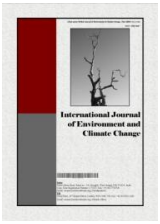

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Effect of Livelihood Interactions on Farmers' Adaptive Capacity to Climate Change: Insight from Medenine Governorate, Southeast Tunisia

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Authors' contributions

This work was carried out in collaboration between both authors. Authors FA and MS conceptualized the study, performed the statistical analysis, wrote the methodology, wrote and edited the final version of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The Sustainable Livelihood Approach (SLA) assumes that all capitals are complementary and that more capital assets would lead to greater adaptive capacity. However, the SLA neglects the interactions and transformations between different livelihood capitals. This paper suggests a methodological approach to understand how different capitals may be structured, transformed, and used to improve the farm households' adaptive capacity to climatic stresses. Data for this study were gathered by means of a questionnaire survey during 2018 from 100 farm households representing the main farming systems of Medenine governorate, Southeast of Tunisia. The analyses were carried out using three tools following a stepwise approach. First, to understand the interactions that exist between the different capitals, a Principal Component Analysis (PCA) was carried out. Then, the adaptive capacity was calculated using the PCA results. Finally, using the Pearson's correlation index, the impact of livelihood assets on adaptive capacity was tested. The results demonstrated that households are trying to compensate for the lack of certain assets through interactions with others in order to improve their adaptive capacity. Moreover, human,

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natural and financial capital seem to better influence the adaptive capacity of farmers, while the impacts of physical and social capital are relatively less important. These results have improved our comprehension of the livelihood capital purpose for strengthening the existing approaches that enhance the adaptive capacity. Finally, this study has demonstrated that exploring the interactions between livelihood capitals is a first concern, which should be incorporated into adaptive capacity planning and policy development.

Keywords: Adaptive capacity; capital assets; climatic stresses; farm households; interactions; sustainable livelihoods approach.

1. INTRODUCTION

The adaptation, a component of climate change vulnerability, reflects the capacity of a system to make adjustments in response to different risks [1,2]. Several studies have reported that households that depend on agriculture for their livelihoods generally have a limited adaptive capacity [3]. Moreover, livelihood activities and opportunities for farm households are governed by resource availability and the socio-economic processes that affect livelihoods sustainability. According to the Sustainable Livelihood Approach (SLA), livelihood resources are grouped into five categories of capital: human, physical, financial, social and natural capital [4,5,6]. These asset categories are widely used as the basis for indicators to measure the adaptive capacity [6,7]. This is based on the assumption that the extent of access to capitals influences the household's ability to adapt to different risks [8]. The SLA assumes that all capitals are complementary and that a greater amount of capital leads to greater adaptability, neglecting the interactions and transformations between the five types of assets. However, previous studies have pointed out a set of interactions between livelihood capitals [9]. For instance, human capital affects the ownership of other capital, financial capital turns into other capitals and social capital promotes human capital development [10]. Such interactions raise doubts on the hypothesis that only increased capital enhances the adaptive capacity.

Therefore, to accurately assess the adaptive capacity, we assume that it is governed by the overlapping interactions among livelihood capitals. This paper proposes a methodological approach that aims to answer three key questions related to the adaptive capacity of farm households: i) To what extent are livelihoods interacting? ii) What is the kind of these interactions? And iii) How do interactive asset associations help to improve the households' adaptive capacity? Thus, this study contributes to filling a research gap that limits our understanding of how resources can be better invested in improving the adaptive capacity of farm households to climate change.

2. METHODOLOGY

2.1 Study Area and Data Collection

This research was carried out among farm households in Medenine governorate, located in South East Tunisia (Fig. 1). Medenine is generally renowned for its agricultural activities and is one of the most vulnerable governorates to climate change effects due to seasonal rainfall and recurrent droughts [11]. Indeed, projections by the Intergovernmental Panel on Climate Change (IPCC) have shown that the forecast increase in temperatures by 2050 in Medenine is between 2.1°C and 2.6°C. For precipitation, an average decrease of 30% is expected over the same period [12]. Data were collected by means of a questionnaire survey during the period of March-May 2018 from 100 farm households that represent the main farming systems of Medenine governorate. The questionnaire has collected the necessary data to analyse the five capital assets affecting farm households' livelihoods (Table 1).

2.2 Capital Assets Quantification

Based on a literature review on the Sustainable Livelihoods Approach [4,5], this study has formulated a system of 21 indicators on household livelihood assets (Table 1). These indicators were calculated from the database generated by our field survey. Due to the heterogeneity of units obtained from the raw data, it was essential to normalize each indicator using equation 1 [13]:

$$\text{Index } I_m = (I_m - I_{min}) / (I_{max} - I_{min}) \quad (1)$$

Where Index I_m is the normalized value of the raw indicator of household m, I_{min} and I_{max} are respectively the minimum and maximum value of the variable among all households.

2.3 Data Analysis

The analysis was performed using three steps. In a first step, to understand the overlapping interactions between the different capitals, a Principal Component Analysis (PCA) with the varimax rotation method was performed. This factor analysis is widely used in research on vulnerability and adaptation to climate change [14]. Its aim is to reduce a large number of variables into a small set of synthetic factors. In order to determine the number of factors to retain (which explains the maximum variability), the Kaiser-Guttman rule was used. It consists of considering the factors with an eigenvalue > 1 [17,18]. The selected factors were then named according to the significance of the strongly correlated indicators with each factor [14]. These factors are used in analysing the interactions between livelihood capitals.

In a second step, the results of the factor analysis were used to calculate the adaptive capacity. The contribution of each factor to the cumulative variance was used as a weight to calculate the adaptive capacity (AC) [19]:

$$AC = \sum_{i=1}^{n}(Fi\ Vi / \sum_{i=1}^{n} Vi) \quad (2)$$

Where: F_i is the score of the common factor, V_i is the rate of contribution to the variance of the common factor and n is the number of the chosen common factors. Statistical analyses were performed using XLSTAT and TANAGRA software.

In a third step, we tested the correlation between the interacting indicators and the farmers' adaptive capacity. Using Pearson's correlation analysis, the relationship between indicators of interacting capitals and adaptive capacity was tested [20]. Pearson's correlation coefficient is a test that measures the statistical relationship, or association, between two continuous variables. It provides information on the extent of the association, or correlation, as well as the direction of the relationship [21].

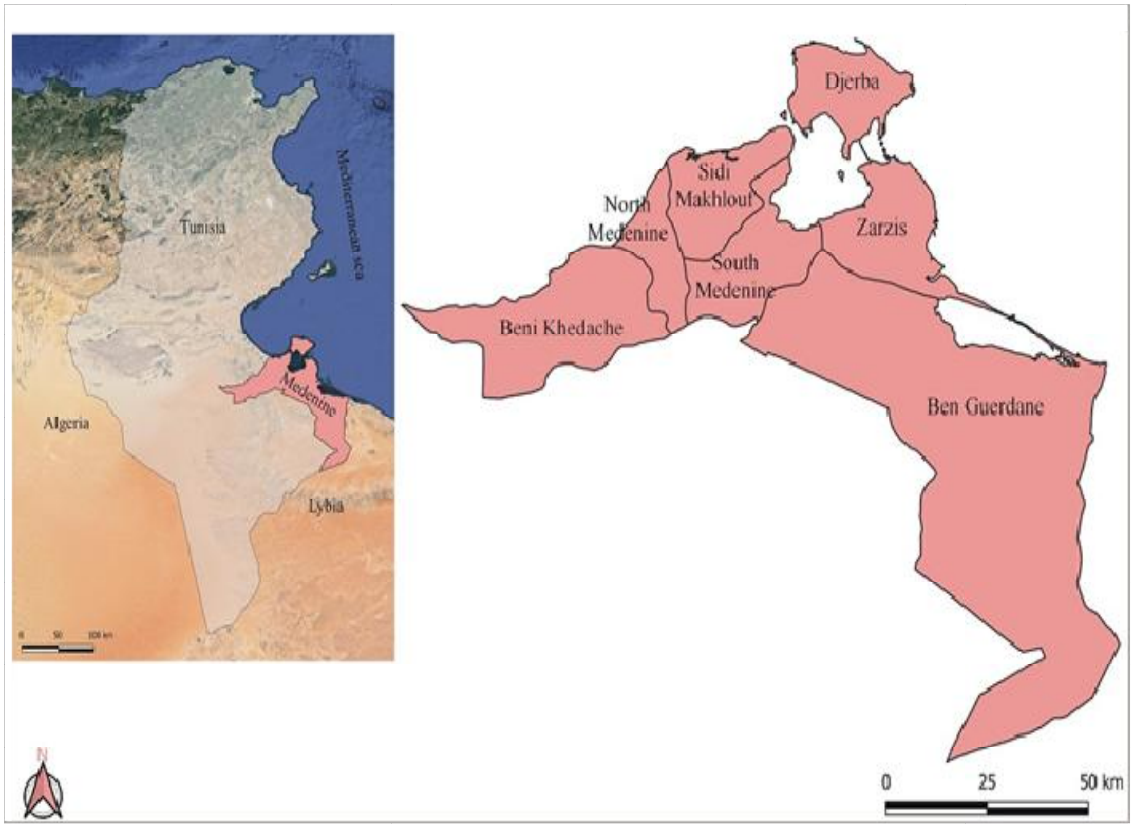

Fig. 1. Geographical location of Medenine governorate

Table 1. Description of indicators of livelihood capital

Livelihood assets	Indicators	Description	Units	References
	Age	Age of household head	Years	[10]
	Hh_size	Household size	Number	[13]
Human	Dep_ratio	Dependency ratio: Ratio between the population aged under 15 and over 65 and the population aged 16 to 64	Ratio	[13]
	Educ	Number of years of education of the head of household	Years	[14]
	Trainings	Number of training carried out by the household	Number	New
	Exp	Number of years of experience in agricultural of the household head	Years	[15]
Natural	Ag_area	Agricultural area by household	Hectare	New
	Irr_area	Irrigated area by household	Hectare	[16]
	Nb_plots	Number of plots by household	Number	New
	Nb_trees	Number of olive trees by a household	Number	New
	Crp_index	Crop diversification index: 1 / (1 + number of crops grown by a household)	Ratio	[10]
	Hrd_size	Herd size by household	LU	New
Physical	Ag_equip	Value of agricultural equipment by household	Local currency (TD)	[3]
	Nb_build	Number of buildings on the farm	Number	New
Social	Memb_org	Membership of a household member to an organization	1=yes, 2=no	[16]
	Dist_mark	Distance to market	Kilometer	New
	Nb_mig	Number of migrant members by household	Number	New
Financial	Savings	Amount saved by a household in the survey year	Local currency (TD)	[3]
	Nn_ag_inc	Non-agricultural income of the household head	Local currency (TD)	[16]
	Ag_inc	Farm income of the farm manager	Local currency (TD)	[14]
	Subsidies	Value of obtained subsidies	Local currency (TD)	[7]

3. RESULTS AND DISCUSSION

Sustainable livelihoods require an analysis of how households organize, transform and combine their capitals. This section begins with an explanation of the interactions between capitals, which is one of the main objectives of this study. After exploring the overlapping properties between capital assets, analysis continues to identify how capital assets can improve the adaptive capacity.

3.1 Interactions between Livelihood Capital Indicators

The Principle Component Analysis (PCA) was carried out on the 21 indicators (Table 1). The indicators that did not contribute, or contribute very little, to the explanation of the dispersion were gradually eliminated. Finally, the analysis was carried out with 16 indicators (Table 2).

The Kaiser's measure of sample adequacy (MSA) is equal to 0.52 > 0.5, presented in Table 3, shows that the indicators of interacting

capitals are suitable for factor analysis (Field, 2009). In addition, by applying the Kaiser-Guttman rule, which consists of taking the factors with an eigenvalue > 1, five factorial axes representing 60.57% of the total inertia were retained (Table 3).

The PCA results help to understand the interactions between the different assets. Based on these findings (Table 2), we consider the type of livelihoods interactions and their implications for the livelihoods' sustainability. The significance of the factors is explained by the relative importance of the indicators in the total inertia of each factor:

3.1.1 Productive resources ownership facilitates the access to other capital

Indicators linked to agricultural productivity (agricultural area, irrigated area, value of agricultural equipment) and to financial capital (agricultural income) are strongly correlated with the first factor. The latter is therefore called “productive capital”. Our investigations revealed that households with considerable productive capital generate significant agricultural income allowing them to invest in the purchase of equipment and in planting irrigated crops (Table 2). This result confirms the fact that farmers with significant agricultural income are investing in improving their physical assets [16]. In turns, farmers with significant physical capital (e.g. irrigation or mechanization facilities) are receiving higher financial capital. Hence, the first factor illustrates the interactions between indicators of natural, financial and physical capital.

3.1.2 The household head level of education is associated with financial capital

The second factor called "off-farm work" contains indicators related to household education (for example, the number of years of education and the number of training by farm household) and financial capital (non-farm income). This result suggests that households with higher education levels have more off-farm work opportunities and more incomes, which supports the argument that investment in education can generate higher income (Table 2). In fact, households resort to off-farm work to reduce the climatic risk that affects agriculture [22]. This practice may secure the household’s income when agricultural resources are limited. Therefore, they could profit from strategic complementarities among several activities [23].

3.1.3 The household head experience reduces the dependence on social capital

The third factor is called "Agricultural experience". It hosts variables related to the household head experience. On the one hand, the age of the household head and the number of years of experience in agriculture are positively correlated. On the other hand, the variable "membership in organizations" is negatively correlated with this factor (Table 2). This result is explained by the fact that household heads who have considerable experience in managing climate stresses believe that their skills are sufficient to maintain livelihoods and continue to manage climatic risks. This belief explains the low adherence of elderly household heads to extension services.

Table 2. Contribution of the indicators on the selected factorial axis after rotation

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Ag_area	**0.746**	-0.125	-0.145	-0.282	0.009
Irr_area	**0.732**	0.028	-0.070	0.119	0.265
Ag_equip	**0.703**	-0.349	-0.188	0.103	0.019
Ag_inc	**0.659**	0.312	0.255	-0.169	-0.035
Educ	-0.118	**0.815**	0.052	0.059	-0.128
Trainings	-0.007	**0.774**	0.268	0.167	0.065
Nn_ag_inc	-0.053	**0.638**	-0.355	-0.069	0.285
Hh_size	0.064	**0.582**	0.281	-0.129	0.200
Memb_org	0.098	-0.121	**-0.581**	0.137	-0.105
Exp	0.100	-0.054	**0.544**	0.284	0.043
Age	-0.198	0.268	**0.538**	0.002	-0.117
Hrd_size	0.075	-0.125	0.183	**0.753**	-0.136
Subsidies	0.179	-0.097	0.234	**-0.630**	-0.208
Crp_index	-0.190	0.447	0.136	**0.549**	-0.328
Nb_build	0.086	-0.067	0.263	0.010	**0.826**
Savings	0.134	0.213	-0.161	-0.081	**0.805**

Table 3. Eigenvalues contribution to the inertia of the selected factorial axes

Factorial axes	Eigenvalues	% of variance	% cumulative
Factor 1	3.5	21.12	21.12
Factor 2	2.4	14.59	35.71
Factor 3	1.5	8.98	44.68
Factor 4	1.4	8.28	52.97
Factor 5	1.29	7.6	60.57
Factor 6	0.97	7.44	68.01
Factor 7	0.88	5.75	73.76
Sampling adequacy Kaiser measure: 0.52			

3.1.4 Access to natural capital does not facilitate access to subsidies

The fourth factor hosts indicators related to natural capital (herd size and crop diversification; positively correlated) (Table 2) and an indicator of financial capital (subsidies; negatively correlated). The large herd size and the crop diversification by households require very expensive inputs but rarely subsidized. Household statements revealed that local institutions rarely support their livelihood strategies. They expressed an attitude about how extension services do not provide assistance to support livelihood activities. This factor is called “institutional support”. Therefore, institutional and organizational malfunctioning may limit the potential of asset mixes in sustaining livelihood activities.

3.1.5 Financial capital improves physical capital

The "building" and the "savings" variables are correlated with the fifth factor. The latter is called "infrastructure". It confirms the importance of financial capital for improving physical capital. This result confirms the idea that when savings exceed a critical level, the farm households invest in constructing houses and livestock buildings. In turn, farm households with greater physical capital (eg. Agricultural equipment) obtain higher financial capital (savings and incomes) [16].

3.2 Effect of the Interaction between Capital Assets on Adaptive Capacity

3.2.1 Calculation of adaptive capacity

The adaptive capacity of agricultural households is attributed to productive capital (F1), off-farm work (F2), agricultural experience (F3), institutional support (F4) and infrastructure (F5). According to equation (2) and Table 3, the index of farm households’ adaptive capacity is as follows:

$$AC = 0.348*F1 + 0.24*F2 + 0.148*F3 + 0.136*F4 + 0.125\ F5 \quad (3)$$

3.2.2 Correlation between the adaptive capacity and capital indicators

The Pearson coefficient was calculated to understand the relationship between the adaptive capacity and the variables obtained from factor analysis. The results revealed that all capital assets were positively correlated with the adaptive capacity and that human capital was the most correlated (2.036), followed by natural (1.853), financial (1.701), physical (0.917) and social capital (0.568) (Table 4).

For households who depend on agriculture, agricultural experience and productive capital are needed to secure their livelihoods. This is consistent with the argument that human capital is central to livelihoods and that natural capital plays an important role in choosing livelihood strategies [10]. Indeed, the quantity and quality of human capital determine directly the ability and scope of households to control other livelihoods. The agricultural experience has an effect on livelihoods, as experienced households know the necessary adaptation approaches and are able to choose the most appropriate adaptive measures to improve their adaptive capacity.

Increasing financial capital improves the capacity of farm households to reduce climate risks. Financial capital can be used to purchase the material resources needed to deal with climate risks. Indeed, it has been observed that when incomes become satisfactory, households invest in improving

Table 4. Correlation between adaptive capacity (AC) and capital indicators

Livelihood assets	Variables	Pearson correlation coefficient	Total coefficient*
Human	Age	0.298	2.036
	Hh_size	0.28	
	Educ	0.264	
	Trainings	0.656	
	Exp	0.538	
Natural	Ag_area	0.785	1.853
	Irr_area	0.656	
	Crp_index	0.179	
	Hrd_size	0.233	
Physical	Ag_equip	0.477	0.917
	Nb_build	0.44	
Social	Memb_org	0.335	0.568
	Nb_migr	0.233	
Financial	Savings	0.009	1.701
	Nn_ag_inc	0.312	
	Ag_inc	0.887	
	Subsidies	-0.493	

**The total coefficient is the sum of the correlation coefficients for each type of capital*

the farm capital (purchase of agricultural equipment, drilling wells, installation of an irrigation network, purchase of livestock, building construction, etc.) to adapt to climate change. In turn, households with more farm capital receive higher financial capital and therefore more secure livelihoods.

4. CONCLUSION

According to the Sustainable Livelihood Approach, capital assets are the cornerstones of sustainable livelihoods face to climate risks and uncertainties. However, the organization of capital follows a complex process that is relatively under-explored in the sustainable livelihood literature. This paper has proposed a methodological approach to understand how different assets interact to improve the adaptive capacity of farm households. In order to overcome the shortcomings of simply quantifying adaptive capacity by the five types of capital, interactions between capital indicators were integrated to quantify and interpret adaptive capacity at the farm household level.

Overall, this paper has confirmed the hypothesis that households are trying to compensate for the lack of certain capital by interactions with other types of capital in order to increase their adaptive capacity. Given these interactions, we can conclude that testing the association among livelihood assets is a priority, which should be included within adaptive capacity policymaking. To enhance the farmers' adaptive capacity to climate change, policies should concentrate on investing in the capital that is most correlated with adaptive capacity. For agricultural households in the governorate of Medenine, human, natural and financial capital seem to better influence the adaptive capacity of farmers, while the impacts of physical and social capital are relatively less important. Therefore, farmers should be encouraged to invest in their human, financial and natural capital to improve their capacity to adapt to climate change.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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