AATCC Journal

07 April 2026: Received
06 May 2026: Revised
10 June 2026: Accepted
08 July 2026: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Perception and adaptation to climate change: econometric evidence of the determinants and resilience of farming households in Sare Bidji (Senegal)

Malick Ndiaye[1], Malick Touré*[1] and Ibrahima Thiam[2]

[1]Higher Institute for Agricultural and Rural Training (ISFAR), Alioune Diop University, Senegal
[2]Department of Economic and Social Sciences, Iba Der Thiam University of Thies, Senegal

ABSTRACT

This study examines how farming households in the municipality of Sare Bidji, Senegal, perceive climate change and adapt to it in practical terms. It is based on a field survey of 320 family farms spread across 35 villages, combined with an econometric analysis (Probit, Logit, Negative Binomial, Multinomial Logit, and OLS) to identify the factors influencing households' adaptation decisions and resilience. This research faced challenges related to the remoteness of certain data collection areas and the low educational attainment of household heads, requiring the interviews to be adapted to the local context. The results show that farmers have a clear and direct perception of climate change: drought (78.5%), irregular rainfall (71.3%), and rising temperatures (64.8%) are the most frequently mentioned indicators. Farmers with better access to climate-related information and extension services are also more likely to implement adaptation measures. Furthermore, access to climate information and technical assistance significantly increases the likelihood of adopting adaptation strategies (by 9% and 12%, respectively). The study also highlights the central role of technical assistance (β=0.6) and irrigation (β=0.35) in strengthening household resilience ($p < 0.001$). These levers enable farmers to reduce their dependence on rainfall and secure their incomes in the face of climate shocks. These results underscore the importance of strengthening climate services, technical support mechanisms, and farmer organizations to bolster the resilience of Sahelian agricultural systems.

Keywords: *climate change; perception; adaptation strategies; resilience; econometric analysis; Senegal; smallholder agriculture; food security; farming households; Kolda.*

1. INTRODUCTION

Located in the heart of the Sahel, Senegal is among the regions most exposed to climate hazards. Rainfall patterns have become increasingly erratic in both their spatial and temporal distribution, with a marked declining trend, while temperatures are steadily increasing. Agriculture, the backbone of the economy, is almost entirely dependent on rain: annual precipitation ranges from 300 mm in the north to 1,200 mm in the south, and the rainy season lasts only 3 or 4 months [1]. Added to these constraints are poor soils, erratic weather conditions, limited access to quality seeds and fertilizers, and a glaring lack of infrastructure, resulting in an underperforming agricultural sector that is unable to feed a rapidly growing population [2].

Historical observations also reveal a temperature increase of +0.9°C since 1975 nationwide [3], and +1.4°C since 1990, accompanied by a decrease in rainfall (-8%) over this period in the Kolda region (ANACIM, 2021).

Corresponding Author: **Malick Touré*
*Email Address: **malick.toure@uadb.edu.sn***

DOI: https://doi.org/10.21276/AATCCReview.2026.14.03.07

Future scenarios paint an alarming picture: temperature increases of 1.1 to 1.8 °C by 2035, up to 3 °C by 2060, increasing rainfall (50-100 mm) in Casamance but a sharp decline in the east, increased evapotranspiration, and a litany of extreme events such as endless droughts or recurring floods [4, 5]. These upheavals, the result of a natural cycle disrupted by humans, reduce harvests and expose farmers to increased vulnerability. Climate variability recorded over the past decade has led to critical yield declines, notably 27% for peanuts and 29% for millet [6]. These shocks result in a decline in agricultural income, with net losses estimated between 7% and 24% in certain cereal-growing areas [7]. In Sebikotane, irrigated farmers earned $6,000 gross per hectare per year, twenty times more than rain-fed farmers in vegetable production [8]. Therefore, a question arises: how do farmers experience these changes and how do they adapt?

Globally, perceptions of these shocks - erratic rainfall, drought, floods, and temperature fluctuations - have been analyzed to inform potential responses [9, 10, 11, 12,13]. Similarly, studies have analyzed adaptation strategies: crop adjustments, crop diversification, and income diversification [12, 14, 15, 16]. However, these choices vary according to age, experience, education, income, training, social capital, or access to information, as demonstrated by studies in Pakistan [17], in India [11], in Ethiopia [18], in Uganda [19], in Benin [16], and in sub-Saharan Africa [15].

In Senegal, some studies have explored farmers' perceptions and adaptation strategies to climate change [20, 21, 22], but they pay relatively little attention to the socioeconomic determinants underlying these decisions. Yet, understanding these local perceptions and adaptation tactics is crucial for developing relevant regional and national policies. That is why this study focuses on the adaptation mechanisms in the municipality of Sare Bidji (Kolda). More specifically, it aims to: (i) identify the main key indicators of climate change; (ii) analyze the strategies deployed by farmers, and the factors that influence their adoption; and (iii) evaluate the levers of climate and economic resilience for agricultural households. The remainder of the article is structured as follows. The second section outlines the methodology. The third section presents and discusses the results. The fourth and final section is devoted to the conclusion and economic policy implications.

2. METHODOLOGY

2.1. Background of the study area: Sare Bidji (Kolda, Casamance)

Sare Bidji, a rural commune in the department and region of Kolda (Fig. 1) in southern Casamance (Senegal), covers 375 km² of rolling terrain with slopes and shallow depressions [23]. With 21,843 inhabitants in 2020 (density: 58 people/km²), it is home to extended households (averaging 10-15 people) and an ethnic mosaic dominated by the Fulani (80%), followed by the Mandinka (11%) and the Balante, Diola, Wolof, and Diakhandé (9%) [24 ,23].

Sudan-Sahelian, its climate contrasts a short rainy season (June-October; 1,114 mm/year on average over 30 years, with peaks of 1,500 mm) and a long winter dry season (November - May), with temperatures ranging from 16–34 °C (cool) to 25–39 °C (hot) [23]. Predominantly sandy-clay tropical ferruginous soils (deck dior >90% of the area) are supplemented by sandy zones (Diatoumang, Sare Bidji, Sare Kolidiang) and marginal stony areas on plateaus; they are vulnerable to erosion, salinization, and depletion.

Water resources consist of a branch of the Casamance River (22 linear km) and 23 seasonal ponds (Sare Kolidiang, Sare Bilaly, Sare Bidji), supporting floodplains and lowlands [23]. Agriculture, the dominant activity, accounts for over 80% of the working population and relies on rain-fed family farms, supported seasonally by day laborers from Guinea-Bissau [24]. Food crops (rice, millet, maize, fonio, sorghum, cowpeas) and cash crops (peanuts, cotton) dominate, with vegetable gardening in valleys and tree cultivation in orchards; proximity to Kolda ensures market access. Extensive Fulani livestock rearing (cattle, sheep, goats, horses, donkeys, pigs, poultry) completes the picture, valued as a socio-cultural asset based on pastures, mares, and centuries-old traditions [23]. Ancillary activities include agroforestry, artisanal fishing, and carpentry. This agro-pastoral ecosystem, exposed to increasing climate hazards, fully justifies the study of local perceptions and adaptations.

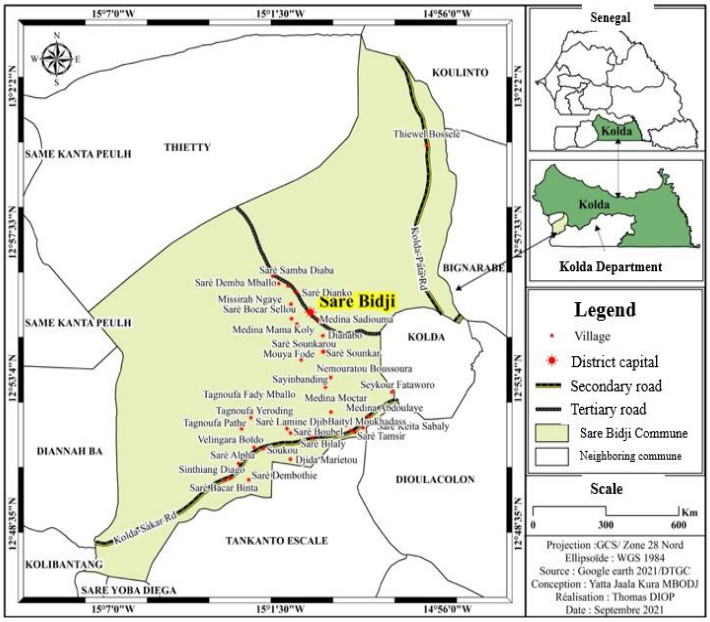

Fig 1: Map of the study area
Source: *Authors, 2021*

2.2. Data

This study employs a mixed-methods approach - combining quantitative and qualitative methods - to examine perceptions of climate change, the adoption of adaptation strategies, and the resilience of farming households in the municipality of Sare Bidji (Kolda). Primary data were collected through a field survey conducted in 2022 among 320 heads of farming households, selected from 35 villages participating in the 4R program.

Sampling followed a rigorous multistage design:

- random selection of beneficiary villages;
- systematic selection of farming households proportional to their density in each locality.

Data collection relied on a structured questionnaire, administered face-to-face by eight interviewers trained over two weeks, supplemented by six focus groups (8-10 participants) to contextualize the quantitative responses. This protocol ensures representativeness and analytical depth.

The survey collected the following data:

- Socioeconomic characteristics: age, gender, education, household size, cultivated area, diversified income;
- Climate perception: observed indicators (rainfall, temperatures, extreme events);
- Adaptation strategies: adjustment of planting dates, resistant varieties, irrigation, crop/economic diversification;
- Resilience: composite index incorporating aid received (WFP, NGOs, government), access to climate information, and human capacity.

The cleaned and weighted data allow for robust econometric analyses (probit, negative binomial, multinomial logit, OLS) while capturing local heterogeneities - a rare strength in sub-Saharan studies on climate adaptation.

2.3. Empirical Analysis Methods

The analysis is based on a microeconomic framework of climate change adaptation behaviors, inspired by the seminal work of Deressa and *al.* (2009), and Fosu-Mensah and *al.* (2012) [25, 26]. A farmer adopts an adaptation strategy if he/she actually perceives climate variations, understands their implications and has technically and economically viable solutions. Three sets of econometric models are mobilized; they are adapted to the nature of the dependent variables and to the specific objectives.

Model 1: Determinants of climate perception

The perception of climate change (dichotomous variable: 1 = perceives a change; 0 = otherwise) is modeled by a binary probit:

$$P(PERCEPT_i = 1) = \Phi(\beta_0 + \beta X_i + \varepsilon_i \quad (1)$$

Φ denotes the distribution function of the standard normal distribution and *Xi* includes the following characteristics: gender, age, education, household size, cultivated area, membership in associations, access to climate information, assistance received, main activity, agro-ecological zone, and access to credit.

Model 2: Determinants of the adoption of adaptation strategies

The heterogeneity of practices requires three complementary models:

- ***Probability of adopting at least one strategy (binary logit)***

$$STRATEG_i = f(PERCEPT_i, EDUCA_i, CLIMINFO_i,$$
$$ASSIST_i, GEN_i, SIZE_i, MEMBERSHIP_i) \quad (2)$$

This model allows us to identify the factors that influence the decision to enter the adaptation process.

- **Intensity of adaptation (negative binomial model)**

The number of strategies adopted (NB_STRAT, overdispersed count variable) is estimated by:

$$E(NBSTRATEG_i) = exp(\alpha_0 + \alpha X_i) \quad (3)$$

This model measures the effect of household characteristics on the intensity of adoption, i.e., the number of strategies implemented.

- **Choice of strategy type (multinomial logit)**

The categories DIG_STRA (adjustment of sowing dates), VARIET_STRA (resistant varieties), IRRIG_STRA (irrigation), and DIVERSIF_STRA (diversification) are modeled via:

$$P(STRAT_j = 1) = \frac{\exp(\beta_j X_i)}{\sum_k \exp(\beta_k X_i)} \quad (4)$$

Xi includes sociodemographic characteristics, climate perception, access to information, organizational membership, and the recurrence of climate shocks.

Model 3: Determinants of agricultural household resilience

Resilience (RESILIENTi, composite score) is analyzed using OLS:

$$RESILIENT_i = \gamma_0 + \gamma W_i + \varepsilon_i \quad (5)$$

Where Wi incorporates assistance (public/private), adopted strategies, human capital, and access to climate information. This model quantifies the contribution of adaptations and institutional support to economic and climate resilience.

3. RESULTS AND DISCUSSION

3.1. Socio-demographic and economic profile of households

Table 1 summarizes the socio-demographic and economic characteristics of the 320 households surveyed, which form the basis for subsequent econometric models. Dominated by men (83%), the sample reflects the patriarchal nature of rural farms in Sare Bidji, consistent with the 92% of male heads of household reported by the ANSD (national agency for statistics and demography) in the Kolda region [27]. The average age of farmers (47.6 years) indicates a relatively young agricultural population, likely to possess significant adaptive capacity and sensitivity to climate signals. Human capital remains limited, with an average of 3.7 years of schooling reflecting the persistent low level of educational attainment in Kolda [27]. Large households (9 members), rely on family labor - a productive resource - but are vulnerable to climate shocks, as noted elsewhere in West Africa [28]. Farms, which are small (2.4 ha on average), are also highly exposed to rainfall variability. Finally, membership in producer organizations (46%) and access to credit (21%) - both below critical thresholds - limit diversification and resilience.

Table 1: Descriptive statistics of household characteristics

Variable	Mean	Std. Dev.	Min	Max
Male household head (%)	0.83	0.37	0	1
Age (years)	47.6	11.4	22	85
Education (years of schooling)	3.7	4.9	0	18
Household size (persons)	9.2	4.5	1	25
Cultivated surface area (ha)	2.4	1.6	0.2	8.0
Producer organizations (%)	0.46	0.50	0	1
Access to credit (%)	0.21	0.41	0	1

***Source**: Authors' calculations*

3.2. Descriptive statistics on perceptions and adaptation strategies

Figure 2 illustrates the main indicators of climate change as perceived by farming households in Sare Bidji. Among these, drought is the dominant concern, cited by 78.5% of respondents, followed by variability in rainfall (71.3%) and rising temperatures (64.8%). These phenomena are closely intertwined: drought often results from prolonged periods of low rainfall, exacerbated by higher temperatures that accelerate evaporation from the soil and water reserves. Thus, awareness of decreasing rainfall is growing, and this awareness in turn heightens sensitivity to drought itself.

The frequency of floods (46.2% of households) and strong winds (32.9%), although significant, is perceived less by farmers as indicators of climate change. This subjective view of climate risks plays a decisive role in the choice of adaptation strategies.

Aware of these changes, farmers often opt for early-maturing seed varieties, crop diversification, adjustments to the agricultural calendar, or the development of complementary activities such as livestock farming or small-scale commerce.

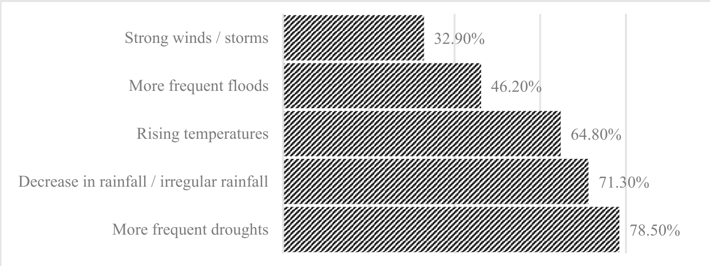

Fig 2: Perceived indicators of climate change
***Source**: Authors' calculations*

Figure 3 illustrates the adaptation strategies implemented by the surveyed farming households to counter the impacts of climate fluctuations. These choices depend closely on the primary threats identified by farmers, such as drought, erratic rainfall, shifting seasons, or soil depletion.

Most producers (61.8%) focus on drought-resistant varieties to secure their harvests in the face of these recurring hazards. More than half (54.6%) opt for diversification, combining various crops, livestock, and small-scale trade; this spreads risks and increases sources of income. Additionally, nearly 48.3% adjust their planting dates based on ANACIM (National Civil Aviation and Meteorology Agency) bulletins to better synchronize planting with unpredictable seasons.

Finally, nearly one in five producers (19.4%) explores non-agricultural options to offset yield losses and ensure economic and social stability. These measures - such as temporary migration, forestry, intensive livestock farming, or community assistance - serve as safety nets in the face of repeated crop failures.

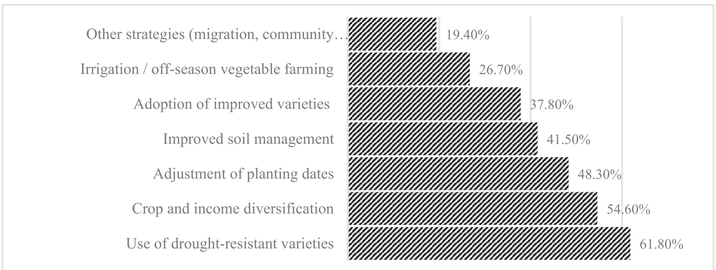

Fig 3: Frequency and distribution of adaptation strategies used
***Source**: Authors' calculations*

3.3. Econometric analysis of determinants and household resilience

3.3.1. Determinants of Perception

To identify the factors underlying farmers' perceptions of climate change in Sare Bidji, we use a binary logit model, the results of which are presented in Table 2. This econometric framework reveals that socio-demographic, agricultural-productive, and institutional determinants exert a statistically robust influence on the probability of recognizing climate hazards. With a pseudo-R^2 of 0.24, the model captures a substantial portion of the variance, in line with standards for rural socioeconomic studies.

Gender (male) and age exhibit significant negative coefficients ($p < 0.05$), indicating lower sensitivity among men and older individuals. This dynamic can be explained by the gendered division of agricultural labor: women, who are often responsible for daily tasks (water management, soil monitoring), and young people, who are more exposed to modern information flows, are better able to detect rainfall disturbances, droughts, or soil erosion. In contrast, education exerts a marked positive effect ($p < 0.01$), with a marginal effect of 0.03 per year of schooling - representing a 3% increase in the probability of perception - highlighting the pivotal role of human capital in environmental cognition.

Household size and cultivated land area emerge as powerful predictors ($p < 0.01$ and $p < 0.05$), reflecting cumulative exposure to climate shocks for extended family and landholding units. Agriculture as a primary activity also reinforces this vigilance ($p < 0.05$), with households 100% dependent on crops being the most attentive to warning signals.

Access to climate information accounts for 12% of the perception of exposure per unit ($p < 0.01$), while technical assistance contributes 10% ($p < 0.01$). Membership in a farmers' organization and ties to financial institutions confirm their positive role ($p < 0.05$), promoting the dissemination of knowledge and resilience. General ecological sensitivity, however, remains non-significant ($p = 0.32$), suggesting that concrete experiences take precedence over abstract attitudes.

Table 2: Determinants of climate change perception among producers

Variable	Coefficient	Standard error	p-valeur	Marginal effect
Constant	-1.05	0.30	<0.001	—
Gender (1 = Male)	-0.25	0.11	0.023	—
Age	-0.020	0.007	0.004	—
Education	0.10	0.03	0.001	+0.03/year
Cultivated surface area	0.06	0.03	0.045	—
Producer organization	0.20	0.09	0.026	—
Climate information	0.40	0.12	0.001	+0.12/unit
Technical assistance	0.35	0.13	0.007	+0.10
Primary occupation (agriculture)	0.18	0.08	0.025	—
Relationship with an organization	0.12	0.06	0.045	—
Ecological knowledge	0.05	0.05	0.320	—

***Note**: ***p < 0.01 ; *p < 0.05 ; p < 0.10*
***Source**: Authors' calculations*

3.3.2. Determinants of the adoption of adaptation strategies

The adoption of at least one adaptation strategy (binary logit, N=320) depends primarily on prior perception of climate hazards (β=1.20***), technical assistance (β=0.90***), and access to climate bulletins (β=0.65**). The marginal effects indicate respective probability increases of 18%, 12%, and 9%, placing these factors among the most effective drivers. Structural characteristics (farm size, cooperative membership) play a complementary role, while being male slightly reduces receptivity (β=-0.40*).

Tableau 3: Factors influencing the adoption of at least one adaptation strategy among producers

Variable	Coef	Std.Err.	Z	p-val.	dy/dx
Climate perception	1.20	0.30	4.00	***	0.18
Climate information	0.65	0.22	2.95	**	0.09
Technical assistance	0.90	0.28	3.21	***	0.12
Gender (1 = Male)	-0.40	0.20	-2.00	*	—
Cultivated surface area	0.08	0.03	2.67	**	0.01
Pseudo-R^2	**0.28**	LL=-170.5	N=320		

Note: ****p < 0.01 ; *p < 0.05 ; p < 0.10*
Source: *Authors' calculations*

The negative variance model (mean=2.8 strategies/household) identifies more diverse determinants of adaptation intensity (Table 4). Household size (β=0.020***), experience with repeated droughts (β=0.22*), and membership in producer organizations (β=0.28**) increases technical responses to cumulative shocks. Paradoxically, age slightly inhibits innovation (β=-0.01*).

Tableau 4: Estimation of the determinants of the intensity of strategy adoption

Variable	Coef	Std.Err.	z	p-val.
Cultivated surface area	0.020	0.005	4.00	***
Climate information	0.30	0.08	3.75	***
Technical assistance	0.40	0.10	4.00	***
Drought	0.22	0.09	2.44	*
Producer organization	0.28	0.11	2.55	**
Age	-0.01	0.004	-2.5	*
A	**0.65***	Surdispersion		

Note : *Poisson LR vs NB : ***p < 0.01 ; *p < 0.05 ; p < 0.10*
Source: *Authors' calculations*

An analysis of table 4 reveals marked heterogeneity in strategic adaptation choices. The multinomial logit estimation highlights distinct decision-making patterns depending on the adaptation strategies chosen (Table 5). Adjusting the agricultural calendar is preferred by households with higher human capital (education: β = 0.061**), larger farms (area: β = 0.089**), and those belonging to high-performing producer organizations (β = 0.538***). Irrigation techniques are particularly attractive to recipients of technical assistance (β = 0.685***) who have experienced repeated droughts (β = 0.601***), reflecting a targeted response to structural water deficits. Crop and activity diversification is universally explained by access to climate information (β = 0.498***), confirming the pivotal role of ANACIM services in multifaceted strategic trade-offs.

Tableau 5: Determinants specific to different adaptation strategies

Déterminant	Calendrier	Variétés	Irrigation	Diversification
Climate information	0.532***	0.401**	0.712***	0.498***
Technical assistance	0.417**	0.398	0.685***	0.371**
Producer organization	0.538***	0.421**	0.333	0.417**
Drought	0.352	0.492**	0.601***	0.299
LR χ^2(48)	**183.6***	R^2=0.241	N=320	

Note: ****p < 0.01 ; *p < 0.05 ; p < 0.10*
Source: *Authors' calculations*

Climate information shapes all adaptive trajectories, while producer organizations catalyze organizational innovations. Experience with water shortages drives the adoption of irrigation, confirming the rationality of trade-offs in the face of local constraints.

This logic of qualitative specialization naturally extends to the quantitative scale of the responses implemented. The scope of adaptive measures in response to climate hazards varies significantly depending on the resources and experiences of farming households. The OLS model (table 6, adjusted R^2 = 0.36) identifies the perception of climate impacts as the primary determinant (β = 0.45***). With each unit increase in the index raising the intensity of deployed measures by 45%. Technical assistance emerges as the second key factor (β = 0.30**), reflecting an increased ability to combine multiple strategies among beneficiaries of technical support.

Tableau 6: The determinants of the scope of adaptive measures

Variable	B	Std.Err.	p-val.
Climate perception	0.45	0.12	***
Technical assistance	0.30	0.09	**
Agricultural income	0.22	0.07	**
Climate information	0.18	0.06	**
Access to resources	0.15	0.06	*
Access to credit	0.10	0.05	*
Financial institutions	0.09	0.04	*
Primary occupation (Agriculture)	0.11	0.05	*
Household size	0.02	0.01	*
Cultivated surface area	0.07	0.04	*
Project/NGO support	0.08	0.04	‡
Constant	0.12	0.08	Ns

Note: ****p < 0.01 ; *p < 0.05 ; p < 0.10*
Source *: Authors' calculations*

Economic drivers shape the scale of responses: agricultural income (β = 0.22**) and cultivated area (β = 0.07*) unlock technical investment capacity, while access to credit (β = 0.10*) and financial institutions (β = 0.09*) facilitate their implementation. Main agricultural activity (β = 0.11*) reinforces this dynamic, contrasting with the insignificance of secondary activities.

However, do perception, adoption, and adaptive intensification truly determines households' ability to maintain income stability and food security in an uncertain Sahelian context? The following analysis identifies the structural determinants of this effective resilience.

3.3.3. Determinants of agricultural household resilience

Resilience - measured by a composite score incorporating production stability, food security, and post-shock recovery - relies on targeted institutional and technical support. The binary logit model (pseudo-R^2 = 0.33) identifies technical assistance (β = 0.60***) and irrigation (β = 0.35***) as key factors, enabling greater autonomy from irregular rainfall and securing household yields.

Tableau 7: The determinants of farming household resilience

Variable	Description	β	Std.Err.	p-val.
Technical assistance	Technical assistance (1=Oui)	0.60	0.12	***
Irrigation	Irrigation practiced (1=Oui)	0.35	0.10	***
Project/NGO support	Development project support	0.30	0.11	**
Activity diversification	Activity diversification	0.28	0.10	**
Climate information	Access to ANACIM forecasts	0.25	0.10	**
NGO support	NGO support	0.20	0.10	*
Improved varieties	Improved varieties	0.20	0.08	*
Education	Years of schooling of household head	0.09	0.05	‡
Constant	—	-1.56	0.48	***
Pseudo-R^2	0.33			

***Note**: ***p < 0.01 ; *p < 0.05 ; p < 0.10*
***Source :** Authors' calculations*

Development projects (β = 0.30**) and diversification (β = 0.28**) reinforce this foundation, while climate information (β = 0.25**) acts as a facilitator by disseminating early warning signals. Resistant varieties (β = 0.20*) contribute marginally, confirming a hierarchy in which water infrastructure and management take precedence over varietal adjustments.

3.4. Discussion

Our findings on climate perception corroborate the trends observed in southern Senegal, where Sall and *al*. [20] and Salack and *al*. [29] document a sharp decline in rainfall and increased seasonal irregularity. Sensitivity to prolonged droughts (78.5%) and rainfall variability (71.3%) align with the pan-African surveys by Maddison [30], who had already noted, among 9.000 farmers in 11 countries, near - unanimous recognition of rising temperatures and water deficits - particularly pronounced among experienced farmers. ANACIM data for Kolda, showing an 8% decrease in precipitation and a 1.4°C rise in temperature since 1990, empirically validate this local awareness (ANACIM. 2021).

The strategies identified were resistant varieties (61.8%), diversification (54.6%) - faithfully mirror the responses documented by Mertz and *al*. [31] or Tombo and *al*. [32] in West Africa: calendar adjustments and mixed cropping as the first lines of defense. Below and *al*. [33] and Sarr and *al*. [28] confirm the limited expansion of irrigation, hampered by input costs, while Fadina and *al*.[16] in Benin highlight conservation soil management as an accessible alternative.

The predominant effect of education (+3% per year) and climate information (+12%) on perception aligns with Maddison [30], who linked these factors to a keen detection of signals. Ndiaye and *al*. [34] and Kumar and *al*. [35] extend this chain: community radio stations and ANACIM catalyze not only vigilance but also multiple adoptions, via GIE as innovation hubs. Male inertia (β= -0.25**) aligns with Bryan and *al*. [36], who attribute to women a greater daily immersion in agro-climatic markers; Deressa [25] similarly explain ageism through a cyclical interpretation of hazards among seniors.

Adaptive intensity, driven by experience with shocks (droughts β=0.22*), builds on Diouf and *al*. [37]: forecast bulletins favoring diversified technical portfolios. Below and *al*. [33] and Iglesias and *al*. [38] confirm that GIE and extension services accelerate this escalation, with farmer organizations democratizing access to inputs and credit [39].

Final resilience, rooted in irrigation (β=0.35***) and assistance (β=0.60***), validates the work of Fraiture & Wichelns [40]: water management as the Sahelian foundation. Zougmoré *et al*. [41] and Gbetibouo *et al.* [42] support the role of tolerant varieties, while Deressa [25] emphasize external support (WFP 4R) to mitigate structural vulnerabilities.

4. CONCLUSION AND ECONOMIC POLICY IMPLICATIONS

This study analyzed the determinants of farmers' adoption of climate change adaptation mechanisms in the municipality of Sare Bidji (Senegal). Specifically, the paper identified the main perceived indicators of climate change, analyzed the primary adaptation strategies employed by farmers along with their determining factors, and assessed the variables that strengthen climate resilience. The results show that farmers primarily perceive the following climate change indicators, in order of importance: the frequency of droughts, decreased and variable rainfall, rising temperatures, the frequency of floods, and strong winds. Regarding adaptation strategies, the majority of farmers use drought-resistant varieties to stabilize yields, slightly more than half of households diversify crops and income sources through small-scale trade and livestock production, and just under half adjust planting dates to directly address seasonal irregularity. A significant proportion of farming households adopt improved soil management strategies through the use of compost and animal manure, as well as non-agricultural strategies to bridge the income gap caused by climate change. The study shows that perceptions of climate change are determined by sociodemographic, agricultural, and institutional factors. In terms of sociodemographic factors, women, older individuals, and those with a higher level of education are more likely to perceive climate change. From a production perspective, household size, cultivated area, and agriculture as the head of household's primary activity are key factors that increase the perception of climate change. From an institutional and informational perspective, access to climate information, technical assistance, membership in an effective farmers' organization, and relationships with financial institutions enhance the agricultural household's ability to perceive climate change. The key factors determining the adoption of adaptation strategies are primarily: perception of climate change, access to climate information, access to technical and financial assistance, membership in farmers' organizations, and gender (women). Agricultural households thus adopt the following strategies under the influence of several factors (sociodemographic. institutional. and productive): adjusting planting dates, using resistant varieties, employing irrigation techniques, and diversifying crops and other productive and commercial activities. Regarding the determinants of household resilience to the effects of climate change, the results highlight the following key factors: access to technical assistance and irrigation practices. Additionally, support from development projects, NGOs, and access to information on climate variability are critical to the resilience of farming households.

These study findings suggest several strategic directions for improved climate risk management and the resilience of farming households. Specifically, for policymakers:

- develop climate information systems (community radio, SMS, digital platforms) to provide households with effective access to weather forecasts so they can better anticipate risks and adjust production methods;
- strengthening technical advisory and agricultural extension services to encourage farming households to adopt innovative and resilient climate-smart technologies in irrigation, improved crop varieties, and soil conservation;

- promote mechanisms for women's economic empowerment (access to land, credit, and leadership development) to help them realize their full potential in production and the adoption of resilient strategies;
- support investments in irrigation, water management, and the adoption of improved varieties through targeted subsidy policies. participatory financing, and the promotion of agronomic action research; and
- support farmers' organizations to facilitate the dissemination of climate information, access to financing and markets and the sharing of experiences.

Findings from Sare Bidji suggest several avenues for further research. Extending the analysis to additional agro-ecological zones in Senegal would permit comparative assessments of regional resilience capacities. Longitudinal studies are needed to evaluate the long-term effectiveness of digital tools (SMS, online platforms) for disseminating and promoting uptake of climate information among producers.

Acknowledgements
We thank the 320 household heads in the commune of Sare Bidji for their participation and the valuable information they provided during field surveys. We also acknowledge the eight enumerators for their diligence, the local authorities of Sare Bidji for logistical support.

Declaration of conflicts of interest
- **Competing interest***: The authors have no relevant financial or non-financial interests to disclose.*
- **Funding***: No funding was received for conducting this study.*

References
1. Gaye. A. T.. Lo. H. M.. Sakho-Djimbira. S.. Fall. M. S.. & Ndiaye. I. (2015). Sénégal: Revue du contexte socioéconomique. politique et environnemental.
2. CIAT. BFS. & USAID. (2016). *Climate-smart agriculture in Senegal* (CSA Country Profile Series). *International Center for Tropical Agriculture* (CIAT).
3. Funk C., Jim R., Adoum A., Gary E.. James. V.. & Libby. W. (2012). *A Climate Trend Analysis of Senegal. U.S. Geological Survey* Fact Sheet http://pubs.usgs.gov/fs/2012/3123/FS12-3123.pdf.
4. Centre de Suivi Écologique (CSE). (2010). *Rapport sur l'état de l'environnement au Sénégal*. Dakar. Sénégal : Ministère de l'Environnement et du Développement Durable. République du Sénégal.
5. Jalloh. A.. Nelson. GC. Thomas. TS. Zougmoré. RB. & Roy-Macauley. H. (Eds.). (2013). *Agriculture ouest-africaine et changement climatique : une analyse complète*. Institut international de recherche sur les politiques alimentaires.
6. Sagna. P.. Ndiaye. O.. Diop. C.. Niang. A. D.. & Sambou. P. C. (2016). Les variations récentes du climat constatées au Sénégal sont-elles en phase avec les descriptions données par les scénarios du GIEC?. Pollution atmosphérique. Climat. santé. société. (227).
7. Amikuzuno. J.. & Hathie. I. (2013). *Climate change implications for smallholder agriculture and adaptation in the White Volta Basin of the upper east region of Ghana*.
8. Seck. M.. Moussa Na Abou. M.. Wade. S.. & Thomas. J.-P. (2005). *Adaptation to climate changes: The Sebikotane farming system case study (Senegal)*. ENDA T.M. Linking Climate Adaptation Project.
9. Amin. D.. Elshamy. M.. Fouda. S.. & Kassem. T. (2021). Évaluation du risque de sécheresse dans l'est du Nil dans les conditions climatiques actuelles et futures.
10. Abid. M.. Schilling. J.. Scheffran. J.. & Zulfiqar. F. (2016). Vulnérabilité. adaptation et perceptions des risques liés au changement climatique au niveau des exploitations agricoles du Pendjab. Pakistan. *Science of the Total Environment. 547*. 447-460.
11. Funk, C., Peterson, P., Landsfeld, M., Davenport, F., Becker, A., Schneider, U., ... & Shukla, S. (2020*). Algorithm and data improvements for version 2.1 of the Climate hazards center's infrared precipitation with stations data set.* In *Satellite Precipitation Measurement: Volume 1* (pp. 409-427). Cham: Springer International Publishing.
12. Khanal. U.. Wilson. C.. Hoang. V. N.. & Lee. B. (2018). *Farmers' adaptation to climate change. its determinants and impacts on rice yield in Nepal. Ecological economics. 144*. 139-147.
13. Singh. S. (2020). Perception du changement climatique et décisions d'adaptation des agriculteurs : une preuve au niveau micro de la région de Bundelkhand. en Inde. *Ecological Indicators*. *116*. 106475.
14. Parven. A.. Pal. I.. Witayangkurn. A.. Pramanik. M.. Nagai. M.. Miyazaki. H.. & Wuthisakkaroon. C. (2022). *Impacts of disaster and land-use change on food security and adaptation: Evidence from the delta community in Bangladesh. International Journal of Disaster Risk Reduction. 78*. 103119.
15. Jalón. S. G.. Iglesias. A.. & Neumann. M. B. (2018*). Responses of sub-Saharan smallholders to climate change: Strategies and drivers of adaptation. Environmental science & policy. 90*. 38-45.
16. Fadina. AMR. & Barjolle. D. (2018). Stratégies d'adaptation des agriculteurs au changement climatique et leurs implications dans le département de Zou au Sud-Bénin. *Environnements. 5* (1). 15.
17. Fahad. S.. & Wang. J. (2020). Changement climatique. vulnérabilité et ses impacts dans le Pakistan rural : une revue. *Environmental Science and Pollution Research. 27* (2). 1334-1338.
18. Marie. M.. Yirga. F.. Haile. M.. & Tquabo. F. (2020). *Farmers' choices and factors affecting adoption of climate change adaptation strategies: Evidence from northwestern Ethiopia. Heliyon. 6*(4). e03867. https://doi.org/10.1016/j.heliyon.2020.e03867
19. Atube. F.. Malinga. GM. Nyeko. M.. Okello. DM. Alarakol. SP et Okello-Uma. I. (2021). Déterminants des stratégies d'adaptation des petits exploitants agricoles aux effets du changement climatique: données provenant du nord de l'Ouganda. *Agriculture & Food Security*. *10* (1). 6.
20. Sall. M.. Tall. S. M.. Tandian. A.. & Samb. A. (2011). Changements climatiques. stratégies d'adaptation et mobilités. Evidence à partir de quatre sites au Sénégal. *International Institute for Environment and Development (IIED). London*.
21. Sow. B. L.. Bah. A.. Sow. P.. Yaffa. S. (2024). *Farmers' awareness and adaptation to climate change in Senegal*. Journal of Environment and Earth Science.
22. NIANG1-hamady. H.. & Niang. H. Environnement et changement climatique: repenser les liens entre la nature et l'humain depuis le Sud global.
23. PDC (2020). Plan de Développement Communal (PDC) 2020–2024. Commune de Saré Bidji. Région de Kolda. Sénégal : Conseil municipal de Saré Bidji.
24. Agence Nationale de la Statistique et de la Démographie (2017). *Recensement Général de la Population et de l'Habitat (RGPH-5) – Rapport régional Kolda*.
25. Deressa. T.. Hassan. R.. Ringler. C. (2009). *Assessing household vulnerability to climate change in the Nile Basin of Ethiopia*. IFPRI Discussion Paper.
26. Fosu-Mensah. B. Y.. Vlek. P. L. G.. MacCarthy. D. S. (2012). *Farmers' perception and adaptation to climate change in Ghana*. Environment. Development and Sustainability. 14. 495-505.

27. Agence Nationale de la Statistique et de la Démographie - RGPH-5 (2025). Rapport définitif. Thème 5. Caractéristiques des ménages. juillet. 2025.
28. Sarr. B.. Atta. S.. Ly. M.. *and al.* (2015). *Adapting to climate variability and change in smallholder farming systems in West Africa*. Regional Environmental Change. 15. 1-12.
29. Salack S. Muller B. Gaye AT Gaye. 2011. *Rainbased factors of high agricultural impacts over Senegal*. Part I: integration of local to subregional trends and variability. Theoretical and Applied Climatology. doi : 10.1007/s00704- 011-0414-z.
30. Maddison. D. (2007). *The perception of and adaptation to climate change in Africa*. World Bank Policy Research Working Paper.
31. Mertz, O., Mbow, C., Reenberg, A., Genesio, L., Lambin, E. F., D'haen, S., ... & Sandholt, I. (2011). *Adaptation strategies and climate vulnerability in the Sudano-Sahelian region of West Africa. Atmospheric Science Letters*, *12*(1), 104-108.
32. Tambo. J. A.. & Abdoulaye. T. (2012). *Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. Mitigation and Adaptation Strategies for Global Change*. *17*(3). 277-292.
33. Below. T.. Mutabazi. K.. Kirschke. D.. and *al.* (2012). *Can farmers' adaptation to climate change be explained by socio-economic household-level variables?* Global Environmental Change. 22(1). 223-235.
34. Ndiaye. S.. Sambou. P. A.. Diedhiou. L.. and al. (2022). *Perception and adaptation to climate change among smallholder farmers in southern Senegal. Climate and Development*.
35. Kumar S. Pramanik S. Yessofou A N. Gondwe T. Worou O N. Whitbread A. (2022). *Gender-differentiated farmers' perception of climate risk and adaptation strategies in Senegal. AICCRA Case Study. Accelerating Impacts of CGIAR Climate Research for Africa.*
36. Bryan. E.. Ringler. C.. Okoba. B.. and al. (2013). *Adapting agriculture to climate change in Kenya: Household strategies and determinants*. Journal of Environmental Management. 114. 26-35.
37. Diouf. N. S.. Ouedraogo. I.. Zougmoré. R. B.. Ouedraogo. M.. Partey. S. T.. & Gumucio. T. (2019). *Factors influencing gendered access to climate information services for farming in Senegal. Gender. Technology and Development*. *23*(2). 93-110.
38. Iglesias. A.. Mougou. R.. Moneo. M.. & Quiroga. S. (2011). *Towards adaptation of agriculture to climate change in the Mediterranean*. *Regional Environmental Change*. *11*(Suppl 1). 159-166.
39. Tesso, G., Emana, B., & Ketema, M. (2012). *Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia*. *Agricultural Sciences*, *3*(06), 871.
40. De Fraiture. C.. Molden. D.. et Wichelns. D. (2010). Investir dans l'eau pour l'alimentation. les écosystèmes et les moyens de subsistance : un aperçu de l'évaluation globale de la gestion de l'eau en agriculture. Agricultural Water Management. 97 (4). 495-501.
41. Zougmoré. R.. Läderach. P.. Partey. S. (2018). *Climate services for farmers in West Africa*. CCAFS Working Paper.
42. Gbetibouo. G. A.. Ringler. C.. & Hassan. R. (2010). *Vulnerability of the South African farming sector to climate change and variability: An indicator approach*. In *Natural resources forum* (Vol. 34. No. 3. pp. 175-187). Oxford. UK: Blackwell Publishing Ltd.

