"Livestock for resilience": Revisiting the role of livestock in the major agricultural production systems of the MENA region

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Abstract:

This paper aims to analyze the contribution of livestock to the resilience of major agricultural systems in the MENA region. We considered study areas from Jordan, Tunisia, and Morocco. We started by providing a typology of resilience profiles of production systems in these study areas and then we calculated resilience indexes for the identified farm types in the different countries. Secondly, we analyzed the role of livestock in each of these systems by testing the correlation between a set of "livestock variables" and the resilience indexes. Results show that livestock is playing a crucial role in enhancing agricultural systems resilience in the MENA region. Mixed crops-livestock systems, in addition to the pastoral production systems, identified in the considered countries, were found to have significantly high resilience indexes. Beside being an important source of income in the dry rain fed areas, animal heads are being considered as assets that could be easily converted into cash to face financial shortage and crisis. Our results also show that livestock producers appear to be more socially engaged and more open to their neighborhood, this is mainly due to practicing transhumance and sharing rangeland with other farmers, which enhances their positioning over the resilience scale.

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Abstract.

The objective of this paper is to analyze the contribution of livestock to the resilience of major agricultural production systems in the MENA region. We considered study areas from Jordan, Tunisia, and Morocco. We first started by providing a typology of resilience profiles of agricultural production systems in these study areas and then we calculated resilience indexes for each of the identified farm types in the different countries. Secondly, we analyzed the role of livestock in each of these systems by testing the correlation between a set of “livestock variables” and the resilience indexes. Results show that livestock is playing a crucial role in enhancing agricultural systems resilience in the MENA region. Mixed crops-livestock systems, in addition to the pastoral production systems, identified in the considered countries, were found to have significantly high resilience indexes. In addition of being an important source of income in the dry rain fed areas, animal heads are being considered as assets that could be easily converted into available fund to face financial shortage and crisis. Our results also show that livestock producers appear to be more socially engaged and more open to their neighborhood, this is mainly due to practicing transhumance and sharing rangeland with other farmers, which enhances their positioning over the resilience scale.

Keywords: resilience index, production systems, livestock, correlation tests, Tunisia, Jordan, Morocco.

Introduction

In the Middle East and North Africa (MENA) region, the number of live animal heads[1] have more than doubled over the past 40 years increasing from around 125 million head in the late 1960's to over 300 million in 2009, with an increase in meat production from 2.1 to 6.5 million tons. In most MENA countries, livestock contribution to agricultural GDP is higher than 30%, with even higher values reaching 50% of total agricultural GDP in some countries. The livestock sector in these countries encompasses feed production, animal production and in some cases a manure management chain; with also high implications in terms of rangeland management and sustainability, since grazing is considered an important source of feed in these dry areas. The agro-pastoral livelihood systems of the region encompass around 200 million hectares and are home to more than 50 million people (World Bank, 2002). In the same time, aridity index across this region ranges from 0.05 to 0.20, reflecting a range of arid to hyper arid environments.

By looking at aggregated statistics about the importance of livestock activities, in addition to the type of dominant arid agro-ecologies of the region, it is worth concluding that farmers in the region would largely be agro-pastoralists, producing crops where water is available and grazing livestock on arid rangelands. Furthermore, most related studies are showing that livestock production is a key risk-reduction strategy for vulnerable agro-pastoral communities that predominantly focuses upon small ruminants and dromedaries. This livelihood activity is an important provider of nutrients and draft-power traction for associated crop cultivation production units within smallholder agro-pastoral systems. Some key commodities produced from less-water demanding fruit trees including olives, almonds, figs and cactus make a significant contribution to community livelihoods. However, livestock production offers a range of livelihood options, and provides stocks of wealth for smoothing out income and consumption during periods of environmental and economic shocks, or more contemporarily when faced with civil strife and conflict. Nevertheless, the potential for livestock interventions to impact overall farm productivity and risk management strategies for agro-pastoral systems has not been comprehensively investigated nor understood. This is particularly true in terms of a better appreciation and more detailed understanding of the influence and actual relation of livestock production with production systems resilience in the region.

The overall objective of this paper is to analyse the contribution of livestock to the resilience of major agricultural production systems in the MENA region. In this regard, a first specific objective will be to provide a typology of production systems based on their resilience profiles and to stress the role played by livestock production in each of the identified farm types. A second specific objective will be to calculate the precariousness index, which reflects the resilience levels of each of the identified production systems and to test possible correlation of farmers' resilience levels with a set of livestock-related variables. This will help us shedding light on the specific role played by livestock in a wide range of agricultural production systems of the region, and how livestock can actually further contribute to enhance resilience of agricultural systems in the region. Three case studies from Tunisia, Morocco, and Jordan will be considered for this analysis, with more than 1000 observations from the three countries.

[1] (including cattle, dromedaries, sheep and goat)

The remaining of the paper is divided into different sections. The next section presents the conceptual framework of our analysis; while the third section includes a description of the methodology used. Fourth and fifth sections respectively present the results and the main discussions.

Literature background on systems resilience

Adger (2000) defined resilience in ecological and social systems as being "The ability of communities to withstand external shocks to their social infrastructure". He added, in the same context, the following description for resilience in 2003 "The ability to persist (i.e., to absorb shocks and stresses and still maintain the functioning of society and the integrity of ecological systems) and the ability to adapt to change, unforeseen circumstances, and risks". Thus, Edgar focuses on the dependence of communities on ecosystems in creating their livelihoods and browsing their economic activities. Wilson (2010) thinks that it is useful to define community resilience as an "outcome" as well as a "process". On one side, when linked to improved adaptive capacity, it is considered an "outcome". While, on another side, it is considered "a process" when linked to changes, community knowledge and their willingness to take control of their rural development pathway.

Another definition of resilience refers to the capacity of individuals, social groups or social-ecological systems (SES) to adapt to stress and turbulences, to self-organize and to learn in order to sustain basic structures and functions; or in order to improve them (Berkes and Folke, 1998; Carpenter et al., 2001; Walker et al., 2002; Berkes et al., 2003; Folke, 2006; Adger, 2003, 2006). Therefore, resilience is also linked to human agency and to social structures within system-oriented approaches (Bohle et al., 2009; Obrist et al., 2010) and three major attributes, which are composed of several proxy indicators (Carpenter et al., 2001; Milestad and Darnhofer, 2003; Milestad, 2003), can be identified; buffer capacity, self-organization and capacity for learning (Speranza et al., 2014). According to Speranza, resilience is maintained when buffer capacity exists and is not weakening, self-organization exists and is endorsed and learning occurs (2014).

The inter-connection and strong link between agriculture and ecology explains the interest in the application of resilience concept, it is always a major aim to produce food and maintain ecosystem services'. Darnhofer et al. (2010) examine farming as part of a set of systems across spatial scales, from farm to global, encompassing agro-ecological, economic and political-social domains. Thus, understanding the functioning of the system as a whole permits a better understanding of its behavior, vulnerability and adaptive capacity to shocks. All humanly-used resources are embedded in social-ecological systems (Ostrom, 2009), of which agricultural production systems are principal components and play a major role in contributing to rural livelihoods and maintaining human life. Hence, resilience early insights highlighted the need to focus on coupled social-ecological systems using holistic approaches, to understand the complex functioning of these systems; and that are able to depict the deficiency, or the efficiency, of this functions. In our case, we focus on endorsing livestock role in contributing to social-ecological systems resilience in a specific context of MENA region characterized by climate aridity, lack of resources and geopolitical complexity.

Social-ecological systems' resilience emphasizes the persistence of ecosystems with their allied social institutions (actors) (Anderies et al., 2004), it consists of the system's aptitude to apply necessary changes and reorganizations in order to absorb disturbance and maintain functionality (Jarzebski et al., 2016). Within SES studies, resilience is described by the stability landscape concept entailing ''basins of attraction'' that represent other favourable and stable conditions, as well as alternative less desirable states (Walker et al. 2004; Scheffer et al. 2012). A basin of attraction is defined by Jarzebski et al. (2016) as "an alternative state adjacent to the existing system state and is separated by the basin's edges, representing thresholds of state transformation" (see Figure 1).

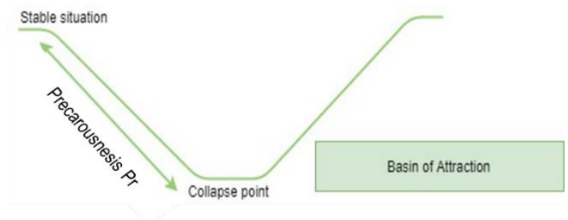

Figure 1: Basin of attraction of SESs (Source Jarzebski et al. 2016)

Within a basin of attraction, resilience is determined by three features: precariousness, latitude and resistance (walker et al., 2004). Precariousness, of a system within a basin of attraction, is the distance from the current state of this system to another state of stability within another basin of attraction. Latitude is the maximum amount of change a system can endure before transformation, it is the width of the basin; and resistance measures how difficult it is to modify the system's state (Jarzebski et al., 2016). Individual and collective human agency emphasizes the community capacities to endure or adapt to continuous change in nature and society (Magis, 2010; Jarzebski et al., 2016). Wilson (2010, 2012) refers to the capitalization approach, including the human domain as a key driver and a major agent to manage community "transition" in a changing environment (Jarzebski et al., 2016). The interactions and desired balance between social, economic and natural capitals are the main determinants for resilience levels; weak, moderate and strong, as highlighted and developed by Wilson (2013) and known as community resilience framework. Jarzebski et al., stated that "consideration of mutual interactions and convertibility of the three forms of capital, economic, natural and socio-cultural, is necessary within social-ecological system analysis" based on Berkes and Folke (1998) and on the demonstration developed by Abel et al. (2006) that introduced the capital framework as an operating dynamic assessment tool representative for social-ecological systems resilience.

Methodological approach

The conceptualization of this work starts from the argument that SES systems are highly diverse and heterogeneous, even within a same context. This diversity is not only related to the complexity and divergence of interactions between subsystems of SES, but also to the different contexts and dynamics within those subsystems (Quinn & Wood, 2017). Individual and communal preferences for environment types are guided by resources availability and institutional context in addition to agricultural practices that are mostly related to market trades, alimentary needs, etc. Social-ecological systems are thus diverse, on the three scales: national, regional and even local. This requires a closer look to each type of SES and a deeper analysis of its dynamics. Hence, this work starts with a clusters analysis of agricultural production systems of MENA using PCA, hierarchical clustering, and a set of system characterization and resilience-related variables. The aim of this first step analysis is to generate a typology of agricultural production systems based on their resilience profiles.

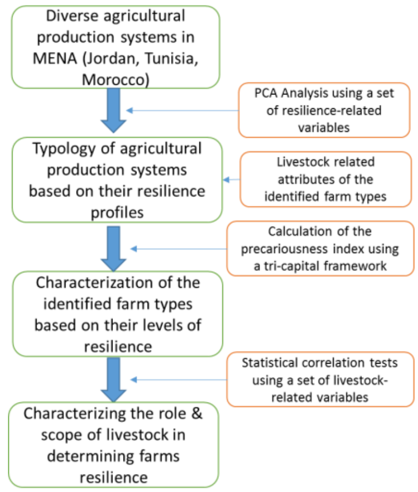

Figure 2. Conceptual framework of the analysis.

Once different farms types are detected in the three considered countries, a first scanning of the livestock related attributes of these types will be presented and briefly discussed. A following step will be to use the precariousness index (based on the tri-capital framework: see next methodological section) to calculate the level of farms resilience, for each individual farm in our samples. These resilience scores will also be summarized and compared across farm types. Finally, correlation test will be conducted to depict any significant relationship between a set of livestock-related variables, and the resilience levels of farmers.

Cluster analysis

The cluster analysis was done using a "Principal Components Analysis" (PCA) followed by a k-Mean clustering. PCA can be viewed as a de-noising method which separates signal and noise (the first dimensions extract the essential of the information while the last ones are restricted to noise). Without the noise in the data, the clustering is more stable than the one obtained from the original distances. Another good reason for the use of PCA is related to the combination of continuous and binary variables which the analyst may need to use for clustering. In the clustering procedure, the PCA is usually followed by a multivariate analysis which can be of different types (K-Means, and Hierarchical methods are the most used). K-Mean method was chosen in this study due to the large number of variables used and to the high size of the sample. Given that we aim to cluster SES based on their resilience profiles, we thus used variables which reflect the main attributes of the production system (human, natural, physical, and financial assets), in addition to variables reflecting their resilience attributes. The latest includes three categories of variables reflecting: i) the buffer capacity; ii) self-organization; and iii) capacity for learning (Speranza et al., 2014) of the considered systems. The set of selected variables in each country can be summarized as shown in table 1.

Table 1 Number of variables used in the typology per category per country*

	Number of variables used in the typology per category and per country		
Categories of variables	***Jordan***	***Tunisia***	***Morocco***
Demographic characteristics (age, education, experience etc.)	3	2	3
Natural assets (land use, land size, resources etc.)	7	5	8
Physical assets (livestock, machinery etc.)	3	2	3
Financial assets (crops income, livestock income, off-farm income etc.)	3	5	4
Buffer capacity (access to credit, etc.)	4	2	4
Self-organization (extension etc.)	2	3	2
Capacity for learning (social participation and openness, etc.)	3	3	3
Total number of variables	25	22	27

Source: own elaboration. *please see appendix 1 for a complete list of variables

The precariousness index: proxy of systems resilience

This section provides an explanation of the approach we used to assess resilience through measuring and quantifying the three forms of capitals; it reveals the list of indicators identified to provide a snap shot of the current economic, social and natural state of the system. Based on previous knowledge of communities' situations and existing literature analysis, a set of indictors was identified and adapted to the contextual needs and data availability. The objective is to assess communities, in general, and specifically household ability to perform a sustainable intensification theme through measuring its resilience to shocks and its transformation capacities. The core basis of indicators choice is the previously cited resilience determinants used in the typology of social-ecological systems resilience profiles. We acknowledge existing frameworks that identify indicators to analysis of dynamic human-environment interactions such as that of Ostrom (2009); and also indicators of community resilience building such as that of Berks and Ross (2013) and Jarzebski et al. (2016). For our study, we adjusted, and created, relevant indicators based on the existing literature to sort out five to ten composite indicators for each of the three forms of capital: Natural, Economic, and Social. ***Natural capital indicators*** shed the light on land availability and land use as land is a main livelihood source and food origin. Land description is highlighted by land's physical state (Ekins et al., 2003); according to soil fertility index in addition to physical size of land and share of cropped area compared to the total available land. Water availability is also incorporated in the description of natural capital. Natural capital indicates localization of rural livelihood and aptitude for operational sustainable intensification. ***Economic capital*** is subdivided into two categories: financial capital (FC) and physical capital (PC). Physical capital incorporates variables that describe livestock production regarding number of heads of cattle and small ruminants beside transportation and machinery while the financial capital has an interest in scoring the contribution of different sources of income to livelihood and access to credit. Economic capital is a proof of household capacity to respond to financial crisis and of the development of the local community. Finally, ***Social capital*** is divided to two categories as well: human capital and cognitive capital. Human capital consists of scoring the educational level, dependency ratio and farming experience within a household. Social participation, interaction and openness in addition to structural organization are sub-indicators of cognitive capital. Social form of capital is the most complicated to measure and least understood (Jarzebski et al., 2016), for this study, we tried to simplify the choice of indicators to reflect the social and organizational state of identified social-ecological systems.

Capital indicators are either qualitative or quantitative, formed by continuous, discrete or binary variables. Scores are based on either three grades scale (1: weak, 2: moderate, 3: strong) or four grades scale (1: weak, 2: moderate, 3: moderately strong, 4: strong). Therefore, continuous and discrete quantitative variables of three forms of capital, NC, EC and SC have been allocated scores from 0 to 3 or 0 to 4 according to the values obtained in the data set. Discretization, scaling and thus scoring are performed by SPSS (Statistical Package for Social Sciences) software. Binary data were combined into a set of two variables whenever they occurred and scored upon the context and significance of the set. For example, in the case of natural capital, water availability(NC5) and soil physical state (NC4) are both binary variables, if soil state is judged good (by referring to soil fertility index) then it is 1 and water is also judged available (by referring to water quantity index) then it is another 1, the couple (NC4 1; NC5 1) receives 4 as an upper limit score, now if the water is available but the soil is not fertile, the couple (NC4 0; NC5 1) receives a score of 3 because water is considered more important than soil fertility in these contexts; in the opposite case (NC4 1; NC5 0) it receives a score of 2 and finally, in case both are not performant, the couple (NC4 0;NC5 0) receives a 1 score. Another example of binary variables within the economic capital set of variables, if the household has reliable allowance that guarantee his access to credits (FC3.1) and he has not experienced any shortage in funds (FC3.2) then the couple (FC3.1 1; FC3.2 1) receives 4 as an upper limit score which highlights, not only the positive access to credits, but also the household capacity to manage his allowance and assets. However, the couple (FC3.1 1; FC3.2 0) reveals that in despite of the existence of reliable resources for borrowing, the household is not able to have access to credits or is not able to manage the credits in case they occur and thus FC3 should receive 1 as lower limit score. A household who does not have access to credits and haven't experienced funds shortage (FC3.1 0; FC3.2 0) receives 3 and a farmer who does not have access to credits and have experienced funds shortage (FC3.1 0; FC3.2 1) gets a 2 score. The scores of each forms of variables were computed as demonstrated in appendix 2. This operation would be applied to every SES group of farmers issued from the clustering analysis in each country. The score of each form of capital, for each group is presented by the median value; median value is considered more representative of the central tendency of a set of values and it resists to outliers (Bryman et al., 2001).

NC, EC and SC median values were then utilized to calculate the Pr value as a main resilience determinant in our study. The three forms of capital determine the location of different SESs in the tri-capital space of resilience and Pr determines the distance that separates the SES from collapse point (Jarzebski et al., 2016). The community Pr was computed using a distance equation that was derived from analytical spatial geometry (Leung and Suen, 1994), Eq (1):

$$Pr = \sqrt{NC^2 + EC^2 + SC^2} \quad \text{Eq (1)}$$

Median values of capitals were used to calculate Pr values on household and SES level; regarding the generated median values, a one and common Pr scale was developed for the three countries of our study and which will be discussed in next section of results.

Case studies

In Tunisia, our study area was located at Sidi Bouzid governorate. Sidi Bouzid is located in Central Tunisia. It covers an area of 7405 km2 and it has an arid climate with an annual rainfall between 200 and 300 mm. Its population counts over 400 thousand inhabitants, 77% of this population is rural and their income is generated by agricultural activities. Official rate of poverty in the governorate is about 40%. Data was collected from Jelma district, in the northwest of Sidi Bouzid. Jelma is known by the lack of water resources and the dominance of livestock production as well as the existence of collectively shared resources (grazing land, water...) which requires collective management. The sample is composed of 250 households who were randomly selected according to representativeness criteria, 105 households are from Selta sub-district and they represent 17 communities while 145 households are from Zoghmar sub-district and they represent 34 communities. The average land size in Selta is 10.2 ha and it is of 6 ha in Zoghmar. Jelma district counts only 17 deep wells which translates the vulnerable hydric resources in the area.

In Morocco, the Meknes-Saiss area, which was considered in this study, covers an area of about 1694 km² in the north of Morocco, with a 20% of rural population. The area has a semi-arid to sub-humid climate. Average annual precipitation is relatively high, ranging from 500 to 800 mm. The rainfed mixed system is the dominant system in the region. Crops in this system are primarily rainfed. Common crops are wheat, chickpeas, lentils, faba bean and fodder crops. There are tree crops (olives and fruit trees) and grapes. Three representative locations of the main agricultural region where selected: Ain Jemaa, Sidi Slimane, and Bitit locations. A multi-stage random sample technique was used. Villages were selected randomly using topographic maps. A subgroup of 28 villages were considered, which represents 49% of total villages in the three locations. Distribution of the selected villages was as follow: 14 villages in Ain Jemaa from a total of 29; 10 villages for Sidi Slimane from a total of 20, and 4 villages from Bitit from a total of 8 villages. The total sample size is of 508 households.

In Jordan, our study area was located at the Karak Governorate, 120 km south-west of Amman. Karak Governorate is subdivided into 7 administrative units located in different agro-ecological zones, ranging from the rift valley in the west, highlands in the central region, and a semi-desert in the eastern and south eastern regions. The climate is characterized by hot dry season starting from April to October and a rainy wet season that starts from November and lasts until March. Average temperature varies between 4 during winter and 32°C during summer. Rain ranges between 200 and 350mm. The Jordan sample included 468 households who were randomly selected.

Results

Farming systems and their main characteristics

The clustering analysis identified 4 main groups in Tunisia, 4 in Jordan, and 3 in Morocco. The description and the frequency distribution of these farms is provided in Table 2. The main segregating variables for the identification of these groups were related to the existence of irrigation vs rainfed agricultural areas, importance of the livestock activity in the overall farm income, the importance of the farm income in the overall household income, the existence of trees cultivation (mainly olives).

Table 2. Clusters of farming systems and their distribution in the considered countries.

Cluster's abbreviation & description	Number of observations	Percentage of total sample
Tunisia		
T-SES1: Medium size rain fed cropping system with livestock integration: These are medium size farms with an average agricultural area of 13 ha. Most of this area is cultivated with rain fed crops. These farmers also integrate cattle and sheep production to a minimum extent. The average number of small ruminant heads is about 15 but it contributes with more than 60% to the total farm income. In the Tunisian study area, this farm type is dominating with a frequency of 66%.	166	66.4%
T-SES2: Small-sized tree-specialized cropping system: The average land size of this farm type is less than 10 ha. They are cultivating tree crops (mainly olives and almond) with a total average area, allocated to tree crops, of about 55%. Total number of small ruminant heads is about 13, in average, with less than half of the farm income (45%) is generated from this small size flock.	31	12.4%
T-SES3: Large rainfed farms with high livestock integration: The average land size is 20 ha; livestock production, which is based on small ruminants, contributes to almost 67% of total farm income, generated from an average flock size of 25 heads. Total farm income is high which gives the farmers of this group relevant economic status compared to the rest of the groups.	41	16.4%
T-SES4: Pastoral agricultural system (based on livestock grazing): This group largely relies on livestock production as it contributes with up to 65% to the total farm income. It involves farmers who have more than 25 heads of sheep and most of their land is a fallow.	12	4.8%
Total (number of observations) Tunisia	*250*	*100.0%*
Jordan		
J-SES1 Mixed (crop-livestock) rain fed agricultural system: Consists of 98 farmers. The average total land size is of 28 ha of which 88% are under rain fed crops. In average, livestock contributes with around 20% to the total farm income, with a herd size of small ruminants' of about 31 heads, in average. Whereas, farm income contributes to less than 50% of total household income.	198	35.4%
J-SES2 Rainfed agricultural system with low livestock integration. Main income source is based on off-farm activities. In fact, farm income contributes to only 15% of the total household income. Water resources are very rare and soils are not fertile according to soil fertility index. The average size of land on group level is less than 10 ha and the average ownership share of cultivated area is 43%. The rainfed area share on total land is 64% while 8% of the land is used as follow land.	145	25.9%
J-SES3 Irrigated agricultural system, with very low livestock integration. It includes 29 farms of the study area with an average land size of about 21 ha, of which 42%, in average, is irrigated. The average number of small ruminants is 18 heads and they only contribute with less than 3% to the total farm income. This is showing that livestock is a very marginal activity for this type. Water resources are abundant compared to the other three groups.	29	5.2%
J-SES4 Tree-based agricultural system, with low integration of livestock: Average land size is about than 26 ha, of which the largest share is allocated to tree-production, mainly olives. Minimum integration of livestock is highlighted with a contribution to farm income that is less than 8%, generated from an average flock size of about 10 small ruminant heads.	187	33.5%
Total (number of observations) Jordan	*559*	*100.0%*
Morocco		
M-SES1: Mixed (crop-livestock) rain fed farming systems. This is the largest identified group in the Moroccan study area, with 281 farms. It is characterized by rain fed cropping practices with low integration of livestock, exclusively cattle, and an average number of about 4 cows by farm, the farmers do not have any small	281	55.2%

ruminant heads which limits livestock (only cattle) contribution to the total farm income to 25%. Average share of owned land is less than 50% and the average household age is about 55 years old.		
M-SES2: Pastoral agricultural system. These are farmers whose vocation is founded on livestock production. It consists of 15 households; on average, at least 4 members of the household have an educational level above elementary. Livestock is a major source of income; it contributes to almost 60% of farm income; principally small ruminants whose average number of heads is 19 per farm while cattle average number of heads per farm is only 4.	15	2.9%
M-SES3: Small mixed (crop-livestock) irrigated agricultural system. Farmers, whose main agricultural activities are based on irrigated crops with an integration of livestock production, both cattle and small ruminants. It is also characterized by small farmers with less than 5 ha of land on average, 64% of this group households have less than 2 ha of land. Livestock contributes with only around 15% of the farm income. Households depend on auto-consumption of their own garden products.	213	41.8%
Total (number of observations) Morocco	*509*	*100.0%*

Source: own elaboration. (T: Tunisia, J: Jordan; M: Morocco)

Results of farms identification (as presented in Table 2) are showing some structural differences among the studied areas in the three countries. In Morocco, the study area is receiving an average of 500 mm of rain annually, with farmers having access to groundwater resources. Thus, livestock production is mostly based on cattle and milk production, considered as a complementary source of income to the main crop production activity. For that reason, the pastoral group in this study area is the smallest (only 3%) in the considered sample.

In Jordan and Tunisia, livestock activities are rather focusing on small ruminant, especially sheep, production. This activity can either be extensive and based on grazing (pastoral), or integrated with tree based crops. These two main patterns were depicted in both countries. Irrigated systems in Jordan and Tunisia do not significantly incorporate livestock as these are highly specialized in vegetable production under green houses, which is a highly lucrative activity thus leaving the contribution of livestock marginal.

Livestock contribution to systems resilience in the three countries:

Table 3 illustrates the levels of different resilience indexes (including The Natural, Economic, and Social capitals, and the precariousness indexes) together with the percentage of livestock contribution to the overall farm income and other livestock-related characteristics in the different farming systems of the three countries. The number of cattle and small ruminant heads also shows a structural differences among the three countries. In Tunisia, a small ruminant number of around 16 head is contributing with an average of 65% to the total farm income; while in Jordan, a similar number (of 14 heads) is contributing with around 10% only to the total farm income. In Tunisia and Morocco, farmers diversify their livestock flocks with presence of both cattle and small ruminant in all of the identified farming systems. in the same line, farmers who do have the best balance between both types of livestock activities in these countries are also the most resilient (farm type 4 in Tunisia and farm type 3 in Morocco). It is also important to note that farming in Jordan can be considered as a secondary activity with a very high level of off farm income at the household level, which can also be reflected by the high economic and social capital levels in this country, where at least a household member has an off-farm job, in public or private sector.

Table 3. Livestock-related characteristics (averages) of the identified farm types in the three selected countries

Country	Farm Types	Percentage of income generated from livestock	Annual Livestock income (in LC)	Number of cattle heads	Number of small ruminants	Total Land	Natural capital	Econom ic Capital	Social capital	Precario usness
Tunisia	1	68.36	4810.60	.53	14.63	13.14	2.29	2.05	1.83	3.60
	2	45.84	2900.32	.29	13.35	10.16	2.39	1.93	2.04	3.71
	3	65.73	10053.17	.32	24.39	19.81	2.23	2.15	1.96	3.69
	4	65.92	7248.33	.83	25.25	14.67	2.21	2.20	2.64	4.12
	Total	65.02	5550.52	.48	16.58	13.94	2.29	2.06	1.92	3.66
Jordan	1	19.49	1013.88	0.00	31.52	32.46	2.11	2.34	2.12	3.84
	2	8.25	195.13	0.00	7.77	17.59	2.13	2.31	2.15	3.84
	3	2.86	68.97	0.00	17.97	21.69	2.08	2.27	2.06	3.75
	4	8.68	356.68	0.00	10.60	26.48	2.10	2.38	2.13	3.86
	Total	10.44	423.31	0.00	14.50	24.51	2.11	2.34	2.13	3.84
Morocco	1	23.61	18129.97	3.04	.51	10.40	2.17	1.61	1.84	3.31
	2	23.36	17032.79	3.18	.47	8.20	2.27	1.59	1.84	3.37
	3	15.30	10334.44	2.78	2.63	6.30	2.33	1.61	1.89	3.43
	Total	23.09	17398.15	3.07	.61	9.51	2.21	1.61	1.84	3.33

LC: Local Currency.

We also proceeded with an ANOVA test in order to capture the significance of differences among the identified groups in each country (see table 4). The ANOVA test showed that most of livestock-related variables in addition to the resilience indexes were significantly different among the Tunisian farm types. While in Jordan, despite the significant differences of most livestock-related variables, resilience indexes were not significantly different among the identified farm types. In Morocco, only the Natural capital (most probably related to the access to groundwater and soil quality) was significantly different among the identified farm types.

Table 4. ANOVA Test for difference of mean between farm types, in each of the considered countries

	Tunisia		***Jordan***		***Morocco***	
	F	***Sig.***	***F***	***Sig.***	***F***	***Sig.***
Percentage of income generated from livestock	5.198	0.002	6.146	0.000	0.937	0.393
Annual Livestock income	4.898	0.003	7.073	0.000	0.480	0.619
Number of cattle heads	0.888	0.448			0.139	0.870
Number of small ruminants	5.062	0.002	4.217	0.006	2.888	0.057
Total area	0.412	0.744	1.189	0.313	1.217	0.297
Share of land left as fallow	19.845	0.000	0.591	0.621	0.723	0.486
Natural Capital	1.870	0.135	0.130	0.942	3.480	0.032
Economic Capital	2.929	0.034	1.681	0.170	0.081	0.922
Social Capital	21.205	0.000	0.639	0.590	0.216	0.805
Precariousness	7.942	0.000	0.565	0.638	1.482	0.228

Statistical analysis is further complemented by bivariate correlations of the livestock-related variables and the calculated resilience indexes. The correlation matrix shows some relevant issues which can be summarized as follows:

The percentage of livestock contribution to the overall farm income is positively correlated with the level of social capital in Morocco, and negatively correlated with the same type of capital in Tunisia. This is showing that livestock activity involves more social participation and openness of farmers within and outside their communities in Morocco, while in Tunisia, higher contribution of livestock will be translated by a lower social involvement. This can be again related to the structural differences of the livestock activities in both countries, where milk production is involving higher participation and involvement in farmers associations compared to the livestock production. Given the fact that social capital is a main determinant of precariousness, and thus resilience, it should be worthy thinking about enhancing the social capital of sheep producers in Tunisia in order to improve their overall resilience levels.

Annual livestock income is highly and positively correlated with the economic capital (EC) and with the precariousness index, in both Morocco and Tunisia. This is again showing the importance of this source of income not only in enhancing the economic situation of farmers but to also enhance their resilience levels. Within this perspective, the number of cattle heads is positively and significantly correlated with NC, EC, and Pr in both Tunisia and Morocco. This means that cattle can only exist under acceptable natural condition mainly related to the existence of irrigation for forage production. With contrast to cattle, the number of small ruminant heads is however only correlated to the EC and to the Pr. This means that small ruminant activity does exist under marginal natural conditions, but it still significantly contributes to the overall farms resilience even under these conditions. This is mainly due to the accessibility of small ruminants to alternative sources of feed; provided by transhumance for example; likewise, goats are able to move to further distances and climb mountains to find grazing fields; thus, unlike cattle production, small ruminants activities, generally, do not rely a lot on water availability.

Other relevant results in terms of correlations between different resilience indexes show that the natural and the social capitals are significantly and positively correlated in both Jordan and Morocco. This is intuitively showing that when natural capital increases, social capital will also be high, which can be explained by the need for social interactions to collectively manage natural resources, including soil and water. This correlation didn’t appear in Tunisia. On the other side, social and economic capitals where positively and significantly correlated in both Tunisia and Morocco. In these both countries, most of the household income is generated from the agricultural activity which can explain why Jordan do not appear to have the same type of correlation. This relation between EC and SC can be interpreted in both senses, dependently on the context specificities.

Lastly, it has been revealed that the Natural Capital had the strongest correlation to the Pr level of resilience in Morocco, showing that farms resilience in Morocco is mostly determined by natural assets who mainly consist of the existence and management of water resources. While in Tunisia, the social capital had the strongest correlation with the Pr showing the importance of social openness and farmers organizations in enhancing the overall resilience of agricultural systems in the region and which highlights the need to an institutional re-structure of natural resources management patterns, mainly those directly related to livestock activity as being a main source of livelihood and a relevant asset, particularly in time of crisis.

Table 5. Bivariate Correlations of livestock variables and resilience indexes in the three considered countries

		Jordan				Morocco				Tunisia			
		NC	EC	SC	PR	NC	EC	SC	PR	NC	EC	SC	PR
Percentage of Income generated from livestock	Pearson Correlation	-.044	-.021	.003	-.029	-.021	.078	.099*	.056	-.232**	.388**	-.152*	-.015
	Sig. (2-tailed)	.347	.657	.946	.536	.631	.080	.026	.209	.000	.000	.016	.812
Annual Livestock income	Pearson Correlation	-.004	-.043	.033	-.006	.214**	.400**	.044	.313**	.080	.350**	.000	.230**
	Sig. (2-tailed)	.935	.351	.483	.899	.000	.000	.322	.000	.208	.000	.999	.000
Number of cattle heads	Pearson Correlation	.[b]	.[b]	.[b]	.[b]	.240**	.511**	.004	.366**	.128*	.309**	.034	.253**
	Sig. (2-tailed)					.000	.000	.935	.000	.044	.000	.593	.000
Number of small ruminants	Pearson Correlation	-.026	-.047	-.042	-.050	.047	.173**	.003	.101*	.115	.530**	.173**	.432**
	Sig. (2-tailed)	.568	.311	.369	.284	.293	.000	.948	.023	.069	.000	.006	.000
Total Land	Pearson Correlation	-.072	-.033	.014	-.043	-.122**	-.024	-.002	-.075	.226**	.115	-.015	.178**
	Sig. (2-tailed)	.121	.477	.763	.354	.006	.591	.968	.091	.000	.069	.813	.005
Share of Fallow	Pearson Correlation	.009	-.038	.012	-.011	.004	.007	.046	.027	-.035	-.036	.068	-.003
	Sig. (2-tailed)	.840	.409	.802	.811	.919	.878	.305	.549	.583	.567	.287	.965
Natural capital	Pearson Correlation	1	-.006	.162**	.714**	1	.324**	.101*	.778**	1	.053	.073	.575**
	Sig. (2-tailed)		.900	.000	.000		.000	.023	.000		.401	.247	.000
Economic Capital	Pearson Correlation	-.006	1	.083	.540**	.324**	1	.164**	.679**	.053	1	.128*	.623**
	Sig. (2-tailed)	.900		.073	.000	.000		.000	.000	.401		.043	.000
Social capital	Pearson Correlation	.162**	.083	1	.586**	.101*	.164**	1	.566**	.073	.128*	1	.665**
	Sig. (2-tailed)	.000	.073		.000	.023	.000		.000	.247	.043		.000

Source: Own elaboration. **. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The objective of this study was to analyze the actual contribution of livestock to the major agricultural production system resilience in selected MENA countries. We started by clustering farm types in each country based on their resilience profiles. We then calculated different resilience indexes for each of these clusters and established correlations with livestock-related variables. Our results were showing some structural differences among the agricultural systems in MENA. In the three countries, irrigated systems are lowly integrating livestock, mixed crops livestock rain fed system is dominant, while pastoral systems mostly based on livestock do also exist, especially in Tunisia and Jordan. The fact these systems appeared in our clustering analysis means that they are significantly different in terms of resilience profiles; since our clustering was based on resilience-based variables, among others.

Results were also showing livestock related variables; such as the percentage of livestock contribution to farm income, annual livestock income, and number of heads, do have significant correlations with the level of resilience of farmers in most of the cases. Farm types with balanced livestock flocks involving both cattle and small ruminants were found to be the most resilient. By looking at the correlation strength, we found out that natural capital is the most correlated to resilience in Morocco, while the social capital is the most related to resilience in Tunisia.

Resilience quantification and analysis, thus, is another tool to facilitate tasks of policy makers who face sustainability challenge on an ongoing basis particularly with the rural-transformation paradigm the world is undergoing and that is mostly affecting low and middle-income countries, such as MENA countries. If livestock activity is proved significantly and positively-correlated with resilience level of households as well as SESs than this type of analysis can be used to help targeting and prioritizing interventions that aim to improve the resilience of agricultural systems in a given country or region.

References

Abel N, Cumming DHM, Anderies JM (2006) Collapse and reorganization in social-ecological systems: questions, some ideas, and policy implications. 11(1): 17 http://www.ecologyand society.org/vol11/iss1/art17/

Adger, W.N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography* **24**, pp. 347–364.

Adger, W.N., (2003). Social capital, collective action and adaptation to climate change. *Economic Geography*. 79 (4), 387–404.

Adger, W.N. (2006). Vulnerability. *Global Environmental Chang*e 16 (3), 268–281.

Anderies, J., Janssen, M., & Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and society*, 9(1).

Berkes, F., & Folke, C. (1998). Linking social and ecological systems for resilience and sustainability. Linking social and ecological systems: management practices and social mechanisms for building resilience, *1*, 13-20.

Berkes, F., Colding, J., Folke, C. (Eds.) (2003). Navigating Social–Ecological Systems. Building Resilience for Complexity and Change. *Cambridge University Press*, Cambridge.

Berkes F, Ross H (2013) Community resilience: toward an integrated approach. *Society Natural Resources* 26:5–20. doi:10.1080/08941920.2012.736605

Bryman A, Duncan C (2001) Quantitative data analysis with spss release 10 for windows: a guide for

social scientists. Routledge, East Sussex
Bohle, H. G., Etzold, B., & Keck, M. (2009). Resilience as agency. *IHDP Update*, *2*(2009), 8-13.
Carpenter, S., Walker, B., Marty Anderies, J., Abel, N., (2001). From metaphor to measurement: resilience of what to what? *Ecosystems* 4 (8), 765–781.
Darnhofer, I., Fairweather, J. and Moller, H. (2010). Assessing a farm's sustainability: insights from resilience thinking. *International Journal of Agricultural Sustainability* **8**, pp. 186–198.
Ekins P, Folke C, De Groot R. (2003) Identifying critical natural capital. *Ecological Economics* 44:159–163. doi:10.1016/S0921-8009(02)00271-9
Folke, C., 2006. Resilience: the emergence of a perspective for social–ecological systems analyses. *Global Environmental Chang*e 16 (3), 253–267.
Ifejika Speranza, C., Wiesmann, U., & Rist, S. (2014). An indicator framework for assessing livelihood resilience in the context of social-ecological dynamics. *Global Environmental Change*, *28*(1), 109–119. https://doi.org/10.1016/j.gloenvcha.2014.06.005
Jarzebski, M. P., Tumilba, V., & Yamamoto, H. (2016). Application of a tri-capital community resilience framework for assessing the social–ecological system sustainability of community-based forest management in the Philippines. *Sustainability Science*, *11*(2), 307-320.
Leung KT, Suen SN (1994) Vectors, matrices and geometry. Hong Kong University Press, Hong Kong
Magis, K. (2010). Community resilience: An indicator of social sustainability. *Society and Natural Resources*, *23*(5), 401-416.
Milestad, R. (2003). Building farm resilience: challenges and prospects for organic farming. (Dissertation)Swedish University of Agricultural Sciences Uppsala. http://pub.epsilon.slu.se/170/1/91-576-6410-2.fulltext.pdf
Milestad, R., Darnhofer, I., (2003). Building farm resilience: the prospects and challenges of organic farming. *Journal Sustainable Agriculture*. 22 (3), 81–97.
Obrist, B., Pfeiffer, C., Henley, R., (2010). Multi-layered social resilience: a new approach in mitigation research. *Program Develpment Stud*ies 10 (4), 283–293.
Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science* 325:419-422. http://dx.doi.org/10.1126/science.1172133
Quinn, J. E., & Wood, J. M. (2017). Application of a coupled human natural system framework to organize and frame challenges and opportunities for biodiversity conservation on private lands. *Ecology and Society*, *22*(1). https://doi.org/10.5751/ES-09132-220139
Scheffer, M., Carpenter, S. R., Lenton, T. M., Bascompte, J., Brock, W., Dakos, V., ... & Pascual, M. (2012). Anticipating critical transitions. *science*, *338*(6105), 344-348.
Walker, B., Holling, C. S., Carpenter, S., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and society*, *9*(2).
Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G.D., Pritchard, R. (2002). Resilience management in social– ecological systems: working hypothesis for a participatory approach. *Conservation Ecology* 6 (1), 14. (Online).
Wilson, G. (2010). Multifunctional 'quality' and rural community resilience. *Transactions of the Institute of British Geographers* **35**, pp.364–381.
Wilson GA (2012) Community resilience and environmental transitions. Routledge, New York
Wilson, G. A. (2013). Community resilience, policy corridors and the policy challenge. *Land Use Policy*, *31*, 298-310.
World Bank, 2002. Reaching the rural poor. A rural development strategy for the Middle East and North Africa Region. Rural development Strategy. Regional development Strategy. July 2002, pp 48.

Appendix 1

List of variables used in the typology: for each country a number of selected variables of the list below has been used.

Category	Variable description	variable's name
Demographic characteristics	Age of HH* head	DC1
	farming experience	DC2
	Family total size	DC3
	% of family members with educational level above elementary	DC4
	Membership in a community organization (Yes, 1; if not then 0)	DC5
Natural Assets	total land (ha)	NA1
	share of rainfed area (%)	NA2
	Share of irrigated area (%)	NA3
	share of trees planted area (ha)	NA4
	share of fallow are (%)	NA5
	commonly owned source of irrigation (if yes then 1, if not 0)	NA6
	Privately owned water source (if yes 1, if not then 0)	NA7
	Water quantity index (if bad then 0, if medium or good then 1)	NA8
	Soil fertility index (if bad then 0, if medium or good then 1)	NA9
Physical Assets	Cattle –number of heads	PA 1
	Small ruminants -number of heads	PA 2
	Machinery value	PA 3
	transportation means value	PA 4
Financial Assets	Contribution of farm income to total income	FA1
	Contribution of livestock to farm income	FA2
	Income from rainfed crops	FA3
	Income from irrigated crops	FA4
	Total income DT	FA5
Buffer Capacity	Dependency ratio	BF1
	share of owned land in total exploited land (%)	BF2
	Existence of reliable source for borrowing (if yes 1, if not then 0)	BF3
	Use of garden products (1 if auto-consumed, 0 if other)	BF4
Self-Organization	Total visits of HH to extension offices	SO1
	Total visits of extension offices to HH	SO2
	Total information sessions attended by HH	SO3
Capacity for learning	number of hosted demonstrations on the farm for the HH within the last 12 months	CL1
	Interaction of HH with research institutions within the last 12 months	CL2
	Interaction of HH within his social context within the last 12 months	CL3
	Number of workshops attended by HH within the last 12 months	CL4

Source: Own elaboration *HH: household

Appendix 2

Natural Capital Indicators

NC= (NC1+NC2+NC3+(NC4*NC5))/4
NC1 : physical size of land per person per household
NC2 : land ownership : share of owned area from total cultivated area
NC3 : Land use : share of season cropped area compared to the total available land
NC4 : physical state of soil: soil fertility index (if good or medium then 1, if not then 0)
NC5 : water availability : water quantity index (if good or medium then 1, if not then 0)

Economic Capital Indicators

EC= (FC+PC)/2		
FC =(FC1+FC2+FC3)/3	FC1: income sources diversity FC1=(FC1.1+FC1.2+FC1.3)/3	FC1.1: Livestock share in in total income (%)
		FC1.2: Contribution of farm income to total household income (%)
		FC1.3: contribution of off-farm oncome to total household income
	FC2: Income level	FC2: Income level against poverty threshold (total household income/ country poverty threshold)
	FC3: access to credits FC3= (FC3.1*FC3.2)	FC3.1: existence of reliable allowance for borrowing (if yes then 1, if not 0)
		FC3.2: occurrence of critical shortage because of lack of funds for farming activities (if yes then 1, if not 0)
PC =(PC1+PC2+PC3)/3	PC1: Machinery	PC1: machinery value in local country currency
	PC2: Transportation	PC2: cars and trucks value in local country currency
	PC3: Livestock	PC3: Livestock: number of heads (total cattle and small ruminants)

Social Capital Indicators

	SC= (HC+CC)/2	
HC: Human capital HC= (HC1+HC2+HC3)/3	HC1: Dependency ratio	HC1: share of household members who are less than 14 and more than 65 compared to the share of those between 15 and 64
	HC2: Education level	HC2: share of household members who have attended education institutions above elementary (%)
	HC3: Farming experience	HC3: number of years spent on farming
CC: Cognitive capital CC= (CC1+CC2+CC3)/3	CC1: Participation CC1= (CC1*CC2)	CC1.1: a household member is a member in a local organization (if yes then 1, if not 0)
		CC1.2: Had the household participated in a workshop during the last 12 months (if yes then 1, if not 0)
	CC2: interaction and openness CC2= (CC2.1+CC2.2)/2	CC2.1: number of times household members interacted with private or public research institutions during the last 12 months
		CC2.2: number of times household members interacted with neighbor farmers, cooperatives, farmers organizations and media during the last 12 months
	CC3: organizational structure CC3= (CC3.1*CC3.2)	CC3.1: reliance on government support (if yes then 1, if not 0)
		CC3.2: Household members in community leadership role (if yes then 1, if not 0)
	CC4: Field training	CC4: number of times household had participated in field training days during the last 12 months.