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Climate change and farming systems in the region of Setif (Algeria)

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Abstract: In Setif region (Algeria), the constraints of the semi-arid climate already limit farm profitability. Throughout the years, local farmers have modified their farming systems to mitigate the negative effects of climate. This paper aimed to describe the trend of climate change and at what extent it could affect the farming systems. The climate evolution was analyzed through the annual rainfall time series (1970- 2011) of 50 observation stations spread over the study area. A study of modifications in farming activities engendered by climate change, such as a shifting to new farming systems, was carried out on a sample of 537 farms spread over in three agro-ecological regions: the northern, central and southern zones. The annual rainfall of the period 1970-2011 over the study area was 457mm, However the annual rainfall maps for the periods 1970-1990 and 1991-2011 showed a high spatiotemporal variability, where some areas tended to become more wet, in contrast others areas were affected by drought severity . The main changes in agricultural activities for adapting to climate constraint were a reduction of areas devoted to rainfed crops (cereals) and the adoption of an intensive farming system based on poultry, cattle breeding and intensive crops, especially in the central and the southern zones. Challenges of **a**gricultural development programs in the context of future climate change will be to manage the conversion of the ancestral farming systems to sustainable systems, preserve the social value of agriculture and boost the economic profitability of farms without affecting natural resources.

Keywords: Climate change; Rainfall; Farming system; semi-arid; Algeria.

Introduction

The Mediterranean is regarded as a climate change hot spot both in terms of projected stronger warming of the regional land-based hot extremes compared to the mean global temperature warming (Seneviratne *et al.*, 2016). In the fifth Assessment report of the Intergovernmental Panel on Climate Change (IPCC) in 2013, Overall predictions showed a high confidence of strong increases in dryness and decreases in water availability in the Mediterranean and southern Europe from 1.5ºC to 2°C of global warming by 2050. The rain events will be less frequent but more intense. The spatial and temporal distribution of precipitations is also expected to change, affecting agriculture (Dorsouma, 2008), the main user of soils and consumer of 70% of the water resources in this region (Iglesias *et al.* 2006). Yields could decrease 10-20% by 2050 (Jones and Thornton, 2003).

In Algeria, mean temperature is projected to increase by 1.2°C-1.8°C by 2050 (Sivakumar, 2013), however, annual rainfall will decrease by 10% (Touitou, 2018). The spatial and temporal distribution of rainfall will change irregularly over the country. Due to its geographical position and climatic characteristics, Algeria is particularly vulnerable to the effects of climate change. Arable land represents only 3.5% of the total area of the country. The availability of agricultural land (in ha) per capita declined from 0.75 in 1962 to 0.24 ha in 2008 (Sahnoune *et al.*, 2013) as a result of human pressure (industrial, construction, pollution), desertification, soil erosion and vegetation cover loss. Even a small rise in temperature would consequently lead to various socio-economic problems that might hinder the development of the country. Local analysis of these effects is however lacking and the impact on the farming systems poorly considered.

The nature and intensity of climate change effects are associated to the perception and practices of farmers and the cultural and social factors that can facilitate or limit the adaptation processes. Farmers have a long and rich experience with climate variability in the short term (Vincent, 2004). Provided that the rate of change is slow enough, the use of retrospective studies would permit to know to which extent farmers were able to adapt in the past and estimate how they could adapt in the future (Adger and Brooks, 2003). Therefore, the objectives of the present study were to analyze i) the rainfall trends in three ecological zones in Setif region, based on a historic set of observation, ii) its perception by the farmers, and ii) the potential effect on cropping systems and main agricultural practices at the farm and regional levels.

Material and Methods

Regional context

The province of Setif which covers 6,549 km² (0.27% of the national territory) is situated in the Eastern part of Algeria, between 35.0° and 36.5° of latitude North and 5° and 6° of longitude East. The mountains, which are mainly oriented west east, reduce the Mediterranean influences. Therefore, it has a continental semi-arid climate with cold and wet winter and dry and hot summer. The Province is traditionally subdivided in three agro-ecological zones. The North has black and deep vertic soils, with a clay to clay-loamy texture (Lahmar, 1993) and an annual rainfall of 600 mm. This agro-ecological zone was represented by the northern study zone; characterized by a mountainous topology and rugged lands. However, the central study zone or plains zone; characterized by wide plains suitable for agro-pastoral activities. The southern zone included the mountain chain of Boutaleb, culminating at 1886 m a.s.l. (Djaouti, 2010) where the annual rainfall does not exceed 300 mm (Baldy, 1974) and soils are brown calcareous. The last farming census showed a total cultivated area in Setif Province of 357,646 ha, i.e., 4% of the cultivated area of the country, with a majority of familial farms (MADR, 2001). Djenane (1997) highlighted that 12,000 farms (10% of the total number) having an area between 2 and 5 ha per farm. However 3,472 farms comprised an area between 20 and 50 ha, representing 30% of the whole cultivated area. Given the uncertainties of the climate, the association between cereals and livestock allows to ensure minimum incomes and reduce risks related to climate hazards (Rouabhi *et al.*, 2012). The agricultural statistics showed in 2013, that the main crops are durum wheat (104,120 ha), barley (47,130 ha), bread wheat (22,995 ha), oat (6,285 ha) and horticultural crops including potato (10,254 ha) and legumes (929 ha). Livestock is playing an increasing role in the farming systems, with 504,564 sheep, 2,197,320 broilers, 2,416,454 laying hens and 128,374 cattle (MADR, 2013). The insufficiency and irregularity of rainfall, which mainly falls between October and February, drastically affect the cereal crops. Additionally, seasonal hot winds (sirocco) occurring during the end of the vegetative cycle could increase temperature and evapotranspiration (Souidi *et al.,* 2010).

Methodology

The methodology goes through two parallel research paths to converge to the study objective: namely to estimate the impact of climate change on local agricultural practices. The first axis is in line with the assessment and quantification of the local climate trend, these results may be useful in several scientific disciplines regarding the study area. The second axis is based on the information issued from surveys of farmers, aiming at the study of the evolution of agricultural practices over time and at what extent are influenced by climate variation. The combination of results from the two axes, if having both a significant climate change and a real agricultural transformation due to the climate. Hence this finding will conclude and reinforce the postulate of the impact of the effects of the climate change on the transformations of the local agricultural practices.

Climate data processing

The observation network used in this study belonged to the National Meteorological Office (NMO) and the National Water Resources Agency (ANRH), covering the period (1970-2011). Unfortunately, the extent of the climate dataset was limited to 2011 because of the unavailability of climate data after this period. Indeed, the climatic analysis will focused on the annual rainfall, because of the role that played in *agricultural* production, household welfare, maintaining and distributing the vegetation cover (Berrayah, 2009). The network included 50 stations, covering the territory of the province and its immediate vicinity (Fig 1). The analysis should ensure both statistical rigor and geographical coherence between the stations. Some of statistical restrictions were applied in order to screen the stations that will be implemented in the study; hence retained stations should have less missing data and outliers. The study period was divided into two sub-periods of 20 years for each (1970-1990) and (1991-2011). The probability and rainfall maps will be performed at different time scales to illustrate the spatial pattern of the climate variability.

The rainfall maps as well as the probability maps were carried out using the geostatistical interpolation; namely the universal kriging technique on “ArcGis10” software. The rainfall maps were drawn up on the basis of having 5 rainfall abacuses. However, probability maps have been developed under the condition that annual precipitation exceeds the threshold of 400 mm. Indeed, this annual precipitation level is considered as the minimum threshold in semi-arid climate (Tassin, 2010).

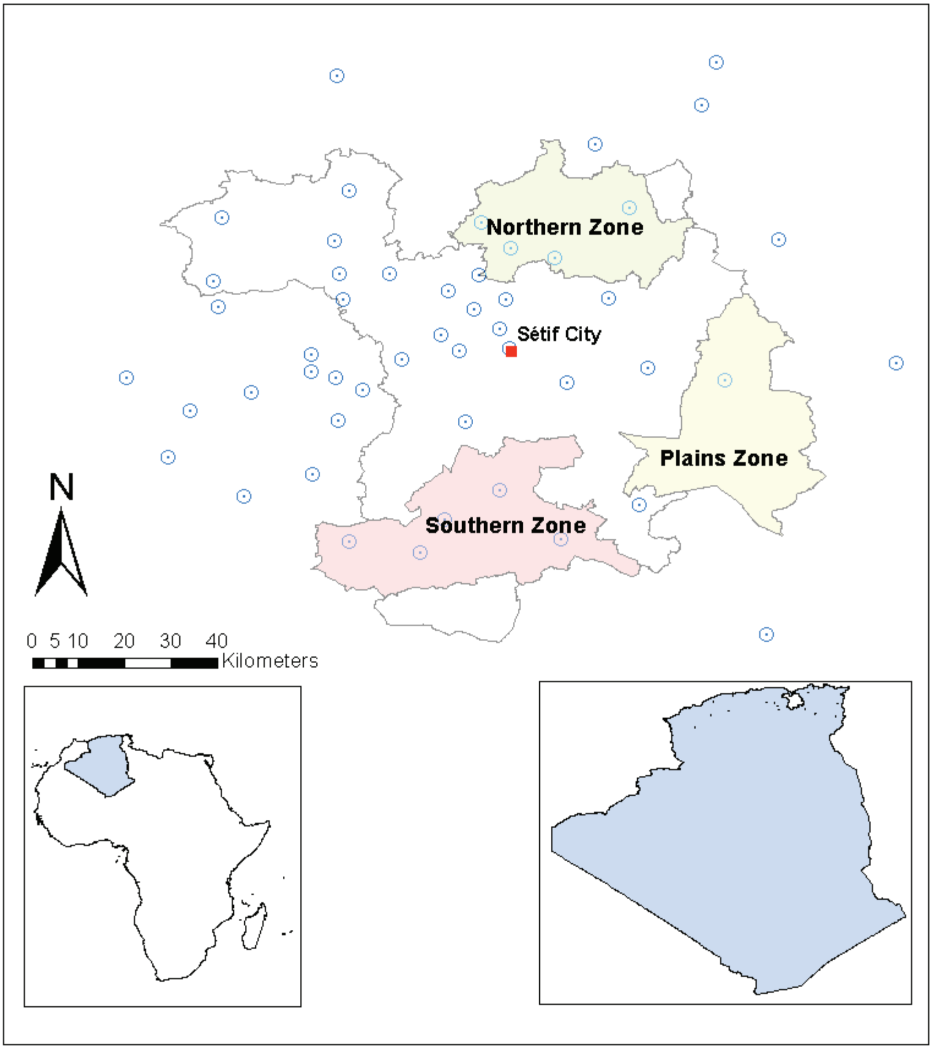

Figure 1 - Situation of the study areas within Setif province and the geographic distribution of the weather rainfall gauges (represented in light blue circlets)

Survey and farming systems diagnosis

The importance of this study emerges from its originality in the region of Setif. Indeed, it is the first and unprecedented study that deals in detail the evolution of agricultural practices during three consecutive years (2012- 2013 and 2014) in relation to climate effects in the three zones (Table 1). The northern zone survey included nine municipalities and covered 758.67 km^2 (11.58% of the total area of the Province). The central zone survey included six municipalities and covered 887.91 km^2 (13.57% of the total area of the Province). Finally, the southern zone survey included six municipalities and covered 1025.75 km^2 (15.66% of the total area of the Province).

Table 1 - Number of farmers and municipalities constituting the sample of considered zones

Zone	Municipalities	Sample size (farm)
Northern	*Ain el Kebira, Serdj el Ghoul, Tizi N'bechar, Amoucha,Oued el Bered, Dehamcha, Maaouia, Béni Aziz, Babor*	125
Central	*Belaâ, Bir el Arch, El Oueldja, Hammam sokhna, Taya, Tella*	188
Southern	*Ain Azel, Ain Oulmene, Bir Haddada, Ouled Tebene, Rasfa, Saleh Bey*	224

The sampling model was a stratified dispositive in which the municipalities were considered as subgroups or strata (Tittonell, 2005; Sang, 2008), where the individual farms were sampled randomly within each strata. The survey, conducted in 537 farms representing about 5% of the total number of farms of the region, aimed at collecting information about the structure of the farms, the socio-economic context and the potentialities and constraints of the farming system as these characteristics may influence preferences and abilities of the farmers to deal with emerging transformations, induced in some way by the climatic effects namely the rainfall scarcity and it's interannual instability. The economic evaluation of agricultural activity was expressed by the Economic Performance (EP), based on self-reported financial satisfaction. EP was scaled from 1 to 10, according to his capacity to generate financial benefits as in a Likert scale, taking into account the relative optimism and thriftiness of farmers.

The data were analyzed using the SPSS v18.0 software. A two-step analysis developed by Chiu et al (2001) was used to classify and to transform the numerical variables into ordinal variables that were further used in multivariate analyses, such as the Multiple Correspondence Analysis (MCA) (Le Roux and Rouanet 2004;

Greenacre and Blasius 2006) and the Categorical Principal Component Analysis (CatPCA) (Leunda *et al.*, 2009). The MCA was used to describe the socio-economic context and the CatPCA to evaluate the transformations in the farming management practices and to build up the typologies. The impact of climate change on the farming system was assessed through the perception of climate change by farmers, especially the decrease of rainfall and via a set of explanatory variables such as the decline or not of the water table, at what degree the water table dropped and what are the reasons for abandoning farming activities.

Results

The spatiotemporal evolution of the rainfall pattern

During the period (1970-2011), the annual rainfall recorded an average of 457.89mm; while, the periods 1970-1990 and 1991-2011 respectively recorded 442,46mm and 456,41mm. The rainfall map of the 1970-2011 series showed a South/North rainfall gradient (fig 2a). The maximum rainfall abacus is located at the extreme north, behind the massif of *Babor*, culminating at 2004m of altitude (Ahmim and Moali, 2011). This part recorded the highest rainfall rate (900-1260mm) because of its direct exposition to the marine stream coming from the north. Gsell (1913) points out that the ancient climate of the northern part of Sétif was of a very important rainfall exceeding 1000mm, notably behind *Babor* mountain chain.

The pluviometric abacus (750-900 mm) characterized the part of the southern side of the mountains of *Babor* and *Beni Aziz*, this zone is relatively deprived of the maritime flows coming from the north. The rainfall abacus (500-750) crossed the whole region, going from the mountains of small *Kabylie* in the west to *Maaouia* and *Djemila* municipalities in the east. These three first abacuses represented the subhumid bioclimatic stages, while the last two fringes represented the semi-arid bioclimatic stages. In fact, the rainfall abacus (350-500mm) favorable to the cultivation of cereals, including a large part of the center of the province and a small part of the extreme south. The abacus (237-350mm) covered most of the southern area of the province, often characterized by broad plains with a moderate altitude (700-900m). Given this annual rainfall deficit, the agricultural production system is based on agropastoral activities and cropping conducted under the drip irrigation system. The probability map showed that the northern zone had an occurrence greater than 75% to exceed the threshold of 400mm per annum (Fig 2b). However, the central part of the province, including the plains zone was characterized by an occurrence of (50-75%) to receive an annual rainfall more than 400mm. While, the southern part annual precipitation had a low probability of occurrence (25%) exceeding the threshold.

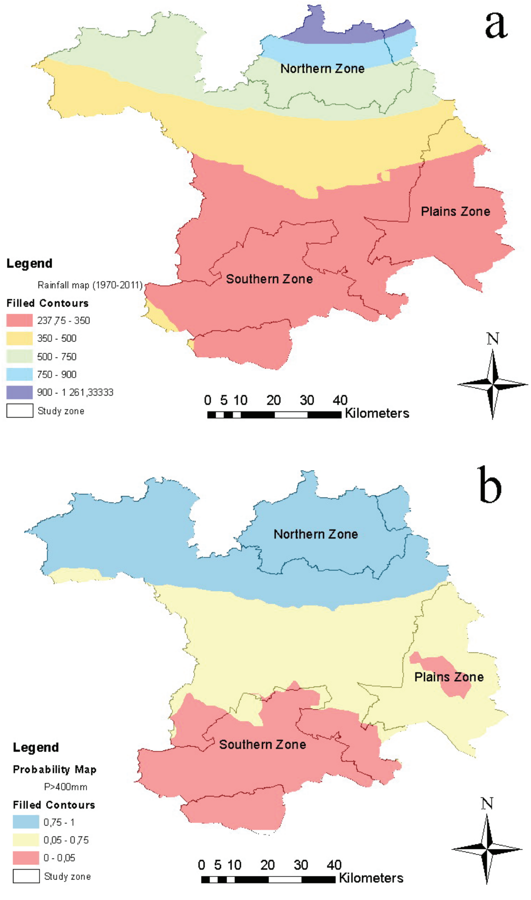

Figure 2 - (a) Annual rainfall map (1970-2011); (b) Probability map of the annual rainfal exeeding 400mm

Rainfall maps according to the ancient period (1970-1990) (fig 3a) and the period (1991-2011) (fig 3b) showed significant annual rainfall variability. During the period (1991-2011), an important shrinkage of the abacuses superior than 750mm was noticed in the north. In contrast, the abacus (500-750mm) becomes more deployed during the same period and regains more area especially on the northwest zone. However, the rainfall abacus (350-500mm) becomes more disturbed and wider, hence the appearance of this range of rainfall in both high latitude and extreme south areas. The rainfall abacus of less than 350 mm is reduced in particular on the east side of the province during the period (1991-2011). In general, the rainfall gradient of the period (1991-2011) shows more disturbances compared to the first observation period. It should be noted that the decrease in precipitation between the two periods affects more the north zone which is the rainiest zone. However, the appearance of some areas of the abacus (350mm to 500mm) in the north, supports the hypothesis of Le Houérou (1959) postulating that the process of climate change must Globally lead to a displacement of the Mediterranean bioclimatic stages towards the North. Relatively, the central and the southern zones of the province did not support high rainfall variations; by maintaining annual rainfall rates between 240 and 500 mm.

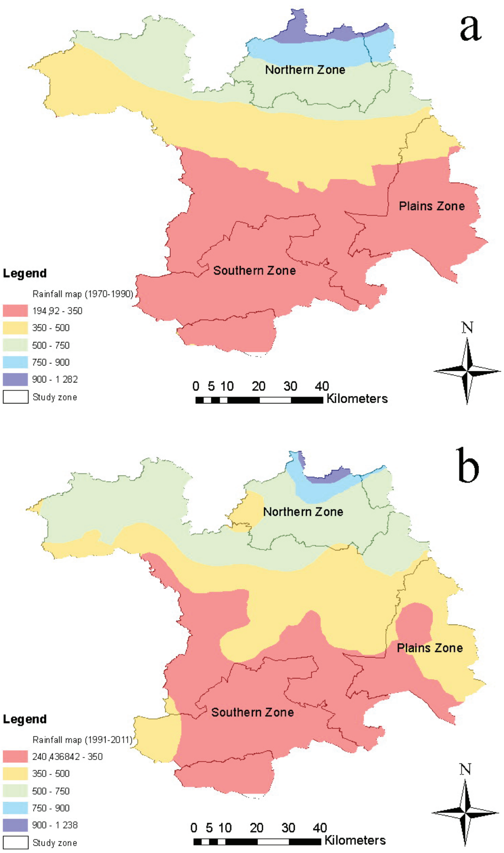

Figure 3 - (a) Annual rainfall map (1970-1990); (b) Annual rainfall map (1991-2011)

In Algeria, Meddi (2007) consider that rainfall variability increases towards the arid regions. Hence, it could affect areas and cereal yields by 50% and 58% respectively (Smadhi *et al.,* 2009). According to Lazri *et al*., 2015, the Algerian north will experience more dry periods and the probability of occurrence of extreme events will increase from 0.2650 in 2005 to 0.5756 in 2041.

The transitions of farming systems

In the study area, the young farmers (less than 30 years old) represented only 8.94% of the total number of farmers (Table 2). In the southern zone, the proportion of young farmer reached 15.63%. Old farmers (more than 50 years old) represented 49.16% of the total number of farmers, while 41.9% of farmers were between 30 years and 50 years old. The education level of farmers was low. More than 45% of farmers never attended school and 13.1% only had an elementary level. Only 18.25% had secondary or university levels. The majority of farmers had a long agricultural experience. Farmer's motivation to join the governmental subsidy programs was considerably low, with 69.83% of farmers having never benefited. The proportion of farmers who practiced non-agricultural activities was 34.82%.

Table 2 - Main characteristics of the farmers in the study zones

Variable	Modalities	Northern zone (%)	Central Zone (%)	Southern zone (%)	Average (%)
Age	Young (<30years old)	9.60	0.53	15.63	8.94
	Middle (between 30 and 50)	32.00	42.55	46.88	41.90
	Advanced (>50years old)	58.40	56.91	37.50	49.16
Education level	No education	47.20	63.30	29.46	45.44
	Primary	15.20	10.11	15.18	13.41
	Medium	23.20	12.23	31.70	22.91
	Secondary	9.60	10.11	15.63	12.29
	University	4.80	4.26	8.04	5.96
Farming experience	Short (<10 years)	14.40	3.19	10.27	8.75
	Medium (10 to 20 years)	26.40	12.77	26.34	21.60
	Long (>20years)	59.20	84.04	63.39	69.65
Investment on equity	No	53.60	35.64	42.41	42.64
	Yes	46.40	64.36	57.59	57.36
Adhesion to subsidy programs	No	56.80	75.00	72.77	69.83
	Yes	43.20	25.00	27.23	30.17
Practicing non-agricultural activity	No	52.00	62.23	75.00	65.18
	Yes	48.00	37.77	25.00	34.82

The UAA (Utilized Agricultural Area) by farm was in average 17 ha which 24% was irrigated (Table 3). Cereal area was about 13.58 ha with some disparities among zones. The northern zone, characterized by elevated annual rainfall, had the highest areas of rainfed crops and the lowest proportion of irrigated area (12%). The northern zone had the lowest area for fodder, fruit trees with 1.26 ha and 1.08 ha, respectively, and the lowest number of hives (8.11). The central zone, characterized by its flat topography, cereals and gardening crops covered in average 20.25 ha, and 2.70 ha, respectively. Farms of the central zone were the most dedicated to livestock. The southern zone, affected by the lack of rainfall and the long period of drought which imposes to farmers a strict management of the little amount of available water was characterized by water drilling and greenhouse crops. The EP of farms was 5.30 across the study area with low disparities between different zones. The most performing farms were those of the southern zone with an average score of 5.76.

Table 3 - Main characteristics of the farms in the study zones

Variables	Northern zone	Central zone	Southern zone	Average
UAA (ha) including irrigated area (%)	13.08 (12%)	23.59 (20%)	13.74 (31%)	17.04 (24%)
Cereals (ha)	9.94±1.07	20.25±3.28	10.67±1.09	13.58±1.26
Fodder (ha)	1.26±0.23	0.39±0.06	0.32±0.08	0.56±0.07
Gardening (ha)	0.82±0.2	2.70±0.31	1.13±0.1	1.56±0.12
Fruit plantation (ha)	1.08±0.15	0.24±0.05	0.46±0.07	0.52±0.05
Well (units)	0.43±0.08	0.59±0.04	0.14±0.03	0.34±0.02
Drilling (units)	0.06±0.03	0.65±0.05	0.98±0.04	0.65±0.03
Bovine (heads)	3.46±0.58	20.46±2.88	4.22±0.49	9.72±1.09
Ovine (heads)	17.38±2.93	47.22±4.65	20.92±2.54	29.30±2.13
Aviculture (hen)	296±77	7020±1034	1398±285	3103.9±401.24
Greenhouse crops (unit)	0.06±0.03	0.05±0.04	2.44±0.52	1.04±0.22
Beekeeping (hive)	8.11±1.68	0.21±0.1	1.36±0.39	2.53±0.44
EP (score/10)	5.42±0.16	4.68±0.14	5.76±0.11	5.30±0.08

The CatPCA model used to build the typologies of farms explained 62.09% of the total inertia, the first and second axis explaining 42.72% and 19.36% of the inertia, respectively (Fig. 4). The first type of farms was characterized by large-scale farming and by the importance of cereals and ovine. The second type represented medium-scale farms, including those with large irrigated and gardening areas and those with bovines and poultry. This type was highly represented in the central zone. The third type was characteristic of small-scale farming, where farms had more fruit plantation areas and high beekeeping livestock, typical of the northern zone.

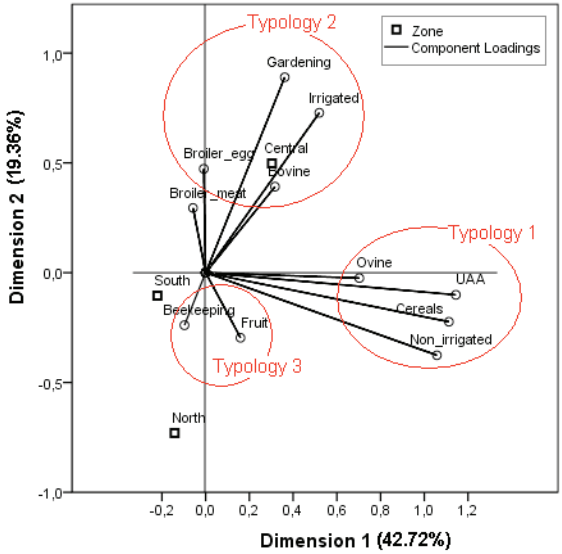

Figure 4 - The main typologies observed in the study area

The MCA carried out to demonstrate the causes and conditions that led to changing agricultural practices explained 67.8% of total inertia, distributed over the first (45.38%) and the second (22.36%) axis (Fig 5). In the northern zone, farmers were less sensible to climate change and less affected by the decline of the water table. According to farmer's statements, major constraints were anthropogenic, such as isolation, degradation of roads, lack of means of production and a hard topography for farming. In the central and southern zones, drought was the most frequent reason why farmers abandoned farming.

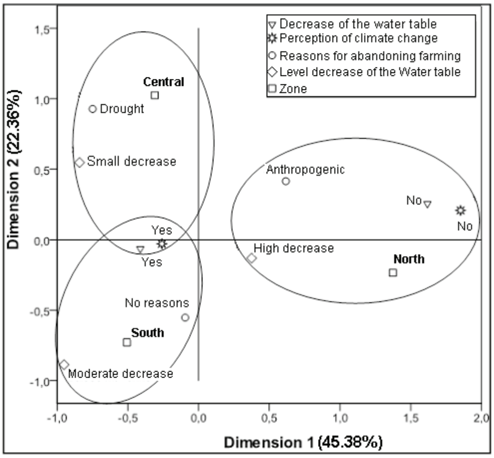

Figure 5 - Impact of some climate change aspects on farming activities

Discussion and conclusions

Each zone, characterized by local socioeconomic and climatic characteristics, however reacted differently to climate change. The northern zone faced during the 90' a great socioeconomic upheaval related to the unstable security situation due to terrorism, especially in rural areas. As a consequence, many farmers left their lands and settled in northern cities of the Setif region, seeking for a more peaceful live and this exodus deeply affected the farming systems (Boukemoum and Boucheloukh, 2011). The central zone is characterized by more rigorous and dry climate with the emergence of hydro-pedological concerns, such as water salinity, soil structural instability and edaphic poverty. Deep changes affected the ancestral farming systems, traditionally based on cereals as a staple crop, combined with ovine livestock. As reported by Djenane (1997), many farms moved towards intensive farming and the development of livestock activities (particularly cattle and poultry). These changes in farming systems can be explained by a reduced dependency of these activities from climate. The southern area is the most exposed to climate constraints, where drought is becoming a chronic problem. The evolution of farming systems and their intensification was major, compared to the central and northern zone. The response of farmers to climate change in the southern zone was to use less water through intensification and the development of farming practices that reduce water loss, as reported in other conditions by Amigues *et al.* (2006) and Brisson and Levrault

(2010). Moreover, the emergence of the so-called “localized production system” (LPS), characterized by a geographical clustering of economic activities can be noted in this zone (Rouabhi *et al.* 2016). For example, the municipalities of *Bir Hadada* and *Rasfa* are now largely devoted to greenhouse crops and tobacco cultivation respectively, this finding can be assumed as an unexpected outcome of this study. Moving to greenhouse crops also represented a quick response to the lack of water irrigation, this system being conducted using the drip irrigation system in order to minimize water needs (El Kolli and Mokhneche 2012). The adoption of tobacco cultivation was not governed by the climatic factors but was highly profitable, being related to the proliferation of the illegal trade and counterfeiting of tobacco products. Finally, because of the limited opportunities of agricultural investment due to the complexity of administrative procedures, and the deficiency of the financial sector which hindered the agricultural profitability (Haid 2012), the areas affected by drought also moved to non-agricultural activities. Indeed, trading was the main off-farm income observed in the region.

The approach used in this study highlights the importance of agro-ecological zoning to analyze the evolution of farming systems and agricultural practices in relation to climate change. It can represent a valuable support tool for decision makers and designers of agricultural development programs. It showed that the main response of farmers to climate change was the development of livestock and intensive crops at the expense of traditional rainfed crops, especially in the central and the southern zones, affected by drought. The upward trend to drought and the annual rainfall variability particularly during the last decades led farmers to switch to less water dependent agricultural activities. However, in the northern zone that was less affected by drought severity, farmers were more conservative, maintaining their ancestral activities. Whilst; the observed cases of abandoning farming activities were not caused by climate change but by anthropogenic factors. This information is of great interest to design and implement agricultural development programs in the context of expected climate change. By allowing a better understanding of response to climate change, it would help farmers to held a sustainable development without affecting natural resources and contribute to better manage the conversion of traditional farming systems to more sustainable systems and preserve the social value of agriculture. This study gives new horizons to go ahead in diagnosis of farming according to climate impacts. In the future, such studies would be more efficient by improving the sampling size of farmers and hence enlarging the geographical spread of the study area and the length of the climate dataset.

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