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Analysis Of The Determinants Of Resilience To Food Insecurity In An Arid Environment: The Case Of Small-Scale Farmers In The Souss Valley In South-Central Morocco

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Abstract

Climate change is affecting food security in Morocco, particularly for small farmers in arid and semi-arid zones like the Souss valley. Principal component analysis of the FAO's four pillars of resilience RIMA-II model has enabled us to narrow down the important data for each pillar. Six components are considered as predictors of household food security, and their contribution is significant at the $p<0.05$ threshold. Breeding practice, Access to credit, Housing conditions, Access to irrigation water, Distance to basic services and Migrant remittances. Food Consumption Scores (FCS) and Household Food Insecurity Access Scale (HFIAS) scores are used as indicators of household food security, and dependent variables in a multiple linear regression. Access to irrigation water, animal husbandry and access to basic services appear to be the main determinants influencing the resilience to food insecurity of smallholder farming households in the Souss valley.

Keywords: Resilience, Small farmers, Principal component analysis, Food security, Multiple linear regression.

1. Introduction

In the context of climate emergencies, the concept of resilience to food insecurity has progressively imposed itself on researchers and decision makers. They aim to measure the capacity of a household or community to absorb the negative effects of shocks (Constas & Barrett, 2013). Better articulating agricultural development and food crises has become a real challenge for the scientific community and within policy circles (Blanchet, 2008).

The literature on food security addresses the issue of resilience as a function of the nature of shocks. For a household, a shock is a detrimental event that alters its normal functioning and threatens its food security. The ability of each household to react is different depending on the nature of these shocks. It can be an idiosyncratic shock that affects isolated individuals or households or a covariate shock that affects several individuals at once (Ansah et al., 2019).

In Morocco, although food insecurity is not very marked, it seems that with climate change things are beginning to change, particularly in arid and semi-arid areas. A debate has therefore gradually begun involving scientists, public decision-makers and civil society. And it is to take part in this debate that we have chosen to analyze this issue. The aim is to conduct a statistical and analytical exercise on the extent of climate change and the rate of resilience of populations affected by this phenomenon in the Souss Valley in south-central Morocco.

The choice of this area is explained both by its strategic economic position and its natural and social characteristics that make it a good testing ground for some public policies of adaptation to climate change. The region has long been known for its national supremacy in the production and export of vegetables and citrus fruits. It is also famous for its vast forests of Argan trees and its flourishing food agriculture. Lately, under the pressure of recurrent droughts, the area has gradually turned into a semi-arid, even arid.

The remainder of this paper is organized as follows. Section 2 presents the conceptual framework used to approach our research problem. Section 3 details the methods and tools employed for sample construction, data collection, and the empirical strategy for analysis. Section 4 discusses the results obtained in detail. Finally, the conclusion summarizes the main findings and presents some implications for economic policies.

2. Literature Review

Resilience refers to the amount of change a system can undergo without losing its major functions and structure (Nelson et al., 2007). Holling argues that resilience, as an approach, is based on the idea of change (not equilibrium) remaining the natural state of a system (Holling, 1973). The occurrence of change is, therefore, inevitable, even if its nature and magnitude are not always predictable (Nelson et al., 2007). As a result, and according to the latter, systems must be managed from a perspective of flexibility rather than continuity of a steady state.

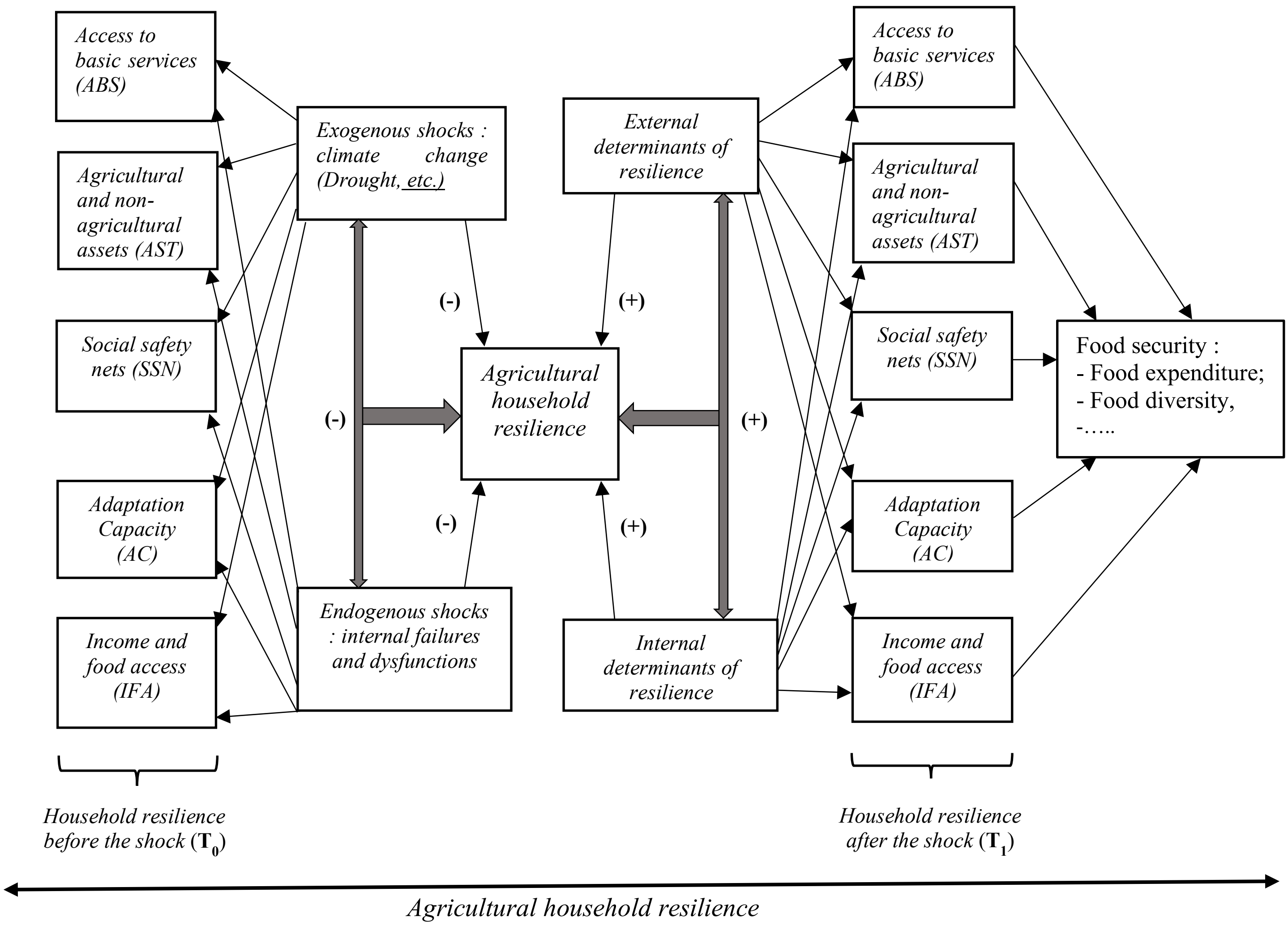

Figure 1: Conceptual framework of resilience (Adapted from Alinovi et al., 2010)

If we attempt to succinctly trace the history of this concept of resilience, we find that it has its origins in an early thought in ecological literature, flourishing in technical settings (Ciani & Romano, 2014; Rutter, 2006). Subsequently, in the 1960s-1970s socio-environmental scientists, environmental and development institutions found it a source of inspiration to further their thinking and research on adaptation (Maxwell et al., 2014). In many studies, the concept of resilience, has remained dependent on the researchers' field of interest (economics, ecology, engineering...) and to their scientific affiliations (Ado et al., 2019). Indeed, the concept differs across disciplines and locations due to its changing nature (Alam et al., 2018; Mussetta et al., 2016).

The relationship between vulnerability and resilience has been the subject of much scientific work (Serfilippi & Ramnath, 2018). The literature (Alinovi et al., 2010; Gitz et al., 2016) is replete with attempts to represent this relationship, which still remains a topic of debate (Serfilippi & Ramnath, 2018). Resilience is a component of adaptive capacity for some (Adger et al., 2003; Folke, 2006), for others (Burton et al., 2002; O'Brien et al., 2004; Smit et al., 1999), adaptive capacity is a component of vulnerability (Serfilippi & Ramnath, 2018). Furthermore, resilience and vulnerability are for Cutter et al., (2008) intertwined concepts. For Gallopin (2006) and Turner et al., (2003) nested concepts but within an overall vulnerability structure (Serfilippi & Ramnath, 2018).

The question of resilience of social-ecological systems (SES) is strongly posed. SES gives humans and nature an equally important presence in the analysis (Folke, 2006). In this framework, resilience is related to the extent to which the system is able to self-organize, learn, and adapt (Cumming GS, Peterson GD, 2017). Humans and nature form linked systems, and humans should be considered part of nature, not outside of it (Bahadur et al., 2010). Humans and the ecosystem interact with each other in a dynamic way (Berkes and Folke, 1998). As a result, the resilience framework was developed with the idea of complex systems. Social and ecological components are interconnected and work together (Béné et al., 2012). The focus is not on the functioning of each component individually, but rather on the interdependent relationships between the different components of the system (Béné et al., 2012).

Measuring and assessing resilience remains one of the questions that the literature has attempted to answer. Several frameworks and approaches have been proposed by researchers to quantify household resilience, which acknowledge that the measurement of resilience must be indexed to a concept of well-being (d'Errico et al., 2018). In this sense, Frankenberger et al, (2014) clarify that resilience is not an outcome sought per se. Rather, positive livelihood outcomes, as measured by development indicators such as food security, nutrition, and poverty, should be the goal (Schipper & Langston, 2015). Typically, indexing is done on a desired development outcome in terms of food security or a poverty level (d'Errico et al., 2018). Thus, it could be understood that even in the face of a shock, a resilient food system maintains its essential functions of ensuring food security (Ansah et al., 2019).

The objective of this research work is to study the determinants of the pillars of resilience of smallholder farming households in Souss. In the literature on resilience to food insecurity, it is a measure of the ability of a household or community to absorb the negative effects of unpredictable shocks (Constas & Barrett, 2013). The magnitude of shocks and the ability of households to cope with them determine the nature and extent of resilient practices undertaken and to be undertaken. The conceptual framework in Figure 1 proposed by Alinovi et al. assumes that a household's resilience to food insecurity at a given point in time, time T_0, depends on the options it has for earning a living (Alinovi et al., 2010). These options are access to basic services, available farm and non-farm assets, social safety nets, coping capacity, and income.

Between time T_0 and T_1, stressors are assumed to hit households. To cope with these exogenous and endogenous shocks, households have a range of responses. The response options or devices allow the household a capacity to bounce back or bounce forward (Darnhofer, 2014). Households' ability to adapt and the assets available to them decide the outcomes of responses. Figure 1 displays a clear difference in the components of resilience between time T_0 and T_1. These components differ markedly as a result of the stressors or shocks experienced by households at time T_0.

The RIMA (Resilience Index Measurement and Analysis) approach allows us to identify the determinants of resilience (d'Errico & Di Giuseppe, 2018). We can infer that this index is not directly observable, but calculated based on the pillars of this approach: Access to Basic Services (ABS), Assets (AST), Social Safety Net (SSN) and Adaptive Capacity (AC). An analysis of the resilience capacity index allows us to compare households. For example, compare households in one locality with those in another. This helps to understand why some groups or social categories are more resilient than others to shocks and stressors such as climate change. In order to estimate the resilience index, we need to estimate the pillars that make up the model, which are also latent variables.

3. Materials and Methods

3.1. Sample Construction

The rural household is a relevant unit of analysis to better understand issues related to climate change shocks and stressors (Atara et al., 2020). It is considered an entry point for understanding the sources and dynamics of resilience to food insecurity (Atara et al., 2020). Thus, in the context of food insecurity shocks, this approach has attracted the interest of the scientific community and the attention of international organizations (Atara et al., 2020). It looks at the capacities and resources that a household possesses in an attempt to improve its resilience (Atara et al., 2020).

Due to the lack of a reliable and credible sampling frame, we used the quota sampling method. The control variable is the three strata of territorial communes that we identified, according to the degree of intensity of the impact of climate change on water resources: Commune very affected by climate change (Stratum 1); Commune affected (Stratum 2) and Commune little affected (Stratum 3). Our proximity to and knowledge of the study area enabled us to carry out this stratification, with regard to the availability of water for agricultural use. We took the depth of the dug wells as the main determinant (from more than 300 m to the west of the valley in the area of Ouled Teima to about 100 m to the east in the area of Ouled Berhil).

The province of Taroudant has 26 rural communes of plains and 55 rural communes of mountain. Those of the plain have 515 villages, constituting most of the rural space of the Souss valley, with 54214 households[1]. If we divide these 26 villages into the three strata mentioned above, we obtain the following table:

[1] According to the last General Census of Population and Habitat (HCP, 2014).

Table 1: Distribution of demographic and administrative characteristics by stratum

Strata	Number of territorial communes	Number of villages	Number of households²	Number of selected communes
1	11	161	26 614	4
2	9	170	18 367	2
3	6	184	9 233	1
Total	26	515	54 214	7 (Survey rate 25%)

Source: our survey

We estimate that 7 communes are sufficient to ensure representativeness within the three strata previously defined. That is 27% of the 26 communes located in the Souss valley. After having decided on the number of territorial communes to be surveyed by stratum, these communes are determined by simple random sampling in Excel 2016. The software performs a random classification of the communes in each stratum. Then, the first 4 communes in the stratum "Communes very affected: 1" are chosen. Then, the first 2 communes in the stratum "Communes affected: 2". And the first commune in the stratum "Communes little affected: 3".

The 2014 General Census of Population and Habitat (commissariat au Plan-Maroc, 2014) provides the data base for the number of villages and rural households in each of the seven communes sampled for data collection (Table 1). Subsequently, we move on to identify the two uses of agricultural land, irrigated and rainfed, to ensure their representativeness in our sample. We refer to the communal inventory of the province of Taroudant (HCP, 2011), to our knowledge and proximity to the study area. A categorization according to the type of the dominant agricultural development (Rainfed/Irrigated) of the villages is made within each commune of the sample.

Next, we drew up a list of villages in each of the seven communes with predominantly irrigated land. Then, another list is established for rainfed agriculture land. The lists were processed in Excel 2016 using a simple random sampling technique. The objective is to identify the first representative irrigated village and the first representative rainfed village for each commune. In this way, we have two villages for each territorial commune sampled. From the Igli commune, only one Rzagna village was taken, which in fact constitutes a grouping of several small villages.

Approximately, there are 54214 households in the study area, of which at least 50% are expected to be adversely affected by climate change (i.e., increased and more intense extreme weather events such as recurrent and prolonged drought). To constitute the sample of households to be surveyed, we applied the following formula (Kothari, 2004):

$$n = \frac{Z^2 * p(1-p) * N}{Z^2 * p(1-p) + (N-1) * e^2} \quad (1)$$

Where *n* is the required sample size, *Z* is the confidence level, *e* is the desired precision level, *p* is the estimated proportion of villages exposed to extreme drought. *N* is the total number of rural households living in the study area (The rural area of the Souss Valley):

$$\mathrm{n} = \frac{1.96^2 * (0.5 * 0.5) * 54214}{(1.96^2 * (0.5 * 0.5)) + ((54214-1) * (0.05^2))} = 381.46 \approx \mathbf{382} \text{ Households.}$$

3.2. Data Collection

The Souss-Massa Water Basin Agency and the Regional Office of Agricultural Development Souss-Massa were asked to provide secondary data. The primary data was collected using a combination of purposive and random sampling strategies on small-scale farmers. In each village, we sampled the respective smallholder households by first discarding the large farms. Then, we tried to avoid similar cases that could arise from the effect of juxtaposition. To do this, we proceeded by an odd numbered order: the 1st household, the 3rd, the 5th and so on.

A first version of the questionnaire was drafted after a literature review and interviews with experts. These are mainly officials of the Ministry of Agriculture at the regional level in Agadir[3] and provincial level in Taroudant[4]. Also, officials from the Souss-Massa Water Basin Agency. Added to these, local actors such as employees of the associations of agricultural water users and some farmers.

In April 2022, this version was administered to 23 small-scale farmers in the study area for further refinement before being finalized. Necessary modifications were then made to the structured questionnaire. Finally, the questionnaire was administered to 382 smallholder households in the study area during the period April-June 2022. Statistical processing of the survey rejected 12 questionnaires and selected 370.

3.3. Empirical Strategy

3.3.1. Pillars of Resilience

In order to build strong empirical evidence on the factors that contribute to resilience, this study adopts the RIMA-II approach (FAO, 2016). This conceptualizes and decomposes resilience into four pillars (Jones & d'Errico, 2019):

-Access to basic services (ABS): a household's access to a favorable institutional and public environment. It includes indicators such as health facilities, education, etc;

-Assets (AST): Assets that enable a household to earn a living. They include both productive activities (land, livestock and other income generating activities) and non-productive assets (house, durable goods...);

-Social security networks (SSN): the network that a household can rely on when faced with a shock. It includes both formal and informal transfers, the social network of solidarity.

-Adaptive Capacity (AC): is the "ability of the household to adapt to the changing environment in which it operates" (FAO, 2016). It includes factors such as education, number of income sources, and income reliability. Indeed, in the event of a shock, whether endogenous or exogenous, the household reacts by using an available response (adaptive capacity) to reach a new level of well-being in the next period (Serfilippi & Ramnath, 2018).

3.3.2. Principal Component Analysis (PCA)

We used Principal Component Analysis (PCA) to narrow down these items and identify key determinants of household resilience (Weldegebriel & Amphune, 2017). Indeed, factor analysis has made PCA an appropriate and compelling tool in much research. The objective is to reveal possible dependencies between several variables by reducing them to a limited number of latent variables called factors (Acal et al., 2020).

Using SPSS 26, we conducted a factor analysis by identifying and reducing the number and characteristics of factors among the items. The analysis we conducted was done in two steps: a PCA and then a rotation with the Varimax method. The aim is to minimize the number of items with strong correlations on each factor. The objective is to simplify the structure of the data and the problem, and thus to be able to interpret it easily (Acal et al., 2020).

3.3.3. Multiple Linear Regression

For each pillar of resilience, PCA analysis provides principal components that capture most of the variation. The Food Consumption Score (FCS) and the Household Food Insecurity Access Scale (HFIAS) are calculated and used in the regression as dependent variables (Table 2). To understand the nature of the contribution of the pillars to the resilience of smallholder households to food insecurity, a linear regression of the FCS and HFIAS (dependent variables) on the pillar components obtained after the PCA (independent variables) is used.

Table 2: Food security indicators used in the regression as dependent variables

Indicateur	Explication
-HFIAS (Household Food Insecurity Access Scale)	-The degree of food insecurity experienced by the household in the past four weeks. It is measured by the HFIAS score (9 questions: 3 points each). The higher the calculated score (approaching 27), the more food insecure the household is. And vice versa, a low score indicates that the household is less vulnerable to food insecurity.
-FCS (Food consumption score)	-To measure the level of food intake during the last seven days, the World Food Programme (WFP) established the food consumption score (FCS) in 1996 (Munawar et al., 2021). The household is asked the number of days they consumed 9 identified food groups in the 7 days prior to the survey (WFP, 2008). As a method, the food consumption score is calculated by multiplying the *weight* for each food group by the *number* of days those food groups were consumed.

Source: our literature review

[3] Agadir is the capital of the Souss-Massa region in central southern Morocco.
[4] Taroudant is the largest agricultural province in the Souss-Massa region, which occupies most of the Souss valley.

The objective of the study is to investigate the effect that the resilience pillar variables may have on the food security indicators: the Food Consumption Score (FCS) and the Household Food Insecurity Access Scale (HFIAS). The following hypotheses will be tested:

-H1: There is a positive significant impact of the resilience pillar variables on the Food Consumption Score (FCS) of smallholder households in the Souss Valley.

-H2: For smallholder households in the Souss Valley, the resilience pillars significantly and negatively impact the Household Food Insecurity Access Scale (HFIAS).

4. Results and Discussion

Our initial sample size was 382 households (Equation 1). Statistical processing of the data entered into SPSS 26 revealed the existence of outliers. In order to avoid any negative impact on the statistical analysis to be carried out later in this research, we pre-processed the data to detect and process the outliers. The software allowed us to detect 12 outliers through a graphical visualization (Box plots), which we removed.

In this section, we undertake a PCA analysis of the four pillars of resilience, as defined by FAO (2016). Before turning to the analysis, it is useful to review the items that comprise each pillar of the FAO model. Our choice of items is supported by the literature and by the realities of our study field.

4.1. Access to Basic Services (ABS)

Among the 13 items observed in our sample counting for the first pillar, the PCA allowed a factorial analysis that identified 6 items. The items thus chosen to compose this pillar with the justification provided by the literature are summarized in Table 3.

Table 3: Access to basic services

Items	Literature	Source
-Owning a home;	-Better housing conditions influence the health status of household heads, which in turn influences their resilience and their agricultural and non-farm activities.	-d'Errico, M., Romano ; -D., & Pietrelli, R. (2018).
-Access to drinking water;	-Guaranteed access to water supply is one of the key elements of any resilience building effort; -Unsafe water is a source of many diseases that reduce resilience;	-Boudreau (2013) ; -Tambo (2016) ; -Pandey et Jha (2012) ;
-Distance to market;	-Market access facilitates individual participation in livestock marketing, and other types of livelihood diversification, thereby improving food security; -Access to the market may provide household members with opportunities for off-farm work, which would improve their income;	-Melketo,T. et al. (2021) ; -Ansah et al. (2019) ;
-Distance to agricultural extension services;	-Access to agricultural extension services improves farmers' knowledge and skills in climate change and resilience practices and technologies; -Access to agricultural extension services improves farmers' knowledge and skills in climate change and resilience practices and technologies;	-Frank et Penrose Buckley (2012) ; -Klein et al., (2011) ; -Tanny et Rahman (2016) ;
- Distance to school (km);	-The increasing distance of the farm from good roads is inversely proportional to the ability to adapt to climate change.	-Byrne(2014) ; - Egyir et al., (2015).
-Access to health services.	-Access to health services can contribute to staying healthy, thereby building resilience;	-Barua et al. (2014) ; -Hahn et al. (2009) ;

Source: Our literature review

In order to decide whether the sample data are suitable (or not) for factor analysis, we used the Bartlett test and the Kaiser-Mayer-Olkin (KMO) index. The first is statistically very significant at the $p<0.001$ level. The second shows a value above the critical threshold of 0.5, i.e., 0.505, which is satisfactory and tolerates the transition to the analytical exercise (Table 4). In addition, the anti-image correlation shows that four of the six items submitted for analysis have a KMO index greater than 0.5. These are the variables "distance to extension office", "access to health service", "distance to school" and "owning a home". They are therefore expected to make a significant contribution to the new factor structure.

Table 4: KMO index and Bartlett's test (ABS Pillar)

-Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy		0.505
- Bartlett's sphericity test	(Khi-square approx.)	264.835
	ddl	15
	Signification	0.000

Source: PCA, SPSS26 output

Examination of the statistics of the total variance associated with the first pillar shows that only three items satisfy the criterion (eigenvalues greater than 1). These three alone explain 69% of the variation in this first pillar. The rotation of the component matrix with the Varimax method allowed us to identify three components that account for most of the variation for this pillar.

The first component (distance to basic services) plays an important role in the estimation of the first pillar (over 26% of the variance). Access to infrastructure is one of the levers that small farmers can rely on to strengthen their resilience to food insecurity. These results are confirmed by the literature. For example, in Malawi, Chamdimba et al. found that access to basic services was positive and significant for food insecurity resilience of farm households (Chamdimba et al., 2021).

Under the second component, access to drinking water is the only variable retained. It alone contributes 24% of the total variance of the first pillar. This result has been highlighted by the literature, which reports that access to drinking water strengthens resilience (Tambo, 2016). On the contrary, any cut or disruption that taints its availability significantly affects the resilience of smallholder farmers (Tambo, 2016).

In relation to the third component, two variables register a high level of correlation: access to home ownership and access to health service (a contribution of about 19% of the total variance). Health and housing status therefore exert an influence on the involvement of the farm household in agricultural and non-agricultural activities (d'Errico et al., 2018). In a study of resilience to shocks and food insecurity in southern Malawi, Chamdimba et al., (2021) came to the same conclusion. According to the results of their study, better access to health care and functional markets significantly improves quality of life and access to services. This preserves labor productivity, thereby increasing resilience to food insecurity.

4.2. Agricultural and Non-Agricultural Assets (AST)

According to our literature review, twenty-seven items were initially identified to compose this 2nd pillar (Table 5). We retained nine of them after a PCA.

Table 5 : Agricultural and non-agricultural assets

Items	Literature	Source
-Possession of agricultural land;	-Agricultural land can increase climate change adaptation and resilience.	-Deressa et al., (2009).
-Total agricultural land area (ha); -Cultivated agricultural area in 2022 (ha); -Cultivated agricultural area in 2021 (ha); -Cultivated agricultural area in 2002 (ha) ;	-Farmers with large farms are more likely to diversify their farming practices to adapt to climate change and thus improve their resilience. -Farmers with larger farms are assumed to be more likely to invest in climate change adaptation and resilience strategies.	-Defiesta and Rapera (2014). -Ojo et Baiyegunhi, (2019).
-Breeding practice; -Tropical Livestock Units (TLU);	-Livestock contributes to the resilience of households to food insecurity.	-Perz (2005); -Tesfahun, (2017) ; Tincani, (2012)
-Agricultural assets ; -Non- agricultural assets.	-Households with higher asset endowments are resilient and likely to adapt to climate change.	-Ziervogel et al., (2006) ; -Bryan et al. (2009).

Source : our literature review

The value of the KMO index and the Bartlett's test are statistically very significant. Also, the anti-image correlation shows that the nine items, taken individually, have a much higher KMO of 0.651 (Table 6). These items can thus make a significant contribution to the new structures to be identified (the components). The first three components alone explain more than 82% of the variation in this pillar. They are therefore retained by the factorial analysis. The orthogonal Varimax rotation allowed us to identify three factors (Components).

Table 6: KMO index and Bartlett's test (AST Pillar)

-Kaiser-Meyer-Olkin (KMO)		,651
- Bartlett's sphericity test	(Khi-square approx.)	1921,799
	ddl	36
	Signification	,000

Source: PCA, SPSS26 output

The first component in the order of importance of the asset pillar (AST) is "Cultivated agricultural area" (over 31% of the variance). This leading position of cultivated land size has been widely reported in the literature. For example, in a study on climate change adaptation of smallholder farmers in central Ethiopia, Alemayehu and Bewket (2017) found that farm size is a major determinant of driving changes in consumption patterns.

The second most important component is that related to livestock pratctice, which contributes about 21% of the total variance in this pillar. It should be noted that 61% of the households in our sample practice livestock. More than a third of them (34.3%) state that this activity contributes significantly to their income. This result is consistent with those of many previous studies, which have emphasized the key role of livestock as a factor in household resilience to food insecurity (e.g. Perz, 2005; Tesfahun, 2017; Tincani, 2012; etc.).

The third component is the stock of agricultural and non-agricultural materials available to the household. It contributes more than 16% of the total variance of this pillar. It constitutes a real mechanism for dealing with anticipated and unforeseen stressors. In fact, selling livestock, renting out land or agricultural equipment, or even selling part of these assets are strategies that the small farmers in our sample use to strengthen their ability to adapt.

The fourth component accounts for 14% of the total variance in this pillar. This factor, which is related to access to ownership of agricultural land, weighs heavily on the households of small-scale farmers in our sample with little or no access to property. This obviously limits the amount of land that can be cultivated, and negatively impacts food security. This correlation was also confirmed by Chamdimba et al (2021) in a study of Malawi. For them, the more land available per adult, the higher the level of household resilience to food insecurity (Chamdimba et al., 2021).

4.3. Social Safety Nets (SSN)

Based on the available literature, we were able to identify nine variables that could represent this third pillar. However, the factorial analysis carried out retained only seven of them (Table 7).

Table 7 : Social Safety Nets

Items (variables)	Literature	Source
-Household head (or member) affiliation with a cooperative; -Number of household members affiliated with an association or cooperative;	-The membership of one or more household members in an agricultural social group can be an important factor in climate change adaptation and resilience.	-Below et al., 2012.
-Duration of membership of household head (or member) in an association or cooperative; -Activity domain of the association or cooperative ;	-Rural institutions are able to mitigate vulnerability to environmental change and build adaptive capacity and resilience to climate change at the local level.	-Bryan et al, 2009.
-Access to credit.	-Access to credit builds adaptive capacity and resilience to climate shocks.	-Boko et al., 2018.
-Transfers from a member of the same household;	-The funds farmers receive play an important role in building their capacity to adapt to climate change;	-Defiesta et Rapera, 2014.
-Transfers from a member of the same family.	-Funds can help improve income and resilience.	-Aryal et al., 2014.

Source: our literature review

With a strong KMO index of 0.842 and a statistically significant Bartlett's test at the p<0.001 threshold (Table 8), we can continue a factor analysis (PCA) for this third pillar. Taken one by one, the seven items associated with this pillar seem to satisfy the condition of the KMO test (value greater than 0.5). They are therefore retained to contribute to the new components.

Table 2: KMO index and Bartlett's test (SSN Pillar)

-Kaiser-Meyer-Olkin (KMO)		0.842
- Bartlett's sphericity test	(Khi-square approx.)	2107.320
	ddl	28
	Signification	0.000

Source: PCA, SPSS26 output

The first three components (factors) have eigenvalues greater than 1. They alone explain slightly more than 77% of the variation in this pillar. Factor saturation was reached after a rotation for the seven original items. Three components emerge and provide a sufficient explanation of the variation of this latent variable.

Our study area is strongly influenced by the culture of membership in cooperative structures, particularly those of the dairy sector. As a result, the first component alone accounts for over 46% of the total variation in this pillar. This is consistent with the literature. Membership of one or more farm household members in agricultural social groups or networks can be an important factor in climate change adaptation and resilience (T. B. Below et al., 2012). Whether formal or informal, these structures typically allow members to organize collectively to better manage climate risks (Campbell et al., 2016; Thomas et al., 2007).

The second component is migrant remittances, which account for 17% of the total variance in this third pillar. After the Second World War, part of the young population of the valley emigrated to Western European countries, in particular to France. Moreover, 59% of our sample declare having benefited regularly from a migratory financial transfer. These funds are of internal origin, but also come from abroad.

The third component relates to access to credit. Its contribution to the total variance of this pillar is around 14%. As a result, it constitutes a support mechanism that makes it possible to strengthen the resilience of certain small farmers to food insecurity. While one-third of the heads of households surveyed claim to have access to credit, the practical arrangements for this operation are quite varied. On the one hand, a good portion of the loans taken out are informal (debt from family members, neighbors, etc.). On the other hand, some small farmers are accustomed to using microcredits, marketed by specialized associations. In addition, members of agricultural and dairy cooperatives receive financial support, mainly in the form of staggered payments for livestock over several years.

The importance of access to credit as a device for building the resilience of smallholder farmers to food insecurity has been highlighted by numerous empirical studies. Deressa et al. have shown that access to credit has a positive and significant impact on smallholder farmers' use of soil conservation and irrigation to combat the impacts of climate change in the Nile Basin of Ethiopia (Deressa et al., 2009). Similarly, Khan et al. found that smallholder farmers in Pakistan who have access to formal loans are more likely to diversify their crops (Khan et al., 2020).

4.4. Adaptive Capacity (AC)

Forty-one items were initially mobilized to measure the adaptive capacity of small farmers. Only eight of them were identified by a PCA to constitute this fourth pillar (**Error! Reference source not found.**).

Table 3 : Adaptive capacity

Items	Literature	Source
-Number of years of farming experience.	-More experienced farmers are more likely to adapt than those with less experience.	-Hassan et Nhemachena (2008).
-Number of farmers in the household.	-A large number of farmers in the household has a positive effect on farm efficiency.	-Ali Chebil et al., 2009 ; -Ajijola et al., 2016 ;
-Access to irrigation water.	-Farmers with access to irrigation infrastructure have a greater capacity to adapt to drought than those without access to irrigation infrastructure.	-Eakin et al. (2011) ; -Aase et al.(2013) ; -Egyir et al. (2015) ;
-Access to climate information.	-Access to climate information increases adaptive capacity. This implies that farmers with better access to climate information are better prepared to adapt to climate change than those with less access to such information.	-Lo and Emmanuel (2013) ;
-Economic dependency ratio.	-Higher dependence will reduce resilience.	-Hahn et al. (2009) ;
-Number of household income sources.	-Diversification of farm income is a strategy for adaptation to climate change.	-Amfo, et E. Baba Ali (2020) ;

-Household labor force.	-Better access to family (domestic) labor improves farmers' adaptive capacity.	-Eakin et al. (2011) ; -Ibrahim (2014) ;
-Adaptive farming practices.	-Farmers adopt a variety of adaptive farming techniques and practices to improve their resilience.	-Ahmad et al. (2013).
-Number of income sources	-A farmer with more diversified income sources has a higher adaptive capacity than a farmer with less diversified income sources.	-Armah et al. (2010) ; -Defiesta and Rapera (2014) ;

Source: our literature review

The KMO index and Bartlett's test show that the data are primed for factor analysis. The KMO index is equal to 0.823 and the Bartlett test shows a p-value <0.001 (**Error! Reference source not found.**). Factor analysis using PCA is then possible for this fourth pillar of resilience. In addition, examination of the correlation coefficients of the anti-image matrix shows that seven out of eight items individually have a KMO greater than 0.5.

Table 10: KMO index and Bartlett's test (AC Pillar)

-Kaiser-Meyer-Olkin (KMO)		,823
- Bartlett's sphericity test	(Khi-square approx.)	1533,143
	ddl	36
	Signification	,000

Source: PCA, SPSS26 output

For this fourth pillar, the first three components have eigenvalues greater than 1 (Kaiser criterion). They alone explain more than 71% of the variation in adaptability. The Varimax rotation method ensures the maximum factorial saturation of each item on the component to which it is related, and brings out three components.

The first component of adaptive practices provides 42% of the total variation in this pillar. The economic dynamics of the region, propelled by irrigated agriculture, is now more than ever faced with the challenge of mobilizing water resources, which has already reached its limits (AFD, 2012). Given the scarcity of groundwater and the pressure on the water table in our study area, the number of small-scale farmers who have access to this resource continues to shrink. Only 41% of our sample report having access to water for agricultural use, and only 23% of them have access to it on a continuous basis.

More than 17% of the total variation in this pillar is provided by the second component, which relates to diversification of household income sources. Income diversification is very positive for climate resilience, especially if it is based on non-agricultural and non-climate dependent income sources (Ifejika Speranza, 2010). Indeed, only 6.2% of smallholder farming households in our sample rely on agriculture as their primary source of income, and they all farm irrigated agricultural land.

The 3rd component of agricultural experience captures 12% of the total variation in the adaptive capacity of smallholder farming households in the Souss Valley. More than 93% of the heads of households in our sample have accumulated more than 20 years of experience in farming. Older heads of households are generally well equipped with indigenous and traditional knowledge to anticipate climate change. Also to adopt the most appropriate type of adaptation strategies. This same finding was highlighted by Deressa et al. who noted that the age of the household head and agricultural experience influence the adaptive practices of smallholder farmers in the Nile Basin of Ethiopia (Deressa et al., 2009).

4.5. Regression

Based on the PCA factors of the four pillars of resilience, a regression is conducted in SPSS26 to estimate the impact of the components of the pillars of resilience on the food security indicators: FCS and HFIAS. This involves running a multiple regression to estimate the extent to which the PCA factors affect the scores obtained for these two food security indicators for smallholder farming households in the Souss Valley. We focus on the household as our basic unit of analysis. The multiple regression method used in SPSS26 is the "enter" model. We first analyze the regression results for the food consumption scores as the dependent variable and then we move to the household food insecurity access scale.

4.5.1. Food Consumption Scores (FCS)

Six components (independent variables or predictors) are taken into consideration and whose contribution is significant (**Error! Reference source not found.**). Our sample is large enough (N=370) to conduct the Kolmogorov-

Smirnov test. SPSS26 shows a value of 0.200 (p>0.05), which leads us to accept the hypothesis of the normality of the distribution of the residuals. Moreover, the value of the Durbin-Watson statistic is close to 2 (2.087) which means that there is no linear autocorrelation of the residuals in our multiple linear regression model (J. Durbin and G. Watson, 1950). This leads us to continue the analysis with Fisher's test to check whether the model is globally significant or not.

The analysis of variance (ANOVA) table indicates that these variables significantly predict food consumption scores: F (6, 363) =80.950, p<0.001. We can infer that the model is globally significant. Another thing, R^2=0.572 indicating that the model explains 57.2% of the variation of the dependent variable.

Taken one by one, the regression coefficients (*β*) obtained by the six predictors are different from 0 and are significant at the p<0.001 threshold (**Error! Reference source not found.**). This leads us to reject the null hypothesis and infer that the predictors have a significant impact on food consumption scores. The collinearity statistics show tolerance scores well above 0.3 (between 0.436 and 0.520), and the correlation coefficients between the independent variables are between -0.7 and +0.7. This excludes the risk of error related to multicollinearity.

The correlation expected by the starting hypothesis (H1) is positive between the dependent variable (Food Consumption Scores) and the predictors. For a household, strong food consumption scores require strong scores on the pillars of resilience. And vice versa, low scores on these pillars imply low levels for food consumption scores. In our case, the regression results indicate that the Access to Irrigation Water component (Pillar AC) makes the highest significant and positive contribution (0.723) to the variance in food consumption scores of households in our sample (**Error! Reference source not found.**). Switching to irrigated agriculture is considered the most widely used coping strategy in the face of recurrent drought in the Souss Valley. Small-scale farmers with access to irrigation are turning to high-value crops, particularly bananas and citrus. This finding is confirmed by that of Alauddin & Sarker (2014) who reported that the more severe the drought, the more likely farmers are to adopt supplemental irrigation in Bangladesh.

The lowest significant and positive contribution (0.108) to the variance of household food consumption scores is recorded by the Migrant Remittances component (**Error! Reference source not found.**). While these transfers help to maintain the livelihoods of agricultural households, they do little to reduce the vulnerability of recipients. The perception of those who receive them is not very reassuring in terms of their ability to maintain stable livelihoods. Only 8% of the households in our sample that received these funds perceive the possibility of maintaining stable livelihoods in the future. However, remittances remain tainted with dependency and vulnerability. As such, this pillar cannot be considered a true strategy for building and strengthening resilience. The same conclusion was reached by R. Sibrian and others in a study on household resilience to food insecurity in Central America and the Caribbean (Sibrian et al., 2021).

The contribution of the distance to basic services (Pillar ABS) component to the variance in household food consumption scores is significant but negative. Indeed, the increasing distance from the farm to basic infrastructure is inversely related to the ability to adapt to climate change and the resilience of smallholder farmers. This result is consistent with those reported in the resilience literature (T. Below et al., 2010; Byrne, 2014; Egyir et al., 2015).

Table 11: Multiple linear regression results of Food consumption scores (FCS) on the pillars of resilience

Components	Standardized beta	*t*	Sig.	Tolerance	VIF
Breeding practice	0.186	3.810	0.000	0.495	2.020
Access to credit	-0.032	-0.674	0.500	0.520	1.923
Housing conditions	-0.032	-0.665	0.507	0.501	1.998
Access to irrigation water	0.723	15.010	0.000	0.507	1.972
Distance to basic services	-0.232	-4.643	0.000	0.471	2.123
Migrant remittances	0.108	2.070	0.039	0.436	2.295

- *N=370*
- *R= 0.756*
- *R^2 = 0.572*
- *Adjusted R^2 = 0.565*
- *Standard error of the estimate = 5.93981*
- *Durbin-Watson= 2.087*

Source: SPSS26 output

4.5.2. The Household Food Insecurity Access Scale (HFIAS)

The same components are considered to test a regression of this indicator of household food security (**Error! Reference source not found.**). The Kolmogorov-Smirnov test in SPSS26 does not verify normality (at the p<0.05 threshold). However, the sample size is sufficiently large (N=370) and the scatter plot shows a distribution of points that is generally between -3 and +3. This shows that the assumption of normality of the distribution of residuals is not a problem for further analysis. The value of the Durbin-Watson statistic is close to 2 (1.758), which means that there is no linear autocorrelation of the residuals in our multiple linear regression model (Durbin & Watson, 1992). We can then continue the analysis with Fisher's test which will verify the significance of the model as a whole.

Fisher's F (6, 363) =167.466, p<0.001 statistic highlights that these variables significantly predict the household food insecurity access scale scores of smallholder farmers in our sample. Also, R^2=0.735 indicates that the independent variables (PCA components) explain 73.5% of the variation in the dependent variable (Household Food Insecurity Access Scale).

The regression coefficients (β) obtained by the six independent variables (predictors) are different from 0 and are significant at the p<0.001 level (**Error! Reference source not found.**). The predictors have a significant impact on the scores obtained on the household food insecurity access scale. In addition, collinearity statistics show tolerance scores well above 0.3 (between 0.436 and 0.520), and the coefficients of the correlation between the independent variables are between -0.7 and +0.7. This excludes the risk of error related to multicollinearity.

Food insecurity access scale scores are inversely related to household resilience. Our original hypothesis (H2) expected a negative effect of predictors on the household food insecurity access scale. The signs of the regression coefficients (β) are negative. This confirms the nature of the correlation expected by the original hypothesis (H2). In this way, the stronger β is in absolute value, the stronger the contribution of the predictor in question to household resilience to food insecurity.

The contribution of the Access to Irrigation Water component is significant and remains the most consistent (-0.576) to the variance of the food insecurity access scale for households in our sample (**Error! Reference source not found.**). Similar conclusions were drawn by Tessema and Simane (2020) in a study they conducted in the Blue Nile basin of Ethiopia. They were able to deduce that irrigation contributes to improving the resilience of smallholder households in the basin by increasing food production and reducing poverty and rural-urban migration (Tessema & Simane, 2020).

Livestock production also makes a significant and important contribution to the resilience of households in our sample to food insecurity (-0.181). Indeed, owning livestock contributes directly and indirectly to household food diversification. Livestock are a kind of savings and store of value for smallholder households. They can convert their livestock into income to cover their food needs, if necessary. Other studies affirm this importance of livestock for household resilience to food insecurity (Melketo et al., 2021; Tatwangire, 2011; Tesfahun et al., 2017; Tincani, 2012).

The contribution of Access to Credit (-0.083) is significant but remains the least consistent among the six components. The use of credit in our study area is less frequent. Only 35% of households report having ever used credit. However, the low contribution of this component in our results runs counter to many of the findings in the literature. Thus, access to credit can increase the disposable income of agricultural households because it is positively associated with a capacity for resilience to food insecurity. This may provide them with more resources to become more resilient to food insecurity (Chamdimba et al., 2021).

Table 12: Multiple linear regression results of Household Food Insecurity Access Scale (HFIAS) on the pillars of resilience

Components	Standardized beta	*t*	Sig.	Tolerance	VIF
Breeding practice	-0.181	-4.714	0.000	0.495	2.020
Access to credit	-0.083	-2.212	0.028	0.520	1.923
Housing conditions	-0.097	-2.542	0.011	0.501	1.998
Access to irrigation water	-0.576	-15.184	0.000	0.507	1.972
Distance to basic services	-0.112	-2.850	0.005	0.471	2.123
Migrant remittances	-0.098	-2.402	0.017	0.436	2.295

- *N=370*
- *R= 0.857*
- *R^2 =0.735*
- *Adjusted R^2 = 0.730*
- *Standard error of the estimate = 3.908*
- *Durbin-Watson= 1.758*

Source: SPSS26 output

5. Conclusion

In Morocco, although food insecurity is not very pronounced, it seems that with climate change things are beginning to change, especially for small farmers in arid and semi-arid areas such as the Souss Valley in south-central Morocco.

This study is based on the RIMA-II resilience framework from FAO (2016). The RIMA-II model is based on four pillars of resilience as latent variables estimated using several observed household-level variables. To identify the main determinants of resilience of smallholder farmers in the Souss Valley, we operated in two steps. First, we used principal component analysis of the four pillars of resilience in RIMA-II to reduce the amount of significant data in each pillar. Eighty-nine variables were mobilized given the complex and multidimensional nature of resilience. The PCA allowed us to identify 13 components, the interpretation of which gives an idea of the main determinants of the resilience of these farming households. These components were then entered into SPSS26 for multiple linear regression.

Six components are considered as predictors of household food security and their contribution is significant at the p<0.05 level. Breeding practice, Access to credit, Housing conditions, Access to irrigation water, Distance to basic services and Migrant remittances. Food Consumption Scores (FCS) and Household Food Insecurity Access Scale (HFIAS) scores are used as indicators of household food security and dependent variables in a multiple linear regression. Access to irrigation water, livestock and access to basic services appear to be the main determinants influencing the resilience to food insecurity of smallholder households in the Souss Valley.

This paper had the merit of analyzing the main determinants of resilience to food insecurity among small-scale farmers in the Souss Valley. It makes at least two important contributions. The first contribution is to enrich the literature on the resilience of small-scale agriculture in an area of the world where this type of research constitutes new areas of investigation. The second contribution is to inform any development project or policy aimed at agriculture in this agricultural region of primary importance to Morocco. In particular, the small-scale farming system in semi-arid to arid environments is changing under the devastating effects of climate change.

According to our results, developing basic infrastructure and services, promoting access to irrigation water, and mobilizing multiple forms of incentives for livestock production are priority measures capable of supporting the resilience of small farmers in the region. They can boost household incomes, keep them in place and contribute to food security for the entire country. Addressing the challenge of food security for these farming households and for society as a whole is becoming a real development issue in a global context of food shortages and overpricing.

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