Impact Assessment of the National Adaptation Programme of Action (PANA) on Strengthening the Capacity-Building and the Resilience of Farming Households to Climate Change in Benin

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Abstract

This study analysed the impact of the integrated climate change adaptation programme to strengthen farming households' capacity-building and resilience on agricultural production, food, and nutrition security in Benin.

The research was carried out in the nine most vulnerable communes to climate change in Benin: Malanville, Ouaké, Savalou, Aplahoué, Sô-Ava, Ouinhi, Matéri, Bopa, and Adjohoun. A combined qualitative and quantitative approach was used to collect data from eighteen villages (nine beneficiary and nine control villages) through group discussions 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, analysis of variance, and logistic regression. The assessment of food insecurity indicators in the communes revealed moderate to severe levels of food insecurity. There were significant differences between beneficiary and non-beneficiary households in 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, the dietary diversity assessment indicated that beneficiary households of the integrated climate change adaptation programme had more diverse diets (23.94%), consuming less than four dietary groups per day, compared to non-beneficiary ones (30.92%). These results clearly show that the interventions of the climate change adaptation programme have strengthened the capacity building of farming households towards sustainable agriculture and food security. The study recommends that government development programmes should be more gender-sensitive.

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

Introduction

In West Africa, enhancing the productivity of production factors is crucial for the success of rural development strategies (Ngondjeb et al., 2014). In Benin, agriculture remains the main 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 worsened conditions for agricultural production (Caquet, 2014; Chanzy, 2015). Such climatic uncertainties concern farmers as they negatively impact agricultural yields by affecting plant growth, development, and varietal diversity (Rahman et al., 2015).

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Progressive soil degradation has 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 among 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, intensifying agriculture, and improving food security, presented an opportunity to enhance agricultural productivity, food security, and water availability (MAEP, 2011). Through its interventions, the PANA1 programme has implemented various participatory and demonstrative research findings to strengthen household resilience for food and nutrition security. This study evaluated the programme's impact on enhancing farmers' resilience and capacity-building in targeted rural communities to achieve food and nutrition security.

Methodology

Study Areas

The study was carried out 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). The intervention programme varied from one commune to another depending on predominant agricultural activities and farmers' choices. PANA1's interventions in animal and fishery production were carried out in Sô-Ava, Adjohoun, Bopa, Ouinhi, and Ouaké. Crop production interventions were conducted in all nine communes and included the supply of improved early maturing varieties of maize, rice, sorghum, cowpea, and improved oil palm varieties, crop production equipment, storage infrastructure, training in sustainable soil fertility management, market gardening, and material and financial support for community and private afforestation. Processing activities were carried out in Ouaké and Matéri, where women received training in modern agri-food processing techniques along with processing equipment and storage infrastructure (Akpovi & Vissoh, 2022).

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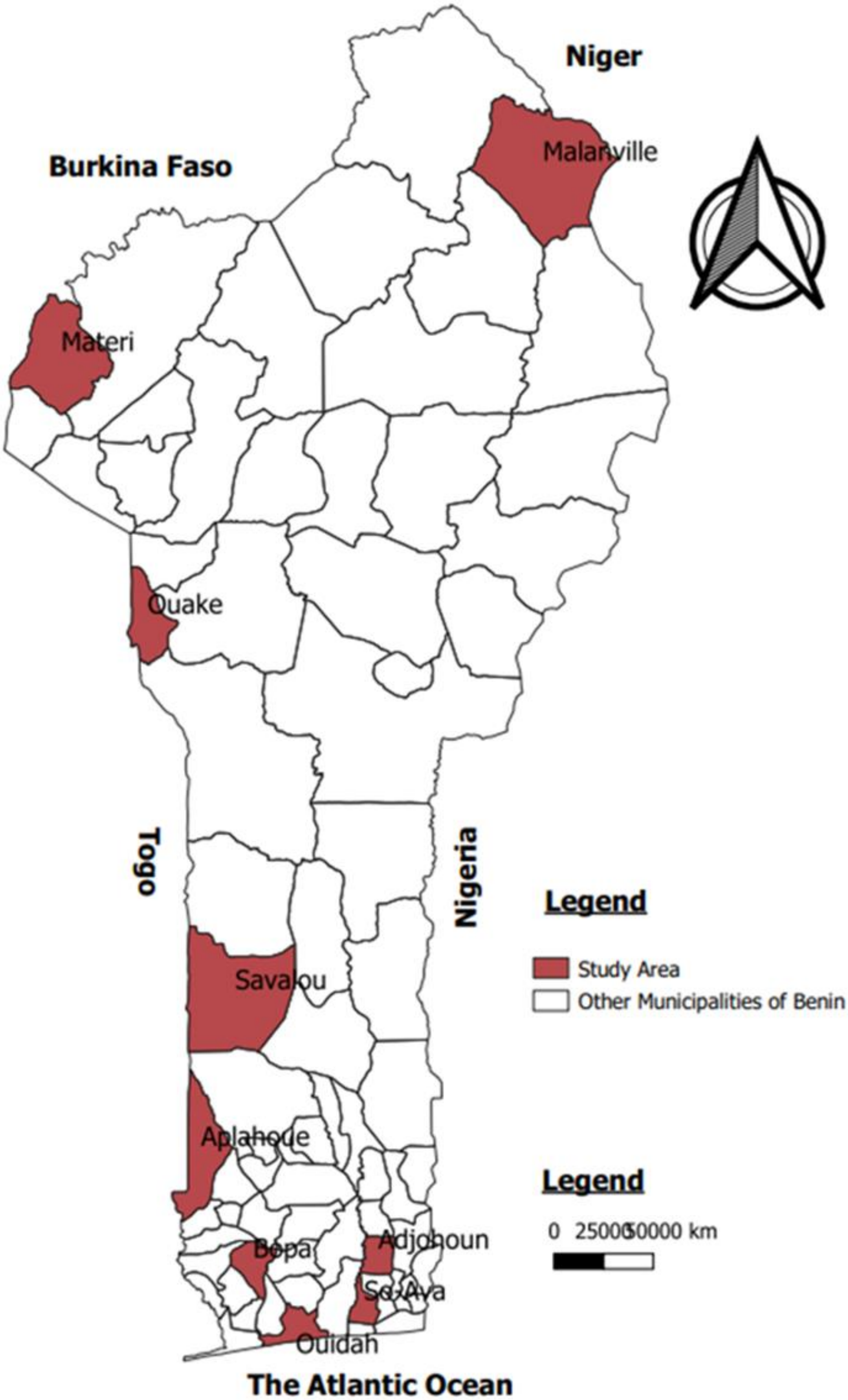

Figure 1: Map of the Republic of Benin showing the study area

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Sampling

According to UN (2010), a representative sample size was calculated using the formula below:

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

Where:
n: required sample size
z: z-score (e.g., 1.96 for 95% confidence)
p: the estimated proportion (usually 0.5)
$\delta\delta$: the margin of error (0.05)

Putting these different elements into the formula gives a calculated sample size n1:

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

The overall non-response rate was estimated at 10%, i.e. n2 = 40 respondents.

Consequently, the minimum sample size of beneficiary respondents to be surveyed for the nine communes was $n = n_1 + n_2 = 425$ respondents , which is sufficiently adequate based on a hypothetical prevalence of 50% to ensure adequate statistical power for comparative analyses between beneficiaries and non-beneficiaries.

The counterfactual approach requires an equivalent number of beneficiaries and non-beneficiaries in each municipality. Therefore, the sample of the study was adjusted to 508 respondents, comprising both beneficiaries and non-beneficiaries, i.e., respondents randomly selected based on the list provided either by the PANA1 programme managers and the list of producers who participated in the PANA1 resilience-strengthening program during the diagnostic study (Akpovi & Vissoh, 2022), and Farmers-Based Organisations (FBO) in each of the control villages (non-beneficiary villages).

Data were collected through focus group discussions and administration of a structured questionnaire to individual households in beneficiary villages of the PANA1 programme, whereas in the control villages, only the structured questionnaire was administered to respondents. The distribution of respondents was made proportionally to the number of farmers per village (Table 1).

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Table 1: Sampling of beneficiaries and non-beneficiaries of PANA1

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

Data Collection

Data collected include: *(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 PANA1 interventions through testimonials (verbatim) during focus group discussions.

Analysis of the Data

The data were collected with the KoBoCollect application installed on tablets and smartphones and extracted in Excel format. Stata 15 and SPSS 20 software were used to calculate frequencies (qualitative variables), means and standard deviations (quantitative variables), and for inferential analyses.

Farming household food security levels were assessed using the CARI approach (Consolidated Approach to Reporting Indicators of Food Security) of the World Food Programme (WFP), which enables the integration of many dimensions of food security in a coherent analytical framework. This approach classifies households into four categories: Food Security (FS), Borderline Food Security (BFS), Moderately Food Insecure (MFI), and Severely Food Insecure (SFI), based on two major dimensions: food consumption status and the adaptive capacity.

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Measurement of Food Consumption: Food Consumption Score (FCS)

The Food Consumption Score (FCS) measures the frequency of food group consumption weighted by their nutritional value over a period of seven days. It is measured using the formula below:

$$FCS = \sum_{i=1}^{n} aixi$$

Where

a_i: weighting coefficient of food group i

Xi: number of consumption days of this group ($0 \leq X_i \leq 7$)

The classification thresholds are as follows:

- FCS < 21: poor consumption
- 21.5 ≤ FCS ≤ 35: limited consumption
- FCS > 35: acceptable consumption

Economic Vulnerability: Share of Food Expenditure

Economic vulnerability is measured from the share of food expenditure in total expenditures of the household over a period of 30 days.

$$Share = \frac{food\ expenditure}{total\ expenditure}\ x\ 100$$

A high share of food expenditures means a higher exposure to food insecurity

Adaptation Capacity: Coping Strategies Index (CSI)

The Coping Strategies Index (CSI) assesses the frequency and the severity of adopted strategies by the households in response to food constraints.

$$\text{CSI} = \sum_{j=1}^{m} \text{fj}\ x\ sj$$

Where:

f_j Adoption frequency of the strategy J and s_j at its severity weigh. A high score indicates greater vulnerability and an increased pressure on household livelihoods

Integration of Indicators: The CARI Approach

The CARI approach combines these indicators into a structured synthetic matrix around two domains: the actual consumption status (based on the FCS) and the adaptation capacity (based on economic vulnerability and the CSI). This integration enables the production of one composit index of food security, ensuring robust assessment, which is multidimensional and comparable between households.

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The Logit model was used to examine the determinants of the respondents' food security level. In the literature, Probit and Logit models are the most commonly used to model the relationship between the probability and the determinants of choices (CIMMYT, 1993). Logit facilitates the interpretation of the β parameters associated with the explanatory variables xi. A logistic regression analysis was therefore used. The choice of this model is related to the fact that it is well-suited to the analysis of determinants when there is a dichotomous dependent variable.

Consider a sample of n individuals with indices i = 1 to n. Therefore, Yi = 1 (if the household is food secure) and 0 (if the household is not food secure) was considered for each individual. This choice allows us to define the probability of food security. The expectation of the variable Y is given as shown below:

$$E\,[Yi] = Pr\,(Yi = 1) \times 1 + Pr\,(Yi = 0) \times 0 = Pr\,(Yi = 1)$$

The expectation of Yi, therefore, gives the probability that households are food secure. The objective of this model is to explain the level of household food security as a function of K observed characteristics (Xi1, XiK) for an individual i in the sample.

$$Y = \{0, \quad Y* \leq 0;\ if\ the\ household\ is\ not\ food\ secured\ 1,$$
$$Y* \geq 1;\ whether\ the\ household\ is\ food\ secured$$
$$(Y) = X\beta + \varepsilon)$$
$$(Yi = 1) = X\beta + \varepsilon)$$

Where Y* is an underlying variable or latent variable, X is a vector of the covariates that determine 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 PANA1 beneficiary households and control villages (Attingli *et al.,* 2016). Binary logistic regression is very useful for understanding or predicting the effect of one or more variables on a binary response variable, 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 of one (1) if the household is food secure and the value of zero (0) if not.

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Explained Variable

The variable explained is food security.

Explanatory variables are given as:

$$Y = \beta 0 + \beta 1\, X1 + \beta 2\, X2 + \beta 3\, X3 + \beta 4\, X4 + \beta 5\, X5 + \beta 6\, X6 + \beta 7\, X7 + \varepsilon$$

Where: Y= Food security

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

Quality of the Model

The overall fit of the model was evaluated by means of the livelihoods ratio (Likelihood Ratio test), which enables the testing of the null hypothesis that all coefficients of the explantory variables are simultaneously zero (0). The results show that this hypothesis is rejected at the 1% or 5% significance level, thereby demonstrating the overall significance of model.

Predictive Power

The explanatory power of the model is assessed through the pseudo-coefficient of determination, specifically McFadden's pseudo-R2, which measures the improvement in the livelihood of the estimated model.

Predicted 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 into and whether this sign is reliable (Table 2).

Table 2: Predicted signs of the 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	-
7	Part of the food expenditure in total Expenditure	PDAL	-

Nutritional security at the household level was measured using the Dietary Diversity Score (DDS), in accordance with the methodology established by the FAO. This indicator relies on a 24-hour dietary recall capturing all food and drink items consumed by the household over a 24-hour period.

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The foods consumed were classified into standardised food groups. For each group, a binary variable is assigned: 1 if at least one food item from the group was consumed, and 0 if no food item from the group was consumed. The Dietary Diversity Score was obtained by summing these variables.

$$DDS = \sum_{i=1}^{k} Gi$$

Where:
G_i denotes the consumption (1 or 0) of the group, while i and k represents the total number of groups considered.

To make the results easier to interpret, the original food groups were aggregated into seven main categories: (i) cereals, roots and tubers, (ii) legumes/pulses, (iii) vegetables, (iv) fruits, (v) meat and fish, (vi) dairy products, and (vii) oils and fats. Based on methodological standards, groups such as sugars and condiments were omitted from the calculation.

The resulting DDS thus ranged from 0 to 7. A threshold was then applied to characterise the severity of household nutritional status.
DDS≥4: Dietary diversity (nutritional security)
DDS<4: Poor/low Dietary diversity (nutrition insecurity)

However, this approach provides a simple and robust measure of household diet quality related to their access to a diverse and nutritious diet. The calculation of this score is reported in Table 3.

Table 3: Calculation of the dietary diversity score

<table>
<tr><th>Food Group</th><th>Food Group</th><td rowspan="17">1. Group the 16 food groups used for the SCA into 7 groups as shown in the table by simply adding up the frequencies.

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.

3. Add up all the binomial variables to create a BMDS.

4. The new variable will have a value between 0 and 7 (the number of food groups collected).</td></tr>
<tr><td>5. Cereals and seeds</td><td rowspan="2">Cereals and tubers</td></tr>
<tr><td>6. Roots and tubers</td></tr>
<tr><td>7. Pulses</td><td>Pulses</td></tr>
<tr><td>8. Plants rich in vitamin A</td><td rowspan="3">Vegetables</td></tr>
<tr><td>9. Dark green leafy vegetables</td></tr>
<tr><td>10. Other vegetables</td></tr>
<tr><td>11. Fruit rich in vitamin A</td><td rowspan="2">Fruits</td></tr>
<tr><td>12. Other fruits</td></tr>
<tr><td>13. Meat</td><td rowspan="4">5. Meat and fish</td></tr>
<tr><td>14. Liver, kidneys, heart and/or other organs</td></tr>
<tr><td>15. Fish/ seafood</td></tr>
<tr><td>16. Eggs</td></tr>
<tr><td>17. Milk and milk products</td><td>6. Milk</td></tr>
<tr><td>18. Oil / fat / butter</td><td>7. Oil</td></tr>
<tr><td>19. Sugar or sweets</td><td>8. Not taken into account</td></tr>
<tr><td>20. Spices/condiments</td><td>9. Not taken into account</td></tr>
</table>

Source: FAO (2012)

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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, 60.04% had no formal education, and very few respondents (0.98%) completed adult education. 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 people per household were engaged in agricultural activities, 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 being inheritance-oriented (69%). However, in southern Benin, where there is a high pressure on land due to increased population density and fragmented land, there were combinations of tenurial systems such as land inherited plus land rented and/or purchased (Table 4). Several crops were grown within the households. These include: maize, rice, cotton, yams, Bambara or Kersting's groundnut, soybean, sorghum, egusi, cowpeas, groundnuts, oil palm, etc. Land allocation depends on the priority set by household heads between cash crops, such as cotton and food crops.

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

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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 the 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

Determination of Food Security Level

The prevalence of household food insecurity is presented on Tables 5 and 6. Analysis revealed that the rate of poor food consumption among non-beneficiary households (5.22%) was higher than that of beneficiary households (4.24%). Moreover, beneficiary households spent a larger proportion of their budget (47%) on food than non-beneficiary households (46%). This could be that they spend more to maintain higher diet quality, e.g., purchasing more fruits, vegetables, and nutrient-dense foods. On the other hand, food-insecure households are compelled to prioritize basic needs. Households benefiting from PANA1 interventions were more food secure (52.51%) compared to non-beneficiary households (49.80%), suggesting that these food-secured households were able to meet their essential food and non-food needs using ecologically, economically appropriate and environmentally-friendly agricultural technologies. On average, 38.46% of households (beneficiaries and non-beneficiaries) were borderline food secure. This could plausibly be that these households had adequate food consumption but could be at risk of becoming food insecure in the occurrence of severe or frequent shocks. Non-beneficiary households were more food insecure

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(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 unadapted coping strategies. In severe cases, this results to food shortage.

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**		*Acceptable*		*Limit*	*Poor*
			Beneficiaries	73.37%		22.39%	4.24%
			Non-beneficiaries	68.27%		26.51%	5.22%
Adaptability	**Economic vulnerability**	**Share of food expenditure**		*Share < 50%*	*50% - 65%*	*65% - 75%*	*Share > 75%*
			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**		*None*	*Stress*	*Crisis*	*Emergency*
			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%**

Gender-based analysis revealed that female-headed households were more food insecure than male-headed households. The food insecurity rate for households headed by females was 15.15% compared to that of male-headed households (8.56%). This could be that women endure harsh and more precarious economic situation, as they have fewer productive assets, earn less income, and are the most indebted. Food insecurity particularly affects the most vulnerable social strata, i.e., households with lower resilience capacity and fragile income-generating activity. These households were likely to be found in villages that did not benefit from the project's 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 PANA1 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

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households to consume the same products almost every day: maize, sugar, and oil.

Table 6 presents the average level of food security in the communes. This table indicates that there was a significant difference among communes at the 5% significance level. 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 level of food security per commune

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

Determinants of Respondents' Level of Food Security

The estimated results of the logit model are presented on Table 7. The estimated model is globally significant at the 1% level (p= 0.000). Therefore, the estimation result was 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 $chi^2(7)$ = 33.54
Prob > chi^2 = 0.0000
Pseudo R^2 = 0.1032

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

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Indeed, the training of farmers significantly improved food security and had a positive marginal effect (0.157) on it. This implies that the more training a member has, the higher his or her level of food security. It could be inferred 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 secure. Gender had a negative influence on improvements in food security, showing a negative marginal effect (-0.075). This could be 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.

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

Nutritional Safety Analysis

The dietary diversity scores of surveyed households are shown in Table 8. Although, mean dietary diversity scores were similar between beneficiary (4.83) and non-beneficiary (4.86) households, a higher proportion of non-beneficiary households showed low dietary diversity: 30.92% consumed fewer than 4 food groups per day, compared to 23.94% among beneficiary households ($p < 0,05$). This difference in the proportion of households with low dietary diversity (rather than in average scores) indicates that the PANA1 interventions were particularly effective in reducing the prevalence of dietary inadequacy among the most vulnerable households.

Table 8: Dietary diversity score

Households	Household dietary diversity score	Households with poor diets (RDS < 4 food groups)
Beneficiaries	4.83	23.94%
Non beneficiaries	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 the 5% level. Similarly, the communes of Matéri and Adjohoun were not significantly different at the 5% level. Likewise, the communes of Adjohoun and Bopa were not significantly different at 5%. The communes of Bopa, Aplahoué, and Sô-Ava on the one hand and that of Aplahoué, Sô-Ava, and Ouinhi, on the other hand, were not significantly different at 5% level in terms of dietary diversity. However, the commune of Malanville had the highest level of nutritional security (5.41), while that of Ouaké has the lowest level (3.44).

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Table 9: Dietary diversity means of the communes

Commune	Value (Mean ± SE)
Ouaké	3.44 ± 0.10 a
Savalou	3.46 ± 0.14 a
Matéri	3.85 ± 0.10 b
Adjohoun	4.06 ± 0.13 bc
Bopa	4.38 ± 0.18 cd
Aplahoué	4.63 ± 0.13 de
Sô-Ava	4.68 ± 0.18 de
Ouinhi	4.98 ± 0.11 e
Malanville	5.41 ± 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. ± 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%) had the lowest rate. It is worth noting that, in the communes of Ouinhi, Bopa, Sô- Ava, Adjohoun, apart from crop production, household heads were also engaged in fishery and market gardening activities. Therefore, households in these communes consume more protein foods, coupled with vegetables. This could plausibly explain their high rate of dietary diversity. Similarly, a high level of diversity was also observed in the commune of Malanville. In fact, this commune has an international market whereby, households get access to a variety of food crop, plus protein they can also obtain from hunting and breeding activities.

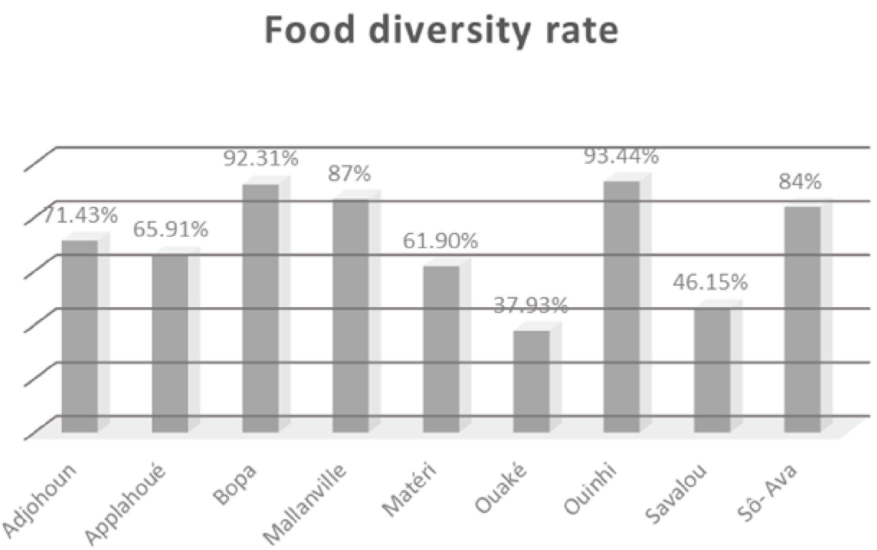

Figure 2: Dietary diversity rate of the communes

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Discussion

This study showed that households who benefitted from PANA1 interventions achieved higher food security compared to those that did not. These results demonstrate that beneficiary households were more food secure (52.51%) than non-beneficiary households (49.80%). This positive impact can be attributed to PANA1 interventions, which included training in agricultural techniques, processing, market gardening, and fish farming that benefited the households. These results are consonant with those of 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 PANA1, 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 indicated that, on average, 24.42% of households in the study area were food insecure. This value is higher than the 9.6% reported in WFP (2017) field surveys in Benin. This discrepancy could be explained by the dynamic nature of food security, i.e., food security is not static, referring to the availability, access, utilization, and stability of food over time. 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 experienced 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

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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 seemed to be a secondary consideration for these households, potentially viewed as a luxury rather than a necessity. This observation is in accordance 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 is 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 (commune of matéri) demonstrates how PANA1 interventions enabled diet diversification beyond cereals, Sibhatu and Qaim (2023) cautioned 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, we acknowledge some limitations. As noted by Barrett et al. (2021), seasonal factors can significantly influence food security measurements. Additionally, Lentz et al. (2023) emphasized 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.

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Conclusion

Food insecurity in Benin is not linked to food availability as such. However, it can be a crucial issue in some communes during the lean season and a lack of access to food (due to financial constraints) in others. Beninese households are regularly confronted with numerous shocks (e.g., irregular rainfalls and droughts, floods, high temperatures and wind, land degradation and pests) that affect their functioning and well-being. Whatever their nature, these shocks have a negative impact on household access to food. In response, these households resort to various food coping strategies or survival mechanisms (e.g., early warning systems, extension and research services, technical and management measures to improve the water use efficiency in rainfed agriculture, diversifying livelihoods and adapting agricultural, fishing and forestry practices, etc.).

The 2015 final evaluation report of the Benin National Adaptation Programme of Action (Integrated Adaptation Programme) underlines the successful enhancement of adaptive capacities across four vulnerable agro-ecological zones. The project improved agricultural production and food security, integrating resilient techniques into local plans. However, based on an assessment of the impact of the programme action on farming households, seven years after its rounding up, the findings revealed that they are no longer strengthened by the programme; rather, the programme improves food security, which could be temporary owing recurring shocks. The PANA1 programme's climate resilience strengthening interventions is associated with better food security outcomes among beneficiary households compared to non-beneficiaries, as well as positive changes in dietary diversity. The achievements of programme intervention lie principally in the intervention approach used, which is active and inclusive participation of the beneficiaries throughout the adaptation and resilience processes.

Nevertheless, these more or less fascinating investigation findings cover up a vital issue, which is that programme beneficiary household heads, despite their relatively strengthened resilience capacity to mitigate the adverse effects of climate change, wish to be supported permanently because of lack of means and funding, ignoring that a project has a beginning and an end. As a matter of fact, at the end of either research or development projects/programmes, the beneficiaries are not able to take advantages of the achievements. The resulting consequences show that they usually go back to their starting point, contributing to the vicious circle of climate change, thereby compromising their well-being and hence increasing their level of poverty. Thus, this is what happened at the end of this integrated development programme on resilience to climate change.

Furthermore, emphasis should be placed on the ownership and adoption of environmentally friendly technologies to mitigate the effects of

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climate change and achieve food and nutrition security. More specifically, decision-makers and/or policymakers and donors should (*i*) expand agricultural training programmes by prioritising female-headed and elderly households, who have been identified as the most food-insecure, (*ii*) design end-of-project financing mechanism that could enable small-scale producers to take ownership of project achievements and adopt them for sustainable agriculture and the attainment of food security, (*iii*) scale up interventions in the lowest-performing communes, i.e., Materi and Cobli, and (*iv*) combine nutritional education with support for agricultural production to lock in the dietary diversity achieved by the project's beneficiary households.

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