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Drought modelling under climate change in Tunisia during the 2020 and 2050 periods

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SUMMARY – For a country like Tunisia, drought is probably the most feared phenomenon of the expected climatic change during the XXI century. The present work, based on simulation results of the most recent general circulation coupled model HadCM3 of the Hadley centre, aims to encode and to specify the severity of the phenomenon. The methodology is based on: (i) the analysis of the variations of the yearly and seasonal average precipitations, (ii) the calculation of ratios concerning the deciles medians in order to analyse years and extreme seasons, and finally (iii) deviation from averages of the considered climatic period. Horizons years are 2020 and 2050 and variations are referenced to the 1961-1990 climatic period. Main results show: (i) slight decreases in precipitation means, around 5 to 10% from north to south on the horizon 2020 and more pronounced reductions, 10 to 30% on the horizon 2050; (ii) decreases of the averages of the very humid and very dry years are expected as well as decreases for springs and very humid and very dry falls; (iii) a global increase of dry years as well as of their successive occurrence two and three in the central and southern part of the country; and (iv) higher disparities between seasons and geographical regions of the country especially on the horizon 2050. These results indicate an accentuation of droughts in Tunisia for the future horizons in relation to the 1961-1990 climatic period and come to specify and to confirm previous works in this domain.

Key words: Tunisia, climate change, drought, modelization, 21st century.

Introduction

Located on southern bank of the Mediterranean and in the north of Africa, Tunisia is a country dominated by an arid climate characterized by a very strong variability. The analysis of the drought severity as well as the variability of the rainfall mode during the 20th century were the subject of several studies (Benzarti, 1994; Sakkis *et al.*, 1991; Sakiss *et al.*, 1994). A total historical analysis of the climatic drought (Ministère de l'Agriculture et des Ressources Hydrauliques, 2000) shows that it is difficult to specify a cyclic frequency of the phenomenon and that this is frequent and scouring (El Frigui, 2000).

According to these investigations, the drought never exceeded 5 successive years, the phenomenon of the isolated dry year is most frequent in the "tellienne" part of the country, it occupies 48% to 66% of the cases. The drought being spread out over 2 years successive is dominant in the Centre (33.5% of the cases). In the South, the 3 years succession dry constitutes 34.6 % of the cases (Hajri, 1996). The longest dry period was raised during the years 1943-1948.The dry years of deficit ranging between 30% and 50% compared to the normal are prevalent, whereas the very dry years of deficit higher than 50% are rare in North but more frequent in the Centre and the South (Ministère de l'Agriculture et des Ressources Hydrauliques, 1999). The one year frequency dry is high in all the country, frequency the two years and more is relatively low in the North, average in the Centre and more frequent in the South. During the period 1985-1997, the three years succession dry was recorded only in North (1987-1990) but no succession higher than four years was recorded. The South was less affected by drought during this period, the years 1988-1989 and 1993-1994 were dry in North but normal in the South. Drought having touched all the country existed during the years 1987-1988, 1994-1995 and 1996-1997, finally the last decades seem to be more charged of which the period 1985-1997 (King and Nasr, 2005).

Concerning future projection, the majority of the models (Giannakopoulos *et al.*, 2005; Hulme *et al.*, 2001) envisage for Tunisia an increase of the drought during next decades. The objective of this study is to use the results of simulations of the most recent model of Hadley Centre (HadCM3) in order to quantify the phenomenon during the future horizons 2020s and 2050s.

Methodology

The results presented below result from simulation by the HadCM3 coupled model developed by Hadley Centre (UK) and largely described by Gordon *et al.* (2000). The selected scenario of projection is the scenario A2 according to the report of the IPCC (2001). To show regional disparities, the country was subdivided in 6 geographical areas, namely Western North (WN), Eastern North (EN), Western Centre (WC), Eastern Centre (EC), Western South (WS) and the Eastern South (ES). We are interested in this part in the analysis of rainfall extremes (year and/or season very dry and very wet) and in the regional drought of the horizons 2020s (2011-2040) and 2050s (2041-2070). The variations are given compared to the based period 1961-1990. The study of extremes is based on the analysis of the medians of the deciles from the population (1st decile, very dry year or season and 9th decile, very wet year or season). For the regional drought, the analysis is centred on the number of dry years as well as the succession of dry years (e.g. 2 dry years [ss] or 3 dry years [sss]). One year is known as dry when the deficit rainfall is between 30% and 50% of the mean of the considered period, and it is very dry when this deficit exceeds 50%.

Results

Falls of mean rainfall by 2020s and 2050s compared to the based period 1961-1990

The general trend of rainfall is to fall, and this fall remains weak by 2020s (Fig. 1). It can vary from 5% in the north, 8% in the centre to 10% in the extreme South.

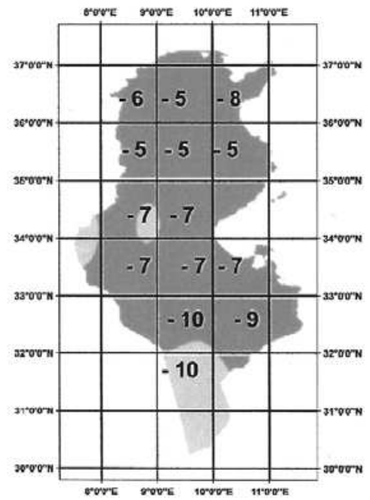

Fig. 1. Falls of rainfall (%) in Tunisia during the 2020s period as compared to the 1961-1990 one according to simulation of the HadCM3-A2 model.

During the 2050s, this fall will have to be accentuated; it varies from 10% in the WN with 30% in the extreme South. One distinguishes overall three zones from variation: (i) the extreme West of the country (-10%); (ii) the South is the zone with stronger fall (-27%); and (iii) the remainder of the country is located as intermediate zone (from -12% to -16%).

Concerning the seasonal variations, the results of the model indicate a downward trend. In the horizon 2020s, the winter can undergo the weakest fall (from 0 to 7%), the summer the strongest fall (from 8% to 40%), from the North to the extreme South. The autumn and spring will be intermediate according to the A2 scenario which indicates falls going to 6% in North and 12% in the extreme South. During the 2050s horizon, this same trend will have to be accentuated. The winter remains the season with weaker fall (3% to 11%), the summer with stronger fall (16% to 50% in the extreme South). Between 2020s and 2050s, the autumn seems to know a stronger fall (12% to 36% from North to extreme South) compared to spring (12% to 20%).

Variations of the rainfall of very wet and very dry years on the basis of ratio of deciles compared to the based period 1961-1990

Horizon 2020s – The North can undergo a weak fall of 2% of the median of the very rainy years and a fall of 7% of the median of the very dry years (Table 1). In the Centre, falls of 3% of medians of very rainy and very dry years are indicated. The South undergoes a fall of 14% for the median of the very rainy years while no change for the very dry years.

Horizon 2050s – In the North, one can observe a fall of 18% of the median of the very rainy years and drops less by 8% of the very dry years. In the centre, a great fall of 30% for the very wet years and a fall of only 7% for the very dry years. In the South, the ratio of the deciles will have to drop by about 17% for the very rainy years and very dry years.

The fall of the medians as compared to the based period 1961-1990 will be slightly more marked for the very wet years than for the very dry. The same trend will have to be accentuated by 2050s. The NW region with weak falls of the medians of the very wet years (2%) and very dry years (5%) proves to be the least unfavourable area.

Table 1. Ratio of deciles between 2020s, 2050s and the based period 1961-1990 of rainfall for different regions of Tunisia according to the HadCM3-A2 model

	Very rainy years		Very dry years	
Regions	2020s	2050s	2020s	2050s
WN	1.03	0.90	0.95	0.95
EN	0.93	0.74	0.91	0.88
WC	0.96	0.65	0.95	0.88
EC	0.97	0.74	0.99	0.96
WS	0.83	0.86	1.00	0.78
ES	0.89	0.71	0.99	0.90

Regional drought analysis

By 2020s, the general trend of the number of dry years is the increase. This same trend will have to be accentuated by 2050s (Table 2).

Table 2. Percentage of dry years during the based period 1961-1990 and future horizons 2020s, 2050s for different regions of Tunisia according to the HadCM3-A2 model

Regions	1961-1990	2020s	2050s
WN	4%	10%	20%
EN	10%	10%	20%
WC	10%	17%	20%
EC	10%	23%	23%
WS	20%	24%	27%
ES	14%	15%	30%

For the North, if the number of dry years ranges between 4% and 10% during the base period, it will increase to 7% to 10% by 2020s and 20% by 2050s. In the Centre, the number of dry years is 10% and will increase to 17% and 23% in the East part by 2020s and will be stabilized by 2050s. The South of the country, where the number of dry years was highest during the base period (14% and 20%) as compared to the North, will increase to 15% and 24% by 2020s and reaches 37% in the ES by 2050s.

For the successions, north is dominated by the isolated dry years (s) during the based period 1961-1990 and will be it according to these results for the 2020s and 2050s periods. For the centre, one can especially attend an increase in the two years successions (ss) by 2050s whereas for the based period, the area was especially dominated by the isolated dry years (s). In the south one notes an increase of two successions (ss) and three successions (sss) especially by 2050s.

Conclusions

Results of the HadCM3 model come to confirm the majority of the models and scenarios for Tunisia with knowing a stressing of the drought during the XXI century. The results resulting from simulations specify this tendency for the various areas where one assists with total falls of the average quantities of precipitations by 2020s, this fall remains weak and will have to be accentuated starting from this expiry. This tendency will be characterized by a regional disparity between North, the Centre and the South as well as a disparity between the seasons. The North of the country can undergo the weakest falls, with the contrario, the South will have to undergo the most significant variations. The winter is the season with weaker fall, the summer with the strongest fall, the autumn and spring are in intermediate situation.

In addition, the analysis of extreme precipitations based on the ratio of the deciles indicates a general fall of the averages of the very wet and very dry years. The North-West is the least touched area or almost saved, with the contrario, the South will have to undergo the strongest variations. The falls of the averages of these extremes will touch more the very wet years and seasons than the very dry years and seasons.

The analysis of the regional drought shows a general increase in the number of dry years by 2020s and 2050s compared as to the based period 1961-1990. The North will remain dominated by the isolated dry years whereas the two years and three years successions can increase in the South of the country.

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