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Livelihood strategies and household resilience to food insecurity: insight from a farming community in Aguie district of Niger

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Abstract

Niger is regularly affected by food insecurity, mainly due to the high sensitivity of its agricultural sector to climate variability. Despite the support from multiple development institutions and households' willingness to address food security, hunger and malnutrition continue to challenge many vulnerable households. This study aims to analyze household livelihood strategies toward food security and assess factors determining their resilience. To address the issue, cluster analysis and the principal component analysis were used to identify the different livelihood strategies and to construct a resilience index, respectively. Regression analysis was used to identify the most significant factors determining households' resilience. The results indicate there were six different household types—pastoralist-extensive agriculturalists, farmers, agro-pastoralists, public service employees, entrepreneurs and wage employees—however, the majority of households obtained their livelihood from both agriculture and livestock (agro-pastoral systems). The principal component analysis highlighted that the pastoralist-extensive agriculturalists are the most resilient followed by public service employees, while households focused on wage labor are the least resilient, followed by entrepreneurs. In terms of gender, the study reveals that households headed by men are more resilient than those headed by women. However, the resilience components including income and food access, assets and adaptive capacity are the most correlated with the households' resilience to food insecurity. Furthermore, the regression analysis results reveal that the household size, crop production, farming experience, livestock size and number of coping strategies are the most significant factors determining household resilience to food insecurity. Consequently, to face the challenges of climate change and food security, rational investments in agriculture are necessary to transit rural household land-use practices to climate-smart agriculture.

Keywords Adaptation · Climate change · Drought · Dryland · Food security · Vulnerability

Abbreviations

A	Assets
ABS	Access to basic services
AC	Adaptive capacity
ICRAF	International Centre of Research in Agroforestry
IFA	Income and food access
IFAD	International Fund for Agricultural Development
R	Resilience
S	Stability
SSN	Social safety nets
UNICEF	United Nations International Children's Emergency Fund
UTL	Tropical livestock units

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Introduction

In 1987, a group of food security experts perceived the global hunger problem to be one of starvation, resulting in chronic undernutrition and affecting a range of vulnerable groups whose common bond is poverty (Gittinger et al. 1987). Since 1996, food security has become a global policy concern due to its important role in sustaining development and human well-being (Xu et al. 2019). However, the current climate change trend intensifies vulnerability to food security, and the most vulnerable populations are those engaged in rain-fed agriculture, livestock, fisheries, and aquaculture (Marsland 2004; Mendelsohn et al. 2000). Households whose livelihood relies on agriculture are expected to be the most vulnerable due to their low capacity to tackle poverty and agriculture's high sensitivity to climate variability. Boko et al. (2007) argue that agricultural production is likely to be severely compromised by climate variability and change because of high rainfall variability, farmers' low adaptive capacity and their high dependency on agriculture. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease (Collier et al. 2008; Kotir 2011; Mubaya et al. 2010). Müller et al. (2011) presage that in some countries, the climate variabilities and change will lead to a decrease in rain-fed agriculture yields by up to 50% by 2020. This would further adversely affect food security and exacerbate malnutrition in the poorest countries.

Niger is a poor country with an economy that is highly reliant on the agricultural sector, which employs 85% of the country's working population and accounts for about 45.2% of its GDP (Rigourd et al. 2016). However, since 1984, Niger has been confronted with agricultural production shocks of varying magnitude, on average a production shock every five year. There were three foremost production shocks (2000/2001, 2004/2005 and 2009/2010) in the last decade (Michiels et al. 2012). These production shocks were mainly caused by drought and locust invasions, resulting in drastic decreases in cereal production and increases in cereal prices, leading to food shortages and a projected long term food crisis. In 2018, the World Economic Forum listed food crises (i.e., inadequate, unaffordable, or unreliable access to appropriate quantities and quality of food and nutrition on a major scale) at the top of the seven global risks in terms of impact. Food crises combined with other socio-environmental threats lead to permanent food insecurity, which jeopardizes the livelihood of many vulnerable households, especially small-scale farmers and women. However, this situation is not uniform across Niger. The Maradi Region, located in the southern part of the country, has seen the highest level of vulnerability (PANA-Niger 2018). This may be due to the region's high population density, the existence of degraded soils and fragmented farms as well as the farmers' low access to agricultural technologies.

Households' resilience to food insecurity can be enhanced by implementing various adaptation strategies based on both indigenous knowledge and knowledge diffused through extension services targeted at alleviating their exposure to climate variability (Ado et al. 2018). However, the effectiveness of coping strategies to handle production shocks may be well determined by households' adaptive capacity, the assets at their disposal, their social safety net, income-generating activities, and their access to quality basic services (Alinovi et al. 2009). Although some crop seasons have resulted in a cereal surplus, the concern of national development institutions about the food security situation in Maradi Region remains constant. Assessing the level of households' resilience to food insecurity and identifying the key factors affecting their resilience through their livelihood strategies may therefore allow these institutions to prevent or anticipate food crises in this region. According to Alinovi et al. (2010), such a resilience analysis gives insights into households' capacity to handle the adverse effects of unpredictable production shocks. Likewise, knowledge of the factors determining household resilience is very important to improve the response mechanisms related to food security and poverty alleviation.

In Niger, there has been very little research to quantitatively assess household resilience to food insecurity. Most of the relevant studies have focused on vulnerability assessments and the methodologies used for these assessments are static, which has not allowed for accurate predictions of forthcoming events due to the multiple dimensions and complexity of the concept of food security (Alinovi et al. 2009, 2010; Gambo et al. 2016). Thus, to overcome this limitation, this study uses resilience index measurement and analysis (RIMA) models, which is the latest model for food security assessment while determining livelihood strategies and household resilience to food insecurity. Specifically, the study seeks to: (1) identify the different household livelihood strategies, (2) assess livelihood strategies' resilience toward food insecurity, and (3) assess the most influential factors determining livelihood strategies' resilience. To do so, the study attempts to answer the following questions: (1) What are the different livelihood strategies employed by households? (2) To what extent the different livelihood strategies are resilient to food insecurity? and (3) What are the factors determining livelihood strategies' resilience to food insecurity?

Methods

Conceptual framework

Resilience is a concept that originated in ancient thought of ecological literature and was developed in engineering and mathematics before being adopted later by environmental institutions for policy-making (Ciani and Romano 2014; Rutter 2006). In the 1960–1970s, resilience inspired socio-environmental scientists and development institutions to deepen their thinking and research on the adaptation, evolution, and accommodation to stress (Bartlett 1937; Coates

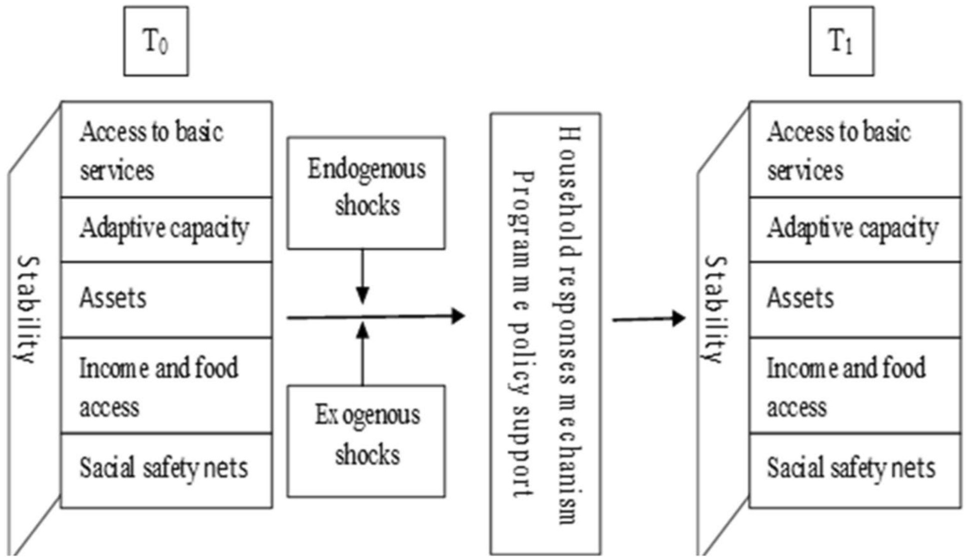


Fig. 1 Conceptual framework for resilience, adopted from Alinovi et al. (2009) and Sjöberg (2000). At time T_1, all the resilience components are expected to change, and its index might be assessed separately to estimate the new level of households' resilience. The resilience R_i for household *i* is given by the following equation: $R_i = \left(IFA_i, AC_i, S_i, SSN_i, A_i, ABS_i\right)$ where *R* is resilience, *IFA* is income and food access, *AC* is adaptive capacity, *S* is stability, *SSN* is social safety nets, *A* is assets, and *ABS* is access to basic services

et al. 2007). Many studies have attempted to define the resilience concept regarding their specific area of interest (e.g. engineering, economy, ecology, mathematics, medicine). However, whatever the definition, it is clear that resilience refers to the ability of a system to withstand and bounce back from shocks or disturbance. Nevertheless, resilience is multi-factorial, and changes depending on the circumstances as well as the system's ability. The type, characteristics, and natural range of variability of stress and disturbance both strongly influence resilience (Mamouda and Cheikh 2010). This statement implies the presence of vulnerability alongside the resilience. Gilligan (1982) and Rutter (1999) argued that resilience and vulnerability may simultaneously coexist within the same system, depending on the degree of the disturbance (Misselhorn 2005).

The study of resilience provides an excellent platform for tracking the evolution of social systems because it provides a framework for the analysis, measurement, and implementation of an effective adaptation mechanism to shocks and constraints in the short-, medium-, and long-term (Amaza et al. 2006). Accordingly, the sources of resilience are various, with the main sources being biodiversity, flexible options for management, norms and rules in human organizations, and cultural and political diversity in social groups (Peng et al. 2002; Sjöberg 2000). Recently, the resilience concept has been applied to household food security to measure the capability of households to absorb the negative effects of unpredictable shocks, rather than to predict the occurrence of a crisis (Mubaya et al. 2010; Nguyen and James 2013; Schreinemachers et al. 2017). The focus of this study is household resilience to food insecurity. In the food security literature, resilience depends on the nature of shocks and the individual household's ability to respond to these shocks. Following previous studies (Alinovi et al. 2010; Collier et al. 2008; Grothmann and Patt 2005a), we assume that a given household's resilience to food insecurity at a given point in time, T_0, depends primarily on the options available to that household to make a living, such as its access to assets, income-generating activities, public services, and social safety nets. These options represent a precondition for the household response mechanisms to a given risk, assuming that between times T_0 and T_1, shocks will affect households. Whether the shocks are endogenous or exogenous to households' control, households use their response mechanisms to bounce back from the shocks. The outcome of these responses depends on households' adaptive capacity as well as the assets they have at their disposal. At time T_1, all the resilience components are quite different than at time T_0. The resilience components depend on the magnitude of shocks received by households at time T_0. Figure 1 presents the conceptual framework for the above-described resilience model.

To estimate *R*, it is therefore necessary to separately estimate *IFA, AC, S, SSN, A* and *ABS*, which are themselves latent variables because they cannot be directly observed in a given survey. Instead, it is possible to estimate them through multivariate techniques.

Sampling technique and data collection

Primary data was obtained through a field survey in Aguie District of the Maradi Region in south-central Niger. The research focused on two purposely selected local villages, namely Guidan Dan May Gari and Guidan Kodaou, located at 13°51′21″N and 08°18′12″E. The two villages were purposely selected with the help of the local government's agricultural services staff through the Extension Services Department, based on the village's level of exposure to

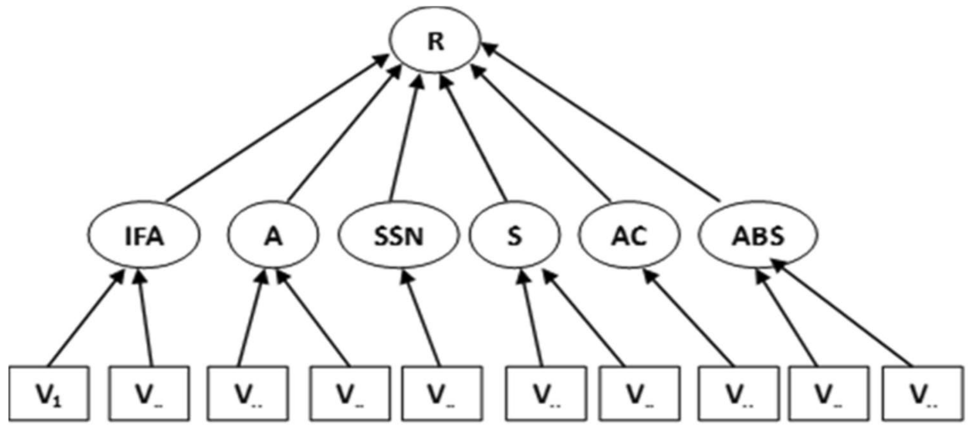


Fig. 2 Analytical model of household resilience (Alinovi et al. 2009). *R* resilience, *IFA* income and food access, *A* assets, *SSN* social safety nets, *S* stability, *AC* adaptive capacity, *ABS* access to basic service, and *V* variable. The variables in circles represent the latent variables whereas the variables in boxes indicate the observed variables (Grothmann and Patt 2005)

rainfall variability (rainfall distribution), the occurrence of crop-related parasite attacks, the number of development projects in the village, and cultural diversity (based mainly on ethnicity). Guidan Dan May Gari village includes a total of 226 households and Guidan Kodaou village includes 220 households. Two reconnaissance visits were successively made to verify the accuracy of the random selection criteria and to test the data collection tools. During the first visit, group interviews were held to obtain relevant background information relative to the existing different livelihood strategies, the different climatic risks and hazards to which households are exposed, households' resilience to food security, factors determining households' vulnerability to food insecurity, coping and adapting strategies to food shock. This information was used in the questionnaire implementation. Likewise, during the second reconnaissance visit, the questionnaire was pre-tested on 10 key informant farmers. The questionnaire items covered the respondents' backgrounds and household characteristics including socio-demographic characteristics, crop production, tropical livestock units (UTL), non-farm activities, access to natural resources, revenue, food expenditure, shocks and disturbances, farm characteristics, infrastructure, support from institutions, and accessibility to public services. After the pre-test survey, the questionnaire was amended accordingly for the formal survey.

To select the participating households to the formal survey, a random, multistage sampling strategy was employed where firstly the household was identified as the unit of analysis. Secondly, the number of households to be surveyed was identified from records at the municipality archives of Aguie District. Thirdly, the respondent households in each of the selected villages were randomly selected based on the household lists provided by the district municipality of local government. A total of 80 households were randomly selected from both villages. At the fourth stage, from each selected household, the household head was interviewed depending on their availability and willingness to participate. A total of 160 randomly selected household heads (35.87% of the population) were interviewed. All interviews were conducted in the local language (Hausa).

Empirical method

In the context of food security, resilience measurement helps to understand and support the capacity of a household to recover from natural and human-induced risks. However, very few studies have quantitatively assessed households' resilience to food insecurity because of its unobservable aspect. The interest of this research is to estimate whether or not a household exposed to food insecurity shock is resilient. To do so, a multistage sampling technique is used. The first step uses cluster analysis to classify households according to their livelihood strategies. The cluster analysis is based on the information on household income sources, productive assets, and occupational activities. Secondly, a multivariate analysis was used to compute the resilience index (Ciani and Romano 2014). Firstly, we used the approach adopted by Alinovi et al. (2009, 2010) to identify the different components determining household resilience. The previous section provides insight into the different resilience components. Observable variables are used to estimate each resilience component separately through factor analysis using the principal component method. The observable variables were chosen based on literature review and data collected in the field. Again, the indexes of the resilience components outlined earlier are used to compute the resilience index through principal component analysis. The analytical schema is given in Fig. 2.

To model the system, we consider that the latent variables (IFA, A, AC, SSN, S, ABS) are not directly observable per se, all that we observe are the sub-components *K* (income, expenditure, education, UTL, strategy…), which, through factor analysis using the principal component method, are used to estimate the components score $(I_{Gi})_{(1 \leq i \leq K)}$ representing *K* latent variables of the resilience index. Again, using the principal component method, the component scores are used to compute the resilience index. The equation of the resilience index (RI) is given by the following form:

$$RI = \frac{\sum_{k=1}^{K} \beta_k I_{Gk}}{\sum_{k=1}^{K} \beta_k} \quad (1)$$

β_k and I_{Gk} represent the weight and the component index of the latent variable *K*, respectively. The weighted sum method was applied to calculate the index of specific factors for which the principal component analysis produced more than 1 factor score of the component index. By doing so, the weighted sum method allows to avoid the risks of multi-collinearity. The weight method used is that proposed by Bartlett (1937) where each factor is multiplied by its own proportion of variance.

A correlation matrix and linear regression using a backward enter method are applied to determine the association between the variables and identify the most influential factors determining household resilience.

Components description and analysis method

Access to basic services (ABS)

This is an important indicator of households' resilience. This indicator is expected to enhance households' resilience by providing key public responses and facilities to quickly withstand and bounce back from shocks. The variables included the level of household education (proportion of household's members who had attended school: from 0 to 1), access to telecommunication services which is a binary variable (1 if yes, 0 otherwise), access to a health center (continuous variable indicating the distance in kilometers from the household to a healthcare center), access to credit service (dummy variable, 1 if yes, 0 otherwise) and access to the market (continuous variable indicating the distance in kilometers from the home to the nearest market). We used factor analysis and scoring method proposed by Bartlett (1937) to construct the household ABS index.

Adaptive capacity (AC)

Adaptive capacity is an indicator related to the ability of households to respond to shocks. The variables used included the number of households' income sources, household's perception of their level of AC which is a dummy variable scaled from 0 to 3, with 0 being a low adaptive capacity level, and the number of coping strategies (ranged from 0 to 10). The factor analysis using principal component method and the scoring were used to construct the household AC index.

Assets (A)

Household assets are another important ingredient representing the household's capital used to quickly cope with stress or shock. The assets included household's tropical livestock units (UTL), farm size (ha), post radio ownership, and mobile phone ownership. UTL and farm size are continuous variables, whereas radio and mobile phone ownership are binary variables which equaled 1 if a member of the household owned these communication devices and 0 otherwise. These variables were used to compute the A index using factor analysis by the principal component method and scoring method proposed by Bartlett (1937). The households with a high A index are expected to be more resilient.

Income and food access (IFA)

This indicator measures households' access to food. The measurement variables included per capita household income (continuous variable in $), a dietary diversity score as a nutritional indicator which was computed using a food security assessment applied to the last 3 days consumption of different food items (categorical variable, 0 = No, 1 = Don't know and 2 = Yes), and per capita household income expenditure (continuous variable in $) (Coates et al. 2007). The factor analysis using the principal component method and scoring method proposed by Bartlett (1937) were run to estimate the IFA indicator.

Social safety nets (SSN)

Social safety is an important dimension of resilience because during shock periods households depend mainly on the assistance received from institutions and relatives. The measurement variables of this indicator included membership of a farmers' association which is a binary variable, equaling 1 if yes and 0 otherwise, the amount of food in kilograms received as assistance from institutions and relatives, and the households' perception of the importance of assistance (dummy scale from 0 to 5). The factor analysis using the principal component method and scoring method proposed by Bartlett (1937) were used to estimate the SSN index. The SSN is expected to improve household resilience.

Table 1 Households' livelihood strategy groups and their characteristics

Livelihood strategy	Frequency	Percent (%)	Income ($)	UTL	Farm size (ha)	Production (kg)
Pastoralist-extensive agriculturalist	6	3.75	5965	14.33	8.92	3260
Farmers	41	25.63	1475	1.75	4.66	1577
Agro-pastoralists	75	46.87	1293	2.57	3.56	906
Public Service employees	8	5.00	2972	1.78	2.75	922
Entrepreneurs	20	12.50	893	1.44	2.70	875
Wage employees	10	6.25	856	0.88	2.70	913
District	160	100	1522	2.51	3.84	1164

Stability (S)

The stability score captured the degree to which a household is exposed to specific risks and shocks. We used the number of times the households were hit by shocks during the last 10 years to estimate the S indicator. The shocks included parasite attacks on crops, flood and drought, human disease, and livestock shock. The factor analysis using the principal component method and scoring method proposed by Bartlett (1937) were used to compute the S indicator. The level of resilience decreases as the S index increases.

Results

Livelihood strategies

A K-Means cluster analysis was run to categorize the households into different strategic groups based on the productive assets (farm size and UTL), the main source of income (share of income from each activity), and main occupational activities. Based on these criteria, the population is divided into 6 groups corresponding to different livelihood strategies. The cluster analysis results and the characteristics of the 6 groups are reported in Table 1.

In the study area, the average household farm size and crop production volume are 3.84 ha and 1164 kg, respectively, while the average UTL and per capita income are 2.51 and $1522, respectively.

The pastoralist-extensive agriculturalists (pastoralists) mainly rely on both farming and livestock and possess a high level of agriculture assets. But these households account for a low proportion of the region's population (3.75%) and 83.33% of them belong to a Fulani ethnic group, who usually live with their animals on the farm. The pastoralists have the largest farm size (8.98 ha), UTL (14.33), crop production (3260 kg), and per capita income ($5965). These households are more oriented towards extensive farming systems.

The farmers' group is the second larger cluster (25.63%) within our sample and are the second largest farm size holders (4.66 ha) and food producers (1577 kg) but have a lower UTL (1.75). Their main activity is growing crops such as *Pennisetum glaucum*, *Sorghum bicolor*, *Phaseolus vulgaris*, *Vigna unguiculata*, *Arachis hypogaea*, *Sesamum indicum*, and *Cyperus rotundus*.

The agro-pastoralists group includes households whose livelihood relies mainly on the combination of crops and livestock. Agro-pastoralism is the most common household livelihood strategy (46.87%). The households belonging to this group hold on average 2.57 UTL and are ranked third in terms of farm size (3.56 ha) and food production (906 kg).

Few households (5.00%) consider public service employment as a main livelihood strategy, with these households ranked second in terms of per capita income ($2972). This group includes households with a member who has completed or is attending a high level of schooling. These households also have at least one member who is working within the education or health care sectors, with the local extension service, or at a development institution. The public service employees are more oriented towards intensive farming systems.

Entrepreneur households includes small traders, haulers, millers, traditional medicine practitioners, carpenters, mechanic attendants and builders and represent only 12.50% of the total population. This is the third most popular livelihood strategy in the study area. Households belonging to the entrepreneur cluster have a small farm size (2.70 ha) and the lowest levels of food production (875 kg) and UTL (1.44).

The wage employees group includes households whose livelihood relies mainly on wage labor. The household members were engaged in varying income-generating activities including as farm laborers, blacksmiths, brick-makers and launderers. Wage labor employees have a farm size below the average (2.70 ha), produce on average 913 kg of food and have the lowest UTL (0.88) and per capita income ($856).

Resilience

Access to basic services (ABS)

The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy shows that the variables used for the principal

Table 2 Correlations of the ABS index with the observed variables

Transformed variables	ABS
Education rate (%)	0.177*
Access to a health center	0.971**
Access to the market	0.966**
Access to credit	0.043
Access to telecommunications	−0.049
N	160

*,**Significant at the 0.05 and 0.01 levels, respectively. Education rate refers to the percentage of person attending school

Table 3 Correlation of the AC index with the transformed variables

Transformed variables	AC
Number of income sources	0.421**
Adaptive capacity perception	0.744**
Coping strategy Index	0.764**
N	160

**Correlation is significant at the 0.01 level

component analysis are relevant (KMO = 0.53). The retained factors include those Eigenvalues are greater than or equal to one (Eigenvalues ≥ 1). The principal component analysis produces 2 factor scores that eigenvalues are greater than or equal to one for the ABS score (see Appendix Table 11). The weighted sum method is thus used to estimate the ABS index by multiplying each factor score by its own proportion of variance.

All the variables are assumed to have positive relations with the ABS latent variable. However, the loading components results show that only the access to telecommunications had a negative and non-significant association with the latent variable. This is because very few of the respondents are exploring this option. Table 2 reports the correlation test results between the variables and the ABS index.

Adaptive capacity (AC)

Adaptive capacity includes households' behaviors and resources to moderate potential damage and cope with the consequences of shocks. Therefore, it is shown to be a necessary condition for the design and implementation of effective strategies to improve resilience. The results of the model significance test show that the model is relevant (KMO = 0.53). The principal component analysis produces one factor score which was considered as the AC index (see Appendix Table 12). The transformed variables show a higher positive correlation with the latent variable. Therefore, the increase of these variables (proxies) will increase the level of AC. Table 3 shows the results of the correlation test between the variables and the AC index.

Table 4 Correlation of the A index with the transformed variables

Transformed variables	Assets index
UTL	0.767**
Farm size	0.792**
Mobile phone	0.161*
Post radio	−0.289**
N	160

*,**Significant at the 0.05 and 0.01 levels, respectively

Table 5 Correlation of the IFA index with the transformed variables

Transformed variables	IFA
Total income	0.799**
Expenditure index	−0.833**
Dietary diversity	0.513**
N	160

*,**Significant at the 0.05 and 0.01 levels, respectively

Assets (A)

The assets the households have at their disposal may well determine their shock-coping capacity. The results of principal components analysis indicate that the model is satisfactory (KMO = 0.52) and produces 2 factor scores for the A index (see Appendix Table 13). Therefore, the weighted sum method was used to normalize the A index.

All the transformed variables are significantly correlated with the A latent variable. However, the post radio variable is negatively associated with the A latent variable. This might be due to the fact that households are now more likely to use the radio application on the mobile phone to access post radio functions. The results of the correlation test between the variables and the A index are presented in Table 4.

Income and food access (IFA)

The principal component analysis results for the IFA variable show that the model is reliable (KMO = 0.55) and produced one factor score (see Appendix Table 14). The correlation results reveal a perfect association between the IFA latent variable and the transformed variables. As expected, household expenditure shows a negative association with IFA because its score increases when the food security decreases. The Table 5 presents the results of the correlation test between the variables and the IFA index.

Table 6 Correlation of the SSN index with the transformed variables

Transformed variables	SSN
Food support	0.775**
Importance of support	0.689**
Association member	0.451**
N	160

*,**Significant at the 0.05 and 0.01 levels, respectively

Table 7 Correlation of the S index with the transformed variables

Transformed variables	S
Pest and parasite	0.202
Flood and drought	0.783**
Human diseases	0.431**
Fire	−0.385**
Livestock shocks	0.781**

*,**Significant at the 0.05 and 0.01 levels, respectively

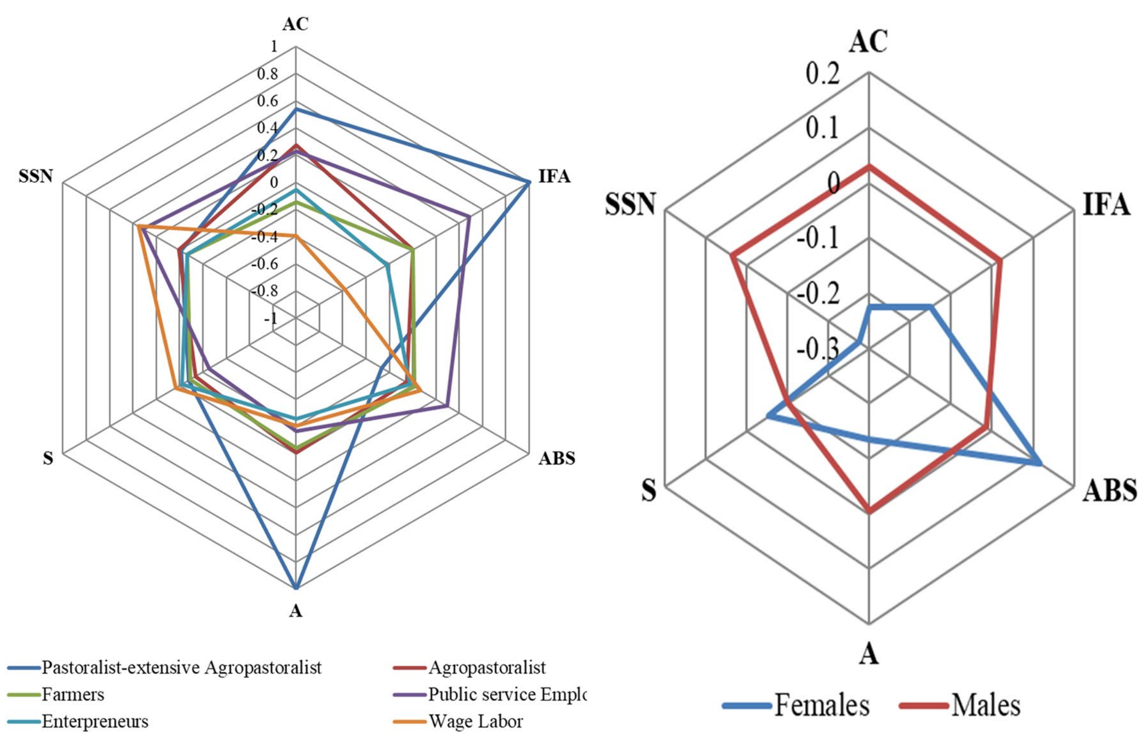


Fig. 3 Radar graph for the resilience components among the different household livelihood strategy groups

Social safety nets (SSN)

Social safety is an important resilience ingredient because during shock or stress periods, households rely more on development institutions and support from relatives to cope with the new circumstances. The principal component analysis produced 1 factor score (see Appendix Table 15) and KMO results reveal that the model is reliable (KMO = 0.52). As expected, all the transformed variables have a positive impact on SSN. The results of the correlation test between the latent variables and the SSN score is summarized in Table 6.

Stability (S)

The S indicator helps to capture households' degree of exposure to natural risks or disasters. This indicator is expected to decrease the resilience level. The component analysis results produced 2 factor scores for the S index (see Appendix Table 16), thus, the weighted sum method was used to normalize the S index. The KMO results show that the model is satisfactory (KMO = 0.57) and all the transformed variables except fire shock have a positive impact on the latent variable S. The results of the correlation test between the variables and the S index are reported in Table 7.

The results of the principal component analysis for the resilience indicators are reported in Fig. 3. This figure captures the variation in the resilience components among the different household livelihood strategy groups.

The results from Fig. 3 show that the resilience components are not normally distributed among the different

Table 8 Correlation of the resilience index with the transformed variables

Variables	Resilience index
Income and food access (IFA)	0.816**
Social safety nets (SSN)	− 0.011
Access to basic services (ABS)	0.616**
Stability (S)	0.282*
Adaptive capacity (AC)	0.620**
Assets (A)	0.624**

*,**Significant at the 0.05 and 0.01 levels, respectively

livelihood groups. The pastoralist-extensive agriculturalists group has the highest scores for A, IFA and AC but the lowest score for ABS and a very low score for the SSN. This group is followed by agro-pastoralists and public service employees' groups that both have high scores for A, AC and IFA. Entrepreneurs have low scores for all the components. The results also indicate that wage employees have the highest SSN index and are therefore the most stable households for this component. This is because entrepreneurs and wage employees depend less on agriculture, and thus own fewer agricultural assets (land, livestock). They are therefore less subject to climate risks (parasite attacks, flood and drought, and livestock diseases). If we assume that A, AC and IFA are the most important explanatory variables for resilience, we can therefore expect that pastoralist-extensive agriculturalists, agro-pastoralists and public service employees may have a satisfactory resilience index.

Resilience index measurement (RI)

The principal component method was performed to estimate the resilience index (RI). The previously estimated components were used as a proxy for the latent variable RI. Before estimating the RI, the factor scores were generated using the principal component method. The principal component analysis produced 3 factor scores for the RI. To avoid the risks of multi-collinearity, the weighted sum method was used to normalize the RI. The correlation analysis was performed to test the association between the transformed variables and the RI. The results are presented in Table 8.

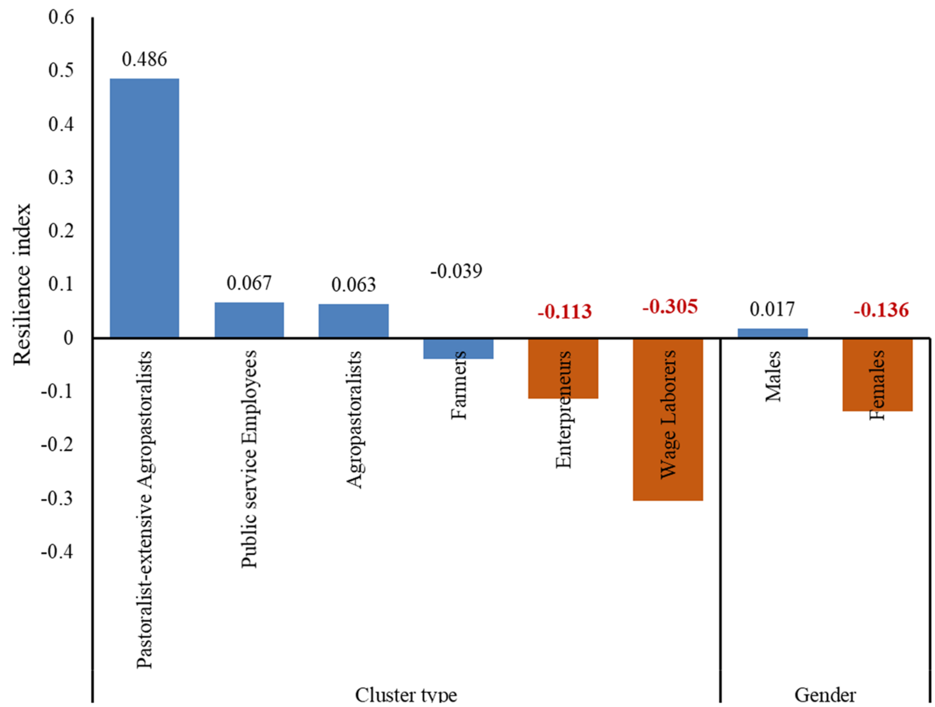
As expected, IFA, ABS, AC and A show a positive and significant association with the resilience index. IFA, A and AC indicate the highest correlation; therefore, we can confirm our hypothesis that these components are the most determinant of household resilience. Surprisingly, SSN indicates a negative association. This implies that the SSN decreases as resilience increases. Observational evidence from the field reveals that in the community, the persons with low levels of resilience tend to enlarge their social network in the hope of benefiting from social support during shock periods. Therefore, the lower the resilience, the greater the chance of social network development.

A comparison of means test was used to analyze the difference in resilience between each household livelihood strategy group and gender in the study area. The results show that the average of the resilience index in the study area is − 0.013, with a 0.213 standard deviation. The high standard deviation demonstrates that the distribution of the resilience index within the sample is very heterogenous. The pastoralist-extensive agriculturalists group who hold the highest scores for A, IFA and AC have the highest level of resilience (0.486), followed by public service employees group (0.067). The group of households depending on wage labor are the least resilient (− 0.305), followed by the entrepreneurs group (− 0.113). Regarding gender, the results show that the households headed by men are more resilient than those headed by women. The results are reported in Fig. 4.

Discussion

The results from Figs. 3 and 4 show that the resilience components and resilience score, respectively, are not normally distributed between and within different livelihood groups. The pastoralist-extensive agriculturalists group, which has the highest resilience score, lack access to a social safety net and basic services; compared to the wage employees who are the least resilient but hold the highest score for access to a social safety net. There are few pastoralist-extensive agriculturalist households among the population of the study area and they belong to a Fulani ethnic group who usually live with large numbers of animals on the farm (an integrated crops and livestock farming strategy). This strategy contributes to reducing the costs related to crops and livestock production by providing organic fertilizer and animal fodder, while also decreasing the exposure of the farming system to biotic and abiotic shocks. As shown by several studies (Teklewold et al. 2016; Zhong et al. 2010), organic fertilizers reduce soil exposure and sensitivity to climate variability and therefore increase the productivity of the farming system. The more the farmer applies organic fertilizers, the higher the chances of improved production. Therefore, there is a need to promote strategies for soil fertility management and to improve the capacity of extension services to help farmers develop and implement more efficient irrigation techniques to help save water. Additionally, in a normal situation (without animal diseases), the crop production has a positive association with livestock, and therefore the better the crop production the greater the livestock production. Hence, an integrated crops-livestock farming strategy strengthens the production system and increases the pastoralist-extensive agriculturalists' resilience to food insecurity. Additionally, the pastoralist-extensive agriculturalists have

Fig. 4 Resilience index by household livelihood strategy



a large farm size and are therefore more oriented towards extensive farming systems which might make them more resilient to climate risks.

Living on the farm far from the village makes the pastoralist-extensive agriculturalists more disconnected from society as well as public services. Hardo, a pastoralist from Guidan Kodaou reported that "one of their big challenges for adaptation is the distance to the market, school for their children, health center and water source." Abdou, from the same village, supported Hardo's statement by reporting that "our children are not attending school because it is not safe for them to travel alone a long distance every day and for public services such as a health center, market as well as water sources, we have to spend long distance of walking". However, income and food access, assets and adaptive capacity are issues for wage employees who are the least resilient and whose resilience relies mainly on their access to a social safety net. Likewise, the results reveal a negative association between a social safety net and the resilience index (−0.011). This means that access to a social safety net may be a good indicator of vulnerability. Thus, the more vulnerable the household the more it develops its social network. This is why Alinovi et al. (2009) reported that social networks increase as resilience decreases. By unifying their weakness, the most vulnerable people become stronger (more resilient). A social network is therefore good capital for vulnerable people who anticipate shocks and a great indicator for the targeting of vulnerable people. In the study area, it appeared that waged labor is a strategy employed by the least resilient due to their inadequacy of household assets.

With regards to gender, households headed by women, who are the least resilient, indicate the highest score for access to basic services. Households headed by women are also the most stable. In contrast, stability is a major issue for households headed by men. Access to public services is facilitated for women by the gender-focused promotion of development institutions (UNICEF, IFAD, and Save the Children). Households headed by women are also less dependent on the agricultural sector. This mean that while access to public services is important, it is less of a determinant factor for household resilience to food insecurity. This result is consistent with the findings of Kebede et al. (2016) who report that weak access to public services increases when households become poorer. Likewise, stability is very important for households whose livelihood relies on farming. The main implication of these results is that assets, income and food access, and adaptive capacity are the most important factors determining households' resilience to food insecurity; and social safety net is a great indicator of vulnerability. Specific attention might be given to women-headed households and households dependent on wage labor to improve their asset base, specifically productive assets such as farmland and animals.

The resilience components analysis by livelihood group is very important for policymakers to identify the most vulnerable groups and to know the focus of the intervention. However, resilience analysis using various components can result in underestimations and mis-classifications of possible

Table 9 Descriptive statistics of selected variables

Variables	Mean	SD
Resilience index	−0.013	0.213
Household size	8.48	4.441
Strategies score	7.07	2.056
Farming experience	31.09	13.10
UTL	2.51	3.48
Food production	1163	1132
Association membership (0 = No, 1 = Yes)	0.33	0.47
Education level (0–2)	0.78	0.89

Table 10 Factors determining households' resilience to food insecurity

Variables	Beta	t	Sig.	Tolerance	VIF
(Constant)		−8.048	0.000		
Household size	−0.210	−4.226	0.000	0.837	1.194
Strategies score	0.271	5.706	0.000	0.921	1.086
Farming experience	0.129	2.613	0.010	0.855	1.169
UTL	0.383	7.715	0.000	0.841	1.189
Crop production	0.500	10.115	0.000	0.848	1.179
Association membership	0.024	0.459	0.647	0.787	1.271
Education level	−0.025	−0.497	0.620	0.842	1.187

food-insecure households (Vaitla et al. 2017). Further, this approach does not tell the entire history of households' resilience and the most influential observed factors determining resilience because within the same livelihood group, there can be a high variance of the resilience index and its components. For example, within the pastoralist-extensive agriculturalists group, the variance is 9.60%, whereas it is 15.00% and 19.70% within the agro-pastoralist and wage employee groups, respectively. Moreover, many variables were used to construct one resilience component; thus, the unobserved aspects of resilience components limited the ability of the key observed factors to determine the resilience. Therefore, regression analysis using observed variables may be more explicit for identifying the observed factors determining household's resilience. Tables 9 and 10 present the descriptive statistics of selected variables and the regression results, respectively.

The selected variables explain almost 68.5% of the variance. The OLS test produces $F = 47.21$ (p value $= 0.000$), so the null hypothesis (constant variance) is accepted. The variance inflation factors (VIF) shown in Table 10 are all very low, so the hypothesis of collinearity is rejected.

Results from Table 10 reveal that crop production is the most important factor determining resilience to food insecurity. The study reveals that crop production significantly increases the likelihood of household resilience to food insecurity. The higher the crop production, the better the chance the household will be resilient.

The regression results indicate that the larger the household size, the less likely the household will be resilient. A one person increase in household size decreases the probability of household resilience by 21%. This might be due to an increase in the inactive population in the household. Amaza et al. (2006) support our finding by reporting that the larger the number of less-active adults and children, the higher the burden of the active members in meeting the cost of minimum household nutrition and hence, the higher the level of household food insecurity.

Being a member of a farmers' association increases the likelihood the household will be resilient. The households connected to farmers' associations benefit in terms of social support from diverse sources, including the association, development institutions and extension services. Keil et al. (2008) reported that during crises, vulnerable households are able to benefit considerably from the support provided by an extensive social network. These authors found that participation in organizations positively influenced household resilience. This is strongly supported by Alinovi et al. (2009), who reported that the individual initiatives, when backed by strong social networks of solidarity, have enabled dryland farming communities to absorb the negative impacts of significant shocks.

UTL (proxy for assets) is expected to be a key factor for resilience to food insecurity. During food shortages or other constraints, households may convert their assets (including livestock) into income or food. This is certainly why Keil et al. (2008) highlighted that assets have a positive impact on household resilience. Likewise, when a shock (such as human disease) occurs or there are social constraints, households will often sell some of their assets to respond.

As expected, household resilience to food insecurity is also significantly influenced by farming experience. This is because of the link between farming experience and farm productivity (crops and livestock). The farmers with a high level of farming experience have greater risk management skills, especially drought risk, which is an important driver of food insecurity in the study area.

Formal education is expected to be an important factor in increasing households' level of resilience. However, the higher the education level of the household head, the less food-secure is the household. This is because such households rely more on markets than crop production for their consumption, and the higher the education level of the household head, the lesser the household depends on agriculture. This is consistent with Amaza et al. (2006), who reported that the livelihood of a household with a high education level relies more on public services than agriculture, and even households depending on agriculture are assumed to have better food management techniques that will ensure a year-round supply of food.

Principal component analysis revealed that adaptive capacity is the most important resilience component after assets and income and food access. The coping strategy score, as the main proxy determining household adaptive capacity, is expected to positively impact household resilience to food insecurity. The regression results reveal that the more the household employed coping strategies, the more likely the household would be resilient. One additional coping strategy increases the level of resilience by 0.27. Ibok et al. (2019) report that a majority of households used several coping strategies when there is a food deficit. This is consistent with the results of with Alinovi et al. (2010), who found that the number of coping strategies adopted by Palestinian farmers increased their level of resilience to food insecurity.

Conclusion

Households' resilience to food insecurity depends on the risks they are exposed to, their capacity to respond to shocks, and their ability to predict future risks. The households' ability to respond to shocks and anticipate risks is highly dependent on their livelihood strategy. Hence, grouping households according to their livelihood strategy is crucial for the design and implementation of targeted adaptation strategies as interventions to strengthen households' resilience to food insecurity. This study therefore aimed to assess the different livelihood strategies and levels of resilience to food insecurity among households in the Maradi Region of southern Niger—a region with a high level of household vulnerability to food insecurity.

The cluster analysis identified six major livelihood strategy groups—pastoralist-extensive agriculturalists (3.80%), farmers (25.6%), agro-pastoralists (46.9%), public service employees (5.5%), entrepreneurs (12.5%) and wage employees (6.3%). The results from the resilience components analysis show that pastoralist-extensive agriculturalists who are the most resilient (0.486), have the highest score for assets (0.987), income and food access (0.988), and adaptive capacity (0.537), but have a very low index for social safety net (− 0.011) and the lowest for access to basic services (− 0.265). The pastoralist-extensive agriculturalists group is followed by the public service employees with a higher index for resilience (0.067), determined by higher score of adaptive capacity (0.229), and income and food access (0.489). The wage employees who are the least resilient (− 0.305) has the highest score for social safety net (0.354), whereas the entrepreneurs group has a negative value for all the resilience components and hold very low level of resilience (− 0.113). Regarding gender, the households headed by men are the most resilient (0.017) and have the highest scores for income and food access (0.019), assets (− 0.005), adaptive capacity (0.029) and social safety net (0.035), whereas the households headed by women have the highest score for access to basic services (0.117), and stability (− 0.054). The main implication of these results is that assets, income and food access, and adaptive capacity are the most important factors determining households' resilience to food insecurity; and social safety net is a great indicator of vulnerability. Therefore, specific attention should be given to small-scale farmers such as wage employees, entrepreneurs and women for resilience capacity building. The inferential analysis results reveal that income and food access (0.816), assets (0.624), adaptive capacity (0.620), and access to basic services (0.616) are highly correlated to households' resilience to food insecurity. More specifically, the regression results show that resilience to food insecurity is significantly determined by household size ($\beta = -0.210$; $p \le 0.000$), number of coping strategies ($\beta = 0.271$; $p \le 0.000$), farming experience ($\beta = 0.129$; $p \le 0.010$), livestock size or UTL ($\beta = 0.383$; $p \le 0.000$), volume of annual crop production ($\beta = 0.500$; $p \le 0.000$). However, it is imperative to know that the group with the highest (or the lowest) adaptive capacity is not necessarily the most resilient. Agro-pastoralists group have the highest score of adaptive capacity, yet they are less resilient than public service employees as a result of high income and food access. Likewise, wage labor employees have more asset than entrepreneurs but are the least resilient. Similarly, the group with the highest stability or access to basic service is not necessary the most resilient. The households headed by men have the lowest score of stability and access to basic services yet are the most resilient resulting from higher score of adaptive capacity and income and food access. This implies that the combination of adaptive capacity, access to basic services, assets, income and food access, stability and social safety net are very important in understanding and determining resilience to food insecurity.

Based on the research findings, the development of institutions to improve farmers' income and food access, and adaptive capacity toward food insecurity could help to increase their resilience to food insecurity. This would inevitably lead to a more sustainable use of natural resources and the improvement in households' production system depending on household's livelihood strategy.

The study's findings are, however, limited by data availability and the sample size. A comprehensive resilience assessment requires substantial data and relevant information is limited, especially data regarding food production shocks and risks assessment or information related to socio-environmental risks in the study area. Climate-related risk information in the study area is particularly difficult to uncover. The sample size is another critical limitation of the study, decreasing the accuracy of results analysis. A related challenge was the limited resources available for undertaking the household interviews. To overcome these limitations, we suggest extending the research into the other ecological regions of southern Niger and allocating more resources for field-based data collection. To address the issue of the dearth of climate-related risk information for the study area, future investigations should focus on this insufficiently covered domain.

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Appendix: Results of the sub index construction

See Tables 11, 12, 13, 14, 15, and 16.

Table 11 Access to basic services

Component	Eigenvalues	Variance %	Cumulative %
1	2.041	40.811	40.811
2	1.416	28.330	69.141
3	0.877	17.536	86.677
4	0.560	11.196	97.873
5	0.106	2.127	100.000

Table 12 Adaptive capacity

Component	Eigenvalues	Variance %	Cumulative %
1	1.314	43.800	43.800
2	0.953	31.767	75.567
3	0.733	24.433	100.000

Table 13 Assets

Component	Eigenvalues	Variance %	Cumulative %
1	1.431	35.765	35.765
2	1.083	27.063	62.828
3	0.845	21.129	83.956
4	0.642	16.044	100.000

Table 14 Income and food access

Component	Eigenvalues	Variance %	Cumulative %
1	1.595	53.172	53.172
2	0.889	29.634	82.806
3	0.516	17.194	100.000

Table 15 Social safety nets

Component	Eigenvalues	Variance %	Cumulative %
1	1.270	42.342	42.342
2	.968	32.270	74.613
3	.762	25.387	100.000

Table 16 Stability

Component	Eigenvalues	Variance %	Cumulative %
1	1.549	30.975	30.975
2	1.042	20.848	51.823
3	0.949	18.982	70.806
4	0.857	17.141	87.947
5	0.603	12.053	100.000

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