RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES

Social Science Journal

Climatic Monitoring To Assess the Crop Status by Modeling Method in the Watershed of Bouregreg in Morocco

By

E. Houssaine OUHARBA
Department of Biology, Faculty of Sciences, Mohammed-V University, Rabat, Avenue Ibn Battouta Agdal, B.P. 1014 RP – Morocco

Z. El Abidine TRIQUI
Department of Biology, Faculty of Sciences, Mohammed-V University, Rabat, Avenue Ibn Battouta Agdal, B.P. 1014 RP – Morocco

Abstract

The Bouregreg watershed is a space for rain-fed agriculture. This study our permit to interpret relation between cereal comportment and meteorological conditions, using agro-climatic contribution and cereal development to increasing model. The objective of this work to describe meteorological conditions of the areas to cereal development, for answer the effect treating problematic of climatic fluctuations on increasing, development and cereal production in Bouregreg watershed. The work done is likely to further contribute to research on cereal crop forecasting, in order to enrich and exploit water information systems and climate projection and assist decision-makers in the development of the master plan for integrated water resources management of the basin - (IWRM), and also in the direct contribution to the Sustainable Development Goals ("2.Food Security", "6.Water Resources" and "13. Fighting Climate Change"). The adoption of modeling could help alert and agricultural drought and quantify agricultural forecasts in advance by water and agriculture management. the assessment of the potential impacts of climate change on water and the assessment of the vulnerability of this sector is essential, the aim of this work is to assess vulnerability in order to identify the current impacts and threats and identify strategies, policies and actions to address climate variability and change and reduce the impacts and future vulnerability of these changes and their assessment on food security in Morocco.

Keywords: Crop, Agro-meteorology, Modeling, Climate, Projection, Watershed-Morocco.

1. Introduction

The Intergovernmental Panel on Climate Change(IPPC,GIEC) References [5], [6] estimated that most of the warming observed over the last 50 years is due to human-induced greenhouse gases. According to the same source, the continuation of these emissions without a serious reduction policy would increase the global temperature from 1.4 to 5.8°C between 1990 and 2100, and the average sea level from 9 cm to 88 cm during the same period, and would continue to increase for centuries. The hydrological cycle will be intensified, leading to more droughts in some areas and floods in others, Houghton [17] and Le Treut et al., [18].

The Reference [14] assessed available scientific information on the impacts of climate change on ecosystems, socio-economic sectors, including the food chain, water resources and human health. The agricultural sector is one of the sectors most vulnerable to climate risks and pastoral activities subject to a decrease in rainfall. The Moroccan climate is characterized by great variability in both spatial and temporal precipitation and temperatures. The Bouregreg watershed, although belonging to the country's wetlands, does not escape this climatic variability, Reference [19].

The work done is likely to further contribute to research on cereal crop forecasting [3], planning and integrated water resources management. The adoption of modeling could help alert and agricultural drought and quantify agricultural forecasts in advance by water and agriculture management. the assessment of the potential impacts of climate change on hydrology [2], [4] and [13] and the assessment of the vulnerability of this sector is essential, the aim of this work is to assess vulnerability in order to identify the current impacts and threats and identify strategies, policies and actions to address climate variability and change and reduce the impacts and future vulnerability of these changes and their assessment on food security in Morocco [8].

2. Materials and Methods

The Agro-Climatological methodology applied in this work as tools of management and decision support is the first established on the study area "Experimental Domain of Marchouch in Rommani (CRRA, INRA - Rabat), by the work of research of my Master thesis Ouharba [11]. The studies of perspectives in my PhD thesis by an assessment of water and agricultural vulnerability in the watershed of Bouregreg, in the face of climate change (Figures 1and 2)

2.1. Study area

The Bourereg watershed is located in north-western Morocco. It covers approximately 1000 km². It is characterized geo-morphologically by a drop altitudes from the East (Aguelmous) to the West from more than 1500m (Rabat-Sale) to 0 m at level of the Atlantic Ocean (Figure 2) (Table 1).

Hydro-logically, it is limited to the North and Northeast by the watershed of Beht wadi, tributary of the left bank of Sebou wadi, at South and South-East by that of Oued Grou, tributary of the great basin of Oued Bouregreg.

3. Results and Discussion

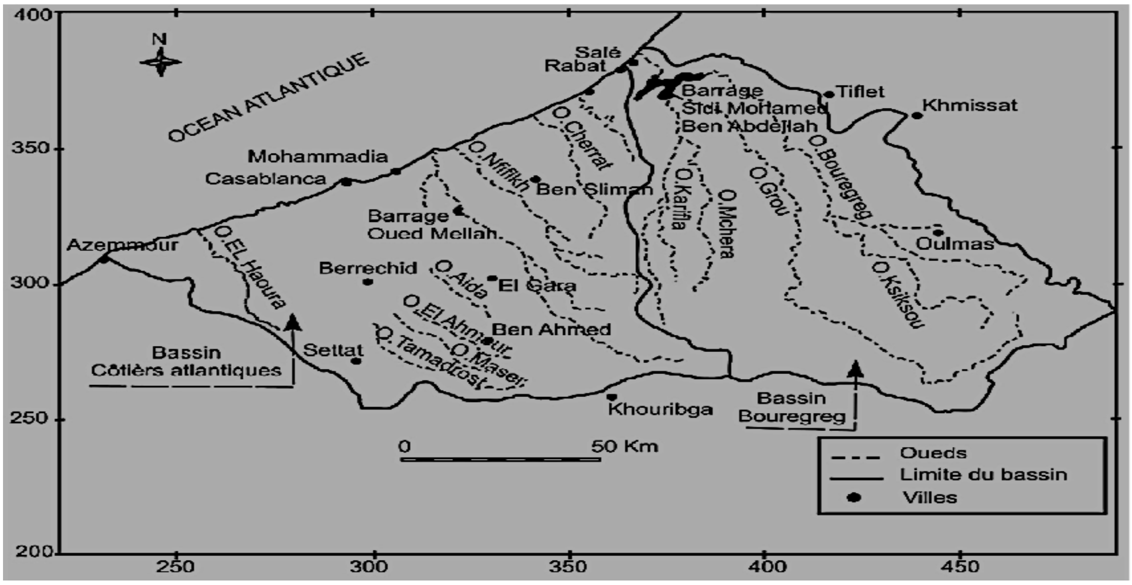

Figure 1: *Bouregreg Basin and Atlantic coasts*

Geographical location:
Coordinates
Latitude: 33 ° 60'41 N
Longitude: 6 ° 71'60 W
Altitude: 339 M

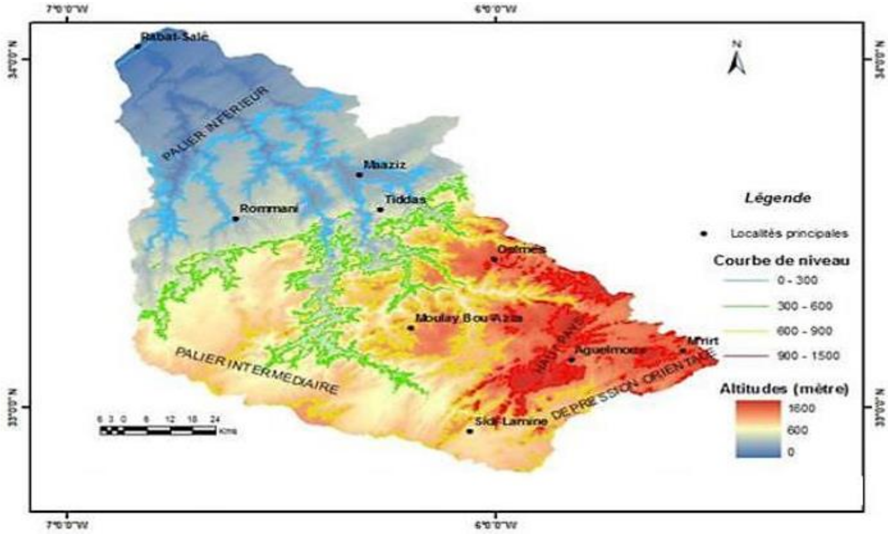

Figure 2: *Geomorphological units of the Bouregreg watershed: the levels are limited by the contour lines in the figure (Beaudet, 1969)*

Table 1: *type of terrain and its percentage (%)*

Plain	13%	24%	25%	18%
Tray	81%	27%	27%	54%
Mountains and hills	0%	21%	2%	8%
Valleys and bowls	6%	29%	46%	20%
Area in ha	44 381	31 631	11 727	87 739
Area in %	51%	36%	13%	100%

Pedology

The role of the soil reconnaissance study is to report on the types of soil in the Bouregreg watershed area, but also to determine the soil erodibility factor necessary for the evaluation of erosion (Figure 3) (Tables 2 and 3).

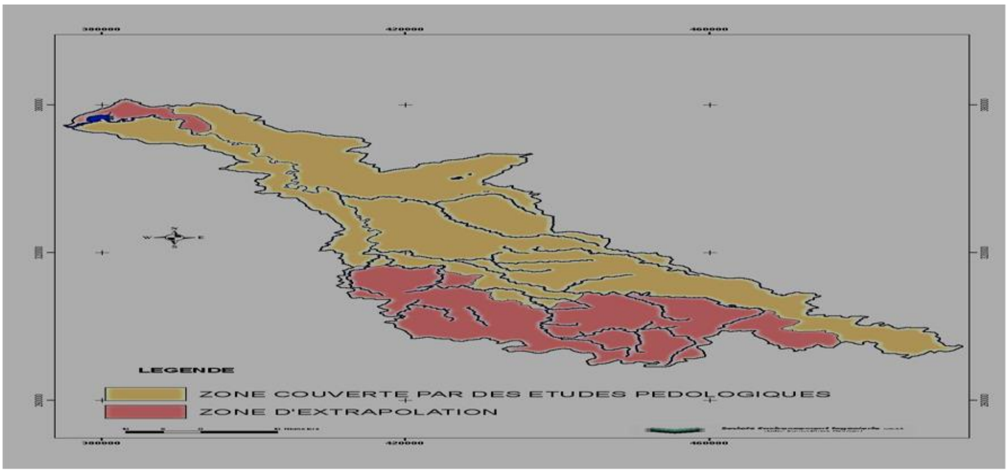

Figure 3: *Location of covered and uncovered areas by soil studies (DREFNO, 2016)*

Table 2: *Rommani Soils Texture (Source: CRRA, INRA-Rabat)*

Floor Type	Brachoua	Marchouch	J. Moullabled	Total
Shots	15 533	21 207	3 987	46%
Hamri	8 876	5 381	3 870	21%
Rmel	0	0	0	0%
Hrach	19 972	5 133	3 870	33%
Area in ha	44 381	31 721	11 727	87 829
Area in %	51%	36%	13%	100%

Table 3: *Soil texture of the Marchouch Experimental Estate (Source: CRRA, INRA-Rabat)*

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	pH
0-20	50,0	37,3	12,7	7,8
20-40	51,3	38,2	10,5	8,2
40-90	52,5	35,1	12,4	8,6

Agricultural production

Downstream of the basin is marked by the existence of forests dominated by Quercus suber (cork oak) to the east of Rabat-Sale (Figure 4). The shrubby vegetation is a mosaic governed by the less and less humid bioclimatic gradient towards the East. Annual herbaceous plants are more abundant and contribute the most to the productivity of Mamora pastures. The cork oak forest occupies the hinterland, at the level of the middle valleys of Grou and Bouregreg, on non-sandy siliceous substrate. Cork oak is associated with Cistusspp. . The cork oak occupies this space of the lower level of the Bouregreg basin with formations of clear or dense forests and matorrals of variable density (Tables 4-6). These matorrals are mosaic with cereal crops and very degraded facies. The intermediate level and the high country are colonized by a clear to dense vegetation of Quercus rotundifolia (evergreen oak) with islands of cork oak and matorrals.

Table 4: *Area of Exploitations of Rommani Region in (ha) (Source: Rommani Works Center)*

Area in (ha)	Brachoua	Marchouch	Jemaa Moullabled	Total
0-5	39%	58%	64%	53%
5-10	23%	16%	19%	20%
10-20	18%	15%	9%	14%
20-50	9%	6%	5%	7%
>50	11%	4%	3%	6%
Number	1114	857	1075	3046
%	37%	28%	35%	100%

Table 5: *Area of Major Agricultural Productions in the Region (Source: DPA Khemisset, 2004)*

(Average of 1995 to 2003) in (ha).	Ha	%
Cereals	244.550	66
Legumes	28.240	7.5
Fruit plantations	21.101	5.6
Vegetable growing	7.151	1.9
Forage crops	18.500	5
Industrial crops	2.420	0.6
Tropical crops	2190	0.6

Table 6: *Yields Achieved for the Main Cultures of the Region in (Qx/ha) (Source: DPA Khemisset 2004)*

Species	Averages yield in (Qx/ha)
Cereals	
Soft Wheat	11.11
Hard Wheat	9.8
Barley	9.6
Corn	6.5
Triticale	19.0
Legumes	
Bean	7.3
Pea	7.3
Lens	7.5
Chickpea	7.7
Haricot	7.1
Forage crops	
Oat	30
Fodder barley	14.7
Rye	28.7
Oats vetch	34.4
Lupine	33.6

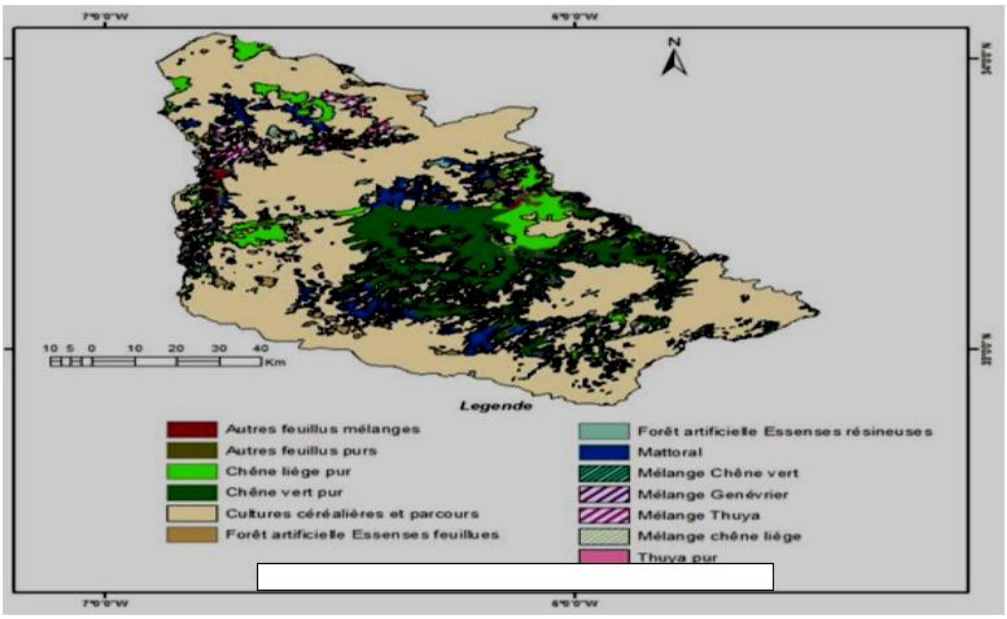

Figure 4: *Main vegetation of the Bouregreg Basin (Source: CERGEO)*

2.2. Climatology

The region's climate is semi-arid. The average annual rainfall varies between 350 and 400 mm [9], (Figure 5).

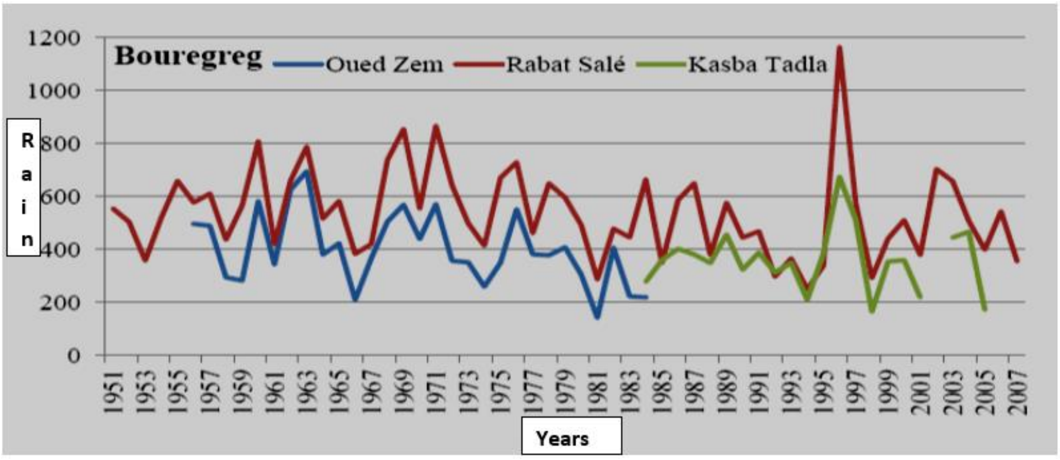

Figure 5: *Evolution of the rainfall Series in the Bouregreg Basin (in mm).*

Ombro-thermic diagram

According to the Bagnouls and Gaussen [1], ombro-thermic 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 6).

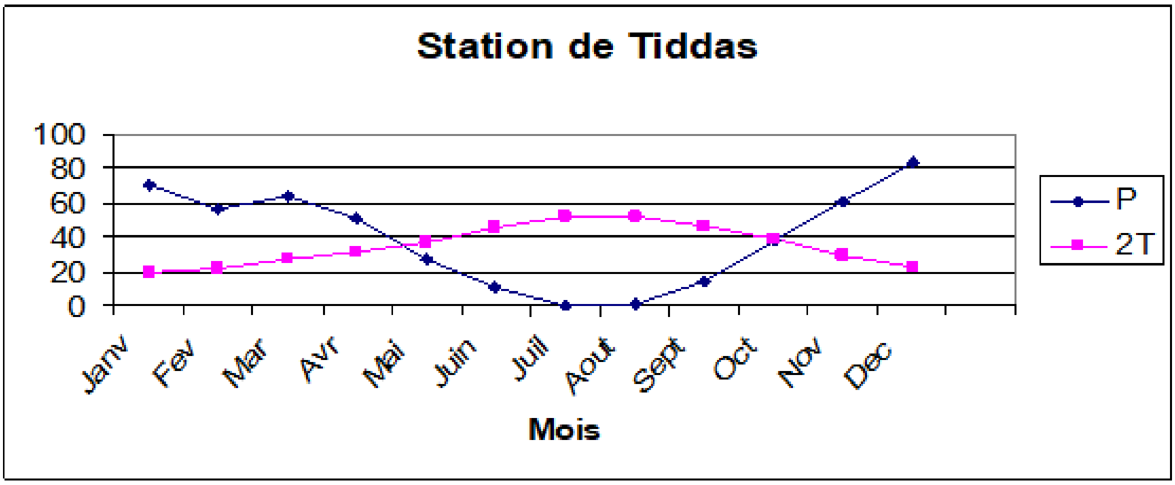

Figure 6: *Ombro-thermic curve of the Tiddas station.*

2.3. Phenology

Table 7: *Calendar of Cereal Growth Cycle Stages in Marchouch (INRA)*

Observation dates	Seedling	Lifting	Tillering	Montaison	Heading	Flowering	Maturity
12 November	x						
22 November		x					
10 January			x				
15 Febrary				x			
25 March					x		
30 March						x	
25 May							x

The varieties of cereals most used in the region are the most adapted to the biotic and abiotic conditions, in terms of yield and quality. They are the most consumed in Morocco, and subsidized by the state (Table 7).

Finally, for projections of future returns according to climate change models, I used the future monthly climate parameters (Tmax, Tmin, Rain) for the year 2030 with scenario B2 and model HadCM3 (Hadley Center Model 3, British Meteorological Service) of ww.worldclim.org/futurdown.htm and retrieve 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. The modeling adopted in this study is the "Crop-Syst" model [12] that approaches the problem of agricultural production in a progressive manner. Three hierarchical levels are identified: potential growth, growth under water stress or nutritional stress (lack of fertilizers) and reduced growth (attack by parasites). If the intake of water (Figure 7) or nutrients below optimal during a phase or the entire growth period, this will lead to limited production due to lack of water or fertilizers.

Climatic factor related to rainfall / water requirements of cereals.

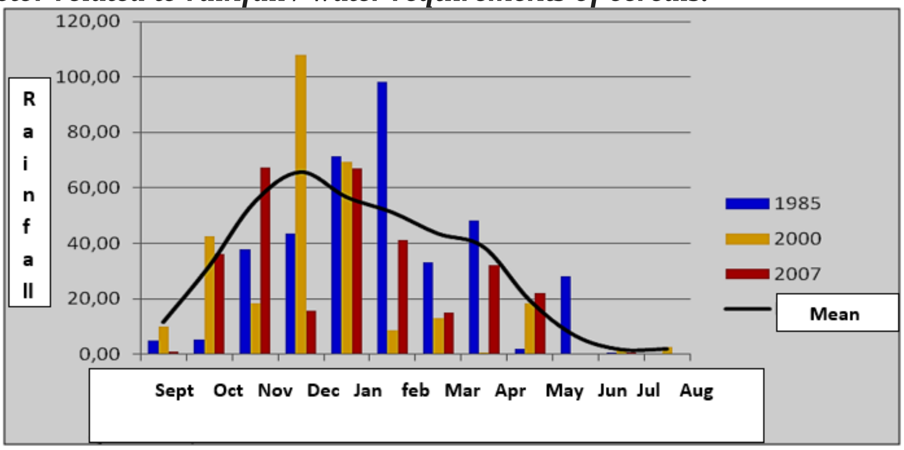

Figure 7: *Average monthly rainfall at the Bouregreg watershed scale in 1985, 2000, 2007*

Vulnerability related to the variability of plant productivity in relation to climate Variability (Figure 8).

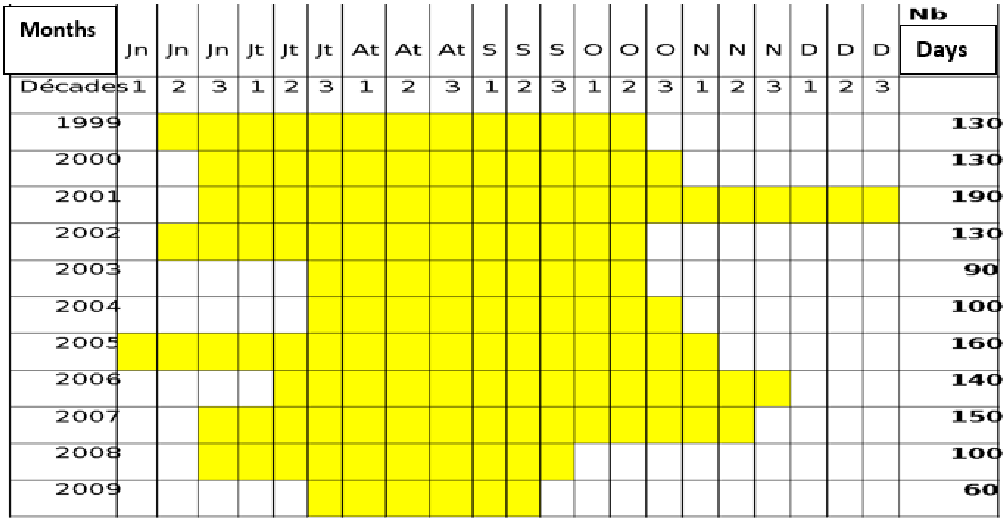

Figure 8: *Variability of early and late seasons with low vegetation cover (NDVI <0.2) in cereal growing zone.*

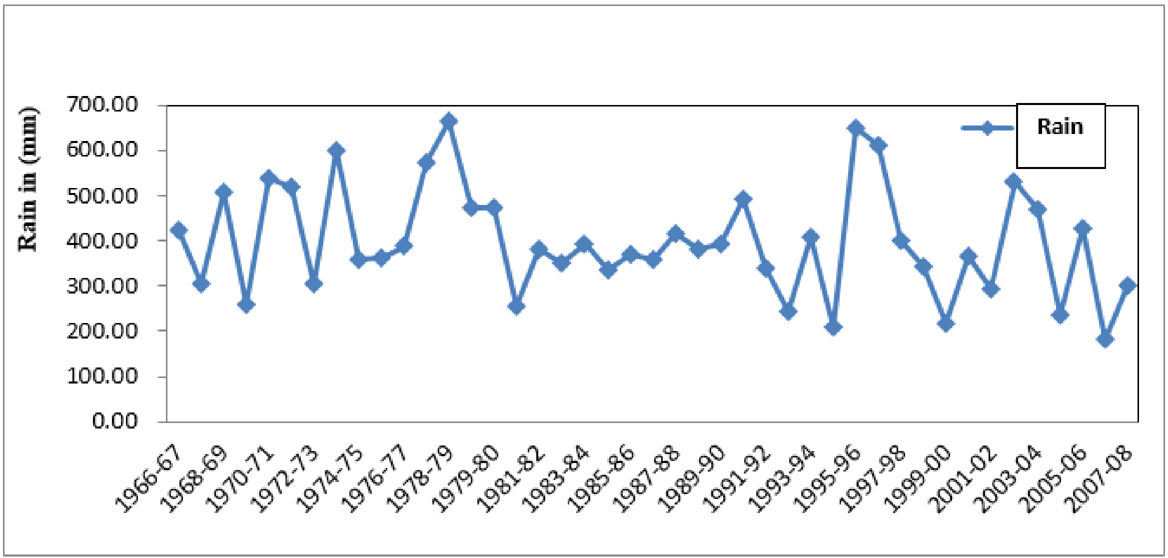

Figure 9: *Rainfall evolution at Marchouch (INRA), from the period (1966-67 to 2007-2008)*

The analysis of the climatic components gives us for the regime of precipitations, an irregularity of the inter-annual rains, in the period 1966/67 to 2007/08 with a peak of 664.50 mm recorded in campaign 1978/1979 and a minimum of 181.10 mm recorded in the 2006/2007 campaign (Figure 9).

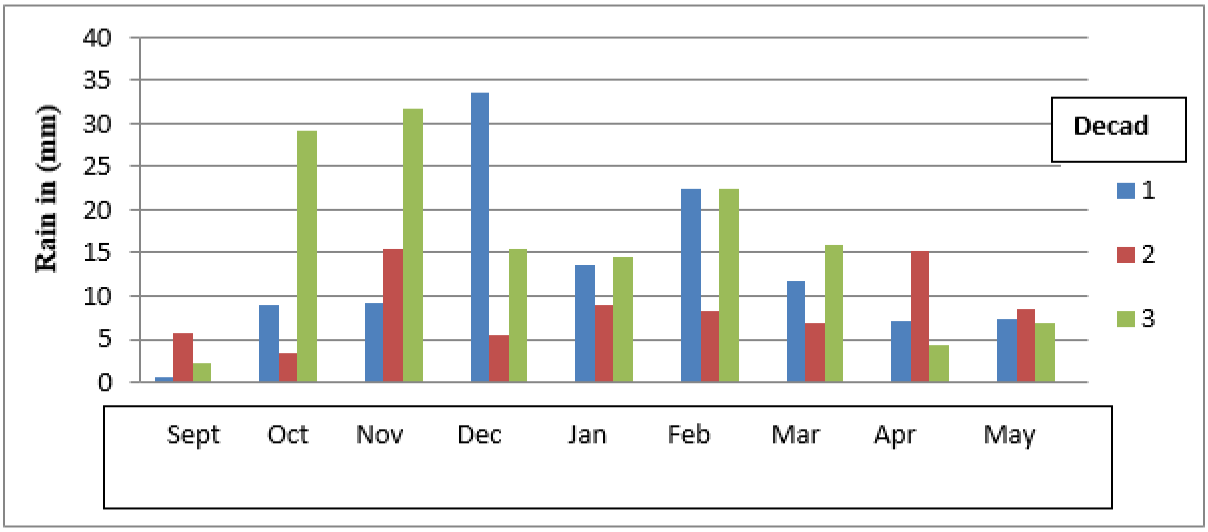

Figure 10: *Decadal Variability of Rains during the Wheat Growth Cycle for the period (2003 to 2009) corresponding to the date of sowing (2nd Decade of November) on the Maturation date (3rd Decade of May) during the Cycle of Growth of wheat in Marchouch (INRA).*

This (Figure 10) illustrates the distribution of the irregularity of the ten-day rains during the wheat growth cycle for the period (2003 to 2009) in Marchouch. Between the months of September and December there is a cumulative increase in the 10-day rainfall, which is important for the early stages of the growth cycle, between December and January a fall in cumulative rainfall that corresponds to the cold phase of the cycle, while in February the rains increase again which is important for the supply of the water reserve because it is the critical stage of the plant growth where the plant needs a lot of water. From the month of March the decadal rains decrease until the end of the cycle. It is the phase of the flowering until the maturity or the degree-days of the temperatures are more important.

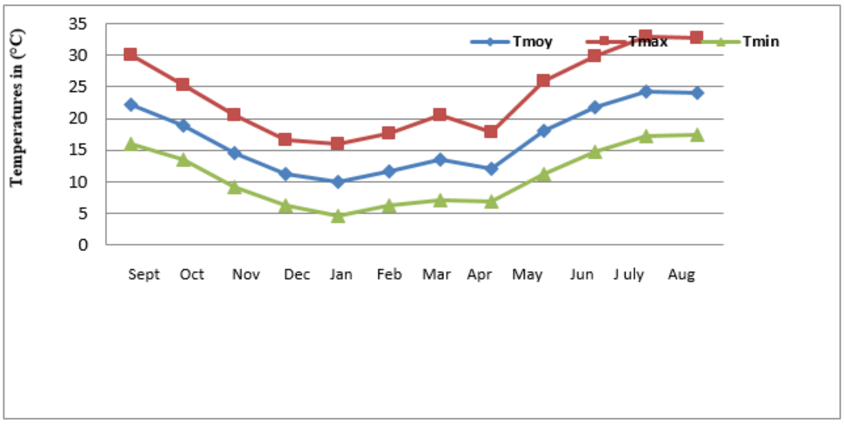

Figure 11: *Evolution of Average Monthly Temperatures (Tmoy, Tmax and Tmin) the Agricultural Campaign for the period (2003 to 2008), in Marchouch (INRA)*

For the temperature regime, there is a change in the irregularity of the monthly average temperatures (T average Tmax and Tmin) between the months of the crop year for the period 2003 to 2008. With a high of 32.93 (°C) recorded in July, a low of 04.63 (°C) recorded in the month of January (Figure 11).

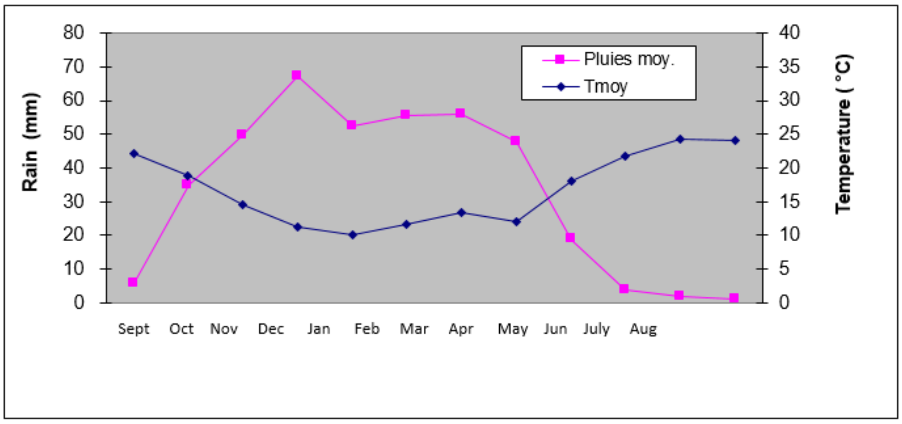

Figure 12: *Ombro-thermic diagram of the Marchouch Experimental Domain (INRA)*

This diagram (Figure 12) provides information on the wet and dry periods during the crop year (September – August) and the plant growth period. The wet season is between the months October and April of the campaign, during which we have the cycle of plant growth, and the dry season between the months May and September, that is to say the end and the beginning of the agricultural campaign.

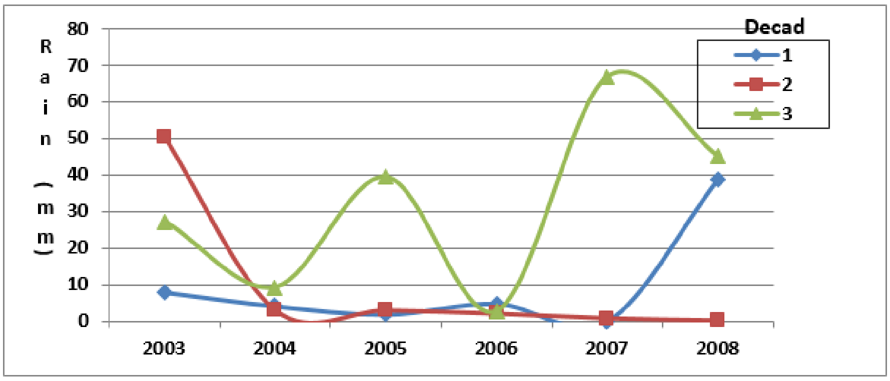

Figure 13: *Evolution of the three decades of the month of November at the Experimental Domain Marchouch, INRA*

The analysis of the growth and production of wheat by an agro-climatic characterization using the dates of sowing and water deficit, shows the temporal evolution of the accumulations of rains of the 3 decads of November for the period 2003 to 2008. It allows us to choose the optimal date of early sowing, which allows us to use the accumulated first rains fallen, in order to satisfy the useful reserve of the water needs for the plant during the emergence phase (Figure 13).

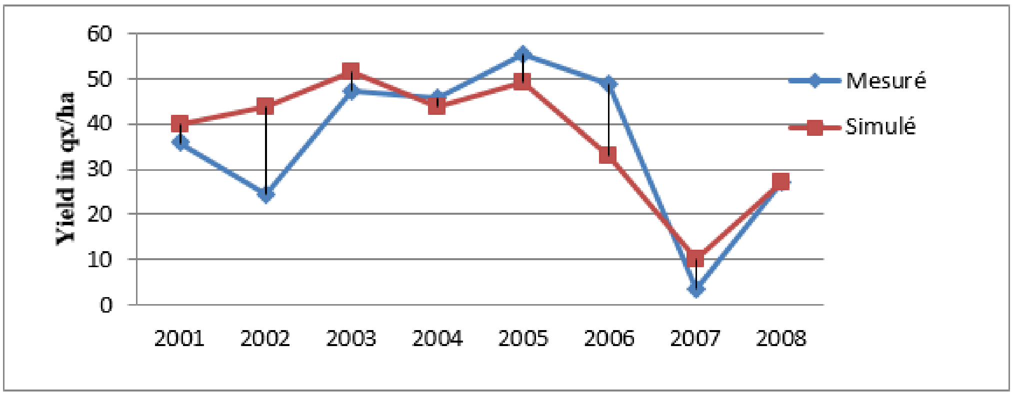

Figure 14: *Comparison between measured and simulated yield at the Experimental Domain Marchouch, INRA.*

The analysis of yields shows the irregularity of average yields of soft wheat from the 2000/01 to 2008/09 crop years. Yields are marked by a peak of 55.24 qx / ha measured in the 2004/05 season and a minimum of 3.42 qx / ha measured during the 2006/07 season (Figure 14).

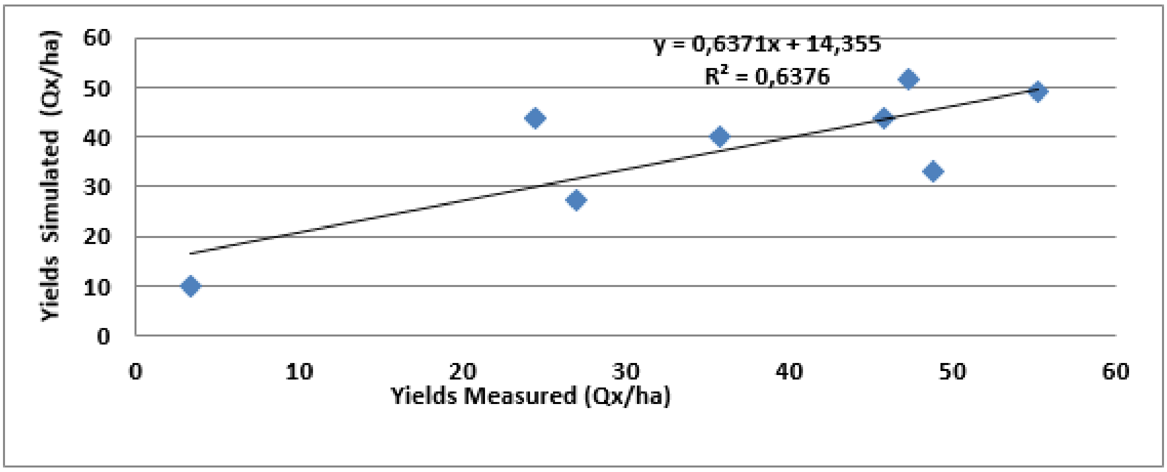

Figure 15: *Relationship between measured and simulated yields in Marchouch.*

The simulation of yields by the Crop-Syst model, Stöckle, Nelson [12] and comparison between measured and simulated yields at Marchouch (Rommani), gives a significant correlation between the measured and simulated yields of $R^2 = 0.6376$ (Figure 15) (Table 8).Taking into account the calibration of the model on the study site which remains estimated in relation to the real characteristics of the environment and crops.

Simulation of returns by the Crop-Syst Model (Stöckle, Nelson, 2005)
3.1. Simulation outputs
Fastgraph document

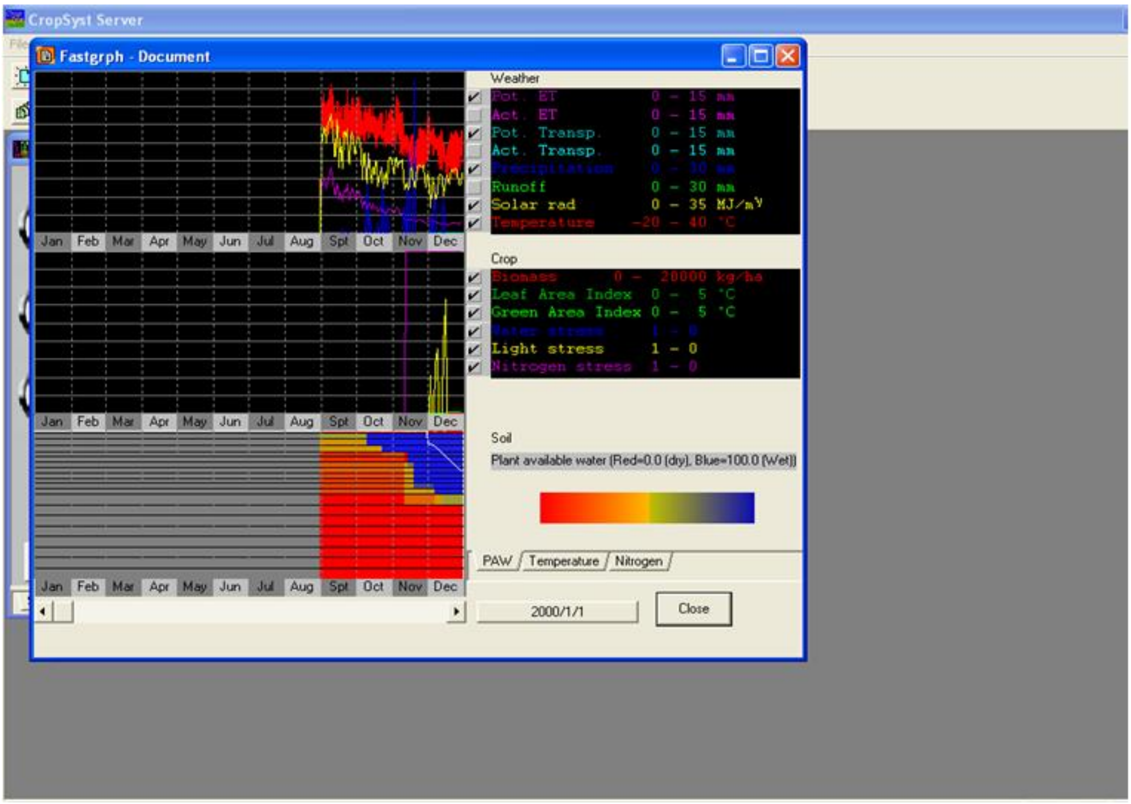

Table 8: *Simulated Harvest Report.*

seedling	Emergence	Flowerisg	Maturation	Maturity	Harvest	Emergence	Actual ETP (mm)	Yield (Qx/ha)	Yield (Qx/ha)	Rain (mm)
								Simulated	*Measured*	
12/11/2000	30/11/2000	28/04/2001	13/05/2001	26/05/2001	11/06/2001	333,2000	171,16	40.00	35.82	161,60
13/11/2001	27/11/2001	28/04/2002	11/05/2002	23/05/2002	08/06/2002	331,2001	309,03	43.89	24.46	362,20
13/11/2002	27/11/2002	02/05/2003	14/05/2003	25/05/2003	10/06/2003	331,2002	308,62	51.51	47.32	457,20
13/11/2003	27/11/2003	05/05/2004	18/05/2004	31/05/2004	16/06/2004	331,2003	276,23	43.65	45.78	437,50
12/11/2004	27/11/2004	03/05/2005	13/05/2005	25/05/2005	10/06/2005	332,2004	167,74	49.00	55.24	168,70
13/11/2005	27/11/2005	03/05/2006	14/05/2006	25/05/2006	10/06/2006	331,2005	211,18	33.00	48.86	268,40
13/11/2006	25/11/2006	05/05/2007	16/05/2007	29/05/2007	14/06/2007	329,2006	237,31	10.00	3.42	188,20
13/11/2007	25/11/2007	26/04/2008	07/05/2008	22/05/2008	07/06/2008	329,2007	156,66	27.21	27.00	158,40

3.2. Climate projection

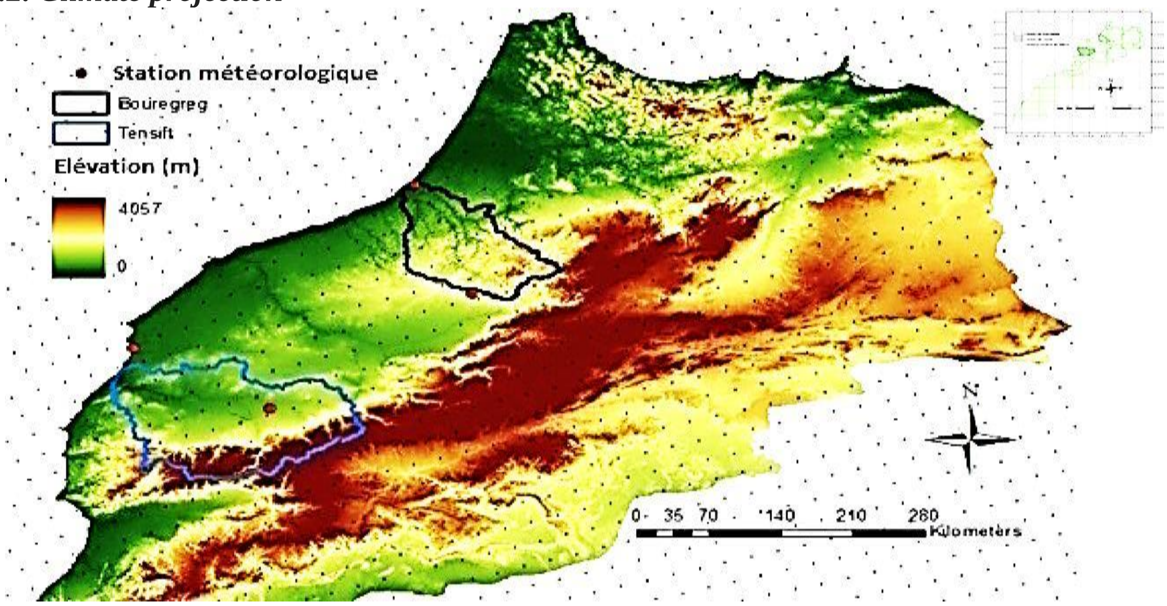

Figure 16: *Grid of regional climate models (Black dots) (SIGMED, 2012).*

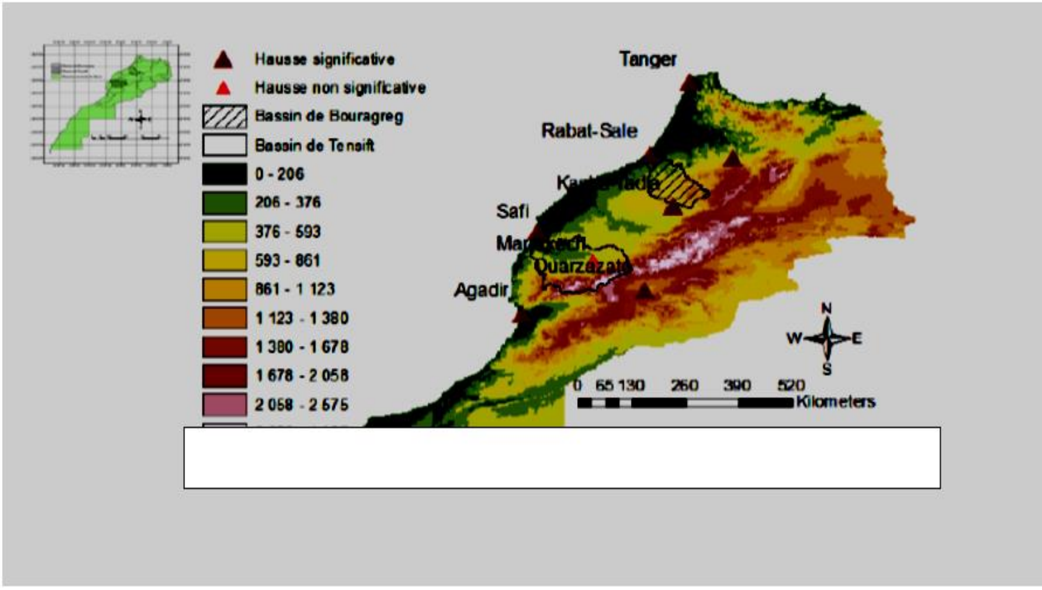

Figure 17: *Temperature projection in the study area) (SIGMED, 2012).*

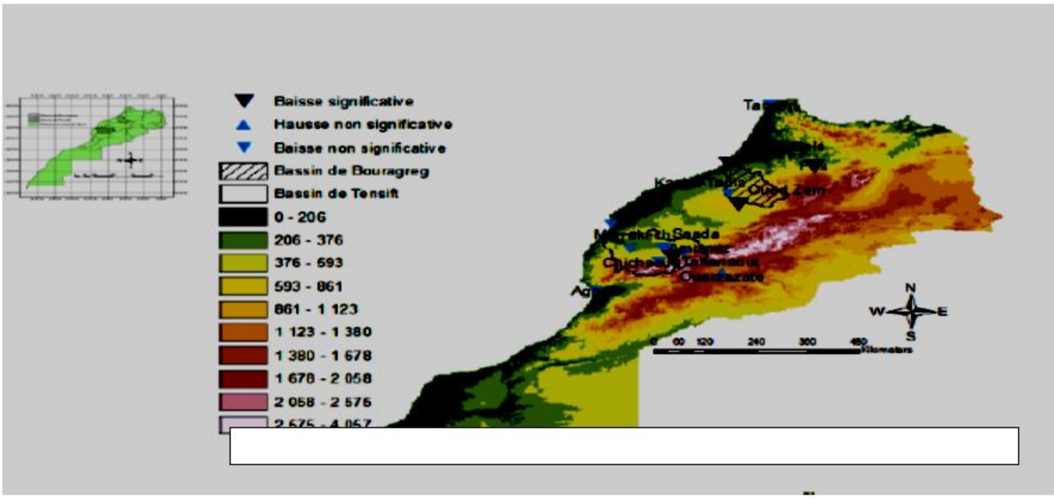

Figure 18: *Rainfall projection in the study area) (SIGMED, 2012).*

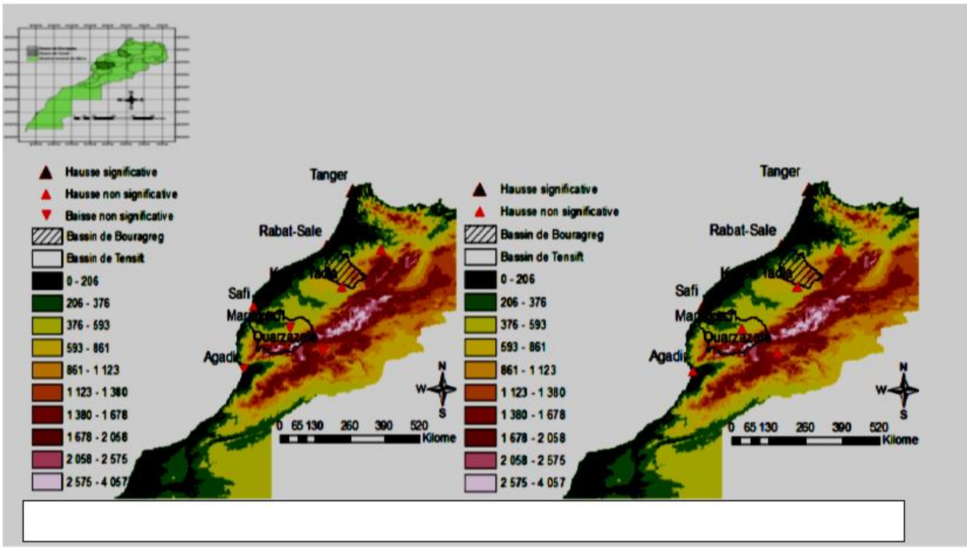

Figure 19: *Projection of maximum temperatures in study sites in summer (left) and in winter (right) (SIGMED, 2012).*

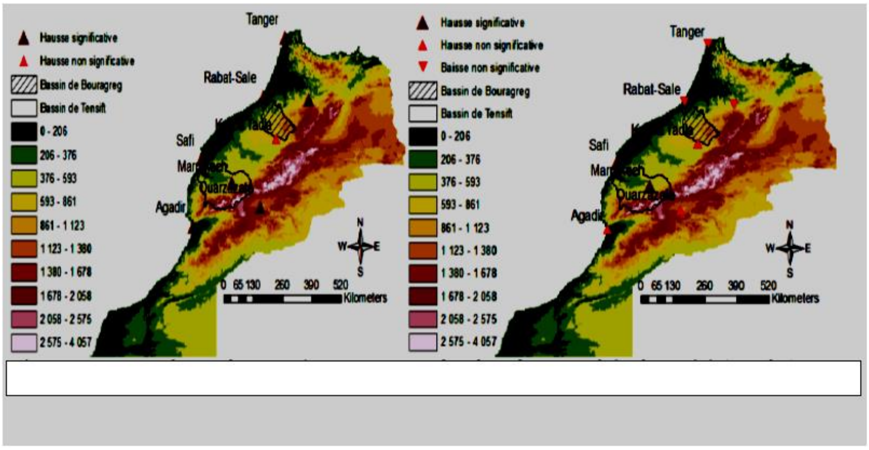

Figure 20: *Projection of minimum temperatures in study sites in summer (left) and in winter (right) (SIGMED, 2012).*

Projection of future returns according to climate change models using in this work scenario B2 to compare between the current maximum temperatures of the campaign (2008-09) and future of the year 2030 (Table 9), the current minimum temperatures of the campaign (2008-09) and future of the year 2030 (Table 10), and the current rains of the campaign (2007-08) and future of the year 2030 (Table 11) of the Experimental Domain Marchouch, INRA.

Table 9: *Comparison between the current maximum temperatures of the season (2008-09) and future of the year (2030) of Exp. Marchouch, INRA*

	Present	Future
	2008-2009	2030
Months	T max	T max
September	28,22	28,40
October	22,44	22,80
November	17,67	16,30
December	15,25	13,10
January	14,33	15,30
Febrary	17,54	17,10
March	20,59	19,40
April	20,26	20,50
May	26,26	26,90
June	30,86	30,70
July	29,22	34,60
August	31,44	33,50
Average/year	22,84	23,22

Table 10: *Comparison between the current minimum temperatures of the campaign (2008-09) and future of the year (2030) of Exp. Marchouch, INRA*

	Present	Future
	2008-2009	2030
Months	T min	T min
September	15,70	16,60
October	12,10	13,30
November	7,60	9,50
December	6,40	6,80
January	5,90	5,20
Febrary	7,40	6,20
March	9,80	7,40
April	7,00	9,30
May	11,70	12,30
June	16,10	15,90
July	15,40	17,60
August	16,20	17,90
Average/year	10,94	11,50

Table 11: *Comparison between the current rains of the season (2007-08) and the future of the year (2030) of the Marchouch Experimental Domain, INRA.*

	Present	Future
Months	Rain	Rain
	2007-2008	2030
September	1,40	7
October	15,94	10
November	67,52	17
December	14,85	8
January	52,87	2
Febrary	45,44	2
March	13,07	3
April	44,74	2
May	45,25	2
June	0,00	0
July	0,00	1
August	0,00	3
Cumulative/year	301	57

For the rains, according to the B2 model proposed for the study area, it turns out that in the future there will be less rainfall (about less than 80%). It is a strong aridity that will settle in the region of the Marchouch Experimental Domain, INRA, according to the climate scenario. For temperatures (T max and T min), according to the climate scenario model B2 [17], there will be a temperature increase of approximately (+1 to 2°C) (Figures 17-20). The study area will become hotter in the future. For future yields under scenario B2, the study area will become more arid in the future which will have direct and negative effects on cereal yields. 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., [8].

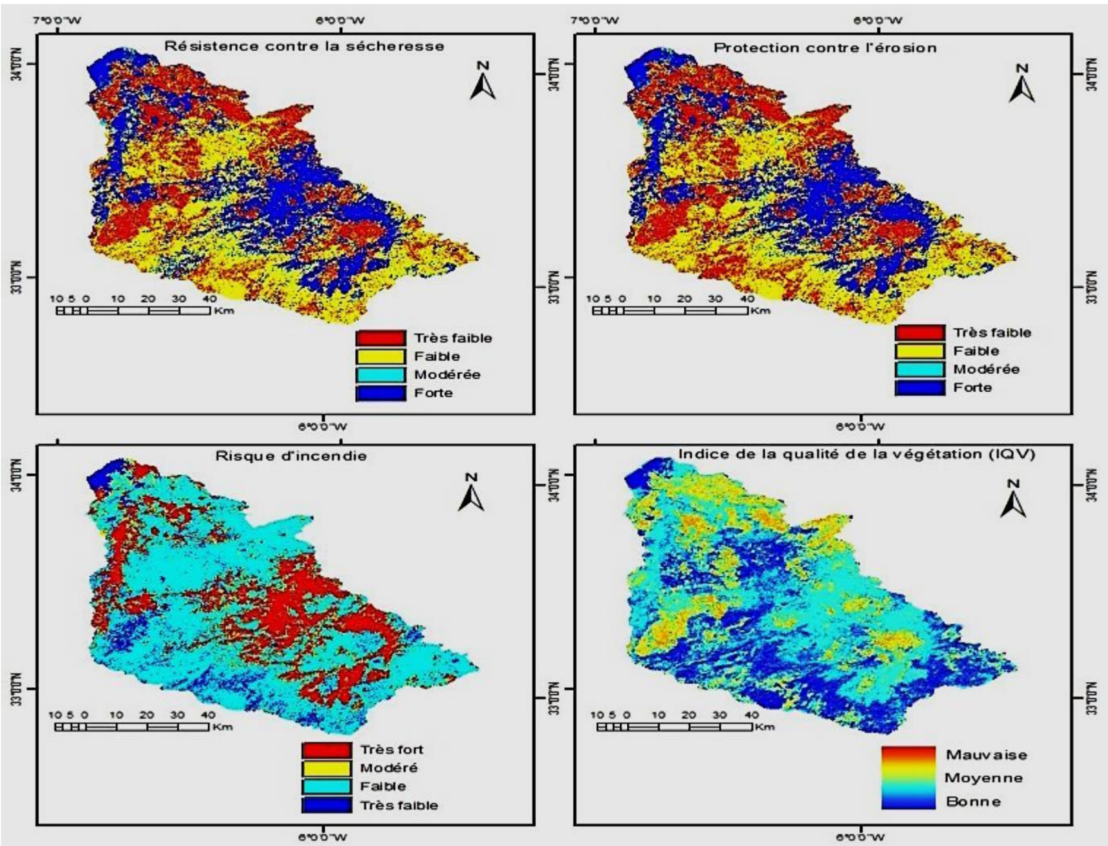

Figure 21: *Characterization of the quality of the vegetation.*

Critical areas in terms of degradation are 2% of the basin [10]. Thus, more than a quarter of the basin is a fragile space in terms of agricultural and pastoral exploitation (Figure 21). The study by the FAO on the state of the environment, already indicated that 54% of the Bouregreg basin should not be cultivated because of their fragility. At the spatial level (Figures 22 and 23), the spaces where the degradation represents a critical risk are located in the southern part of the basin (upstream).

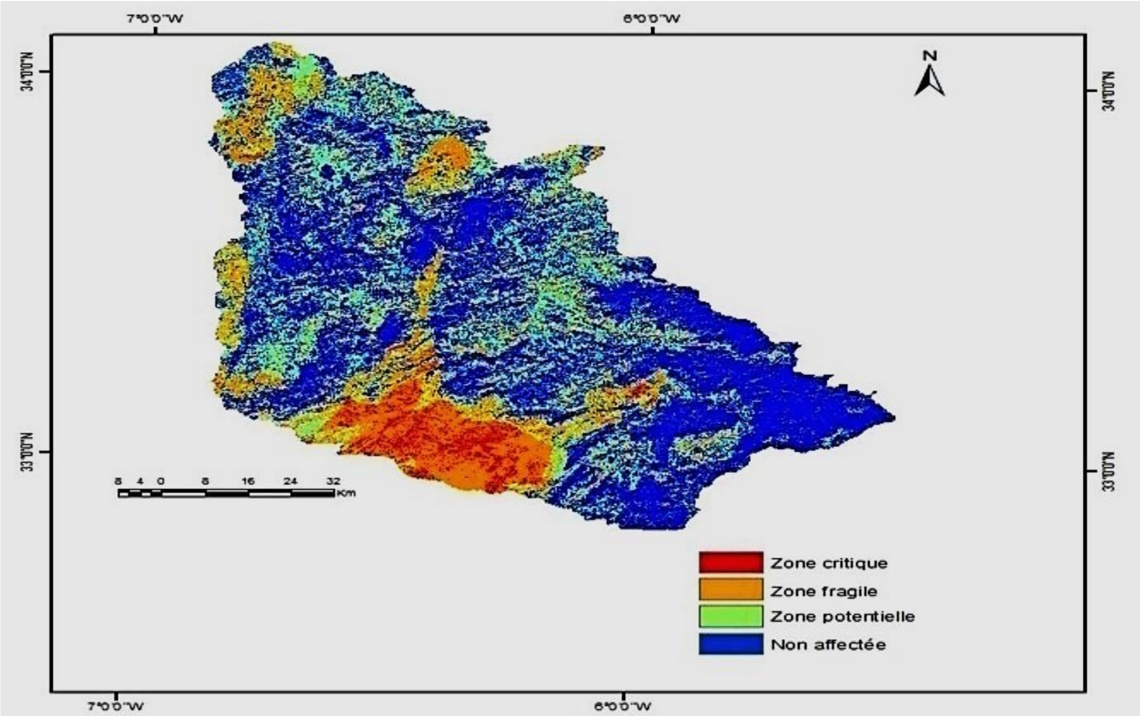

Figure 22: *Map of the risk of soil degradation in the Bouregreg watershed.*

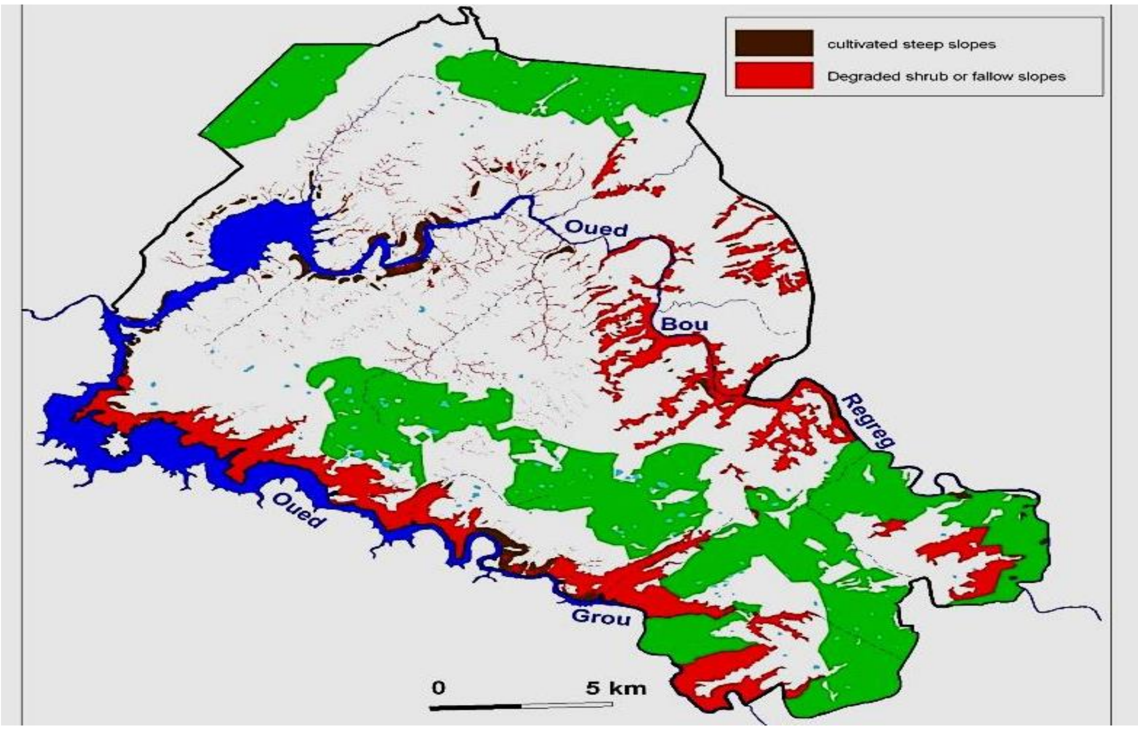

Figure 23: *Dynamics of the courses (The 3 types of course: - Forests, Matorral degraded, Degraded and abandoned cultivated land.*

Rainfed agriculture will disappear.

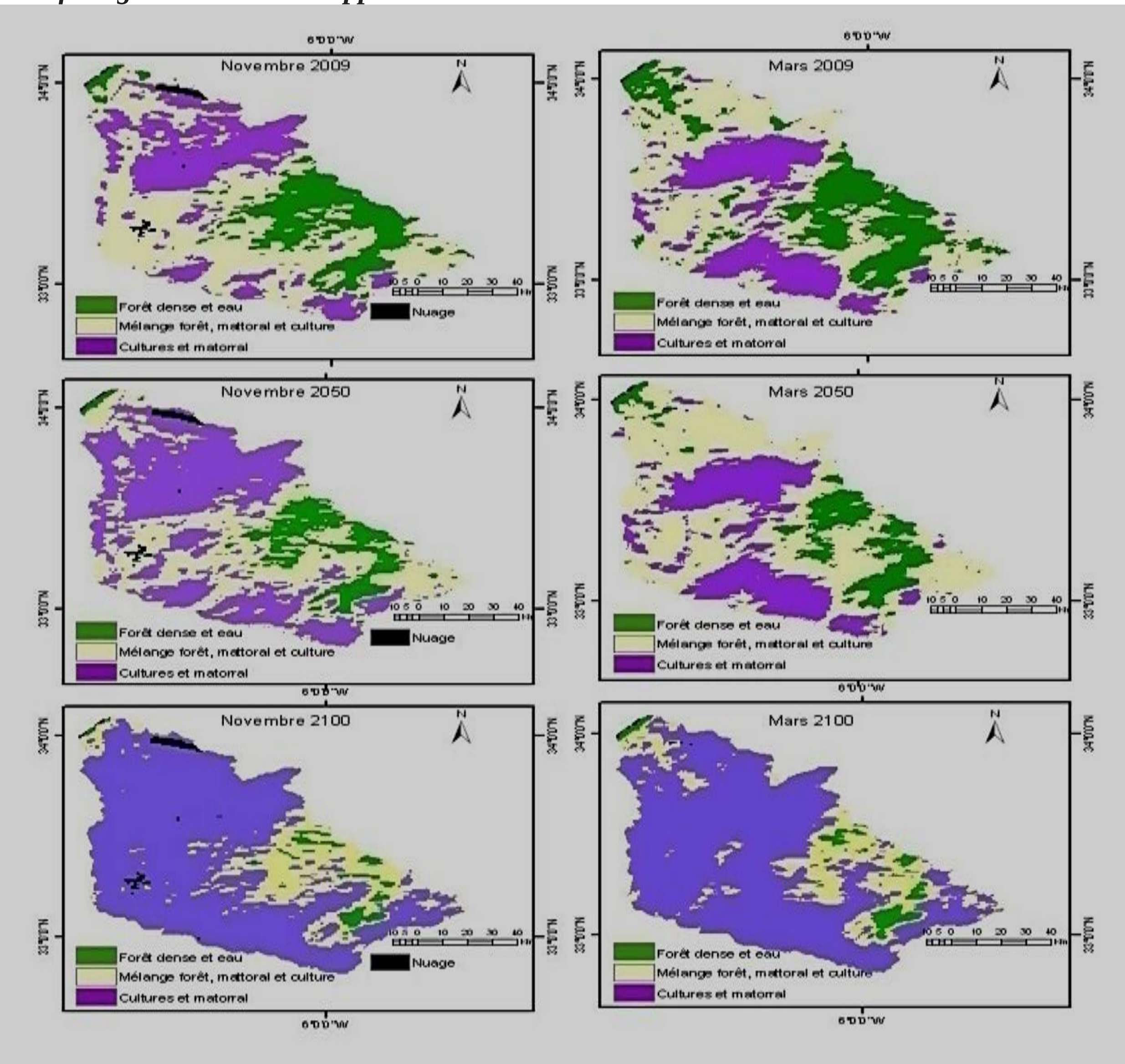

Figure 24: *Evolution of the vegetation determined from the surface temperatures of the MODIS images and MCR-CNRM.*

This (Figure 24) show the same at the beginning (November) as at the end of the agricultural season (March). The rate of degradation is low until 2050. In 2100, the surface temperatures formerly characteristic of forests should only be residual islands, giving a degraded forest landscape in an environment of scrubland under agricultural and pastoral pressure.

4. Conclusion

This work examines climatic hazards that cause significant fluctuations in agricultural production in the Rommani region, which results in a comparison and correlation between yields and meteorological parameters thus giving significant dependence between the two. A modeling approach by Crop-Syst was used to obtain estimated returns and compare them to measured returns. In order to better understand this problem throughout the Bouregreg basin, it would be wise to follow very closely in space and time. And this, by a study of comparison of the studied region with the different regions of the Basin, with an application of the models of simulation of agriculture. Adopting modeling will undoubtedly help decision-makers alert farmers to the risks of agricultural drought and to forecast wheat import requirements in advance, thus helping the country's food security and also; to estimate the impact of climate change on wheat productivity in the Rommani-region.

This is in line with the results obtained in the report "WB/FAO/INRA/DMN" established by the study on Morocco by the World Bank [16]. Projections to 2030 predict a warming of 0.8 to 1.3°C at the scale annual, accompanied by a small increase in the number of summer heat wave days. Annual rainfall amounts are assumed to decrease by 6 to 20%, those in winter by 15 to 35%. (Source: Climate Change Integration Project in the implementation of the Green Morocco Plan).

References

F., Bagnouls, H., Gaussen, ‘’Les climats biologiques et leur classification’’, Annales de Géographie, vol .66, n°. 355, pp. 193-220, Paris, 1957.

R., Balaghi, ‘’Suivi de l’évolution des réserves en eau sous cultures de blé en région semi-aride Marocaine : Calibration et utilisation du modèle SOIL’’, Mémoire de DEA, pp. 1-95, Arlon, FUL-Bélgique, 2000.

R., Balaghi, ‘’Wheat grain yield forecasting models for food security in Morocco’’, Thèse de Doctorat en sciences de l’environnement, pp. 1-103, Ulg-Arlon, Bélgique, 2006.

F., Driouech’’, ‘’Distribution of winter precipitation over Morocco in the framework of a Climate change: downscaling and uncertainties’’, Thesis of Doctorate, University of Toulouse, pp. 1-164, 2010.

GIEC, ‘’Changement Climatique’’, Rapport de Synthèse. XVIII Session du GIEC, Wembley, Royaume–Uni, 24-29 Septembre, pp. 1.249, 2001.

GIEC. ‘’Synthesis Report, Contribution of Working Groups I, II, and III to the Fourth Assessment Report and the Intergovernmental Panel on Climate Change’’, Core writting Team, Pachauri, R.K. and Reisinger (Eds.) IPCC, Geneva, Switzerland, pp. 1-104, 2007.

GIEC,’’ Rapport Spécial du GIEC: Réchauffement à 1,5°C Résumé à destination des enseignants’’, pp. 1-24, Avril-2019.

R., Gommes, T., El Hairech, D., Rosillon, & R., Balaghi, ‘’Impact of climate change on agricultural Yields in Morocco’’, World Bank –Morocco Study on the impact of climate change on the Agricultural Sector. Food and Agriculture Organization of the United Nations (FAO). Roma, Italy, pp. 1-105, 2009.

K., Khomsi, G., Mahe, M., Sinan, et al., ‘’Evolution des événements chauds Rares et très Rares dans les Bassins Versants de Tensift et Bouregreg (Maroc) et identification des types des temps synoptiques associés. From prediction to prevention of hydrological risk in Mediterranean countries’’ Proceedings of the MED-FRIEND International WorkShop on Hydrological Extremes, held At University of Calabria, Cosenza (Italy), pp. 169-182, 2011.

G., Mahe, A., Emran, Y.T., Brou, A.Z., Tra Bi, ‘’Impact de la variabilité climatique sur l’état de surface du bassin versant du Bouregreg (Maroc)’’ European J. Sci. Res. vol. 84, n°. 3, pp. 417–425, 2012.

E.H., Ouharba, ‘’Effet des Fluctuations Climatiques sur la phénologie, la croissance et la production agricole à Rommani, Region de Rabat’’, Memoire de Master, Université Mohammed V- Rabat, FSR, pp. 1-83, 2011.

C.O., Stöckle, M., Donatelli ,R., Nelson, ”CropSyst, a cropping Systems Simulation Model’’, European Journal of Agronomy, vol.18, n°. 3-4, pp. 289-307, 2003.

Z., Tra bi, Z., Kolibi, T., Yaobrou, et al., ‘’Télédétection et analyse statistique de la dynamique de la Végétation dans un contexte de variabilité climatique sur le basin versant du Bouregreg (Maroc)’’, Climate and Surface, changes in Hydrology, proceeding of H01, IAH-IAPSO-IASPEI Assembly, Gothenburg, Sweden, July (IAHS) n°.359, 2013.

IPCC, ‘’Climate Change’’, Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], Geneva, Switzerland, pp. 1-151, 2014.

IPCC, ‘’ Special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening’’, the global response to the threat of climate change, development, and efforts to eradicate poverty, Geneva, pp. 1-630, 2018.

A., Voldoire, E., Sanchez-Gomez, et al., ‘’The CNRM-CM5.1 global climate model: Description and basic evaluation’’, vol.40, n°.4, pp. 2091-2121, 2012.

Houghton, J., ‘’Global Warming’’, the Complete Briefing, Cambridge, (Third edition.) Cambridge University Press, vol.3, n°.3, pp. 1-382, 2004.

H., Le Treut., van Ypersele J.P., Hallegatte S. et Hourcade J.Ch., (directeurs), ‘’Science du Changement climatique, Acquis et Controverses’’, Paris, Claire Weill (édition), Iddri, vol.6, n°.5, pp. 1-108, 2004.

SIGMED, ‘’Approche Spatialisée de l’mpact des activités Agricoles au Maghreb sur les transports solides et les ressources en Eau De grands bassins versants’’, Projets Mediterraneens de Recherche Scientifique Inter-Universitaire (MeRSI)-AUF, Rabat, 2012.