Open Journal of Ecology, 2025, 15(10), 693-712
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Adoption of Climate-Smart Agriculture Practices by Maize Farmers in Southern Senegal: Levers, Obstacles and Challenges

Saboury Ndiaye[1*], Mamadou Ndiaye[2], Philomene Agueno Sambou[3], Landing Diedhiou[1], Boubacar Camara[1], Thierno Abdoucadry Diallo[1], Cheikh Kâ[1], Mamadou Lamine Diallo[1], Fatima Guissé[1]

[1]Laboratoire d'Agroforesterie et d'Ecologie, Département d'Agroforesterie, Université Assane Seck de Ziguinchor (UASZ), Ziguinchor, Sénégal
[2]Institut Supérieur de Formation Agricole et Rurale, Université Alioune Diop de Bambey, Bambey, Sénégal
[3]Laboratoire de Sociologie, d'Anthropologie et de Psychologie, Département de Sociologie, Université Cheikh Anta Diop (UCAD), Dakar, Sénégal
Email: *s.ndiaye@univ-zig.sn

How to cite this paper: Ndiaye, S., Ndiaye, M., Sambou, P.A., Diedhiou, L., Camara, B., Diallo, T.A., Kâ, C., Diallo, M.L. and Guissé, F. (2025) Adoption of Climate-Smart Agriculture Practices by Maize Farmers in Southern Senegal: Levers, Obstacles and Challenges. *Open Journal of Ecology*, **15**, 693-712.
https://doi.org/10.4236/oje.2025.1510040

Received: August 29, 2025
Accepted: October 26, 2025
Published: October 29, 2025

Abstract

This paper surveys 300 maize-growing households in Kolda, Senegal, to assess their perception of climate risks and the adoption of climate-smart agriculture (CSA) practices. Using the SCCRPI, RII, WAI, and PCI indices, the authors find that rising temperatures, drought, and reduced rainfall are the main perceived hazards, while drill seeding, crop rotation, and recommended fertilizer use are the most common CSA measures. Key adoption drivers are food security, yield, and income gains, whereas limited credit access, weak market outlets, and scant government support are the main obstacles. The study recommends stronger extension, capacity building, and financial support to scale CSA practices.

Keywords

Climate-Smart Agricultural Practices, Climate Change, Obstacles, Enabling Factors, Maize Growers

1. Introduction

Maize production, trade, and consumption are vital elements in global agrifood systems and the achievement of the Sustainable Development Goals (SDGs). In many Sub-Saharan African countries, maize serves as a staple food, household calorie intake, and contributes significantly to income and animal feed [1]-[3]. Agriculture is a strategic activity in Senegal, of paramount importance in economic, social, and environmental terms [4]. It is practiced by approximately 60% of the population [5] and represents a pillar of national development, contributing nearly 15% to gross domestic product (GDP) in 2023 [6] [7]. Among the major food crops, maize occupies a prominent place, with a planted area of 27,668 hectares and an estimated production of 787,750 tons during the 2022-2023 season [4]. A staple food for many households, maize contributes significantly to improving producers' incomes, particularly in rural areas, and it is also an essential resource in the manufacture of livestock feed [8] [9]. However, in recent years, the climate, the main driver of agricultural production, has undergone significant disruption, particularly through temperature variations and increasingly irregular rainfall. The risks associated with climate change continue to intensify, placing agriculture among the most exposed sectors due to its dependence on environmental conditions [10]-[13]. In Sub-Saharan Africa, and more particularly in Senegal, these climate disturbances have deleterious effects on agricultural production systems [14]. Rain-fed maize cultivation, in particular, remains highly vulnerable to low and erratic rainfall, extreme temperatures, and strong winds. This situation raises the question about the agricultural practices that should be adopted to ensure food security in a context marked by increasingly unpredictable weather [15].

In a context marked by increasing climate variability, promoting climate-smart agriculture (CSA) appears to be an essential lever for strengthening the resilience of the agricultural sector in general, and the com industry in particular [16]. With this in mind, various development actors have introduced a range of climate-smart practices, including: the selection of varieties adapted to climate hazards, the use of short-cycle varieties, climate insurance, integrated management of diseases, pests, and soil fertility, sustainable land management, rational water management, and agroecological and agroforestry approaches [17] [18]. CSA is recognized as an important strategy for addressing the challenges of food security and climate change. For instance, the earlier studies clearly demonstrated the role of better climate-smart agriculture (CSA) practices in boosting the climate resilience of maze-growing systems in Africa, such as [19]-[21] and [22]. However, in Senegal, research on the adoption of these practices by maize farmers remains limited, with existing studies focusing mainly on rice and millet crops. It is in this context that the present study was conducted in the department of Kolda, one of the main rainfed maize-growing areas in Senegal [23]. It aims to analyze the dynamics of climate-smart agricultural practices adoption by maize farmers through three specific objectives: 1) to assess their perception of climate change risk, 2) identify and classify the most widely adopted climate-smart agricultural practices, and 3) to analyze the motivations, determining factors, and constraints that influence their adoption decisions.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Department of Kolda, located in southwestern Senegal, between 12˚52' north latitude and 14˚57' west longitude (**Figure 1**). Covering an area of 13,721 km^2, approximately 7% of the national territory [24], the department had an estimated population of 306,591 in 2023 [25]. It is bordered to the north by the Gambia, to the east by the Tambacounda region, to the west by the Sedhiou region, and to the south by Guinea-Bissau and Guinea-Conakry [24]. The area is subject to a Sudano-Guinean climate characterized by an average rainfall of 1087.055 mm, with maximum temperatures ranging from 30˚C to 40˚C between March and September and lowest temperatures from 25˚C to 30˚C from December to January [26].

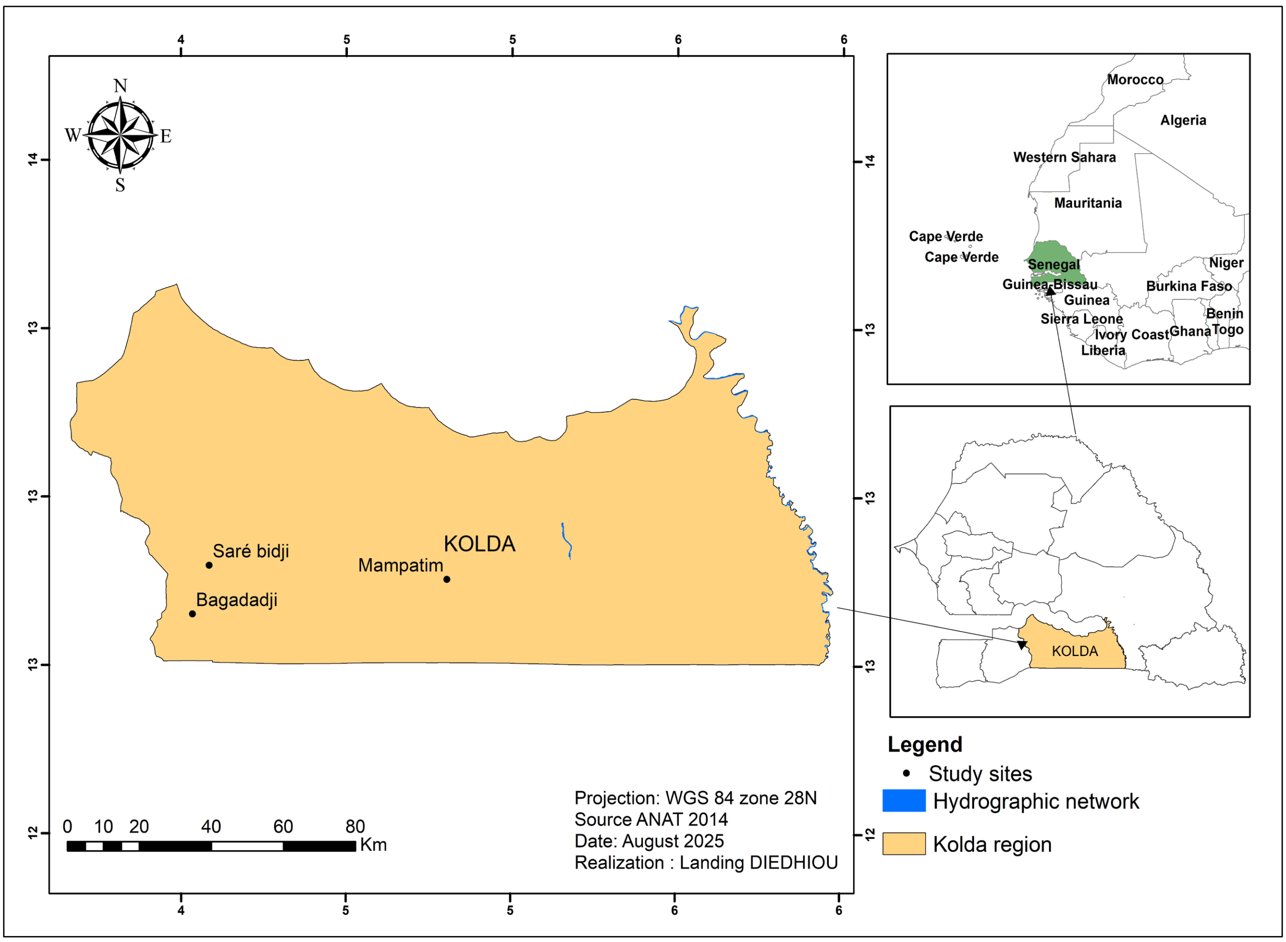

Figure 1. Location map of the study area.

Agriculture is a dominant activity, practiced by 70.07% of households. It relies mainly on rain-fed agriculture, which makes production highly dependent on climatic conditions. The main crops are cereals, legumes, and vegetables. After millet and fonio, maize is the most widely grown cereal on family farms in the Kolda region.

Maize is one of the most important crops, with an area of 10,820 ha sown in 2022 [26]. Generally cultivated around concessions, maize has a crop cycle of 75 to 90 days, from sowing to maturity [27].

2.2. Data collection

2.2.1. Sampling

Since, at the time of the study, there was no database on the size of the maize-growing population in the study area, the sample size was determined using the formula of [28], described by [29]:

$$no = \frac{Z^2 pqN}{e^2 (N-1) + Z^2 pq} \quad (1)$$

with: no: sample size; z: the standard value of 1.96 at a confidence interval of 95% and a precision of ±5%; p: the estimated share of the population = 0.1; q: 1 − p; N: total number of households in the study area (N = 5831); e: the desired level of precision (e = 0.032).

The value of p = 0.1 was chosen based on preliminary information and expert knowledge indicating that only a small share of maize producers was expected to present the characteristic of interest. Using this estimate rather than the conservative p = 0.5 prevented an unrealistically large sample size while remaining consistent with local expectations. The precision level e = 0.032 (±3.2%) was selected as a compromise between the standard 5% margin and field constraints, ensuring reliable estimates while keeping the required sample size feasible.

The resulting sample size is as follows:

$$no = \frac{(1.96)^2 * 0.1 * 0.9 * 5831}{\left[(0.035)^2 * (5831-1)\right] + \left[1.96^2 * 0.9 * 0.1\right]} = 319.5$$

Although the initial target was 319 respondents, according to the value predicted by the sampling method, the survey successfully covered 300 maize growers, representing a robust and diverse sample despite the limited availability of some participants during the data collection phase.

2.2.2. Survey

Data collection was based on a questionnaire developed from an in-depth review of the scientific literature to ensure methodological rigor and the relevance of the information gathered. To adapt the tool to the local context and validate the clarity of the questions, a pilot survey was conducted in the study area. The questionnaire, comprising 118 questions divided into seven main sections: 1) socio-demographic characteristics of respondents, 2) specific features of the maize cultivation system in the area, 3) producers' perception of climate change risk, 4) climate-smart agricultural practices, 5) motivations for adopting climate-smart agricultural practices, 6) factors influencing adoption, and 7) constrains encountered during adoption. The questionnaire was designed using the KoboToolbox platform (version 2.024.05) and then administered via the KoboCollect application (version 2023.2.4), which enabled efficient and secure data collection between October 28 to November 23, 2024.

The survey was conducted in the 13 villages where maize production was highest.

Data collection was carried out using the snowball method, where selected initial participants helped to identify other potential participants. In the interests of a higher response rate and contextual observation, this method was combined with the door-to-door method, which involves going directly to individuals' homes to collect data.

2.3. Data Analysis

Basic descriptive statistics, such as mean, frequency, and percentage, were used to present the results. To assess climate change risk perception, the climate-smart agricultural practices adopted and the associated promoting or hindering factors of their adoption in the study area, scoring criteria were defined, scores calculated, and a ranking made.

2.3.1. Climate Change Risk Perception Score (CCRPS)

Maize growers' perception levels of climate risk were ranked using the Climate Change Risk Perception Score (CCRPS). The respondents were asked to share their views on eight climate change risks to gain a thorough understanding of their perceptions regarding these specific climate change risks. For the estimation of CCRPS, a list of eight questions was asked with a 4-point Likert scale [30]: 0 = "no risk perception"; 1 = "low risk perception"; 2 = "moderate risk perception"; 3 = "high risk perception". Low perception was assigned to households that expressed little concern for climate change and had a low perceived exposure to its effects. In contrast, high risk perception was assigned to households that expressed high concern and high perceived exposure to its impacts. In moderate risk perception, more measured statements about the severity and urgency of climate change were included.

The CCRPS was calculated by using Equation (2):

$$\text{CCRPS} = \text{CCRPn} * 0 + \text{CCRPl} * 1 + \text{CRPm} * 2 + \text{CCRPh} * 3 \tag{2}$$

where: CCRPn: number of households with no perception of risk, CCRPl: number of households with a low-risk perception, CCRPm: number of households with medium risk perception, and CCRPh: number of households with a high-risk perception.

The maximum possible CCRPS value is reached when all 300 maize growers fall into the "high risk perception" category, giving a maximum of 300 × 3 = 900. This reference value was then used in the calculation of the Standardized Climate Change Risk Perception Index (SCCRPI) (Equation (3)), so that the results could be interpreted more easily:

$$\text{SCCRPI} = \frac{\text{CCRPS}}{\text{Maximum CCRPS value}} * 100 \tag{3}$$

Similar methods have been employed in previous studies by [31] and [32] to assess perceptions of climate change risk in Bangladesh and Ethiopia, respectively.

2.3.2. Relative Importance Index (RII)

The climate-smart agricultural practices used were identified and ranked using the Relative Importance Index (RII). In addition to assessing the level of use of these practices, the RII also helps prioritize knowledge and practices in order of frequency of adoption, so that adaptation actions or support can be targeted at the right practice(s). This method has been used in previous research by [33] and [34] to examine the most popular agroecological practices among small-scale farmers in northern and eastern Ghana, respectively. Formula (4) was used to calculate the RII:

$$\text{RII} = \sum \frac{W}{A \times N} \tag{4}$$

where, W is the weighting of a particular response on a Likert scale [30] with 4 response modalities: never used = 1, rarely used = 2, often used = 3, and used every year = 4. A is the highest response (4), and N is the number of respondents taken into account (300).

2.3.3. Weighted Average Index (WAI)

WAI is a statistical analysis method that determines the mean of an outcome by multiplying the weight given to a particular event by the associated quantitative result, then adding up all the results. This is very useful for determining a theoretically expected outcome where each event has different probabilities of occurring. WAI is therefore crucial in determining the factors motivating producers to adopt climate-smart agricultural practices. The WAI was estimated based on a 4-point Likert scale [30]: 1 = "disagree"; 2 = "more or less agree"; 3 = "agree"; 4 = "strongly agree".

Several studies have used the WAI to evaluate climate change adaptation measures [35] [36]. The WAI is mathematically given by Formula (5) [37] [38]:

$$\text{WAI} = \frac{\sum F_i W_i}{\sum F_i} \tag{5}$$

where: F denotes frequency, W represents weight or importance, and it shows the score of each factor and opportunity related to climate-smart agricultural practices, or the score of each factor that can influence the adoption of climate-smart agricultural practices.

2.3.4. Problem Confrontation Index (PCI)

To classify the barriers to the adoption of climate-smart agricultural practices, the Problem Confrontation Index (PCI), given by Formula (6), was used. This index has been used in previous studies, e.g., [35] [36] [39], and [40], to identify and rank perceived barriers that prevent farmers from adopting climate-smart agricultural practices. For the estimation of PCI, a list of questions was asked with a 4-point Likert scale [30] to classify the obstacles that hinder the adoption of climate-smart agricultural practices: 0 = "disagree"; 1 = "more or less agree"; 2 = "agree"; 3 =

"strongly agree".

$$\text{PCI} = Pn \times 0 + Pl \times 1 + Pm \times 2 + Ph \times 3 \quad (6)$$

where Pn is the number of maize growers who rated the obstacle as no problem, Pl is the number of maize growers who rated the obstacle as low-level, Pm is the number of maize growers who rated the obstacle as moderate-level, and Ph is the number of maize growers who rated the obstacle as high-level.

3. Results

3.1. Socio-Demographic Characteristics of Maize Growers in the Study Area

Table 1 shows the socio-demographic characteristics of maize growers in the study area. Analysis shows that men make up the majority in the maize growing activity, representing 66.67% of the sample, compared to women who only represent 33.33%. Looking at the age range, we see that a large proportion of these growers (47%) are adults, aged between 35 and 50, while those who are over 50 and less than 35 are most poorly represented (19%). Regarding ethnic groups, the majority of respondents (94.6%) are Fulani, while other groups have low proportions: Mandingo 4.4%, Diola (0.6%), and others 0.3%. Considering the marital status of the respondents, the majority of them are monogamous (50%) or polygamous (45.67%), while those who are widowed and singles represent a marginal share with 2.33% and 2% respectively. In terms of education level, a large proportion of the growers surveyed have no formal education (32%), unlike the others who have varying types and levels of education, dominated by Qur'anic (28%) and Basic school (26%). The analysis also showed that people with Middle school, High school, and Tertiary education were less represented, with respective frequencies of 8%, 3.67%, and 2.33%. Nearly 81% of growers are members of a farmers' organization. In terms of household size, the average was 13 members. It was also noted that producers have an average of 27.9 years' experience in maize production. The average area dedicated to maize growing is 3.19 hectares, with an average yield of 2179.19 kg/ha in 2023. In the same year, the total volume of maize produced was 8629.59 kg, divided between domestic consumption (740.61 kg) and sales (1330.98 kg). Maize sales generate an average income of 331,316 Fcfa. Furthermore, the labor force devoted to the cultivation system averages 2.2 workers per farm.

3.2. Maize Growers' Knowledge and Perception of Climate Variability

The results presented in Table 2 shed light on how farmers in the study area have perceived climate change risk over the past ten years. The analysis highlights that the most strongly perceived hazards are rising temperatures SCCRPI = 92.11), recurrent droughts (SCCRPI = 87.33), and decreasing rainfall (SCCRPI = 73.67). Other climate phenomena, such as delayed rainfall, shorter rainy seasons, and stronger winds, were also frequently reported by farmers during the same period.

Table 1. Socio-demographic characteristics of respondents.

Parameters	Modality	Number	Percentage (%)
Gender	Male	200	66.67
	Female	100	33.33
Age	>35 years	57	19
	35 - 50 years	141	47
	<50 years	57	19
Ethnic group	Fulani	284	94.6
	Diola	2	0.6
	Mandingo	13	4.3
	Other	16	0.3
Marital status	Monogamous	150	50
	Polygamous	137	45.67
	Widowed	7	2.33
	Single	6	2
Education level	Qur'anic	84	28
	Basic school	78	26
	Middle school	24	8
	High School	11	3.67
	Tertiary education	7	2.33
	No formal education	96	32
Member of a producer group	Yes	243	81
	No	57	19
		Average	
Household size		13 people	
Farming experience		27.9 years	
Area of fields dedicated to maize (ha)		3.19	
Maize yield in 2023 (kg/ha)		2179.19	
Quantity of self-consumed maize (kg)		740.61	
Quantity of maize sold in 2023 (kg)		1330.98	
Income from maize sales (Fcfa)		331,316	

Table 2. Climate change risk perception of households.

Climatic events	0	1	2	3	CCRPS	SCCRPI	Rank
Rising temperatures	0	8	55	137	829	92.11	1
Recurrent drought	0	14	86	200	786	87.33	2
Rainfall reduction	2	34	163	101	663	73.67	3
Delayed onset of rainfall	3	85	176	36	545	60.55	4
Short rainy season	2	95	180	23	524	58.22	5
Strong winds	2	134	102	62	524	58.22	6
Early rains	6	184	88	22	426	47.33	7
Frequent flooding	2	206	79	13	403	44.78	8

Note: 0: No risk perception; 1: Low risk perception; 2: Medium risk perception; 3: High risk perception.

3.3. Climate-Smart Agricultural Practices Adopted by Maize Growers in the Study Area

Table 3 shows the relative importance of climate-smart agricultural practices adopted by maize growers. The analysis reveals that among the 15 identified climate-smart agricultural practices, drill seeding, crop rotation, use of recommended chemical fertilizers, assisted natural regeneration, and early sowing were ranked first, second, third, fourth, and fifth, with RII values of 0.998, 0.864, 0.827, 0.75, and 0.703, respectively. The least adopted climate-smart agricultural practices are planting living hedges or windbreaks (RII = 0.412), the application of water conservation techniques (RII = 0.278), and the use of crop irrigation (RII = 0.272).

Table 3. Climate-smart agricultural practices (CSAPs) used by the maze growers.

CSAP	Never used (1)	Seldom used (2)	Often used (3)	Used in every agricultural season (4)	RII	Rank
Drill seeding	0	0	3	297	0.998	1
Crop rotation	0	10	143	147	0.864	2
Use of recommended fertilizers	2	23	156	119	0.827	3
Assisted natural regeneration	7	69	141	83	0.750	4
Early sowing	10	127	72	91	0.703	5
Use of manure	27	84	122	67	0.691	6
Use of improved varieties	18	115	138	29	0.648	7
Change of sowing date	39	103	138	20	0.616	8

Continued

Crop association	23	165	101	11	0.583	9
Using short-cycle varieties	55	155	73	17	0.543	10
Application of soil conservation techniques	46	194	49	11	0.521	11
Tree planting in plots	82	171	44	3	0.473	12
Planting living hedges or windbreaks	155	100	41	4	0.412	13
Application of water conservation techniques	268	30	2	0	0.278	14
Crop irrigation	276	22	2	0	0.272	15

Note: RII: Relative Importance Index.

3.4. Motivations for Adopting Climate-Smart Agricultural Practices

Table 4 represents the factors that motivate growers to adopt climate-smart agricultural practices. The results show that improving food security, increasing yields, and improving incomes are, in order of importance, the key reasons that motivate producers to adopt climate-smart agricultural practices. However, wind erosion control, soil protection, and maintaining soil fertility are less motivating for the adoption of climate-smart agricultural practices, according to the respondents.

Table 4. Motivations for adopting climate-smart agricultural practices.

Parameters	Modality	Frequency	Percentage (%)
Improving food security	Strongly agree	277	92.33
	Agree	21	7
	More or less agree	2	0.67
	Disagree	0	0
	Strongly disagree	0	0
Increased yields	Strongly agree	210	70
	Agree	89	29.67
	More or less agree	1	0.33
	Disagree	0	0
	Strongly disagree	0	0
Improved incomes	Strongly agree	184	61.33
	Agree	87	29
	More or less agree	27	9
	Disagree	2	0.67
	Strongly disagree	0	0

Continued

Wind erosion control	Strongly agree	1	0.33
	Agree	36	12
	More or less agree	126	42
	Disagree	119	39.67
	Strongly disagree	18	6
Soil protection	Strongly agree	10	3.33
	Agree	130	43.33
	More or less agree	121	40.33
	Disagree	37	12.33
	Strongly disagree	2	0.67
Maintaining soil fertility	Strongly agrees	63	21
	Agree	186	62
	Little agree	49	16.33
	Disagree	2	0.67
	Strongly disagree	0	0

3.5. Influencing Factors of the Adoption of Climate-Smart Agricultural Practices

Table 5 represents the factors favoring the adoption of climate-smart agricultural practices. The results indicate that understanding the effects of climate change, access to weather and climate information, access to secure land, and support from producer organizations are the main factors promoting the adoption of climate-smart agricultural practices, with respective WAI values of 3.91, 3.84, 3.84, and 2.96. And the factors that have less influence on the adoption of the climate-smart agricultural practices are access to sustainable agricultural technologies, government support, and access to agricultural finance to implement those practices.

3.6. Barriers Affecting the Adoption of Climate-Smart Agricultural Practices

The results in Table 6 show that difficult access to agricultural credit (PCI = 738), difficulties in marketing agricultural products (PCI = 718), weak government support (PCI = 628), high cost of agricultural inputs (PCI = 582), lack of capacity building for producers (PCI = 464) are ranked in this order as the most important obstacles that can block the adoption of climate-smart agricultural practices by maize growers. Factors such as unavailability of improved seeds (PCI = 455), lack of manpower (PCI = 427), poor soil fertility (PCI = 394), lack of access to land (PCI = 250), and limited access to weather information (PCI = 190) also appear as limitations blocking the adoption of cli-mate-smart agricultural practices, but to a lesser extent, compared with the first obstacles cited.

Table 5. Influencing factors of the adoption of climate-smart agricultural practices.

Influencing factors	Strongly disagree (1)	Disagree (2)	More or less agree (3)	Agree (4)	Strongly agree (5)	WAI	Rank
Understanding the effects of climate change	0	11	80	135	74	3.91	1
Access to weather and climate information	8	34	46	121	91	3.84	2
Access to secure land	5	18	59	155	63	3.84	2
Support of producers' organizations	40	64	90	80	26	2.96	3
Access to insurance for farmers	60	111	59	49	21	2.53	4
Access to sustainable agricultural technologies	21	153	90	34	2	2.48	5
Government support	128	69	84	14	5	2.00	6
Access to agricultural finance to implement climate-smart farming practices	130	90	57	17	6	1.93	7

Notes: WAI: Weighted Average Index.

Table 6. Barriers affecting the adoption of climate-smart agricultural practices.

Barriers	Disagree (0)	More or less agree (1)	Agree (2)	Strongly agree (3)	PCI	Rank
Difficult access to agricultural credit	9	46	43	202	738	1
Difficulties in marketing agricultural products	14	30	80	176	718	2
Weak government support	13	77	79	131	628	3
High cost of agricultural inputs	26	78	84	112	582	4
Lack of capacity building for producers	80	60	76	84	464	5
Unavailability of improved seeds	43	103	110	44	455	6
Lack of manpower	78	67	105	50	427	7
Poor soil fertility	68	98	106	28	394	8
Lack of access to land	159	59	55	27	250	9
Limited access to weather information	186	55	42	17	190	10

Notes: PCI: Problem Confronting Index.

4. Discussion

This study relied on self-reported data, which may be subject to recall bias and social desirability bias. Recall bias could have led respondents to misremember or simplify past experiences related to climate risks, while social-desirability bias may have encouraged them to provide answers perceived as more acceptable or favorable. These potential biases might have influenced the accuracy of some responses, possibly leading to an over- or underestimation of maize growers' actual perceptions. While these limitations do not invalidate the findings, they should be kept in mind when interpreting the results.

4.1. Socio-Demographic Characteristics of Respondents

This study shows that, in the study area, men are more involved in maize production than women. This predominance of the male gender in this production sector can be explained on the one hand by the fact that men have much greater access to land, and on the other by the fact that women are much more concentrated in households or constitute the labor force. These results concur with those of [41], [32], and [42], where men are predominantly represented in agricultural activities. Most producers are adults in the 35 - 50 age bracket. This can be explained by the fact that most producers are heads of household. These results are in line with those of [32] [43] and [42], who stated in their studies that the majority of producers are adults. Of the farmers who attended school, most stopped at elementary school. This could be explained by the fact that farmers drop out of school early to focus on agricultural activities as their main source of income. These findings are in line with those of [42], who revealed that the majority of farmers in Africa drop out of school very early. The average number of years of farming experience for producers is almost 28 years. This could be explained by the fact that the majority of active producers are adults who have been active in the agricultural sector for a long time. The majority of farmers are Fulani. This may be because the area is largely dominated by this ethnic group.

4.2. Producers' Perception of Climate Change Risk

It was noted that rising temperatures, recurrent droughts, and reduced rainfall were mainly identified as the greatest climatic risks perceived by maize growers in the study area. This can be explained by the fact that these changes are more perceptible because of their direct and depressive influence on agricultural production. These findings corroborate those of [31] and [32], who reported a greater perception of droughts, delayed onset of rainfall, and short duration of the rainy season in Bangladesh and Ethiopia, respectively.

4.3. Climate-Smart Agricultural Practices Adopted by Maize Growers in the Study Area

The results show that drill seeding, crop rotation, assisted natural regeneration, and early sowing are the practices most widely used by growers in the study area.

This could be explained by the fact that this practice is better suited to crop management. In fact, in Senegal, growers cultivate mostly with bovine, equine, or asine traction. In addition, State-owned companies supporting producers, such as ANCAR (National Rural Agricultural Consultancy Agency), supply agricultural equipment such as seed drills, hoes, etc., making it easier for growers to practice drill seeding. In fact, according to [43], line seeding facilitates crop management. These three practices have been considered as CSA by previous studies such as [39] and [43]. State subsidies for chemical fertilizers and their availability on the market make it easier for growers to access these types of inputs. In addition, the training of growers in the use of chemical fertilizers by projects or NGOs also facilitates their use. At the same time, trees play a decisive role in agricultural systems, providing people with a means of subsistence. Growers aware of the importance of trees in their plots tend to assist natural regeneration. Moreover, early sowing is adopted in the study because of the early onset of the rainy season. And as soon as the first rain falls, growers sow the maize so that it can complete their production cycle. The study carried out by [44] in the Kolda region showed the occurrence of early rainfall episodes. These results are in line with those of [39] in Ghana, [45] in Kenya, [46] in Vietnam, and [47] in Guatemala, all of whom reported the use of this practice by growers to improve the structure and fertility of their soils.

However, irrigation and water management techniques remain largely unadopted by producers, largely because maize cultivation in the Kolda region relies primarily on rainfall and covers vast areas, making irrigation difficult, if not impossible. In addition, certain practices such as installing hedges or windbreaks around fields, planting trees within plots, or soil conservation techniques are among the least used. This low adoption rate could be explained by a lack of awareness or outreach about these practices among farmers.

4.4. Motivations for Adopting Climate-Smart Agricultural Practices

The results of this study reveal that, according to producers' perceptions, the application of climate-smart agricultural practices (CSAPs) improves household food security, increases yields, and improves incomes. These are important motivating factors as they regulate the decisions of maize growers in the study area to adopt CSAP. This is linked to the importance attached by small-scale farmers to food security and household income sources. These findings are close to those of several studies in Sub-Saharan Africa where smallholder farmers adopted climate-smart agricultural practices based on their ability to increase household security and improve agricultural yields and on-farm income [48]-[51].

4.5. Influencing Factors of the Adoption of Climate-Smart Agricultural Practices

The results reveal that understanding the effects of climate change, access to secure land and climate information, support from producer organizations, and access to agricultural insurance are factors that facilitate the adoption of climate-smart farming practices. These findings are in line with those of [39], who identified secure land tenure, understanding of the effects of climate change, and access to sustainable agricultural technologies as the main factors promoting the adoption of climate-smart agricultural practices. For instance, [49] observed that households and individuals with access to secured land tenure invested in agroforestry practices as an adaptation practice to improve food and livelihood security. This is linked to the fact that most growers in the study area have access to climatic information. Secure land ownership encourages growers to invest in or implement intelligent farming practices in their crop plots, unlike those without titled plots. What's more, the organizations that support producers often provide training and financing. In addition, agricultural insurance, which compensates for economic losses due to damage caused by unpredictable weather events, encourages producers to develop more resilient farming practices in a context of climate change. It enables farmers to prepare for the risks associated with climatic shocks and to limit the possible consequences in the event of an incident.

4.6. Obstacles Affecting the Adoption of Climate-Smart Agricultural Practices

This study reveals that limited access to agricultural credit is the main obstacle to the adoption of climate-smart agricultural practices. This constraint can be explained in particular by the cumbersome financing procedure, which is often lengthy and unresponsive, as well as by the geographical distance between financial institutions and the areas where producers live. These findings are in line with those of [52] and [46], who asserted that access to credit has a positive correlation with the adoption of climate-smart agricultural practices. As far as the marketing of agricultural produce is concerned, growers are finding it extremely difficult to sell their harvests. This can be explained, on the one hand, by the fact that producers do not have the means to store their produce after harvest and, on the other hand, by the low selling price of produce found on the market. These results are in line with those of [53], who found that marketing constitutes a problem to the intensification of maize production for producers. Among other obstacles, we have low government support, high cost of agricultural inputs, lack of training for producers, unavailability of improved maize seeds, etc. Indeed, the high cost of fertilizers and climate-smart farming interventions requires appropriate access to credit and funds to purchase the necessary inputs.

5. Conclusions

This study examines the dynamics of climate-smart agricultural practices adoption by maize farmers in the Kolda region. The results show that the most frequently perceived climate risks are rising temperatures, recurring droughts, and declining rainfall. Among the most commonly adopted practices are row planting using a seed drill, crop rotation, the use of recommended chemical fertilizers, assisted natural regeneration, and early planting. These choices are mainly motivated by the search for greater food security, increased agricultural yields, and improved household incomes. When it comes to the factors that encourage people to adopt these practices, three things stand out: a good understanding of the effects of climate change, access to weather and climate information, and secure access to farmland.

This study highlights a growing awareness of the benefits associated with climate-smart agricultural practices, while revealing the persistence of several major obstacles that prevent their adoption. The main obstacles identified include limited access to agricultural credit, difficulties in marketing products, lack of institutional support, and the high cost of inputs. In light of these constraints, it appears crucial to intensify the dissemination of these practices by strengthening producers' capacities, improving technical and financial support mechanisms, and implementing public incentive policies.

Furthermore, promoting sustainable partnerships between institutions, non-governmental organizations, and local communities is a strategic approach for creating an environment conducive to resilient agroecological transition in the face of climate change.

Acknowledgements

We would like to thank the staff of the Agroforestry and Ecology Laboratory (LAFE) at Assane Seck University in Ziguinchor, as well as everyone who contributed to this research project in any way. We would also like to thank the respondents who helped provide this valuable information.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Adzawla, W., Setsoafia, E.D., Setsoafia, E.D., Amoabeng-Nimako, S., Atakora, W.K., Camara, O., *et al.* (2024) Fertilizer Use Efficiency and Economic Viability in Maize Production in the Savannah and Transitional Zones of Ghana. *Frontiers in Sustainable Food Systems*, **8**, Article 1340927. https://doi.org/10.3389/fsufs.2024.1340927

[2] Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K. and Prasanna, B.M. (2022) Global Maize Production, Consumption and Trade: Trends and R&D Implications. *Food Security*, **14**, 1295-1319. https://doi.org/10.1007/s12571-022-01288-7

[3] Poole, N., Donovan, J. and Erenstein, O. (2021) Viewpoint: Agri-Nutrition Research: Revisiting the Contribution of Maize and Wheat to Human Nutrition and Health. *Food Policy*, **100**, Article ID: 101976. https://doi.org/10.1016/j.foodpol.2020.101976

[4] Diallo, A., Mbaye, B.B. and Thiaw, K. (2013) Productivité agricole, croissance économique et pauvreté au Sénégal: Analyse par un MEGC dynamique récursif en micro simulation. Direction de la Prévision et des Etudes Economiques, 45.

[5] DAPSA (2023) Rapport de l'Enquête Agricole Annuelle (EAA) 2022-2023. 52.

[6] Hathie, I., Wade, I., Ba, S., Niang, A., Niang, M., Sow, M.K. and Ba, C.O. (2015) Emploi des jeunes et migration en Afrique de l'Ouest (EJMAO). IPAR, 100. https://idl-bnc-idrc.dspacedirect.org/server/api/core/bitstreams/7853b323-a926-45ec-a1b5-ba088d3d8e41/content

[7] Thiam, I. and Touré, M. (2020) Liens empiriques entre financement agricole et sécurité alimentaire au Sénégal. Semantic Scholar.

[8] Broutin, C., Sokona, K. and Tandia, A. (2000) Aperçu de la filière céréales au Sénégal. ENDA GRAF, 18.

[9] Ndiaye, S., Djighaly, P.I., Diedhiou, O.B.A., Badiane, P.D. and Diatta, I. (2020) Effets d'aliments à base de pulpe d'anacarde (*Anacardium occidentale* L.) séchée sur les performances des poulets de chair en phase de croissance en Casamance, Sénégal. *Revue Ivoirienne des Sciences et des Technologies*, **35**, 193-213.

[10] Abubakar, A., Ishak, M.Y. and Makmom, A.A. (2021) Impacts of and Adaptation to Climate Change on the Oil Palm in Malaysia: A Systematic Review. *Environmental Science and Pollution Research*, **28**, 54339-54361. https://doi.org/10.1007/s11356-021-15890-3

[11] Ado, A.M., Savadogo, P., Pervez, A.K.M.K. and Mudimu, G.T. (2019) Farmers' Perceptions and Adaptation Strategies to Climate Risks and Their Determinants: Insights from a Farming Community of Aguie District in Niger. *GeoJournal*, **85**, 1075-1095. https://doi.org/10.1007/s10708-019-10011-7

[12] Alves, F., Leal Filho, W., Casaleiro, P., Nagy, G.J., Diaz, H., Al-Amin, A.Q., *et al.* (2020) Climate Change Policies and Agendas: Facing Implementation Challenges and Guiding Responses. *Environmental Science & Policy*, **104**, 190-198. https://doi.org/10.1016/j.envsci.2019.12.001

[13] Getahun, A.B., Ayal, D.Y., Ture, K. and Zeleke, T.T. (2021) Determinants of Climate Variability Adaptation Strategies: A Case of Itang Special District, Gambella Region, Ethiopia. *Climate Services*, **23**, Article ID: 100245. https://doi.org/10.1016/j.cliser.2021.100245

[14] Sarr, K.Y., Gueye, F. and Sarr, M. (2023) Analyse Couts-avantages des Stratégies d'Adaptation de la Filière du Riz de Vélingara à Kolda au Senegal: Analyse coûts-avantages des stratégies d'adaptation de la filière du riz de vélingara à kolda au sénégal. *Revue Ouest Africaine de Sciences Economiques et de Gestion*, **16**, Article 30. https://doi.org/10.61585/pud-roaseg-v16n102

[15] Fabre, C.C. (2010) L'adaptation des agriculteurs vivriers du Sénégal au changement climatique: Cas de la communauté rurale de Sessène. Master's Thesis, Université de Montréal.

[16] Adger, W.N., Arnell, N.W., Black, R., Dercon, S., Geddes, A. and Thomas, D.S.G. (2015) Focus on Environmental Risks and Migration: Causes and Consequences. *Environmental Research Letters*, **10**, Article ID: 060201. https://doi.org/10.1088/1748-9326/10/6/060201

[17] Ndao, B. (2022) Potentialités, contraintes et stratégies d'adaptation de l'agriculture familiale dans un terroir sud-ouest du bassin arachidier: Cas de la commune de Keur Maba Diakhou (Région de Kaolack). Centre de Ressources Virtuel des Rivières du Sud, 114.

[18] Séne, A.M. and Diamanka, H. (2022) Stratégies d'adaptation des acteurs locaux face aux contraintes environnementales et anthropiques de la riziculture dans la commune de Coumbacara (Région de Kolda, Sénégal). *Espace Géographique et Société Marocaine*, **1**, 85-104.

[19] Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., *et al.* (2022) Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, **19**, Article 3804. https://doi.org/10.3390/ijerph19073804

[20] Okolie, C.C., Danso-Abbeam, G., Groupson-Paul, O. and Ogundeji, A.A. (2022) Cli-

mate-Smart Agriculture Amidst Climate Change to Enhance Agricultural Production: A Bibliometric Analysis. *Land*, **12**, Article 50. https://doi.org/10.3390/land12010050

[21] Karwani, G.M., Meya, A.I., Teshale, M.A. and Philipo, M. (2025) Effects of Climate-Smart Agriculture Technologies on Maize-Common Bean Intercrops Growth and Yield Performances in Smallholder Farmer's Fields in Semi-Arid Areas, Tanzania. *Agricultural Sciences*, **16**, 730-752. https://doi.org/10.4236/as.2025.168046

[22] Omotoso, A.B., Letsoalo, S.S., Daud, S.A., Tshwene, C. and Omotayo, A.O. (2024) Climate-Smart Agricultural Practices, Productivity, and Food-Nutrition Security in Rural South Africa: A Dataset of Smallholder Maize Farmers. *Data in Brief*, **55**, Article ID: 110725. https://doi.org/10.1016/j.dib.2024.110725

[23] Samb, S.B. (2021) Analyse du marché des céréales locales (mil et maïs) au Sénégal. IPAR, 47. https://www.alimenterre.org/system/files/2022-02/1304-ipar-analyse-marche-cereales-sen.pdf

[24] ANSD (2017) Rapport régional définitif: Recensement Général de la Population et de l'Habitat, de l'Agriculture et de l'Elevage 2013-Région de Kolda. 90.

[25] ANSD (2024) Annuaire population du Sénégal. 26.

[26] PDD (2023) Plan départemental de développement de Kolda.

[27] Faye, A., Tounkara, A., Ciss, P.N., Ngom, M. and Camara, I. (2022) Évaluation de la vulnérabilité du secteur agricole aux changements climatiques et identification d'options d'adaptation pour la région de Kolda au Sénégal: Rapport produit dans le cadre du projet Sécurité alimentaire: Une agriculture adaptée (SAGA). FAO, 92. https://doi.org/10.4060/cc0688fr

[28] Cochran, W.G. (1963) Sampling Techniques. 2nd Edition, John Wiley & Sons, 413. https://books.google.com/books/about/Sampling_techniques_2nd_edition.html?id=Y-SxXwAACAAJ

[29] Kothari, C.R. (2004) Research Methodology: Methods and Techniques. New Age International, 401. https://qnamuni.dspace.vn/bitstream/QNA/1934/1/1.%20Research_methodology_methods_and_techniq.pdf

[30] Sullivan, G.M. and Artino, A.R. (2013) Analyzing and Interpreting Data from Likert-Type Scales. *Journal of Graduate Medical Education*, **5**, 541-542. https://doi.org/10.4300/jgme-5-4-18

[31] Ahmed, Z., Guha, G.S., Shew, A.M. and Alam, G.M.M. (2021) Climate Change Risk Perceptions and Agricultural Adaptation Strategies in Vulnerable Riverine Char Islands of Bangladesh. *Land Use Policy*, **103**, Article ID: 105295. https://doi.org/10.1016/j.landusepol.2021.105295

[32] Likinaw, A., Bewket, W. and Alemayehu, A. (2022) Smallholder Farmers' Perceptions and Adaptation Strategies to Climate Change Risks in Northwest Ethiopia. *International Journal of Climate Change Strategies and Management*, **15**, 599-618. https://doi.org/10.1108/ijccsm-01-2022-0001

[33] Yeleliere, E., Nyamekye, A.B., Antwi-Agyei, P. and Boamah, E.F. (2022) Strengthening Climate Adaptation in the Northern Region of Ghana: Insights from a Stakeholder Analysis. *Climate Policy*, **22**, 1169-1185. https://doi.org/10.1080/14693062.2022.2134085

[34] Baffour-Ata, F., Antwi-Agyei, P., Apawu, G.O., Nkiaka, E., Amoah, E.A., Akorli, R., *et al.* (2021) Using Traditional Agroecological Knowledge to Adapt to Climate Change and Variability in the Upper East Region of Ghana. *Environmental Challenges*, **4**, Article ID: 100205. https://doi.org/10.1016/j.envc.2021.100205

[35] Hossain, M.S. and Miah, M.A.M. (2011) Poor Farmers' Problem Confrontation in Us-

ing Manure towards Integrated Plant Nutrition System. *Bangladesh Journal of Extension Education*, **23**, 139-147.

[36] Uddin, L.Q., Nomi, J.S., Hébert-Seropian, B., Ghaziri, J. and Boucher, O. (2017) Structure and Function of the Human Insula. *Journal of Clinical Neurophysiology*, **34**, 300-306. https://doi.org/10.1097/wnp.0000000000000377

[37] Devkota, R., Brant, S.V., Thapa, S. and Loker, E.S. (2014) Two Avian Schistosome Cercariae from Nepal, Including a Macrobilharzia-Like Species from Indoplanorbis Exustus. *Parasitology International*, **63**, 374-380. https://doi.org/10.1016/j.parint.2013.12.009

[38] Ndamani, F. and Watanabe, T. (2015) Farmers' Perceptions about Adaptation Practices to Climate Change and Barriers to Adaptation: A Micro-Level Study in Ghana. *Water*, **7**, 4593-4604. https://doi.org/10.3390/w7094593

[39] Antwi-Agyei, P., Abalo, E.M., Dougill, A.J. and Baffour-Ata, F. (2021) Motivations, Enablers and Barriers to the Adoption of Climate-Smart Agricultural Practices by Smallholder Farmers: Evidence from the Transitional and Savannah Agroecological Zones of Ghana. *Regional Sustainability*, **2**, 375-386. https://doi.org/10.1016/j.regsus.2022.01.005

[40] Kabir, M.S., Radović Marković, M. and Radulović, D. (2019) The Determinants of Income of Rural Women in Bangladesh. *Sustainability*, **11**, Article 5842. https://doi.org/10.3390/su11205842

[41] Kabore, P.N., Barbier, B., Ouoba, P., Kiema, A., Some, L. and Ouedraogo, A. (2019) Perceptions du changement climatique, impacts environnementaux et stratégies endogènes d'adaptation par les producteurs du Centre-nord du Burkina Faso. *VertigO*, **19**, Article 30. https://doi.org/10.4000/vertigo.24637

[42] Zakari, S. (2017) Adoption des technologies et pratiques d'agriculture intelligente face au climat dans les sites CCAFS-(Niger). 46.

[43] Adzawla, W. and Alhassan, H. (2021) Effects of Climate Adaptation on Technical Efficiency of Maize Production in Northern Ghana. *Agricultural and Food Economics*, **9**, Article No. 18. https://doi.org/10.1186/s40100-021-00183-7

[44] Sambou, P.C. (2024) Variabilité pluviométrique et cultures céréalières dans le sud du Sénégal (Département de Kolda). 301-324. https://www.researchgate.net/publication/387940178_Variabilite_pluviometrique_et_cultures_cerealieres_dans_le_sud_du_Senegal_Departement_de_Kolda

[45] Ogada, M.J., Rao, E.J.O., Radeny, M., Recha, J.W. and Solomon, D. (2020) Climate-smart Agriculture, Household Income and Asset Accumulation among Smallholder Farmers in the Nyando Basin of Kenya. *World Development Perspectives*, **18**, Article ID: 100203. https://doi.org/10.1016/j.wdp.2020.100203

[46] Luu, T.D. (2020) Factors Influencing Farmers' Adoption of Climate-Smart Agriculture in Rice Production in Vietnam's Mekong Delta. *Asian Journal of Agriculture and Development*, **17**, 109-124. https://doi.org/10.37801/ajad2020.17.1.7

[47] Sain, G., Loboguerrero, A.M., Corner-Dolloff, C., Lizarazo, M., Nowak, A., Martínez-Barón, D., *et al.* (2017) Costs and Benefits of Climate-Smart Agriculture: The Case of the Dry Corridor in Guatemala. *Agricultural Systems*, **151**, 163-173. https://doi.org/10.1016/j.agsy.2016.05.004

[48] Abegunde, V.O., Sibanda, M. and Obi, A. (2019) Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa. *Sustainability*, **12**, Article 195. https://doi.org/10.3390/su12010195

[49] Antwi-Agyei, P., Dougill, A.J. and Stringer, L.C. (2014) Barriers to Climate Change Adaptation: Evidence from Northeast Ghana in the Context of a Systematic Literature Review. *Climate and Development*, **7**, 297-309. https://doi.org/10.1080/17565529.2014.951013

[50] Myeni, L., Moeletsi, M., Thavhana, M., Randela, M. and Mokoena, L. (2019) Barriers Affecting Sustainable Agricultural Productivity of Smallholder Farmers in the Eastern Free State of South Africa. *Sustainability*, **11**, Article 3003. https://doi.org/10.3390/su11113003

[51] Onyeneke, R.U., Igberi, C.O., Uwadoka, C.O. and Aligbe, J.O. (2017) Status of Climate-Smart Agriculture in Southeast Nigeria. *GeoJournal*, **83**, 333-346. https://doi.org/10.1007/s10708-017-9773-z

[52] Branca, G. and Perelli, C. (2020) 'Clearing the Air': Common Drivers of Climate-Smart Smallholder Food Production in Eastern and Southern Africa. *Journal of Cleaner Production*, **270**, Article ID: 121900. https://doi.org/10.1016/j.jclepro.2020.121900

[53] Tsige, Y., Tadesse, S., G/Eyesus, T., Tefera, M.M., Amsalu, A., Menberu, M.A., *et al.* (2020) Prevalence of Methicillin-Resistant *Staphylococcus aureus* and Associated Risk Factors among Patients with Wound Infection at Referral Hospital, Northeast Ethiopia. *Journal of Pathogens*, **2020**, Article ID: 3168325. https://doi.org/10.1155/2020/3168325