Research Article

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Analysis of livestock breeders' perceptions and their adaptation measures to climate change in Morocco's arid rangelands

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Abstract: The high plateaus of eastern Morocco are already suffering from the adverse impacts of climate change (CC), as the local populations' livelihoods depend mainly on extensive sheep farming and therefore on natural resources. This research identifies breeders' perceptions about CC, examines whether they correspond to the recorded climate data and analyses endogenous adaptation practices taking into account the agroecological characteristics of the studied sites and the difference between breeders' categories based on the size of owned sheep herd. Data on perceptions and adaptation were analyzed using the Chi-square independence and Kruskal-Wallis tests. Climate data were investigated through Mann-Kendall, Pettitt and Buishand tests.

Herders' perceptions are in line with the climate analysis in term of nature and direction of observed climate variations (downward trend in rainfall and upward in temperature). In addition, there is a significant difference in the adoption frequency of adaptive strategies between the studied agroecological sub-zones ($\chi^2 = 14.525$, $p < .05$) due to their contrasting biophysical and socioeconomic conditions, as well as among breeders' categories ($\chi^2 = 10.568$, $p < .05$) which attributed mainly to the size of sheep flock. Policy options aimed to enhance local-level adaptation should formulate site-specific adaptation programs and prioritise the small-scale herders.

Keywords: climate change; perception; adaptation; livestock breeders; arid rangelands; Morocco.

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1 Introduction

Climate change (CC) is unequivocal and its several impacts on human and natural systems are widespread worldwide (IPCC, 2014). Africa is one of the continents most vulnerable to climate change (IPCC, 2007). This vulnerability is mainly due to the low level of economic development in its countries, thus generating a weak and limited adaptive capacity to cope with the harmful effects of CC (Bruckner, 2012). Among North African countries, Morocco is considered to be the most vulnerable to CC, owing to the combination of high exposure to climate impacts (climate trends in the recent past and probably in the future are evolving towards warmer and drier conditions coupled with the increase in the frequency of extreme events), pronounced climate sensitivity (dependency on rain-fed agriculture, water stress) and weak generic adaptive capacity (low income per capita and its unequal distribution) (Yohe et al., 2006; Schilling et al., 2012). Morocco is already experiencing CC impacts. The climate trends observed during the period from 1960 to 2005 show an increase in aridity toward the north of the country (Mokssit, 2012) with an increase in mean annual temperature from 1.0 to more than 1.8°C, while precipitation underwent a general decline ranged from 3 to 30% (Maroc, 2016). Drought has increased during the last three decades in terms of frequency, intensity and length (Moroccan Meteorological Office, 2007). According to future climate projections in Morocco, total annual rainfall could drop by 10 to 20% by 2100 (Mokssit, 2012; Maroc, 2016) while the temperature would rise and could reach 1.0 to 1.2°C by 2050 respectively under the SRES (Special Report on Emissions Scenarios) B1 and A1B scenario conditions (Schilling et al., 2012). Also, the probability of occurrence of droughts would upsurge in the future (Bzioui, 2012; Schilling et al., 2012).

Within this context, the high plateaus of eastern Morocco (HPEM), which are one of the country's largest

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pastoral ecosystems, covering about 35,000 Km^2, already suffering from the effects of CC (Maroc, 2010).

The HPEM have shown widespread manifestations of drier and warmer conditions in recent decades generated by the notorious decrease in rainfall levels, particularly since the mid-1970s (Born et al., 2008; Fink et al., 2010) and the increase of the occurrence of droughts (Moroccan Meteorological Office, 2007).

The pastoralism, based mostly on the sheep farming, is the main livelihood and job provider for the local population. Indeed, the climate change has become a reality in the rangelands of the HPEM, with negative consequences on both human activities and the natural environment. In this pastoral ecosystem, the phenomenon of CC is at the basis of many of its socio-economic and environmental deregulations and dynamics. Livestock breeding activity on natural rangelands is highly vulnerable to CC due to its strong dependence on climate conditions (Bechchari et al., 2014), which, in this region, are characterized by intra and inter-annual variability in precipitation and recurrent droughts (Mahyou et al., 2010; Bechchari et al., 2014). Actually, pastoral activity can be severely affected by the adverse impacts of extreme climate events, as it is practiced in fragile and marginal environments such as dryland ecosystems. These arid lands present an intrinsic natural vulnerability generated by a high exposure to a significant water stress (Hassan, 2010). Furthermore, given that the extreme climate events (droughts), will increase in the future, they will pose significant risks and threats to pastoral activity in these arid areas, such as the declining of pastures and water resources, increased competition over available natural resources and even sometimes brutal conflicts between pastoral communities (Berhanu and Beyene, 2015).

In addition, the decrease in precipitation and recurrent droughts combined with negative anthropogenic actions (overgrazing, rangelands cultivation) have led to the degradation of natural resources and desertification in the study area (Maâtougui et al., 2011). The consequence is a substantial decline of the current agropastoral potentialities on which relays the existence of the majority of the local population (Bechchari et al., 2014). Moreover, increasing the frequency and severity of projected droughts could increase social inequality in semi-arid rural areas in Morocco (Schilling et al., 2012). For instance, during these extreme events, the poorer livestock breeders are likely to face more intense pressure on less available pastoral resources, and to their inability to purchase feeds for their livestock. While the better-off herders are likely to be less affected owing to their relatively low dependence on natural resources for generating their incomes (Kuhn et al., 2010).

Thus, this state of imbalance attributed to ongoing and expected effects of climate change, does not allow for better planning of development and interventions against poverty in the future (Badraoui and Balaghi, 2012) and even threatens the sustainability of these actions. This is why one of the main challenges ahead for Morocco is to increase its capacity to adapt and the resilience of its arid land ecosystems in particular, in order to face the negative effects of this climate phenomenon and effectively reduce its vulnerability (Schilling et al., 2012). In the absence of adaptation measures, farmers and more generally dryland communities would be more vulnerable and agro-ecosystem production would be adversely affected (Hassan and Nhemachena, 2008; Rao et al., 2011). Moreover, the importance of CC adaptation becomes crucial due to the high vulnerability of such fragile communities and ecosystems resulting from a low initial adaptive capacity (Hassan and Nhemachena, 2008). Knowing that many previous empirical studies (Benhin, 2006; Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006) cited by Mano and Nhemachena (2007), have shown that several impacts on agriculture in Africa linked to CC could be significantly reduced if appropriate and effective adaptation measures are put in place.

In addition, the decision of farmers and rural households whether or not to adapt to CC is mainly driven by their perceptions of change in usual climatic conditions (Deressa et al., 2009). In fact, the CC perception is considered the first and most significant step before adaptation (Gbetibouo, 2009) or for the development of relevant adaptive strategies (Speranza, 2010), and more importantly, it is a prerequisite for adaptation, according to Thomas et al. (2007) and Silvestri et al., (2012). Consequently, better understanding of the perceptions of communities in arid lands related to climate change is critical in order to address the CC adaptation issue in these harsh environments (Fraser et al., 2011; Silvestri et al., 2012; Opiyo et al., 2015). Actually, the importance of studying farmers' perceptions on CC stems mainly from three reasons:

(i) To fill knowledge gaps between farmers and policy makers (Tologbonse et al., 2010);
(ii) These perceptions represent a significant factor influencing the success of the adaptation measures to be implemented (Tesfahunegn et al., 2016);
(iii) Comprehensive and well-documented information on farmers' perceptions toward CC helps formulate effective and sustainable adaptation responses

aimed at reducing the impacts and vulnerability to this climate phenomenon (Opiyo et al., 2015; Van Wesenbeeck et al., 2016).

Finally, farmers' adaptations to CC depend on their respective sites-specific socio-economic and biophysical conditions (Below et al., 2012). Hence, the design of relevant CC adaptation policies and strategies should take into consideration these differences within the human and natural contexts (Fussel, 2007) by means of agro-ecology based research (Deressa et al., 2009) and local or farm-level perspective (Below et al., 2012).

Given all of the above, this research intends to explore the perceptions and adaptations of breeders in the study area in the face of climate change, while taking into account the existing socio-territorial differentiation (agroecological sub-zones and breeders' categories). Thus, a thorough examination of endogenous adaptation practices is essential to develop appropriate CC adaptation policies and strategies aimed to enhance the resilience and adaptability of local communities. The specific objectives of this study are: i) To identify livestock breeders' perceptions toward CC and examine whether they correspond to historical climate data recorded, and ii) To analyze herders' endogenous practices in adapting to climate variability and changes. The hypothesis underlying our research assumes that the adaptation of livestock producers to CC is influenced by their respective sites-specific biophysical and socio-economic conditions. Thus, this adaptation differs according to the agroecological sites and the categories of breeders.

2 Materials and Methods

2.1 Study Area

This study was conducted in the high plateaus of eastern Morocco (HPEM), which are located in the 30S UTM zone (Figure 1). They represent one of the most extensive pastoral areas in Morocco since they cover an area of 35,000 km², representing 10% of the total land of the country's rangelands. Pastoralism, based principally on sheep breeding, is the main economic activity and livelihood for local population. The HPEM area has experienced proven trends of climate change over the past decades such as decreased precipitation and recurrent episodes of drought (Mahyou et al., 2010; Maâtougui et al., 2011; Melhaoui et al., 2018). Hence, the HPEM represent a suitable and representative area to explore and comprehend the breeders' perceptions and adaptations to CC in Morocco's pastoral ecosystems.

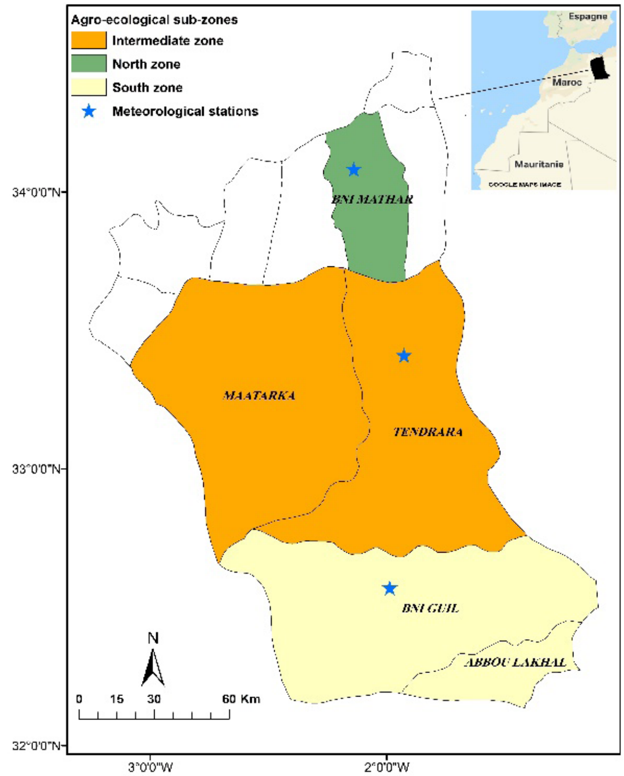

Figure 1: Location map of the study area.

A comparative case-study approach was applied to determine whether the perception and especially the adaptation of the breeders in this vast area depend on site-specific socio-economic and biophysical contexts, by selecting three distinct agroecological sub-zones in the study area. The selected sites are: south zone (rural communes of Bni Guil and Abbou Lakhal), intermediate zone (rural communes of Tendrara and Maâtarka) and north zone (rural commune of Bni Mathar). This site identification and selection was based on a set of criteria:

- (i) nature of the climate (decreasing bioclimate gradient ranging from arid in the north to hyperarid or pre-Saharan in the south);
- (ii) extent of rangelands (the rangelands are more extensive in the intermediate and southern zones compared to the northern part);
- (iii) water potential (water resources are more abundant in the north zone);
- (iv) altitude (an increasing altitude gradient from north to south); and
- (v) type of dominant livestock breeding system (more extensive in the intermediate and southern zones than to the north) (Table 1).

Table 1: Socioeconomic and biophysical characteristics of the study area.

Zone	North	Intermediate	South
Population[1] (number of inhabitants)	8,869	14,869	8,743
Density of population (inhabitants / Km^2)	High	Low	Low
Households[1] (number)	1,469	2,502	1,595
Area[2,3] (Km^2)	1,793	17,359	11,806
Arable land[2,3] (ha)	23,582	9,495	13,168
Irrigated area[2,3] (ha / household)	1.76	0.1	0.6
Maximum altitude[2,3] (m)	1,000	1,668	1,839
Climate[2,3]	Semi-arid to arid	Arid	Arid to hyperarid
Precipitation[2,3] (mm)	193	207	149
Average annual temperature[2,3] (°C)	16.4	17	20
Groundwater[2,3]	Important	Reduced	Reduced
Soil productive potential[2,3]	Low	Low	Low
Level of rangelands degradation[4]	Moderate	Moderate to severe	Severe to very severe
Extent of rangelands [2,3]	Reduced	Great	Average
Type of breeding system[2,3]	Semi-intensive	Semi-extensive to extensive	Semi-extensive to extensive
Sheep numbers[5] (heads/household)	57	154	110
Goat numbers[5] (heads/household)	9	25	31
Bovine numbers[5] (heads/household)	2	3	2
Importance of local livestock market[2,3]	High	Average	Low
Poverty[6] (%)	16.2	26.9	21.25
Vulnerability[6] (%)	23.4	22.65	17.35

Sources: [1]High Commission for Planning HCP (2018). General census of population and housing 2014; [2]Province of Figuig-ADS (2010). Participatory territorial diagnosis of the rural communes of Abbou Lakhal, Bni Guil, Tendrara and Maâtarka; [3]UNICEF Morocco-DGCL-ADO (2010). Communal Plan of Development 2010-2015 of the rural commune of Bni Mathar; [4]Mahyou et al. (2016); [5]Regional Directorate of Agriculture of the Oriental DRAO (2017). Livestock statistics in the Oriental Region; [6]HCP (2010). Communal indicators of poverty, vulnerability and inequality.

As for the southern zone, in addition to the extensive pastoral farming of small ruminants carried out by the majority of households' heads, some ones of them practice the casual wage labor and localized agriculture (cereal crops). The intermediate zone is basically specialized in the semi-extensive or even extensive farming of small ruminants benefiting from its vast pastoral areas. While in the northern part, a diversified production system combining semi-intensive breeding of sheep and bovine cattle, fodder and cereal crops, is observed (UNICEF Morocco-DGCL-ADO, 2010). The northern site has the singularity to have an important groundwater, which allows the development of an irrigated agriculture on an area of 2,500 ha. The soils of the study area are little evolved, from silty to sandy-silty texture, resting on a calcareous crust and their organic matter content is very low.

2.2 Data collection and sampling

2.2.1 Data collection

Method of data collection used a combination of literature review, key informant interviews, focus group discussions and a survey of pastoralist households' heads (Figure 2). Relevant literature available from the extension services and agricultural development agencies were consulted to

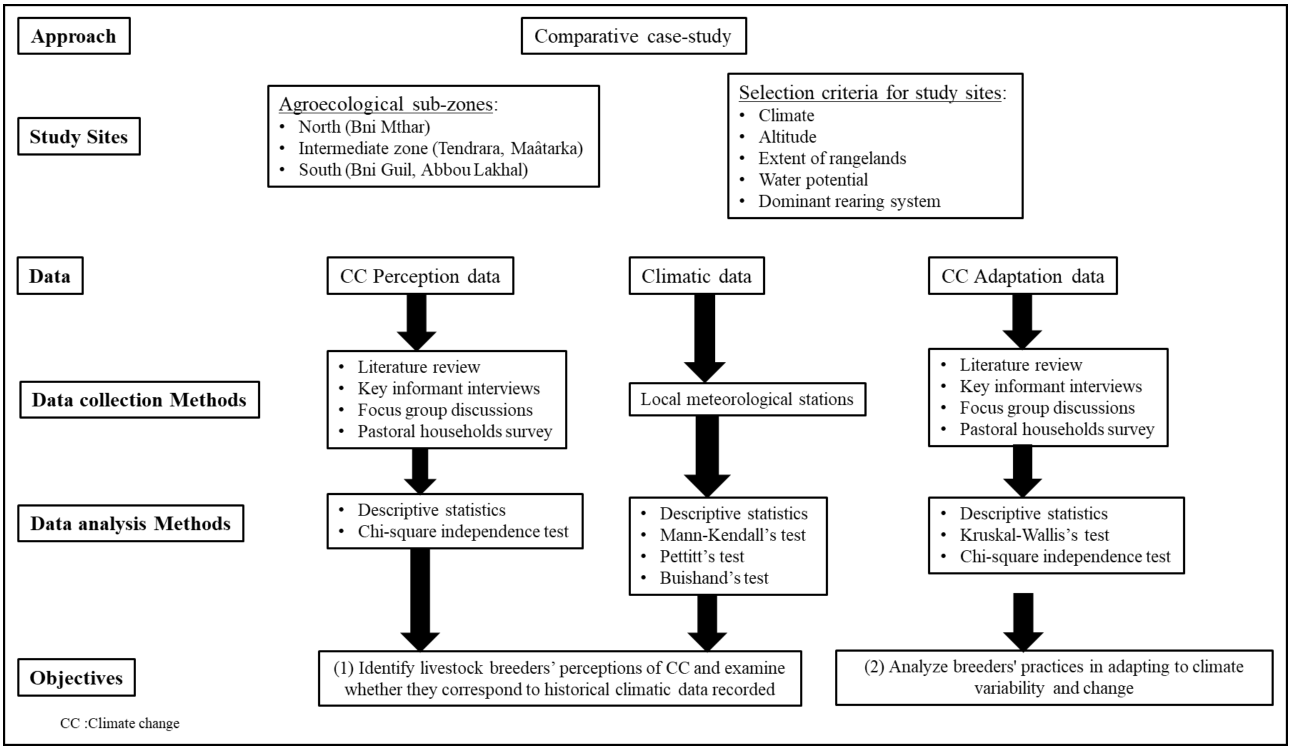

Figure 2: Analytical framework.

acquire mainly the information on the local climate trends, livestock practices and endogenous adaptation measures practiced by the breeders to combat the negative effects of CC in the study area (Annex A).

Prior to the household survey, 11 interviews with key informants, such as representatives of extension services, agricultural agencies and pastoral cooperatives (Annexes B and C), were conducted in July 2015. These interviews aimed to get a global and clear overview about the CC issue in the HPEM, mainly with regard to the identification of major climate change patterns in the last five decades and the local adaptation practices in response to these observed changes. During this phase of field data collection, rainfall and temperature data were gathered from local agricultural development agencies.

The data collected cover the annual rainfall volumes of the three meteorological stations of Bni Mathar (1931-2016), Tendrara (1931-2016) and Bouaârfa (1981-2016) and the temperature data of Bni Mathar station (1970-2016). The long time series of temperature concerning other remaining stations are unavailable. After that, three focus group discussions (FGDs), one per agroecological sub-zone, were organized with the aim to obtain the qualitative data related to the main climate hazards that have occurred in the study area over the last five decades, the changes in rainfall and temperature patterns and the endogenous adaptation practices. The FGDs consisted of groups made up of 12 to 15 participants, including heads of pastoral households with different wealth status (small, medium and large breeders), extension staffs and agricultural agencies representatives. The final stage of fieldwork involved the survey of pastoral households using a closed questionnaire, which covers household's demographic and socio-economic characteristics, perceptions of CC (frequent risks and hazards linked to climate, changes in rainfall and temperature patterns) and the adaptation strategies practiced in response to perceived climate changes (Annex D). The household survey was conducted from September to December in 2015.

2.2.2 Sampling design

To select the livestock producers surveyed in the study area, a multi-step sampling procedure was used by involving purposive and random sampling methods. At the first stage of selection, as mentioned above, three agroecological sub-zones were identified and selected. At the second stage, given the similarity in the agroecological characteristics with other rural communes belonging to the north agroecological sub-zone, the commune of Bni Mathar has been conserved to represent the rest of the

Table 2: Distribution of breeders surveyed by agroecological sub-zone.

Agroecological sub-zones	No. of rural communes	No. of rural communes selected	Total number of households	Sample size
Southern zone	2	2	1,595	55
Intermediate zone	2	2	2,502	82
Northern zone	7	1	1,469	30
Total	11	5	5,566	167

Source: Field study (2015)

neighbouring localities. Thus, five rural communes were purposively selected, these are Bni Guil, Abbou Lakhal (south zone), Tendrara, Maâtarka (intermediate zone) and Bni Mathar (north zone). They cover about 88% of the total area of the HPEM. The third stage involved the random selection of 167 households proportionate to the breeders' population size of the selected rural communes (Table 2). The sample was drawn up as follows: 55 herders in the southern zone, 82 in the intermediate area and 30 breeders in the northern zone. Given that the sheep breeding constitutes the main source of income in the study area and that the ovine species dominates the structure of existing small ruminant herds (83%), the size of the sheep flock in ownership was chosen as the criterion of discrimination between breeders, and this in agreement with the representatives of the local agricultural extension agencies. Therefore, three categories of livestock breeders were identified. The large breeders are those with a sheep flock exceeding 300 heads, medium livestock keepers own sheep flocks of between 101 and 300 heads, and finally the small-scale breeders with the number of sheep owned less than or equal to 100 heads. At the final stage, respondent livestock breeders were randomly selected from the established lists of surveyed rural commune households stratified based on differences in wealth status (the size of the sheep flock). The distribution of the surveyed herders by category identified 96 small livestock producers (14 in north, 50 in the intermediate zone and 32 in the southern part), 47 medium breeders (12 in the north zone, 19 in the intermediate zone and 16 in south), and 24 large herders (4 in north, 13 in intermediate zone and 7 in the southern part). This distribution was based on respecting the representativeness of the three categories of breeders within the five selected rural communes.

2.3 Data analysis methods

The collected data on the livestock breeders' perceptions to CC, were analyzed using descriptive statistics and Chi-square independence test. The latter aims to highlight the possible relationship between the perception of changes in climate parameters and the agroecological sub-zone.

While the data gathered regarding to the practiced adaptation measures were analyzed by the means of Kruskal-Wallis's test and Chi-square independence test. Kruskal-Wallis test is an appropriate nonparametric test for comparing more than two independent samples. It is a rank-based test that can be used to test whether such samples come from the same distribution (Ostertagova et al., 2014). In our case, the Kruskal-Wallis test was used to look for differences in the frequency of adoption of adaptation strategies among three agroecological sub-zones and between three livestock breeders' categories. If the Kruskal-Wallis statistic is significant, the nonparametric multiple comparison method is used to find out which agroecological sub-zones or categories of breeders are different from the others. In addition, a Chi-square independence test was conducted to verify whether this difference within the three agroecological sub-zones is linked to socio-economic conditions at the community level. Finally, quantitative data gathered from household survey were processed using the software called Statistical Package for Social Sciences (SPSS).

Meteorological data were studied to highlight any change in the patterns of precipitations and temperature. The methods used aimed to either study the variability and trends within the climate chronicles through the use of Mann-Kendall's test or to detect breaks within these series by the use of two appropriate homogeneity tests, namely Pettitt's test (Pettitt, 1979) and Buishand's test (Buishand, 1982, 1984). Mann-Kendall's test was carried out to indicate whether there are trends in the studied climate series and the degree of their significance when they exist. This test is often used because of its property that no assumptions are needed on the data to be tested (Sulaiman et al., 2015). The statistical methods for detecting breaks within time series are intended to show a change in the average behavior of the studied climate parameter. As regards to Pettitt's and Buishand's tests, this involves dividing the main series of N elements into two sub-series at each time t between 1 and N-1. The main series shows a break at time t if the two subseries have different distributions (Kingumbi et al., 2000). The null hypothesis of these tests is the absence of rupture. Climate data were analyzed using XLSTAT and Khronostat software.

3 Results

3.1 Livestock breeders' perceptions about climate change

The majority of the surveyed herders perceived many changes in their current climate compared to that of the past five decades, particularly as regards variations in the patterns of rainfall and of temperature (Figure 3). The results indicate that all breeders observed a substantial decline in the rainfall amounts, mostly since the 1970s. In addition, the majority of herders noticed some irregularity and shortening of the rainy season (late onset of the rains, sometimes their early cessation than expected, appearance of drought pockets). As a result, a disorder in the usual calendar of agricultural practices and a disrupting of growing season for pastoral plants and cereal crops. These changes are mostly observed by the breeders of the north and south zones (existence of relatively large cropping areas). The occurrence of heavy rains that can cause serious damage, especially to livestock, houses (tents) and road infrastructures, is primarily noted by the livestock producers of the intermediate zone (93%) and those of the southern part (58%). In fact, the rains in these two localities are sometimes of torrential nature over the very rainy years. Therefore, the results of the chi-square independence test show that there is a significant difference in terms of perceived heavy rains between the agroecological sub-zones studied ($\chi^2 = 69.896$, $p < .001$).

Furthermore, nearly 90% of breeders perceived changes in temperature pattern that occurred in their area over the last five decades. Indeed, the majority of the respondents (82%) observed a significant rise in temperature, principally in the intermediate zone (79%) and the south area (91%). This increase in temperature is more perceived in these localities ($\chi^2 = 12.625$, $p = .013$).

In addition to these major climate changes observed by the interviewed breeders, other climate hazards were mentioned, notably the increase in strong winds and sandstorms. The increased high winds are noticed mainly in the south (100%) and the intermediate (76%) zones. The perceived strong winds differed significantly within the three agroecological sub-zones studied ($\chi^2 = 22.894$, $p < .001$). Similarly, there was a significant difference in terms of perception of increasing sandstorms between the three agroecological sub-zones ($\chi^2 = 15.774$, $p < .001$).

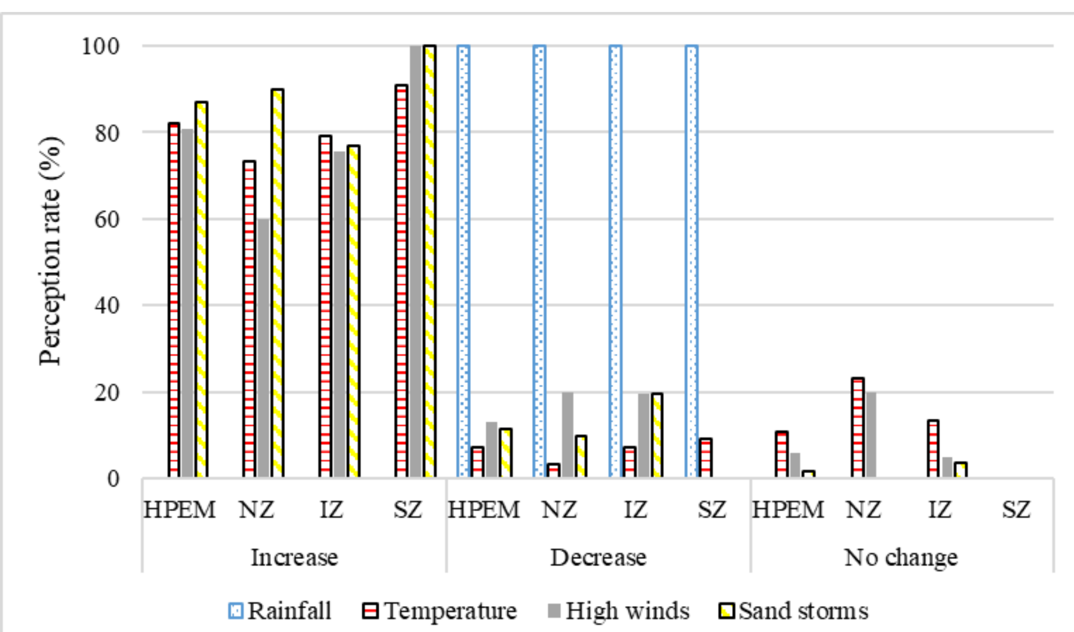

Figure 3: Perception of changes in climate factors for the past five decades in the HPEM's area (in %). HPEM: High plateaus of eastern Morocco, NZ: North zone, IZ: Intermediate zone, SZ: South zone.

Table 3: Analysis of precipitation data in the study area.

Rainfall	Bni Mathar	Tendrara	Bouaârfa
Total years	85	83	35
Mean (mm)	214.755	199.222	146.119
Standard deviation (mm)	73.628	94.177	64.237
Minimum rainfall (mm)	62.00	46.50	57.10
Maximum rainfall (mm)	415.90	391.70	277.30
Median (mm)	218	177.30	131.60
Amplitude of variation[1] (mm)	353.9	345.2	220.2
Coefficient of variation (%)	34.28	47.27	43.96
Trend (mm/year)	-.827*	-.217	-.179
Correlation[2]	-.277* (.01)	-.057 (.607)	-.029 (.870)
Total change calculated from the trend (mm/total years)	-15.3	-130.8	-30.4
Rate of change[3] (%)	-6.7	-59	-20.2

[1]: Amplitude of variation or the extent is the difference between the largest and lowest value of rainfall data.
[2]: Correlation between time and rainfall series. Pearson correlation (significance).
[3]: The rate of change is the difference between the trend line value of the final year and the initial year (VF-VI) relative to the initial year' value.
*: Significant (P < .05).

Indeed, the rise in sandstorms is more perceived in the south (100%) and the north (90%) sites.

Overall, except the unanimity on the widespread decline of precipitation throughout the study area, breeders' perception toward CC varies significantly through the studied agroecological sub-zones. Thus, the results suggest that the intermediate and the south zones are the most vulnerable to climate change compared to the northern area characterized by slightly more favorable climate conditions.

3.2 Analysis of historical climate data

3.2.1 Long-term changes in precipitation in the study area

3.2.1.1 Interannual variability and rainfall trends

The precipitation data collected at the three meteorological stations of Bni Mathar, Tendrara (1931-2016) and Bouaârfa (1981-2016) show a spatio-temporal irregularity of annual rainfall heights. Indeed, the great inter-annual variability is more pronounced in the intermediate and southern zones, as evidenced by the high values of the coefficients of variation. The latter are respectively of 47 and 44% (Table 3).

The recorded data on rainfall reveal a slight downward trend of the annual rainfall in the studied chronic series with a more marked regression of precipitation in the northern region of the study area (Bni Mathar). This one shows a statistically significant decreasing trend. In addition, the correlation between precipitation and time is significant only in Bni Mathar station since its rainfall amounts vary considerably over the years.

This decline in rainfall is probably due to global climate change that has been observed in recent decades.

Furthermore, since average rainfall values in Tendrara (intermediate zone) and Bouaârfa (southern zone) are higher than those of the median rainfall values, respectively of 177 and 132 mm, it can be argued that the average rainfall in these two sites is somewhat influenced by the wet extreme years. Contrariwise, for the Bni Mathar station, its average rainfall is slightly influenced by the dry extreme years because the value of its median rainfall is 218 mm.

In order to determine if there is a significant trend in rainfall series, a Mann- Kendall test was run. The rainfall series of Bni Mathar station, exhibits a decreasing tendency, which is statistically significant (Kendall's Tau statistic $\tau b = -.182$, $p = .014$), unlike precipitation series of the meteorological stations of Tendrara ($\tau b = -.076$, $p = .307$) and Bouaârfa ($\tau b = -.015$, $p = .910$), which do not show significant trend.

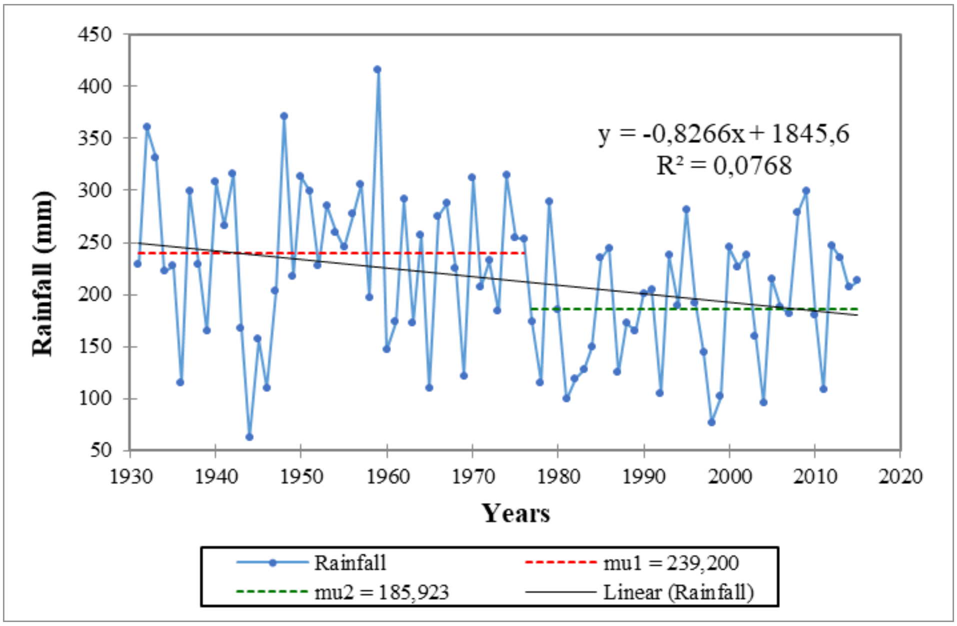

Figure 4: Graph of the homogeneity of annual precipitation at the Bni Mathar station (according to the Pettitt's test).

3.2.1.2 Rainfall homogeneity

In order to confirm these identified trends and to investigate possible rainfall breaks in the three series studied, two homogeneity tests were used. The results obtained by Pettitt's test (K = 752.000, p = .010) and Buishand's test (Q = 15.363, p = .004) show that the calculated p-values are lower than the level of significance alpha (= .05). Thus, the null hypothesis (H_0) of homogeneity of the rainfall series of the Bni Mathar station should be rejected. There is a point or time t from which there is a significant change in the mean of annual rainfall, this point is in 1976.

Figure 4 clearly shows this rupture of stationarity in this studied rainfall series. Contrariwise, according to the results of Pettitt's test (K = 368.000, p = .815 ; K = 90.000, p = .979) and Buishand's test (Q = 6.342, p = .629 ; Q = 4.086, p = .601), respectively, for the stations of Tendrara and Bouaârfa, the calculated p-values are greater than the threshold significance level alpha (= .05). Thus, H_0 cannot be rejected and therefore the precipitation data at these two stations are homogeneous (no shift between two parts of each time series).

Overall, a general regression trend of the annual rainfall amounts is observed between the two recording periods 1931-1976 and 1977-2016. Indeed, the average annual rainfall of the Bni Mathar station decreased from 239 mm to 186 mm, which is a diminution of more than 22%. This decline in annual rainfall over the considered periods is less marked at the Tendrara station, i.e. a decrease of 3.2%.

3.2.2 Long-term changes in temperature in the study area

3.2.2.1 Interannual variability and temperature trends

The slopes of the three trend lines (Tmean, Tmin and Tmax) have a positive value, which indicate an increase in annual temperature over the period 1970 to 2016 at the station of Bni Mathar (Figure 5). Since the factors for modifying the minimum and maximum annual temperature are respectively of .096 and .012, it can be argued that the fluctuation of the minimum temperature was much greater than that of the maximum temperature. To determine if there is a trend in temperature series, a Mann-Kendall test was carried out. For the mean temperature (Kendall's Tau statistic τb = .553, p < .0001) and minimum temperature (τb = .647, p < .0001), the p values indicate that we reject the null hypothesis (no trend) and therefore there is an upward trend in these series, which is statistically significant, unlike the maximum temperature series (τb = .059, p = .557).

3.2.2.2 Homogeneity of temperatures

The series of annual minimum temperatures shows a significant change in the mean observed according to Pettitt's test (K = 502.000, p < .0001) and Buishand's test (Q = 19.608, p < .0001) since the calculated p-values of these two tests are lower than the level of significance alpha (= .05). The rupture date is around 1988. Thus, between

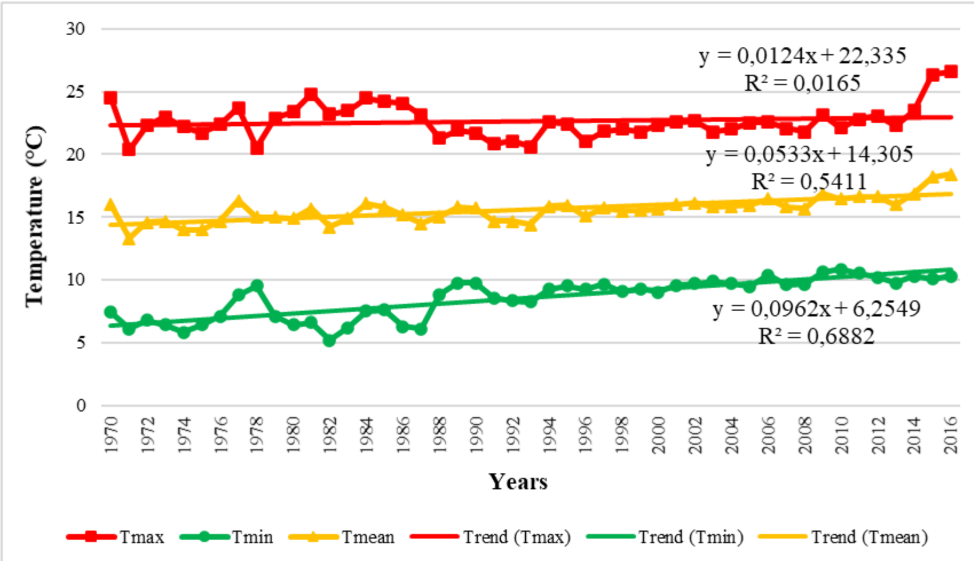

Figure 5: Change in mean, minimum and maximum annual temperature at the Bni Mathar station.

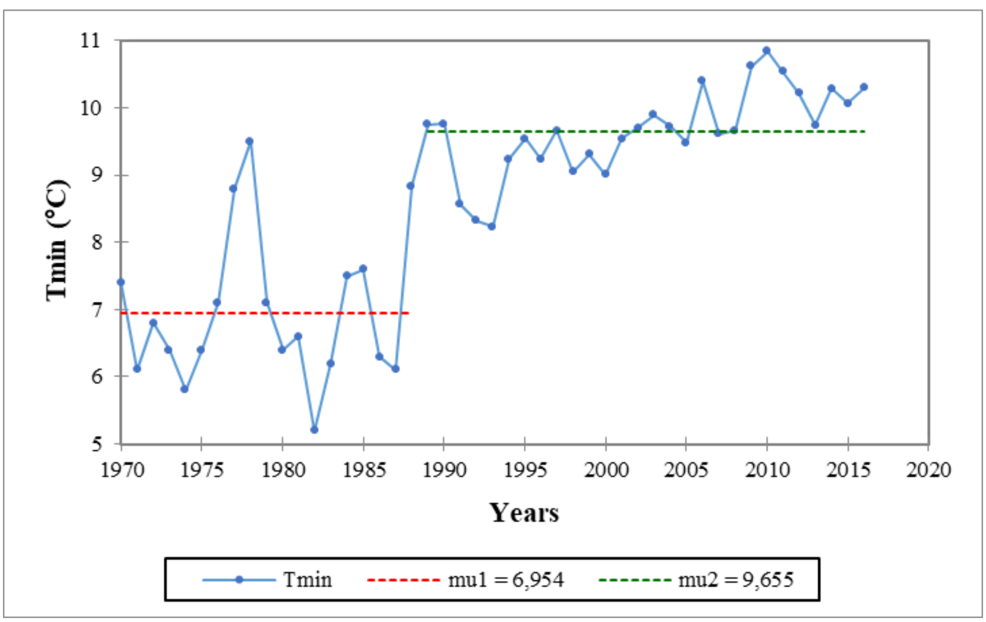

Figure 6: Graph of homogeneity of annual minimum temperatures at the Bni Mathar station (according to the Pettitt's test).

the periods 1970-1988 and 1989-2016, the minimum temperature is increased from 6.95 to 9.65 °C, that a rise of about 39% (Figure 6). Similarly, for the mean temperature, the Pettitt's test (K = 424.000, p < .0001) and Buishand's test (Q = 15.047, p < .0001) suggest that the null hypothesis H_0 of homogeneity of the temperature data of this series must be rejected.

Therefore, mean annual temperature of Bni Mathar station, before and after the 2000 rupture date, is significantly different. Indeed, between the periods 1970-2000 and 2001-2016, the average temperature is increased from 15.12 to 16.49 °C, thus registering a rise of about 9%. However, there is no significant change in the mean of the series of maximum annual temperatures, according to the Pettitt's test (K = 212.000, p = .203) and Buishand's test (Q = 6.705, p = .211).

3.3 Analysis of the endogenous adaptation strategies to climate variability and change

Based on the FGDs conducted, key informant interviews and literature review, 25 adaptation measures to climate variability and change have been identified and are currently being practiced by livestock breeders in the study area. These local adaptation practices can be grouped into three main categories: (i) Adjustment of farm management and pastoral practices; (ii) Diversification of income sources and (iii) Other adaptations. A large part of these adaptation strategies concerns the first dimension. A general divergence between the agroecological sub-zones on all identified practices, was observed (Table 4). In fact, the frequencies of adoption of these adaptation measures differ according to the agroecological sub-zones. The Kruskal-Wallis test showed that there is a statistically significant difference in the frequency of the adoption of adaptation strategies between the studied agroecological sub-zones ($\chi^2 = 14.525$, $p = .001$), with a mean rank of 28.94 for the northern zone, 51.26 for the intermediate zone and 33.80 for the southern area.

This lack of similarity in the frequency distributions of adaptation strategies within the three agroecological sub-zones is due to the presence of a significant difference between the northern and the intermediate zone ($\chi^2 = 12.839$, $p < .001$) and between the southern area and the intermediate zone ($\chi^2 = 8.145$, $p = .004$).

Concerning the first category of adaptation measures, it is noted that the northern area benefits from some specific natural (climate conditions relatively favorable compared to other sites, presence of a large groundwater) and physical assets (existence of an important local livestock' market, geographical proximity of the capital of the Eastern Region of the country). These elements have enabled local development of irrigated agriculture on a perimeter of 2,500 ha, which often acts as a buffer, especially during drought events. As a result, fodder crops (barley, oats, alfalfa) have become increasingly practiced by local breeders. Thus, the availability of on-site forage resources has encouraged many herders to diversify their livestock by introducing bovine cattle (with as a corollary the intensification of prophylactic care), to store animal feed and, above all, to achieve greater integration between livestock and agriculture. The breeding system at this site is market-oriented, as this region is a center of intermediation between the production areas and the regional animal market in Taourirt. This explains the relative high frequencies of animal commercialization practices. At the intermediate zone and because of the aridity of the climate and the recurrence of the drought episodes, the breeders of this locality opted for the diversification of their flock through the rearing of goats and this for their characteristics of hardiness and polyfunctionality. On the other hand, given the immensity of its pastoral lands of approximately 17,360 km^2 and the large numbers of small ruminants owned which are around 450 thousand heads, the systematic use of the motorization and the mobility of herds is more than justified (Bourbouze, 2000). The frequent and regular practice of veterinary care is emerged thanks to the "Livestock and Rangelands Development Project in the Eastern Region of Morocco" and the public programs against unpredictable climate events, which include the improvement of flocks' health particularly by regular vaccination campaigns. In addition, Tendrara's local livestock market is coveted by several animal speculators who seek either to supply the local demand in red meats or to make more profits by supplying large but distant urban agglomerations. Moreover, the supervision of breeders in this locality, by local institutions (National Association of Sheep and Goat Breeders-ANOC, agricultural development agencies) and international cooperation actors (IFAD, USAID), has allowed the improvement of their technical and commercial skills and performances (sheep fattening practice, consolidation of quality butcher, contracts of sale of animal products with several supermarkets).

With regard to the second dimension of adaptation measures, the practices related to the diversification of the livelihoods and research of additional sources of income, are more frequently applied by the livestock producers in the South area. In fact, as a complement to livestock breeding, these herders have been forced to engage in other activities, namely temporary wage labor, services and small activities generating additional income such as collection of truffles. In addition, natural (increased drought or dry years) and economic (fluctuating prices of livestock and livestock feed) insecurity conditions have prompted several breeders in this area to convert their animal capital into real estate capital. Finally, with respect to the third dimension, only the intermediate zone still shows signs of mutual aid and community solidarity.

Similarly, even for the agroecological sub-zones, adaptation practices of the first dimension "Adjustment of farm management and pastoral practices" are most frequently practiced by the breeders in the study area (Table 5). In addition, the analysis of the relative frequencies of adaptation measures indicates a general divergence between categories of breeders. The Kruskal-Wallis test showed a statistically significant difference in the frequency of adopting adaptation strategies within breeders' categories ($\chi^2 = 10.568$, $p = .005$), with a mean

Table 4: Frequencies of adaptation measures in percentage according to the agroecological sub-zones.

	Adaptation measures (%)	North	Intermediate	South
Adjustment of farm management and pastoral practices				
M 1.	Mixed livestock crop farming system*	96.7	92.7	61.8
M 2.	Diversification of livestock species (sheep & goats)*	43.3	87.8	81.8
M 3.	Irrigated agriculture and livestock integration*	73.3	0	0
M 4.	Regular practice of veterinary care*	83.3	75.6	16.4
M 5.	Practice of fattening*	40	39	12.7
M 6.	Selection of animals and conduct of reproduction*	40	29.3	12.7
M 7.	Improved livestock technologies (vaginal sponge)*	3.3	20.7	0
M 8.	Herd mobility*	20	50	36.4
M 9.	Profit of state agricultural programs*	96.7	76.8	72.7
M 10.	Mechanization and equipment*	36.7	89	32.7
M 11.	Storage of animal feed*	90	29.3	52.7
M 12.	Regular Sale of animals to stock up on feed*	66.7	56.1	23.6
M 13.	Sale of the animal in a good physical state*	60	58.5	12.7
M 14.	Use continuously of a favorable pasture site*	10	74.4	14.5
M 15.	Privative appropriation of rangelands	0	31.7	7.3
M 16.	Rangeland enclosure by cereal cultivation	3.3	15.9	5.5
M 17.	Climate multihazard insurance	56.7	39	56.4
Diversification of income sources				
M 18.	Casual labor*	6.7	20.7	65.5
M 19.	Internal or external emigration in search of jobs	26.7	13.4	16.4
M 20.	Collection of truffles as additional income*	0	0	25.5
M 21.	Livestock mixed with income generating activities	6.7	6.1	3.6
M 22.	Possession of an urban center based house*	40	28	58.2
M 23.	Construction of concrete residence in rangelands*	20	31.7	10.9
Other adaptations				
M 24.	Credit from speculators livestock feed*	33.3	25.6	10.9
M 25.	Seeking support from friends and the tribe*	0	25.6	1.8

Note: * Significant difference between distributions within the three agroecological sub-zones (level of significance: .05).
Source: Author's own elaboration.

rank of 47.60 for small-scale breeders, 38.78 for medium herders and 27.62 for large livestock keepers.

Moreover, the distribution of several adaptation measures differs significantly between categories of breeders. This lack of similarity in the frequency distributions of adaptation strategies within breeders' categories is due to the presence of a significant difference between small and large-scale breeders (χ^2 = 9.535, p = .002) and between medium and large breeders (χ^2 = 3.812, p = .05). This shows that breeders' adaptations in the study area depend mainly on their wealth status or economic power, expressed by the size of the sheep herd in possession.

Concerning the first dimension of adaptation measures, the large livestock producers opt for strategies of various purposes. Their strategies include

Table 5: Frequencies of adaptation measures in percentage according to the category of breeders.

	Adaptation measures (%)	Small	Medium	Large
Adjustment of farm management and pastoral practices				
M 1.	Mixed livestock crop farming system*	74	93.6	100
M 2.	Diversification of livestock species (sheep & goats)	71.9	85.1	87.5
M 3.	Irrigated agriculture and livestock integration	8.3	21.3	16.7
M 4.	Regular practice of veterinary care*	44.8	70.2	83.3
M 5.	Practice of fattening*	20.8	31.9	66.7
M 6.	Selection of animals and conduct of reproduction*	11.5	38.3	58.3
M 7.	Improved livestock technologies (vaginal sponge)	8.3	12.8	16.7
M 8.	Herd mobility*	27.1	48.9	75
M 9.	Profit of state agricultural programs	75	83	87.5
M 10.	Mechanization and equipment*	50	63.8	100
M 11.	Storage of animal feed*	36.5	63.8	62.5
M 12.	Regular Sale of animals to stock up on feed	44.8	53.2	45.8
M 13.	Sale of the animal in a good physical state*	33.3	48.9	75
M 14.	Use continuously of a favorable pasture site	40.6	44.7	50
M 15.	Privative appropriation of rangelands*	13.5	17	37.5
M 16.	Rangeland enclosure by cereal cultivation	8.3	12.8	12.5
M 17.	Climate multihazard insurance*	28.1	70.2	83.3
Diversification of income sources				
M 18.	Casual labor*	42.7	27.7	4.2
M 19.	Internal or external emigration in search of jobs	13.5	21.3	20.8
M 20.	Collection of truffles as additional income*	13.5	2.1	0
M 21.	Livestock mixed with income generating activities	6.3	2.1	8.3
M 22.	Possession of an urban center based house*	29.2	44.7	75
M 23.	Construction of concrete residence in rangelands*	13.5	34	37.5
Other adaptations				
M 24.	Credit from speculators livestock feed*	18.8	19.1	41.7
M 25.	Seeking support from friends and the tribe	14.6	8.5	16.7

Note: * Significant difference between distributions within the three categories of breeders (level of significance: .05).
Source: Author’s own elaboration.

the diversification of their productions (integration of livestock breeding and cereal farming, rearing of mixed flocks of sheep and goats), improving the quality of red meat offered (practice of fattening as well as the selection and reproduction of well sought races), mobility or transhumance of short duration and low amplitude, intensification of production factors (mechanization and acquisition of means of transport, regular or frequent veterinary care) and market orientation (final products of good taste quality). In fact, all these adaptation measures require the mobilization of substantial financial resources, which explains the differences in frequency distribution of these responses relatively less important among the medium and small-scale breeders. Thus, taking advantage of their wealth status and their relational networks, the better-off breeders tend to obtain more and more rangelands for their private use by capturing large expanses of collective pastures. This is reflected in the significant differences between the average available agricultural areas, which are 86, 37 and 15 hectares respectively for great, medium and small livestock keepers. Recently, the subscription to the multi-risk insurance climate has become a common practice, particularly for large livestock producers and to a lesser extent among the medium breeders. The adoption of this adaptation measure by large and medium-sized breeders has two objectives. Climate insurance contracts represent, according to local breeders, justifications demonstrating the legitimacy of the property ownership while they are indeed acts of annexation of collective pastures. In addition, this practice allows to this category of breeders, but also to the medium herders, to obtain important financial revenues via compensation of climate vagaries (drought in particular) that can reach 600 MAD per ha.

As regards to the second dimension of adaptation measures “Diversification of income sources”, the small breeders are forced to engage in other small-scale activities, such as temporary labor, collecting truffles and small trades. These activities allow satisfying both the needs of their families and those of their meager herds especially during prolonged drought event. As for the large livestock producers, to circumvent the conditions of climate and economic insecurities linked to the increasingly competitive livestock activity, they invest in activities of speculation including the real estate.

4 Discussion

4.1 Coherence between herders’ perceptions of CC and recorded climate data

To assess livestock breeders’ perception toward climate variability and change, the study examined how this local perception corresponds to climate data recorded at meteorological stations in the HPEM area. Thus, we compared climate changes perceived by livestock producers with the evolution in meteorological stations’ recorded data (variability and trends). At first, we looked at if our findings of climate analysis are consistent with those of previous climate studies conducted in the HPEM. Indeed, the results obtained from the statistical analysis of climate data corroborate those of these studies, since the latter have shown that rainfall is characterized by large inter-annual variability with a decreasing trend, while temperature has increased over the years (Mimouni and Mahyou, 2006; Jorion, 2009; Mahyou et al., 2010; François et al., 2016; Melhaoui et al., 2018). Jorion (2009), using rainfall series (1936 - 2006) from the stations of Bni Mathar and Tendrara, highlighted a declining precipitation trend, especially during the spring season, towards the end of the 1970s. Thus, the Bni Mathar station showed a break in the rainfall series by 1976, recording a regression of precipitation by 23%. He also noted an upward trend in temperatures in particular the mean and the minimum temperatures. Similarly, François et al. (2016) found that in Eastern Morocco, since 1981, annual rainfall amounts have decreased by 29%, while the temperature has increased. Melhaoui et al. (2018), based on precipitation series from 1935 to 2015 regarding Bni Mathar and Tendrara stations, pointed out a significant downward trend with a climate rupture, located in 1976/1977, within the rainfall data of the first meteorological station. While, even the Tendrara’ rainfall series shows a decrease in precipitation, there is no statically significant trend in the studied data.

Given that all interviewed breeders perceived a decrease in rainfall amounts, mainly since the 1970s, and most of them (82%) noticed an increase in temperature over the past five decades, so we can conclude that livestock breeders’ perception is consistent across the entire study area and that it is in agreement with the meteorological stations data. In addition, these perceptions (decrease in precipitation and increase in temperature) are in perfect concordance with those reported by several authors in different African countries: Benin (Vissoh et al., 2012), Ghana (Ndamani and Watanabe, 2016), Burkina Faso (Ouédraogo et al., 2010), South Africa (Gbetibouo, 2009), Ethiopia (Tamiru et al., 2014) and Kenya (Opiyo et al., 2015). Likewise, Berhanu and Beyene (2015) and Opiyo et al. (2015) emphasize that the recorded trend of increased temperature and decline in precipitation in the last three decades is found to correspond with pastoralists’ perception of CC, respectively in southern Ethiopia and northwestern Kenya. For their part, Gbetibouo (2009) and Ouédraogo et al. (2010) highlight this concordance between farmers’ perception and observed climate trends, respectively in Limpopo basin of South Africa and Burkina Faso.

Moreover, 81 and 87% of the respondents observed a rise of strong winds and sandstorms, respectively, and this notably in the intermediate and the southern zones. Indeed, regarding these other climate-related risks, Mahyou et al. (2016) and Melhaoui et al. (2018) reported that hot dry winds, in the two aforementioned localities, are recurrent and generate strong sandstorms, particularly in the summer. Vissoh et al. (2012) and Yila and Resurreccion (2013) highlighted that winds are stronger, mainly during the dry season, respectively in southeast Benin and Northeastern Nigeria.

4.2 Analysis of the endogenous adaptation strategies to climate variability and change

The results showed that livestock producers in the intermediate zone adopt, with higher frequencies, most of the endogenous adaptation strategies in response to the experienced climate variability and change, compared to those of the other two agroecological sub-zones. This difference could be attributed to several biophysical, economic and socio-cultural factors. Melhaoui et al. (2018) found that this locality has the highest coefficient of variation of annual rainfall, i.e. 47% versus 34% and 44% respectively for the northern and southern sites. In addition, according to these same authors, the frequency of dry years during the period between 1981 and 2015 is much higher (51%) in the intermediate zone compared to the north and south zones, which record frequencies about 36 and 33% respectively. Gutu et al. (2012) pointed that the farmers of the zones where the rainfall is low and the temperature is high, adopt easily adaptation measures compared to those belonging to areas receiving more precipitation and less temperature. Similarly, Atinkut and Mebrat (2016) emphasized that the households of the woina dega (Ethiopia) are more likely to implement adaptation strategies because this site receive less amounts of precipitation with high variability and frequent drought. Deressa et al. (2009) highlighted that decreasing precipitation significantly rises the probability of adopting soil conservation, changing crop varieties, changing planting dates and irrigating. Ouédraogo et al. (2010) stated that the adoption of water and soil conservation techniques and organic fertilization in the Sahelian zone (rainfall between 300 and 600 mm) is more important compared to the Sudanian zone (precipitation between 900 and 1,200 mm). These same authors added that adaptation strategies are more adopted in vulnerable area to CC (Sahelian zone). Contrariwise, Below et al. (2012) showed that the differences in the frequencies of adaptation practices between two wards in Tanzania (Mlali: sub-humid climate with average annual precipitation of 890 mm and Gairo: semi-arid climate with average annual precipitation of 499 mm) are significant. Furthermore, the distribution of most adaptation practices also differs significantly between the two wards, in favor of Mlali site, which has high agroecological potential.

In addition, breeders in the intermediate zone have specialized over time in the extensive rearing of small ruminants, while those of the northern zone have taken advantage of the availability of water to practice, in addition to breeding, a localized irrigated farming. On the other hand, due to the aridity of the climate and the low agricultural potential of the southern zone, herders, especially the poor among them, have been forced to practice certain activities independent of livestock farming such as casual labor, small trades and the collection of truffles to obtain additional income necessary for their survival. The chi-square independence test confirms this observation since it has shown that there is a highly significant relationship between the exercise of an ancillary activity in addition to livestock farming and belonging to an agroecological sub-zone ($\chi^2 = 38.094$, $p < .001$). Indeed, more than half of the livestock producers in the intermediate site (56%) do not carry out any ancillary activity generating additional income, unlike 21% and 23% respectively for the southern and northern areas. This local specialization of the production system also stems from the extent of available rangelands and the large numbers of small ruminants held by breeders in the intermediate zone (Table 1). Thus, given the fact that the occupation of the farmer is an indication of the total amount of time available for farming activities (Gbetibouo, 2009), off-farm employment may constrain technology adoption because it competes for on-farm managerial time (McNamara et al., 1991).

Other socioeconomic factors turned out to be statistically significant in explaining this difference in terms of adoption frequency of CC adaptation practices within agroecological sub-zones. The chi-square test shows that breeders, belonging to the intermediate zone, are better endowed with the necessary equipment for extensive and transhumant breeding activities such as trucks ($\chi^2 = 38.094$, $p < .001$), water tanks ($\chi^2 = 38.094$, $p < .001$) and pastoral hydraulics infrastructure for watering herds ($\chi^2 = 82.644$, $p < .001$) and employ more shepherds to guard their flocks ($\chi^2 = 6.779$, $p = .03$). Moreover, they are more present in the rangelands as evidenced by the type of prevailing habitat in this locality, that is the tent “Kheima” ($\chi^2 = 108.855$, $p < .001$). The herders belonging to the intermediate zone benefit the most from the training actions regarding livestock breeding, development and management of rangelands and other technical topics of interest ($\chi^2 = 25.701$, $p < .001$), adhere massively to a technical supervisory structure, namely the National Association of Sheep and Goat Breeders- ANOC ($\chi^2 = 8.596$, $p = .01$) and are of high average ages ($\chi^2 = 7.219$, $p = .02$). These last elements suggest that breeders belonging to the intermediate zone have accumulated a great experience in pastoral breeding compared to their counterparts in the other sites. In line with these findings, Hassan and Nhemachena (2008) and Ouédraogo et al. (2010) found that ownership of heavy machinery or agricultural equipment enhances significantly and positively the ability of farmers to adapt in response to climate change. Piya et al. (2013) and Tiwari et al. (2014) pointed out that the received training affects positively and significantly the probability that livestock producers will adopt adaptive strategies to deal with CC impacts. Tiwari et al. (2014) and Taruvinga et al. (2016) expressed that membership in community-based organizations increases the adoption of CC adaptation practices. Yila and Resurreccion (2013) and Mabe et al. (2014) emphasized that farming experience significantly and positively affects the implementation of CC adaptation strategies, respectively in the semi-arid Nguru Local Government Area, Northeastern Nigeria and in Northern Ghana.

In addition, breeders in the intermediate zone have been able to preserve socio-cultural values specific to pastoral communities (social cohesion and solidarity, habits of the nomadic way of life, receptivity, socio-cultural value of livestock and breeding, pastoral pacts with distant communities). These socio-cultural values attracted various development projects of rangelands and livestock rearing in the HPEM area. Berhanu and Beyene (2015) have argued that traditional pastoralism represents a resilient and unique system of adaptation to hostile and unpredictable climate variability in dryland ecosystems.

Lastly, the significant difference in the adoption frequencies of CC adaptation practices between the three studied agroecological sub-zones suggests that living in different agroecological regions, influences the adoption and the implementation of CC adaptation measures. Because these measures mainly vary according to local biophysical and socio-economic conditions (Deressa et al., 2009; Ouédraogo et al., 2010; Below et al., 2012; Piya et al., 2013; Tiwari et al., 2014; Atinkut and Mebrat, 2016). Therefore, the adaptation in response to climate change seems to be site-specific. This finding is supported by many previous literatures attributing the difference in the adaptation measures to CC between different agroecological zones to climate factors (Ouédraogo et al., 2010; Below et al., 2012; Atinkut and Mebrat, 2016), soils and other natural resources (Atinkut and Mebrat, 2016), as well as to socioeconomic characteristics of local communities (Tiwari et al., 2014).

Furthermore, the study showed a significant difference in the adoption frequencies of CC adaptation practices between different wealth groups of breeders, which are based on the size of sheep flock in ownership. Thus, better-off herders are much more committed to implementing CC adaptation strategies in comparison with small-scale livestock keepers. Indeed, given that the sheep farming is by far the main economic activity of the households in the study area, the sheep herd size provides information on the level of breeder' wealth and then could influence his decision to embrace adaptation strategies to climate variability and change. In line with this finding, Berhanu and Beyene (2015) and Opiyo et al. (2015) have found that herd size had a positive and significant effect on the likelihood that pastoralists adapt to CC. In addition, it is widely recognized that the implementation of adaptive strategies requires the provision of substantial financial resources such as a great livestock flock (Opiyo et al., 2015). In fact, holding of large livestock herds represents a sign of pastoralists' wealth (Watson and Binsbergen, 2008; Deressa et al., 2009) and provides economic and socio-cultural values required for adaptation (Opiyo et al., 2015).

4.3 Methodological discussion

In order to compare farmers' perceptions with meteorological stations' recorded data, several studies have performed the same type of analysis using linear trend tests of annual means of rainfall and temperatures. For instance, Gbetibouo (2009) compared the precipitation and temperature data trend in the Limpopo river basin of South Africa with the responses given by 794 farmers if they had noticed changes in temperature and rainfall over the past 20 years. Berhanu and Beyene (2015) examined the pastoralists' perception toward CC compared to actual recorded trends of increased temperature and decline in precipitation in a climate series from 1964 to 2012. In addition to the analysis of climate trends, we used the homogeneity tests of climate series to detect possible ruptures. Indeed, these tests are very useful to know exactly when the changes in climate parameters occurred (break dates) and if they are statistically significant. These statistical methods have been used by some authors as El Ibrahimi et al. (2015), Lubès-Niel et al. (1998) and Paturel et al. (1996, 1998).

To examine whether the adoption of CC adaptation practices significantly differs according to three different agroecological sub-zones in the study area and between three breeders' categories, we carried out the Kruskal-Wallis test. This test was useful because we had one nominal independent variable, each with three modalities (agroecological sub-zone or breeder category) and one dependent variable (frequency of adoption). Similarly, Gbetibouo (2009) assessed if the perceptions toward climate change differed significantly, according experience level (three classes) and education level (four classes) by using the Kruskal-Wallis test. Below et al. (2012) pointed out a significative difference in the adoption frequencies of adaptation strategies between two distinct agroecological sites, namely Mlali and Gairo in Tanzania by using Mann-Whitney test. Note that the difference between Mann-Whitney and Kruskal-Wallis tests is simply due to the fact that this last can compare more than two independent groups. Other authors have used regression models to highlight the effect of the agroecological zone on the adoption of CC adaptation measures in Burkina Faso (Ouédraogo et al., 2010) or the influence of this factor on the farmers choice of adaptation strategies in Dera woreda, Ethiopia (Atinkut and Mebrat, 2016).

5 Conclusions

In the study area, livestock producers are faced with frequent extreme climate events such as recurrent droughts (perception rate: 98%), strong winds (81%) and sandstorms (87%). Precipitation is characterized by high spatial and temporal variability with a downward trend since the late 1970s. This drop in rainfall is very marked in the northern zone (1976 as the date of rupture) and slightly visible in the other sites. Analysis of the temperature series from 1970 to 2016, for the Bni Mather station located in the northern part of the HPEM, showed a significant increase in the annual temperature, more precisely the minimum temperature, which increased by 39 % (date of rupture in 1988). Overall, livestock producers' perceptions toward climate change are consistent with meteorological recorded data and actual climate trends. This suggests that breeders' perceptions regarding long-term climate change should be incorporated into future climate research in the study area.

The significant differences observed in the frequency of adoption of CC adaptation strategies in the HPEM area can be mainly attributed to the contrasting biophysical and socioeconomic conditions within the three studied agroecological sub-zones and the level of herder' wealth (expressed in terms of the size of the owned sheep herd). In addition, the distribution of most adaptation practices differs significantly according agroecological sub-zones and breeders' categories.

The findings underscore the imperative need to tailor climate change adaptation interventions to agroecological zones and the livestock keepers' status of wealth. Since small breeders are the most vulnerable group, programs and public incentives should target them as a priority.

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Annex A: List of relevant literature review related to climate change and climate risks in the study area

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Annex B: List of key informants interviewed

Agricultural agencies
- Director of the Provincial Directorate of Agriculture of Figuig (over 12 years of experience in the study area)
- Head of the Division of Agricultural production chains - Regional Directorate of Agriculture of Oriental-Morocco (over 20 years of experience in the study area)

Agricultural extension services
- Provincial Director of the National Office of the Agricultural Council (ONCA) - Province of Figuig (over 25years of experience in the study area)
- Head of the Center of the Agricultural Council - Rural Communes of Tendrara and Maâtaka (over 22 years of experience in the study area)
- Head of the Center of the Agricultural Council - Rural Communes of Bni Guil and Abbou Lakhal (over 17 years of experience in the study area)
- Head of the Center of the Agricultural Council - Rural Commune of Bni Mathar (over 8 years of experience in the study area)

Representatives of pastoral cooperatives
- President of the federation of pastoral cooperatives of the high plateaus of eastern Morocco (68 years old)
- President of the Union of pastoral cooperatives of the tribes of Bni Guil- Tendrara and Maâtrka (57 years old)
- President of the Union of pastoral cooperatives "Union of Rangelands" (33 years old)
- President of the Union of pastoral cooperatives "Ouahda" (58 years old)
- President of the pastoral cooperative "Faress" (65 years old)

Annex C: Interview guide for key informants in the study area

1. Perceptions des changements climatiques *Perceptions regarding climate change*
Pour vous, à partir des cinq dernières décennies, la tendance est : For you, from the last five decades, the trend is:

1.1. Pour la pluviométrie *For rainfall*
- Plus de pluie [ ] ; Moins de pluies [ ] ; Pas de changement [ ] ; Ne sait pas [ ]
- Nombre de jours de pluie : Augmentation [ ] ; diminution [ ] ; Pas de changement [ ] ; Ne sait pas [ ]

1.2. Pour la température *For the temperature*
- Fait-il :
- Plus chaud (Oui [ ], Non [ ]) ; Pas de changement [ ] ; Ne sait pas [ ]
- Plus froid (Oui [ ], Non [ ]) ; Pas de changement [ ] ; Ne sait pas [ ]

Température maximale : Augmentation [ ]; Diminution [ ] ; Pas de changement [ ] ; Ne sait pas [ ]
Température minimale : Augmentation [ ] ; Diminution [ ] ; Pas de changement [ ] ; Ne sait pas [ ]

1.3. Pour le vent *For the wind*
- Plus de vent [ ] ; Moins de vent [ ] ; Pas de changement [ ] ; Ne sait pas [ ]

Ces dernières années, les vents ont tendance à être :
- Plus forts [ ] ; Moins forts [ ] ; A la fois plus forts parfois et plus faible d'autrefois [ ] ; Pas de changement [ ] ; Ne sait pas [ ]

1.4. Pour les inondations et les crues *For floods*
- Les inondations/ crues ont tendance à être :
- Durée : Plus longue [ ] ; Moins longue [ ] ; Pas de changement [ ] ; Ne sait pas [ ]

Ampleur :
- Etendue : Plus étendue [ ] ; Moins étendue [ ] ; Pas de changement [ ] ; Ne sait pas [ ]
- Niveau d'eau : Plus élevé [ ] ; Moins élevé [ ] ; Normal [ ] ; Ne sait pas [ ]

1.5. Classer par ordre d'importance ou d'occurrence ces risques (1 : le plus important)

Rank these risks in order of importance or occurrence (1: most important)
Risques *Risks* :
- Mauvaise répartition des pluies et accourcissement de la saison des pluies (par retard des pluies ou part arrêt précoce des pluies)
- Accroissement de vents violents
- Chaleur excessive/ fort ensoleillement
- Sécheresse saisonnière/ poches de sécheresses plus fréquentes
- Sécheresse aigue
- Pluies intenses
- Inondations fluviales (par crues)
- Ensablement/ désertification
- Envasement des cours d'eau
- Dégradation des parcours

1.6. Autres perceptions des changements climatiques : ***Other perceptions of climate change*** ……………………………
………………………………………………………………………………
2. Conséquences des changements climatiques *Consequences of climate change*

Consequences on the natural and physical environment, water supply, the daily life of breeders, livestock farming and household living conditions

2.1. Dans votre zone d'action quels sont les conséquences des changements climatiques les plus visibles sur le milieu ? (Espèces végétales, Espèces animales, Points d'eau temporaires ou bas-fonds, Champs ou terrains inondés temporairement, Erosion)

2.2. Quelles sont pour vous les conséquences les plus importantes de ces changements sur le quotidien des éleveurs ces dernières années ?

2.3. Quels sont les autres conséquences sur l'approvisionnement en eau ?

Mauvaise qualité des eaux : Oui [ ] ; Non [ ]

Autres : ………………………………………………………………………

2.4. Quels sont les problèmes causés par les CC sur l'élevage dans votre zone d'action ?

Conséquences sur	Ovins	Caprins	Bovins
Apparition de certaines maladies. Si oui, Lesquelles ?...	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Recrudescence de certaines maladies. Si oui, Lesquelles ?....................................	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Disparition de certaines maladies ? Si oui, Lesquelles ?....................................	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Difficultés de pâture pour alimentation ?	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Difficulté d'abreuvement du cheptel ?	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Baisse de performances ?	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]
Autres....................................	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]	Oui [ ] ; Non [ ]

2.5. Pensez-vous que ces changements ont un effet sur les conditions de vie du ménage ?
Oui [ ] ; Non [ ]. Si oui, comment ? Augmentation du revenu ? Oui [ ] ; Non [ ] ; Baisse du revenu ? Oui [ ] ; Non [ ] ; Autres ? (Préciser)...

3. Adaptation aux changements climatiques *Adaptation to climate change*
Adaptation options to climate variability and change undertaken and those that your organization can envisage; the most common strategies that breeders have developed to deal with climate change

3.1. Quels sont les options d'adaptation à la variabilité et au CC entreprises par votre organisation ?
(Exemple d'options d'adaptation : Restauration pâturages, Points d'eau, Techniques d'irrigation, Reforestation pentes et bassins versants, Travaux du sol, Espèces résistantes à la sécheresse, Création assurances et primes climatiques, Autres :.................)

3.2. Y-a-t-il d'autres techniques ou aménagements que vous envisagerez d'entreprendre pour faire face aux changements climatiques ? : Oui [ ] ; Non [ ]
Si oui, lesquels ?..

3.3. Quelles sont les stratégies les plus répandues que les éleveurs ont développé pour faire face aux changements climatiques ?

Annex D : Pastoral household survey

PARTIE1 : CARACTERISTIQUES SOCIO-ECONOMIQUES DE L'ELEVEUR
PART 1 : SOCIO-ECONOMIC CHARACTERISTICS OF THE BREEDER

1.1 Identification de l'éleveur *Identification of the breeder*

Nom et prénom	
Age	
Niveau instruction*	
Coopérative	
Fraction de tribu	
Commune rurale	

*1= sans ; 2= Coranique ; 3=Primaire ; 4= Supérieur ; 5= Formation Professionnelle.

1.2 Caractéristiques sociodémographiques *Sociodemographic characteristics*

Activité princip. (1)	Activité second.	Nb d'enf : 0< 15 ans	Nb d'enf : > 15 ans	Nb MO familiale	Nb MO salariée	Nb d'enf. émigrés Maroc	Nb d'enf. émigrés Etranger	SAU tot. (ha)	SAU irriguée (ha)

(1) : 1= Elevage ; 2= Elevage+ Agriculture ; 3= Agriculture ; 4= Autre à préciser

1.3 Statut foncier, habitat et matériel agricole *Land status, habitat and agricultural equipment*

Statut foncier de la SAU	Type Habitat		Matériel	Nb	Matériel	Nb	Services sociaux	Oui/Non
[ ] Melk	[ ] En dur		Camion		Charrette		Electricité ONE	
[ ] En indivision	[ ] Kheima		Pickup		Citerne		Eau potable ONEP	
[ ] Collectif	[ ] Les deux		Tracteur		Motopompe		Distance marché le + proche (km)	
[ ] Location	[ ] Gourbi		Remorque		Autres à préciser		Accès au crédit formel	

PARTIE2 : Systèmes de production
PART 2 : Production systems

2.1 Système de production végétale (compagne agricole 2014-2015) *Crop production system*

Spéculations	Superficie (ha)	Rendement (qx/ha)	Production totale (qx)
Orge			
Blé tendre			
Blé dur			
Luzerne			
Maïs fourrager			
Olivier			

2.2 Elevage: Cheptel animal *Breeding: Animal livestock*

Espèces	Nb total	Eff. du troupeau mère		Espèces	Nb total
Ovins BG				Bovins	
Ovins OJ				Equidés	
Caprins				Chevaux & dromadaires	

PARTIE3 : ALEAS CLIMATIQUES & ACTIONS D'ADAPTATION FACE AU CHANGEMENT CLIMATIQUE
PART 3: CLIMATE HAZARDS & ADAPTATION ACTIONS FACING CLIMATE CHANGE

Par rapport à **l'époque des parents**, quels sont les aléas et risques climatiques les plus fréquents dans votre CR ?

A. Pluies : ***Rainfall***
1. [ ] Baisse des pluies ; [ ] Augmentation des pluies
2. Diminution du nombre des jours des pluies : Oui [ ] ; Non [ ]

3. Début tardif des pluies : Oui [ ] ; Non [ ]
4. Augmentation de la fréquence des poches de sécheresse dans la saison des pluies (multiplication des ruptures de pluies au début et à la fin de la saison pluvieuse entrainant des stress hydriques) : Oui [ ] ; Non [ ]
5. Pluies violentes causant des dégâts : Oui [ ] ; Non [ ]
6. Sécheresses plus fréquentes (prolongement de la durée de la saison sèche) Oui [ ] ; Non [ ]

B. Température : *Temperature*
[ ] Augmentation, [ ] Diminution [ ], Pas de changement [ ]

C. Vents & Tempêtes de sable *Winds & Sand storms*
1. Vents violents : [ ] Augmentation, [ ] Diminution [ ], Pas de changement [ ]
2. Tempêtes de sable : [ ] Augmentation, [ ] Diminution [ ], Pas de changement [ ]

D. Pratiques d'adaptation : *Adaptation practices*
Quelles sont les actions d'adaptation face à la sécheresse que vous entreprenez ?

	Actions d'adaptation			**Actions d'adaptation**
[ ]	Transhumances exceptionnelles hors CR		[ ]	Possession d'une maison au centre urbain
[ ]	Utilisation de terroirs complémentaires		[ ]	Changement d'activité (Si oui, laquelle ?)
[ ]	Stock fourrager		[ ]	Utilisation de l'éponge vaginale (pounja)
[ ]	Vente régulière d'animaux pour s'approvisionner en aliments de bétail		[ ]	Mise en culture (ou extension des mharets)
[ ]	Crédit auprès des spéculateurs d'aliments de bétail		[ ]	Pratique de l'engraissement
[ ]	Association de l'élevage avec d'autres AGR (petits éleveurs : Intermédiation [ ], petits métiers [ ] / grands éleveurs : Commerce [ ], immobilier [ ])		[ ]	Vente de l'animal dans un état physique assez bon ou fini
[ ]	Emigration interne ou externe à la recherche d'emplois		[ ]	Appartenance à l'ANOC
[ ]	Appropriation de l'espace pastoral (petits & moyens éleveurs : Zniga [ ] / grands éleveurs : Tagdal (hourm/oukar) [ ])		[ ]	Profit des actions d'amélioration pastorale (MR, points d'eau, plantations)
[ ]	Possession d'un mharet		[ ]	Travail occasionnel
[ ]	Possession ou exploitation quasi continue d'un maader		[ ]	Assurance multirisque climatique
[ ]	Construction en dur dans le parcours		[ ]	Pratique régulière des soins vétérinaires
[ ]	Soutien ou solidarité familiale ou ethnique		[ ]	Profit du programme de sauvegarde (orge)
[ ]	Collecte des truffes		[ ]	Apiculture
[ ]	Formation en élevage/agriculture		[ ]	Possession d'un lot de terrain irrigué