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Perception of drought by farmers and its impact on farming and irrigation practices

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Abstract. Climate change scenarios predict negative impacts on agriculture in the southern Mediterranean regions. Preparedness for increasingly frequent droughts requires a good knowledge on how chronic water shortages may affect production and cropping systems. This work investigates recent variations in agricultural production and in cropping practices in Tunisia as induced by a rapidly changing environment. Using production statistics and climatic records over the period 1984-2005, our analysis shows that variation of the agricultural production could be explained by the Standardized Precipitation Index (R^2 = 0.45), and that resilience to drought could be evaluated in the same manner. Data from surveys was used to identify adjustments adopted by farmers under the pressure of water scarcity in semi arid (Nabeul) and arid (Medenine) environments. Contrasting changes in cropping systems seem to be taking place for both regions. Contrast is also observed between irrigation strategies adopted by farmers. In Nabeul, large citrus growers having access to water from canal tend to over irrigate whenever water is available in order to minimize risks of water delivery failure from public networks. In contrast small farmers using shallow wells in Medenine seek practices such as deficit irrigation and intercropping in order to optimize water use. It is our view that options to face drought under increasing environmental stress should have a dynamic nature integrating adaptive practices used by farmers.

Keywords. Climate change – Agriculture production – SPI – Water scarcity – Tunisia.

Perception de la sécheresse par les agriculteurs et impact sur les cultures et les pratiques d'irrigation

Résumé. *Les scénarios des changements climatiques prévoient un impact négatif sur l'agriculture méditerranéenne. Une meilleure préparation face aux sécheresses fréquentes nécessite une bonne connaissance de la façon dont le manque d'eau affecte la production et les systèmes de culture. Le présent travail analyse les variations récentes de la production agricole et des pratiques culturales en Tunisie induites par les changements rapides de l'environnement. En utilisant les statistiques de production et les données climatiques relatives à la période 1984-2005, l'analyse montre que la variation de la production agricole peut être expliquée à l'aide de l'indice de précipitation standardisé (R^2=0.45). Des données d'enquêtes ont été utilisées pour identifier les ajustements adoptés par les agriculteurs en situation de manque d'eau dans les environnements semi-aride (Nabeul) et aride (Médenine). Des changements contrastés ont été observés au niveau des systèmes de culture et des pratiques d'irrigation. A Nabeul, les agrumiculteurs ayant accès à l'eau du canal tendent à sur-irriguer lorsque l'eau est disponible afin de minimiser le risque de coupure d'eau. Les agriculteurs de Médenine utilisant des puits de surface cherchent plutôt des pratiques d'irrigation déficitaire et de cultures intercalaires pour optimiser l'usage de l'eau. Il est de notre avis que des options permettant d'atténuer les effets de la sécheresse sous des pressions multiples devraient être dynamiques et prendre source dans les réponses adaptatives des agriculteurs.*

Mots-clés. *Changements climatiques – Production agricole – SPI – Manque d'eau – Tunisie.*

I – Introduction

Within the context of climate change, most simulation models predict a reduction of water availability as a result of changes in temperature and precipitation regimes. Rainfall intensity and variability with extreme droughts are expected to increase significantly. The scenarios are especially consistent in predicting drier soil over the Mediterranean in all seasons (Wang, 2005).

Climate change will also result in an increase of irrigation demand due to the combination of decreased rainfall and increased evaporation (Bates *et al.*, 2008) and in a change in water quality which is particularly critical for irrigated agriculture.

Farming in the Mediterranean, particularly in the semi arid and arid areas, will face increased drought vulnerability and risk of the production systems due to land and water resources degradation (over-extraction of groundwater, soil salinization and soil erosion). This will affect food availability and the livelihood of rural farmers. To meet the challenge of climate change and mitigate impacts of drought, a learning process from innovation and adaptive measures used by farmers under the various stressors, should be initiated in our region.

Our work deals with the question of drought, its perception and impacts on crop production and on irrigation water management strategies. In this paper we present results concerning the impact of rainfall variation on agricultural production in Tunisia and on management adjustments adopted by farmers in two typical situations of the semi arid and arid areas. For the study we selected Nabeul in northern Tunisia and Medenine in the more arid part of the country, with respectively a long term rainfall averages of about 450 and 150 mm and annual reference evapotranspiration of 1100 mm and 1500 mm.

II – Perception of drought

As defined by the US Weather Bureau, "drought is a lack of rainfall great as so long continued to affect injuriously the plant and animal life and to deplete water supplies...". Drought can be seen from different facets; however it refers to precipitation deficit compared to the normal values. Economic, social and environmental problems are associated with drought; their importance depends on its duration, its frequency and its intensity. Characterization of drought events aims at determining appropriate response to climatic risks. Decision making requires precise information for appropriate water supply planning and management and for authorizing assistance to farmers affected by drought.

Several indices have been developed to simplify this complex situation and summarize a large amount of data on rainfall, stream flow, and other water supply indicators into a single number. Most of them measure the deviation of precipitation from historically established norms for a given period and location. Palmer Drought Severity Index has been used by the US Department of Agriculture to monitor emergency drought assistance. The deciles method, a more simple method, has been instead selected by the Australian Drought Watch System for the same purpose, while other indices more or less complex are used by the water supply planners. The Standardized Precipitation Index (SPI) as proposed by McKee *et al.* (1993) is probably the most popular method used as a measure of drought intensity.

Drought indices are used for assessing impact on crop yields (Quiring and Papakryiakou, 2003; Wu *et al.*, 2004; Todisco *et al.*, 2008). Using remote sensing data Vincente-Serrano (2007) showed that vegetative activity is well correlated to SPI in dry-farming areas of the Ebro in Spain. In Australia, SPI correlates well with fluctuations in shallow ground water table in irrigation areas, and can also capture major drought patterns (Khan *et al.*, 2008).

SPI has the potential to assess several aspects of agricultural and environmental processes related to drought. However, in Tunisia, this method hasn't known applications beyond the research circle. We consider that SPI is effective in detecting annual droughts, however for operational applications, other factors should be considered to better estimate water availability to crops. With annual SPI, the start and the end of a drought event could not be set precisely. Whereas for shorter periods the index cannot be linked to crop growth, because it considers rainfall variation around the mean uniformly, regardless of the received amount. This shortcoming is particularly important for summer precipitations, since small shower may result in high SPI values while the impact on soil moisture increase is negligible.

III – Impact on crop production

Characterization of recent drought events in terms of severity was carried out using the SPI method and monthly rainfall data over the periods 1940-2006 for Nabeul and 1925-2006 for Medenine stations. SPI mean values between the two stations was used to assess quantitatively the impact of drought on agriculture.

Total agricultural production is obtained from the summation of all products of fruits, vegetables, cereals and olive oil for the period 1984-2005 as reported by the Ministry of Agriculture (Minagri, 2007). The trend summarizing the technological progress was removed from actual values in order to compare production variation with rainfall fluctuation. Figure 1 shows the range of variation of total production in million tons in relation to SPI.

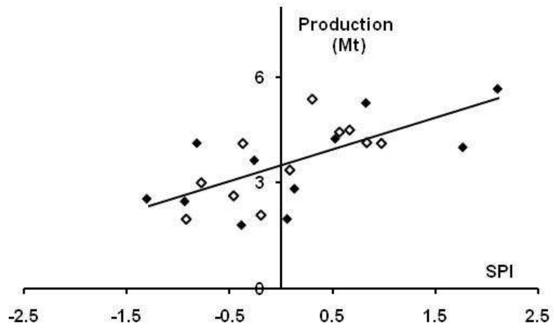

Fig. 1. Annual production variation in relation to SPI. White and black marks refer respectively to the periods (1984-1994) and (1995-2005) showing more extreme events for the last period.

A good correlation between the total agricultural production and SPI seem to hold ($R^2 = 0.45$). Production relative to dry years of the period 1995-2005 is mostly above the regression line, except for 2002 which is the third dry year in a row. Comparing production and SPI over the periods 1984-1994 and 1995-2005 we observe an overall increase of variance for both parameters. For below-normal years the first period showed lower production and higher SPI compared to the latter one. Respectively we obtained 2.75 Mt/y for an SPI of -0.54 and 2.90 Mt/y for -0.74. Apparently a significant gain in productivity has been achieved by the entire sector. Actions for drought mitigation were aimed to mobilize more water, develop irrigation and provide incentives to improve water productivity. Important investments concerned the construction and interconnection of dams and the development of small reservoirs. Other measures were taken to improve irrigation efficiency by subsidizing investments in water saving equipments.

IV – Impact on irrigation practices

Significant changes in irrigation strategies occurred during the last twenty years. After launching the national program for supplemental irrigation of cereals in the late 1980s, practices such as irrigation of winter crops, inter cropping and deficit irrigation have been gaining wide adoption in most regions.

Analysis of data on Nabeul and Medenine obtained from national surveys (Minagri, 1996, 2006) shows contrasting changes in these typical regions within the ten-year period 1994-2004. In Nabeul, irrigated areas increased by 21% with a clear trend to high value crops such as fruit trees. Vegetables regressed wheras forages have known a substantial development apparently because of important development in animal production. In Medenine, there has been a decrease in the cropped area and the number of farms respectively by 3% and 18%. The total irrigated area decreased by about 10% probably because of groundwater depletion induced by overexploitation and salinization problem. However, unlike Nabeul there seems to be a shift from fruit trees to growing more vegetables.

The participatory research work with farmers from the two sites allowed identifying changes in irrigation practices induced by chronic water shortages. Table 1 summarizes the main adjustments used by farmers.

Table 1. Differential impact of drought on irrigation practices and reactive responses of farmers under two contrasting environments

Survey area	Investigated farms	Observed adjustments
Nabeul (semi-arid, 450 mm)	12, large state and private citrus growers	Over irrigation early in the season, deficit irrigation in summer, supplementation from groundwater having higher salt concentration
Medenine (arid, 15 adjustments 0 mm)	16, small private properties on shallow wells	Use of very saline water from shallow wells (3-7 dS/m), shift to winter production of vegetables, development of inter-cropping with drip irrigation

Drought is perceived by farmers as a diminution of water resources, soil degradation, and a decrease of agricultural production and income. As consequence of successive droughts, farmers developed management strategies to reduce drought impacts. For both sites there seems to be an urgent need for more knowledge and human capacity building in order to adapt to a rapidly changing environment.

V – Conclusion

Drought sequences have direct impacts on both production and cropping systems. The Standardized Precipitation Index is a valuable mean for a first hand analysis of the overall impact of rainfall deficits on agricultural production. However long term changes in cropping systems and irrigation practices require specific identification of production determinants. Concerning preparedness to increasing water scarcity in the region, practices used presently by farmers in semi arid and arid areas could be considered as "adapted responses" to all constraints including water, market and population increase. Recent adjustments can provide key elements for devising appropriate dynamic water management strategies for the Mediterranean region.

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