Livestock Breeders' Adaptation to Climate Variability and Change in Morocco's Arid Rangelands

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Abstract

Since the mid-1970s, the high plateaus of eastern Morocco have experienced proven trends of climate change (CC) such as a significant decrease in rainfall amounts and an increase in the droughts' frequency. Consequently, the CC threatens the sustainability of this pastoral ecosystem and negatively affects the

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breeding of small ruminants, the main local-level livelihood, which becomes more vulnerable due to its high dependence on climatic conditions. This chapter aims to analyze breeders' adaptation practices by taking into account their social stratification based on the size of the sheep flock in possession. Data were analyzed using descriptive statistics, Kruskal-Wallis and Mann-Whitney tests to examine the differences in the adoption' frequency of CC adaptation measures according breeders' classes and Chi-square independence test to identify the factors explaining these observed differences. The analysis of local adaptation practices reveals that they are endogenous but above all curative, aiming at a short-term logic and have a low to medium relevance compared to the specific objective of adaptation to CC. In addition, there are significant differences in the frequency of adoption of CC adaptation strategies (chi-square value = 8.1112, $p = 0.017$, df = 2) within categories of breeders, in particular between small and larger breeders (U statistic = 58.000, $p = 0.008$). The significant factors explaining these differences are socioeconomic (age, household size, equipment, training, and membership of a basic professional organization). It is therefore recommended to target small breeders as a priority and to set up support measures (equipment, training, funding, organization of breeders).

Keywords

Climate change · Adaptation · Pastoralists · Arid rangelands · Morocco

Introduction

Currently, climate change (CC) has become obvious, due to its manifold effects on human and natural systems, affecting all countries of the world (IPCC 2014). Africa is considered one of the most vulnerable continents to climate change and extreme events (Garcia 2008). This vulnerability is principally attributed to the low level of economic development in its countries, thus generating a weak and limited adaptive capacity to deal with the negative physical, human, and socioeconomic impacts of CC (Besada and Sewankambo 2009; Bruckner 2012).

Within North African countries, Morocco is seen as the most vulnerable to climatic change and extremes, due to the combination of high exposure to climate consequences, marked climate sensitivity (high dependency on rain-fed agriculture, recurrent water stress), and a weak generic adaptive capacity (low income per capita and its unequal distribution) (Yohe et al. 2006; Schilling et al. 2012). Indeed, Morocco has already suffered the impacts of climate change, evidenced by the climate trends observed during the period from 1960 to 2005. Thus, aridity has increased from the south to the north of the country (Mokssit 2012), rainfall had seen a widespread decline (Schilling et al. 2012) of between 3% and 30% (Ezouine and Bouaza 2019), while the temperature has risen (Hulme et al. 2001) from 1.0 to more than 1.8 °C (Morocco 2016). In addition, the frequency, intensity and duration of droughts have increased during the last three decades (Moroccan Meteorological

Office 2007; NIC 2009). Climate change projections for Morocco, exhibit a decrease in annual rainfall amounts of 10–20% by 2100 (Mokssit 2012; Morocco 2016) and an increase in temperature until 2050 between 1.0 °C to 1.2 °C (Schilling et al. 2012) or ranging from 2 °C to 3 °C according to Paeth et al. (2009). Also, the frequency and the duration of droughts are forecasted to rise (Beniston et al. 2007; Bzioui 2012; Schilling et al. 2012). In short, negative climatic changes already observed are likely to continue in the twenty-first century, resulting in warmer and drier conditions (Schilling et al. 2012). Agriculture, the key economic sector and the main provider of jobs, is the most negatively affected by the effects of CC (Morocco 2016). Thereby, rural populations whose rain-fed agriculture is the major source of income are hardest hit because of their high vulnerability to the harmful consequences of climate change (Morocco 2011).

In this context, the study area, namely, the high plateaus of eastern Morocco (HPEM), has experienced proven climate change trends since the late 1970s, such as a substantial decrease in rainfall (Fink et al. 2010; François et al. 2016; Melhaoui et al. 2018) and an increase in temperature and frequency of droughts (Moroccan Meteorological Office 2007; François et al. 2016; Melhaoui et al. 2018). Livestock breeding on rangelands, based mostly on the sheep farming, is the main livelihood and job provider for the local population. This economic activity is vulnerable to CC due to its high dependence on climatic conditions (Bechchari et al. 2014), which are characterized by high intra- and inter-annual variability in rainfall and recurrent droughts (Mahyou et al. 2010; Bechchari et al. 2014). In fact, livestock breeding on arid rangelands is severely affected by the adverse impacts of extreme climate change events since it depends on natural resources and practiced in a fragile and marginal environment such as the pastoral ecosystem of the study area. As highlighted by Hassan (2010) drylands present an intrinsic natural vulnerability generated by a high exposure to significant water stress. Indeed, climate change and extremes in the high plateaus of eastern Morocco threatened the sustainability of pastoral livestock rearing, accentuated the precariousness of the poorest rural households and increased the flow of potential emigrants. Also, extreme climatic events (drought in particular), that have occurred in the HPEM in the past, have caused fodder and water scarcities leading to higher competition for available natural resources and to sometimes brutal pastoral conflicts (Bourbouze and El Aich 2000).

The increase in the occurrence and intensity of climate change-induced droughts and their prolongation over time exacerbated social inequalities among local breeders (Schilling et al. 2012). Indeed, at the time of drought event, small-scale livestock owners face both increased pressure on available pastoral resources and an inability to purchase higher-priced livestock feeds. Thereafter, the size of their herds decreases considerably, while large breeders, their strategy of decapitalization seems to be well under control and their ability to replenish herds is much greater (Bourbouze 2000; Bechchari et al. 2014). In fact, better-off herders are slightly less vulnerable because they are not exclusively or largely dependent on natural resources, have the financial resources to buy livestock feed, and can even take advantage of this opportunity created by the decapitalization of the poorest livestock owners (Kuhn et al. 2010; Bechchari et al. 2014).

In addition, decrease in rainfall and increased droughts' frequency have contributed to the degradation of rangelands in the HPEM, which has also been caused by overgrazing, plowing and anarchic cultivation of marginal areas, uncontrolled land clearing and sedentarization (Mahyou et al. 2010; Maâtougui et al. 2011; Schilling et al. 2012). Furthermore, climate change and extreme weather events, especially, have often limited the success and sustainability of local public interventions in terms of development and poverty reduction.

To deal with or overcome the negative impacts of climate variability and change, livestock herders in the HPEM have undertaken a diversified range of coping and adaptation practices such as pastoral mobility (transhumance), reciprocal grazing agreements with distant pastoral tribes, rearing of mixed species herds, social networks, and intracommunity solidarity to mitigate income shocks (Bourbouze 2000; Bourbouze and El Aich 2000; Schilling et al. 2012). Complementing these traditional coping actions, contemporary adaptation strategies, which are widely implemented in the study area, include: association of cereal crops and livestock farming, breeding of mixed herds of sheep and goats, new form of mobility based on motorization, income diversification and use of emigrants' remittances, commercializing of livestock, storage of livestock feed, using subsidized livestock feed and public programs against drought effects, sale of animals to purchase supplementary livestock feed (Bourbouze 2000; Bourbouze and El Aich 2000; Schilling et al. 2012), and recently the subscription to insurance climatic multi-risks which covers land cultivated with cereals, but not mobile or sedentary livestock rearing.

Nevertheless, these adaptation strategies are in large part of curative scope, low efficient and are less sustainable over time (Bourbouze 2000; Bourbouze and El Aich 2000). In addition, many of these adaptive practices show a relative or low relevance regarding to the specific objective of adapting to climate change and extremes, since they are seen rather as alternative livelihoods more than adaptation actions itself. Thus, they are undertaken by some breeders in order to secure or diversify their livelihoods, for instance, casual work, emigration and the practice of income-generating activities in complement to livestock rearing.

In addition, the adaptive capacity of the herders in the HPEM's area to climate variability and changes depends on the size of the livestock held and the financial and material resources available. So, their adaptive behaviors rely on their respective socioeconomic status (Bechchari et al. 2014). Thereby, small-scale breeders have less options for adaptation, are more severely affected by the observed adverse climatic trends, and are more threatened by the abandonment of livestock rearing (Bourbouze 2000). More globally, Lazarev (2008) pointed out that the main criteria for differentiation between categories of breeders in the study area are socioeconomic characteristics such as the size of the herd exploited and the capital available. Similarly, it is accepted that the susceptibility to the effects of CC and the adaptation capacities differ according to the farmers. In fact, since that the farmers' CC adaptation depends on their respective specific socioeconomic conditions (Below et al. 2012), the design of an effective and appropriate adaptation CC policy and strategies, must take into consideration these differences within human contexts (Fussel 2007) by using local-level analyses (Below et al. 2012).

In view of all of the above, the study is aimed at filling the knowledge gaps relating to the adaptation of breeders in the study area to CC, mainly with regard to the effect of social differentiation within livestock herders on the adoption (implementation) of adaptation strategies to this phenomenon. Concretely, the specific objective is to analyze breeders' practices in adapting to climate variability and change, by taking into account their contrasting socioeconomic conditions mainly the existing differences in the size of the sheep flock in ownership.

Materials and Methods

Study Area

Located in the northeast of the country (30S UTM zone), the high plateaus of eastern Morocco (HPEM) are one of the largest pastoral areas in Morocco, covering about 3.5 million hectares. Their soils are generally shallow, low in organic matter and therefore susceptible to wind and water erosion (Mahyou et al. 2016). Water resources are very limited. The HPEM have two gradients going from north to south: the altitude increases regularly from 900 to 1400 m and the climate fluctuates from semi-arid to lower arid and pre-Saharan. Indeed, the climate is of Mediterranean type, but under of a great influence of the Sahara. Average annual rainfall is highly variable, ranging from 143 mm in the south to 201 mm in the north, with respective coefficients of variation of 45% and 34% (Melhaoui et al. 2018). Dry and hot winds which can cause real sandstorms, especially in summer, are frequent. The rangelands of the HPEM are dominated by specific steppe vegetation consisting of steppes at *Stipa tenacissima*, Chamemic steppes at *Artemisia herba alba* and steppes at Chenopodiaceae (*Artrophytum scoparium*). The vast majority of local population derive most of their income from livestock farming, in particular sheep breeding. The herds in the possession of the breeders in the study area are made up of more than two million heads of small ruminants, usually conducted according to an extensive to semi-extensive rearing system. The HPEM area can be seen as a suitable and representative site for better understanding of adaptation to CC in Morocco's pastoral ecosystems.

Data Collection

Data collection method consisted of a literature review and a survey of 167 breeders, heads of pastoralist households. Relevant literature available from local extension and agricultural development agencies were consulted to acquire a complete and clear overview about the CC issue in the HPEM's area, mainly with regard to livestock practices and core endogenous adaptation measures implemented by the breeders in response to climate variability and change. The survey of herders focused on the socioeconomic characteristics of households and the adaptation practices embraced to reduce the effects of perceived CC. The basic study unit is the

pastoralist household, as at this level, decisions relating to adaptation to climate variability and change are taken (Below et al. 2012).

Given that sheep farming is the main activity of the pastoralist households in the study area, the size of the sheep flock in ownership was chosen as the criterion of discrimination between herders. Thereby, three classes of livestock breeders have been identified and this in agreement with local agricultural extension agencies. Large breeders are those with a sheep herd exceeding 300 heads, medium breeders with own sheep flocks of between 101 and 300 heads and the small livestock owners with the number of sheep in possession is less than or equal to 100 heads. Based on the respective representativeness of these three breeders' categories in the study area (Bechchari et al. 2014), respondent herders were randomly selected. The distribution of breeders surveyed by class is as follows: 96 small, 47 medium, and 24 large breeders to give a total of 167 livestock producers.

Data Analysis

Data collected on the adaptation practices implemented by the livestock herders in the study area were analyzed using descriptive statistics and the tests of Kruskal-Wallis, Mann-Whitney U and of Chi-square independence. Descriptive statistics have been made, with regard to the socioeconomic characteristics of breeders surveyed and the different local adaptation measures. The Chi-square independence test was used to highlight the relationship that may exist between the developed endogenous practices and the categories of herders (small, medium, large). In addition, the strength of this possible statistical association was measured using Cramer's V. coefficient. This test was also carried out to verify whether the observed differences within the three breeders' classes is linked to their respective socioeconomic conditions at household level. Furthermore, Kruskal-Wallis test is an appropriate nonparametric test for comparing more than two independent samples. It is a rank-based test which can be used to test whether such samples come from the same distribution (Ostertagova et al. 2014). The null hypothesis is the following: all the populations have the same median or no significant difference between the groups (samples). In our case, the Kruskal-Wallis test was used to testing for difference in the frequency of adoption of adaptation strategies among three livestock breeders' classes. If the Kruskal-Wallis statistic is significant, a nonparametric multiple comparison method (Mann-Whitney U test) is used to find out which classes of herders are different from the others. Also, using the Mann-Whitney U test, we assessed if the adoption of adaptation practices to CC differed significantly between the three classes of breeders which are based on the size of the owned sheep herd. Indeed, this test was realized to show if there is a significant difference between the "adoptive" and "non-adoptive" groups according to the number of sheep in possession. Generally, the Mann-Whitney U test is a non-parametric statistical test used to determine if two independent samples come from the same population or from 2 different populations. Indeed, this test was used because the assumptions of use of the Student's t test were not verified (non-comparable variances and non-normal distribution of the dependent variable).

Results and Discussion

Socioeconomic Characteristics of Breeders Surveyed

The average age of breeders is 52 years with almost 60% of them who have an age greater than or equal to 50 years. Livestock breeders are in large part without level of education (70%). The rearing of small ruminants is the main economic activity for 83% of herders sampled. Approximately 35% of respondents are engaged in an ancillary activity (mainly the temporary employment: 26%). The size of households is an average of 8 people. The average number of labor force by household is around 2 persons. The employ of shepherds is observed in 36% of cases. The rate of emigration is low and is close to 17%. The types of dominant habitat are the tents and concrete houses with respectively 36% and 24%. The rate of connection to the public electricity network is low, either almost 20%. The distance to the nearest market is relatively long and is 60 km.

The majority of the breeders (83%) had agricultural land, but only 16% of the herders surveyed owned an irrigated plot. In effect, on average, arable land was about 31 ha and irrigated area did not exceed the 0.37 ha. Breeders are moderately equipped, since more than 61% of them possesses at least one agricultural equipment and/or transport (possession trucks: 27%, tractors: 14% and water tanks: 50%). The average number of sheep and goats are respectively of 166 and 33 heads/breeder. More than 52% of the herders have at least one head of bovine cattle.

Access to formal credit is low not exceeding 23%.

Analysis of Pastoralists Adaptation Practices in the HPEM

Table 1 showed that the breeders in the HPEM have implemented, over time, a wide and diversified range of adaptation practices to cope with the harmful effects of hazards and climate changes.

These adaptation and coping measures are almost all of endogenous origin, thus attesting on a great intrinsic capacity for adaptation based on the accumulation of experiences and initiatives of the breeders in this arid pastoral ecosystem where climatic conditions are difficult and unpredictable. Local adaptation practices to climate variability and change can be grouped into two main categories: (1) Adjustment of farm management and pastoral practices and (2) Partial shift to alternative livelihood options. A large part of the adaptation actions identified concerns the first dimension.

Contemporary adaptive strategies in the study area are mostly individualized. This testifies to the spectacular rise of an individualism of spirit and action and of refocusing on the individual to the detriment of the social group to which he belongs (Bourbouze and El Aich 2000). These authors added that it is now at the individual level that one must know how to protect oneself from environmental and economic risks and no longer at the community level. Whereas during the first half of the last century, local customary institutions organized the access and use of collective

Table 1 Distribution of herders surveyed according to adaptive measures implemented (in %)

Adaptation practices	Freq.	Perc.	Dur.	Inten.	Adeq.
(1) Adjustment of farm management and pastoral practices					
Mixed livestock crop farming system	139	83.2	LT	P	M
Profit of state agricultural programs	132	79	ST	C	M
Diversification of livestock species	130	77.8	LT	P	M
Climate multi hazard insurance	80	47.9	ST	C	H
Storage of animal feed	80	47.9	ST	C	H
Herd mobility	67	40.1	ST	C	H
Regular Sale of animals to stock up on feed	79	47.3	ST	C	L
Sale of the animal in a good physical state	73	43.7	LT	P	M
Practice of fattening	51	30.5	ST	C	M
Credit from speculators livestock feed	37	22.2	ST	C	L
Privative appropriation of rangelands	30	18	ST	C	M
Irrigated agriculture and livestock integration	22	13.2	LT	P	H
(2) Partial shift to alternative livelihood options					
Conversion of livestock capital into land capital	67	40.1	LT	P	L
Casual labor	55	32.9	ST	C	L
Internal or external emigration in search of jobs	28	16.8	LT	P	L
Collection of truffles as additional income	14	8.4	ST	C	L

Freq.: Frequency. Perc.: Percentage. Duration: ST (Short term); LT (Long term). Intention: C (Curative action); P (Preventive action). Adequacy: H: High; M: Medium; L: Low

pastoral resources and guaranteed intra- and inter-tribal solidarity for the survival of their ethnic groups in times of climate crisis. The decline of these traditional structures for several decades has been caused mainly by a public policy which has fragmented tribal organizations in favor of modern administrative and elected institutions and encouraged sedentarization (Rachik 2007). Negative practices of breeders, especially the large and influential among them, such as the cultivation of rangelands and their appropriation for private use, have also contributed to the weakening of these tribal structures (Bourbouze 2000; Bechchari et al. 2014).

In addition, the majority of the adaptation measures adopted are part of a short-term temporal perspective, thus allowing breeders to buffer climate risks and reduce their negative consequences through the practices of curative type (for example the regular sale of animals to purchase livestock feed, benefit from public interventions such as subsidized fodder). This testifies to the predominance of short-term and reactive vision of adaptation at local level. Furthermore, most local adaptive practices show a low to medium adequacy in relation to the main objective of adaptation to CC, as their purpose is not a specific response to this phenomenon. They are embraced by breeders either to improve their rearing productivity and, thus, contribute to reducing their vulnerability to hazards and hostile climatic changes, such as diversification of livestock species and practice of fattening (medium adequacy) or to increase their income, meet the financial needs of their farms and maintain their economic activity, e.g., regular sale of animals to purchase livestock feed, credit from resellers of livestock feed and casual employment (low adequacy). Only four

adaptation measures which were highly relevant in relation to climate change. They are: transhumance or herd mobility, storage of livestock feeds, subscription to climate insurance and the integration of livestock breeding and irrigated agriculture. However, these adaptive actions depend on the socioeconomic status of the breeder (mostly implemented by large herders) or they are very spatially localized like irrigated agriculture.

In line with our findings, Bourbouze (2000) and Bourbouze and El Aich (2000) highlighted that most adaptation practices to variability and climatic risks (drought in particular) implemented by the breeders in the HPEM are of curative type and provide only relative protection. The only really effective strategies against climatic hazards were the cereal-livestock association, livestock feed supplements purchased through animal sales, remittances of emigrants and irrigated agriculture by pumping, but even these are little effective in a sustainable way. Bechchari et al. (2014) emphasized that the adaptive capacity of herders in the HPEM's area with regard to climate-related risks and changes, closely depends on their respective socioeconomic characteristics. In fact, the socioeconomic status of breeders in the study area largely affects their drought adaptation responses and more generally their pastoral practices and their way of using the rangelands (Mahdi 2007; Lazarev 2008).

Differentiation of Adaptation Measures According to Breeders' Classes

The Table 2 showed general divergence in the frequencies of adaptation measures implemented within the categories of breeders (small, medium and large) which are based on the size of the sheep flock in ownership. Thus, large livestock owners adopt with higher frequencies, most of the endogenous adaptation practices in response to perceived climate variability and change, compared to the two other categories. In addition, practices of the first dimension of adaptation measures are more frequently implemented by large breeders. They include strategies for the diversification of the productions (integration of livestock breeding and cereal farming, breeding of mixed flocks of sheep and goats), improvement of rearing productivity (practice of the fattening, selection and reproduction of powerful races), transhumance and market orientation (finished products of good taste quality). In fact, all of these adaptation strategies require considerable financial resources, which manifests itself in much lower adoption frequencies among small and medium-sized breeders.

By relying on their social status and their relationship networks, large breeders adopt an opportunistic land strategy by constantly conquering vast new areas of collective rangelands for their private use. As evidenced by the significant differences between the average available agricultural areas, which are 86, 37 and 15 hectares respectively for great, medium and small breeders. Recently, large herders and some medium breeders have massively subscribed to climatic multi-risk insurance. The adoption of this practice has two objectives. First, climate insurance contracts represent, in the eyes of local breeders, justifications approving the legitimacy of the ownership of conquered rangelands in order to annex them definitively

Table 2 Frequencies of adaptation measures in percentage according to breeders' classes and results of the Chi-square independence test

Adaptation practices	Small (n = 96)	Medium (n = 47)	Large (n = 24)	χ^2 Pearson	Cramer's V
Mixed livestock crop farming system[a]	74	93.6	100	14.384 (0.001)	0.293^{M}
Profit of state agricultural programs	75	83	87.5	2.423 (0.298)	0.120^{L}
Diversification of livestock species	71.9	85.1	87.5	4.718 (0.095)	0.168^{L}
Climate multi hazard insurance[a]	28.1	70.2	83.3	36.493 (0.000)	0.467^{S}
Storage of animal feed[a]	36.5	63.8	62.5	11.865 (0.003)	0.267^{M}
Herd mobility[a]	27.1	48.9	75	20.466 (0.000)	0.350^{M}
Regular Sale of animals to stock up on feed	44.8	53.2	45.8	0.917 (0.632)	0.074^{L}
Sale of the animal in a good physical state[a]	33.3	48.9	75	14.273 (0.001)	0.292^{M}
Practice of fattening[a]	20.8	31.9	66.7	19.072 (0.000)	0.338^{M}
Credit from speculators livestock feed[a]	18.8	19.1	41.7	6.189 (0.045)	0.193^{L}
Privative appropriation of rangelands[a]	13.5	17	37.5	7.518 (0.023)	0.212^{M}
Irrigated agriculture and livestock integration	8.3	21.3	16.7	4.920 (0.085)	0.172^{L}
Conversion of livestock capital into land capital[a]	29.2	44.7	75	17.355 (0.000)	0.322^{M}
Casual labor[a]	42.7	27.7	4.2	13.736 (0.001)	0.287^{M}
Internal or external emigration in search of jobs	13.5	21.3	20.8	1.685 (0.431)	0.100^{L}
Collection of truffles as additional income[a]	13.5	2.1	0	7.917 (0.019)	0.218^{M}

Note: Cramer's V. value: S: Strong (between 0.40 and 0.80); M: Moderate (between 0.20 and 0.40); L: Low (between 0.10 and 0.20). Values in parentheses in χ^2 Pearson represent the asymptotic significance (bilateral)

[a]Significant at 5% level

later. Also, this measure (insurance) allows subscribers significant financial compensation following of climatic hazards (drought in particular) equals to 600 MAD per hectare.

Large livestock owners have benefited from contracts of sale with supermarkets of many urban agglomerations in the north of the country during the feasts of sacrifice, thanks to the USAID' initiative. Thus, they were able to achieve very interesting butcher performances (well-finished animal products with appreciable gustative qualities). This explains the strong orientation of their breeding

activity towards the market. In addition, thanks to their accumulated savings, large livestock keepers invest more and more in activities of speculation, including the real estate, in order to overcome the unfavorable climatic and economic conditions affecting their livestock rearing activity.

As for small herders, they frequently shift to additional off-farm livelihoods to complete or diversify their income sources. Thus, they are forced to engage in other small-scale activities in addition to the livestock breeding, such as temporary labor, collecting truffles and small trades, in order to satisfy both the needs of their families and those of their meager herds especially in the event of climatic vagaries (drought) prolonged in time. The poorest of them, after the sale of all their herds, find themselves decapitalized. In the absence of support from relatives or the State, they opt for rural exodus as the final solution.

In addition, the results of the Chi-square independence test revealed that there was a statistically significant relationship between most adaptation practices (11/16 measures identified) and livestock breeders' classes (Table 2). The Cramer's V. coefficient measuring the strength of this statistical relationship has medium to high values. This association of significant magnitude indicates, thereby, that the larger the size of the sheep herd in possession, the higher the frequency of adoption (implementation) of adaptation practices.

As highlighted by Bourbouze (2000), the choices for small breeders regarding adaptation to adverse impacts of climate variability and extremes are much narrower and their most common strategy is to regularly sell animals in the souk so that they can buy livestock feed, water their herds and feed their families. Thereafter, either they abandon livestock rearing after having sold all their flocks, or they migrate to the nearest urban centers in search of small trades. Whereas the decapitalization strategy seems well controlled among large breeders (Bourbouze and El Aich 2000), they can even take advantage of periods of climatic crisis to increase the size of their herds to the detriment of the poorest breeders (Schilling et al. 2012). Bechchari et al. (2014) underlined that the portfolio of strategies for adapting to variability and climate change implemented by large breeders is much denser and more diversified. It includes the acquisition of equipment (trucks, tractors, water tanks), the appropriation of large areas of rangelands, the profit of the best grazing sites and the commercial speculation in livestock in order to make a good profit on their invested capitals. In contrast, the possibilities offered for small breeders, are very limited and mainly boil down to the regular sale of their herds, the search for additional activities to breeding and rural exodus.

The Kruskal-Wallis test was conducted to examine the differences in the frequency of adoption of climate change adaptation practices according to the classes of breeders. Significant differences (chi square $= 8.1123$, $p = 0.017$, df $= 2$) were found between the three categories of herders. In addition, the distribution of the majority of adaptive measures differs significantly between classes of breeders (Table 3).

After the Kruskal-Wallis test led us to reject the null hypothesis of similarity between breeders' categories in terms of frequency of adoption of adaptation and coping actions, we performed pairwise comparisons using the Mann-Whitney test to

Table 3 Results of the Kruskal-Wallis test

Adaptation practices	Chi-square value	Sig-p
Mixed livestock crop farming system**	14.298	0.001
Profit of state agricultural programs	2.408	0.300
Diversification of livestock species	4.690	0.096
Climate multi hazard insurance***	36.275	0.000
Storage of animal feed**	11.794	0.003
Herd mobility***	20.344	0.000
Regular Sale of animals to stock up on feed	0.912	0.634
Sale of the animal in a good physical state**	14.187	0.001
Practice of fattening***	18.958	0.000
Credit from speculators livestock feed*	6.152	0.046
Privative appropriation of rangelands*	7.473	0.024
Irrigated agriculture and livestock integration	4.891	0.087
Conversion of livestock capital into land capital***	17.251	0.000
Casual labor**	13.654	0.001
Internal or external emigration in search of jobs	1.675	0.433
Collection of truffles as additional income*	7.869	0.020

Note: Significance: ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$; Degree of freedom = 2

determine which classes of breeders are different. The results of this test show that there is a highly significant difference (U statistic = 58.000, $p = 0.008$) between small and large breeders in adopting CC adaptation practices. The other differences between on the one hand small and medium breeders (U = 92.000, $p = 0.174$) and between medium and large herders on the other hand (U = 79.500, $p = 0.067$) were found not to be significant. This shows that breeders' adaptation in the study area depends mainly on their social status or economic power, expressed by the size of the sheep herd in possession.

Factors Influencing the Adoption of Climate Change Adaptation Practices

In order to confirm this relationship between the adaptation measures to climate variability and change implemented by the breeders in the study area and the size of the sheep herd in possession, we carried out the Mann-Whitney U test. This test is often employed to compare differences between two independent groups when the dependent variable is continuous, but not normally distributed. In our case, the two independent groups are the "adopters" and "non-adopters" of CC adaptation practices, while the continuous dependent variable is the sheep herd size. The mean rank column shows mean rank for the two groups tested (adopters and non-adopters groups). This column is very useful because it indicates which group can be considered as having the higher size of sheep herd, overall; namely, the group with the highest mean rank. In this case, the adopter group had the highest size of sheep herd. Indeed, the first group (adopters) have higher mean ranks than those of

non-adopters, except for the case of two coping actions, namely, "Casual labor" and "Collection of truffles as additional income" (Table 4). In fact, these two practices are usually pursued either as a complement to a breeding activity that does not allow the household to meet its needs or in the event of abandonment of livestock farming (decapitalization frequently caused by successions of prolonged episodes of drought). They are practiced mainly by the small breeders with respectively 75 and 93%.

Furthermore, the Test Statistics column shows us the actual significance value of the Mann-Whitney U test. Specifically, this column provides the test statistic, U statistic, as well as the asymptotic significance p-value. From our data, it can be

Table 4 Mann-Whitney U test showing the relationship between sheep herd size and adaptive practices

	Mean rank			
Adaptation practices	Yes	No	(U, *p*)	Z
Mixed livestock crop farming system	92.64	41.11	(745, 0.000)	−5.149
Profit of state agricultural programs	87.16	72.07	(1892.5, 0.100)	−1.643
Diversification of livestock species (sheep & goats)	90.33	61.76	(1582, 0.002)	−3.174
Climate multi hazard insurance	105.35	64.37	(1772, 0.000)	−5.476
Storage of animal feed	96.01	72.96	(2519.5, 0.002)	−3.079
Herd mobility	107.60	68.19	(1768.5, 0.000)	−5.168
Regular Sale of animals to stock up on feed	91.88	76.93	(2853.5, 0.046)	−1.997
Sale of the animal in a good physical state	100.18	71.44	(2250, 0.000)	−3.813
Practice of fattening	105.96	74.34	(1838, 0.000)	−3.895
Credit from speculators livestock feed	98.43	79.89	(1871, 0.039)	−2.059
Privative appropriation of rangelands	106.17	79.15	(1390, 0.006)	−2.774
Irrigated agriculture and livestock integration	97.68	81.92	(1294, 0.154)	−1.425
Conversion of livestock capital into land capital	101.54	72.25	(2174.5, 0.000)	−3.841
Casual labor	59.39	96.08	(1726.5, 0.000)	−4.612
Internal or external emigration in search of jobs	94.36	81.91	(1656, 0.214)	−1.243
Collection of truffles as additional income	27.46	89.17	(279.5, 0.000)	−4.574

Note: U: U statistic of Mann-Whitney test, *p*: the value of p of the test

concluded that the size of the sheep herd in the adopter group was significantly higher than in the non-adopter group for the majority of adaptation strategies practiced by the livestock owners in the study area.

In line with our findings, herd size influences positively and significatively the likelihood that pastoralists implement adaptation strategies in the face of climate change (Balew et al. 2014; Berhanu and Beyene 2015; Opiyo et al. 2015).

Other socioeconomic characteristics at household-level, using the category of the breeder as a classification variable, could explain significant observed differences in the frequency of climate change adaptation practice's adoption (implementation) within breeders' classes (small, medium, large). The results of chi-square independence test contained in the Table 5 show that there is a significant relationship between the category of herder and the following factors: age of breeder ($\chi^2 = 19.020$, $p = 0.000$), household size ($\chi^2 = 30.720$, $p = 0.000$), no practice of ancillary activity ($\chi^2 = 25.662$, $p = 0.000$), employment of shepherds ($\chi^2 = 42.124$, $p = 0.000$), land ownership ($\chi^2 = 14.384$, $p = 0.001$), possession of truck ($\chi^2 = 17.754$, $p = 0.000$), possession of tractor ($\chi^2 = 49.740$, $p = 0.000$), possession of water tank ($\chi^2 = 33.902$, $p = 0.000$), possession of a motor pump ($\chi^2 = 39.048$, $p = 0.000$), veterinary care ($\chi^2 = 16.005$, $p = 0.000$), training received ($\chi^2 = 7.850$, $p = 0.020$) and membership to a technical supervisory structure, namely, National Association of sheep and goat breeders- ANOC ($\chi^2 = 27.454$, $p = 0.000$).

Large livestock producers have a higher average age, 62 years, compared to 49 years for small breeders (Table 6). They are ones who benefited the most from training actions in livestock rearing, development and management of rangelands and other technical topics of interest (42% vs. 17%), adhered massively to the breeders' organization, namely, ANOC (58% vs. 11%). These elements indicate that large herders have accumulated a great pastoralism experience compared to small-scale breeders. Piya et al. (2013) and Tiwari et al. (2014) pointed out that the training received improved the adaptive capacity of farmers in the face of climate change. As highlighted by Tiwari et al. (2014) and Taruvinga et al. (2016), membership in the community-based organizations increases the adoption of climate change coping strategies. Yila and Resurreccion (2013) and Mabe et al. (2014) underlined that farming experience significantly and positively influences the implementation of CC measures, respectively in the semiarid Nguru Local Government Area, Northeastern Nigeria, and in Northern Ghana. In addition, large breeders are far largely more endowed with production factors than small breeders such as labor force (4 vs.. 1 people), employment of shepherds (88 vs. 19%), land size (86 vs. 15 ha), small ruminants herd size (684 vs. 72 heads), bovine cattle flock size (7 vs. 1 head), number of equipment owned (5 vs. 1) and veterinary care (83 vs. 45%). In line with our findings, Yila and Resurreccion (2013) pointed out that labor force was a significant determinant for farmers' adaptation practices to climate change in the semiarid Nguru Local Government Area, Northeastern Nigeria. Debalke (2011) and Ndamani and Watanabe (2016) highlighted that land size was a determinant factor that influences farmers' climate change coping strategies, respectively, in north shoa zone of Amhara region Ethiopia and Lawra district of Ghana. Berhanu and Beyene (2015) and Opiyo et al. (2015) have found that herd size affected positively and

Table 5 Significant factors (categorical variables) explaining the differences observed in the frequency of adoption of adaptation practices between categories of breeders

Categorical variables	Small (%)	Medium (%)	Large (%)	Chi-square value	Sig-p
Age				19.020	0.000
<50 years	54	32	8		
>=50 years	46	68	92		
Ancillary activity				25.662	0.000
Yes	47	28	8		
No	53	72	92		
Household size				30.720	0.000
<8 people	70	38	12		
>=8 people	30	62	88		
Employment of shepherds				42.124	0.000
Yes	19	47	88		
No	81	53	12		
Land ownership				14.384	0.001
Yes	74	94	100		
No	26	6	0		
Favorable pastures				12.160	0.002
Yes	14	36	38		
No	86	64	62		
Equipment				20.399	0.000
Yes	50	64	100		
No	50	36	0		
Possession of truck				17.754	0.000
Yes	17	32	58		
No	83	68	42		
Possession of tractor				49.740	0.000
Yes	2	17	58		
No	98	83	42		
Possession of cart				9.995	0.007
Yes	21	2	8		
No	79	98	92		
Possession of tank				33.902	0.000
Yes	34	55	100		
No	66	45	0		
Possession of pump				39.048	0.000
Yes	12	30	75		
No	88	70	25		
Veterinary care				16.005	0.000
Yes	45	70	83		
No	55	30	17		
Training received				7.850	0.020

(continued)

Table 5 (continued)

Categorical variables	Small (%)	Medium (%)	Large (%)	Chi-square value	Sig-p
Yes	17	17	42		
No	83	83	58		
BO Membership				27.454	0.000
Yes	11	38	58		
No	89	62	42		

Note: BO: Breeder Organization

Table 6 Significant factors (continuous variables) explaining the differences observed in the frequency of adaptation practices' adoption between categories of breeders

Variable	Category	Minimum	Maximum	Mean	Standard deviation
Age	Small	22	85	49	13.94
	Medium	24	79	53	12.66
	Large	44	79	62	8.60
Household size	Small	1	14	6	2.63
	Medium	3	16	9	3.00
	Large	5	23	12	4.47
Labor force	Small	0	3	1	0.93
	Medium	0	6	2	1.47
	Large	0	12	4	2.32
Land size	Small	0	52	15	14.81
	Medium	0	196	37	41.05
	Large	8	300	86	82.68
Equipment	Small	0	4	1	1.19
	Medium	0	6	2	1.77
	Large	2	14	5	2.96
Small ruminants herd size	Small	0	180	72	37.31
	Medium	101	500	214	78.57
	Large	355	1400	684	260.00
Bovine cattle herd size	Small	0	10	1	2.20
	Medium	0	13	3	3.70
	Large	0	50	7	10.38

significantly the probability that pastoralists put in place CC adaptation measures. Hassan and Nhemachena (2008) and Ouédraogo et al. (2010) stressed that ownership of heavy machinery or agricultural equipment improves the coping capacities of farmers to deal with the negative effects of climate variability and extremes.

Furthermore, large breeders have specialized over time in the extensive breeding of small ruminants, while small-scale herders have been forced to practice non-farm activities such as casual labor, small trades, and the collection of truffles to obtain additional income necessary for their survival. In fact, almost all large livestock

owners (92%) do not carry out any ancillary activity generating additional income, unlike 53% for small herders. Given that the occupation of the farmer was an indication of the total amount of time available for farming activities (Gbetibouo 2009), the off-farm employment may present a constraint to the adoption of technology because it consumes time which must be devoted to the management of agricultural activities (McNamara et al. 1991). Also, large breeders are the ones who benefit most from the best grazing sites (38 vs. 14%). Berhanu and Beyene (2015) expressed that the traditional pastoralism represents a resilient and unique system of adaptation to hostile and unpredictable climatic variability in dryland ecosystems.

In accordance with the results presented above, several previous studies showed that the significant factors influencing African farmers' adaptation to climate change are socioeconomic household-level variables, and this in many countries such as Ethiopia (Balew et al. 2014; Berhanu and Beyene 2015), South Africa (Taruvinga et al. 2016), Ghana (Ndamani and Watanabe 2016), Tanzania (Below et al. 2012), Nigeria (Obayelu et al. 2014), Kenya (Opiyo et al. 2015), and Uganda (Nabikolo et al. 2012).

Conclusion

In response to perceived climate changes and extremes, livestock breeders in the high plateaus of eastern Morocco have implemented differently many adaptation practices, depending on their respective socioeconomic conditions at household level. Thereby, contrasting socioeconomic characteristics, mainly the size of sheep flock in ownership, allowed large breeders to adopt (put in place) with higher frequency most of adaptive measures compared to small-scale herders who have much more limited possibilities or choices. This social inequality could be exacerbated in the future due to adverse climatic trends (increase in the frequency and intensity of droughts, reduction in rainfall amounts) caused by current and future climate change, in the absence of support measures targeting primarily small breeders who are the most vulnerable group to this climatic phenomenon.

In addition, future studies relating to climate change adaptation in the study area should first investigate the perceptions of livestock producers. Indeed, local perceptions toward climate change influence farmers' decisions on whether or not to adapt (Deressa et al. 2009), are useful for the development of relevant and appropriate adaptation policies and strategies (Opiyo et al. 2015), and are also an important factor influencing the success of the adaptation actions to be implemented (Tesfahunegn et al. 2016).

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