Agricultural Systems 128 (2014) 44–54

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Livelihood strategies and the role of livestock in the processes of adaptation to drought in the Coastal Zone of Western Desert (Egypt)

V. Alary [a,*], S. Messad [b], A. Aboul-Naga [c], M.A. Osman [c], I. Daoud [d], P. Bonnet [b], X. Juanes [b], J.F. Tourrand [b]

[a] CIRAD International Centre of Agricultural Research for Development/ICARDA International Centre of Agricultural Research in Dry Areas, 11th Floor, 15G Radwan Ibn El Tabib Street, Giza, P.O. Box 2416, Cairo, Egypt
[b] CIRAD, UMR SELMET Tropical and Mediterranean Animal Production Systems, TA C-112/A, 34398 Montpellier Cedex 5, France
[c] APRI Animal Production Research Institute/Agricultural Research Centre, Nadi El-Said St., Dokki, Giza, Egypt
[d] Governorate of Marsa Matruh, Directorate of Education, Technical Agriculture Education Department, Egypt

ARTICLE INFO

Article history:
Received 12 February 2013
Received in revised form 4 February 2014
Accepted 24 March 2014
Available online 26 April 2014

Keywords:
Livestock adaptation
Drought
Capital assets
Measure of income
Multi-factorial analysis
Egypt

ABSTRACT

Analyses of the roles of livestock in household livelihood in the context of global change and the different stresses triggered by such changes are not rare. However, the many changes that threaten the actual functioning of the systems and trigger many uncertainties concerning capacities to adapt to external shocks require new research approaches. In this paper, we explore the links between capital assets, risk perception, measure of income, and livestock adaptation using a typology value based on multiple factorial analyses. We examine the specific role of livestock in the processes of adaptation to a 15-year drought. The study is based on a farm survey of 182 Bedouin families in the Coastal Zone of Western Desert of Egypt in 2011. Our results show that livestock is still a core component of Bedouin society with a significant typology value. However, for Bedouin families located inland, livestock is mainly an economic safety net in the case of drought; whereas for family members who recently moved to town, livestock is a social safety net vis-à-vis the traditional society which enables them to cope with economic hardship and participate in social events. How livestock is managed during drought events and the role of livestock in the process of adapting to drought depends less on the size of the herd before the drought in the rain-fed zone and more on traditional social and official networks. Consequently, limiting the impact of drought in this zone requires paying more attention to the management of collective action, including livestock policies and feed subsidies.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

As part of the ELVULMED research project "role of livestock activities in the process of adaptation and reducing vulnerability of Mediterranean societies facing global changes", we examined the roles of livestock in processes of adaptation to climate change, mainly long-term drought, in Bedouin livelihoods in the Coastal Zone of Western Desert of Egypt (CZWD) in 2011–2012. The CZWD extends 450 km from Borg el Arab to El Saloum (Fig. 1). It is an arid zone with less than 150 mm annual rainfall. The majority of the population is Bedouin. In the early 1950s, orchard cultivation expanded in both the coastal region (extending less than 5 km from the coast southwards) and in the wadi zone (in the bed of the wadi, between 5 and 10 km from the coast). Today, orchards are a key component of the Bedouin system, which is based on trees, barley and livestock. This system has been encouraged by public settlement policies with the aim of controlling the movement of the Bedouin population.

However traditional practices and institutions including tribal organization remain strong. The majority of the Bedouin population continues to pursue a lifestyle based on the transhumance of multi-purpose livestock to have sufficient milk and meat for home consumption, social exchange, and sale. At the same time, the settlement of pastoralists along with associated social and material transformations explains why these systems vary continually in terms of the type of stock reared and the pastoralists' transhumance strategies, as well as alternative livelihood strategies, which often blur the character of Bedouin society. Like many pastoral societies described by McPeak and Barrett (2001), Bedouin have a complex and changing range of economic activities based on a range of assets. The diversification of capital assets and their interconnections though social bonds at the family and community

* Corresponding author. Tel.: +20 2 3568 1254x106; fax: +20 2 3572 8099.
E-mail address: veronique.alary@cirad.fr (V. Alary).

http://dx.doi.org/10.1016/j.agsy.2014.03.008
0308-521X/© 2014 Elsevier Ltd. All rights reserved.

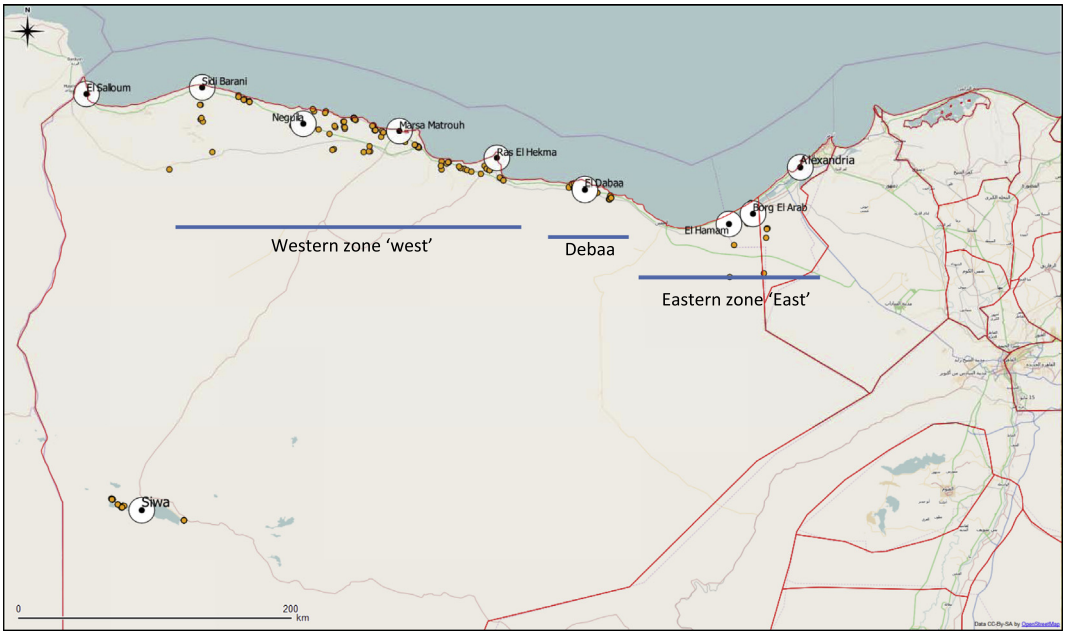

Fig. 1. Map of the six geographical units and the four zones (West, Debaa, East and Siwa) in the Coastal Zone of Western Desert of Egypt (source: from Bonnet, 2013, QGIS, OSM in Bonnet et al., 2014).

level complicate the analysis of the direct and indirect impacts of drought on livelihood.

In recent years, many researchers have underlined the importance of the "human support capacity" of livestock in African pastoral societies, thanks to the production and consumption of milk and meat (e.g., Payne, 1990; Davies and Bennett, 2007). In parallel, an overriding view in the literature has been the non-monetary aspirations and goals of pastoralists and their ability to manage risks (Roe et al., 1998), which may minimize the impacts of climatic or economic changes on their capacities and on the resilience of their livelihoods. One of the main hypotheses in the literature (Ashley and Carney, 1999; Scoones et al., 1996) was that, in the context of climatic events like drought, livestock could be an important buffer activity thanks to the ability of the animals, especially camels and small ruminants, to survive hot dry conditions. This resistance was assumed to be based on the capacity of these species to explore large areas, their resilience below the thresholds of feed requirements, and because animals are easy to exchange for other assets.

However, recent social changes in Bedouin society in the NCWD in Egypt that have accompanied settlement, the construction of new infrastructure (electricity network, water supply) have profoundly affected their living conditions as well as their aspirations. In addition, although periods of drought lasting two or three years with annual rainfall of less than 150 mm were frequent and were considered normal in this arid rainfed zone, the last 15-year drought saw the development of a variety of other activities to enable the Bedouin to keep their remaining livestock and to satisfy the needs of their family.

According to Chambers and Conway (1992), "a livelihood comprises the capabilities, assets (including both material and social resources) and activities for a means of living" (p7). The livelihood approach emphasized entitlement (access to present and potential resources) and claims (reciprocal arrangements embedded in social networks and the resulting obligations and rights) which determined capacities and poverty (Ellis, 2000; Scoones, 2009). As shown by Ashley and Carney (1999), Moser (1998) and Alary et al. (2011), assets played a role in determining poverty, and in reducing vulnerability by enabling a household to exploit available opportunities, hence reducing their sensitivity to shocks and increasing livelihood resilience. On the other hand, Davies and Bennett (2007) claimed that "although poor people are generally vulnerable, not all vulnerable people are poor" (p. 493). This paper focuses on the link between capital assets – including human and social capital – risk perception and monetary poverty and the role of livestock as a capital asset in these interactions.

Some authors developed integrative indicators to approach vulnerability index (Hahn et al., 2009) or aggregate index of adaptive capacities (Vincent, 2007). The main challenge is to avoid influencing our results by our perception of vulnerability, i.e., by giving more or less weight to one indicator over another. In this purpose, we chose to use groups of indicators that reflected a part of the overall system of the family. The proximity (or lack of) of links between the different components of the systems were analyzed through the multi-factorial analysis. Although the analysis in main components have been widely used, multi-factorial analyses (MFA) crossing quantitative and qualitative data are far less common. In the literature, there is increasing recognition that methods that cross qualitative and quantitative data are needed to capture the complexity of human processes like adaptation (Booth et al., 1998; White, 2002). In this paper, we show how this approach can help understand and build on complex adaptive capacity by highlighting interactions between groups of indicators.

2. Materials and methods

2.1. Materials

This research was conducted along a west-east transect from Sidi Barani (located approximately 100 km from El Saloum on the Libyan border) to Borg El Arab (located 60 km from Alexandria) in the Matrouh governorate. The study area comprised seven geographical units distributed in four zones: the rain-fed zone in the western zone that comprises four regional units (Sidi Barani, Neguila, Matrouh and Ras el Hekma) (called 'west'), the newly reclaimed lands in the eastern zone (that cover the regional unit of El Hamam and Borg en Arab) (called 'east'), Debaa in-between and Siwa oasis

(Fig. 1). Except Siwa, each zone can be divided into five agro-ecological strips from the coast (north) to the desert in the south (Table 1). 95 Families were surveyed in the rainfed zone and between 26 and 31 in the three other zones. The families were selected along a north–south gradient from the coast to the desert area based on the number of livestock they owned. All the interviews were conducted *in situ*. In this study, a 'family' unit included one or several households who depend on each other for livestock and land assets and cash income. Each household represented a standard nuclear family (husband, wife and their children). The head of the family was the authority for all economic and social decisions.

The survey was based on a structured questionnaire that was presented during interviews with individual families. The questionnaire contained five sections: (i) a description of the immediate and extended family, the head of the family, the level of education of family members, the facilities in the home (television, mobile phone, refrigerator, and water supply), the identity of the decision makers and managers of the main activities related to land, livestock, and social events, (ii) the land and cropping system, (iii) the livestock structure and management (including feeding, health care, sales and purchases), (iv) the nature of the link and the degree of trust in the main stakeholders (from the tribe to governmental and non-governmental institutions such as development projects) and (v) the interviewee's general perception of changes in climate, productivity, and in social relations. The data from this survey of 182 families were used to build the indicators.

2.2. Choice of indicators for capital assets

In Chambers and Conway's (1992) definition of livelihood (cited above), the authors link the assets and the practical options people have to maintain or develop a set of activities that produce the income the family needs to survive and maintain the minimum level of human and social needs. This minimum level of human and social needs corresponds to what Drèze and Sen (1989) called capabilities, namely, the ability of individuals to realize their potential as human beings. This approach was used in several studies (Hussein and Netson, 1998; Scoones et al., 1996, Ellis, 2000). However, as mentioned by Ellis (2000), assets comprise multiple components related to economic categories (i.e., physical or financial assets) and other categories, such as claims or access to resources. In our study, we distinguish five categories of assets: the physical assets land, livestock and housing capital, plus human and social capital.

In the Bedouin communities we surveyed, the two main physical types of capital were land and livestock. In our study, the term 'land' covers 'cultivated land' and 'pastureland' that covers the land (whether attributed or not) used for grazing by the family. To take into account the uncertainty linked with land access, we distinguished the 'attributed land' from the 'total land used'; the last one includes attributed land, common pastureland land used by an individual and rented land. The term 'cultivated land', covers three types of land: (1) low lying land in the bed of the wadi (named 'wadi area') where farmers can plant tree crops such as figs and olives; (2) land under barley (named ''rainfed area'') where only barley can be grown; (3) 'irrigated area' in Siwa oasis and the newly reclaimed lands in the eastern region. The economic potential of the wadi land depends on tree plantations. For this reason, we also took the size of the orchards into account, expressed as 'number of trees'. The 'total (number of) feddans per household' (1 feddan = 0.42 ha) allowed us to link the land asset to the size of the family (see Table 2).

Survey results showed that livestock represented both productive capital and savings. In Bedouin society, sheep breeding has traditionally been the main economic activity in terms of generating income from livestock, and goats are kept for home consumption of milk and meat. In the southern region, in addition to sheep and goats, camels still represent a buffer during long periods of drought due to their resistance. Cattle were only observed in Siwa and in the eastern region and are raised mainly to produce calves for sale and milk for family consumption. So the first criteria we considered were the number of the different species of livestock. As living capital, livestock are vulnerable to external shocks. The capacity of the livestock to face shocks depends on general health and thus on feed and health management. Three livestock health indicators were used: (1) the rate of 'vaccination coverage' estimated as the number of vaccinations or regular treatments each year, (2) the 'rate of (infection by) internal and external parasites' and (3) the 'average feed supplement' given to sheep (kg/day/head) to represent the health status of the herd (see Table 2).

Another physical asset was housing. In this category, the differences were the building materials (concrete or wood) used for the roof, access to drinking water and electricity (on which the purchase of a television, refrigerator, or mobile phone depended), and ownership of a means of transport like a car.

Human capital encompasses personal resources such as education, training or experience, and capability in the sense of health or labor potential (Schultz, 1961). In the literature, the importance of education is widely recognized as a way to access social networks in addition to the importance of diversification (Ellis and Ndoe, 2003). However, there are other ways to access knowledge besides schooling: professional training, television, radio, mobile phones. Consequently, in addition to educational indicators concerning the head of the family ('education of the head of family') and family labor ('percentage of educated adults'), we included 'mobile phone' and 'television' as human capital in the sense that they reduce isolation and provide a flow of information. We also included more common variables such as family members ('total number of persons in the family') and family labor ('men able to work'). Experience was covered by 'age of the head of family', the number of 'members of family who are shepherds' and the 'percentage of off-farm jobs' in the family (see Table 2). All these variables highlight personal knowledge and the capacities of the members of the family.

Table 1
System characteristics from the north west coast to the south (source: El-Nahrawy and Mikhiel, 2004).

Area	Distance from the coast in km	System characteristics and land use
1	0–5	The wadi delta: annual rainfall 140 mm, good soil, orchards and cultivation of vegetables. Inhabitants are sedentary
2	5–15	Annual rainfall 100–140 mm, poor soil, livestock breeding (especially sheep and goats) and barley cropping, no reliable water supply. Inhabitants are sedentary
3	15–50	Annual rainfall 60–100 mm, sheep and goat raising, some barley cropping. Bedouins are predominant, mixture of sedentary and nomadic lifestyles
4	50–100	Annual rainfall about 50 mm. Livestock raising (especially camels) and grazing system. Nomadic Bedouin tent society
5	100–200	Little or no rainfall. Severe desert environment, limited camel raising. Scattered human settlements

Table 2
Key variables chosen to illustrate each type of capital assets.

Category	Name	Key variables
Physical asset	'Land'	Total used land; attributed land; cultivated land; pastureland; rainfed area; wadi area; irrigated area; number of trees; total feddan per household
	'Livestock'	Total head of ewes, does, cattle and camel; vaccination coverage; rate of internal parasites; rate of external parasites; average feed supplementation (kg/day/sheep)
	'House'	Roof made of concrete (yes/no); electricity (yes/no); water (1. network, 2. reservoir, 3. nothing); car (yes/no); refrigerator (yes/no)
Human capital	'Family'	Age of the head of family; education of the head of family; extended family (yes/no); total number of persons in the family; men able to work; members of family who are shepherds; percent of off-farm jobs; television; mobile phone; percentage of educated adults
Social capital	'Social'	Mother tribe; link with the head of the *bait*[a]; distance to Omda and Sheikh (km); trust in Omda and Sheikh, trust in development project; frequency of contact with Omda and sheikh; link with Omda and Sheikh, with agricultural extension service and development project; benefits from agricultural extension service and development projects; loan from friends/relatives; loan from trader
Risk perception	'Risk'	Number of good events; number of bad events; type of good events; type of bad events; perception of relations with the family in the future; perception of relations between poor and rich; change in soil quality, change in water quality, change in drought events, change in rainfall, change in temperature, change in number of shrubs on pastureland, change in type of plants on pastureland, change in animal productivity
Impact	'Poverty'	% Income from livestock in total income and agricultural income; net income per household and per capita; cash income per household; % off farm income; occasional job; government job; number of off farm jobs in the family
Livestock adaptation	'Adapt'	Changes in the size of the sheep, goat herd between 1995 and 2011 (%); month of transhumance; distance of transhumance; concentrate during transhumance; concentrate outside transhumance; sold ratio of sheep and goat for the whole flock and then the reproductive animals; son left at home

[a] Each mother tribe is divided in sub-tribe that is composed with different families called '*bait*'.

According to the definition of Ellis (2000), social capital may be reflected by the access to options through institutions or social relations. In this study, we dealt with social capital by first focusing on the social network and then on the relations within and between social groups at different levels of social organization according to Woolcock (1998). In the study area, the social capital is first embedded in the traditional tribal organization of Bedouin society. Five mother tribes are present with two representative bodies: the *Omda*, who represents the interests of the tribe at the central level, and the *Sheikh*, who is in charge of internal tribal regulations. The tribes are distributed along east–west and north–south axes. For instance, the Ali Al Ahmar tribe, which is located in the coastal region, has different opportunities than the Senena tribe in the south who, traditionally, is camel breeders. The main individual tribal unit is the *bait,* which comprises 2–3 generations. So the 'mother tribe' and the 'link with the head of the *bait*' were the two first indicators chosen. The social network also includes development project managers who influence access to infrastructure (reservoir, dykes, etc.) and the extension service, which influences access to inputs, mainly feed or seeds. In our survey, social capital was expressed as the relationships the head of the family had with the main representative of the traditional societies (*Omda* and *Sheikh*) or with development projects or with government agencies. The nature and intensity of the link were illustrated by four indicators: physical distance (in km), frequency of contact, the degree of trust (as declared by the head of the family), and the family head's perception of the benefits of this link. In Bedouin society, the majority of loans are contracted with traders or relatives and friends mainly thanks to their social network. For this reason, the indicators 'loans from friends/relatives' or 'loans from trader' were included in the social capital.

In tackling the capacity of an individual to mobilize his internal or external resources to face a shock, it is recognized that this capacity varies according to the experience of the individual concerned and to his perception of change. Although the majority of older breeders had a longer experience of drought and then they could adapt more easily than younger breeders, the younger generations benefited from the experience of the older generations thanks to the social and hierarchical control between generations in Bedouin society. Nevertheless, this collective capacity varied with each individual and each tribe, depending on the position of the individual within the tribe and on the position of the tribe in Bedouin society as a whole, and some headstrong individuals might find themselves isolated when they had to face a shock. Moreover, the capacity also depended on the individual's psychology (Santé Canada, 2007). One can assume that a breeder who mentioned two or three bad events was more averse to risk than a breeder in the same locality who only mentioned one bad event ('number of good events' and 'number of bad events'). This depended on the type of events ('type of good events' and 'type of bad events'). Naturally, faced with climate change, perception also differed depending on the locality, and on the support the family could expect from the community. A head of family who considered that social relations within the family or within the community were bad might be more affected by external shocks because he cannot rely on the community to help him. For these reasons, two indicators were chosen: 'perception of relations with the family in the future' and 'perception of relations between poor and rich' in the community. Finally in this category of parameters, we also included the perception of changes in: (1) natural capital: soil, water, the type of plants and the density of shrubs in pastureland and (2) climate changes: temperature, rainfall, and drought. In this category, we also included the perception of animal productivity. All these indicators were classified under the heading 'risk' (Table 2).

All the parameters classified as human, social, physical ('land', 'livestock', 'house') assets and perception ('risk') (Table 2) may explain the capacity of farmers to face external risks. Vulnerability is normally defined as including impact (exposure and sensitivity) and adaptive capacity. To prevent confusion between the two dimensions, we distinguished two other groups of indicators: the first to illustrate impact, notably in terms of income (called 'poverty') and the second focused on livestock adaptation (called 'adapt') to understand the specific role of livestock during this period. The first group included annual 'net income per household and per capita' calculated on the basis of all agricultural and non-agricultural outputs and inputs recorded during the survey period from March 2010 to February 2011. The annual 'cash income per household' only includes monetary transactions in the calculation. A second set of variables in this group dealt with the relative contribution of each type of activity including livestock, off-farm job, or more specifically, occasional or governmental job. The second

group 'adapt' included all variables related to any change in livestock management due to the drought. In this group, we calculated: (i) the variation in each animal species in the herd between 1995 and 2011, (ii) changes in the transhumance in terms of duration ('month of transhumance'), location ('distance of transhumance') and use of feed concentrates ('concentrate during transhumance' and 'concentrate outside transhumance' per day and per head) and (iii) the ratio of sheep and goats sold to the whole flock and then to the reproductive animals. We also included a variable 'son left at home' because this decision had a direct link with livestock adaptation.

2.3. Multiple factorial analyses (MFA)

Our objective was to highlight the factors that determined the capacity of the families to face external risks, in particular drought events in arid zones. We used multiple factorial analyses (MFA) (Escofier and Pagès, 1994) to obtain a summary of the range of situations of families in the four regions. Multiple factor analysis can depict the thematic structure of variables that describe the livelihood of a family. These themes corresponded to the abovementioned assets ('land', 'livestock', 'house', 'family' and 'social' see Table 2). MFA was used both as a classic factorial analysis to depict the complexity of the situations described by the selected criteria within each set of variables, and at the same time, a summary of each group's role (or each theme) in the construction of a comprehensive typology of families.

MFA uses a different weighting for variables that belong to thematically homogeneous groups. This weighting is related to the strength of relationships between variables in order to better take into account the heterogeneity between groups of indicators and then analyze their roles in an overall typology. Because we were interested in the links between assets, we manipulated groups of indicators in a typological approach. This allowed us to circumvent the difficulties of indicator research for both exploring their relations and analyzing the different regional situations.

The technical details of the MFA are described in Escofier and Pagès (1983, 1994). MFA allows the comparison of n individuals (families) measured on K groups of variables. Each table $X^{(k)}$ ($k = 1,\ldots, K$) corresponds to a set of variables k for a given asset and possesses a different number of variables v_k. The analytical framework of the MFA can produce different results. In this article, we only focused on the use of inter-structure or typology of groups of variables. This analysis compared the contribution of each set of variables to the overall typology. We defined the quantities denoted Lg ($0 \leqslant Lg \leqslant 1$), which were measurements of links between variables v_k of the group $X^{(k)}$ and the factor of rank α denoted z_α:

$$L_g(z_\alpha, X^{(k)}) = \sum_{k \in X^{(k)}} \text{projected variance of } v_k \text{ on } z_\alpha$$

where z_α is the linear combination of all the variables of the K groups that summarizes a certain amount of total variance. Proximities measured by L_g between tables allowed us to conclude on the existence of common factors for all or part of the set of tables involved, indicating whether building a common typology was relevant or not. Similarly to a recent study of congruence markers in population genetics (Laloë et al., 2007), we chose the L_g value as a numerical measure of the typological value of the group of variables k, i.e., as a measure of adequacy of the analysis of group k with respect to the summary (MFA) of all the tables. All calculations were performed using R software (R Core Team, 2012) and the additional package FactomineR (Lê et al., 2008).

3. Key findings

3.1. Local determinants of the perception of risk

Fig. 2 shows the projection of the 182 families on the first factorial map (1–2) of the multiple correspondence analysis based on the perception of risk variables. Families are grouped by geographical units to keep the regional diversity. Tables 3 and 4 show the variables that, respectively, contribute or not to the perception of risk in each geographical unit to help understand the differences along the geographical gradient.

The most striking result was the contrast between Siwa and the other regions in the CZWD. This contrast is due to the specific socio-geographical characteristics of Siwa oasis, which is located in a deep basin in Egypt's northwestern desert zone 60 km from the Libyan border. Siwa is mainly inhabited by Berber and Sheita, a branch of the Awlad Ali tribes from the north coast. About 5000 hectares of land were cultivated in the oasis. Soil salinity was the result of inappropriate soil management and uncontrolled water flow from wells and springs as well as from bad drainage (Al-Kadi, 2003), leading to a drop in agriculture income (Abo-Ragab et al., 2008). The main livestock species are goats, sheep and camels. In some places large scale land reclamation has been undertaken and the Egyptian government was selling off parcels of land for intensive cropping, mainly of vegetables. The result has been a major reduction in livestock, mainly sheep. In addition, a new regulation controlling access to common natural grazing land in a small depression located 60 km northwest of the oasis, has reinforced this trend. And, due to changes in cropping systems, the main risk perceptions concerned soil salinity due to the intensification of irrigation on cultivated land in the reclaimed land zone. The perception of climatic risk, mainly drought or its impact on natural vegetation (shrubs or plants) was almost zero (Tables 3 and 4).

The region of Borg el Arab and El-Hamman in the eastern zone differed from the other zones due to the recent land reclamation program and the development of fodder and cash crops thanks to canal irrigation. Like in Siwa, due to irrigation of sandy soil, one of the major risks mentioned by farmers was the degradation of soil quality and the appearance of plant and animal diseases due to the new intensive cultivation system. The recent agrarian reform has caused major social changes at the community level that also differed from those we observed in the western rainfed region and in Siwa oasis. The families interviewed in the eastern zone were mainly Bedouin whose land – tribal land – was expropriated by the government during the land reclamation project. The Bedouin families purchased the reclaimed land – the land that is considered as tribal land by them – from university graduates and other beneficiaries in the last decade. Now they are legal owners of their land and no longer depend on the tribal authority to access or to cultivate land. Moreover, due to the proximity of the delta and the cities of Alexandria and Cairo, these families have undergone major changes in their way of life compared to populations in the western region. Their families (wife and children) usually live in urban areas. As a result they perceived a breakdown of social links at the community level, mainly in the form of links with their tribe, but their perception of the future of the household was better due to the positive economic impact of irrigation.

In the western rainfed region extending up to Debaa, climate change, mainly the intensity and duration of drought, was cited as the main perceived risk. The majority of families were aware of the major impact of the last 15-year drought (1995–2010) on the density of plants and shrubs in pastureland, an increase in temperature, and severe wind erosion of the soils after the drought due to

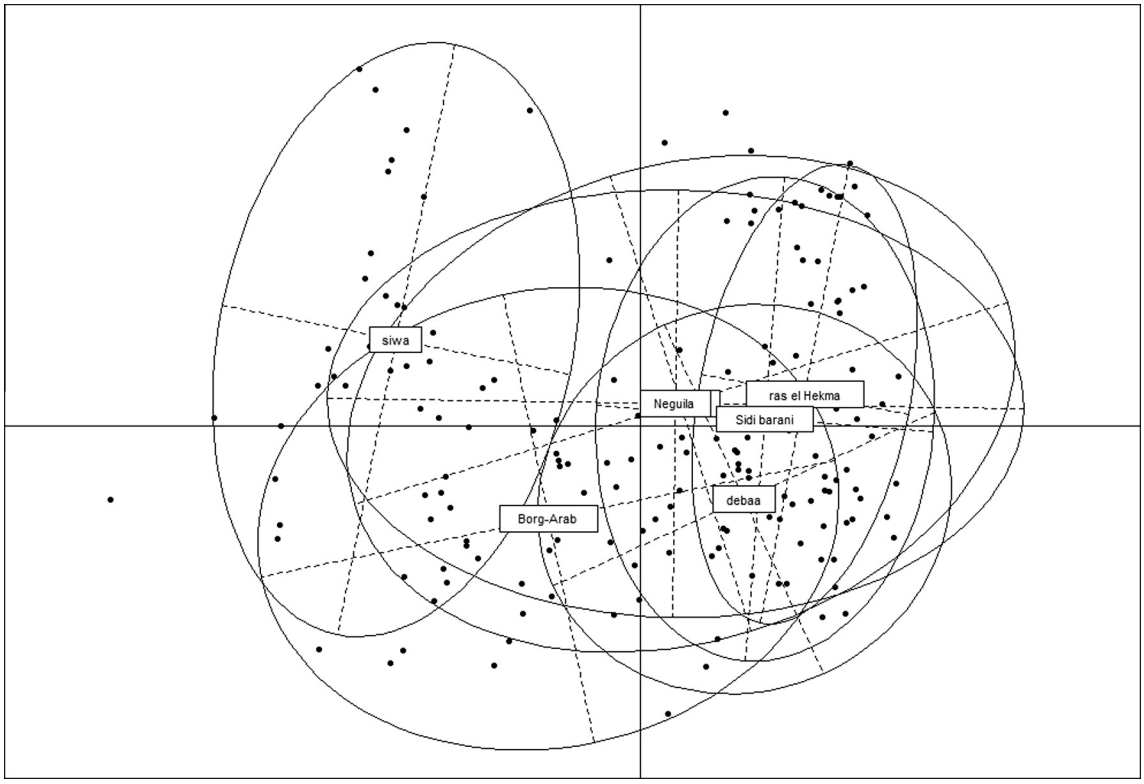

Fig. 2. Distribution of the 182 families on the first factorial map (factor 1 horizontally; factor 2 vertically) of the multiple correspondence analyses based on the risk perception criteria. Points represent families. The label of each geographical unit is the average factorial coordinates of the families that belong to the region concerned. An inertia ellipse containing 95% of the points is shown to illustrate the variability of the distribution of risk perception by families within each region.

Table 3
List of the most contributive factors to the perception of risk for each geographical unit (the factors with the highest contributions in bold).

Risk perception items	Sidi Barani	Neguila	Matrouh	Ras el Hekma	Debaa	El-Hamam and Borg El Arab	Siwa
Change in animal productivity	Decreasing	No change, increasing		Decrease due to disease			
Change in drought			Increase in intensity		Increase in intensity		**No change**
Change in rainfall				Irregular	Decreasing, irregular		**No change**
Change in shrub and plant density				Disappearing	Decreasing, irregular	No change	No change
Change in soil quality	Decreasing						
Change in temperature				Increasing	Increasing		No change
Change in water			No change				**Salinity**
Perception of family future			No change			**Improvement**	Social change
Main bad event	**Drought**	**Drought**		**Drought**		**Plant and animal disease**	Climatic change
Main good event	Rainfall					Economic change	Infrastructure
Perception of family relations						**Declining**	
Relation between rich and poor						Strong	

the absence of vegetation. This long drought may have the strongest impacts in Ras el Hekma with the disappearance of some shrubs and the drastic reduction in animal productivity.

These preliminary results on variables related to risk perception revealed the influence of locality on the perception of risk that affected social behavior at both family and community levels. We consequently decided to analyze the link between capital assets, risk perception, measure of income and livestock adaptation as defined in Table 2 in the four main regions.

3.2. Link between capital assets, impact of income and adaptation at regional level

We performed separate analyses of the links between capital assets, measure of income and adaptation for each zone. The variables were coded for each agro-climatic region to account for the specificities of each and to limit the number of missing data in one zone that could influence the results of the multiple factorial analyses. Based on the previous results, the four regions were:

Table 4
List of the least contributive factors to the perception of risk for each geographical unit.

Risk perception items	Sidi Barani	Neguila	Matrouh	Ras el Hekma	Debaa	El-Hamam and Borg El Arab	Siwa
Change in animal productivity	No change or increasing			No change or increasing			Decreasing
Change in drought			No change, decreasing		No change, decreasing		Increasing
Change in rainfall				No change or increasing	No change or increasing		Irregular
Change in shrub and plant density	No change or increasing			No change, decreasing		Decreasing	Decreasing
Change in soil quality							
Change in temperature					No change		Increasing
Change in water	No change or increasing					No change, increasing	
Perception of family future						No change	No change
Main bad event			Animal and plant disease	Animal and plant disease		Drought	Drought
Main good event						Infrastructure	
Perception of family relations							
Relation between rich and poor							

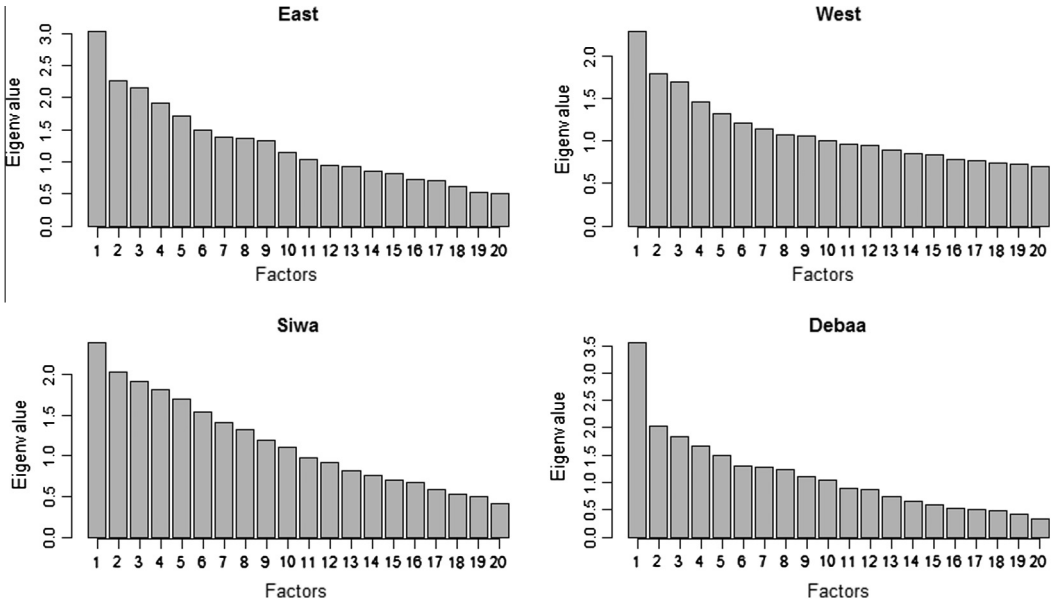

Fig. 3. Distribution of the eigenvalues of the multiple factorial analyses for each of the four zones. The eigenvalues correspond to the amounts of variance synthesized by the factors. Their distribution represents the structure of relationships between variables. Because the structure of the variance decomposition is usually studied from the prime factors, only the first 20 factors are represented.

Siwa oasis, the eastern irrigated zone, the western rainfed zone, and Debaa. The group 'adapt' with the groups of variables related to capital assets were active and defined the factorial map. The variables related to the perception of risk ('risk') and measure of income ('poverty') which measured the vulnerability (perceived or dealt with in terms of income) were only projected on the multiple factorial map defined by the groups of variables related to capital assets ('land', 'livestock', 'house') and livestock adaptation ('adapt'), the aim being to study the relations between the assets and adaptation and impact on income.

Fig. 3 shows the distribution of eigenvalues from separate multiple factor analyses for the four agro-climatic regions. Except for the western region ('west') and Siwa oasis, the histograms present one-dimensional structures. The first common factor (F1) is the strongest in Debaa (inertia ratio of 0.65) followed by the eastern region ('east') (0.59). This reveals a stronger relationship between variables than in Siwa oasis and the western zone.

In Debaa, the common factor is well represented by three groups of variables that illustrate the physical capital assets: 'livestock', 'land' and 'house'; in the eastern zone, the main representative groups of variables are 'family' and livestock'. However, Fig. 4 shows different adaptation strategies related to livestock used during the last 15 years in these two regions. The group of variables related to adaptation processes ('adapt') is positioned at the intersection of the two main factors (F1 * F2) in Debaa, unlike in the eastern zone ('east') where this theme is linked to livestock, family, and social components. This means that the adaptation process related to livestock is not related to the same asset components. The position of the income component ('poverty') also differs in the two regions. In the graph of the eastern zone, the income

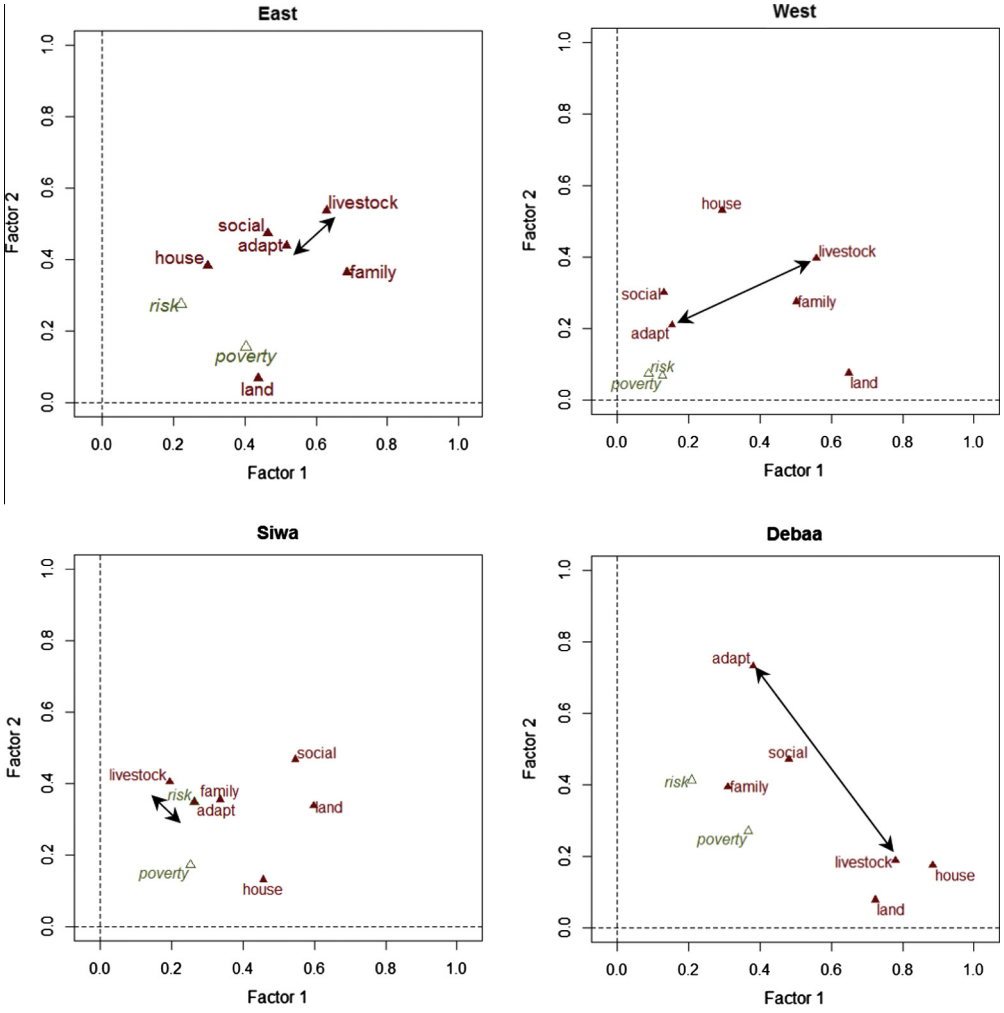

Fig. 4. Typology of sets of indicators for each of the four zones. This figure represents the projected inertia of the groups of variables on the first factorial map (factor 1 horizontally; factor 2 vertically) of the multiple factorial analyses (MFA) according to each zone. The projected inertia is an indicator of contribution of each set of indicators at the overall typology. The groups of indicators called 'poverty' and 'risk' did not participate in the calculation of MFA's factors. Their projected inertia can be read as a measure of the links with the other sets of indicators. The differences between zones in the relationships between sets of indicators 'adaptation' and 'livestock' are shown with a double arrow.

component ('poverty') is positioned close to the 'land' asset – the main productive asset. In Debaa, the adaptive process is independent of livestock and is mainly embedded in the ability to find off-farm jobs. In the eastern region, although irrigated land was the main source of cash, farmers had little leeway as far as labor was concerned and the main adaptive capacity to external shocks (mainly economic and social shocks) was breeding livestock.

In Siwa, the typology of assets is less clear (Fig. 3). Fig. 4 shows that land capital and social assets are linked on the horizontal axis. In the last 15 years, with the land reclamation and the recent difficulties involved in obtaining access to common grazing land, the Siwi population has considerably reduced the size of their herds. And if the tribal link appeared to be limited in the Bedouin tribe (notably the link with the Sheikh), one of the main social factors that differentiated the two populations was the Bedouin's ability to obtain loans from close friends and relatives, compared to that of Berbers.

In the western region, the physical assets 'livestock' and 'land' are well represented on the horizontal axis with 'house' on the vertical axis. We were surprised that 'adapt' and 'social' were not well represented in the western rain-fed region where adaptation processes – mainly the sale or purchase of animals – was the usual strategy to face climate events like drought. And kinships are well recognized in Bedouin society. In practice, all the farmers reduced the size of their herd due to the duration of the last drought (1995–2010) and independently of the initial number of animals in the herd. The second differentiation factor in the rain-fed region was the family home. Depending on the distance from their village to the main town and to the coast, some villages did not yet have a supply of electricity. The water system (only rainfall, cistern, and wells) also had a considerable effect on the degree of adaptation to a shock like drought. Infrastructure is thus one of the main factors of differentiation in the western region.

On the factorial map (F1 * F3) (Fig. 5), the 'social' and 'adapt' groups are positioned close together and explain the third factor. The third factor shows that a main factor of adaptation thanks to livestock management was linked to the social network. This matches empirical observations. For instance, access to common pastureland was mainly managed at the tribal level, and feed supplementation depended mainly on the link with an agricultural association, and then with the extension services, and so on.

In sum, the monetary component was shown to be as important as other indicators including physical or social assets and it was not redundant with physical assets. This means that the family income did not only depend on agricultural assets or official off-farm jobs. Many farmers increased their assets thanks to the

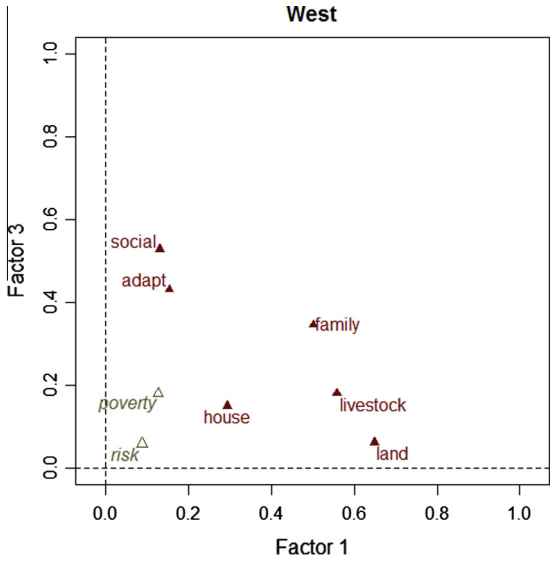

Fig. 5. Typology of sets of indicators for the rain-fed zone called 'west'. This figure represents the projected inertia of the groups of variables on the third factor (factor 1 horizontally; factor 3 vertically) of the multiple factorial analysis (MFA). Set of indicators 'poverty' and 'risk' are projected as supplementary elements to the MFA analysis.

migration of some family members to Libya. Furthermore, the adaptation process related to livestock varied from one region to another. In the newly irrigated zone, where the distribution of land was quite homogenous, the adaptation process was mainly linked to livestock assets. Livestock also had a relatively high typological value (Fig. 4) in the three coastal regions. This means that the group 'livestock' still clearly differentiated families between regions after 15 dry years.

4. Discussion

4.1. Role of livestock in increasing adaptation and/or reducing vulnerability

These results underline the key role of livestock in the regions of the CZWD in Egypt, with the exception of Siwa oasis located further inland where a massive reduction in livestock has taken place due to political and social pressure on land and to the agrarian reform that followed land reclamation. In Siwa oasis, livestock has become marginal in economic management at the level of the family but remains a key factor in food security, as goats continue to be the main or even the only source of milk. This explains the high percentage of goats in herds in Siwa (42.3%), compared to 18–19% in the western region and in Debaa, and only 9.2% in the eastern region in 2011 (Aboul-Naga et al., 2012).

Although livestock is important in the three other regions, its role varies. Faced with the exceptional length of the last drought (15 years), the majority of breeders in the rainfed zone of the western region were obliged to sell reproductive females to buy feed and to keep part of their herd. But our results show that the reduction in livestock was not linked to criteria of income or monetary poverty or to the size of the herd. Some of the wealthiest farmers decided to sell the majority of their herd to invest in a more lucrative activity such as building on the coast or even by investing in modern poultry production units. The less wealthy tried to get governmental jobs or occasional off-farm work (as temporary workers) depending on their level of education. Whatever job they found, all the breeders reduced their livestock, but few completely abandoned livestock breeding. In 2011, the livestock asset remained a good indicator of the overall physical capital asset of the family. Finally, in the western region, factorial analysis showed little differentiation between families based on adaptation of livestock system and income. Physical assets such as land, livestock, house, and human capital remained predominant. These assets are also the main indicators of wealth in Bedouin society. This means that majority of income from off-farm activities was always invested in agricultural and social assets. During drought events, the market value of animals increased with the increase in the price of feed. This economic trend confirms the role of livestock as a capital asset and not as a speculative activity in the western region at that time. This also confirms the dominant role of livestock throughout the region.

In the eastern region, livestock turned out to be one of the main factors of adaptation. In this region, which is comprised of newly reclaimed land, available land has already been appropriated and the capacity and opportunity to extend the land asset is extremely limited due to the price of land and competition for irrigated land. Therefore, if land is the main productive and remunerative asset thanks to the development of vegetable and fodder crops, improvement in wellbeing depends on the diversification of activities. One activity chosen by the Bedouin society in this region was livestock, mainly small ruminants. Consequently, in this zone, livestock was a factor of capitalization and subsequently of increasing wealth. At the same time, these farmers, who originated from Bedouin society, have an ancestral knowledge of sheep and goat breeding compared to farmers from the Nile valley and delta. Large-scale breeders in this zone may also keep two or three dairy cows for milk, and a horse to ride when herding their animals.

Between these two extremes is the very specific case of Debaa. In this region, physical assets remain the first factor of discrimination but the adaptation processes related to livestock are independent and mainly based on diversification away from agriculture. This situation originates in the socio-political context of this region where a large project to build a nuclear power station affected access to land, and where the presence of mines dating from the Second World War continues to cause injuries to the population. According to Mahieu (2002), the resilience threshold comes into play when possible substitution between capacities is limited or even blocked. This was almost the case in Debaa where the increase in occasional jobs to compensate for the reduction in land and livestock did not cover the basic needs of the family.

However, beyond the local or individual observations, livestock remains a key factor of management to cope to drought in the whole study area, except Siwa oasis. But the way livestock is managed during a drought and the role of livestock in the process of adaptation during drought appears to be independent of initial number of animals in the rain-fed region and more dependent on traditional social and official networks. So limiting the impact of drought requires more attention to the management of collective action, including livestock policies and feed subsidies, in this zone. Conversely in the irrigated zone, collective actions may be based on livestock capital.

4.2. The choice of indicators

The main scientific challenge of this study was the choice of indicators able to deal with the complexity of adaptive strategies used by families. Moreover, policy makers and developers would like to have more simple indicators or indications to design their own action plans. Our results not only underline the importance of the social network in facing a shock like drought, but also the difficulty of directly linking a set of capital assets to the degree of vulnerability mainly tackled in terms of income poverty.

The first problem is the contextual embeddedness of the parameters and the time period, especially those concerning livestock.

The reduction in livestock activity we observed in our study does not mean that the person will never return to livestock breeding. Livestock may be a way to invest in other activities including a private business; as soon as the climatic conditions improve, any profits from the new activity may be re-invested in livestock. The sale of livestock is the standard procedure in 'normal' periods of drought, i.e., that last two or three years. The herd is reduced every year, and then increases in the same annual proportion at the end of the drought. However due to the high mortality rate and low reproductive performance in these regions, when droughts last more than two to three years, the live capital is quickly exhausted (Alary et al., 2012). So to understand the role of livestock in reducing vulnerability during climatic events, we need to link the reduction in live capital to the development of other assets. We also need to analyze the investment mechanisms over a long period. The robustness of total capital assets in the face of risk will depend of the nature of the assets and their links with other global changes like social and economic changes as shown in the analyses.

The income per capita or per household is also a standard indicator of monetary poverty and then gives a measure of impact. Even if all vulnerable people are not poor, all the poor can be considered as vulnerable. Our results revealed the ambiguity of this parameter in a livestock breeding society like the Bedouin in the western region. As is true of many other pastoral societies, the per capita income of large-scale breeders can be very low if they invest all their profits in live capital or other assets such as housing or in private business, like investing in apartments along the coast. In this border society, one of the main factors of enrichment used is the legal and illegal traffic across the border with Libya, about which it was difficult to obtain information. To try and clarify this situation, in our analysis we included the link between capital assets, livestock adaptation variables, and measure of income. Our results confirm that adaptation processes such as reduction in livestock herds may be a flexible way to cope with drought; the ratio of reduction was more embedded in the social network than the the size of the farmer's herd before the 15-year drought. In contrast, in the eastern region, given the limited opportunity for other activities, changing the number of animals was the main factor involved in increasing or diminishing wealth.

Finally this study shows that perception of risk is highly sensitive to the way the question is formulated and to the timing of the interview. We observed a tight correlation between a pessimistic or optimistic view of the environmental indicators and the recent events that had affected the farm. For instance, our survey was conducted in 2010–2011. The farmers interviewed in March/April 2011 almost all mentioned the negative impacts of the drought, whereas the farmers interviewed in May/June started to mention the positive effect of rainfall as rainfall had been good in spring 2011, and some even mentioned the damage caused by the rain in this dry area. Interpreting the answer is quite easy in the case of an external event like rainfall, but is more difficult in the case of family events. Perceptions of trends in family and tribal relationships may be greatly affected by recent events that have occurred in the family such as an argument with their children or a recent conflict with a neighbor. This makes the interpretation of this group of variables more difficult.

5. Conclusion

During extreme events like the recent 15-year drought, Bedouin society lost two pillars of its adaptive strategies: first, mobility of the herd because drought affected the entire region including rangeland productivity, and second, the dispersion of members of the family, leading to a reduction in social cohesion. In response, human mobility increased with more migration to Libya during the last years of the drought (until 2010) and new family units settling in urban areas. Although mobility through migration has always been way to increase income, migration to town may have a long-term impact on this traditional society by changing the patterns of life and access to education for the young generations. However, in this new configuration, livestock will probably remain the main safety net, a sort of bank for the extended family, while other activities become the main sources of income. According to interviews conducted in 2011 and 2012 (the first years with a good climate in the last two decades), families have reinvested in livestock and family members living in urban areas contributed to this process financially. The main uncertainty in this region may thus be the sustainability of the whole family pattern we managed to capture thanks to multiple factorial analyses, and this sustainability is strongly linked to the local social network.

This study also underlined the advantage of factorial analysis for sorting out the answers to the types of questions asked during this survey, particularly for building the typology, but the main difficulty was the choice of variables to account for complex situations. The indicator of typological value described helps get round this difficult in two ways. First it makes it possible to change points of view by focusing not only on the descriptors, but also on the themes. This is particularly useful when the phenomena concerned are complex and have different dimensions, especially livelihood and the farm environment. Moreover, using a typological value makes it possible to extract similarities among assets represented by the different themes and thus to summarize the complementarities of the different assets to get a better picture of the contribution of each asset to the adaptive process. In sum, a typological value is useful to prioritize the contribution of each group of variables or theme to the construction of a compromise typology and to analyze the differences in contribution of groups of variables between regions. This helps answer general questions with multiple dimensions such as: what are the links between capital assets and poverty or adaptation? This, in turn, helps identify the main areas of intervention for policy makers.

Acknowledgments

The ELVULMED project was a collaborative project between CIRAD (*Centre International de recherche Agronomique pour le développement*) and INRA (National Institute of Agricultural Research) in France and APRI (Animal Production Research institute) and DRC (Desert Research Centre) in Egypt funded by ANR (National Agency of Research, France) in the research program on Society and Environment (ANR CEP&S, 2011). The authors wish to thank the ANR for funding the research and all the staff involved in the household survey from Marsa Matruh and colleagues from APRI, DRC, CIRAD and INRA who on many occasions took part in discussions on how to tackle the contribution of livestock to reducing vulnerability. Our special thanks to all the families in the study sites.

References

Aboul-Naga, A., Alary, V., Osman, M.A., Hassan, F., Daoud, I., Tourrand, J.F., 2012. Raising goats as adaptation process to prolonged drought incidence at the Coastal Zone of Western Desert in Egypt. In: XIth International Conference on Goats, Session 9: Economy, Sociology, System of production, September 2012, Canary Islands, Spain.

Al-Kadi, M., 2003. Environmental factors in the desert community and its effects on sustainable development – an applied study in Siwa oasis. Institute of Environmental Studies & Research, Ain shams University, Master Degree, Egypt, p. 151.

Abo-Ragab, S.A., 2008, Water Management of the Siwa oasis, Western Desert, Egypt. In: 33rd International conference for statistics, Computer Science And It's Applications 6–17 April, pp. 198–223.

Alary, V., Corniaux, C., Gautier, D., 2011. Livestock's contribution to poverty alleviation: how to measure it? World Dev. 39 (9), 1638–1648.

Alary, V., Daoud, I., Salama, O., Aboul-Naga, A.D., Merveille, N., Tourrand, J.F., 2012. Adaptation des sociétés bédouines de la côte nord-ouest de l'Égypte au changement global. Autrepart 62, 183–200.

Ashley, C., Carney, D., 1999. Sustainable Livelihoods: Lessons from Early Experience. Department for International Development, London.

Bonnet, P., Aboul-Naga, A., Alary, V. (Eds), 2014. Atlas of changes in livestock farming systems of the north west coast of Egypt – livelihoods and landscapes. ElVulmed project. Available online: <http://elvulmed.cirad.fr/cartographie/territoires-cote-nord-ouest-egypte> (in March 2014). (in press.)

Booth, D., Holland, J., Hentschel, J., Lanjouw, P., Herbert, A., 1998. Participation and Combined Methods in African Poverty Assessments: Renewing the Agenda. DFID Soc. Dev. Div. Afr. Div.

Chambers, R., Conway, G., 1992. Sustainable rural livelihoods: practical concepts for the 21st century. IDS discussion paper 296, Brighton.

Davies, J., Bennett, R., 2007. Livelihood adaptation to risk: constraints and opportunities for pastoral development in Ethiopia's Afar region. J. Dev. Stud. 43 (3), 490–511.

Drèze, J., Sen, A., 1989. Hunger and Publication. Clarendon Press, Oxford.

Ellis, F., 2000. Rural Livelihoods and Diversity in Developing Countries. University Press, Oxford.

Ellis, F., Ndoe, N., 2003. Livelihoods and rural poverty reduction in Tanzania. World Dev. 31 (8), 1367–1384.

El-Nahrawy, M., Mikhiel, G., 2004. Effect of protection on plant species and growth of natural vegetation in the Western North Coast in Egypt. In: Ferchichi, A. (Ed.), Rangeland and Pasture Rehabilitation in Mediterranean Areas, Zaragoza, Spain, CIHEAM-IAMZ, 433-436. <http://ressources.ciheam.org/om/pdf/c62/04600202.pdf>.

Escofier, B., Pagès, J., 1983. Méthodes pour l'analyse de plusieurs groupes de variables. Application à la caractérisation des vins rouges duVal de Loire. Revue Stat. Appl. 31, 43–59.

Escofier, B., Pagès, J., 1994. Multiple factor analysis (AFMULT package). Comput. Statistics Data Anal. 18, 121–140.

Hahn, M.B., Riederer, A.M., Foster, O., 2009. The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate Variability and Change- A case study in Mozambique. Global Environ. Change 19, 74–88.

Hussein, K., Netson, J., 1998. Livelihood diversification. IDS Working paper, Brighton, IDS.

Laloë, D., Jombart, T., Dufour, A.-B., Moazami-Goudarzi, K., 2007. Consensus genetic structuring and typological value of markers using multiple co-inertia analysis. Genet. Sel. Evol. 39, 545–567.

Lê, S., Josse, J., Husson, F., 2008. FactoMineR: an R package for multivariate analysis. J. Stat. Software 25 (1), 1–18.

Mahieu, F.R., 2002. La soutenabilité sociale des politiques de développement en Afrique. Séminaire transversal sur: Durabilité sociale du développement, Centre d'économie et d'Ethique pour l'Environnement et le Développement, Université de Versailles St. Quentin en Yvelines, Paris. <http://mapage.noos.fr/RVD/marchetrop1.htm>.

McPeak, J.G., Barrett, C.B., 2001. Differential risk exposure and stochastic poverty traps among east African pastoralists. Am. J. Agric. Econ. 83 (3), 674–679.

Moser, C.O.N., 1998. The asset vulnerability framework: reassessing urban poverty reduction strategies. World Dev. 26 (1), 1–19.

Payne, W.J.A., 1990. An introduction to animal husbandry in the tropics. Longman Scientific and Technical, London.

R Core Team, 2012. R: A language and environment for statistical computing. In: R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, <http://www.R-project.org/>.

Roe, E., Huntsinger, L., Labnow, K., 1998. High reliability pastoralism. J. Arid Environ. 39, 39–55.

Santé Canada, 2007. Risque, vulnérabilité, résilience: implications pour les systèmes de santé: document de référence, table ronde, réflexions, applications choisies. Direction générale de la promotion et des programmes de santé (Ed.), p. 78.

Scoones, I., Chibudu, C., Chikura, S., Jeranyama, P., Machaka, D., Machanja, W., Mavedzenge, B., Mombeshora, B., Mudhara, M., Mudziwo, C., Murimbarimba, F., Zirereza, B., 1996. Hazards and Opportunities. Farming Livelihoods in Dryland Africa: Lessons from Zimbabwe. Zed Books, London.

Scoones, I., 2009. Livelihoods perspectives and rural development. J. Peasant Stud. 36 (1), 171–196.

Schultz, T.W., 1961. Investment in human capital. Am. Econ. Rev. 51, 1–16.

Vincent, K., 2007. Uncertainty in adaptive capacity and the importance of scale. Global Environ. Change 14, 12–24.

White, H., 2002. Combining quantitative and qualitative approaches in poverty analysis. World Dev. 30 (3), 511–522.

Woolcock, M., 1998. Social capital and economic development: toward a theoretical synthesis and policy framework. Theory Soc. 27, 151–208.