

Title: Farmers' relations to climate variabilities and changes: the case of groundwater users of coastal aquifers in France, Portugal and Morocco

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Introduction

According to experts, climate change is likely to exacerbate quality and quantity water related problems in the Mediterranean area (Plan Bleu, 2008) and therefore conflicts between water users. Experts on climate change call for setting adaptation measures to anticipate future crisis. This challenge will be better taken-up if participative foresight methods are used. Such methods can enhance water users' capacity to identify adaptation strategies required to cope with climate changes predicted by experts. The way such participatory process will be set up will have to take into account possible gaps between expert modeling results and water users – and in particular farmers - experience of climate.

The Mediterranean climate is a special type of climate characterized by a regime of hot summer with low rainfall and winter rain in the mid-latitudes, north of the subtropical climate zone. This climate occurs most noticeably in the regions around the Mediterranean area, but also in coastal areas of Portugal, California, South Africa and southern parts of Australia. In many Mediterranean coastal areas, agriculture, drinking water supply, tourism and industry strongly depend on groundwater resources. As a result of significant economic development over the last three decades along the Mediterranean coast (agricultural intensification, growth in tourism activities, population migration), abstraction from coastal aquifers has greatly increased. This has often resulted in a significant decline in water tables that has, depending on the local geological context, increased the risk of seawater intrusion (European Environment Agency, 2006; Santos et al., 2002). Therefore, coastal zones of the Mediterranean areas are very sensitive to possible changes in the climate.

In this context, the article presents an analysis of farmer's representations of climate and water resources, and based on this, their predisposition to discuss water resource management. The chosen case studies are three relatively small Mediterranean coastal areas characterized by important use of groundwater resources: the Roussillon aquifer in France, the Querença Silves aquifer in Portugal and the Chaouia aquifer in Morocco. These resources are either in a situation of current overexploitation and seawater intrusion (in the Chaouia case), or at risk of overexploitation (cases of Querença Silves and Roussillon). The study was undertaken in the frame of the Aquimed project funded by the Circle-Med program and develops methods to support local stakeholders in undertaking foresight analyses. It will focus on groundwater management, which remains to date a resource whose institutional settings lag behind compared to those of superficial water resources. These methods will support genuine involvement of stakeholders in dealing with resource models, climate change data and scenarios.

The article is organized as follows. The first section presents scientific assessment of climate changes in the studied areas. Next section presents the methods. In order to ease the reading, presentation of each of the cases studies was made within the result section. A final section proposes some elements of discussion based on a cross-analysis of results from the three case studies.

1. Current and future climate evolution in study areas: what scientists say

In the Mediterranean region, increasing strong climatic seasonal contrasts in the last century (severe droughts and storms) have already been highlighted by several studies (EEA, 2004; Haas, 2002). More specific analyses exist for each of the studied areas.

In the Roussillon case study area, the analysis of long time series of temperature and evapo-transpiration (1970-2006) shows the presence of general increasing trends for annual average temperature and evapo-transpiration but no clear change in average annual precipitation (Chaouche et al., forthcoming). An in depth analysis at the monthly time step shows a clear seasonal variability of changes: evapo-transpiration increases in spring and rainfall increases in autumn but decreases in spring.

In Portugal, studies on the evolution of the air temperature in the 20th century (Santos et al. 2002) show a similar tendency to that observed in the Mediterranean area: i) the average air temperature increased up to 1945, then cooled down slightly, and went back up again, more intensely, from 1975 onwards; ii) much of the temperature rise is due to an increase of minimum temperatures, “attributed to a reduction in how often extremely low temperatures occur” (Santos et al., 2002). The last IPCC data (2008) pointed the Mediterranean areas (including southern Portugal) as one of the most affected European regions by drought.

According to the De Martonne (1926) aridity index, the climate of the Chaouia study area is semi-arid. The El Jadida meteorological station (15 km from the research area) shows an average of 383 mm in annual total rainfall for the 1981-2007 periods. The evolution of rainfall during this period is not significant and is sensitive to changes in the selection of the study period. Therefore, analyses were made with the Casablanca station (40 km from the research area), where climate is similar and which has a longer period of data. During the 1960-2007 period, total rainfall amounts decreased with an average of -2.9 mm/yr (i.e., approximately a decrease of 7% per decade), with in particular a strong decrease in rainfall events at the end of the rainy season. Mean and maximum duration of periods with no rain also increased. With regards to temperature, El Jadida station data for the 1981-2007 period indicates an increase in the annual minimal and maximal temperature, which leads to an increase in the annual mean temperature of 0,4C°/decade, and an increase in the 10th percentile of daily minimum temperature and in the 90th percentile of daily maximum temperature. Casablanca data on a longer period shows similar trends.

These contrasts are likely to be exacerbated by global warming leading to warmer and dryer summers and more precipitation during warmer winters despite shorter rainy seasons (Gibelin and Déqué, 2003). Another significant indirect impact of climate change on agriculture is the evolution of hydrological regime of rivers and the recharge of aquifers. In the Mediterranean region, river discharges are expected to increase during fall and winter, snowmelt to take place earlier, periods of lower low flows to become longer and aquifer recharge to decrease (Caballero et al., 2005). The reduction of river base flow may also result in a shift of agriculture water supply source from surface to groundwater, increasing the pressure on aquifers. All these changes will have drastic impact on irrigation systems and water resources management. Agriculture is likely to be also directly impacted by these changes. Due to the rise of temperature, some crops (or varieties) may no longer be adapted to regions where they have been grown for decades, if not centuries. Changes in precipitation may compel farmers

to develop irrigation systems in regions where rainfed agriculture has always been the rule. Climate change may generate new technical problems, in terms of pest control, soil preparation, irrigation management, etc. compelling farmers to change their crop practices. Changes in varieties could also be required, generating a high cost for all permanent crops (orchards and vineyards).

2. Farmers facing climate variability and its impacts on water resource

2.1. Farmer representation of climate and water resources

Social representation is a socially designed and shared practical knowledge oriented towards communication, understanding and control over social, material and intellectual environment (Jodelet, 1984). A social representation may be characterized by two dimensions: i) the attitude which defines, a general orientation (positive or negative) with respect to the object of representation; ii) the information, possessed with respect to this object (Salesses, 2005). According to Hulme et al. (2009), climate is a constructed representation. People adapt their representation of normal climate during their lifetime, according to their own experience and memories of what took place. This takes place over a period of a maximum of 20 years: over a longer period of time, people only remember extreme events. Meteorological evolutions are not sufficiently rapid over such a period of 20 years: therefore people usually not see any change in the “normal climate”. Moreover, climate change, even when acknowledged, is rarely ranked as a top priority compared to other issues (Shisanya, 2007).

Farmers’ relationship to groundwater, and felt responsibility for its sound management, may be linked to their general farming choices (e.g. traditional versus pro-environmental practices) (Michel-Guillou and Moser, 2006). However, more generally, information on groundwater resource (its limits, its dynamics, the amount of water pumped, recharge rates, etc.) is complex and difficult to obtain, which makes it difficult to set up management rules (Schlager, 2007).

2.2. Vulnerability and adaptation to climate variability and change, and their impact on water resources

There is not yet a common definition of vulnerability (Adger, 2006; Fussel, 2006). Fussel (2006) distinguishes between a nature science approach and a social science approach, which starts from current abilities of individuals to adapt to current climate variability. Vulnerability is usually measured by three elements: 1) *exposure*: nature and frequency of climatic events

to which farm systems are in contact; 2) *sensitivity*: degree with which the system is affected to an exposure to climate events; and 3) *adaptive capacity*: the system capacity to face these exposures and limit damages (Yin et al. 2009). Adaptation to climate change shares many common features with risk management to natural hazards, but involves specific methodological challenges (Fussler, 2007).

There has been a wide range of studies dedicated to assess vulnerability and adaptation of farmers. These studies usually involve: 1) indicators used by farmers to describe climate variability; 2) impacts of climate variability; 3) farmer adaptive strategies (Deressa et al., 2009; Smit and Skinner, 2002; Thomas et al., 2007; Ziergovel et al., 2006). Some studies focus specifically on how farmers coped with a specific climatic event, such as a drought (Campbell, 1999; Roncoli et al., 2001). Adaptive strategies may take place both at local, farm level and more regional level (Adger et al., 2005; Osbahr et al., 2008). Other studies looked at global modification in agriculture over a long period due to on-going climate change (Yang, 2007).

3. Methodology

The study was based on individual, qualitative interviews as the main source of information. The interviews were based on a similar semi-directive grid in the three studied cases, structured according to four dimensions: i) farms and cropping systems, in particular the type of crop, the irrigation systems and the origin of the water (it included questions on technical innovation introduced in farms and the economic organization of farms, although these will not be analyzed at length in this paper); ii) climate and climate changes: description of farmers' perceptions of the climate, of its variations and of striking climatic events, and encouraging farmers to reflect on the future; iii) use of groundwater: farmers' perceptions about the availability of water and the relationship between farmers' water use and aquifers; and finally iv) participation and management of aquifers: the way farmers perceive the role of public institutions in the management of these resources, the relations that actually take place, and how different entities communicate and provide users with information and support.

Main characteristics of interviewed farmers and their farms are presented hereafter and in Table 1. In the Roussillon case, fifteen farmers and two technicians were interviewed. All farmers irrigate with groundwater. Except two wine growers, all farmers have also access to surface water network. Two are tree growers (apricot, peach, cherry) and three winegrowers. Eight produce market crops (salad, cucumber, tomatoes, potatoes, artichoke, and melon):

some farmers are specialized and others produce more than 10 products. Two retired farmers carried out all these types of production. Four farms are devoted to organic agriculture. In Querença-Silves, interviewed farmers were generally aged and all were landowners. The main type of culture is citrus, although some farmers venture into fruit culture (peach, melon, watermelon, avocado, vines...) and market crops (tomato, cabbage, potato) and all of these farmers still have rainfed cultures (almond, carob, fig and olive trees). Only one farmer produces organic agriculture. Regarding the Chaouia zone, ten farmers and a technician were interviewed. All interviewed farmers were born in the region and are landowners.

	Roussillon	Querença-Silves	Chouia
Number of interviewed farmers	15	15	10 farmers
Gender	2 women	2 women	No women
Ages	1 below 35, 4 between 35 and 50, and 10 above 50.	2 below 35, 4 between 35 and 50, and 9 above 50.	3 below 35, 3 between 35 and 50, and 4 above 50.
Main occupation	Agriculture (2 retired)	Agriculture	Agriculture
Farm size	3 between 1 and 10, 7 between 10 and 20 hectares, 3 above 30 hectares	5 farmers have between 1 and 20 hectares; 6 have up to 40 hectares and more than 40, 4 have over 100 hectares.	3 farmers have below 5 ha, 3 between 6 and 10 and 4 above 10 ha
Main cultivated crops	Trees (apricot, peach, cherry) (1), vineyards (4), market crops (salad, cucumber, tomatoes, potatoes, melon,...) (5) mixed farming (5).	Citrus trees	Market crops

Table 1. Main characteristics of interviewed farmers and their farms

4. Case studies and results

4.1 Roussillon

Study area

The Roussillon Basin is located along the southernmost part of the French Mediterranean coast, near the Spanish border (Figure 1). For centuries, water has been a limiting factor for agriculture, compensated by the development of irrigation canals and wells, and more recently reservoirs and deep boreholes.

The exploitation of the aquifers developed with diffusion of drilling techniques in the 1960's. Groundwater resources consists of a multilayer aquifer, which is intensively used for drinking water use, tourism related activities along the coast and for agriculture (irrigation of orchards,

fruits and vegetable crops). The superficial aquifer and the deep aquifer has been increasingly exploited, in particular by municipalities but also by large-scale vegetable producers.

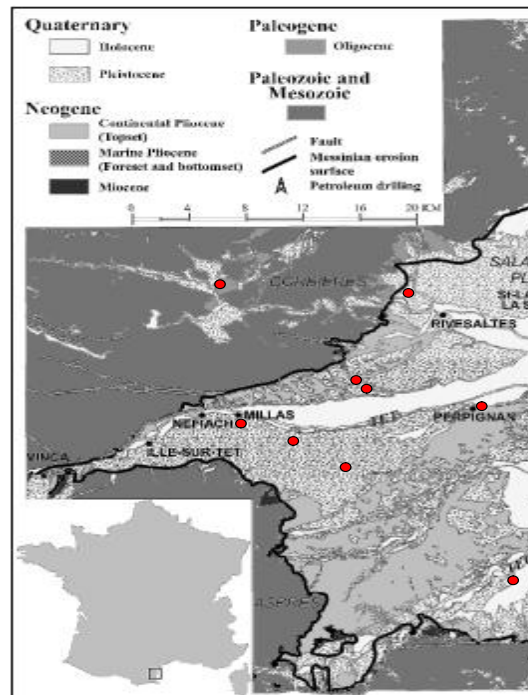


Fig 1. The Roussillon Plain multilayer aquifer (Aunay et al., 2007) and the location of the interviewed farmers.

The resulting decline in the water tables, which has been observed over the last 20 to 30 years, is expected to continue as the population keeps growing and the farming sector progressively abandons ancient surface canal irrigation systems in favour of new drilled irrigation wells and boreholes. This over-exploitation problem could be reinforced by climate change and in particular by a decrease of future rainfall.

A climate of extremes

A winegrower who described the climate of the Roussillon plain immediately said “*it is always extreme*” (R1). He mentioned the 1956 frost when olive trees died to the 2009 storm when the wind destroyed greenhouses. This last event took precedence over the 2007-2008 droughts in the memories. Farmers easily remember past strong events, such as the 1999 floods, frost in 1962; heavy snow falls in 1981, 1986 and 1992 (breaking down all green houses). Some events touched the whole plain, others were more localized. Events are recalled with emotions. Many farmers are fatalistic about these climate excesses which threaten their holdings (see also testimonies in Pelras, 2008). Climate is seen as the “sword of Damocles” over their heads. But it is also a key asset, with less frost than in other regions and

favourable temperature in spring, allowing early arrival on markets. Cold winters and frequent wind also prevent from diseases in particular for vegetable crops. This favourable climate, together with a good network of irrigation canals and an early development of the railway allowed the region to become “the garden of France” in the first half of the 20th century. However, climate is only perceived as an asset because men have been able to overcome the water availability constraint by constructing canals wells and dams, adapting their cropping practices and water management institutions to secure water resources (Riaux and Richard, 2007).

Farmers’ scepticism about the climate change discourse: the risks are elsewhere

Five interviewed farmers say they noticed changes in climate. One refers to changing date of vineyard harvest in the Roussillon. He did not however perceive local changes in rain or temperatures. Four farmers noticed a current trend towards milder and dryer winter and warmer summer. « *Seasons were more differentiated in the past* » said a farmer (R7) with nostalgic memory of a “normal” weather. Yet there was no shared vision on the way climate evolves locally. Most of interviewed farmers (among them the oldest) did not see changes or did not want to answer to the question arguing they had not enough hindsight to judge.

All farmers heard about climate change in the media. But they view it with a certain distance and tend to see local climate evolution as to the result of cycles. This representation corresponds to what elders told them. One of the senior winegrower who did not see any evolution in its agricultural calendar said: “*Global warming, it makes me smile because I do not see changes. Even if one tells me so. When climate wants to be cold, it is cold, and when it wants to be hot, it is hot. I heard that, with regards to climate, there are periods for 20 to 30 years that are hotter or colder, or more humid. There are cycles. It is like that. Human life is so short to see this type of change*” (R1). He added that farmers were starting to be concerned about climate change because the last 3 summers had been very dry (2006, 2007 and 2008). However, winter 2008-09 was so wet that the idea of climatic cycle was ultimately reinforced.

They did not criticise scientists’ discourse on global warming. They however did not feel concerned because global warming is a long term threat whereas they have to face short term risks such as market risks. Also they have not “*waited for the technocrats to write rules on papers to adapt to the rhythm of the seasons*” (testimony in Pelras, 2008). It is part of farmer capacities to adapt to climate variability. Farmers use many indicators to adapt to climate. Farmers growing market crops often subscribe to meteorological services on the internet.

They are used to deal with scientific indicators but they also use local markers to adapt their practices. For example, they observe the level of snow on the nearby Canigou Mountain to predict drought (. A farmer insisted that farm vulnerability to climate highly depends on farmer's practices. For example irrigated trees are more sensible to wind because of their short roots. Some interviewed farmers were pessimistic about future and claimed it was more important to talk about the future of agriculture markets and land uses than water uses.

Relationship to the aquifer

Farmers generally have a fair knowledge of groundwater in the place they operate, mainly based on personal experience and observation of their wells or drills. A few others knew the multilayer structure of the aquifer and its functioning, and had access to scientific or technical knowledge. Most of them know that canal leakage and irrigation may refill aquifers. Farmers have experienced that groundwater resources are very sensitive to rainfall patterns. The last drought and wet winter confirmed the link between rainfall and the superficial aquifer level. Five of the interviewees noticed that the level of the superficial aquifer has diminished for the past 7 to 20 years. Most of farmers do not see groundwater shortage as a risk. All farmers underlined the high quality of the underground water compared to surface water. This is of importance since it complies with the quality standards imposed by the distributors, who require water analysis prior to signing a contract. However, a farmer talked about the risk of sea water intrusion and another one worried about underground water pollution.

Water for agriculture: a limiting factor but not a risk

Lack of water is not considered as a key issue for all farmers. « *In the Pyrénées Orientales, we have the mountains, snow and canals. We have plenty of water.* » (R3). However, farmers are concerned with the over-exploitation of the aquifer. Yet according to them, they are not the ones who waste water and overexploit this resource. They keep repeating that the largest groundwater users are the other sectors, such as drinking water, tourism, golf courses, swimming pools and public and private gardens. While drinking water is seen as a legitimate use, they argued that their productive use is more legitimate than recreational uses. Farmers claimed that they do not use groundwater in an excessive way, having improved the efficiency of their irrigation systems (e.g. monitoring of humidity in the soil, etc). Some of them have shifted from canal resources to underground resources to carry out micro-irrigation, which according to them minimizes the use of water and fertilizer. Some farmers ask for social recognition of this rational use and they refuse a status of scapegoat for groundwater problems.

Besides, many farmers are opposed to an increased control of their water use practices. There reported on tensions with the River Basin Management Authority which planned to charge a groundwater abstraction tax, as required by the law since 1992. Most of the farmers refused to pay this tax because they considered they already paid for water when investing in a borehole. This denotes a strong sense of private ownership of groundwater. Whereas the management of surface water resources relies on collective rules, farmers feel independent with groundwater resource and are not keen to engage into collective management. This attitude reflected in farmers' reluctance to accept interviews on water issues or to suggest names of colleagues the authors could meet. Concerning adaptation to water scarcity, many farmers first explore solutions at farm level. They then also propose to build new water storage to increase available water resources. Nevertheless some farmers criticized this stance and the strategy of not participating to negotiations around water management. For example R14 agreed with reinforcement of law and collective rules. He recalled the tacit agreement made taken between water users during the negotiation preceding constructions of dams in the 60s to keep deep aquifer for drinking water (see Broc, 1992). He pleaded for a new social contract and for incentive measures to support farmers in decreasing their production costs. Three farmers proposed to set up incentives for farmers to use surface water.

4.2 Querença-Silves

Case study

Located in the South of Portugal, in the heart of the Algarve Region, the Querença-Silves aquifer is the largest and the most important of the 17 aquifers identified in the region (Fig. 2). Its main hydro geological characteristics are its karstic nature, its thickness, its dimension and its capacity for annual and interannual regularisation. The Querença-Silves aquifer is part of the hydro geological unit of the Meridional rim. The 318 km² area encompasses approximately 3966 ha (Nunes et al., 2006). This aquifer is located in one of the most tourist seaside areas of Portugal, in which there is a tenfold population increase in the summer months. During the eighties, when farmers and landowners could not use water from the upstream dam, the aquifer was used by numerous private wells. The aquifer is also used by hotels, holiday houses and golf courses and industries. It is not easy to define which sector is the main user of the aquifer resources, due to the large number of illegal reservoirs (Reis, 2007) but irrigation agriculture, propelled by a large number of private reservoirs, has been pointed out as one of its principal users. The other large-scale consumer is urban supply, through wells of the Algarve Water Company, and supplementary municipal reservoirs, under

the responsibility of local authorities. However, recent data on water extraction brought about some controversy on the respective importance of each of these uses. This situation will soon be clarified as an inventory of all wells and boreholes was soon initiated.

The main problems in this area stem from a tendency to increase the use of the aquifer and a decrease in the quality of the water. The Portuguese aquifer had an important role in the drought of 2005 (the worst in the last 40 years) when authorities had to leave the superficial supply system to groundwater supply system. That summer, the aquifer was brought to record low recharge levels and its use was compromised due to the threat of saltwater intrusion in the underground freshwater reserves. Authorities took several measures such as restricting water withdrawal to 50% and resorting to alternative water supply solutions. This led public institutions to call for caution in the use of the aquifer, and to limit the authorization of wells.

This concern led to the creation, in 2005, of the drought committee – composed by the Institute of Water, government boards, environmental and agricultural associations, industry and water supply firms. Several reports including the AdA Contingency Plan (2007) refer to it as the emergency source of water for the Algarve (Lopes et al., 2005). The participation of stakeholders is just beginning with the Public Participation Process for Water Resources¹, taking into account the characteristics of the Querença-Silves Aquifer as a critical point of management.

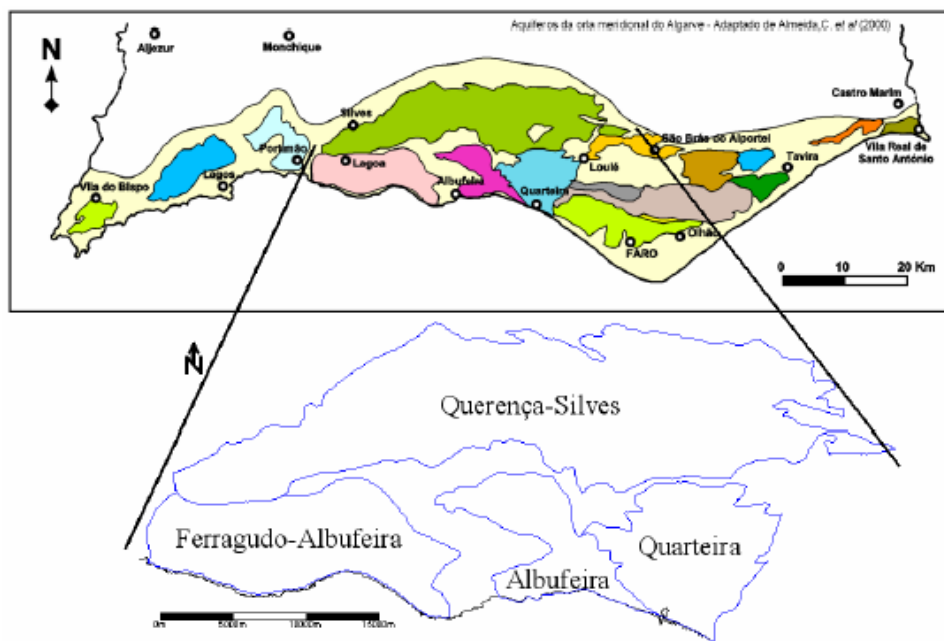


Fig 2. The Querença-Silves Aquifer, Portugal (Almeida et al., 2000)

¹ See Significant Questions for Water Management (2009) available at <http://www.arh Algarve.pt>.

A good climate for agriculture

The farmers we interviewed describe the climate of the region as being “mild”, “moderate” and “good”, a climate that is “*favorable for citrus production and development*”. Their perceptions regarding the climate are clearly related to their agricultural activity – for much of the activity involved in citrus production and horticulture, rain and air temperature are crucial. Farmers’ main concerns are the reduction of the rainfall and marked differences in terms of air temperature. But as regards the impact of the climate on their activity, farmers’ narratives show that the level of risk and vulnerability related to the climate is not linear and varies according to the geographic context. For instance, some farmers mention areas that are more exposed to temperature variations, while others describe a climate that is more protected by the geographic situation of the fields. In fact, this “case by case” perception of the climate seems to agree with the individual adaptation strategies chosen by farmers of this region. But it also shows that there is no uniform discourse about the impact of the climate change which will be an obstacle if this issue is to be transformed into a collective matter, demanding collective behaviors.

Climate is viewed not quite in terms of evolution but in terms of variation, and is described as being cyclical and periodical. While all farmers agree that the climate is undergoing changes and state that “*the climate is different*”, their perception is not associated with the global phenomenon of climate change. The extreme climatic events farmers most recall correspond to droughts and frost, the most severe episodes affecting their farms. Droughts are considered to be “*periodical and cyclical*” and their chronology does not make consensus, although several farmers pointed out extreme variations every 10 years (1930-40, the 1980s, the 1990s, the 2000 decade). These are certainly episodes that bring up the most intense memories, vividly remembering the lack of water, namely lower levels of water in wells and reservoirs. These reports also explain technological evolution in the use of water in equally difficult periods as well as the farmers’ technical adaptation when confronted with this vulnerability. Some farmers remember very clearly the decline of the “*hortas*” (gardens) near the water sources and the kilometers that people had to walk for catching water. Frost episodes also arise in the farmers’ discourses, due to the heavy impact and the damage they caused during this last year of production (2009).

With respect to climate change, their ideas are not clear. Above all it is viewed with skepticism. Portuguese farmers are not yet very familiar with this phenomenon and their

testimonies show it: *“2008 was a good year for farmers, but farmers don’t know the difference between a normal year and a year of climate change”*(Q8).

The richness of the groundwater

Algarvian farmers are found to have representations about how aquifers work, just like other aquifer users do. In the case of the Querença-Silves aquifer, everyone knows it is the largest aquifer in the Algarve, with an extremely rich capacity. Everyone also knows about the geology of the lands where it is located, referring to the permeable nature of the soil, which in turn enables a strong capacity for the rain to infiltrate: *“This aquifer is in a karstic area... an area with great permeability (...) soil with plenty of broken rock. A simple drop of water infiltrates the soil and goes on to the caves”* (Q8). The farmers express the image they have of an aquifer through words like «caves» and «caverns». Most of them know the origin of that water: *“it comes from the rain in the first place”* (Q15) *“All the water from the rain... water that infiltrated many, many years ago is accumulated there.”* (Q4). Despite understanding certain features of aquifers, they are humble in showing their knowledge: *“if there are experts who carry out studies, those are the ones who know best about the aquifer”* (Q11). They also reveal knowledge about the relationship between superficial and ground waterlines: *“according to my intuition and empirical knowledge, the main water supply of the aquifer comes from the Alte and Algibre streams”* (Q5). They know the retention areas and the sense of certain fluxes: *“I’ve heard that the water of the aquifer comes from the Querença area”* (Q11) *“The aquifer rises somewhere in Querença and it flows into the Estombar fountains”* (Q13) *“We’re not sure that the real origin of the water is in the Alentejo. Or if the Algarve Mountain has areas of infiltration, I have no idea.”* (Q4).

Their knowledge regarding the aquifer also derives from their social knowledge of the region (location of agricultural activity, location of the reservoirs, and so on). When questioned about the capacity of the aquifer, they mention that the water is abundant and point out how there are many reservoirs in the whole area of the aquifer, which is currently a great source of water supply. This knowledge allows them to give a better explanation about the level of vulnerability of their farms when faced with lack of water. *“The farms are located in the final stretch of the aquifer, where its level is at “level 0”. The good thing about being at this final stretch is that there is more of a water load and the bad thing is that there is more pollution. But I don’t think the phreatic levels suffer much fluctuation.”* (Q10); *“The Farm is located in an area where the phreatic levels are very favourable so there is no need to drill lower (...)*

the aquifer must be really good. Fortunately we haven't yet had any problems of lack of water." (Q6).

The farmers mention that their knowledge of the aquifer grew with the emergence of the drilling technique in the 1950s. They explain that before changing to the irrigation system, local agriculture was dominated by rainfed cultures. Therefore, it was only later, when the first drills were made, that they became aware of the existence of groundwater - "*the aquifer was only discovered way after the 1950s. My father did one of the first drills here in the region*" (Q12). However, the farmers recall their ancestors talking about the aquifer; at that time, their knowledge stemmed mainly from the use the populations made of the water of the fountains (such as the Benémola and the Estombar fountains), related to fishing and leisure or to agricultural activity in the farms close to the fountains.

Lack of water is not an issue for the farmers of the Querença-Silves aquifer, in that they verify the existence of water in the individual wells and a reinforcement of the Algarve's water supply via the Odelouca dam (in its final stage of construction). But despite this comfortable situation regarding their access to water, the farmers are concerned, on the one hand, with the over-exploration of the aquifer, caused by an excessive number of wells and subsequent withdrawal of water, and, on the other hand, with the lack of rainfall in the last few years. Some of the younger farmers even warn that the invisibility of the aquifer may delude the farmers about water availability.

Farmer adaptation to climate variability and change

As regards adapting to the climate and to the lack of water resources, the farmers clearly state that they are not over exploiters of the aquifer's water. They reinforce this notion by explaining that each time a farmer uses a well, he tries to reduce the cost of bombing as based on logic of savings on electricity. Most importantly farmers perceive a deep social divide between the different users and beneficiaries of the water. They keep reinforcing the idea that the largest consumers of the aquifer's water are the other sectors, such as local authorities, the Algarve Water Company, tourism and golf courses. This tendency to see other groups as damaging to water resources decrease farmers' ability to put their own practices into question. This is consistent with other studies such as Guillou and Moser's (2006): farmers are ready to take partial responsibility for certain problems but minimize their responsibility for the degradation of environment.

The most often mentioned actions of adaptation have to do with monitoring water usage by measuring the levels of humidity in the soil. Some farmers also carry out a set of procedures aimed at improving the efficiency of the irrigation systems, such as watching the sprinklers, maintaining the bombs and adopting new irrigation techniques. They also refer to the inclusion of less polluting chemicals in their activity, thanks to the technical support provided by a group of professionals seeking to inform producers and raise their awareness about the adoption of agro-environmental actions (Ministry of Agriculture, Co-ops). The law forces them to have a more environmentally conscious use of chemicals but, regardless of the legal obligation, farmers view these new practices as a requisite to access to a better position in a competitive market. However, a number of problems related to the use of water still arise: leaks in the sprinklers that are not duly and regularly inspected, illegal reservoirs, permissions for agro-businesses such as floriculture in protected areas of the aquifer, absence of hydraulic studies on the capacity of the sprinkler system in relation to the size of the plots, poor management of the aquifer by the State and the lack of concerted long-term plans regarding groundwater resources.

4.3 The Chaouia area

Case study

The Chaouia Coastal Aquifer forms a 65-km long and 20 km-wide band between Casablanca and Azemmour cities. This 1200 km² large area is bordered by the Atlantic Ocean to the North, the Bouskoura River to the East, the Oum Er Rbia to the West and outcrops to the South. Water comes exclusively from rainfall: neither inland mountains nor the Oum Er Rbia River fill in the aquifer. The bulk of water pumped from the aquifer is used for irrigation of market crops, such as tomatoes. There is no surface water, so all farmers turn towards groundwater for irrigation. Farmers use both wells and boreholes.

Overexploitation of water in the littoral has led to salt water intrusion, with water salinity reaching up to 10mS/cm. This led to abandon of irrigated agriculture in a 10-km stretch of littoral land. At a distance of approximately 4 km from the seashore, there is an intermediary area where farmers face decreasing groundwater levels and lack of sufficient water during summer. Last drought periods have led many farmers to drill more in-depth their wells and boreholes, or to drill new ones. More in land, there is not yet problems of overexploitation. Though the aquifer dynamics have been monitored for the past 20 years, there is no institutional setting to face the overexploitation issue.

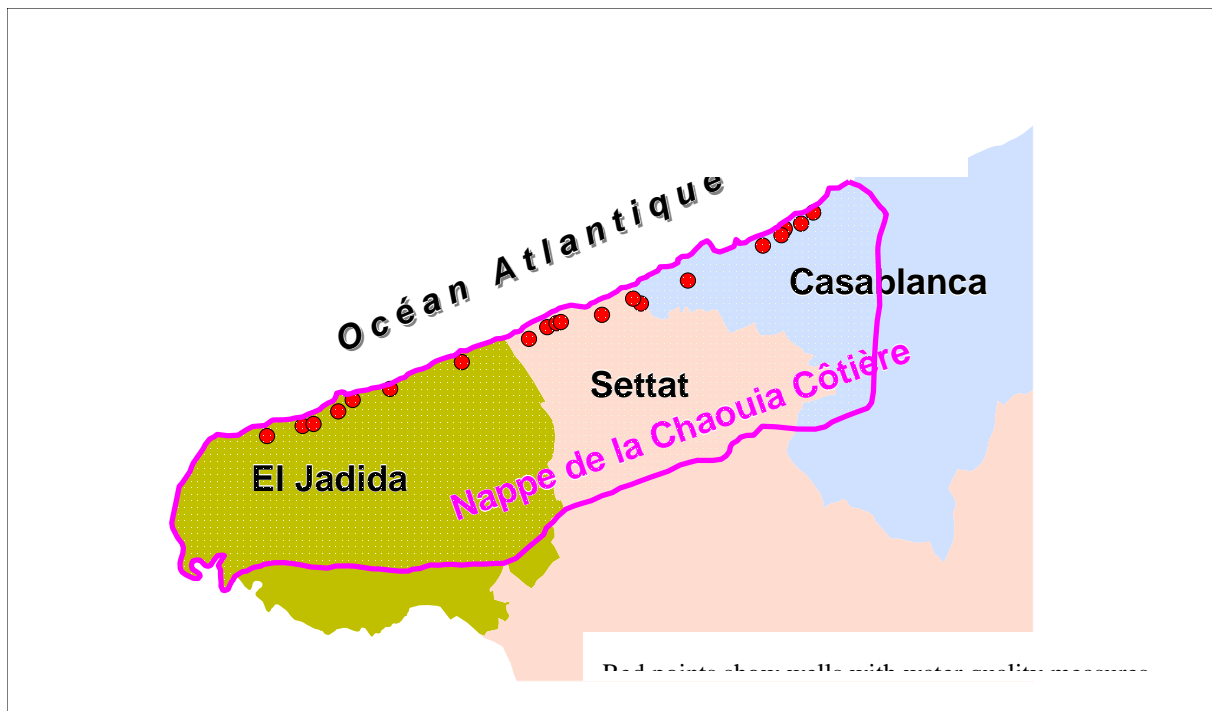


Fig. 3. The Coastal Chaouia Aquifer, Morocco (source: Bouregreg Catchment Management Agency).

The climate

Farmers describe the climate mainly in terms of rain distribution and temperature. Possible climate events include warm winds, hail and frost. Farmers define a “good” climatic year as based on sufficient and well-distributed rains, mild temperature and absence of such climatic events. Farmers singled out rain as the most important component of climate. They do not describe precise farming seasons, because the calendar of agricultural activities depends mainly on occurrence of rains.

Farmers do not see an evolution in rain patterns, between current situation and as remote in the past as they remember (i.e., at least in the past 20 years). There has been overall a drought period in the past ten years, with in particular very dry summers in 2006 and 2007. However, winter 2008/09 was exceptionally wet. Therefore, farmers tend to see rain distribution over the years as a cycle. There is no shared vision on the way temperature evolves. Two interviewed farmers did not see any changes. Three farmers refer to temporary increases in temperature in the 90s, and three think there is a clear trend towards increased temperature: “before, high temperatures did not harm the crops as they do these days” (C9). Finally, farmers recall easily past strong events, such as drought in 1985, floods in 1996 or hail in 2004.

Lack of farmer perception of decrease in rainfall may be compared to the fact that, while rainfall decrease is statistically measurable on a period of 60 year time (1960-2010), there is no decrease during the past 20 years. Another element contributing to this lack of perception is that farmers mainly produce market crops, which have very short production cycles: production dates usually shift from one year to the other, depending on climate characteristics such as rainfall and temperature. One of interviewed farmers was a senior farmer having old orange trees, but he did not see any evolution in the agricultural calendar of his trees, such as date for flowering. Besides, in comparison to other studied cases, farmers are less linked to the “global media” and only one farmer said that he heard about climate change on the radio.

Water resources

Farmers share a common representation of groundwater resources. The latter are not seen as a continuous structure, but as rivers under the ground. Such representation enables them to explain that farmers may not find water if they dig a well in a place situated in-between two of these rivers. *“Groundwater is made of subterranean rivers, parallel to each other and sometimes having curves. If a farmer drills a well between two of these rivers or in a curve of one of these rivers, he will not find water”* (C1). All farmers think that groundwater comes from the mountains and the nearby river. While farmers do not describe groundwater as scientists do, they identify most of the same factors identified by scientists that influence groundwater dynamics (a result similar to Bekkar et al., 2009). First, farmers have experienced that groundwater resources are very sensitive to rainfall patterns: During dry summers, water levels drop and, close to the sea, groundwater becomes more saline. If, after this, a wet winter occurs, they observed that water levels go up and that salinity decreases. However, over a period of several years, salt water intrusion progresses towards inland areas (farmers say 500 m on average per year), and groundwater level decreases steadily in the intermediary area. In their opinion, salinity is caused by the several droughts that the region has faced since the 80s: they do not link this with the development of wells close to the sea shore (this lack of correlation was repeatedly confirmed in many other interviews in the region). Second, nine out of the ten interviewed farmers make a connection between the number of wells and groundwater decreasing levels. *« In our village, a farmer drilled a well at a 30 meter distance from the wells of his neighbours. He took so much water from his well that he took the water of his neighbours, that did not have water left”* (C1). Farmers think that interdependent wells are either in an upstream/downstream relation (and in that case, influence may stretch up to 2 km) either close-by. In the latter case, farmers think that

groundwater river is wide enough for the two wells to use the same river. During summer times, some farmers irrigate during the night as they observed that they were less affected by neighbouring wells.

Most farmers indicate that, while water officially belongs to the state, farmers are completely free to manage it locally as he wants. *“Water belongs to God and then to the state. We are part of the state, so that when a farmer drills a well, he starts owning the groundwater he finds”* (C6). This position limits considerably discussion on groundwater management: some farmers mention a legally defined limit of 200 m between two wells, but this rule *“is not implemented: if my neighbour wants to drill a well close to mine, I will not prevent him from doing it”* (C1).

Vulnerability and adaptation

Some climate events, such as frost and hail, directly impact farmers’ production. Apart from one farmer, all others say that increases in temperature do not impact much on crop production. According to farmers, the single most important factor is rain, as it affects them in both a direct and an indirect way, since it impacts also on groundwater resources. Farmers have designed a broad range of adaptations to face declining groundwater levels and salt intrusion, ranging from fundamental decisions affecting the whole family-farm to coping farming practices during the campaign. In the same time as they adapt, many farmers still consciously take risks. For instance, when they decide to plant irrigated crops in spring, they do not know whether groundwater will be sufficient (in the intermediary area) or saline (in the coastal zone). They take a decision based on information such as the amount of rain during winter. In summer 2008, many farmers lost their production of tomatoes due to unexpected rise in salinity. Three of interviewed farmers have devices enabling them to measure salt content in a precise way, and these measures rapidly diffuse in the neighbourhood. A farmer said that, during summer period, the main question asked in coffee shop was: “how is the water at your place?”

5. Discussion

5.1. Climate variability perceptions

For what relates to climate variability, farmers propose different descriptions. Farmers from Querença describe climate as stable, farmers from Chouia as having some variability, and farmers from Roussillon as being quite unstable and extreme. In Roussillon and Chaouia

areas, farmers put forward the vulnerability of their farm to climate events (mainly inundations, droughts, wind). However, in Roussillon and Querença, access to water resource is currently not an issue and climate variability is not perceived as an important difficulty compared to, for instance, production and marketing issues. In Querença-Silves, the issue is framed in a perspective of future; in fact, farmers argue that tension will increase as new users with new interests will appear and demand for using the groundwater. In Roussillon, tourist and leisure uses are already blamed. By contrast, in Chaouia, climate variability and access to water resources is one of the two top issues put forward by farmers (with access to markets).

5.2. No perception of climate change

Most farmers interviewed in the three cases, do not perceive changes in climate as identified by scientists. They rather perceive cycles, especially with regards to drought events. This confirms Hulme et al. (2009) analysis that people are not sensitive to evolutions occurring on a period larger than 20 years and that there are discrepancies between the way weather scientists and society define, perceive and compare evolution in normal climate. Even when farmers are aware of the global media discourse on climate change (Querença, Roussillon), they are firm in saying that at local level and within the time frame they deal with, they do not see such changes. At their level, climate is something that may not be scheduled. For Moroccan farmers, there is a strong sense of fatality in the way they describe climate events. But also for French and Portuguese farmers, nature has a strength that is not compatible with foresight and scheduled agendas.

5.3. Behaviours related to the perception of vulnerability

The perception of vulnerability is closely related to the adaptation behaviour. Farmers of Chaouia are already adapting to decreasing water resource availability. By contrast, in Roussillon and Querença, farmers are currently not limited in their water access. They are conscious of the necessity to ensure that the groundwater resources will be managed in a sustainable way in the future. The understanding of perceptions of climate and adaptation is relevant for action; knowing how farmers confront their responsibility to environment, the way they read the climate and relate it to their actions can be very useful for a more sustainable management.

In the three cases local institutions are aware of this and as such support research on those matters, even if this studies are not yet very clearly applicable to them especially in the Portuguese and Moroccan cases. To map the perceptions and the actions linked to climate can

enable communication between experts and farmers and is a good starting point for conducting public discussion. One of the central topics related to groundwater is the risk of water scarcity. But farmers' perceptions of this risk vary and this has consequences for discussion groundwater management. Farmers of Chouia do not accept collective or- and external management groundwater use, because: 1) rain events are of much more importance than overexploitation in groundwater dynamics; 2) farmers are free to decide the use of their groundwater; 3) they are not aware of institutions in charge of this. Farmers of Querença and Roussillon think groundwater is sufficient, but they are aware of the need to protect groundwater in the future. However, they say: 1) other uses such a drinking water and golfs are the ones which increase their pumping; 2) that they already have an efficient use of water.

All in all, consequences on farmers' action and predisposition towards involvement in groundwater resource management and adaptation to climate changes differ among the cases studied. In the Roussillon and Querença-Silves areas, farmers do not yet face limitations in groundwater extractions and in the same time face increasing difficulties to go on farming: in these areas, discussion on climate change and groundwater management will need to be integrated with a discussion on the future of agriculture. In the Chaouia area, farmers already face groundwater overexploitation and seawater intrusion. In a situation of lack of initiative towards groundwater resource management, farmers implement a series of adaptative actions at farm level.

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