Farmers' adaptation strategies to water scarcity and evolving water access: lessons from the Lebna watershed in Cap Bon and the Kairouan plain (Tunisia)

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Introduction

Irrigating farmers in Tunisia are facing a variety of risks, including increasingly frequent water shortages, due to institutional, political and climate changes. To protect themselves from these risks, farmers implement a variety of adaptation strategies that can be classified into four categories: (i) water management adaptations; (ii) investments in irrigation equipment; (iii) changes in farming practices and productions; and (iv) farm-household management options (Molle et al., 2010; Harmanny and Malek, 2019). Understanding the factors driving farmers' choices is crucial to support them in their strategies to mitigate and cope with water scarcity. Economic literature related to farmers' vulnerability and adaptation has pointed out the role of various livelihood assets (natural, physical, financial, human and social), as important factors to reduce farmers' vulnerability (Quandt, 2018; Singh and Nair, 2014). More recently, several studies, based, among others, on the Protection Motivation Theory (PMT), showed that psychological factors are of crucial importance in the adaptation to water scarcity (Dang et al., 2014). PMT assumes that an individual's decision to adapt to a risk is based on two cognitive processes: the individual considers firstly how he/she perceives the probability of occurrence of the risk and the severity of its consequences; then, he/she takes into account how he/she perceives the efficacy of the various possible measures, and his/her own capacity to implement them. Following these works, we address two research questions in this study: (i) how did Tunisian irrigating farmers adapt to various water scarcity events in the recent past? and (ii) What are the respective role of assets endowment and psychological factors to explain their past adaptation strategies?

Methods

Case studies

Our two case studies are located respectively, in the Cap Bon region, in the northeastern part of Tunisia, and in the Kairouan plain, in central Tunisia. The Lebna catchment area, in Cap Bon, covers an area of 210 km². The main crops in the watershed (market gardening) are high value and high water demanding. Irrigation water supplied by the public schemes either originates from the Lebna dam (e.g. Lebna barrage and Asfour schemes) or the Medjerda-Cap Bon Canal transferring water stored in dams along the Medjerda River Valley in Northern Tunisia (e.g. Lebna village and Teffeloun schemes). An increasing number of farmers complement their water supply with private wells taping shallow groundwater. Our case study in the Kairouan plain corresponds to the seepage area of the Oued Merguellil downstream of the El Haouareb dam, which covers about 355 km^2. The area is characterized by (i) a high agricultural potential (olive groves, fruit orchards and market gardening cultivated mostly in intercropping); (ii) a large and easily accessible aquifer; and (iii) unregulated access to groundwater via public irrigated schemes (e.g. Ben Salem 2 and 3 schemes) and private wells and boreholes, mostly unauthorized. In addition to groundwater, some irrigated schemes are supplied from the El Haouareb dam (e.g. Haouareb 1 and 2 schemes). In each case study, four public irrigation schemes with varying balance between surface and ground water sources were selected for the survey. In both areas, major drought periods affected farmers in the recent past. In addition, farmers also experienced water shortages due to dysfunctions in the management of public irrigation schemes.

Methodological approach

To answer our research questions, we adopted a four-step approach: (i) Territorial diagnosis: existing literature on the case studies was complemented by interviews with local actors (agricultural administration, water user associations managers) and field visits; (ii) Survey design: the questionnaire is composed of three parts. The first is devoted to socio-economic data and the description of livelihood assets; the second aims

to identify recent situations where farmers had to cope with water scarcity and their adaptation measures; the third is devoted to the measurement of Protection Motivation Theory concepts: perception of risks associated with water scarcity, assessment of the effectiveness of adaptations and farmer's implementation capacity, subjective norms, etc. (iii) Farmer survey: 58 irrigating farmers were surveyed in the Lebna catchment in May-June 2021 and 100 in the Kairouan plain in June-July 2022; (iv) Data analysis: data collected were analyzed using descriptive statistics and multivariate data analysis techniques.

Results and discussion

Characteristics of the surveyed farms

While irrigated annual crops (mostly market gardening) are dominant in downstream Lebna (92% of the cultivated area in winter and 82% in summer), permanent crops occupy 65% of the cultivated area of the surveyed farms in the Kairouan plain. In both areas, irrigation allows the intensification of cropping systems, which takes the form of two successive annual crops in Lebna, and the association of various species of permanent crops or intercropping of annual crops with permanent crops in the Kairouan plain.

Surveyed farms are characterized by the high age (52% and 41% are aged 55 or above respectively in Lebna and Kairouan plain) and low education level of farm heads, and the frequent use of casual labour. Average farm size is low (5.3 ha in Lebna, 7.6 ha in the Kairouan plain). Consequently, two thirds of the farming households in the Kairouan plain (but only 28% in the Lebna) complement their income with off-farm activities. Almost half of the land is rented in Lebna, while direct farming dominates in the Kairouan plain.

Farmers access water from different sources (Figure 1), with a combination of water sources varying with the irrigation scheme. Farmers' perception of the state of the collective irrigation network varies greatly with the irrigation scheme. In general, Lebna farmers enjoy a higher flexibility of water supply than in the Kairouan plain. Indeed, in Lebna most farms have more than one type of water source (67% against 15% in the Kairouan plain), and own a private well or borehole (66% against 34% in the Kairouan plain). Despite their more flexible water supply, Lebna farmers consider the water availability more constraining than Kairouan farmers. In both areas, the share of farmers satisfied with their water availability is higher among those who own a private borehole than those who rely only on the public irrigation scheme.

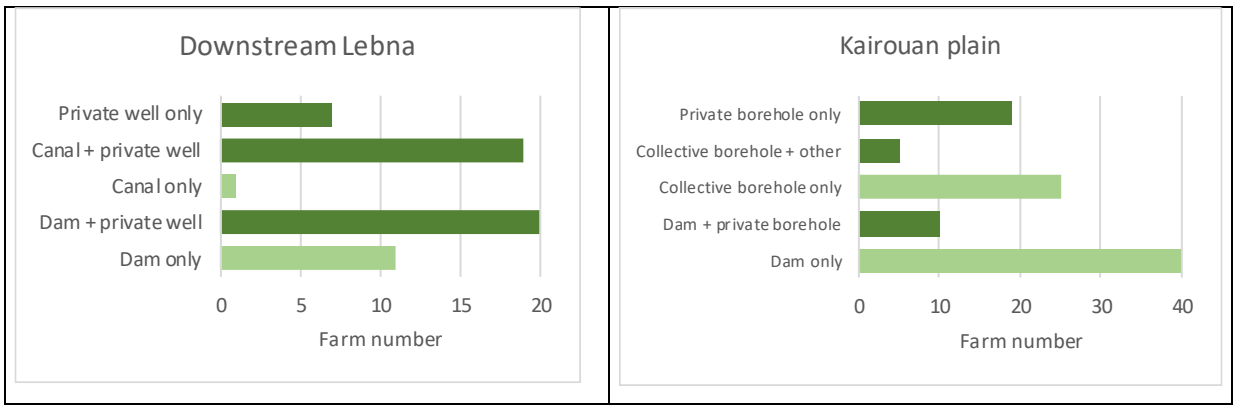

Figure 1 : Type of water access in Lebna downstream catchment and Kairouan plain

Diversity of adaptation strategies according to the irrigation scheme and time of adaptation

Drought is the main cause of water scarcity acknowledged by the interviewed farmers, the second - much less frequent - is a failure of the collective water distribution system. All farmers identified the most recent years as the most severe situations of water scarcity. Faced with water scarcity, the interviewed farmers implement a high diversity of adaptations, often several of them at the same time (8.5 measures per farm in Lebna, 13.4 in the Kairouan plain). In the Lebna, adaptations related to water management (changes in irrigation doses, reallocating water among crops, water storing, seeking alternative sources) are dominant when the drought occurs, while in the medium term adaptations more often concern crop choices and management (fallowing, choice of crops with low water needs, change of varieties, diversification of crops...) (Figure 2). Except for the decreasing of non-essential family expenses and decapitalization, adaptations affecting the household as a whole are less frequent. In the Kairouan plain, the distinction between adaptations implemented when the water shortage occurs and later on is less clear. Indeed, in this area,

farmers declared that 88% of adaptation measures were implemented at the time of water scarcity (against 27% in the Lebna). This may be due to some long-lasting situations of water scarcity (up to several years), but also to a confusion between the time the decision is made and the time the measure is actually implemented. In the short and medium term and in both areas, adaptation strategies vary according to the irrigation scheme, depending on the mix of water sources available to farmers. Differences between irrigation schemes are more pronounced in the short term in Lebna and in the medium term in the Kairouan plain (Figure 2).

The distribution of adaptations across the main categories (water management, water investments, production management, household management) is similar in both areas. However, the most frequent measures within each category differ between the areas: the most frequent water management measure is the change in irrigation doses and calendars in the Kairouan plain, and the use of alternative water sources in Lebna. Regarding irrigation equipment investments, plot-level equipment is more frequent in the Kairouan plain, whereas storage equipment and individual borehole drilling dominate in Lebna. Similarly, among measures related to production management, changes of cropping practices are more often adopted in the Kairouan plain whereas fallowing is more frequent in Lebna. Finally, the reduction of non-essential family expenses is the most often adopted household management measure in both areas.

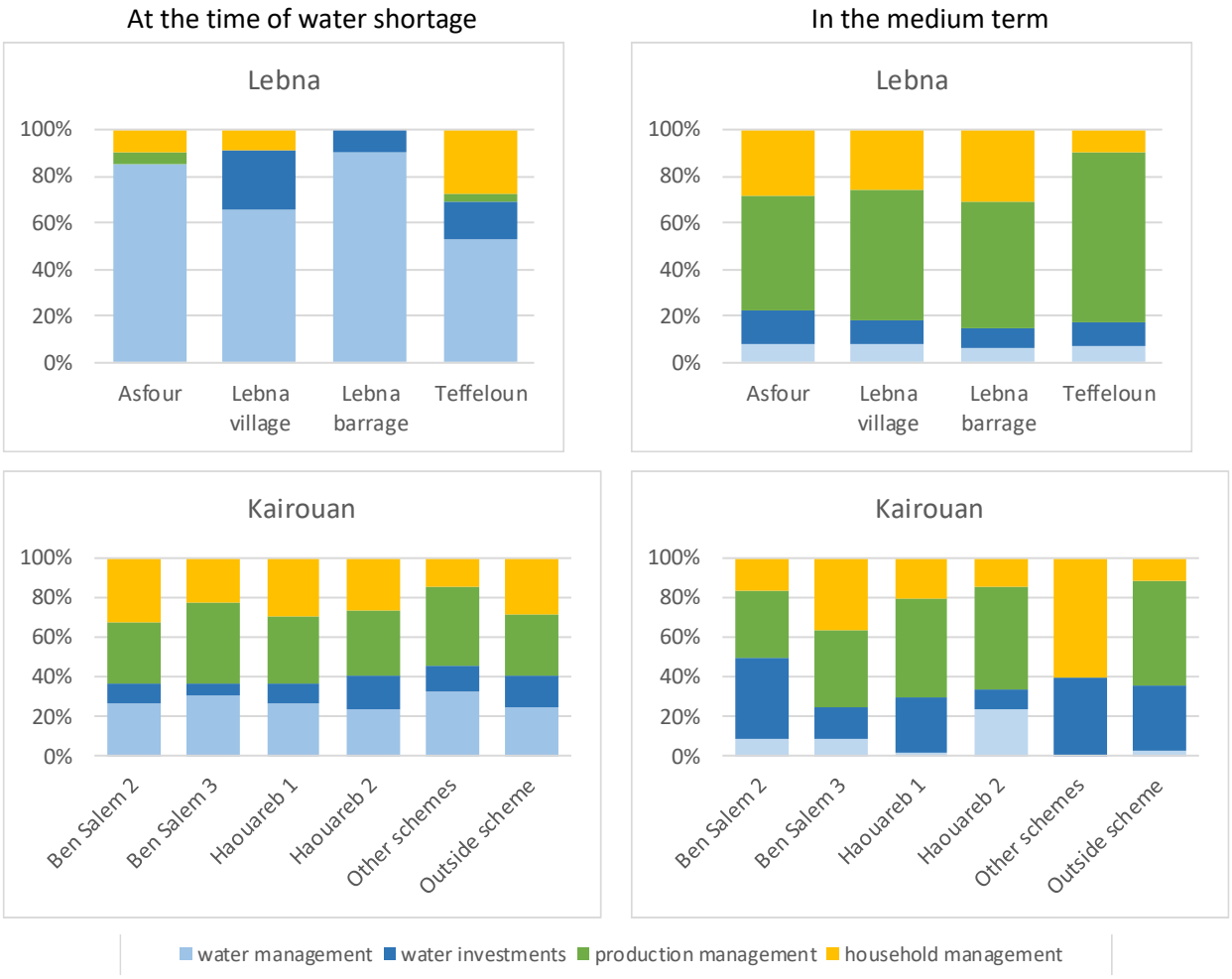

Figure 2 : Diversity of adaptations to water scarcity according to the study area, the irrigation scheme and the time of implementation

Role of psychological factors

In general, the vast majority of the farmers are conscious of the likeliness of water shortages in the future and the severity of the damages caused by water shortages on different aspects of their lives. Perceptions are relatively homogeneous, except for the effects of water scarcity on relations with other farmers. In accordance with the perception of the water constraint, the perception of the likeliness and the severity of detrimental effects of water scarcity is higher in the Lebna than in the Kairouan plain.

As expected, the most frequently implemented adaptations are also those assessed by farmers as the most effective and those they feel they are more capable to implement, with the exception of two emergency measures: the abandonment of the irrigation of certain crops and the reduction of non-essential family expenses, used when farmers have no other alternatives. Conversely, perceived effectiveness and implementation capacity of the less frequently adopted measures are among the lowest in both areas.

Responses of farmers to the questions related to psycho-cognitive factors of adaptation show that the farmers are sensitive to the adaptation choices of their peers but less to their prescriptions, are generally reluctant to change their current, long-standing practices, and express a certain fatalism and powerlessness about water scarcity, in relation to religious traditions. These attitudes seem stronger in the Lebna area than in the Kairouan plain.

Furthermore, farmers are very critical of the administration's (in)action to support them in their adaptations. According to farmers, the only public adaptation measures cited, the increase of water and energy prices, have influenced greatly their adaptation behavior. Their opinion on water management by water user associations is more contrasted and varies with the irrigation scheme.

Conclusion

Adaptation to water scarcity is a complex process that involves several types of factors, not only socio-economic but also psycho-cognitive. However, the influence of the latter is little explored in the literature on farmers' adaptation. Preliminary results presented in this paper shows that irrigating farmers' adaptation strategies to water scarcity in Tunisia are diverse and vary with the context of water access (typically the irrigation scheme and geographical area in which they are located). Results also suggest that some psycho-cognitive factors such as farmers' perception of the efficiency of adaptation measures and of their own capacity to implement them may have an influence on their choice of adaptations. On the other hand, the homogeneity of their perception of the probability and severity of the risk of water shortages, and of their attitude towards subjective norms suggests that these have little effect on their choices. Data analysis will be pursued with an additional survey in Lebna, in order to strengthen the statistical validity of the results, the construction of a typology of farms in each of the areas, based on their asset endowment, and the econometric modelling of the relationships between adaptation strategies, asset endowment and psycho-cognitive factors.

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