

Strengthening Household Resilience Capacity to mitigate Climate Change for Sustainable Food and Nutritional Security in Benin

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Abstract

This study analysed the impact of the integrated adaptation programme to mitigate the adverse effects of climate change on agricultural production and food security in Benin to strengthen household resilience capacity for food and nutritional security. The research was carried out in the nine most vulnerable communes to climate change of Benin: Malanville, Ouaké, Savalou, Aplahoué, Sô-Ava, Ouinhi, Matéri, Bopa, and Adjohoun. A

combined qualitative and quantitative approach was used for data collection from eighteen villages (nine beneficiary and nine control villages) through group discussion and individual interviews using checklists and structured questionnaires. Using a counterfactual approach, 508 respondents (i.e., 254 beneficiaries and 254 non-beneficiaries) were interviewed. Data analysis comprised descriptive statistics, food and nutrition indicators, comparison tests, and logistic regression. The assessment of food insecurity indicators in the communes identified moderate and severe levels of food insecurity. There were significant differences between beneficiary and non-beneficiary households in terms of both food and nutritional security ($p < 0.05$) and food insecurity ($p < 0.05$). Female-headed households had a higher probability of experiencing food insecurity (15.15%) compared to male-headed households (8.56%). Binary logistic regression results indicated that age, gender, and education were the determinants of food security status. Furthermore, dietary diversity assessment indicated that the integrated adaptation programme to mitigate the adverse effects of climate change on agricultural production and food security in Benin beneficiary households had more diverse diets compared to non-beneficiary households.

Keywords: Climate change, food and nutrition security, food diversity, resilience, Benin

Introduction

In West Africa, enhancing production factor productivity is crucial for the success of rural development strategies (Ngondjeb et al., 2014). In Benin, agriculture remains the primary economic activity, employing 70% of the workforce in smallholder farming (GIZ, 2015). Over the past decade, approximately 2.2 million hectares of agricultural land were degraded, representing 19% of the national territory (Cornell, 2016). Multiple factors contributing to this degradation include: unsustainable agricultural practices, overgrazing, bush fires, excessive mowing, pesticide overuse, and water and wind erosion, all exacerbated by climate change in recent decades. These factors have increasingly exacerbated agricultural production conditions (Caquet, 2014; Chanzy, 2015). Such climatic uncertainties concern farmers as they negatively impact agricultural yields through their effects on plant growth, development, and varietal diversity (Rahman et al., 2015).

The progressive soil degradation led to declining crop productivity, resulting in food insecurity and significantly reduced farmer incomes (GIZ, 2015). Globally, severe food insecurity affects 689 million people, with Africa being one of the most concerning regions (FAO et al., 2017). According to Vall et al. (2017), improving cereal and livestock yields is essential for enhancing household food security. Agricultural growth

represents an effective approach to reducing hunger and malnutrition, particularly as rural populations largely depend on agriculture and related activities for their livelihoods (Ken et al., 2016; Silva et al., 2015).

Addressing these challenges requires identifying sustainable, ecologically sound, and socio-economically viable solutions to achieve adequate production levels at the farm scale (Guibert et al., 2016). In response, the "Integrated Adaptation Programme to Combat the Adverse Effects of Climate Change on Agricultural Production and Food Security in Benin" was developed and implemented in the most climate-vulnerable communes. This programme, aimed at mitigating climate change impacts, intensive agriculture, and food security, presents an opportunity to enhance agricultural productivity, food security, and water availability (MAEP, 2011). Through its interventions, the PANAI programme has implemented various demonstrative research findings to strengthen household resilience for food and nutrition security. This study evaluates the programme's impact on enhancing the resilience capacity building of farmers in targeted rural communities to achieve food and nutrition security.

Methodology

Study areas

The study was conducted in nine departments of Benin—Alibori, Atacora, Atlantique, Collines, Couffo, Donga, Mono, Ouémé, and Zou—specifically in the municipalities of Benin comprising Malanville, Matéri, Bopa, Sô-Ava, Savalou, Aplahoué, Ouaké, Adjohoun, and Ouinhi (Figure 1). Project interventions varied by commune based on predominant agricultural activities and farmer preferences. PANAI's interventions in animal and fishery production focused on Sô-Ava, Adjohoun, Bopa, Ouinhi, and Ouaké. Crop production interventions covered all communes and included the provision of improved short-cycle seeds, production equipment, storage infrastructure, training on soil fertility management and market gardening, and support for community and private forest plantations. Processing activities were concentrated in Ouaké and Matéri, where women received training in modern agri-food processing techniques along with processing equipment and storage infrastructure (Akpovi et Vissoh, 2022).

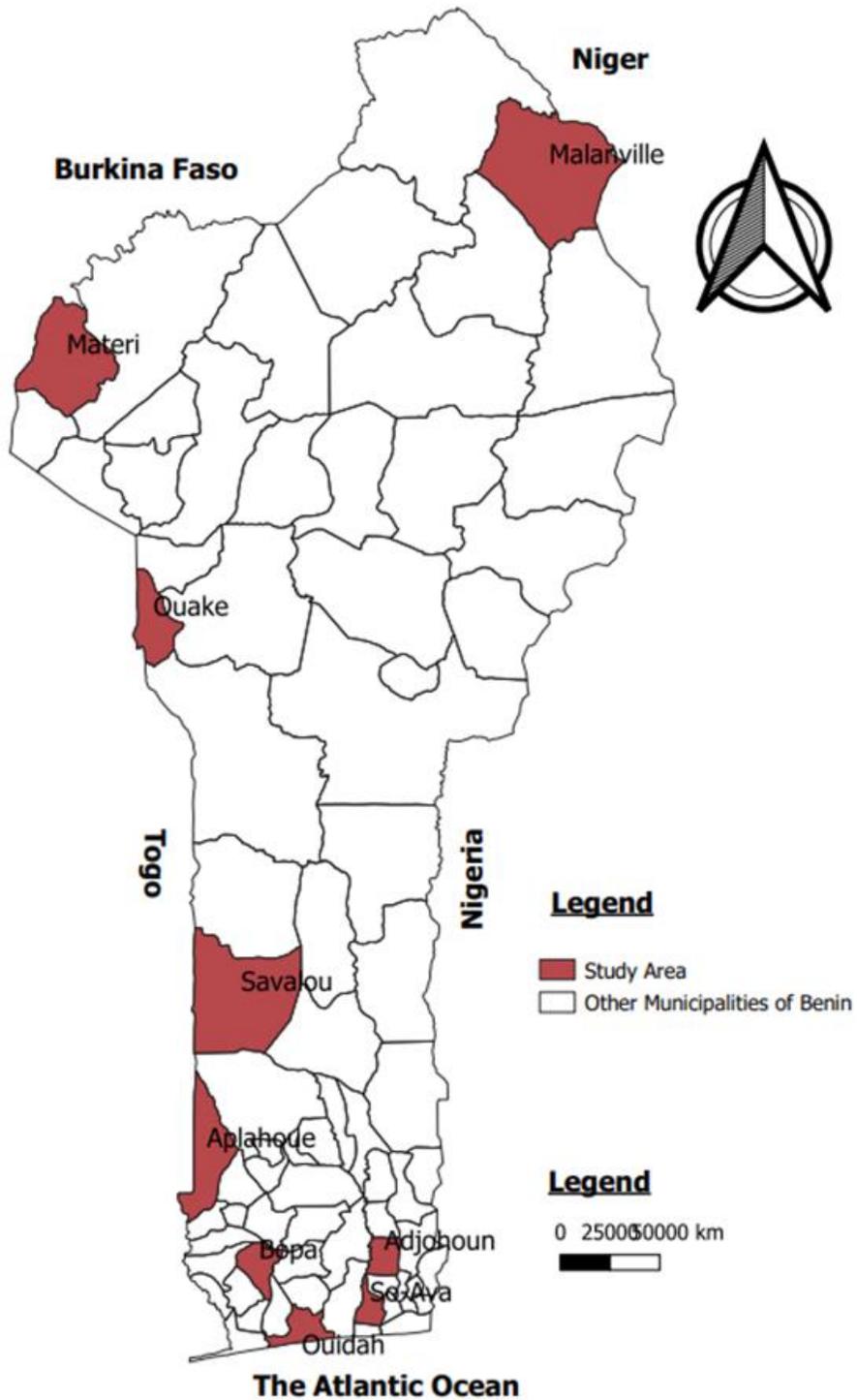


Figure 1: Map of the Republic of Benin showing the study area

Sampling

The sample size estimation was carried out in order to have a representative sample for reliable point estimates of the main relevant outcomes in the study area. To determine the sample size,

The formula of UN (2010) was used as follows:

$$n = \frac{(z)^2 * (p) * (1 - p)}{(\delta)^2}$$

Thus, on the following assumptions:

- 95% confidence level ($\alpha = 0.05$); $z = 1.96$;
- prevalence of beneficiaries and non-beneficiaries = 50%; $p = 0.5$
- margin of error = 5 % ; $\delta = 0,05$.

Replacing the components of the formula with their values gives the following sample size n_1

without taking into account the non-response rate:

$$n_1 = \frac{(1,96)^2 * (0,5) * (1-0,5)}{(0,05)^2} = 385 \text{ respondents}$$

The overall non-response rate was estimated at 10%, i.e. $n_2 = 40$ respondents.

Consequently, the minimum size of beneficiaries' respondents to be surveyed for the nine communes was $n = n_1 + n_2 = 425$ respondents

A sample size of 425 is sufficient for a prevalence of 50% of beneficiaries and non-beneficiaries' respondents. The counterfactual approach would require an equivalent number of beneficiaries and non-beneficiaries in each municipality (Table 1). In total, data were collected from a sample of 508 (beneficiaries and non-beneficiaries).

These respondents were spread across nine (09) municipalities that were beneficiaries of the PANAI programme interventions. In each commune, two villages were selected. One beneficiary village and one non-beneficiary village, making a total of eighteen (18) villages. The respondents in these eighteen (18) villages were then divided into two groups: all non-beneficiaries of the PANAI programme interventions, called controls, and all beneficiaries of PANAI programme interventions, called beneficiaries (Table1). These 508 respondents were randomly selected. Data were collected through focus groups and administration of a structured questionnaire to individual households.. The administration of the questionnaire involved both beneficiary and non-beneficiary household heads. The number of households per village was chosen according to the proportionality rule (Table1).

Table 1: Sampling of beneficiaries and non-beneficiaries of PANAI

Municipalities	Villages	Beneficiaries	Non Beneficiaries
Adjohoun	Houéda	24	
	Ouêdo-Wo		24
Applahoué	Lagbavé	23	
	Wakpé		23
Bopa	Sèhomi	13	
	Zizagué		13
Mallanville	Toumboutou	46	
	Madécali		46
Matéri	Kankini-Séri	42	
	Tantéga		42
Ouaké	Kadolassi	43	
	Mami		43
Ouinhi	Adamè	31	
	Ouokon		31
Savalou	Damè	20	
	Lama		20
Sô-Ava	AhomeyHounmey	12	
	Kinto Dokpakpa		12
Total		254	254
			508

Data collection

The data collected related to: (i) socio-economic and demographic characteristics of households, (ii) vulnerability indicators, (iii) technology adoption indicators and (iv) food security (food availability) at the household level as well as beneficiaries' perceptions of PANAI interventions through testimonials (verbatim) during focus group discussion.

Analysis of the data

The data collected with the Kobocollect application installed on the tablets and Smartphones were extracted in Excel format. Stata15 and SPSS.20 software were used to calculate frequencies (qualitative variables), means and standard deviations (quantitative variables) and for generalisation analyses. The level of food security was determined using the World Food Programme's (WFP) Consolidated Approach to Reporting on Food Security Indicators (CARI). This approach allows food security indicators to be combined in a systematic and transparent way in order to establish an explicit classification of households. On the basis of the CARI, each surveyed household head was classified according to a composite food security index (Food Security Index) into four categories: Food Secure (FS), Borderline Food Secure (BFS), Moderately Food Insecure (MFI), or Severely Food Insecure (SFI). The classification algorithm was based on a combination of indicators including at least one indicator to measure current

food consumption (in this study this is the food consumption score); an indicator measuring economic vulnerability (i.e. the share of food expenditure) and the livelihoods-based coping strategies indicator (N'diaye, 2014). Household food expenditure is calculated in relation to the last 30 days. The proportion of food expenditure in overall expenditure is obtained by dividing overall food expenditure by total household expenditure, i.e. food and non-food expenditure expressed as a percentage.

Example: 20kg of millet consumed in the last 30 days = X FCFA (1).

(Wood, gas, oil, soap) consumed in the last 30 days = X FCFA (2).

(Clothing, education, health and other) consumed in the last 30 days valued per month = X FCFA (3).

$$\% \text{ food expenditure} = (1)/(1)+(2)+(3) * 100$$

$$\text{NB: Overall expenditure} = (1) + (2) + (3).$$

The Food Consumption Score (FCS) approach was used to determine the food security status of households based on the nutritional value of foods consumed in the surveyed households during a week, taking into account the weighting coefficients defined by WFP for 8 product categories: 2 for cereals and tubers, 3 for pulses, 1 for vegetables and fruits, 4 for meat and fish, 0.5 for sugar and oil, and 4 for dairy products.

This indicator classifies the food situation of households into three categories, namely poor (FCS < 21), borderline (between FCS 21.5 - 35) and acceptable (FCS > 35) (Ndiaye, 2014; FAO and WFP, 2013). The formula used to determine this indicator was:

$$\text{SCA} = a_{\text{cereals}} \times x_{\text{cereals}} + a_{\text{legumes}} \times x_{\text{legumes}} + a_{\text{vegetables}} \times x_{\text{vegetables}} + a_{\text{fruit}} \times x_{\text{fruit}} + a_{\text{animal}} \times x_{\text{animal}} + a_{\text{sugar}} \times x_{\text{sugar}} + a_{\text{milk}} \times x_{\text{milk}} + a_{\text{oil}} \times x_{\text{oil}} \text{ (FAO and WFP, 2013).}$$

Where, a_i : Weighting coefficient assigned to the food group; x_i : Number of days of consumption for each food group ($d \leq 7$ days).

The Coping Strategies Index (CSI) was calculated to determine the level of household vulnerability but also the level of risk to household livelihoods. In terms of frequency, a strategy used every day has a score of 7 points; often 4.5 points; rarely 1.5 points and never 0 points. The severity weight of a strategy is in the range of 1 to 5. For this indicator, households with a high SSI are the most vulnerable and have a low capability structure. Households with an SSI between 0 and 1 will be considered non-vulnerable households, those with an SSI between 2 and 3 are medium vulnerability households, and households with an SSI between 4 and 5 will be at risk of vulnerability.

The formula used to find the SSI was:

$$\text{ISS} = \text{strategy 1 (frequency} \times \text{severity)} + \text{strategy 2 (frequency} \times \text{severity)} + \text{strategy 3 (frequency} \times \text{severity)} + \dots \text{ (FAO and WFP, 2013).}$$

The food security reporting table is the final product of the CARI approach. It combines this set of food security indicators into a single indicator called the food security index that presents the overall food security status of the surveyed population. The table represents two key dimensions of food insecurity. The "current status" domain measures whether the current food consumption of households is satisfactory. The 'coping capacity' domain employs indicators that measure economic vulnerability and depletion of household assets. The Logit model was used for the determinants of the respondents' food security level. In the literature, the Probit and Logit models are the most commonly used to specify the relationships between the probability of choice and the determinants of choice (CIMMYT, 1993). Logit has the advantage of facilitating the interpretation of the β parameters associated with the explanatory variables x_i . A logistic regression analysis was therefore used. The choice of this model lies in the fact that it is well suited to the analysis of determinants when there is a dichotomous dependent variable.

A sample of n individuals with indices $i = 1$ to n . For each individual and we pose: $Y_i = 1$ (if the household is food secured) and 0 (if the household is not food secured) was consider for each individual, $Y_i = 1$ (if the household is food secured) and 0 (if the household is not food secured). This choice makes it possible to define the probability of food security. As the expectation of the variable Y since: $E[Y_i] = \Pr(Y_i = 1) \times 1 + \Pr(Y_i = 0) \times 0 = \Pr(Y_i = 1)$.

The expectation of Y_i therefore gives the probability that households are food secured. The objective of this model is then to explain the level of household food security as a function of K observed characteristics (X_{i1}, X_{iK}) for an individual i in the sample.

$$Y = \begin{cases} 0, & Y^* \leq 0; \text{ if the household is not food secured } 1, \\ & Y^* \geq 1; \text{ whether the household is food secured} \end{cases}$$

$$(Y) = X\beta + \varepsilon,$$

$$(Y_i=1) = X\beta + \varepsilon$$

Where Y^* is an underlying variable or latent variable,

X is a vector of the covariates which determines the food security characteristics and β is a vector of the associated coefficients.

ε represents the logistic error of the distribution.

➤ Specification of the empirical model

The binary logit model was used to determine the socio-economic variables influencing food security in PANAI beneficiary households and control

villages (Attingli *et al.*, 2016). Binary logistic regression is very useful when one wants to understand or predict the effect of one or more variables on a variable with a binary or Boolean response, i.e. one that can only take two values, 0 or 1 (Zossou *et al.*, 2021). The reference situation chosen is one where the dependent variable "food security" takes the value one (1) if the household is food secured and zero (0) if not.

✓ **Explained variable**

The variable explained is food security

✓ **Explanatory variables**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$$

Where: Y= Food security

X1= SEX; X2= AGE; X3= Education level; X4= FORM; X5= REV; X6=TM; X7 =PDAL

✓ **Quality of the model**

It is given by the significance threshold of the Fisher value. At a given threshold (1% or 5%), the model is globally significant when the calculated F-value is higher than the theoretical Fvalue at k and (n-k-1) degrees of freedom.

✓ **Predictive power**

It is given by the value of the adjusted coefficient of determination (R2-adjusted) and gives the proportion of the total variation of the dependent variable explained by the variations of the independent variables included in the model.

✓ **Signs of the estimated coefficients and their significance**

Each sign of the coefficients has an associated significance which is of great importance. This significance is given by a probability which indicates, which confidence interval the sign falls in and whether this sign is reliable (Table 2).

Table 2: Description of model variables

N°	Variables	Abbreviations	Expected signs
1	Age	AGE	+
2	Gender	SEXE	+
3	Level of education	NI	+
4	Training	FORM	+
5	Agricultural income	REV	+
6	Household size	TM	-
	Part of food expenditure in total	PDAL	-
7	Expenditure		

The level of household nutritional security was determined by the dietary diversity score. The FAO dietary diversity tool (year) uses an open recall method to collect information on all foods and beverages consumed by the individual (individual-level survey) or by the household (household-level

survey) in the 24 hours preceding the survey. The foods and drinks consumed are then highlighted in one of 16 standard food groups. Verification and confirmation questions are used to capture the consumption of any food groups not mentioned in the open recall (FAO, 2012). A score 1 was assigned when a food from a particular group was consumed at least once during the reference period, and a score of 0 is assigned otherwise. The score is calculated by adding the scores for each food group. If the score is greater than or equal to 4, the household diet is considered diversified and the household is nutritionally secured; if it is strictly less than 4, the household diet is non-diversified and the household is not nutritionally secured. The calculation of this score is reported in Table 3.

Table 3: Calculation of the dietary diversity score

Food group	Food group	
5. Cereals and seeds	Cereals and tubers	1. Group the 16 food groups used for the SCA into 7 groups as shown in the table groups simply by adding up the frequencies;
6. Roots and tubers	tubers	
7. Pulses	Pulses	
8. Plants rich in vitamin A	Vegetables	
9. Dark green leafy vegetables		2. For each group, create a new binomial variable that can take 2 values: 1-Yes: the household/individual has consumed a food from this group 0-No: they did not consume this food
10. Other vegetables		
11. Fruit rich in vitamin A	Fruits	3. Add up all the binomial variables to create a BMDS;
12. Other fruits		
13. Meat	5. meat and fish	
14. Liver, kidneys, heart and/or other organs		
15. Fish/ seafood		4. The new variable will have a value between 0 and 7 (the number of food groups collected)
16. Eggs		
17. Milk and milk products	6. milk	
18. Oil / fat / butter	7. oil	
19. Sugar or sweets	8. Not taken into account	
20. Spices/condiments	9. Not taken into account	

Source: FAO (2012)

Results

Socio-demographic and economic characteristics of respondents

The respondents were predominantly adult men (80.51%) and women (19.49%). Their ages ranged from 20 to 84 years, with an average of 46 years. Their level of formal education was low. Only 25.8% of the surveyed household heads attended primary school (25.5%), while 60.04% had no education and very few respondents completed adult education (0.98%). More than fifty percent (51.38%) were Christian). Almost all the respondents were married and the average household size was nine persons. Less than half of the household members were engaged in agricultural

activities. On average, four (4) agricultural workers were counted per household, while 86.42% of the household heads surveyed had farming as their main source of income.

The average household farm size was 5.13 ha. The prevailing land tenure system remains inheritance-oriented (69%). However, a more complicated land tenure systems include combination such as land inherited coupled with land rented or purchased, mostly in the south, where population density is very high and land is extremely fragmented. Several crops are grown within the households. These include: maize, rice, cotton, yams, Bambara or Kersting's groundnut, soybean, sorghum, sesame, cowpeas, groundnuts, etc. The farm size area allocated to each crop varies in accordance with the priority set by households to each crop. Some crops, such as cotton, are grown mainly as cash crop, while other food crops are produced for home consumption and the surplus is sold (Table 4).

Table 4: Socio-economic and demographic characteristics of the respondents

Qualitative variables	Frequency	Percentage
Gender		
Male	409	80.51
Female	99	19.49
Total	508	100
Age		
20-33	73	14,37
34-46	199	39,17
47-59	149	29,33
60-72	72	14,17
73-85	15	2,96
Total	508	100
Religion		
Traditional religion	91	17.91
Muslim	156	30.71
Christian	261	51.38
Total	508	100
Marital status		
Married	478	94.09
Divorced	03	0.59
Single	08	1.58
Widow(er)	19	3.74
Total	508	100
Level of education		
No education	305	60.04
Primary education	131	25.80
Secondary education level 1	40	7.87
Secondary education level 2	24	4.72
Higher education level	03	0.59
Adult education	05	0.98
Total	508	100

Occupation		
Agriculture as main activity	439	86,42
Secondary activities	69	13,58
	508	100
land tenure		
inherited land	351	69.09
rented land	20	3.94
borrowed land	18	3.54
purchased land	93	18.31
Gifted land	16	3.15
Pawned land	10	1.97
Total	508	100

Quantitative variables	Average	Standard deviation
Average age	46	12,51
Average household size	9	4,99
Number of agricultural workers in the household	4	3,32
Average farm size	5 ha	4,98

Determining the level of food safety

Tables 5 and 6 present the prevalence of household food insecurity. Analysis shows that the rate of poor food consumption among non-beneficiary households (5.22%) was higher than that of beneficiaries ones (4.24%). Moreover, beneficiary households spent a larger proportion of their budget (47%) on food than non-beneficiary households (46%). It can be deduced that food security shows relatively large disparities depending on the type of household. Households benefiting from PANAI interventions were more food secure (52.51%) than non-beneficiary households (49.80%), which could mean that these food-secure households were able to meet their essential food and non-food needs without using strategies that could jeopardise their livelihoods. On average, 38.46% of households (beneficiaries and non-beneficiaries) were at borderline food secure. It could be that these households had adequate food consumption, but were at risk of becoming food insecure in case of severe or frequent shocks. Non-beneficiary households were more food insecure (12.05% moderate) than beneficiary households (7.72% moderate). This could plausibly be that these households were either food consumption deficient or could only meet their minimum food needs by using irreversible coping strategies leading, in severe case, to a significant loss of livelihoods or large food deficits.

Table 5: The overall food security index

Domain		Indicator	Food safety (1)	Food safety limit (2)	Moderate food insecurity (3)	Severe food insecurity (4)	
Current Status	Food consumption	Food Consumption Score	<i>Acceptable</i>		<i>Limit</i>	<i>Poor</i>	
		Beneficiaries	73.37%		22.39%	4.24%	
		Non-beneficiaries	68.27%		26.51%	5.22%	
Adaptability	Economic vulnerability	Share of food expenditure	<i>Share < 50%</i>	<i>50% - 65%</i>	<i>65% - 75%</i>	<i>Share > 75%</i>	
		Beneficiaries	67.08 %	9.3%	7.08 %	16.54%	
		Non-beneficiaries	61.04%	10.44%	7.63 %	20.89%	
	Depletion of assets	Livelihood-based survival strategies	<i>None</i>	<i>Stress</i>	<i>Crisis</i>	<i>Emergency</i>	
		Beneficiaries	47.40%	25.48%	26.76%	0.38%	
		Non-beneficiaries	40.10%	32.40%	27.02%	0.48%	
Food security index			Beneficiaries	52.51%	39.77%	7.72%	0%
			Non-beneficiaries	49.80%	38.15%	12.05%	0%

The gender-based analysis revealed that female-headed households were more food insecure than male-headed households. The food insecurity rate for households headed by female was 15.15% compared to 8.56% for male-headed households. This could be that women face a more precarious economic situation, as they had fewer productive assets, earned less income and were the most indebted. Food insecurity particularly affects the most vulnerable social strata, i.e. households with a lower resilience capacity, including a fragile income-generating activity. These households were likely to be found in villages that did not benefit from the project interventions. This was especially the case in the villages of Tantéga (Matéri), Mami (Ouaké) and Lama (Savalou). Some households were food insecure (27.43%) due to the low diversity of their food consumption resulting from the lack of availability of certain types of food. Indeed, the PANAI project's interventions to address food insecurity have made it possible to fill the cereal gap.

However, other foodstuffs such as cowpeas (legumes in general), milk and animal proteins in general (including meat and fish) were not available everywhere. Thus, the unavailability of these products forced some households to consume the same products almost every day: maize, sugar and oil.

Table 6 presents food security among communes. This table reveals that there was a significant difference at 5% among the communes. The commune of Savalou had the highest level of food security (0.97), while that of Matéri, showed the lowest level of food security (0.84).

Table 6: Average food security

Commune	Food Security (Mean \pm SE)
Matéri	0.84 \pm 0.03 a
Ouinhi	0.87 \pm 0.03 ab
Ouaké	0.87 \pm 0.03 ab
Sô-Ava	0.88 \pm 0.05 ab
Bopa	0.88 \pm 0.05 ab
Aplahoué	0.93 \pm 0.04 ab
Adjohoun	0.93 \pm 0.04 ab
Malanville	0.94 \pm 0.03 b
Savalou	0.97 \pm 0.04 b

Means with the same letter in the same column are not statistically different at the 5% level ($p < 0.05$) with the Student Newman-Keuls test.

\pm : standard error

Determinants of respondents' level of food security

Table 7 presents the estimation of the logit model results. The estimated model is globally significant at the 1% level ($p = 0.000$). Therefore, the estimation result is efficient. The econometric estimation showed that the variables that significantly affect household food security were training (capacity building) (1%), gender (5%) and age (5%).

Table 7: Estimation of the logit model

Variables	Z	P-Value	Marginal effects (dy/dx)
Age	-1.93	0.054	-0.002**
Gender	-2.28	0.023	-0.075**
Level of education	-1.39	0.163	-0.015 ns
Training	4.30	0.000	0.157***
Agricultural revenue	1.36	0.175	2.13,10 ⁻⁰⁸
Household size	0.70	0.481	0.002 ns
Share of food expenditure in total expenditures	-1.31	0.191	-0.065 ns

Logistic regression

Number of obs = 508

Log likelihood = -145.66843

LR chi²(7) = 33.54

Prob > chi² = 0.0000

Pseudo R² = 0.1032

*Significant at 10%; ** significant at 5%; *** significant at 1%; ns: non-significant

Indeed, the training of a farmer significantly influenced the improvement of food security and had a positive marginal effect (0.157). This could imply that the more trainings a member has, the higher his or her level of food security. It could be inferred that that training was a factor that raised the probability of improving the level of food security. Thus, farmers who received training in farming techniques, processing, market gardening and fish farming were the most food secured. Gender had a negative influence on the improvement of the level of food security with a negative marginal effect (-0.075). The explanation could be that the fact that the majority of female-headed households were more likely to be food insecure. In other words, as the number of households headed by female- increases, the number of food secure households is likely to decrease. The explanation could be that they were constrained by a more precarious economic situation as they might have fewer productive assets.

Similarly, Age had a negative marginal significant effect (-0.002). It could be that an increase in age reduces the level of food security. This result revealed that elderly people were incapable in ensuring their food security and therefore, were less resilient to the adverse effects of climate change.

Nutritional safety analysis

Table 8 presents the dietary diversity scores of surveyed households. Analysis reveals that dietary diversity is significantly lower among non-beneficiary households, with 30.92% consuming less than 4 food groups daily, compared to 23.94% among beneficiary households ($p < 0.05$).

Table 8: Dietary diversity score

Households	Household dietary diversity score	of households with poor diets (RDS < 4 food groups)
Bénéficiaires	4,83	23,94%
Non bénéficiaires	4,86	30,92%

Table 9 shows the dietary diversity means of the Communes. This table reveals that the communes of Ouaké and Savalou were not significantly different at 5% which means that dietary diversity was not statistically different between these communes. Similarly, the communes of Matéri and Adjohoun, were not significantly different at 5% meaning that dietary diversity was not statistically different between these communes. Likewise, the communes of Adjohoun and Bopa were not significantly different at 5%, indicating that their dietary diversity was not statistically different between these communes. The communes of Bopa, Aplahoué and Sô-Ava, were not significantly different at 5% in terms of dietary diversity. Also, the dietary diversities of the communes of Aplahoué, Sô-Ava and Ouinhi were not statistically different at 5%. The commune of Malanville .The commune of

Malanville had the highest level of nutritional security (5.41), while that of Ouaké, the lowest level (3.44) of nutritional security.

Table 9: Comparison of dietary diversity means of the Communes

Commune	Value (Mean \pm SE)
Ouaké	3.44 \pm 0.10 a
Savalou	3.46 \pm 0.14 a
Matéri	3.85 \pm 0.10 b
Adjohoun	4.06 \pm 0.13 bc
Bopa	4.38 \pm 0.18 cd
Aplahoué	4.63 \pm 0.13 de
Sô-Ava	4.68 \pm 0.18 de
Ouinhi	4.98 \pm 0.11 e
Malanville	5.41 \pm 0.09 f

Means with the same letter in the same column are not significantly different at $p < 0.05$ with the Student Newman-Keuls test. \pm indicates the standard error

Food diversity rate per municipality

Figure 2 presents the rate of food diversity by commune. It shows that the communes of Malanville (87%), Bopa (92.31%) and Ouinhi (93.44%) had the highest food diversity rate; while, the commune of Ouaké (37.93%) the lowest rate. It is worthwhile to reveal that in the communes of Ouinhi, Bopa, Sô- Ava, Adjohoun, apart from crop production, household heads were also engaged in fishery activities. Therefore, protein foods coupled with vegetable were consumed more by households in these communes. This could plausibly explain their high rate of dietary diversity. Similarly, a high rate of diversity was also noted in the commune of Malanville. In fact this Commune has an international market whereby, households for their meals get access to a variety of food crop stuffs plus protein they can also get from hunting and breeding activities.

Food diversity rate

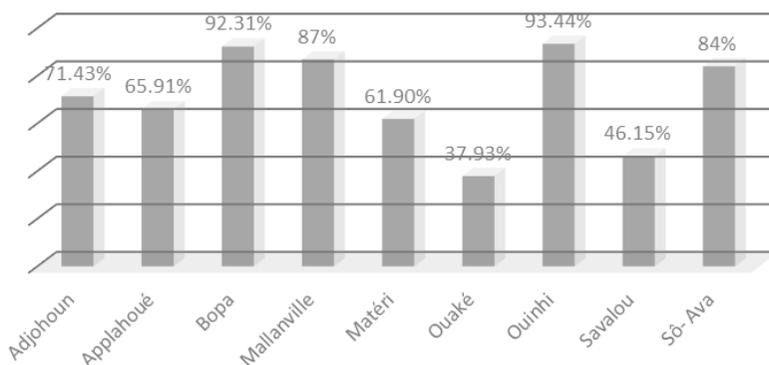


Figure 2: Dietary diversity rate of the Communes

Discussion

This study showed that households who benefitted from PANAI interventions achieved higher food security compared to those who did not. These results demonstrate that beneficiary households are more food secure (52.51%) than non-beneficiary ones (49.80%). This positive impact can be attributed to PANAI interventions through training in agricultural techniques, processing, market gardening, and fish farming that benefitted the households. These results are consonant with the findings by Amoussa et al. (2019), who found significant differences in food security indicators between intervention and non-intervention areas in South Benin.

The observed improvements in food security through targeted interventions are consistent with research by García de Jalón et al. (2023), who demonstrated that climate-smart agricultural practices similar to those implemented by PANAI can significantly improve household resilience to climate variability. Additionally, Rippke et al. (2022) found that strengthening local adaptation capacities through integrated approaches is critical for building resilience against climate-related food insecurity, particularly in West African agricultural systems.

Analysis of food insecurity prevalence rates indicates that on average 24.42% of households in the study area are food insecure. This value is higher than the 9.6% reported in field surveys carried out by WFP (2017) in Benin. This discrepancy could be explained by methodological differences, including data collection tools (Kobocollect versus ENA software) and data processing techniques (Stata15 and SPSS.20 versus CsPro). Furthermore, as noted by Smith et al. (2023), different food security measurement approaches can yield varying results even within the same population. More importantly, this study specifically targeted the most vulnerable communes to climate change, while the WFP assessment covered a broader national sample.

Gender-based analysis revealed that female-headed households experience higher rates of food insecurity (15.15%) compared to male-headed households (8.56%). These results are consistent with findings by Bougma et al. (2021) in Burkina Faso and consonant with research by Deubel and Nyarko (2022), who documented greater climate vulnerability among female-headed agricultural households across sub-Saharan Africa. Kosec and Mo (2022) similarly found that women farmers typically have reduced access to productive resources, extension services, and inputs, thereby constraining their adaptive capacity to climate change.

The results from the logistic regression model confirm that gender, age, and training are significant determinants of household food security. The negative relationship between age and food security (-0.002 marginal effect) is supported by findings from Gandonou et al. (2019) and corresponds with research by Akinoso et al. (2023), who found that older household

heads in rural Nigeria were less able to adapt to changing agricultural conditions, thereby increasing vulnerability to food insecurity.

Training emerged as the strongest positive determinant of food security (marginal effect of 0.157), highlighting the importance of capacity building in adaptation strategies. This finding is supported by Balehegn et al. (2021), who demonstrated that farmer field schools and participatory learning approaches significantly improved adaptive capacity and food security outcomes in East Africa. Similarly, Danso-Abbeam et al. (2022) found that agricultural training programs significantly improved household food security by enhancing production efficiency and climate resilience in Ghana.

The dietary diversity assessment revealed that beneficiary households maintain more diverse diets (23.94% consuming at least 4 food groups) compared to non-beneficiary households (30.92% consuming fewer than 4 food groups). This disparity could be attributed to the lack of nutritional education among non-beneficiary households, who prioritize food quantity over dietary diversity (Sibhatu et al., 2015). These households tend to favor energy-dense foods, a pattern that typically correlates negatively with dietary diversity and the consumption of fruits and vegetables (Ruel et al., 2013; Jones et al., 2014). The concept of nutritional balance appears to be a secondary consideration for these households, potentially viewed as a luxury rather than a necessity. This observation aligns with previous findings by Kennedy et al. (2017) and FAO (2021), suggesting that nutritional education plays a crucial role in promoting diverse dietary practices and improving household food security outcomes. This pattern, somewhat in consonance with findings by Bellizzi et al. (2022), who documented positive associations between farm production diversity and dietary diversity across multiple African countries. Moreover, Headey et al. (2022) found that integrated agricultural interventions similar to PANA1 improved dietary diversity through both production and income pathways.

While the testimonial of the 48-year-old woman from Kankini-Séri demonstrates how PANA1 interventions enabled diet diversification beyond cereals, Sibhatu and Qaim (2023) caution that market access and education are essential complements to production diversity for achieving nutritional outcomes. This suggests that future interventions should continue to integrate market linkages with production diversification.

Despite these fascinating results of this stuff, we acknowledge some limitations. As noted by Barrett et al. (2021), seasonal factors can significantly influence food security measurements. Additionally, Lentz et al. (2023) emphasize that cross-sectional studies may not fully capture the dynamic nature of food security over time, particularly in the context of

increasing climate variability. Future research would benefit from longitudinal designs to assess the sustainability of observed improvements.

Conclusion

Food insecurity in Benin is not linked to a lack of food availability, but to a lack of access to food (lack of financial means). Beninese households are regularly subjected to numerous shocks that affect their functioning and well-being. Whatever the nature of these shocks, they have a negative impact on households' access to food. Indeed, in order to overcome the difficulties caused by these shocks, these households resort to various food coping strategies or livelihoods-based coping mechanisms. However, the various climate change resilience building interventions of the PANAI project have had a positive impact on the food security of beneficiary households and have led to a significant change in their diet. Therefore, emphasis should be put on.

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