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Abstract. This study addresses the impact of drought events on olive production and cereals, particularly durum wheat in Tunisia. In the case of olive production, during three decades since the seventies the frequencies of wet, normal and dry years were calculated for several locations in central and southern Tunisia according to a five levels scale. The same trend was observed for all the studied locations (8) with an increase of dry and particularly extremely dry years. Dry episodes were identified. According to locations specificities and vulnerability it was accepted that a sequence of one dry spring and one dry autumn could be qualified as drought. After identification of drought episodes, their impacts on olive production were assessed. During the last drought episode (1999-2002), the decrease of olive production was more than 90% affecting farmers' income. In the case of cereals, a comparative analysis of durum wheat vulnerability to the drought phenomena in rainfed areas is undertaken in three bioclimatic stages, through an assessment of the output and farmers' income variability between normal and dry years, as identified through the standardized precipitation index. Durum wheat is revealed to be vulnerable, especially in the semi-arid stage, and has a negative impact on farm's budget. Expanding irrigated cereal areas would be an alternative and a promising practice to enhance and stabilize cereal production.

Keywords. Drought – Olive production – Rainfed olive growing – Olive grower – Durum wheat – Variability.

Apparition de la sécheresse et son impact sur la production d'olives et de céréales en Tunisie

Résumé. *La présente étude se propose d'analyser l'impact de la sécheresse sur l'oléiculture et sur les céréales, particulièrement le blé dur, en Tunisie. Les fréquences des années pluvieuses, normales et sèches ont été déterminées dans le centre et le sud de la Tunisie durant trois décades depuis les années 70. Ceci a été réalisé en se basant sur les déciles et une échelle de 5 niveaux. La même tendance a été observée pour toutes les zones avec l'augmentation des années sèches et extrêmement sèches. Une succession d'un automne et d'un printemps secs a été considérée comme une période de sécheresse en tenant compte des spécificités des régions concernées. L'impact de la sécheresse sur la production oléicole a été déterminé pour la dernière période de sécheresse. Il en ressort une chute de production dépassant les 90%. De ce fait le revenu des oléiculteurs se trouve automatiquement réduit. Dans le cas des céréales, une analyse comparative de la vulnérabilité du blé dur conduit en régime pluvial aux phénomènes de sécheresse a été menée, moyennant l'indice de précipitations standardisé à l'échelle de trois étages bioclimatiques : l'humide, le semi-aride et l'aride. Le blé dur s'est avéré vulnérable, particulièrement dans l'étage semi-aride, engendrant un effet négatif sur le revenu de l'exploitant. L'extension des céréales irriguées pourrait constituer une alternative permettant d'améliorer et de stabiliser la production.*

Mots-clés. *Sécheresse – Production oléicole – Oléiculture pluviale – Oléiculteurs – Blé dur – Variabilité.*

I – Introduction

Over the twentieth century the rainfall decreased throughout the Mediterranean basin (Ragab and Prudhomme, 2002). Mediterranean climate is also characterized by extreme climatic conditions such as floods and droughts. Due to the observed and predicted decrease of rainfall droughts are likely to become frequent and hard especially in the arid and semi-arid regions (IPCC, 2001; Fischlin *et al.*, 2007) like central and southern Tunisia. In this area olive growing is among the most important speculations and in several cases the only cultivation able to grow in these environmental conditions. Indeed, olive tree capacity to face water shortage is acknowledged (Bonazzi, 1997; Spennemann and Allen, 2000; Loumou and Giourga, 2003). Cereals have a great importance in the Tunisian agricultural sector; they are all the more vital as the country is looking to improve production, particularly for durum wheat, considered as the first important cereal, as it represents almost 80 percent of total production, while soft wheat accounts for the reminder. The agricultural production has to adapt to the newest climate conditions for sustainability. The more vulnerable cultivations in this case are those slow to adapt like perennial cropping system, which include long-lived crops and therefore change much more slowly than annual systems (Petit *et al.*, 2005; Lobell *et al.*, 2006). Cereal crops are highly dependent on climatic conditions and subject to frequent droughts (Slama *et al.*, 2005) Olive tree is a perennial crop cultivated in rainfed conditions under the minimum viable rainfall. For this reason it is indubitably one of the more at risk crops. Consequently it seems necessary to confirm the trend of dry years and drought frequencies increasing in arid and semi-arid olive producing area of Tunisia. Then, the impacts of drought episodes on olive production have to be assessed in order prospect socio-economical impact of drought on olive farmers. The study addresses the issues and impact of drought on two sectors in Tunisia: olive production and cereals, particularly durum wheat. In the first case, the aims are: (i) to assess the trend of dry years occurrence through the analysis of three decades since the seventies; (ii) to identify the latest drought episode; and (iii) to study the impact of this drought episode on olive production in several producing locations of central and southern Tunisia. In the second case, the aim is characterize the negative effect of drought on durum wheat production using a comparative assessment of income in three bioclimatic stages: humid, semi-arid and arid stages.

II – Methodological approach

1. Impact of drought on olive production

A. Assessment of dry years frequency

Dry and wet years are defined as a deviation from normal conditions. Thus it is necessary to define normal conditions. The precipitation is the key parameter to identify annual dry or wet conditions; median instead of the arithmetic mean is less influenced by these extreme values and thus can represent the normal conditions in a more reliable way (Tsakiris and Pangalou, 2009). The frequency of dry and wet years was calculated according to the rainfall deciles (Gibbs and Maher, 1967). This technique divides the distribution of occurrences over a long-term precipitation record into tenths of the distribution. Each of these categories is called a decile. By definition, the fifth decile is the median, and it is the precipitation amount not exceeded by 50% of the occurrences over the period of record. The deciles are grouped into five classifications (Table 1). Since the seventies every year was ranked according to deciles and the percentage of wet, normal and dry years was calculated for each decade. This was done for 8 selected locations in the center east (2), center west (2), south east (3) and south west (1) of Tunisia. The eastern part is costal one and the western part is more in land.

B. Identification of last drought period

The last drought episode was that declared in Tunisia in the end of nineties. The beginning and the end of drought were identified according to deciles (Tsakiris and Pangalou, 2009). This was applied to our climatic data (series from 115 year to at least 32 years) for the selected locations. According to locations specificities (rainfed agriculture with monoculture) and vulnerability it was accepted that a sequence of one dry spring and one dry autumn (normally rainy periods) could be qualified as hard drought.

Table 1. Classification of weather conditions according to deciles

Decile classes	Corresponding weather conditions
Deciles 1-2: lowest 20%	Much below normal
Deciles 3-4: next lowest 20%	Below normal
Deciles 5-6: middle 20%	Near normal
Deciles 7-8: next highest 20%	Above normal
Deciles 9-10: highest 20%	Much above normal

C. Assessment of drought impact on olive production

In the studied zones such as Center East, Center West, South East and South West 10 location were selected in order to estimate the impact of drought on olive production. In these zones the average production for the ten years before the drought occurrence were calculated and designed as normal situation. Then, the olive productions during drought were calculated for the same areas and the production reduction was calculated as percentage of normal situation.

2. Impact of drought on cereal crops: The case of durum wheat

This part of the study consists of comparing the variability of durum wheat between normal years and dry years in rainfed systems for three bioclimatic stages: humid, semi-arid and arid stages. The Standardized Precipitation Index (SPI) was used to in the historical reconstruction of dry events and characterizes the rainfall variability over the study period (1990-2009) following Khan *et al.* (2008). The SPI is computed by dividing the difference between the normalised seasonal precipitation and its sample mean by the standard deviation:

$$SPI = \frac{X_t - X_m}{\sigma}$$

where X_t is the precipitation in year t, X_m the sample mean and its standard deviation. Since the SPI is equal to the z-value of the normal distribution, McKee *et al.* (1993, 1995) proposed a seven category classification for the SPI: extremely wet ($z > 2$), very wet (1.5 to 1.99), moderately wet (1.0 to 1.49), near normal (-0.99 to 0.99), moderately dry (-1.49 to -1.0), severely dry (-1.99 to -1.5) and extremely dry (<-2.0).

In a second step, average yields are determined for normal and dry years. The difference between the two averages obtained is then equal to the loss due to drought. The economic loss is obtained by multiplying the loss by the producer price. Then the ratio between the loss and the average income in normal years is calculated as a percentage.

III – Results and discussion

1. The case of olive production

The evolution of frequency of wet, normal and dry years showed the same trend for all the studied locations (Fig. 1). The percentage of dry years in one decade increased over the studied period. In Monastir region located in the costal central part of Tunisia the percentage of dry years reached 40% during the nineties while it was at least of 50% for all other locations. During the seventies the maximum observed value for dry years occurrence was 33% for Kairouan located in Center west and Medenine which is the more in south location near desertic climate. The frequency of extremely dry years increased in all of southern locations to be more than 30% with a maximum of 40% in Jerba in the nineties. This situation was confirmed in the central eastern part of the country but with lesser importance where ¼ of the years during the nineties was extremely dry. In three locations (Kairouan, Sidi Bouzid and Gafsa) the eighties were drier than the nineties with 60% of dry years. The concerned area is located inland far from the influence of the sea. Conversely, the extremely wet year proportion tends to decrease since the seventies in all locations. The extremely wet years disappeared in Sidi Bouzid during eighties and nineties. Moreover, in the South during the nineties the frequency of wet years was reduced to 25% or less. The frequency of normal years did not show clear trend nor increasing or decreasing.

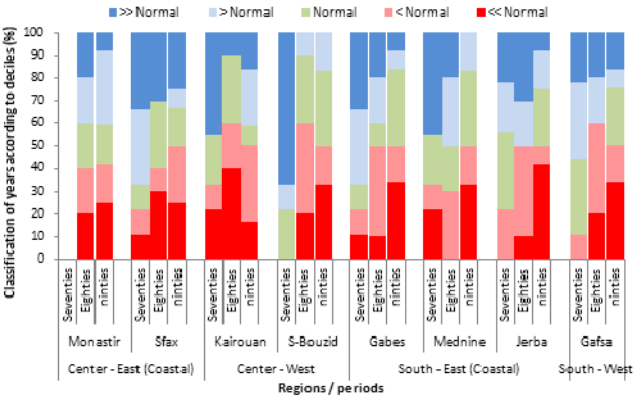

Fig. 1. Frequency of wet, normal and dry years during the seventies, eighties and nineties in central and southern Tunisia.

According to these results the general trend during the studied period is the increase of the frequency of dry and extremely dry years. Thus the climate of central and southern Tunisia seems to becoming drier than the seventies. These findings are in accordance with retrospective and prospective studies which claim that during the last century the precipitation has decreased by about 30% (IPCC, 2001; Ragab and Prudhomme, 2002), and also that the Mediterranean basin will be one of the areas subject to the most drastic reduction in precipitation (IPCC, 2001; Petit *et al.*, 2005). Accordantly, drought periods are expected to be more frequent with higher impacts.

The beginning of the nineties was classified as a wet period while their end was drought episode (Fig. 2). Until September 1999 an alternating appearance of wet and dry years was recorded. Then, a three or four years drought (Kairouan) was detected in all inland and southern locations. In the central costal area this drought was two years long. This drought had significant impacts on olive growing. Indeed in a previous work we reported that the whole number of wilting olive trees was more than 7.8 millions, located in the Center and in the South, of a total of about 60 millions trees (Gargouri *et al.*, 2008). Moreover, the most affected trees were located in the zone which faced only two years drought whereas in the more inland regions the impact of drought on olive tree was of less intensity. This drought should have important impact on population, especially rural one, due to the fact that the concerned trees are located were the olive growing is the only economically viable agricultural crop. The olive production in rainfed orchards showed a drop of 95.1% in the Center East, 91.4% in the Center West, 95.5% in the South east and 96.1% in the South West. Thus, the olive production was highly reduced in all the studied zones either in those face two years drought or in those under three years drought. This tendency was also confirmed for the whole country which had a drop of 91%. Indeed the average production of precedent 10 years was 837,500 tons and in 2001 it was 75,040 tons (FAO, 2010).

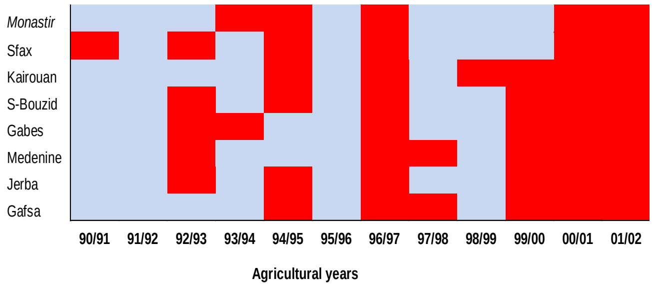

Fig. 2. Drought occurrence in the studied regions according to agricultural year and deciles; dark: drought and pale: out of drought.

2. The case of durum wheat

Since the cereals cycle generally extended from November to May, the SPI was calculated over a six months period, from November to April. Several studies have shown that the SPI has many advantages over other indices and is relatively simple, spatially consistent and allows observation of water deficits at different scales. Figure 3 characterises the drought level in each year during the last two decades. In rainfed systems, the highest average yields are commonly recorded in the humid stage, followed by the sub-humid stage, whereas the lowest yields are recorded in the semi-arid and arid stages. Previous studies indicated that drought generates generally important physical and economic loss particularly for bread wheat, compared to durum wheat and barley. Such result may not be unexpected since barley is less demanding for water. However, bread wheat is revealed to be more vulnerable to drought, compared to durum wheat.

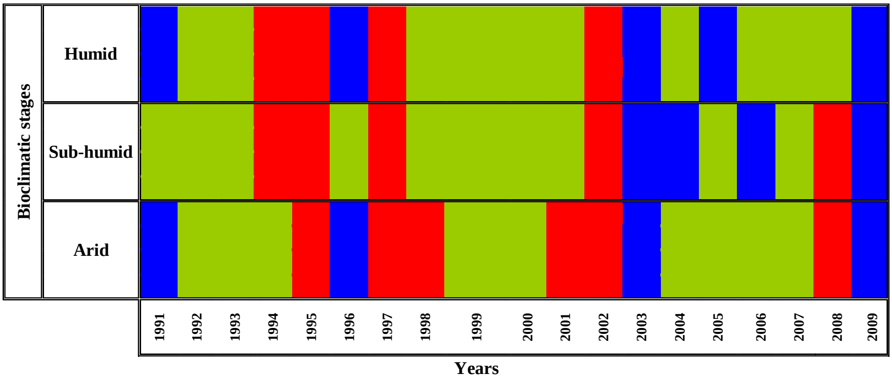

Fig. 3. Drought occurrence in the studied bioclimatic stages during the last two decades, based on ther SPI index (black: wet year; pale grey: normal; grey: dry year).

In the semi-arid climate, durum wheat is revealed to be vulnerable to drought, compared to humid bioclimatic stage. Farmers' technical knowledge and varieties adaptation are among the factors that make durum wheat better suitable to soil and climate conditions of such areas. However, the variability of durum wheat yields remains important and must be attenuated. Recorded losses are important and have an effect on production and farmers' income as they reach almost 70% (Fig. 4). Compared to the other regions, the arid bioclimatic stage is characterised by low yields that may reach very low levels, especially in drought episodes. Even if the difference seems to be weak in terms of physical loss, it remains rather important in terms of relative variation (44%). The highest loss variation corresponds to the sub-humid stage. In rainfed systems, the yield variability for durum wheat is mostly the result of fluctuations of weather conditions, especially of precipitations, that are reflected in long term averages. The risk in dry areas will be greater than in regions with higher average precipitation.

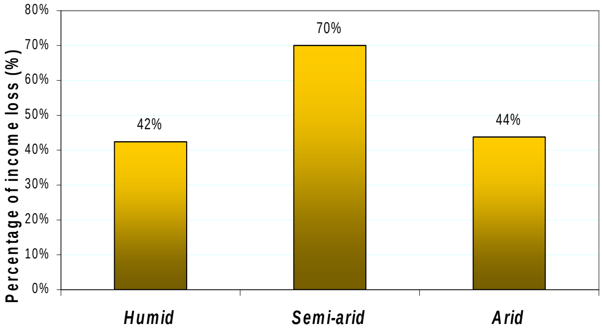

Fig. 4. Percentage of loss in farmer income due to drought for durum wheat.

IV – Conclusion

Climate change is expected to be more pronounced in the Mediterranean Basin than in most other regions of the world (IPCC, 2001). In addition the impact of climate change is and will be the increasing frequency and severity of drought. This phenomenon was confirmed through three decades since the seventies with the occurrence of a long drought at the end of nineties. The olive production was dramatically affected and since it is the only economically viable agricultural crop in most of the arid part of Tunisia, the farmer livelihood is highly reduced. In the case of durum wheat, besides outputs, yield variability due to drought is a vital important aspect as it has a negative effect of farmer income. The instability of yields at farm and regional level is revealed to be of interest to decision makers because of food security concern. Extension of irrigated cereals areas should have a beneficial effect on the crop outlook and should improve not only outputs but also farmer's income.

Acknowledgments

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