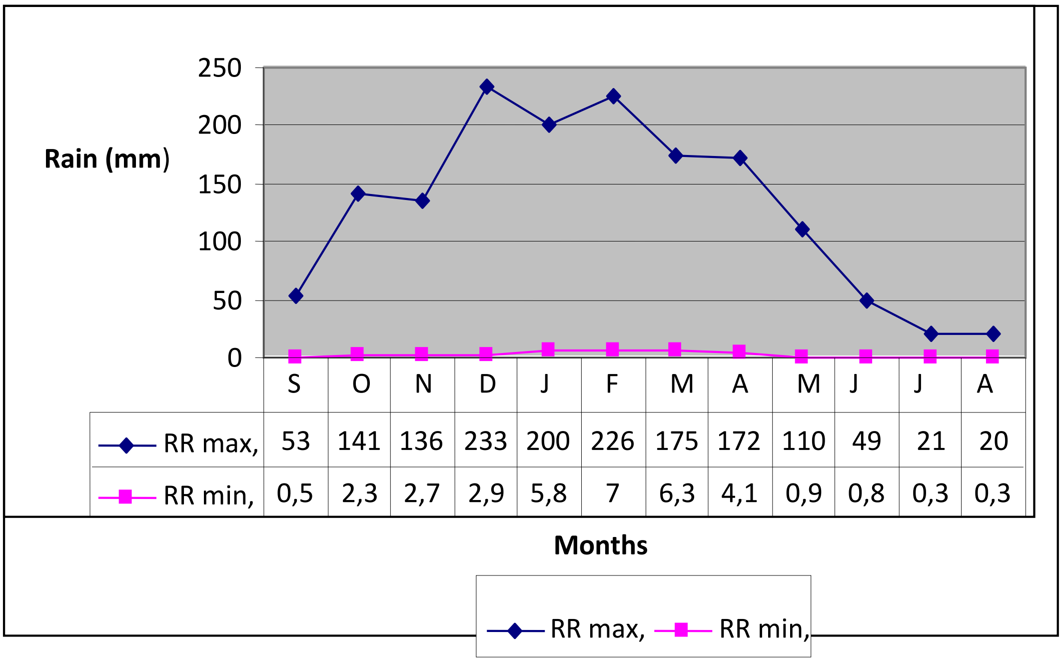

Figure 15: Graphical representation of average monthly precipitation.

2.2.2.3. Bioclimatic synthesis

2.2.2.3.1. Pluviothermic Quotient of Emberger.Q2

The Emberger quotient makes it possible to characterize the Mediterranean climate from the ecological point of view (Sauvage C.H., 1963). This quotient is defined as follows:

Q2 = 1000P/ ((M+m)*(M-m)/2)

P : Monthly average precipitations (mm)

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M : Average daily maxima of the hottest month (Kelvin degree)

M (°K) = t°C + 272,6

m : Average of the daily minimums of the coldest month (kelvin degree)

m (°K) = t°C + 272,6

This quotient makes it possible to distinguish a variety of bioclimatic stages prevailing at the watershed level. These bioclimatic stages range from semi-arid to subhumid with cool to hot variants. The main bioclimates encountered in the basin are described in **(Table n°1).**

Table 1 : Bioclimate of the catchment area.

Station	**Max (°C)**	**min (°C)**	**Q2**	**Bioclimate**
Rabat	28.4	8.1	83.99	Hot subhumid.
Roummani	36.0	4.0	37.82	Semi arid temperate
Oulmès	33.8	3.2	69.49	Subhumid temperate
Khénifra	40.3	1.2	55.0	Semi arid fresh
Tiflet	35.8	5.6	56.4	Semi arid temperate
My Bouazza	33.7	3.2	67.5	Subhumid temperate
Sidi Ahsine	35	3.2	79.6	Subhumid temperate
Tiddas	35.1	4.5	53.4	Semi arid temperate
Khémisset	36	5	62,0	Subhumid temperate
Timeksaouine	34	4	64.2	Subhumid temperate

Source : CNRF, Rabat and study documents.

2.2.2.3.2. Ombrothermic Diagram

According to the Bagnouls and Gaussen ombrothermic diagrams of the stations for which data are available, it turns out that the dry period corresponds to the months of June to September for all stations as shown in (**Figure 16 and Figure 17).**

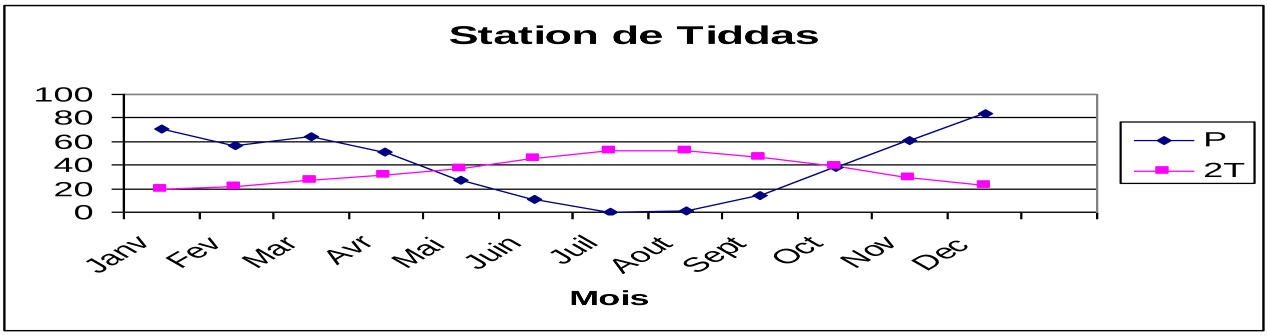

Figure 16: Ombrothermic curve of the Tiddas station.

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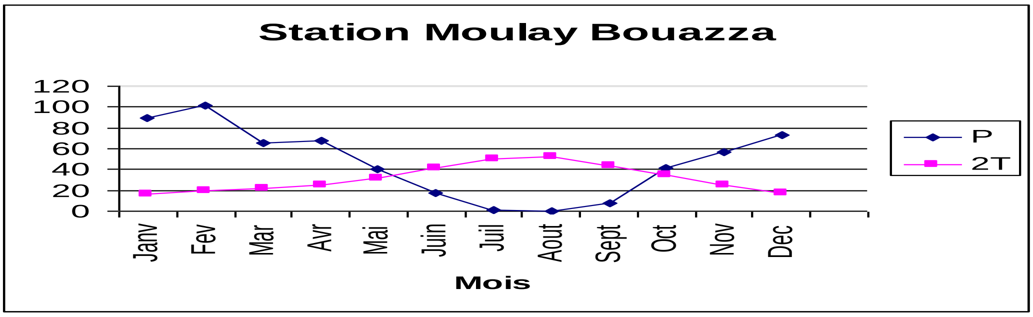

Figure 17: Ombrothermic curve of the Moulay Bouazza station.

2.2.3. Soil Resources

2.2.3.1. Description of the main soil types

The soils encountered and their distribution in the watershed are summarized in the soil type map. Then single units and two complex units (CI and C2) have been identified.

-Ground Mineral Soils; -Sol low Evolute; -Vertisols; - Calcimagnetic soils; - Isohumic soils
-Brown ground; -Serquioxide Iron Soils; - Hydromorphic soils; -Sodium sols;
-Units complex.

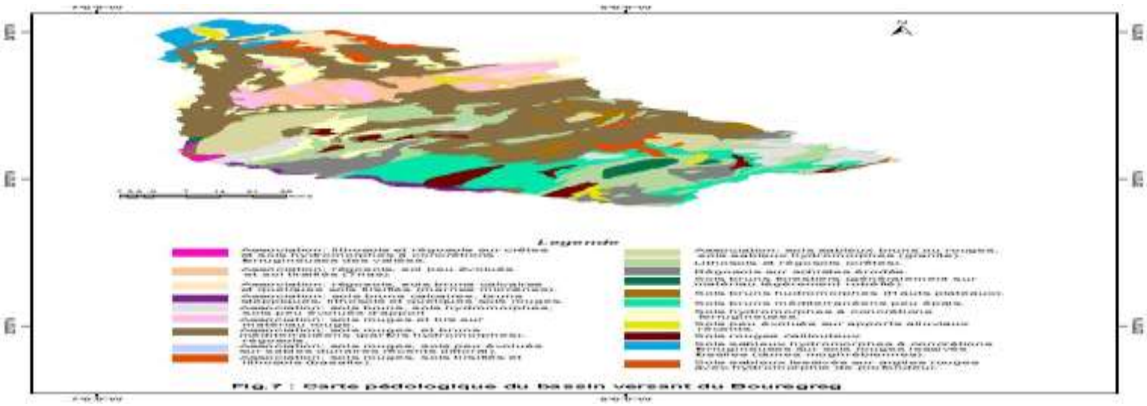

Figure 18: Soil map of the Bouregreg catchment area.

The soil and climatic conditions of the Bouregreg basin form predominantly sclerophyllous vegetation. The downstream basin is marked by the existence of forests dominated by Quercus suber (cork oak) east of Rabat-
Sale. In the form of fairly light forest or coppice on stump, these plant formations stand on sand more or less deep, crossed by valleys cultivated and interrupted on varying surfaces by islands of reforestation with Eucalyptus spp. Acacia cyanophylla and Pinusspp. The shrubby vegetation (shrub layer and herbaceous layer) is a mosaic governed by the increasingly humid bioclimatic gradient towards the East and by the depth of the clay-based sandy horizon, and by the density of the shading created by the cork oak itself. The perennial herbaceous layer is scarce because of strong grazing pressure. The islets of cork oak and matorrals. [3] et [10]

2.2.4. Upstream :

Figure 19: View of Jbel Mzourgane from the highest point of the basin.

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Figure 20: M'Rirt plateau cultivation fields associated with rangeland in zones rugged.

-Tarhat (Khenifra region)

Coordinates géographiques : Latitude : 32,99 N
Longitude : -5,643 W
Altitude : 1036 m.

2.2.4.1. Temperatures

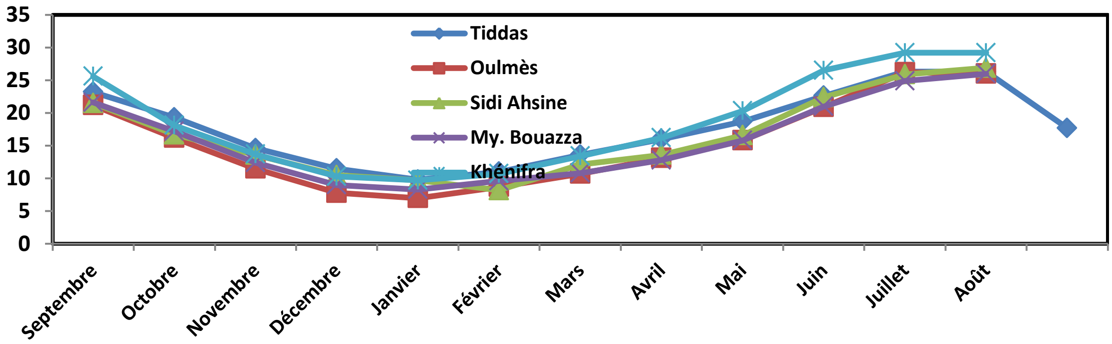

Figure 21: Monthly average temperatures upstream of the Bouregreg watershed.

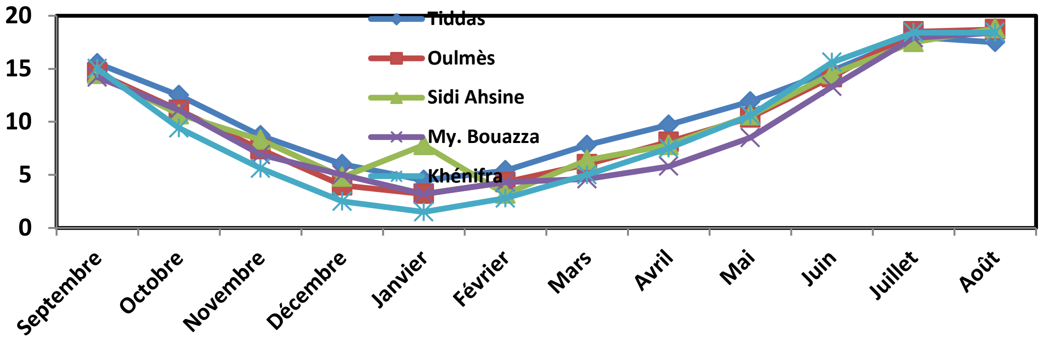

Figure 22: Monthly minimum temperatures upstream of the Bouregreg watershed.

However the average minimum reached 3.2 ° C in Oulmes, Sidi Ahsine and Moulay Bouazza and less than 2 ° C in Khénifra for the coldest month. It is 4.5 ° C in Tiddas.

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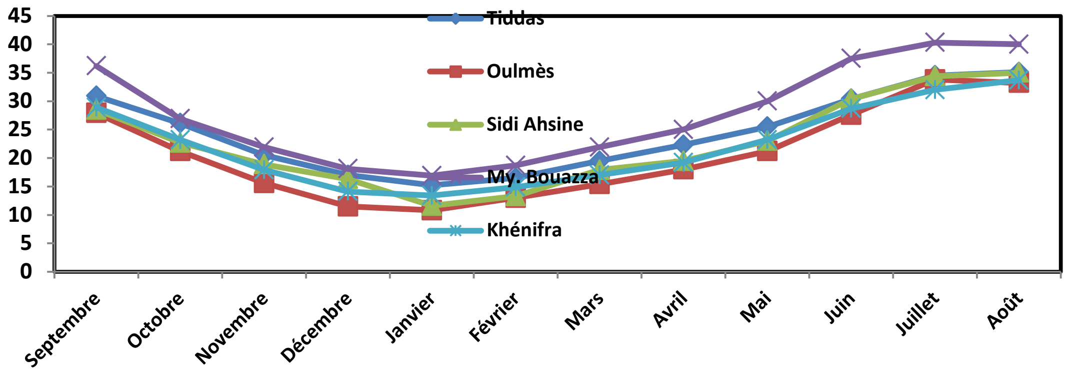

Figure 23: Maximum monthly temperatures upstream of the Bouregreg watershed.

The highest values of the hottest months are recorded in June, July and August and reach between 30 and 40 °C. [3] and [9]

2.2.4.2. Rains

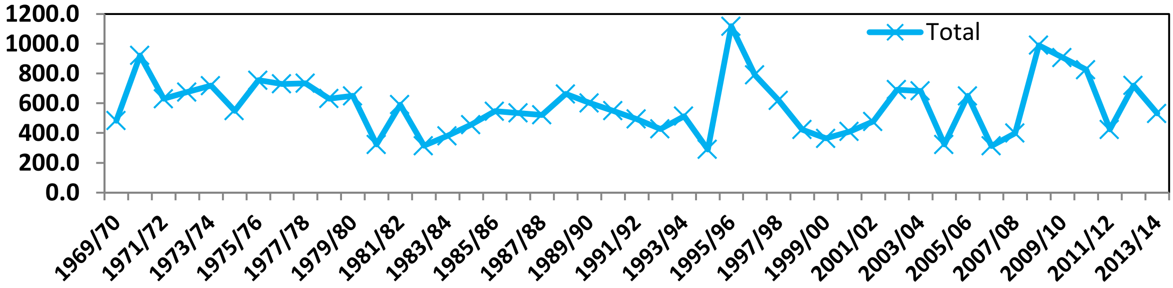

Figure 24: Cumulative annual rainfall of Khenifra for the period (1969-70 to 2013-14).

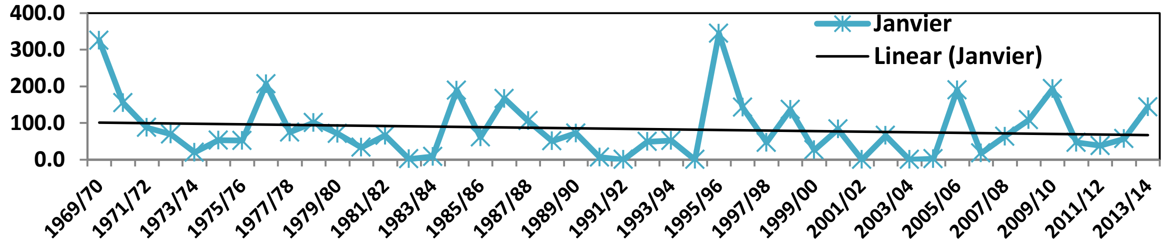

Figure 25: Rain of the month of January from Khenifra for the period (1969-70 to 2013-14).

Figure 2: Overview of the topography and landscape of the Middle Bouregreg.

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2.2.5. Basin Center

2.2.5.1. Rains

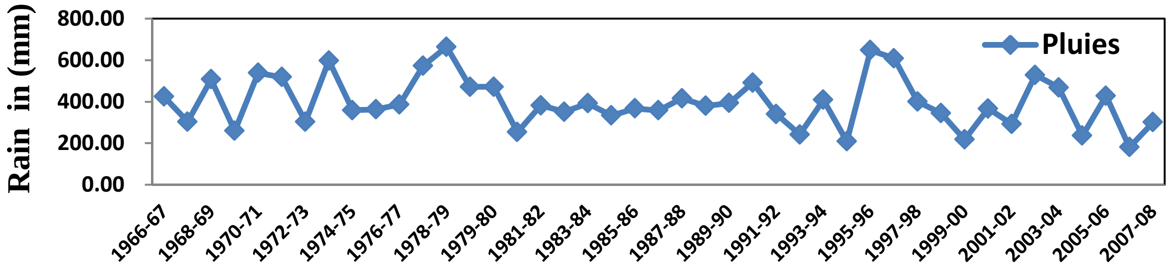

Figure 27: Rainfall evolution at Marchouch (INRA), from the period (1966 - 67 to 2007 - 2008)

2.2.5.2. Temperatures

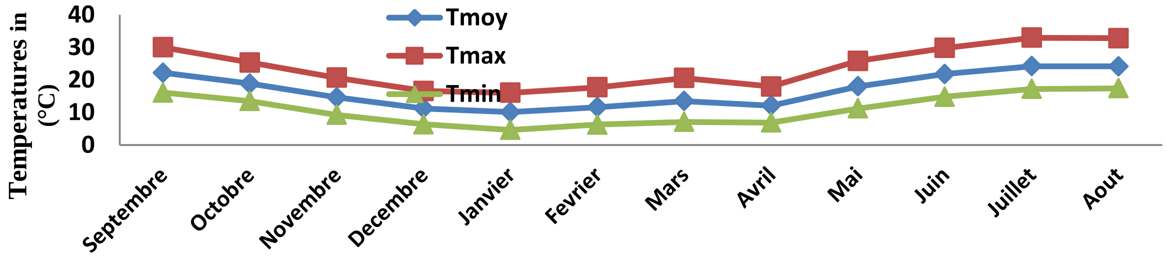

Figure 28: Evolution of Average Monthly Temperatures (Tmoy, Tmax and Tmin) Period (2003 to 2008), Marchouch (INRA).

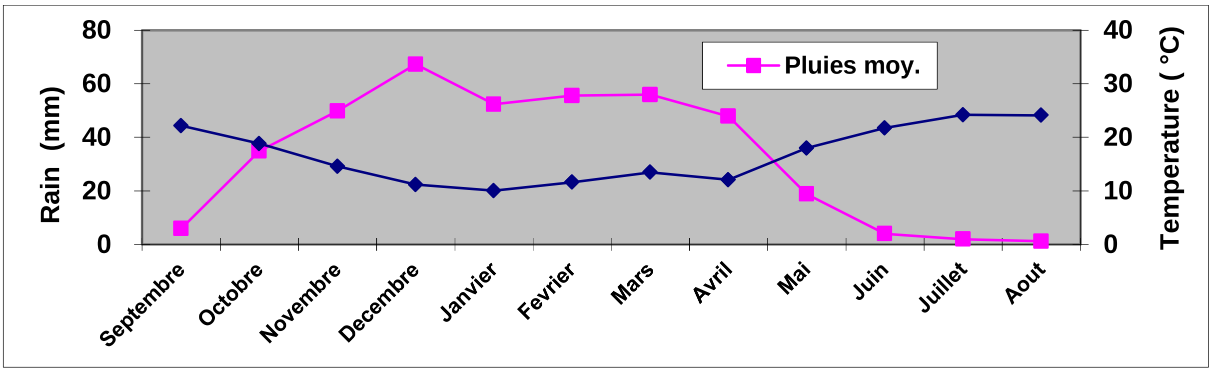

Figure 29: Ombrothermic diagram of the Marchouch Experimental Domain (INRA).

2.2.6. Downstream of the basin:

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Figure 30: Part of the reservoir of the SMBA dam where the Bouregreg Oued directly flows.

Rabat-Sale and Shouls (Sale region)

Coordinates : Latitude : 34°03'00 N
Longitude : 06°45'00 W

Altitude : 74.715 M

Figure 31: Thuya degraded stand in the Shoul region (SBV).

Table 2 : Climatic classification according to the Emerson Martonne and Quotient index in Rabat-Sale

Martonne Index 1961-2012	Quotient of Emberger 1961-2012
19.8 (Boundary between semi arid and subhumid)	94 (Subhumid)

2.2.6.1. Rains

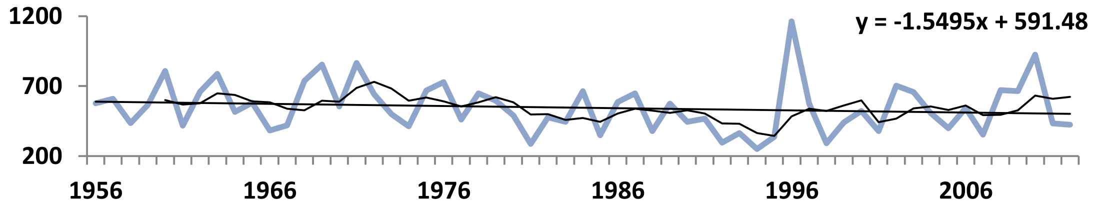

Figure 32: Evolution of annual cumulative precipitation during the period (1956- 2012) (Rabat-Sale).

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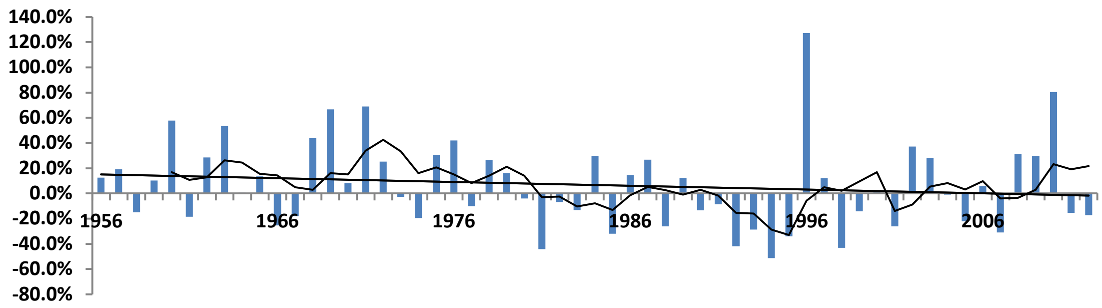

Figure 33: Difference from annual rainfall to normal

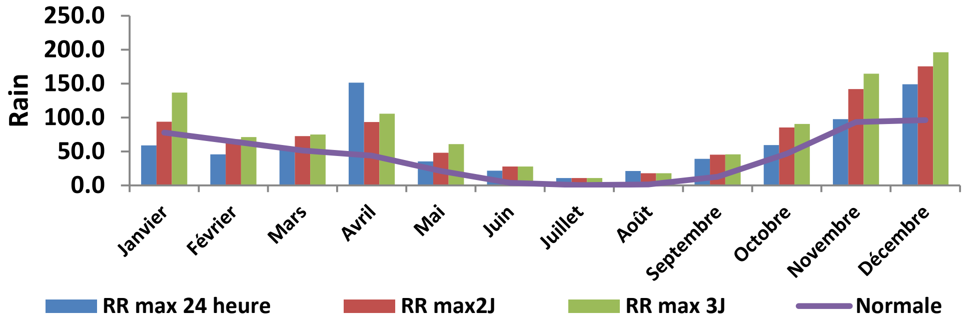

Figure 34: maximum rainfall collected in one day, two and three days.

2.2.6.2.Temperatures

2.2.6.2.1. Mean temperature

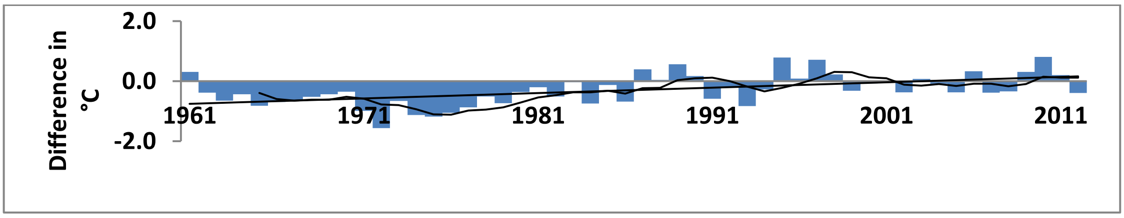

Figure 35: Evolution of the difference between the average annual temperature and normal (1961-2012) (Rabat-Sale)

2.2.6.2.2. Minimum temperatures

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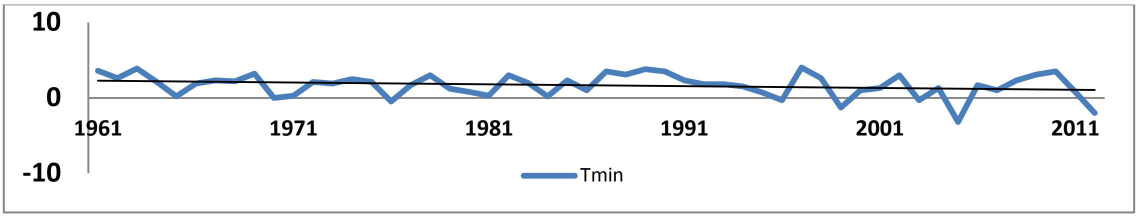

Figure 36: Evolution of minimum annual temperatures (1961-2012) (Rabat-Sale)

2.2.6.2.3. Maximum temperatures

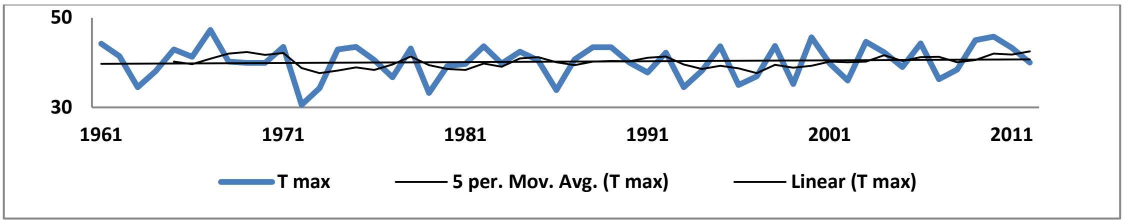

Figure 37: Evolution of maximum annual temperatures (1961-2012) (Rabat-Sale)

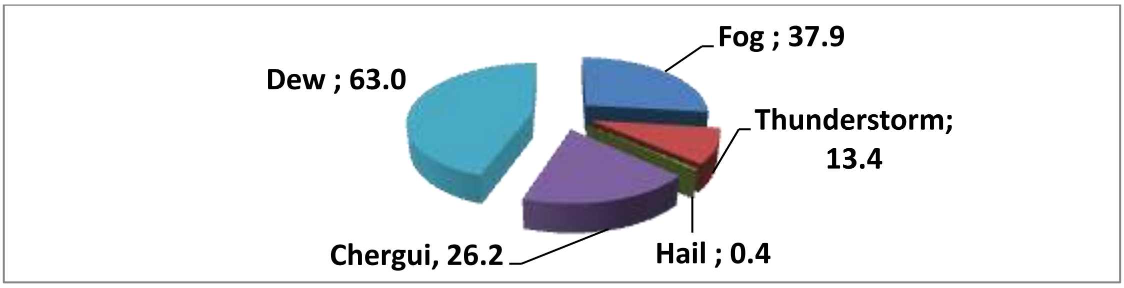

Figure 38: Annual number of days of the most important weather events from the region of Rabat.

[3], [5], [8] et [9].

2.2.7. Modeling

2.2.7.1. Model Data MCG

2.2.7.1.1. HadCM3 Model (SRES scenarios)

The **HadCM3** model (Hadley Center Model 3, British Meteorological Service) from *www.worldclim.org/futurdown.htm* and extract them by ArcGis software for visualization and display, then compare them with the current monthly climate data of the year (2007-2008) for the Marchouch experimental site, INRA.

- **(SRES) Scenarios.** [7]

Scenario B2 :

This is an optimistic scenario that describes a world where the focus is placed on local solutions, in a sense of economic, social and environmental viability.

The world's population is growing steadily but at a slower pace than in A2. There are intermediate levels of economic development and Technological evolution is slower and more diverse. In our research, we have opted for scenarios A2 and B2, these two scenarios are the closest to the trajectory of the evolution of Moroccan society and the changes associated with the indicators. climatic conditions (Gommes et al., 2008). They are widely used at present in the modeling work carried out with the most complete coupled models. [7]

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2.2.7.1.2. CNRM-CM5 Model (RCPs scenarios)-CNRM-CM5 Model

The new version of the CNRM-CM global circulation model was developed by CNRM-GAME (National Center for Meteorological Research-Group of Meteorological Atmosphere Studies) and Cerfacs (European Center for Research and Advanced Training) in order to contribute to phase 5 of the inter-comparison project of the Coupled Model (CMIP5). The study's proposal is to describe its characteristics a preliminary assessment of the average climate demand. CNRM-CM5.1 included the ARPEGE-climate atmospheric model (v5.2), the NEMO Ocean model (v3.2), the ISBA schematic land surface and the GELATO (v5) sea ice model coupled across the OASIS system (v3).

RCPs Scenarios [15]

In preparation for the IPCC's 5th Assessment Report, an international panel of experts has identified four baseline scenarios, referred to as representative trends in concentrations (RCP, for *Representative Concentration Pathways)* of greenhouse gases (GHGs), ozone and aerosol precursors for the 21st century and beyond. These scenarios may correspond to greater or lesser efforts to reduce GHG emissions globally. For each of these four "representative profiles", climatologists deduce the associated climatic conditions and climate change impacts. In parallel, sociologists and economists are working on scenarios with various characteristics of socio-economic developments and various adaptation and mitigation strategies. Five scenario families, named (***Shared Socioeconomic Pathways) (SSP),*** have been defined. Such an approach allows a parallel and coherent work of climatologists and economists. The IPCC has decided to define new scenarios to take better account of this new context and to allow economists and climatologists not to work in a sequential but parallel way. Finally, unlike the SRES scenarios, these new scenarios are not defined by the IPCC itself, but have been established by the scientific community to meet the needs of the IPCC. The approach followed for the definition of scenarios for the 5th report therefore proceeds of a different nature to the previous one. Beyond the conception of new scenarios, it is a real methodological turn that the community operates scientist. Previously, the analysis was conducted following a sequential logic. The reflection was based on a bundle of "possible futures" for our societies, integrating a wide range of determinants - the evolution of national economies, the technological offer, the energy choices, the demography, the behaviors individual, etc. To gain speed and responsiveness, the scientific community now applies a different method. Scientists have defined representative profiles of gas concentration evolution greenhouse gases, ozone and aerosol precursors representative of an increase in the energy balance: the RCPs (*Representative Concentration Pathways)*. From these reference profiles, teams work

Simultaneously and in parallel: climatologists produce climate projections using RCPs as input, while sociologists and economists develop scenarios leading, at the exit, to greenhouse gas emissions consistent with the RCPs. [15]

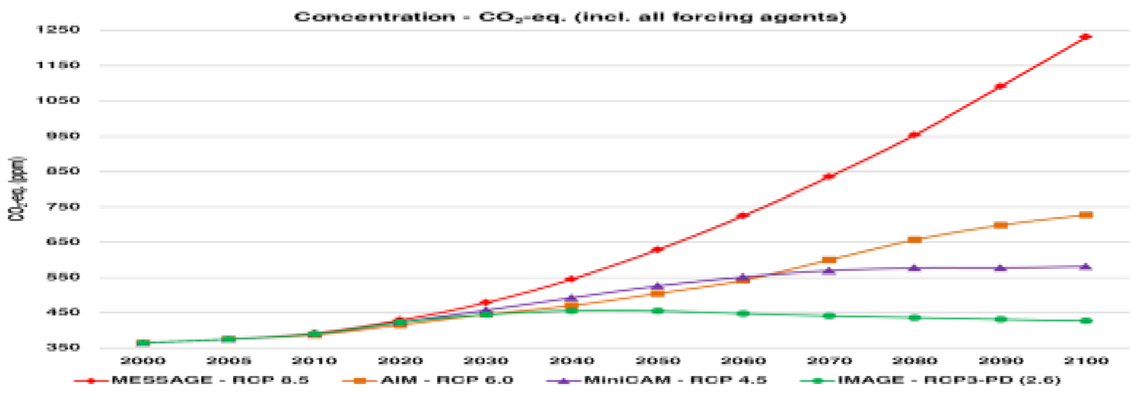

Figure 39 : CO2 concentration with all forcing agents.

The RCPs profiles are described until 2300, whereas the SRES scenarios of previous IPCC work stopped in 2100.

2.2.7.1.2.1. Statistical Analysis of Precipitation and Temperatures Maximum and minimum

2.2.7.1.2.2. Downscaling

For simulations at a regional level, a "downscaling" method (Figure 49) is used, using the development of regional models, with resolutions ranging from 10 to 50 km, which take finer account of the topography. These models are themselves relayed by local impact or adaptation models, with a horizontal resolution of the order of one kilometer. [5] ,[14] and [15]

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3. RESULTS AND DISCUSSION

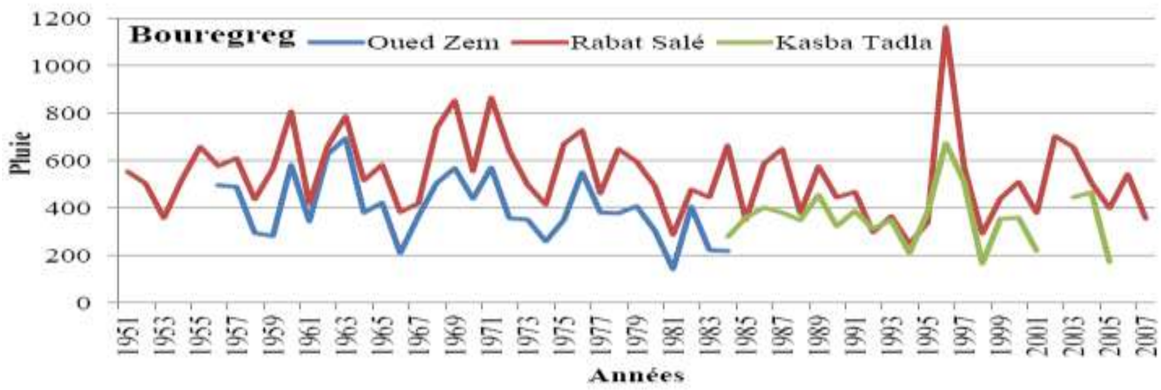

Figure 40: Evolution of Pluviometric Series in the Basin of Bouregreg (in mm).

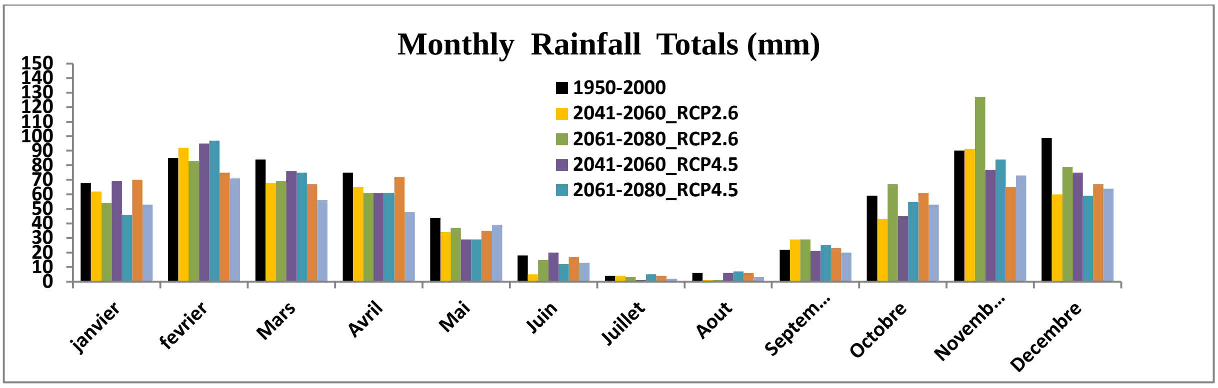

Figure 41: Monthly rains of Tarhat (Khenifra region) for the past period (1950-2000) and The Future Periods (2041-2060) and (2061-2080) for the RCPs (2.6, 4.5 and 8.5).

We note that :

Trend for decreasing rainfall during the winter season (Dec-Janv) for the RCP2.6 scenario, while for the RCP4.5 and RCP8.5 scenarios there is a decrease for December and no significant change for January. Decrease of the rains during the spring season (March-April-May) and the beginning of the winter season for the three scenarios with the exception of November for the RCP2.6 scenario where there is a clear increase in average rainfall over the period 2061-2080.

The two months November and February are the most humid compared to the reference period, the scenarios RCP2.6 and RCP4.5 provides for the conservation of this property with the exception of the RCP8.5 scenario.

The RCP8.5 scenario predicts a decrease in precipitation during the months of November to March with the exception of January. It can also be seen that the average rainfall for the RCP4.5 scenario remains almost stationary during the two projection periods 2041-2060 and 2061-2080 during the end of the wet season. This can be interpreted to mean that the RCP4.5 scenario predicts a stabilization of the CO2 concentration from the year 2050 **(Figure 39).** almost stationary during the two projection periods 2041-2060 and 2061-2080 and this, during the end of the wet season. It can be seen that there is little variability in the monthly rainfall totals for the wet season (October-April). For the future periods (2041-2060 and 2061-2080) for the RCPs (2.6, 4.5 and 8.5) compared to the period basic (1950-2000). But, the graph illustrates a cumulative rainfall higher than the future for the wettest months of the region (November and February) compared to the past period. And also, a decrease in the cumulative rainfall per month for the critical months of growth of cereals from the region (February-May).

The correlation of rainfall between 2050 and the past (1950-2000) is **93.15%** and the mean difference is **-8.33**, the correlation between 2070 and the past is **91.27%** and the mean difference is **-2.42**, and the correlation between 2050-2070) is **93.01%** and the average difference is **5.92. (Figure n °41)**

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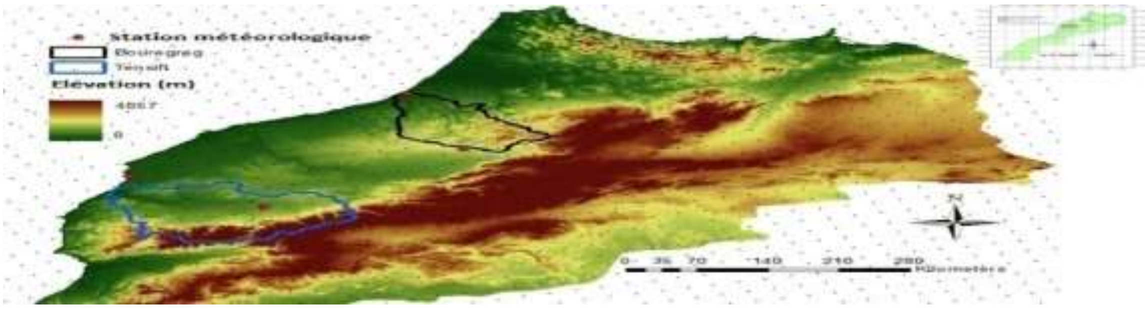

Figure 42: Grid of regional climate models (Black dots).

Figure 43: Rainfall trend in the study area.

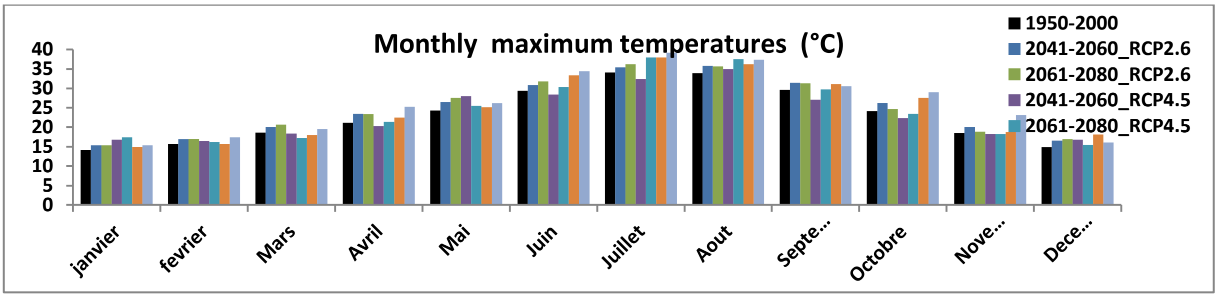

Figure 44: Maximum monthly Tarhat temperatures (Khenifra region) for the period past (1950-2000) and the future periods (2041-2060) and (2061-2080) for the RCPs (2.6, 4.5 et 8.5).

General trend towards higher maximum temperatures compared to the reference period. The rise is more marked during the summer season (June-August). The rise is less significant during the months of February,

November and December. The RCP4.5 scenario predicts lower maximum temperatures than those predicted by the RCP2.6 scenario during the beginning and end of the wet season. In most cases, the RCP8.5 scenario

predicts a very marked increase in maximum temperatures, especially during the projection period 2061-2080. The graph shows an increase in the maximum monthly temperatures for the periods (2041-2060 and 2061-2080) for the RCPs (2.6, 4.5 and 8.5) for the RCP 8.5 scenario compared to the reference (1950-2000). This will give the wet period (October-April) warmer. The correlation of maximum temperatures between 2050 and the past period (1950-2000) is 99.86% and the average difference is 23.36, the correlation between 2070 and the past is 99.46% and the average difference is 24.20, and the correlation between 2050-2070) is 23.19% and the average difference is 23.19 **(Figure 44).**

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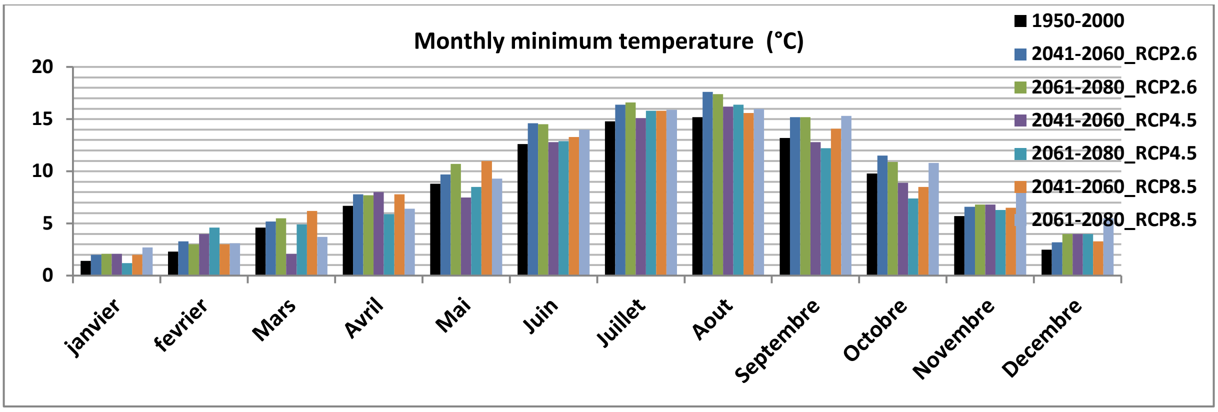

Figure 45 : Minimum monthly Tarhat temperatures (Khenifra region) for the period past (1950-2000) and future periods (2041-2060) and (2061-2080) for the RCPs (2.6, 4.5 and 8.5).

General trend of higher minimum temperatures compared to the reference period. The rise is more marked during the summer season (June-August). The rise is less significant during the months of January,

November. The RCP2.6 scenario predicts a more significant increase during May-October than the other scenarios. The RCP8.5 scenario predicts lower minimum temperatures during February-March-April. The RCP8.5 scenario predicts a more pronounced increase in minimum temperatures during September-January **(Figure n° 45),** above, gives us an increase in the Minimum Monthly Temperatures for the periods (2041-2060 and 2061-2080) of the RCPs (2.6 and 8.5) compared to the previous period (1950- 2000). This will make the wet period very hot. The correlation of minimum temperatures between 2050 and the past is 99.87% and the average difference is **8.36**, the correlation between 2070 and the past is **99.85%** and the average difference is **8.34**, and the correlation between (2050-2070) is **99.69%** and the average difference is **8.13**. According to the SRES (B2) and RCPs (2.6, 4.5 and 8.5) scenarios, the study area will become more arid in the future which will have effects

direct and negative effects on crops and especially cereal yields, and also on water resources. This is in line with the results obtained in the WB / FAO / INRA / DMN report prepared by the World Bank Morocco study (Gommes et al., 2009).

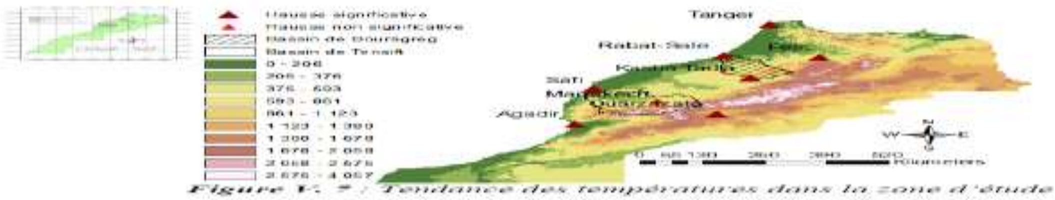

Figure 46: Temperature trend in the study area.

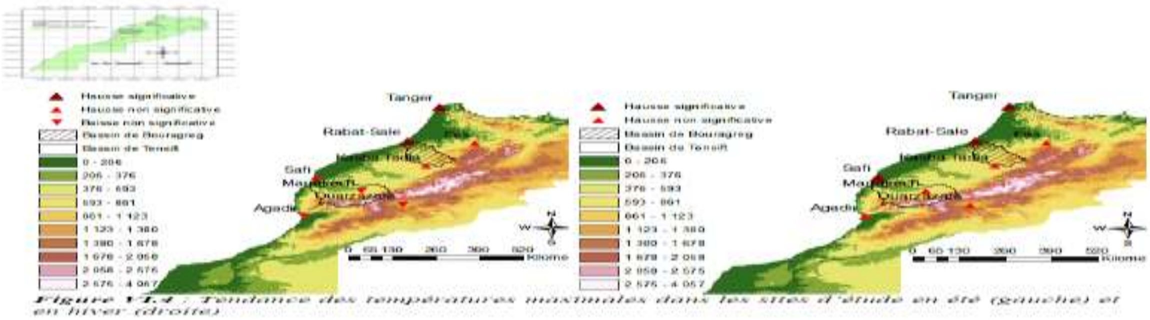

Figure 47: Trend of maximum temperatures in study sites in summer (left) and in winter (right).

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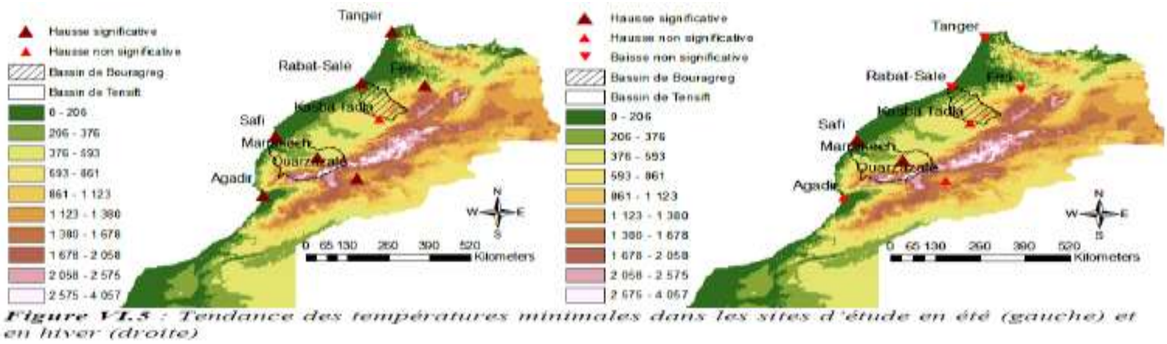

Figure 48 : Trend of minimum temperatures in study sites in summer (left) and winter (right)

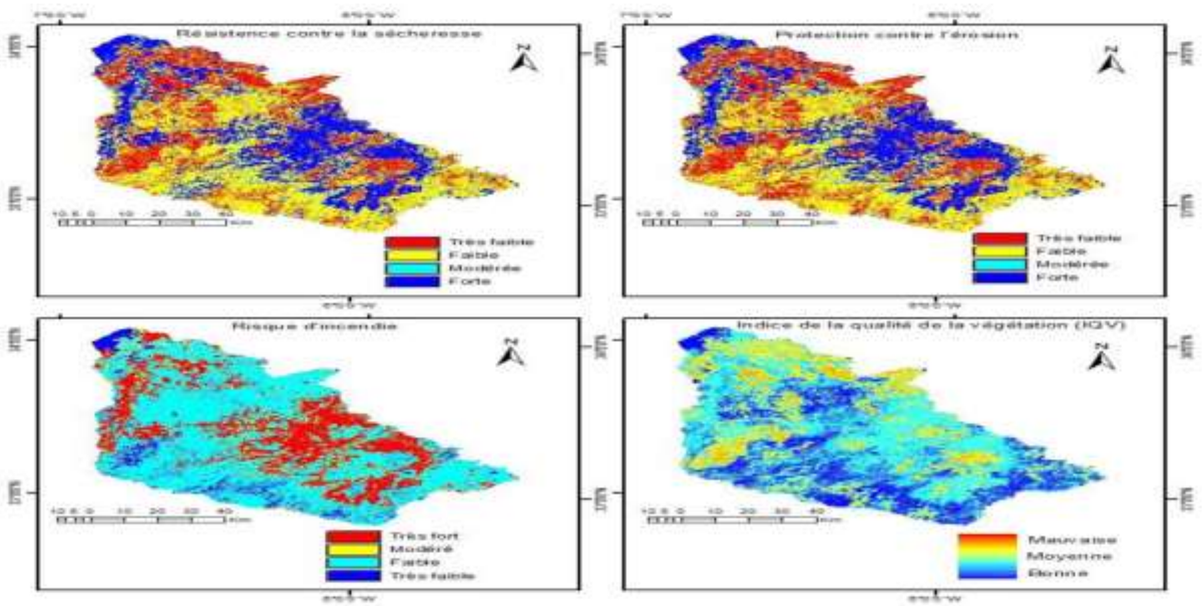

Figure 49: Characterization of the quality of the vegetation.

Critical areas in terms of degradation are 2% of the basin. Thus, more than a quarter of the basin is a fragile space in terms of agricultural and pastoral exploitation. The 1975 FAO survey on the state of the environment (REEM, 1999) already indicated that 54% of the Bouregreg-Chaouia basins should not be cultivated because of their fragility. At the spatial level **(Figure 50),** the areas where degradation represents a critical risk are located in the southern part of the basin (upstream).

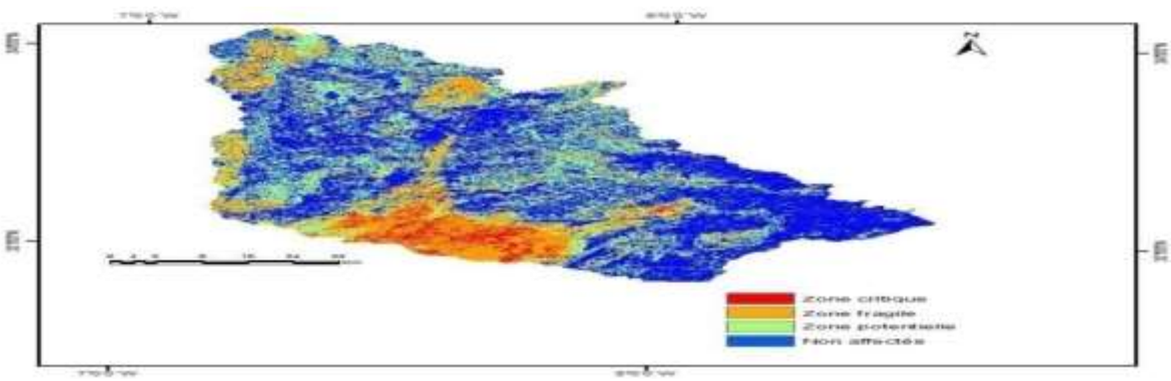

Figure 50 : Map of the risk of soil degradation in the Bouregreg watershed.

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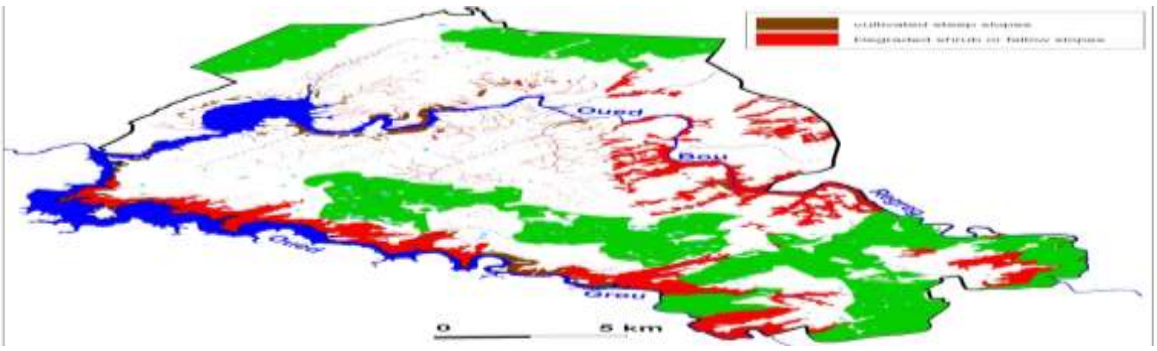

Figure 51: Dynamics of the courses (The 3 types of course : - Forests, -Matorral degraded, -Degraded and abandoned cultivated land.

-Analysis of basin climate change scenarios and potential impact on agriculture.

3.1. Regional climate models used: ALADIN, CRCM, RACMO.

Coupled Ocean-Atmosphere General Circulation Models (MCGOA or GCM) enable numerical modeling of the climate. These models have spatial resolutions of 200 to 300 km, which is not suitable for local studies of climate change and these impacts. To fill this state of affairs, GCMs are reduced by two main techniques: [5], [8], [11], [14] and [15]

- Dynamic reduction methods and reduction methods statistical scale

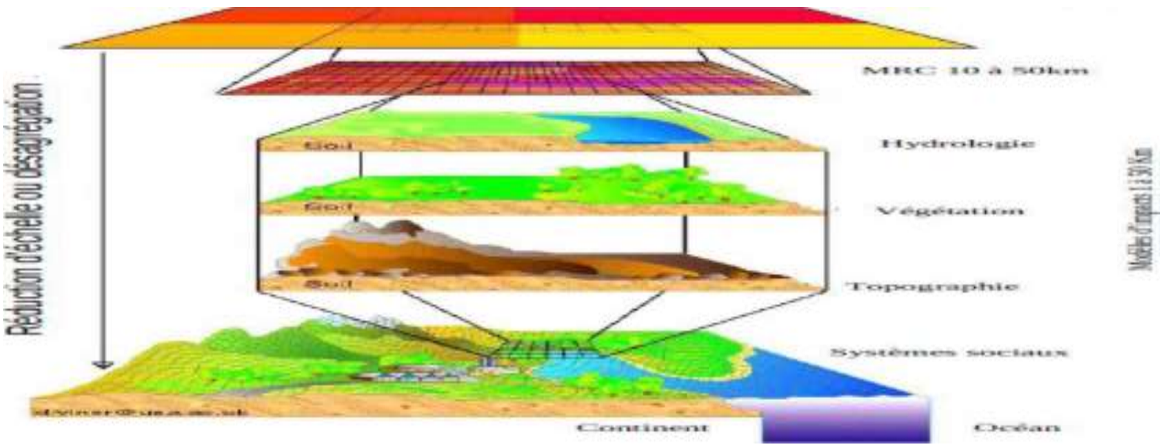

Figure 52 : Diagram of the concept of downscaling (after D. Viner, Climatic Research Unit - University of East Anglia, United Kingdom, http://www.cru.uea.uk/cru/info/modelcc/)

- Bioclimatic evolution (2050-2100) of the Bouregreg basin.

3.2. Future interannual climate change in the watershed of the Bouregreg.

The climate of the Bouregreg watershed will be marked, according to the numerical simulation models, by a decrease of the precipitations of approximately 25% and an increase of the temperatures of more than 1 ° C. This dynamic raises the question of the future evolution of the semi-arid climate of this basin. The analysis of temperature data and precipitation, through the aridity index of De Martone (Lebourgeois and Piedallu, 2005), allows to have a knowledge of the changes to come. This index is expressed by the formula: where

I = aridity index of De Martone

P = total annual precipitation

T = average annual temperature It indicates different classes of aridity that are:

<5 = hyper arid climate

5 -10 = arid climate

10 -20 = Dry sowing climate

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Rainfed agriculture will disappear

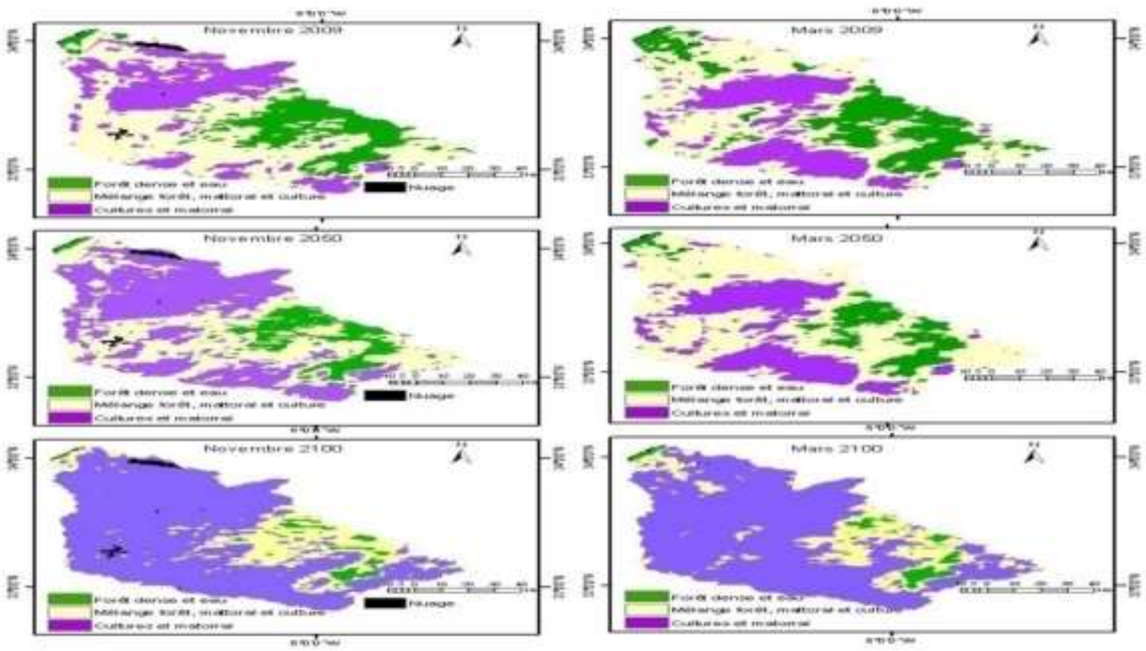

Figure 53: Evolution of the vegetation determined from the surface temperatures of the images MODIS and MCR-CNRM

4.CONCLUSION

The analysis of the risk of degradation of the physical environment of the basin, based on the observed dynamics of anthropogenic and natural factors, confirms that the Bouregreg watershed remains a fragile area. For this purpose, Soil quality is generally poor to average on a topographic support that is often uneven. As for the quality of the climate, only the upstream part of the basin has good water conditions. Also, are the vegetation development conditions medium to poor, especially in Agricultural spaces. Thus, the strong pressure related to urbanization and livestock farming in this natural environment poses significant risks of degradation of the basin in its upstream parts, downstream south and in the forest areas. The analysis of the future dynamics of this basin, in the climate change conditions foreseen by the RCMs, makes It should be noted that these risks of degradation observed by the interaction between anthropogenic factors and the physical environment will be accentuated by the evolution of the climate. Indeed, RCMs predict significant drops in rainfall amounts after 2050. These decreases are accompanied by a rise in temperatures of more than 3°C at horizon 2100. This climate change will be characterized, at the seasonal level, by a shortening of the wet season, especially at the end of the season. Thus, after 2050, the months of February to May, as well as the months of November and December should change their water behavior to become drier. Related to the natural conditions of rainfed agriculture, cereal production should be affected without irrigation water. Moreover, the analysis of the future evolution of surface temperatures shows that, in such a climate change scheme, the search for land to fill the agricultural productivity gap should lead to a gradual disappearance of forest formations. To put in
relief the impact of human activities and climate variability on vegetation and land uses, the current study calls for multidisciplinarity. This methodological choice is explained by the desire for a general understanding of all the human and natural factors that interact with each other and that impact the landscape of the Bouregreg watershed.

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