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Addressing the challenges of agro-pastoral farming systems to strengthen their resilience

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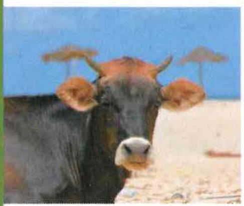

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Analysis of livestock assets, diversity and resilience for family farm systems in three different agro ecological zones in Egypt

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Abstract. The present work analyzes the diversity of livestock assets and management, in relation to human and land assets and its contribution to the household resilience. The analysis conducted on 452family farms surveys in three agro ecological zones of Egypt: the rain fed agro-pastoral zone in the Coastal Zone of Western Desert (CZWD), the hot arid desert oasis in the New valley (NV), and the irrigated hot area of Nile Valley in Upper Egypt (UE). The traditional family farming in Egypt usually include multi-animal species-herd composed of large ruminants (cattle and/or buffalo) and small ruminants (sheep and/or goats), and eventually camels in desert areas, with backyard poultry. The diversity of household faming systems was analyzed according to four dimensions, i.e., human and land asset, livestock diversity and household resilience. The cross analysis based on Multiple Factorial Analysis (MFA) shows very close links between land and crop assets, livestock diversity assets and management under different agro-ecological conditions. There is no exclusive link with either groups, but resilience is positioned as a synthesis of different capacities of households to adapt hazards. The perception of adaptive capacity of local breeds highlights the major external constraints in each location. Overall, increase of monetary and food resilience are linked with livestock activity diversification, even with livestock management embedded in the agro-ecological environment and land asset constraints.

Keywords. Diversity – Resilience – Family farm – MFA – Egypt.

Analyse des actifs de l'élevage, de la diversité et de la résilience des systèmes agricoles familiaux dans trois zones agroécologiques différentes en Égypte

Résumé. *Le présent travail propose d'analyser la diversité des systèmes d'élevage en lien avec les autres actifs du ménage et la résilience des systèmes d'exploitation familiale. Cette analyse est conduite sur la base d'une enquête semi-structurée auprès de 452 ménages répartis dans trois zones agro-écologiques d'Egypte : la zone agropastorale pluviale au Nord-Ouest du désert occidental (CZWD), les zones oasiennes dans la Nouvelle Vallée (NV) et les zones irriguées de la vallée du Nil en Haute-Égypte (UE). La diversité des systèmes d'élevage est abordée à partir de 4 lots de variables : la diversité multi-espèces, la diversité de fonctionnement, la diversité de valorisation des produits, et enfin la diversité de perception. L'analyse factorielle multiple montre des liens étroits entre les actifs fonciers et agricoles et les actifs de diversité et de gestion de l'élevage. Il n'y a pas de lien exclusif entre diversité des systèmes d'élevage ou autres actifs ; la résilience se positionne comme une synthèse des différentes capacités des ménages à s'adapter aux aléas. La perception de la capacité d'adaptation des races locales met en évidence les contraintes environnementales de chaque zone. Dans l'ensemble, l'augmentation de la résilience monétaire et alimentaire est liée à la diversification des activités d'élevage, elle-même conditionnée par les autres actifs du ménage en lien avec les contraintes et atouts de chaque zone agro-écologique.*

Mots-clés. *Diversité – Résilience – Agriculture familiale – MFA – Egypte.*

I – Introduction

Assessment of livestock contribution to vulnerability reduction and improvement of farmers living conditions, is a real challenge in the rural areas of developing countries, in relation to climatic and population pressure on crop and land. Recently there is increasing literature related to livestock contribution to poverty reduction (Freeman *et al.*, 2008; Otte *et al.*, 2012) and adaptive capacity to global changes (Alary *et al.*, 2014). Livestock raises also many challenges related to climate change (Rojas-Downing *et al.*, 2017 and Thornton and Herrero, 2010). In parallel, resilience as broad range of scientific disciplines became common concept in the last decades (Scheffer *et al.*, 2015; Ge *et al.*, 2016). Adger (2003) defined resilience as the ability of communities to withstand external shocks, ability to persist and adapt the unforeseen circumstances and risks. The resilience and its relation to adaptive capacity of the whole ecosystem, in the medium and long term, had been described by Walker *et al.* (2006), Folke *et al.* (2002, 2003) and Berkes (2007). They identified four major factors that highly influence the properties of a system to enhance adaptability: (i) the ability to 'learn to live' with changes and uncertainties, (ii) the maintenance of diversity within the system, (iii) the combination of different sources of knowledge, and (iv) the safeguarding of self-organizing capabilities and multi-scale connections.

Interest in resilience and robustness of livestock system to environmental conditions increased substantially in the past decade (Klopcicet *et al.*, 2009; Hermesch and Dominik, 2014). In this line, the livestock contribution to the family farm resilience is often searched in its inter-and intra-species composition, population dynamics and management adjustments, allowed by the intrinsic mobility of the herd and local herd rusticity (Nardone, 2000). Colditz and Hine (2016) described livestock resilience as the capacity of the animal to withstand the stress and recover rapidly to its physiological, behavioral, and production status pertained before exposure to stress. Livestock is an essential mean of protection during times of crisis and is crucial for the farm resilience, and contributes in several ways to the family daily subsistence (FAO, 2016).

The traditional family farming system in Egypt usually include multi-animal species-herds composed of large ruminants (cattle and/or buffalo), small ruminants (sheep and goats), and eventually camels in desert areas, with backyard poultry (Aboul-Naga *et al.*, 2014). Each animal species produces different final or intermediary products at different time scale (daily for milk and eggs, weekly for chicken, semi-annual or annual for kids from ruminant's species). So livestock produces a diversity of products (dairy products, skin, and manure, wool and draft power). Final products like milk and meat cover family expenses or even agricultural investment over the time. The resilience of the whole system is assessed according to three dimensions: (i) coverage of monetary and food needs at the short term, (ii) transmission of the farm to next generation and (iii) the environmental sustainability in link with pastureland and biomass management at medium and long terms.

The present work analyses the diversity of livestock assets and management, in relation to the other human, land assets, and its contribution to the overall household resilience. The analysis was conducted on a set of 452 household surveys in three agro-ecological zones of Egypt: the rain fed agro-pastoral zone in the Coastal Zone of Western Desert, the hot arid desert oasis (New valley) and the irrigated hot area of the Nile Valley (Upper Egypt).

II – Material and methods

1. Presentation of the studies areas

The objective of the present study is to analyze the diversity in livestock systems, including livestock assets and livestock management and its contribution to family farm resilience, in three different agro-ecological zones of Egypt. Integrated crop- livestock systems are dominant in the studied areas, but with different components and management. Three agro-ecological zones were involved in the study (Fig. 1): (1) Rain fed area at the Coastal Zone of Western Desert (CZWD), extensive system under hot dry conditions; (2) Desert oasis in the New Valley (NV), semi intensive system under hot dry and intensive solar radiation conditions; and (3) Irrigated Nile Valley of Upper Egypt (UE), with intensive agriculture system under hot conditions.

The number of family farms involved in the study were 207 in CZWD, 135 in the NV and 110 in UE, totaling 452 farms. The surveys were based on a semi-structured questionnaire including six components: (1) family structure and working load; (2) land and cropping system; (3) livestock structure and management; (4) costs and financial issues; (5) adaptation of local breeds to the prevailing environmental conditions; and (6) perception of the farmers for the advantages and disadvantages of sheep and goats local breeds. Local breeds prevailed are mainly Barki sheep and goats in the CZWD, Wahati sheep and goats in the NV and Saidi sheep and goats in UE.

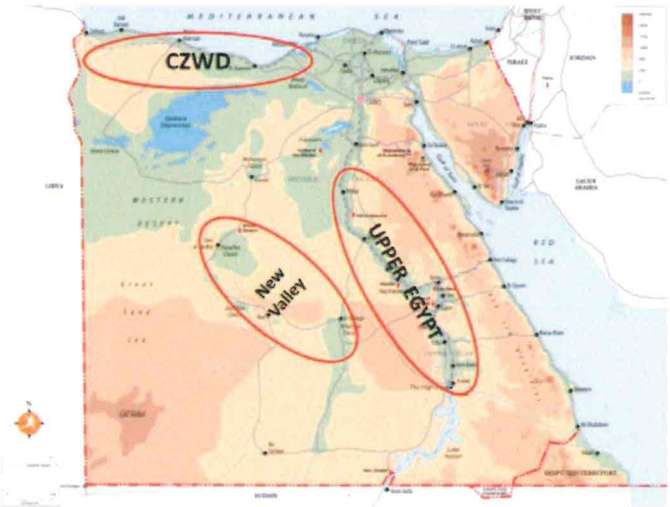

Fig. 1. Map of the studied agro-ecological zones.

2. Analysis of the links between the groups of assets, livestock diversity and the overall diversity

Each group of assets or capacity were addressed by a set of variables (Tables 1 and 2). In total, five main sets have been chosen in link with our main objective to understand the links (causal or correlated) between the human and land asset, the livestock diversify and perception, and the overall resilience of the family farm system.

The livestock diversity is analyzed according to threeperspectives (Table 1). The first one is related to the assets' diversity in link with the flock composition in terms of species and the percentage of reproductive females for each species. The second one is based on livestock management in link with feeding and health management. The third one is related to animal marketing valorization in link with live animals, milk and wool commercialization.The resilience approach is based on three components, i.e. the monetary poverty in relation to the poverty threshold in the country, the transission to next generation in link with land and livestock potential transmission, the food autonomy in relation to milk and meat consumption and, finally, the environmental perspective in link with manure use and the grazing potential.

Table 1. List of quantitative variables

Themes	Variable	New variable label	Mean ± SD
Human assets	Household size	HHsize	8.62 ± 5.52
	Age of the family head	age	45.24 ± 13
	Education level of the family head	edu	2.79 ± 1.33
	Number of women	women	1.64 ± 1.37
	Number of adults	adult	5.36 ± 4.30
	No of family members employed out farm	employ	0.35 ± 0.74
	No of family members working as temporary workers	tempLab	0.27 ± 0.81
Land and crops assets	Total cultivated area_ha	cultiArea	17.43 ± 46.68
	Pastureland area_ha	pasture	15.35 ± 39.64
	Rented land_ha	landRent	0.49 ± 1.34
	Irrigated land_ha	landIrrig	0.53 ± 1.71
	Cultivated land in trees_ha	tree	4.26 ± 12.63
	Cash crops area_ha	cashCrop	0.98 ± 1.16
	Crop income/total income	incCrop	0.418 ±
Livestock diversity	No of animal species	nbspecies	2.78 ± 1.02
	Sheep and goats flock size	sheepGoat	194.52 ± 308
	Large ruminant flock size	cattleBuf	3.8 ± 6.41
	Total TLU*	TLU	38.04 ± 53
	Sheep and goats/ total TLU	sheepGoatTLU	0.74 ± 0.32
	Cattle and buffalo/total TLU	cattleBufTLU	0.26 ± 0.31
	Reproductive females/ sheep flock	RSheep	0.56 ± 0.21
	Reproductive females/ goats flock	RGoat	0.44 ± 0.25
	Reproductive females/ cattle flock	RCattle	0.30 ± 0.34
	Reproductive females Buffalo flock	RBuf	0.05 ± 0.20
	Grazing months	grazing	2.61 ± 2.97
	Maximum distance of grazing	grazDist	8.69 ± 22.27
	Forage crop in winter	forageW	0.28 ± 0.36
	Forage crop in summer	forageS	0.17 ± 0.34
	Dry matter intake from mixture/ total DM intake	DMmixt	0.24 ± 0.31
	Health cost/sheep	healthCost	18.25 ± 31.23
	Self-consumed milk/total milk production (cattle milk)	bovMilkCons	0.19 ± 0.39
	Self-consumed milk/total milk production (goat milk)	goatMilkCons	0.05 ± 0.14
	Wool Sheep sale	sheepWool	0.11 ± 0.31
Resilience	Net income per family member per day	netIncPov	7.69 ± 10.18
	Family cash divided by the poverty threshold	familyCash	90.98 ± 197
	Land transmission (total area divided by children)	landTrans	4.38 ± 13.98
	Livestock capital divided by no. of children	capitalLive	23932 ± 39226
	Milk self-consumption (liter/day/person)	milkCons	0.95 ± 2.19
	Meat self-consumption (kg/person/day)	meatCapita	0.15 ± 0.27
	Wheat consumption (kg/day/person)	wheatCons	0.35 ± 0.91
	Manure (in kg DM/feddan)	manure	11.29 ± 28.31

*TLU:total livestock units.

Table 2. List of qualitative variables

Variable				
Sheep and goat perception			**Sheep (%)**	**Goats (%)**
	Adapted to environmental conditions (desert conditions)		16.9	19.2
	Adapted to climate conditions (drought, hot and cold)		28.5	29.4
	Adapted to walk and grazing		4.2	4.3
	Adapted to feed shortage		9.1	9.7
	Adapted to disease		4.5	4
	Best breed (productivity)		15	15
	Good meat		4.7	4.7
	High demand(good market value)		10.9	7.1
	Cultural value		6.2	6.6
Grazing land quality		**CWZD**	**UE**	**NV**
	Low quality (%)	92.7	4.1	3.2
	Medium quality (%)	0	76.3	23.7
	High quality (%)	0	43.7	56.3

In the first step of the analysis,the quantitative variables were transformed into classes to account for their heterogeneous distributions and deviations from normal distributions. Then, we have conducted a multiple factorial analysis (MFA) (Escofier and Pagès, 1994) to analyze the similarities between different sets of variables (called themes, detailed in Alary *et al.*, 2020). This analysis allowed us to have a cross analysis between the three first dimensions, i.e. assets basis, the livestock diversity and the overall family resilience.We presented the projection of the variance of the themes on each factor of the MFA,which helps to evaluate the contribution to the total variance and the similarities between tables (Pagès, 2004). The correlations between the tables were estimated using the multivariate correlation coefficient RV (Robert and Escoufier, 1976) which measures the global correlation between the variables of two tables. Based on the coordinates of the individuals on the first factorial plan, we have conducted a clustering analysis (HCA, Ward method) to identify and characterize the main profiles of resilient farming system in the three studied agroecological zones.

3. Co-inertia analysis to study the links between diversity and household resilience

The co-inertia analysis is a general multivariate method of coupling two tables (Dray, 2003). To study the links between the indicators of diversity related to livestock activity and the indicators of household resilience, we were inspired by approaches used in quantitative ecology to study biodiversity by analyzing the links between environmental variables and indicators of plant or animal populations (Dolédec and Chessel, 1994).The principle of co-inertia is as follows. For two sets of variables, the analysis looks for new synthetic variables (t and u) that maximize both the correlation between the variables and their variance. This quantity is called the covariance (cov) or co-inertia and it is maximized for each pair t and u. All pairs of uncorrelated synthetic variables are computed until the total covariance between the 2 tables is reconstructed.

Each pair of factors t and u called scores synthesize the similarities between the individuals and the correlations between the variables on factorial maps. These proximities are visualized on the factorial co-inertia maps which are interpreted in the same way as for a classical factorial analysis. In complement, a statistical test of randomization based on random permutations of the rows of the two tables (Heo and Gabriel, 1997; Thioulouse and Lobry, 1995) was performed to assess the significance of the correlation structure observed and measured by the RV coefficient. This Monte Carlo test which compares the repeated simulated covariance and the observed covariance is a prerequisite before investigating potential relationships between the variables in the two tables. In this study, we chose to perform the co-inertia analysis with the original quantitative variables (continuous or ordinal scores). The continuous variables were previously log-transformed in order to reduce the skewness of their distribution and to help linearize the pattern of links between continuous variables. All calculations and graphics were made with the R software (R Core Team, 2020) using the factoMineR (Le *et al.*, 2008) and ade4 (Dray *et al.*, 2007) R packages.

III – Results

1. Cross-analysis of assets, livestock diversity and household resilience

The cross analysis of the different dimensions based on the MFA shows very close links between the land and crop asset ('Asset land') and the livestock diversity asset and management ('Livestock diversity') in link with the agro-ecological conditions ('Location'). Moreover, the whole resilience of the systems is the combination of the land and livestock assets and secondly the human asset ('Asset HH'). We can see that the perception of adaptive capacity of local breed ('Perception') is not an important structuring factor. This perception should be put in link with household asset, notably the experience of the family head.

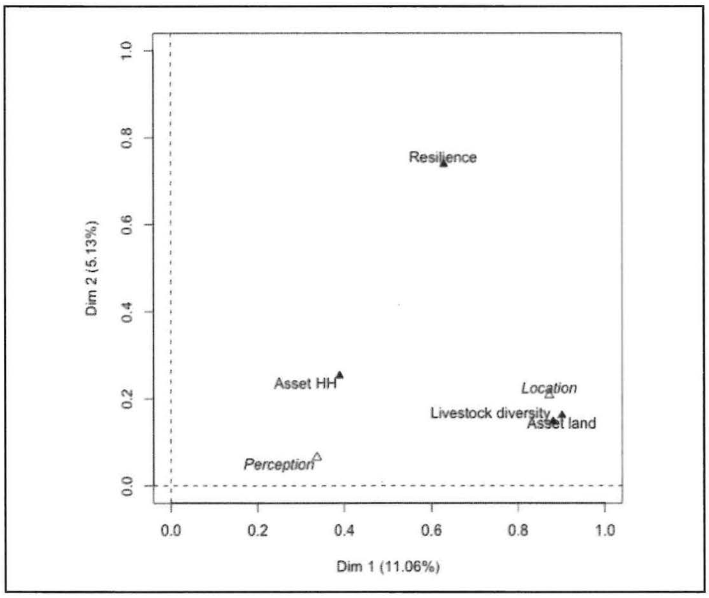

Fig. 2. Representation of the MFA projected variance of the groups of variables in the factorial map (Dim 1 x Dim 2). The active and supplementary variable groups are represented with a filled and an empty triangle respectively.

Overall, we can confirm that the overall resilience of the household farming system is more linked to the livestock diversity (RV=0.41) than the land and crop asset (RV=0.37) or human asset (RV=0.12).

2. Description of the resilience profiles

Based on the MFA, we have developed a clustering analysis that allows to identify 4 profiles of household systems (Fig. 3). Firstly, we can see that the different profiles combining land asset, livestock diversity and resilience are strongly embedded in the three agroecological zones that condition the crop and livestock opportunities. From that, we can identify 2 profiles in the UE (P1) and NV (P2) and 2 profiles in the rain fed zones of CZWD (P3 and P4), which are distinguished according the land and crop system. In one hand, the farming systems in the UE and NV are mainly composed of small plots of land cultivated with wheat and clover in winter and corn and darawa in summer, the two forage crops being used for large ruminants, i.e. cattle and buffaloes. These two profiles differ regarding to the land and livestock assets. In the New Valley (P2), farmers have access to around 10 feddan (or 5 ha) allowing to raise around 10 large ruminants, compared to the average small-scaleland farm system (P1) with around 3 feddan (less than 1.5 ha) in the Nile Valley allowing 5 large ruminants. In the other hand, the farming systems in the CZWD are mainly rain fed systems based on olive and fig trees and cultivated land with barley for sheep and goats. Two FS can be differentiated according to the average flock size (from 300 for P3 to 475 heads for P4), with a higher family food autonomy and diversification in P4.

Overall, we can see an increase of monetary and food resilience in link with livestock activity diversification although livestock management appears mainly embedded in the agro ecological environment and land asset constraints.

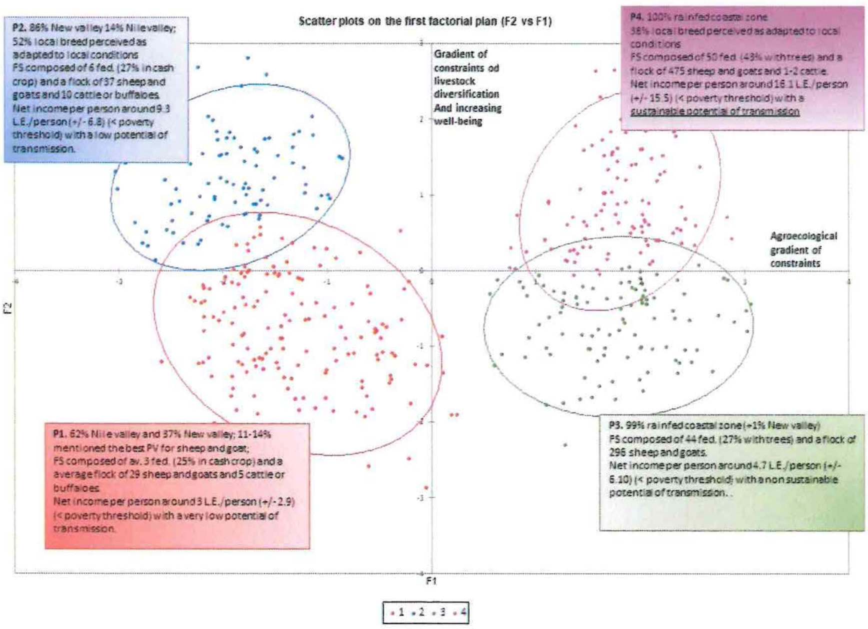

Fig. 3. Identification and description of Resilience profile based on clustering analysis.

In Table 3, percentage of positive answers for different types of adaptive capacity perception (mentioned as first and second importance), was calculated either for sheep and goat. Firstly, we can see similar perception of the adaptive capacity of the animals for the two species, except for the market value, which remains quite similar to sheep in NV and NV, but drops dramatically in the rain fed zone. Secondary, we can see that the desert conditions are more predominant in the rain fed zone that in the irrigated zones of the Nile and New valley, explaining the relative importance of sheep and goats in the two contexts. We also see clearly that sheep and goat constitute an important asset regarding feed shortage in the less resilient profiles of the two main agroecological contexts in link with irrigation access. Globally more than 10% of the farmers for P1 in irrigated zone and P3 in the rain fed zones mention the capacity of sheep and goat to cope with feed shortage. Finally, the percentage related to the productivity of the breeds and the marketing value reveals clearly the higher role of sheep and goats as source of cash in the irrigated zone compared to rain fed zone where the two species constitute one of the main assets and as savings.

Table 3. Perception of the main adaptive capacities of sheep and goat in each profile

	For sheep (%)					For goats (%)				
Responses to perception of adaptive capacity	P1	P2	P3	P4	Av.	P1	P2	P3	P4	Av.
Adapted to environmental conditions (desert conditions)	10	12	33	28	17	12	12	34	30	19
Adapted to climate conditions (drought, hot and cold T°C)	31	33	21	22	29	33	35	22	22	29
Adapted to walk and grazing	2	0	9	13	4	1	0	6	13	4
Adapted to feed shortage (feed shortage, low feed requirement)	10	6	11	9	9	13	4	13	9	10
Adapted to disease	6	4	3	2	4	6	4	3	2	4
Best breed (productivity)	17	21	7	6	15	18	21	8	7	15
Good/famousmeat	2	3	9	10	5	2	2	8	11	5
High demand, good market value	15	11	1	8	11	9	11	2	3	7
Cultural value	6	10	6	3	6	6	12	5	2	7

3. Links between livestock diversity and resilience indicators

In Fig. 4, the factor maps of co-inertia analysis of livestock diversity and resilience indicators allows to analyze the links between the livestock-induced diversity and the resilience at the household level. The covariance between the 2 sets of data is summarized with 2 factors; the first one representing 75% of the covariance. The Monte Carlo test of the existence of a co-structure showed that it was significant (RV=0.29, p>0.001). On the one hand, variables such as total livestock stock (TLU), the percentage of sheep and goats in the total livestock asset (sheepGoatTLU), as well as indicators of pasture feeding practices (grazing and grazingDist) that concern the CZWD are correlated with the total livestock capital per family member (capitalLive), the potential land transmission per child (land Trans) and the ratio of cash flow compared to the poverty threshold (familyCash) and net income per family member (netIncPov). In the semi-intensive and intensive farming areas, the links between diversity and resilience are described through the production of on-farm forage in winter (forageW) and summer (forageS), the composition of the herd in large ruminants (cattleBuf) and, as a result, percentage of bovine milk consumption (bovMilkCons). These diversity indicators are most closely linked with the wheat consumption per capita (wheatCons), the milk home-consumption (milkCons) and the manure production per feddan (manure).

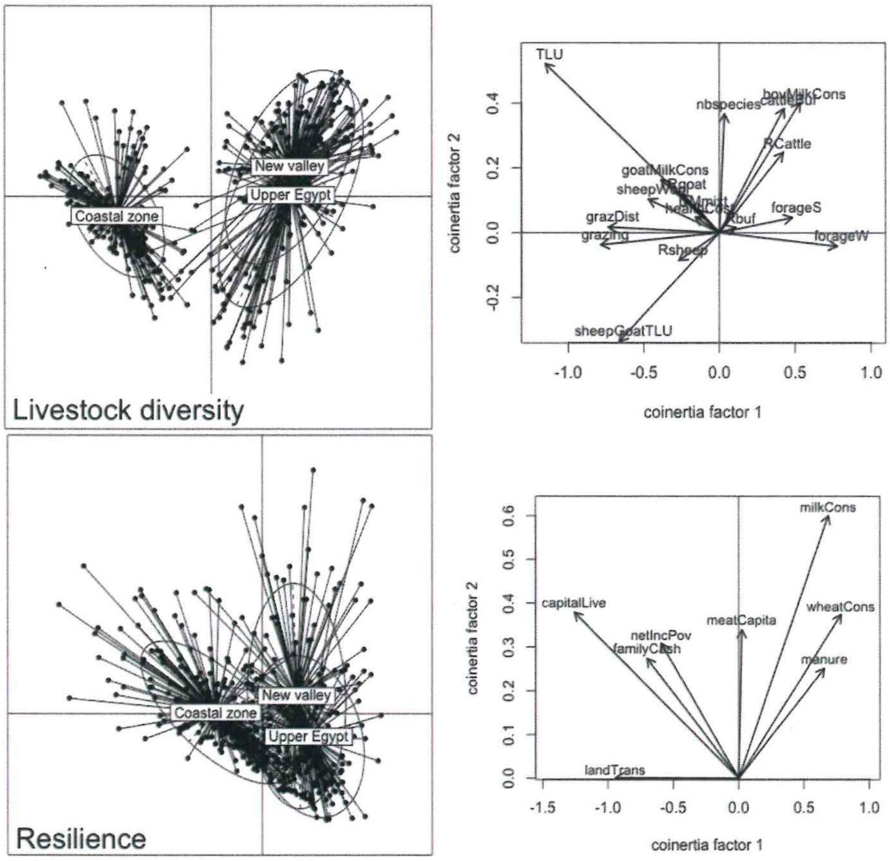

Fig. 4. Factor maps of co-inertia analysis of livestock diversity and resilience indicators. The co-inertia factor 1 (75%) and factor 2 (17%) are reproduced in each graph. Farm scores (left) for each group of variables are represented by agro-ecological zone. The variable scores (right) are represented for each dataset for ease of reading.

IV – Discussion and conclusion

This crossed analysis of livestock diversity in link with land and crop asset, human asset and the overall resilience reveals the significant contribution of livestock diversity to the overall resilience of the family farm systems in the three agro-ecological zones, confirming the crucial contribution of livestock in small-scale family farms, like observed in FAO 2012. Overall, these results confirmed that the livestock diversity is part of the strategy of the farm diversification, especially in land-fragmented and self-sufficiency households farms, as observed in many regions of the Asia and Africa continents. Broadly, approximately 80%of the world's 1.3 billion poor people keep livestock (FAO, 2006, 2009; McDermott *et al.*, 2010; Alary *et al.*, 2011, 2018). In these small-scale farming systems where land property is too small, livestock is often the only opportunity to build up a heritage and an alternative livelihood support. Moreover, animal products accounted for a significant contribution to the daily balanced diet to those who are undernourished or malnourished (FAO 2006).

However, we can deduce different kinds of combinations of strategies behind the livestock diversity in the household resilience according to the farming system and the agro-ecological zone. A first differentiation is related to the agro- ecological zone that differentiate the livestock system between the Nile and New valley zones and the rain fed zone in the NWCZ (see Fig. 4). As soon as irrigation is possible to allow to cultivate forage crops like berseem and darawa, the majority of farmers attempt to keep a mixed multi-species flock with large ruminants (like cattle or buffalos) and small ruminants (sheep and goats). In these irrigated zones, the majority of milk self-consumption is based on the large ruminant flock. We can see however a differentiation regarding meat consumption and meat marketing valorization between the Nile and New valley. In the Nile Valley, small ruminant constitutes a critical source of cash flow to cover annual expenses, in difference to the farms in the New valley where meat from small ruminant animals contribute significantly to the household consumption (Alary *et al.*, 2015). This can also be explained by the sanitary regulation of the live animals' trade between the New valley in the rest of the country. However, this reveals also the specific context of the New Valley in terms of food systems with a higher local valorization of the animal products and co-products in the zone favoring a higher resilience.

In the rain fed zone, we observe positive links between the tree-planted land area and the sheep and goats flock size without significant difference on total cultivated lands in the Wadi or rain fed lands. This means that in the rain fed tree-crop-small ruminant systems that is the dominant system in this zone, there is a sort of trade-off between tree and livestock investments according to the climatic year. Tree plantation allows to invest in the flock after destocking in a drought-period and vice versa the flock secures the income in case of drought that affects directly the olive and fig trees. This strategy is well reflected in the perception where more than 50% of the breeders mentioned the adaptive capacity of the local Barki sheep and goat to their desert and climatic environment, but also in the high link between the percentage of sheep and goats in the total livestock asset with the indicators of resilience in Figure 4. This confirms also the role of net safety of the flock due to the animal adaption to harsh environment (Nardone, 2000; Colditz and Hine, 2016). However, this strategy is completely related to the nature of land access between the wadi and rain fed zone, itself in link with the social position of the family in the traditional society. A limited Wadi area access fragile the overall household resilience (like observed for the profile P3 in our population). This highlights the critical role of the complementarity between crop and livestock activity in the overall resilience of rural household, even in the rain fed zones.

Finally, the perceptions of the various adaptive capacities of sheep and goats confirm the contrasted role of these species in the overall resilience of the family farm system, especially in terms of security in harsh environment (due to desert condition in the NWCZ or hot conditions in the New and Nile Valley, representing in total more than 40% of declarations by farmers), and food and cash diversity in link with small ruminant productivity and marketing value (22 and 26 respectively for goats and sheep). We note that the adaptive capacity of small ruminants to feed short age is mainly mentioned in the irrigated zones and, finally, meaning that this capacity is more crucial when facing economic uncertainty.

In summary, livestock diversification in link with resilience strategy should be examined the interaction between the different combined functions of the livestock species at the farm level. This combination is also dynamic in function of external and internal conditions of the systems. This dynamic role of the livestock diversity can be related with the notion of plasticity and or flexibility of livestock as capital, income generation at different time scale and food self-sufficiency. This calls for rural integrated policies more than agricultural sectorial policies in the 3 agro-ecological zones. Finally, the performance improvement of the animal species in each location should be examined in link with the different dimensions of resistance and the multi-purpose valorization of the animal products and co products.

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