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Adaptation Strategies to Climate Change and Impacts on Household Income and Food Security: Evidence from Sahelian Region of Niger

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Abstract: Sahelian countries, particularly Niger, are more vulnerable to climate change due to the high dependence of most of their populations on rain-fed agriculture and limited capacities to respond to climate variability and change. This paper examines the factors influencing climate change adaptation strategies and the impacts on household income and food security in rural Niger. For this purpose, we collected data from 1783 valid rural households in four main agricultural regions of Niger. The results showed that crop diversification (72.74%), income diversification (67.97%) and changing planting times (55%) are the main adaptation strategies adopted by households. The majority of respondents had noticed changes in rain patterns (93.21%), in the amount of rain (91.25%) and in the intensity of rain (81.82%) during the last five years. We categorized these adaptation strategies into six major groups namely climate-resilient crop varieties, improved agronomic practices, irrigation and water conservation practices, crop diversification, income diversification, and agroforestry. We ran logit regression to identify the determinants of each individual group. The results show mixed effects of independent variables on these categories of adaptation strategies. Using matching techniques, we found adaptation strategies have positive and significant impact on both household income and food security. The farmers who adopt climate change adaptation strategies are more likely to increase household income by 7721.526 FCFA compared to those households with zero adaptation strategies. Similarly, the adapters have 7% to 9% more chance to be food secure compared to those who did not adopt strategies. These results suggest that strengthening the awareness of the effects of climate change on farmers and the choice of appropriate adaptation strategies are necessary to enhance household resilience. Strengthening institutional factors such as access to credit and market, extension services, and using drought-resilient crop varieties would surely improve agricultural production.

Keywords: adaptation strategies; climate change; households; logit regression; matching techniques

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1. Introduction

The global climate is continuously changing and has severe impacts on human life [1]. It consists of changes in the variation of temperature, rainfall, and wind patterns [2]. The impacts will be greater in the areas where the human livelihoods depend on the subsistence farming system [3]. Climate change and variability significantly affect crop production, especially in drought-prone areas, where farmers depend only on rainfall. Climate change is one of the crucial factors which has threatened the agricultural sector for decades, and the sector is more sensitive to climatic conditions [4]. In the Sahel, climate change seriously affects food security. According to the Inter-State Committee for the Fight against Drought in the Sahel (CILSS), climate change, which threatens the integrity of ecosystems already weakened by a rapidly growing population, will further exacerbate competition around natural resources, and generate movements of populations and conflicts in the region [5].

The households adopt different strategies to cope with the severe weather conditions and climatic variations. The human capacity to adapt to the effects of climate change is uncertain because of the socioeconomic conditions of the population, which may differ according to geographic locations [6–8]. Several adaptation strategies have been reported in the literature, including the adoption of drought-tolerant crop varieties, changing planting dates, crop rotation, intensive irrigation, expansion farm plots, implementing different soil conservation mechanisms, and diversifying household income sources [3,9–11].

Climate models are unable to capture some basic features of present-day climate variability in West Africa. This makes it difficult to analyze climate model projections in terms of impacts and provides little guidance to inform decision-making on adaption and resilience-building [12]. Household adaptation and mitigation strategies tend to depend on local- and context-specific conditions. Long-term adaptation methods in the farming sector require financial capital or government support, which are often unavailable to smallholder farmers [13]. Several factors influence farmers' decision to adopt strategies to mitigate climate change's impact on household welfare. A recent study revealed that the household head's age, education, and gender, the farm's size and the household's size, assets, livestock ownership, poverty status, and use of extension services, are all significantly correlated with the households' choices regarding adaptations to cope with climate change [14]. Similar results were reported in Southern Nigeria [15].

The agricultural sector's vulnerability to climate change can be reduced through appropriate adaptation methods [16,17]. Appropriate policies to tackle the negative impact of climate change require a better understanding of the factors influencing household adaptation strategies [18,19]. In fact, in Niger, the rural sector employs more than 80% of the population and contributes 45.2% to the gross domestic product (GDP). However, this sector continues to face several constraints linked to climate change and variability, soil erosion, and poverty, as well as almost permanent pressure from pests, some of which have become endemic. Niger is the Sahel country most affected by the effects of climate change and rising temperatures. According to national statistics, between 100,000 and 120,000 hectares of land are lost each year due to desertification and soil erosion. Droughts often result in increases in the prices of millet, sorghum, and other staples and dramatic decreases in livestock prices [20]. In this context, finding ways to adapt Niger agriculture to climate change is important to reduce household vulnerability to hunger. This is because the negative impacts of climate change on household livelihoods are increasing and measures to tackle the matter should be taken [14,21,22].

This present study aims to investigate the factors influencing household adaptation strategies to climate change and the impacts on household income and food security in rural Niger. The remainder of the paper is structured as follows: Section 2 introduces the study area, the data, and the empirical strategy. In Section 3, we report the descriptive statistics and the empirical results and discussion, and Finally, Section 4 provides a concluding remark.

2. Methodology

2.1. Study Area

The study area covered four regions of Niger (Tillaberi, Dosso, Maradi, and Zinder) where the project Climate Smart Agricultural Technologies (CSAT) is being implemented. The project aims to introduce climate-smart technologies and agricultural innovations in the Sahel, Sudan, and arid Savanna regions of Niger, improving livelihoods in rural environments, food, and nutritional security. The project intervenes in four regions, 32 communes (8 communes per region) and 160 villages (40 villages per region and 5 villages per commune).

Niger is a vast country located in the heart of the Sahel region with a land mass of 1,267,000 km^2 and a population of 17 million inhabitants in 2012. Three quarters of the country is occupied by the Sahara Desert. Its economy is not well diversified and depends primarily on agriculture, which accounts for 40% of its gross domestic product (GDP). Despite significant strides made by Niger over the past decade to reduce the country's poverty rate, the extreme poverty rate remained very high at 41.4% in 2019, affecting more than 9.5 million people [23].

Niger is one of the hottest and driest countries in the world and high intra- and inter-annual climate variability constrain health outcomes and water resources and contribute to chronic food insecurity such that food production does not meet consumption even in good years. A long, intense dry season occurs from November–May and a brief, irregular rainy season is linked to the West African monsoon; rainfall peaks in August. Annual rainfall has high inter-annual and inter decadal variability; rainfall levels are highest in the south (800 mm), shifting to lower levels in the Sahel–Sudan (400–600 mm) and Sahel (300–400 mm) zones, to almost no rain in parts of the Sahara–Sahel (200–300 mm).

Agriculture consists largely of a subsistence-oriented, rained crop production system, combined with livestock rearing and other commercial activities. Crop production (mainly millet, sorghum, cowpea, and rice) is predominantly rainfed and reliant on the region's low and highly variable rainfall, making it extremely vulnerable to climate variability and change. Land degradation, particularly due to soil fertility depletion and soil erosion, is a serious constraint to agricultural productivity. Due to harsh environmental conditions, not all crops can be grown in Niger, thus limiting agricultural production to few crops. People are highly vulnerable to climate shocks that drive down agricultural production and increase food prices. With more than 80 percent of its population living in rural, agricultural production plays an important role in Niger food security. Good harvests are expected in Niger, following generally favorable weather conditions throughout the growing season. The country faces serious food security challenges and is heavily dependent on cereal imports, even in good years. As most rural households do not produce enough to meet their consumption needs, food purchases account for more than 60 percent of expenditures [24]. The Figure 1 below shows the trend in annual variations of temperatures in Niger.

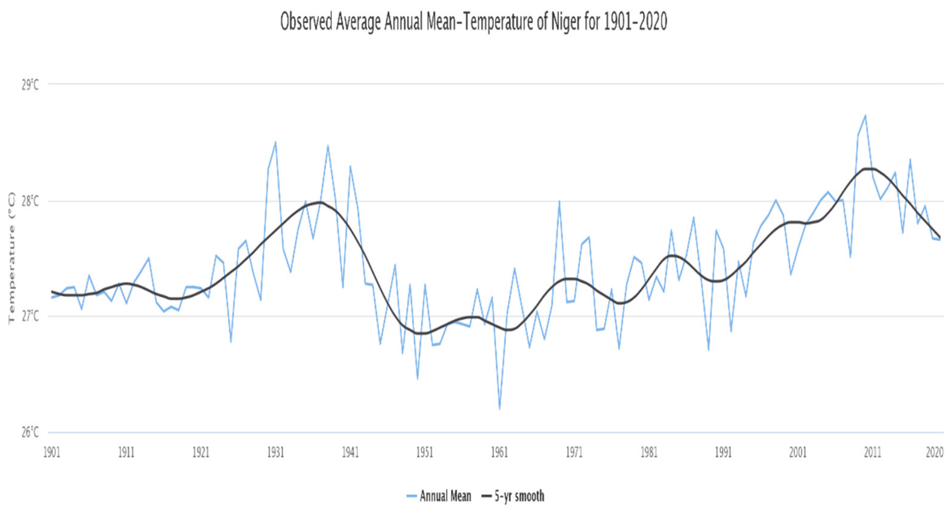

Figure 1. Observed annual mean -temperature of Niger (1901–2020). Source: climateknowledgeportal.worldbank.org (accessed on 03 December2021).

2.2. Sampling, Questionnaire, and Data Collection

The data used for this study are based on a farm household survey in Niger conducted during 2019. The data were collected for the baseline survey to implement the CSAT-Niger project. The sample frame covered all the four selected regions, namely Dosso, Tillabery, Maradi, and Zinder, which are the project target zones.

A multistage sampling technique was employed to select communes first and then villages from each region and households from each village. In the first stage, four regions

(Dosso, Tillaberi, Maradi, and Zinder) were purposively selected for the project implementation based on the intensity of cereal and legume production, agroecology, accessibility, and security. In the second stage, eight communes were purposively selected from each of the selected project regions. In the third stage, five intervention and five non-intervention villages were selected, considering accessibility, security, production of the project's main target crops (maize, sorghum, millet, cowpea, groundnut, and soybean), and the villagers' willingness to participate in the survey. The intervention villages are villages where project activities are being implemented, while non-intervention villages are satellite villages that are not benefiting from the project activities.

The final stage is the random selection of the households through the farmers listing and communal consultation forum. Households were selected from intervention and non-intervention villages. A total of 2240 farm households were interviewed. The sample size was distributed evenly among all the selected regions, thus the sample size per region for the intervention and non-intervention villages was 280 households each. Seven households were sampled from each of the selected 80 villages (intervention and non-intervention) per commune. The sampled households were selected through the farmers listing and stakeholder consultation at the community level.

A well-structured questionnaire was used as the main instrument for the data collection.

The data were collected using a pre-tested structured questionnaire by trained and experienced enumerators who know the farming systems and speak the local language.

The questionnaire was designed in French but administered to the respondents in local languages (Hausa and Zarma). All the enumerators and supervisors were trained for an average of 2 days to ensure that they were well instructed and familiar with the questionnaire before the field survey. The questionnaire contained different modules, such as household demographic and socioeconomic characteristics, climate change adaptation, perception and signs, food insecurity and hunger assessment scale, adoption of improved practices, and food and non-food expenditure. Finally, the information collected from 1783 households was valid and used for the analysis.

2.3. Conceptual Framework

2.3.1. Factors Influencing of Climate Change Adaptation Strategies

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts [25]. Rural households adopt different adaptation strategies to face the harsh climate conditions. For instance, a Sahelian farmer aware of the effects of climate change (drought) on their production may adopt soil management practices such as mulching or tillage to increase soil moisture to improve their crop output. Meanwhile, another household may sow an early maturing or a drought-tolerant crop variety on their farm to avoid the risk related to rainfall shortage to increase their production output. In one way or another, if the farmer is willing to have high returns, they will either imitate, innovate, or adopt recommended technology packages or face the risk of being squeezed into smaller profits [14,26].

We aimed to determine the factors influencing the farmers' decision to use a specific adaptation strategy. In this study, we categorized the household adaptation strategies into six major groups: climate-resilient crop varieties, improved agronomic practices, irrigation and water conservation practices, crop diversification, income diversification, and agroforestry (see Table 1). Each group was used individually as binary dependent variable. We then employed a Binary logit model to identify the factors that determine each category of the above six groups of smallholder farmers' adaptations to climate change [27–30].

The logit function for the farmers' likelihood of adopting a climate adaptation strategy can be specified as:

$$\text{Logit}(P) = \log(\frac{p}{1-p}\Big) \tag{1}$$

$$\text{Let, } Pi = \Pr\left(\frac{Y=1}{X=xi}\right) \tag{2}$$

Then, the model can be written as:

$$\Pr = (y = \frac{1}{x}) = \frac{exp^{xb}}{1-e^{xb}} = \log\left(\frac{P}{1-Pi}\right) = \text{Logit}(Pi) = \beta 0 + \ldots + \beta i\ xi \tag{3}$$

where, Pi is the probability to adopt an adaptation strategy (response variable), xi' s are the explanatory variables, $\beta 0$ is the intercept and βi are the regression coefficients for socio-economic variables.

Table 1. Adaptation strategy categories.

Categorization of Adaptation Strategies	Adapters (%)
Irrigation and water conservation practices	31.12
Income diversification	18.89
Improved agronomic practices	18.86
Climate-resilient crop varieties	12.71
Crop diversification	12.24
Agroforestry	6.15

2.3.2. Impact of Adaptation Strategies on Household Income and Food Security

To assess the impact of climate change adaptation strategies on household income and food security, we used matching techniques. We employed Propensity Score Matching (PSM) to estimate the impacts of the number of adaptation strategies used on household income and food security [31,32]. PSM is used to estimate the average treatment effect (ATE) of adoption of strategies on income and food security.

Here, we match treatment individual (people who adapted strategies to climate change) with control individuals (who did not adapt). Indeed, the basic idea is to match each adapter with an otherwise identical non-adapter (the comparator) based on observed pretreatment characteristics and then to measure the average difference in the outcome variable between the participants and the comparison group [33]. In practice, a model (probit or logit for binary treatment) is estimated in which participation in a treatment/program is explained by several pre-treatment characteristics and then predictions of this estimation are used to create the propensity score that ranges from 0 to 1.

We estimate the propensity score (PS) as the probability of adopting climate adaptation strategy, using the vector X as conditioning factors [34].

$$PS = P(D = 1 \mid X)$$
$$ATE = E[Y(1) - Y(0)] = E[Y(1)] - E[Y(0)]$$

The estimation was made from logit models of climate change adaptation strategies by controlling all the variables X which affect, meanwhile, the adaptation strategies and outcome variables.

Despite the fact that PSM tries to compare the difference between the outcome variables of adapters and non-adapters with similar inherent characteristics, it cannot correct unobservable bias [35]. Because PSM only controls for observed variables (to the extent that they are perfectly measured).

We used STATA version 16-teffects psmatch-command to estimate both ATE and ATET. The treatment and outcome variables are represented in Table 2.

Table 2. Variables.

Outcome Variables	
Income	**Total Household Income in FCFA**
Household food security (HFS)	Binary variable equal to 1 if household experienced food insecurity in last five years and 0 otherwise
Treatment variable = use at least one adaptation strategy	
Plant different crops/mixed cropping Change planting times Use drought tolerant/early maturing crop varieties Plant trees for shading and shelter Implement soil conservation techniques Irrigation Adopt other crop varieties Adopt minimum tillage Increase water conservation Swift farm to swamp area Farm more in Fadama areas Diversify from crops to livestock production Crop diversification Migration Income diversification (non-farm income sources)	

3. Results and Discussion

Summary of variables used in the analysis are presented in Table 3. These include the household demographic characteristics (household size, age, gender, household), the institutional factors such as access to credit, being member of a group, contact to extension services and other climate related factors.

Table 3. Definition of variables and descriptive statistics.

Variable	Description	Mean	SD
	Household and farm characteristics		
Gender	Dummy = 1 if household head is male	0.82	0.37
Age	Age of the household head	49.19	13.83
Household size	Total size of the household	10.99	6.32
Farm size	Total size of landholding in hectares	5.14	5.89
Literacy	Dummy = 1 if head of household can read and write	0.73	1.26
Farming experience	Number of years of farming	27.00	14.63
Migration	Dummy = 1 if head of household migrant	0.48	0.49
Quantity of household asset	Total quantity of assets	0.49	1.66
	Institutional factors		
Access to Credit	Dummy = 1 if the household has access to credit	0.33	0.47
Membership	Dummy = 1 if household head is member of an organization or an association	0.03	0.17
Contact with extension agent	Dummy = 1 if household has contact with public extension services	0.39	0.48
Training	Dummy = 1 if one (at least) household member attended training	0.15	0.35
Obtention of climate information	Dummy = 1 if household obtained information on rainfall and temperature	0.62	0.48
Awareness of improved seed varieties	Dummy = 1 if household is aware of improved seed varieties	0.30	0.45
Awareness of improved cropping systems	Dummy = 1 if household is aware of improved cropping systems	0.22	0.41
Access to Market	Distance to the nearest main road (in kilometers)	12.20	15.35
	Others		
Drought	Dummy = 1 if experienced drought in last five years	0.29	0.45

3.1. Sources of Farmers' Climate Information

Farmers' access to climate information offers great potential to enable them to make informed decisions, better manage risk, take advantage of favorable climate conditions, and adapt to change. The results reported in Table 4 show that more than 60% of the respondents received information on temperature and rainfall. More than 47% of the interviewed farmers received information from radio/TV, while 30% obtained information from friends. Few farmers received climate information from the government (less than 2%) and non-governmental organizations (NGOs) (less than 4%). A recent study found that radio and TV are potential sources of climate information for farmers in Eastern Cape Province, South Africa [36]. According to the climate change, agriculture, and food security (CCAFS) program, due to climate-informed advisory services and other innovations, climate information reaches about 7 million farmers through rural radio in Senegal. The dissemination of climate information through local radio/TV should be encouraged to widen farmers' knowledge on climate prediction. However, the availability of information only is not enough; it must be translated into actionable advisories supported effective communication processes, and training to understand and use such information.

Table 4. Farmers' sources of climate information.

Received Information on Temperature and Rainfall (*N* = 1784)	Frequency	Percent (%)
No	666	37.33
Yes	1118	62.67
Source of climate information (*n* = 1729)	Frequency	Percent (%)
Government	34	1.96
Radio/TV	813	47.02
Fellow farmer	303	17.52
Friends/relatives/neighbor	518	30
NGOs	61	3.52

3.2. Farmers' Perceptions of Climatic Change

The knowledge of farmers about climate change and risk is important for mainstreaming climate adaptation into agricultural development strategies and plans [37]. For the implementation of adaptation strategies, assessing the farmers' perception of climate change is needed. Considering the knowledge and perceptions of farm households in designing adaptation policies will definitively result in a fruitful and sustainable adaptation response to the effects of climate change [38]. In this study, the respondents were asked whether they have noticed changes in items reported in Table 5 during the period 2015–2019. With regard to rainfall variability, the majority of respondents had noticed changes in rain patterns (93.21%), in the amount of rain (91.25%), and in the intensity of rain (81.82%). Over 81% of respondents had perceived a delay in rainfall and more than 66% noticed an early end to rainfall. The results also revealed that most of the respondents had noticed heavy storms before rainfall (74%) and an increase in pests and diseases of crops (71%). The respondents also agreed that there was a high daily temperature (72.68%) and an increased frequency of drought (57%) and flooding (43.77%).

Table 5. Farmers' perceptions of climatic change (*N* = 1783).

Farmers' Perception of Climate Change	Responses Yes (%)
Change in rain patterns	93.21
Change in amount of rain	91.25
Change in intensity of rainfall	81.82
Delay in rainfall	81.15
Heavy storms	74.60
High daytime temperature	72.68
Increase in pest and diseases	71.4
Early end to rainfall	66.96
Increase in the intensity of cold	66.8
Early onset of heat and cold period	58.94
Frequency of droughts	57
Long duration of heat and cold period	39.5
Flooding	34.77

3.3. Farmers' Perceived Causes of Climate Change

Scientists believe that climate change is caused by global warming due to CO_2 emissions. The results in Table 6 show that 40.45% and 35% of respondents agreed that perceived causes of climate change are punishment for human sins and a sign of the end times, respectively. Over 95% of Niger people are Muslims, and fundamental Islamic teaching reveals that God punishes human beings because they do not abide by His law. In some sayings, you harvest what you have planted. Approximately 40.49% of the respondents perceived the cause of climate change as a natural occurrence, while only 24.67% believed that it is caused by a distortion of atmospheric composition.

Table 6. Farmers' perceived causes of climate change.

Causes of Climate Change	Agree (%)
Deforestation (human causes)	43.52%
Natural occurrence	40.49%
Punishment for human sins by God/gods (spiritual)	40.45%
Sign of the end times (spiritual)	35%
Indiscriminate bush burning (human causes)	34.09%
Distortion of atmospheric composition (scientific phenomenon)	24.67%

The results showed that the participants also believed that climate change is caused by human abuse of scarce natural resources such as bush burning (34.09%) and deforestation (43.52%). Bush clearing and burning are common phenomena in rural Niger. In fact, firewood is the main source of energy in Niger. Approximately 94% of households rely on wood as a primary source of energy, especially used for cooking both in rural and urban areas [39]. Similar results were reported in a study on farmers' perception of and adaptation to climate change in the savannas of Borno State of Nigeria [10].

3.4. Households' Adaptive Strategies

In rural Sahel and in Niger particularly, most of the households rely on their own production for food security [40]. Adapting agriculture to climate change is, therefore, a perquisite for the farm households to increase production and income in order to be safe from hunger. Different adaptation strategies work in different ways depending upon the type of crop, climatic conditions, crop management practices, and the area where the particular adaptation is implemented [41]. Table 7 presents the different adaptation strategies used by the households. When we look at each strategy individually, the results revealed that crop diversification (72.74%), income diversification (67.97%) and changing planting times (55%) are the main strategies adopted by households. Sofoluwe et al. (2011) stated that late planting could be associated with the convenience and no direct cost to the farmers, other adapting strategies include use of drought tolerant crops (49.6%), planting trees for shading and shelter (45.7%), implementation of soil conservation techniques (39.6%), migration (31%) and adoption of irrigation (28.65%). An exploratory and systematic synthesis of quantitative and qualitative data from 63 studies covering more than 9700 rural households from Sub-Saharan African drylands on household adaptation strategies revealed that strategies related to crop, livestock, soil and water management are, by far, the most common [13]. Because of the short duration cropping season, rural- urban household migration is also commonly practiced. The main destinations for Nigerien migrants are regional coastal countries such as Ivory Coast, Ghana, Togo and other neighboring countries [42]. This voluntary migration is practiced not because the effects of climate change on households, but this may be due to the hope to find better life. Indeed, the head of household usually goes on exodus when the harvests are bad to leave the little harvested to the family and in the hope of sending some things as soon as possible to mitigate the effect of the shock.

Table 7. Household adaptation strategies to climate change (N = 1783).

Household Adaptation Strategies	Adapters (%)
Plant different crops/mixed cropping	72.74
Crop diversification	70.44
Income diversification (non-farm income sources)	67.97
Adopt other crop varieties	55.24
Change planting times	55
Use drought tolerant/early maturing crop varieties	49.6
Plant trees for shading and shelter	45.7
Implement soil conservation techniques	39.6
Diversify from crops to livestock production	34.88
Increase water conservation	33.53
Adopt minimum tillage	32.13
Migration	31
Irrigation	28.65
Farm more in Fadama areas	25.85
Swift farm to swamp area	19.46

The purpose of adaptation is to reduce vulnerability and enhance resilience face to climate actions [43]. The households with access to remittances have comparatively high resilience capacity [44,45].

3.5. Determinants of Household Climate Change Adaptation Strategies

To identify the determinants of the adoption of the household climate-change adaptation strategies, we grouped these strategies into six main categories. These are climate-resilient crop varieties, improved agronomic practices, irrigation and water conservation practices, crop diversification, income diversification, and agroforestry as stated above. The household characteristics are considered to have differential impacts on adoption or adaptation decisions [17].

Logit regressions were carried out to determine the influence of household socio-demographic and economic characteristics on the farmers' adoption of adaptation strategies. The results of logit models for the six categories are presented in Table 8.

Table 8. Logit regression of drivers influencing farmers' adoption of climate adaptation strategies.

Explanatory Variables	Household Climate Change Adaptation Strategies					
	Climate Resilient Crop Varieties Model 1	Improved Agronomic Practices Model 2	Irrigation and Water Conservation Practices Model 3	Crop Diversification Model 4	Income Diversification Model 5	Agroforestry Model 6
Gender	−1.062 ***	0.810 ***	0.430 **	−1.529 ***	1.111 ***	0.465
Age	0.002	0.030 ***	−0.004	−0.020 ***	−0.023 ***	0.005
Household Size	−0.051 ***	−0.040 ***	−0.011	0.041 ***	0.042 ***	0.046 **
Farm size	−0.033 *	−0.033 **	0.0361 ***	0.015	−0.042 ***	−0.023
Literacy	0.064	−0.009	−0.031	0.307 ***	−0.095 *	−0.633 ***
Farming experience	0.007	−0.023 ***	0.008	−0.006	0.027 ***	−0.011
Access to credit	0.894 ***	−0.625 ***	0.0004	0.836 ***	−0.941 ***	0.405
Attended training	−0.459 **	−0.131	−0.477 ***	0.104	0.394 **	1.624 ***
Membership	−1.330 ***	1.209 ***	0.277	−1.039 **	0.085	−0.536
Contact extension services	0.340 **	0.408 ***	−0.097	0.091	−0.286 **	−1.152 ***
Access to climate information	0.547 ***	−0.672 ***	0.160	0.378 ***	0.350 **	−1.169 ***
Awareness of improved seed varieties	0.052	0.117	−0.721 ***	−0.408 ***	0.693 ***	0.609 ***
Access to market	0.020 **	−0.067 ***	−0.032 ***	0.077 ***	−0.012	0.044 **
Household asset	−0.056	−0.288 ***	0.060 ***	−0.112 **	0.029	0.039
Awareness of improved cropping systems	0.246	−0.005	0.417 ***	−0.046	−0.530 ***	−0.391 *
Migrant head of household	0.038	−0.026	0.194	0.596 ***	−0.727 ***	−0.752***
Experience of drought	−0.343 **	−0.254 *	0.423 ***	0.359 **	−0.117	−1.202 ***
constant	−1.511 ***	−1.128 ***	−1.396 ***	−1.463 ***	−2.144 ***	−3.077 ***
Numb. of observations	2276	2276	2276	2276	2276	2276
LR chi2(17)	108.14	207.56	160.66	232.99	199.47	243.53
Log likelihood	−792.69298	−1093.2825	1242.6506	−851.81315	−955.24174	−417.76162
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.0639	0.0867	0.0607	0.1203	0.0945	0.2257

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ show the level of significance.

3.5.1. Climate-Resilient Crop Varieties

The purpose of adopting climate-resilient crop varieties is to improve plant productivity in the face of climate change and emerging pathogens and pests. The adaptation of agriculture to climate change requires farmers to adopt suitable varieties to minimize climate risk. Farmers need to adopt improved crop varieties appropriate to their environment. The results of logit regression (Model 1) show that access to credit and market, obtention of climate information and contact to extension services are positively associated with farmers' decisions to adopt climate-resilient crop varieties.

This implies that farmers that have access to credit are more likely to adopt improved crop varieties than their counterparts. In fact, many rural poor farmers cannot afford to buy these highly resilient crop varieties; therefore, access to credit may facilitate the adoption of improved crop varieties. Indeed, households with higher income and more assets are in a better position to adopt new farming technologies [15,46].The adopters of any adaptation strategy have a higher income than non-adopters in all cases according to a study of the perception of climate change and farm-level adaptation choices in central Kenya [47]. The government agencies and development projects often provided these improved crops to farmers for their multiplication, but the farmers usually failed in this assignment.

However, being a male-headed household, family size, farm size, attended training, and experiencing drought are found to have a negative effect on the adoption of climate-resilient crop varieties. This implies that male-headed households are associated with a decreasing probability of adoption of climate-resilient crop varieties. It means that female-headed households are more likely to go for climate-resilient crop varieties than male-headed households. This aligns with the findings of Sinyolo, Nhemachena and Hassan [48,49]. Similarly, farm size is associated with decreasing probability of adoption of improved crops varieties. An additional hectare of farmland is associated with a 5.9% decrease in the chances of using improved crop varieties. Meanwhile the coefficient of household size is negatively associated with adoption of improved climate resilient crop varieties. This implies that the larger the number of people in family, the less likely the adoption of improved crop varieties.

3.5.2. Improved Agronomic Practices

The changing climate pattern gave rise to the need to adopt improved agronomic practices as agriculture is more susceptible to this change. The results of logit regression (Model 2) show that the factors such as being a male-headed household, age, group membership, and contact with extension services are positively associated with the adoption of improved agronomic practices. This implies that male-headed households are more likely to adopt improved agronomic practices than female counterparts. This is in line with the finding of [9,14] that male-headed households are more likely to engage in new technologies and farming practices. Similarly, farmers who are members of a group and in contact with extension services are more likely to use improved agronomic practices. This is confirmed by the previous studies [40,50,51]. Meanwhile, the older farmers are more likely to adopt improved agronomic practices than younger farmers.

However, factors such as household and farm sizes, farming experience, access to credit and market, obtention climate information, the quantity of household asset and experience of drought are found to have negative and significant effect on the probability of adopting improved agronomic practices.

3.5.3. Irrigation and Water Conservation Practices

In the Sahel, water is a limiting factor which reduces seriously the agricultural productivity. Improved irrigation efficiency will become an important adaptation tool to increase agricultural production. The availability of irrigable water at the farm level will allow crops to grow anytime in the season for household consumption and for sale at the local market. The results from Model 3 revealed that being a male-headed household, farm size, household asset, awareness of improved cropping systems, and drought were found to have a positive relationship in adopting irrigation and water conservation practices. This implies that households with more assets are more likely to implement irrigation and water conservation techniques than those with small assets. These results are in line with [11], who found in Ethiopia that the relative wealth status of the household affects positively and significantly the farmer's decision to adopt and implement soil conservation techniques. Similarly, during drought, households are more likely to adopt irrigation and water techniques. Indeed, irrigation can play an important role in agricultural production in areas such as Sahelian of Niger where drought is regular. The combination of Zai and Mulch could be a successful adaptation practice to reduce risk from climate change and improve household resilience in southwest Niger [52].The male-headed households adopt more adaptation methods than female-headed households [31,47].

However, attending training, awareness of improved seed varieties and access to markets were negatively associated with irrigation and water conservation practices. This means that training is negatively associated with a decrease in the probability of implementing irrigation and water conservation techniques. This is contrary to [40,50], who indicated that attending training and awareness workshops on soil and water management practices or climate change adaptation is significantly and positively associated with the adoption of zaï, stone bunds, and composting in Niger and West Africa, respectively.

3.5.4. Crop Diversification

Crop diversification refers to planting crops on the same plot through mixed cropping or intercropping. This farming system can greatly protect food security and production in regions where farmers have little access to chemical, structural, or technological resources [53]. The crop diversification might stabilize the productivity of cropping systems and reduce negative environmental impacts and loss of biodiversity [54]. The households with more than one crop grown tend to be more secure in food supplies and income [55].

The results of Model 4 revealed that household and farm size, literacy level, access to credit and market, obtention of climate information, contact with extension services, being a migrant household, and drought are positively associated with the probability of diversifying crops on the farm. Crop diversification requires some level of education for farmers to know which crops can be grown on the same farm, which implies the positive relationship between literacy and the diversification of crops. Meanwhile, farmers need enough farm equipment and productive assets to carry out different cropping activities on the farm. Credit is an important variable that will give farmers access to agricultural inputs. Access to credit has become a necessity in financing the agricultural production process and for the survival of many rural households [56].The crop diversification as an adaptation strategy to climate change depends on access to credit, access to education, and farm income [57]. This is also supported by [18,58] who noticed that farmers are more likely to adopt if they had access to credit. The access to credit was associated with crop diversification [47]. Similarly, the more educated farmers are more likely to diversify the crops on-farm compared to the less educated ones. This is confirmed [50] who stated that education is important in accelerating the adoption of knowledge-intensive technologies. Similarly, obtention of climate information on the amount of rainfall and the temperature gives household the ability to make informed decisions on how to capitalize upon or prepare for future conditions, increasing their vulnerability to climate shocks and food insecurity. This implies the positive association between crop diversification and climate information.

However, being a male-headed household, age, being member of a group, awareness of improved seed varieties and the quantity of household assets are found to have a negative effect on the probability of adopting crop diversification. This indicates that the female headed households are more likely to diversify the crops on their farms. Similarly, younger farmers are more likely to adapt crop diversification strategy to face the negative impact of climate change on the production.

3.5.5. Income Diversification

Rural households have several ways to diversify their incomes. For instance, beyond farming crops, they can rear livestock, run small businesses to sell and buy goods from village-to-village markets or from rural to urban markets, or household members can migrate to other cities or countries to look for additional financial resources for the family. The results of logit regression (Model 5) show that being a male-headed household, family size, farming experience, training, access to climate information and awareness of improved seed varieties are positively associated with the probability of farmers diversifying their incomes. This implies that the male-headed households and farmers who have more farming experience, are members of a group, received training, and are aware of climate information and improved seed varieties are more likely to diversify their incomes than their counterparts.

However, factors such as age, farm size, literacy level, access to credit, contact to extension services, awareness of improved cropping systems and being a migrant household are found to be negatively associated with the probability of farmers' income diversification. The negative association of age and income diversification implies that younger farmers are more likely to look for diverse sources of income compared to older farmers. This aligns with [15]. As unexpected, being a migrant household is associated negatively with farmers diversifying their incomes. In most Sahelian zones, particularly Niger, farmers migrate to cities or even to other countries after the 3 to 4 months cropping season to look for additional financial resources and return home when the first rain falls or even before the rain starts. This is called seasonal or rural-urban migration.

3.5.6. Agroforestry

Protecting existing forests and planting new plants are surely good things to do to mitigate the effects of climate change on the ecosystem. The results of logit regression (Model 6) show that family size, training, awareness of improved seed varieties and market access are positively associated with the probability of farmers planting trees. This implies that the households with larger family size are more likely to adopt planting trees compared to those with smaller ones.

However, literacy level, extension services, obtention climate information, awareness of improved cropping systems, migration, and drought are found to have a negative effect on the probability of adopting agroforestry. This implies that the probability of adopting agroforestry decreases by 4.7% with an additional increase in farm size. Similarly, farmers with higher education are less likely to adopt agroforestry. This is in line with [59] who found a negative relationship between education and adoption of agroforestry in Uganda.

3.6. Impact of Adaptation Strategies on Household Income and Food Security

The particular interest in this study is to evaluate the impact of household climate change adaptation strategies on household food security and income. We employed the propensity score matching method (logit) to assess the effects of climate adaptation strategies on household food security and income. The Figure 2 shows the propensity score distribution of adapters and non-adapters.

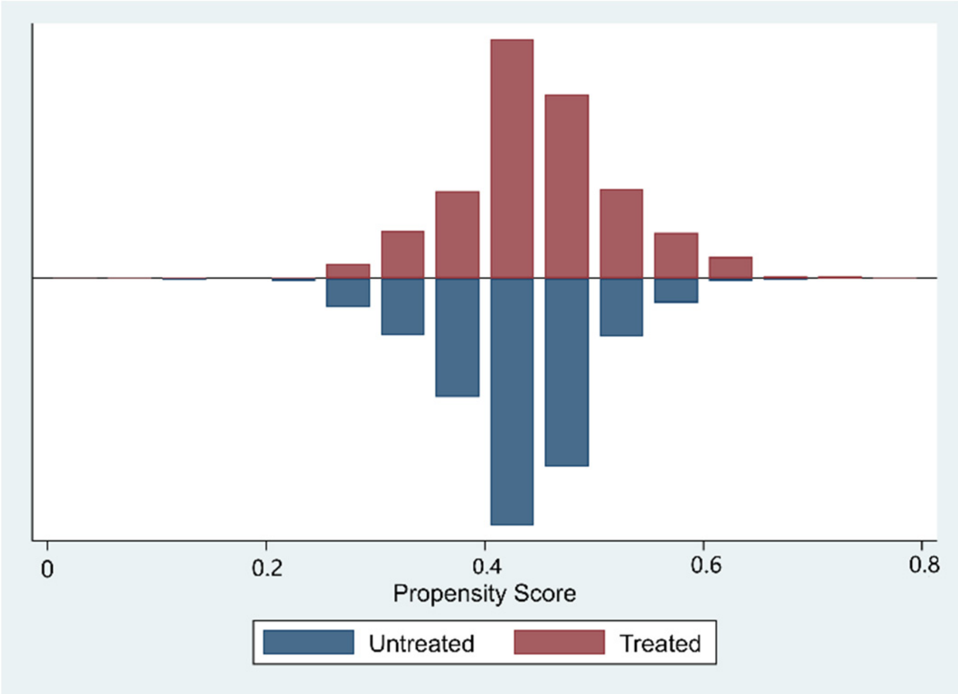

Figure 2. Propensity score distribution.

The results are presented in Table 9. The outcome variables are household income and household food security (HFS) indicating that a household has experienced food insecurity during the last five years. We estimated both ATE and ATET. The average treatment effect (ATE) measures the average impact of an innovation on the entire population. It also represents the expected impact on a person selected randomly from the population. The average treatment effect on the treated (ATET) determines the average impact of an innovation in the subpopulation of the treated. It also represents the expected impact on a person selected randomly from the subpopulation of the treated.

The results show that both the coefficients of ATE are positive but not significant and estimated at 5590.079 for propensity score and 2509.078 for nearest neighbor matching. Meanwhile the coefficients of ATET are positive and significant at 5% level for propensity score and not significant for nearest neighbor matching. This indicate that the farmers who adopt climate change adaptation strategies are more likely to increase household income by 7721.526 FCFA compared to those households with zero adaptation strategies.

Similarly, the results indicate the negative impact of adaptation on household food insecurity. This implies that households that adopt climate change adaptation strategies are more likely to be food secure compared to those who adopt zero adaptation strategy. They are 7% to 9% more food secure compared to those who did not adopt strategies.

Table 9. Matching estimation of the impact of adaptation strategies on farm income and food security.

Matching Algorithm	Outcome Variables	ATE (1VS 0)	ATET(1 VS 0)
Propensity score	Income	5590.079	7721.526 **
Nearest neighbor	Income	2509.078	7993.36
Propensity score	HFS	−0.037	−0.074 *
Invert-probability-weighting	HFS	−0.094 ***	−0.073 ***

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ show the level of significance.

This positive impact of adaptation of these strategies to climate change on household income and food security is supported by the findings of recent studies [60,61].

4. Conclusions

Climate change continues to affect agriculture and adaptations are necessary to reduce its impacts on household livelihoods. Factors that influence farmers' adaptation decisions are very important in designing policies to promote effective adaption in the agricultural sector. Farmers must recognize that the climate is changing to identify and implement climate change adaptation strategies [62]. In this study, 91.25% of respondents perceived climate change as a change in the amount of rain, 81.82% as a change in intensity of rainfall, 93.21% as a change in rain pattern, and 81.15% as a delay in rainfall. More than 62% of respondents attested to receiving information on climate change and more than 47% obtain information from radio and TV.

We categorized these adaptation strategies into six major groups namely climate-resilient crop varieties, improved agronomic practices, irrigation and water conservation practices, crop diversification, income diversification, and agroforestry. We ran logit regression to identify the determinants of each individual group. The results show mixed effects of independent variables on these categories of adaptation strategies. Using matching techniques, we found adaptation strategies have positive and significant impact on both household income and food security. The farmers who adopt climate change adaptation strategies are more likely to increase household income by 7721.526 FCFA compared to those households with zero adaptation strategies. Similarly, the adapters have 7% to 9% more chance to be food secure compared to those who did not adopt strategies.

These results imply that designing a successful rural development program aimed at increasing household resilience in the face of climate change entails a careful analysis of a wide range of factors that could vary in time and space. Indeed, climate risks such as drought and flooding affect seriously agricultural production on which relies a large portion of Niger population.

These findings provide insight for better target interventions to promote the adoption of mechanisms to reduce the impact of climate change on household food security in the Sahel. To reduce these uncertainties in climate change, the study recommends strengthening institutional factors such as access to credit, market, extension services, group membership, and using drought-resilient crop varieties would surely improve agricultural production and food security in the Sahelian region

From the results of impact evaluation, the resilience level of household food security due to climate change adaptation is very low (only 7% to 9% of chance to be food secure). Thus, it is very crucial to choose and implement appropriate adaptation strategies to enhance household resilience to food insecurity.

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References

1. United Nation Framework Convention on Climate Change. *Impacts UNFCC. Vulnerabilities and Adaptation in Developing Countries*; UNFCC: Bonn, Germany, 2007; Available online: https://unfccc.int/resource/docs/publications/impacts.pdf (accessed on 15 May 2019).
2. IPCC (Intergovernmental Panel on Climate Change); Core Writing Team; Pachauri, R.K.; Reisinger, A. *Climate Change 2007: Synthesis Report, Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Geneva, Switzerland; Available online: https://www.ipcc.ch/report/ar4/syr/ (accessed on 15 May 2019).
3. Hailegiorgis, M.T.; Berheto, T.M.; Sibamo, E.L.; Asseffa, N.A.; Tesfa, G.; Birhanu, F. Psychological wellbeing of children at public primary schools in Jimma town: An orphan and non-orphan comparative study. *PLoS ONE* **2018**, *13*, 195377. [CrossRef] [PubMed]
4. Menikea, L.M.C.S.; Keeragala Arachchib, K.A.G.P. Adaptation to climate change by smallholder farmers in rural communities: Evidence from Sri Lanka. *Procedia Food Sci.* **2016**, *6*, 288–292. [CrossRef]
5. Solidarités International. The Sahel at the Heart of Climate Change Issues. 2020. Available online: https://www.solidarites.org/en/live-from-the-field/the-sahel-in-the-midst-of-climate-change/ (accessed on 28 June 2021).
6. Wood, S.A.; Jina, A.S.; Jain, M.; Kristjanson, P.; DeFries, R.S. Small holder farmer cropping decisions related to climate variability across multiple regions. *Glob. Environ. Chang.* **2014**, *25*, 163–172. [CrossRef]
7. Alam, M.G.M.; Alam, K.; Mushtaq, S. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Clim. Risk Manag.* **2017**, *17*, 52–63. [CrossRef]
8. Rosenzweig, C.; Elliott, J.; Deryng, D.; Ruane, A.C.; Müller, C.; Arneth, A.; Boote, K.J.; Folberth, C.; Glotter, M.; Khabarov, N.; et al. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model inter-comparison. *Proc. Natl. Acad. Sci. USA* **2013**, *111*, 3268–3273. [CrossRef]
9. Deressa, T.T.; Hassan, R.M.; Ringler, C.; Alemu, T.; Yesuf, M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Chang.* **2009**, *19*, 248–255. [CrossRef]
10. Tambo, J.A.; Abdoulaye, T. Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. *Reg. Environ. Chang.* **2013**, *13*, 375–388. [CrossRef]
11. Gebru, G.W.; Ichoku, H.E.; Phil-Eze, P.O. Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. *Heliyon* **2020**, *6*, e04356. [CrossRef]
12. Lewis, K.; Buontempo, C. *Climate Impacts in the Sahel and West Africa: The Role of Climate Science in Policy Making*; West African Papers No. 02; OECD Publishing: Paris, France, 2016. [CrossRef]
13. Wiederkehr, C.; Beckmann, M.; Hermans, K. Environmental change, adaptation strategies and the relevance of migration in Sub-Saharan drylands. *Environ. Res. Lett.* **2018**, *13*, 113003. [CrossRef]
14. Funk, C.; Sathyan, A.R.; Winker, P.; Breuer, L. Changing climate—Changing livelihood: Smallholder's perceptions and adaption strategies. *J. Environ. Manag.* **2020**, *259*, 109702. [CrossRef]
15. Obayelu, O.A.; Adepoju, A.O.; Idowu, T. Factors influencing farmers' choices of adaptation to climate change in Ekiti State, Nigeria. *J. Agric. Environ. Int. Dev. JAEID* **2014**, *108*, 3–16.
16. Smit, B.; Skinner, M.W. Adaptation options in agriculture to climate change: A typology. *Mitig. Adapt. Strateg. Glob. Chang.* **2002**, *7*, 85–114. [CrossRef]
17. Gbetibouo, G.A. Understanding Farmers Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin Farmers South Africa. IFPRI Discussion Paper 2009. Available online: https://www.ifpri.org/publication/understanding-farmers-perceptions-and-adaptations-climate-change-and-variability (accessed on 15 November 2020).
18. Bryan, E.; Deressa, T.T.; Gbetibouo, G.A.; Ringler, C. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environ. Sci. Policy* **2009**, *12*, 413–426. [CrossRef]
19. Below, T.B.; Mutabazi, K.D.; Kirschke, D.; Franke, C.; Sieber, S.; Siebert, R.; Tscherning, K. Can farmers' adaptation to climate change be explained by socio economic household-level variables? *Glob. Environ. Chang.* **2012**, *22*, 223–235. [CrossRef]
20. World Bank. *Niger Food Security and Safety Nets*; Report No. 44072-NE; World Bank: Washington, DC, USA, 2009; Available online: http://reliefweb.int/sites/reliefweb.int/files/resources/fullreport_154.pdf (accessed on 15 April 2021).
21. Yila, O.J.; Resurreccion, B.P. Determinants of smallholder farmers' adaptation strategies to climate change in the semi-arid Nguru Local Government Area, Northeastern Nigeria. *Manag. Environ. Qual.* **2013**, *24*, 341–364. [CrossRef]
22. Amare, A.; Simane, B. Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the Upper Blue Nile basin of Ethiopia. *Agric. Food Secur.* **2017**, *6*, 413. [CrossRef]
23. Work Bank. Niger Overview. 2020. Available online: https://www.worldbank.org/en/country/niger/overview (accessed on 11 May 2020).
24. USAID. Climate Risks in Food for Peace Geographies: Niger. 2017. Available online: https://www.climatelinks.org/resources/climate-risks-food-peace-geographies-niger (accessed on 25 July 2020).
25. IPCC (Climate Change); McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S. *Impacts, Adaptation and Vulnerability*; Cambridge University Press: Cambridge, UK, 2001.
26. Molua, E.L. Gendered response and risk-coping capacity to climate variability for sustained food security in Northern Cameroon. *Int. J. Clim. Strateg. Manag.* **2012**, *4*, 277–307. [CrossRef]
27. Ahmed, Z.; Guha, G.S.; Shew, A.M.; Alam, G.M.M. Climate change risk perceptions and agricultural adaptation strategies in vulnerable riverine *char* islands of Bangladesh. *Land Use Policy* **2021**, *103*, 105295. [CrossRef]

28. Saguye, T.S. Determinants of smallholder farmers' adoption of climate change and variability adaptation strategies: Evidence from Geze Gofa District. Gamo Gofa Zone, Southern Ethiopia. *J. Geogr. Environ. Earth Sci.* **2016**, *6*, 147–161.
29. Delaporte, I.; Maurel, M. Adaptation to climate change in Bangladesh. *Clim. Policy* **2016**, 49–62. [CrossRef]
30. Atube, F.; Malinga, G.M.; Nyeko, M.; Okello, D.M.; Alarakol, S.P.; Okello-Uma, I. Determinants of smallholder farmers' adaptation strategies to the efects of climate change: Evidence from northern Uganda. *Agric. Food Secur.* **2021**, *10*, 6. [CrossRef]
31. Ali, A.; Erenstein, O. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Clim. Risk Manag.* **2017**, *16*, 183–194. [CrossRef]
32. Zhu, Y.; Yang, Q.; Zhang, C. Adaptation strategies and land productivity of banana farmers under climate change in China. *Clim. Risk Manag.* **2021**, *34*, 100368. [CrossRef]
33. Haughton, D.; Haughton, J. *Living Standards Analytics: Development through the Lens of Household Survey Data*; Springer Science & Business Media: New York, NY, USA; Dordrecht, The Netherlands; Heidelberg, Germany; London, UK, 2011; pp. 245–267.
34. Verhofstadt, E.; Maertens, M. Can agricultural cooperatives reduce poverty? Heterogeneous impact of cooperative membership on farmers' welfare in Rwanda. *Appl. Econ. Perspect. Policy* **2014**, *37*, 86–106. [CrossRef]
35. Asfaw, S.; Shiferaw, B.; Simtowe, F.; Lipper, L. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy* **2012**, *37*, 283–295. [CrossRef]
36. Popoola, O.O.; Yusuf, S.F.G.; Monde, N. Information Sources and Constraints to Climate Change Adaptation amongst Smallholder Farmers in Amathole District Municipality, Eastern CapeProvince, South Africa. *Sustainability* **2020**, *12*, 5846. [CrossRef]
37. Sarr, B.; Atta, S.; Ly, M.; Salack, S.; Ourback, T.; Subsol, T.; George, D.A. Adapting to climate variability and change in smallholder farming communities: A case study from Burkina Faso, Chad and Niger (CVCADAPT). *J. Agric. Ext. Rural Dev.* **2015**, *7*, 16–27.
38. Gedefaw, M.; Girma, A.; Denghua, Y.; Hao, W.; Agitew, G. Farmer's Perceptions and Adaptation Strategies to Climate Change, Its Determinants and Impacts in Ethiopia: Evidence from Qwara District. *J. Earth Sci. Clim. Chang.* **2018**, *9*, 7.
39. Mijitaba, M.M.; Jing, F.J. Fuelwood consumption in Niger: A review. *Int. J. Res. Stud. Manag.* **2013**, *2*, 67–76. [CrossRef]
40. Zakari, S.; Ying, L.; Song, B. Factors influencing Household Food Security in West Africa: The Case of Southern Niger. *Sustainability* **2014**, *6*, 1191–1202. [CrossRef]
41. Mahmood, N.; Arshad, M.; Kaechele, H.; Shahzad, M.F.; Ullah, A.; Mueller, K. Fatalism, climate resiliency training and farmers' adaptation Responses: Implications for sustainable rainfed-wheat production in Pakistan. *Sustainability* **2020**, *12*, 1650. [CrossRef]
42. Zakari, S. Factors Affecting Niger Food Security: An Analysis at Household and National Levels. Ph.D. Thesis, Huazhong Agricultural University, Wuhan, China, 2014.
43. Smit, B.; Pilifosova, O. Adaptation to Climate Change in the Context of Sustainable Development and Equity. In *Working Group II: Impacts, Adaptation and Vulnerability*; IPCC Assessment Report; IPCC: Geneva, Switzerland, 2001.
44. Babatunde, R.O.; Martinetti, E.C. Impacts of migrant remittances on food security and nutrition of Farming Households in Kwara State, Nigeria. In Proceedings of the Contributed Paper for the International Conference: Shocks in Developing Countries, Paris, France, 30 June–1 July 2011.
45. Abadi, N.; Techane, A.; Tesfay, G.; Maxwell, D.; Vaitla, B. *The Impact of Remittances on Household Food Security: A Micro Perspective from Tigray, Ethiopia*; WIDER Working Paper 2018/40; United Nations University: Tokyo, Japan, 2018.
46. Shiferaw, B.; Holde, S. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: Case study in Andit Tid, North Shewa. *Agric. Econ.* **1998**, *27*, 739–752.
47. Asayehegn, K.; Temple, L.; Berta, S.B.; Ana Iglesias, A. Perception of climate change and farm level adaptation choices in central Kenya. *Cah. Agric.* **2017**, *26*, 25003. [CrossRef]
48. Sinyolo, S. Technology adoption and household food security among rural households in South Africa: The role of improved maize varieties. *Technol. Soc.* **2020**, *60*, 101214. [CrossRef]
49. Nhemachena, C.; Hassan, R. *Micro-Level Analysis of Farmers Adaption to Climate Change in Southern Africa*; Working Paper No. 714; International Food Policy Research Institute (IFPRI)—Centre for Environmental Economics and Policy in Africa (CEEPA): Washington, DC, USA, 2007.
50. Kpadonou, R.A.B.; Owiyo, T.; Barbier, B.; Denton, F.; Rutabingwa, F.; Kiema, A. Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and waterconservation technologies in West African Sahel. *Land Use Policy* **2017**, *6*, 196–207. [CrossRef]
51. Ouédraogo, M.; Houessionon, P.; Zougmoré, B.; Partey, S.T. Uptake of climate-smart agricultural technologies and practices: Actual and potential adoption rates in the climate-smart village site of Mali. *Sustainability* **2019**, *11*, 4710. [CrossRef]
52. Issoufou, A.A.; Soumana, I.; Maman, G.; Konate, S.; Mahamane, A. Dynamic relationship of traditional soil restoration practices and climate change adaptation in semi-arid Niger. *Heliyon* **2020**, *6*, e03265. [CrossRef] [PubMed]
53. Lin, B.B. Resilience in agriculture through crop diversification: Adaptive management for environmental change. *Bioscience* **2011**, *61*, 183–193. [CrossRef]
54. Hufnage, J.; Reckling, M.; Ewert, F. Diverse approaches to crop diversification in agricultural research: A review. *Agron. Sustain. Dev.* **2020**, *40*, 14. [CrossRef]
55. Mango, N.; Makate, C.; Mapemba, L.; Sopo, M. The role of crop diversification in improving household food security in central Malawi. *Agric Food Secur.* **2018**, *7*, 7. [CrossRef]
56. Gentil, D.; Servet, J. Microfinance: Petites sommes, grands effets. *Rev. Tiers Monde Année* **2002**, *172*, 729–735. [CrossRef]

57. Makate, C.; Wang, R.; Makate, M.; Mango, N. Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. *Springerplus* **2016**, *5*, 1135. [CrossRef] [PubMed]
58. Tangonyire, D.F.; Akuriba, G.A. Socioeconomic factors influencing farmers' specific adaptive strategies to climate change in Talensi district of the Upper East Region of Ghana. *J. Ecofeminism Clim. Chang.* **2020**, *2*, 55–68. [CrossRef]
59. Mfitumukiza, D.; Barasa, B.; Ingrid, A. Determinants of agroforestry adoption as an adaptation means to drought among smallholder farmers in Nakasongola District, Central Uganda. *Afr. J. Agric. Res.* **2017**, *12*, 2024–2035.
60. Mekonnen, A.; Tessema, A.; Ganewo, Z.; Haile, A. Climate change impacts on household food security and farmers adaptation strategies. *J. Agric. Food Res.* **2021**, *6*, 100197. [CrossRef]
61. Ogunpaimo, O.R.; Oyetunde-Usman, Z.; Surajudeen, J. Impact of Climate Change Adaptation on Household Food Security in Nigeria—A Difference-in-Difference Approach. *Sustainability* **2021**, *13*, 1444. [CrossRef]
62. Maddison, D. *The Perception of and Adaptation to Climate Change in Africa*; Discussion Paper No. 10; Centre for Environmental Economics and Policy in Africa: Pretoria, South Africa, 2007.