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Perceptions and Representations of Climate Change to the Populations in their Living Environment in the Casamance River Basin (Ziguinchor Region)

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Abstract

The cognitive dimension of climate change remains little invested. However, many studies show the importance of the representations of individuals to allow better adaptation of territories in the face of climate change. Indeed, an analysis of the representations and perceptions of individuals of climate change and the risks associated with it should make it possible to strengthen the adaptive capacity of territories and societies in the face of this phenomenon. A better understanding of how social representations of climate change are constructed will facilitate citizen awareness. In an approach of integrated management of territories, taking into account representations goes in the direction of a co-construction and acceptability of adaptation strategies. It is in this perspective that the present work aims to evaluate the trend and the perception of the populations on the evolution of temperatures and precipitations in the Casamance basin. The data are the result of an exploratory survey of 515 households in the Casamance River basin. The results of the statistical treatments show a significantly increasing average annual maximum, minimum, and mean temperature trend and a decreasing trend in annual and seasonal precipitation in terms of magnitude and intensity. These trends have been verified with the perception of the populations and have an impact on both the environment (drought, water deficit...) and the socio-economic environment (agriculture, livestock, health, social life…). Faced with the adverse effects of climate change, the populations surveyed propose multiple initiatives and develop various adaptation strategies, based on endogenous knowledge. In the agricultural sector, for example, more innovative agriculture is being proposed, even if people have different views on the measures that stakeholders need to pursue to implement it to address climate change.

Keywords: *Climate change, Global warming, Trends, Population perceptions, Adaptation*

1. Introduction

Climate change is a statistically identifiable change in the mean and/or variability of climate, and climate variability is the variation in climatic states caused by natural or human activities at spatial and temporal scales. Since the 1950s, the observed changes in atmospheric and ocean warming, sea-level rise, and snow and ice melt are undoubtedly greater than in the past [1]. The

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current global warming of 1 ° C compared to 1980-1900 is attributed to human activities and will reach 1.5 ° C between 2030 and 2052 [2].

Although climate change is a global phenomenon, it is gaining local attention in terms of climate risks. Warming greater than the global annual average has been detected in many regions with higher levels of risk depending on geographic location, vulnerability, and conditions conducive to adaptation. This situation increases climatic threats with rising sea levels, even more in low-lying coastal areas and deltas [1][2]. Africa is one of the most climate-vulnerable regions of the world and its agriculture is expected to suffer a net negative impact [3][4][5][6]. This great vulnerability of sub-Saharan Africa to climate change is due to its heavy dependence on agriculture and its limited adaptive capacity due to the lack of resources and technologies [7]. Despite its global scale, it is indeed poor regions such as Africa, and particularly West Africa, that will suffer the most from the consequences of climate change due to their high vulnerability [8]. Particular attention should be paid to West Africa for three reasons: this region will be among the most heavily affected by climate change in the future, agriculture is predominant in its economy and the majority of its rural population is highly dependent on the natural environment [9][10].

For some, the increasing frequency and magnitude of extreme weather events such as droughts, floods, or storms: direct consequences of climate change, are already a reality [8]. Health, terrestrial and aquatic ecosystems, and socio-economic systems such as agriculture, forestry, fisheries, and water resources, which are essential for human development and well-being, are sensitive to variations and are already suffering the induced effects of climate change [1][2].

Before proceeding with changing agricultural policy regarding climate change, assessing farmers' beliefs and perceptions of climate change is an important starting point [11]. The participation of populations in proactive climate change adaptation activities follows their perception and understanding of local climate change [12][13]. People with a better perception (receptor stage) of climate change are more likely to be concerned about adaptive actions (behavior, stage of outcome) [5][14].

Perception, a meaningful and complete picture of a phenomenon, is the last part of a psychological process starting with the collection of information (sensory input) and ending with a subjective interpretation of the information collected [15]. Climate change alters local weather conditions [13] and varies on a spatiotemporal scale. It leaves impressions among the people contained in space and time. Thus, people's perceptions of climate change are differentiated according to geographic locations and socio-personal characteristics [12]. An individual's prior experience, the existing culture, and social location develop a personalized interpretation of climatic events, such as temperature and precipitation [16]. A farmer's social location is made up of a wide range of characteristics, e.g., age, gender, education, family size, asset endowment, employment, modes of communication, and knowledge [17]. Messages disseminated by mass media and interpersonal communication mediate the effects of these personal characteristics on perceptions of climate variability [18][19]. Furthermore, depending on experience and availability, farmers' heuristic perceptions may or may not match weather data [20].

The link between risk perception and risk response in the context of water resources management at the individual, household, community, and institutional levels has been the subject of a large number of theoretical and empirical studies around the world. At the individual level, vulnerability, exposure, and cognitive factors are important determinants of the perception and response to risks associated with climate change. At the community level, the perception of risk is determined by culture, social pressure, and group identity. Responses to risk vary depending on the level of social cohesion and collective action. At the national level, public support is a key determinant of the institutional response to climate change, especially for democratic nations [21].

The cognitive dimension of climate change remains little invested. However, many studies show the importance of the representations of individuals to allow better adaptation of territories in the face of climate change [22]. Indeed, an analysis of the representations and perceptions of individuals of climate change and the risks associated with it should make it possible to strengthen the adaptive capacity of territories and societies in the face of this phenomenon. A better understanding of how social representations of climate change are constructed will facilitate citizen awareness. In an approach of integrated management of territories, taking into account representations goes in the direction of a co-construction and acceptability of adaptation strategies. This study is part of this process, which aims to study certain impacts linked to climate change and to propose necessary adaptation measures.

This document analyzes temperature and precipitation trends as well as people's perceptions of climate change. Long ignored, the perception of climate change has become a very explored field of research in recent years [5][10][12][16][19]. In response to the findings of the reports of the Intergovernmental Panel on Climate Change [1][2] which had highlighted serious deficiencies in this area in Africa and more particularly in West Africa, the subject became both relevant and exciting. As proof, the references cited below are the only date from the last 10 years.

To conduct this study, several research questions are put forward: How are the climatic changes (temperature and precipitation) in the Casamance basin? Do these populations of the Casamance basin experience climate change and variability? How are climate changes experienced and perceived by populations in recent years? What are the local indicators of climate change that they perceive? What are the adaptation strategies envisaged by the countries of the Casamance basin? We are trying to identify the climate changes experienced and perceived by the populations in recent years, and the adaptation strategies envisaged in the Casamance basin.

2. Materials and methods

This study, although using the same instrument as the other existing studies, is characterized by its combination in the Casamance basin of both the analysis of climate trends (temperature and precipitation) and the perception of climate change. by the populations in recent years, as well as the adaptation strategies envisaged.

2.1. Study area

The Casamance basin [Figure 1], which extends over three administrative regions (Ziguinchor, Sédhiou, and Kolda), in southern Senegal, is located in latitude between 12°20' and 13°21' North and in longitude between 14°17 and 16°47' West. The basin covers an area of about 20150 km2 and stretches 270 km from west to east and 100 km from north to south [23]. The three administrative regions of the basin concentrate a population of 1,664,600 inhabitants [24]. The climate of Casamance, which is of the coastal and continental southern Sudanese type [25], is strongly influenced by geographical and atmospheric factors [26].

All of the survey respondents live in the Ziguinchor region, which comprises three departments: Ziguinchor, Bignona, and Oussouye. It is located in the southwest of Senegal and covers 7339 km². It has a population of 549,151 inhabitants, or 75 inhabitants per km², and is more than 70% rural. Considered the granary of Senegal, it receives the most rainfall in the country, with climatic conditions generally favorable for an agricultural region [27]. However, agriculture in this region is facing many difficulties linked to the decrease in rainfall (25% decrease in 2013), as well as problems of fertility and soil degradation (salinization, acidification, silting). It also suffers from insufficient product diversification and rudimentary production tools [27].

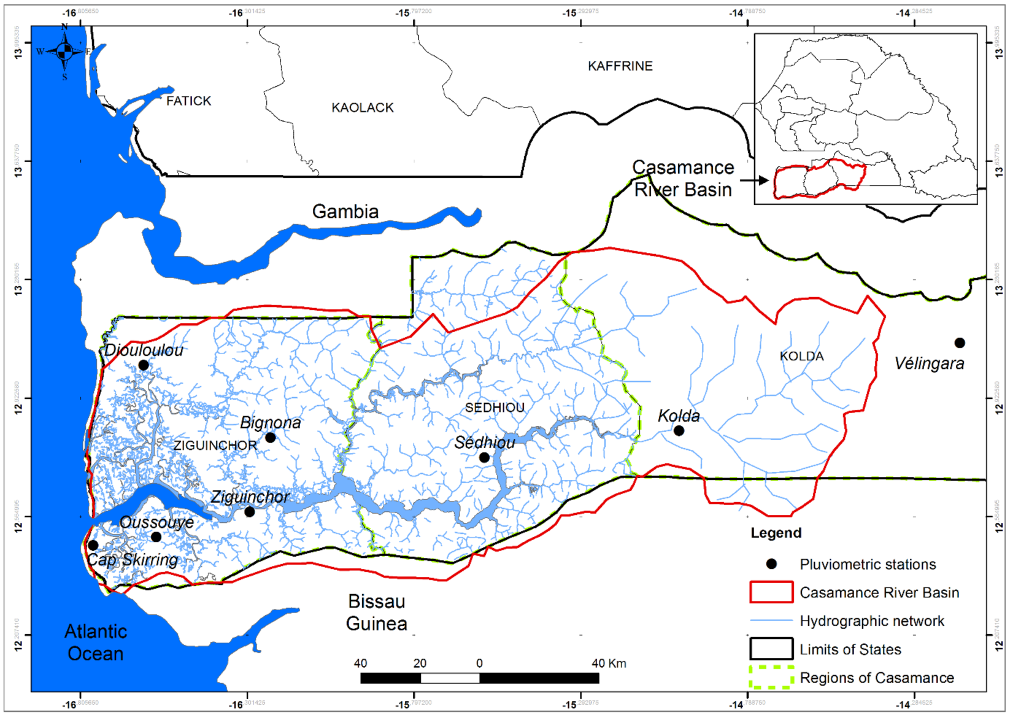

Figure 1. Location of the Casamance Basin and the Ziguinchor region

2.2. Climatic data

The choice of Ziguinchor station for this study was made based on a large number of years of observations and the absence of gaps. The sample size criterion is based on the recommendations of the World Meteorological Organization, which advocates the use of a minimum observation period of 30 years for any study on climate change [28]. The temperature and precipitation data series were collected from the National Agency for Civil Aviation and Meteorology (ANACIM).

Changes in all temperature and precipitation variables are evaluated using statistical tests. While Mann-Kendall's test can detect possible gradual changes in series of extreme variables [29], Pettitt's [30] is a nonparametric test for detecting a break in the series. Based on temperature and precipitation data, the Standardized *Precipitation* and Evapotranspiration Index (SPEI) was calculated and used to monitor and quantify drought in the Ziguinchor region. The SPEI is considered to be an improved drought index, particularly suitable for analyzing the effect of global warming on drought conditions [31]. The calculation of the EPSI in this study follows the method mentioned in the study by Vicente-Serrano et al [32]. For this study, the monthly SPEI was calculated from 1950 to 2018 on 5-time scales (1, 3, 6, 12, and 24 months) for the Ziguinchor zone.

2.3. Survey data

2.3.1. The questionnaire used in the study

The questionnaire used in this study was built based on previous studies. Measures of the effects of climate and atmospheric change have been adapted from Çabuk et al [33], Di Falco [34], Foudi and Erdlenbruch [35], and Moser et al [36]. For elements to assess innovation and its objectives in an agricultural context, this study looked at Durán-Romero and Urraca-Ruiz [37] and Iglesias et al [38]. The scale for measuring the role of institutions was borrowed from Iglesias et al [38]. Elements related to climate and atmospheric change, innovative agriculture and its objectives, and organic and fair-trade agriculture were ranked on a 4-point Likert-type scale, anchored at 1 = strongly disagree to 4 = strongly agree. Socio-demographic factors were measured according to Arslan et al [39], Çabuk, et al [33], Di Falco [34], and Foudi and Erdlenbruch [35].

With a pre-test of the questionnaire (N = 50 respondents), the study aimed to avoid any ambiguity. The pre-test indicated that the questionnaire was clear and easy to complete. Thus, the questionnaire was submitted face-to-face to Senegalese smallholders involved in agriculture from March to June 2015. Surveys, generally carried out online, are not made based on a sample of the population to be interviewed, but on the availability of the person to participate in the survey. For the survey, 578 responses were collected, but some were incomplete, so data from a sample of 515 respondents including small operators were retained. People's perceptions of climate variables and the results of the analysis of annual precipitation and temperature are compared. Similarly, group discussions were held in the area with most people with long experience. The questionnaire includes questions on climate change topics, but also on the potential consequences for the respondent's activities and the possibility of adaptation. The processing of the responses was done in several stages. The tool used throughout the survey process is the Sphinx software, which allows quantitative and qualitative surveys to be carried out, and which assists the analyst from the design of the questionnaire and its distribution to the analysis of the results and their communication. The statistical processing of the results has been completed for greater accuracy using Excel. Analysis of the responses allows trends to be identified.

2.3.2. Socio-economic status of respondents

The analysis of the results begins with the characterization and diagnosis of the socio-economic situation of the respondents [Figure 2]. The survey results revealed that men represent only a little more than a quarter of the respondents (25.8%) compared to 74.2% for women. More than half of the respondents are between 21 and 49 years old (67.9%) and more than a third are between 41 and 49 years old. Those over 50 years of age account for 32.1%, which means that the survey population is adults. The majority of respondents live in large families, plus 66% live in families with 7 or more people and more than 74% have at least 4 children. More than half (63.3%) earn less than 150,000 FCFA per month or just over 6,000 FCFA per day. 15.5% have incomes between 250,000 and 450,000 FCFA per month and 3.9% earn 450,000 FCFA and more. Concerning the function, the sample is varied and is made up first of all of the farmers (38.3% of respondents), then of executives in senior intellectual professions (17.7%), craftsmen-traders-business managers (10.5%), employees (10.1%), and finally of manual workers (8.9%). The remaining Inactive and Unemployed represent 14.5% of the sample.

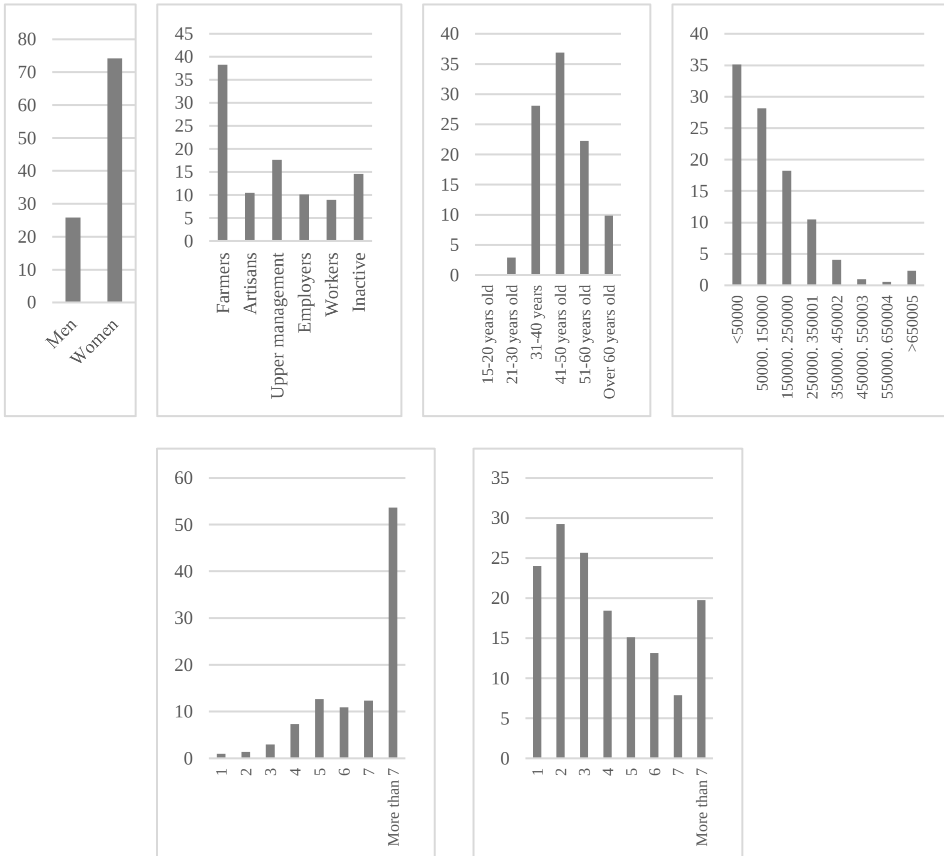

Figure 2. The socio-economic situation of the populations surveyed

3.1. Climate trend analysis

The overall trend is the annual variation in temperatures at the Ziguinchor station. The coefficient of variation is slightly higher for minimum (TN) and mean (TM) temperatures with 0.04 than for maximum (TX) temperatures with 0.03. These three variables TM, TX, and TN increased slightly from 1960 to 2018. In line with global variation [39], this warming appears to have been greater for minimum temperatures (with 0.70°C/year) than for maximum temperatures (with 0.61°C/year), although the difference between the two is very small (0.09). The standard deviation is 0.82°C on the global mean and indicates the magnitude of interannual variability about warming over the period. The average temperature at Ziguinchor has thus risen from a minimum value of 26.1°C (in 1965) to a maximum value of 30°C (in 2016) over a total of 67 years. In the year 2016, the "hottest" year in the series, the maximum temperature reached 38°C and the minimum temperature 22°C. As for 1965, the "coldest" year in the series, the maximum temperature did not exceed 33.1°C and the minimum only 19.2°C.

Annual precipitation totals range from 1938 mm in 1999 to 716.7 mm in 1980. The difference between the maximum and minimum of the series is 1222 mm. Rainfall is therefore highly variable with a coefficient of variation of 0.22. As with temperatures, there is a significant trend of decreasing precipitation over the period 1950-2016. Annual average temperatures and precipitation are standardized by the average for the period 1950-2018. The result is a series of annual temperature and precipitation anomalies, both negative and positive [Figure 3].

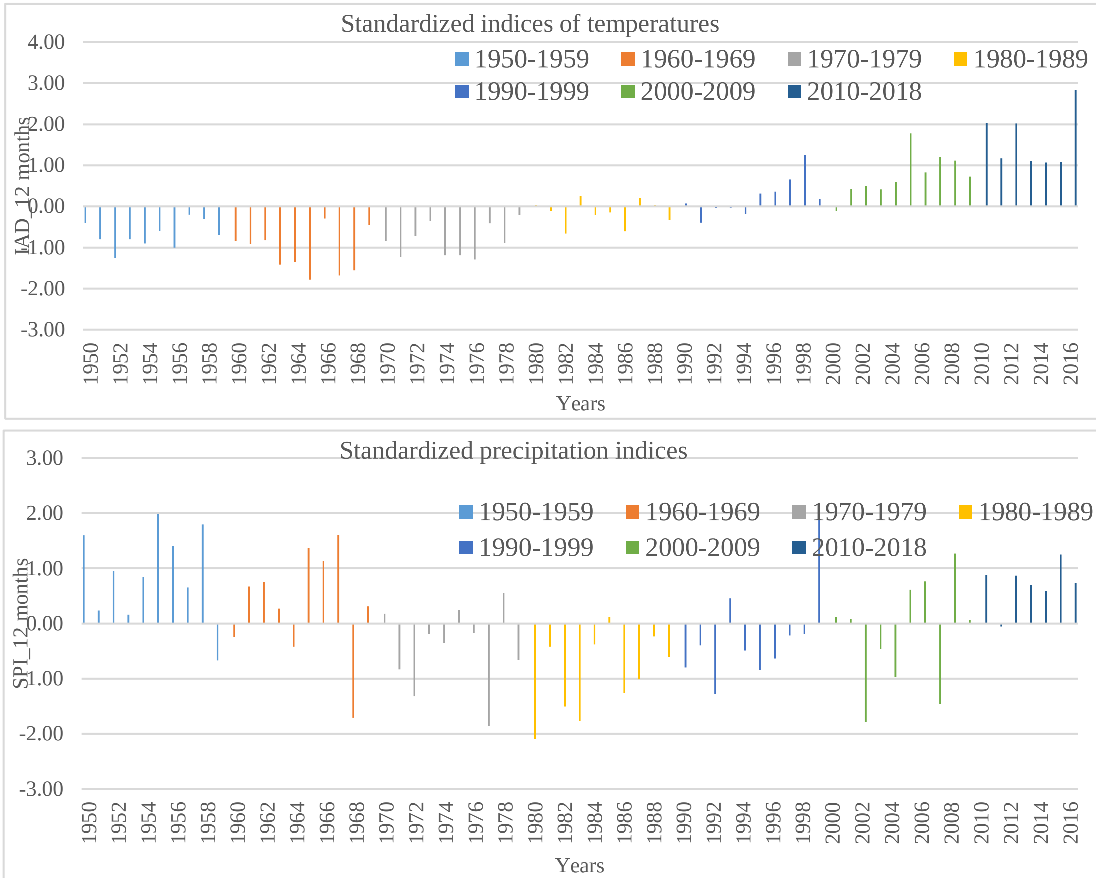

Figure 3. Standardized indices of mean temperature and precipitation at Ziguinchor over the period 1950-2018

For average annual temperatures, we distinguish a first part where the standardized temperature indices are mostly negative (the minimum being -1.78°C in 1965) and a second part where they are mostly positive (the maximum being 2.84°C in 2016). In addition, the negative indices appear to be lower than average than the positive indices, which would be increasingly higher at the end of the series, reflecting a non-homogeneity in warming. [Figure 4] allows 1965 to be retained as an exceptionally "cold" year with a TM of 26.1°C, while the mean value of the TM series is 27.6°C and 2016 as an exceptionally "warm" year with a TX of 30°C compared to a mean value of 34.4°C.

Compared to precipitation, the standardized precipitation indices for the period 1950-2016 are not distributed over time in the same way as for average temperatures. They change the sign from one year to the next, and the maximum number of successive years with the same sign rarely reaches a full decade, despite a significant trend in the evolution of precipitation at Ziguinchor. Nevertheless, the three decades of the 1970s, 80s, and 90s represent the most deficit period in the series. In Fig. 4, 1980 appears like an exceptionally "dry" year with an index of -2.09 and 1999 as an exceptionally "wet" year with an index of 2.00.

[Table 1] shows the results of the Pettitt and Mann-Kendall tests on annual temperature and precipitation at Ziguinchor station from 1950 to 2018.

Table 1. Results of the Pettitt and Mann-Kendall tests on annual temperature and precipitation recorded at the Ziguinchor station from 1950 to 2016

Mann-Kendall test					Pettitt's test				
Descriptors	P (mm)	TX	TN	TM	Descriptors	P (mm)	TX	TN	TM
Trend	O	O	O	O	Rupture	O	O	O	O
Sense of trend	drop	increase	increas e	increas e	test p	0,0013	< 0,0001	< 0,0001	< 0,0001
τ from Kendall	-0,08	0,61	0,70	0,74	Date of termination	1967	2000	1982	1994
S	-187,0	978,0	1118,0	1174,0	Average before breakage	1575	34,0	20,0	27,1
test p	0,31	< 0,0001	< 0,0001	< 0,0001	Average after rupture	1255	35,5	21,4	28,4
Slope	-1,93	0,04	0,04	0,04	Change in % of total	-20,3	4,5	7,2	4,9

****O (yes) = presence of a trend or break; N (no) = absence of a trend or break τ = Kendall's Tau; S = S statistical; test p = one-sided p-value; TX = maximum temperatures; TN = minimum temperatures; TM = mean temperatures; P (mm) = precipitation*

On the minimum, maximum, and average temperatures, both tests (Pettitt and Mann-Kendall) show the presence of a break and/or trend. The Pettitt test indicates 2000 as the date of rupture for TX and 1982 for TN. These breaks are confirmed by the Mann-Kendall test which shows positive Kendall τ with 0.61 for TX, 0.70 for TN, and 0.74 for TM. Thus, the trend is upward and is more significant on NT than on TX. To quantify the temperature variation across the break date, we split the time series into two sub-periods on either side of the break dates. A comparison of the two sub-periods shows a 4.5% surplus in the period after the break for the TX, i.e., an increase of 1.5°C, 4.9% for the TM, i.e., an increase of 1.3°C, and 7.2% for the TN, i.e., an increase of 1.4°C. For precipitation, the Pettitt and Mann-Kendall tests indicate a break in 1967 and a non-significant downward trend in the order of -0.08 mm/year. The evolution of the standardized precipitation indices shows a fall in values, particularly from the 1970s onwards, illustrating the slope of Sen which is negative at -1.93. On either side of the date of rupture, the variation in precipitation is of the order of -20.3% between 1950-1967 and 1968-2016.

To analyze the character and effects of climate change in Casamance, the Standardised Precipitation and Evapotranspiration Index (SPEI), considered as an improved drought index, particularly suitable for analyzing the effect of global warming on drought conditions [31], was used. Figs. 4 and 5 explicitly show an upward trend in drought sequences in the Dakar region. The SPEI series with different time scales all indicate a tendency for Niayes to dry out. According to the SPEI values, the humidity conditions were highly contrasted before and after 2005. However, this drying out is much more apparent on the 12-month time scale, which shows dryness almost every month of every year, especially over the period 1990-2018. Before 1970, the study area was mainly characterized by light to severe moisture conditions (and rarely extreme as noted on the 12-month time scale: this was the case in the 1950s and 1960s). However, droughts have started since 1970 and are generally mild to moderate in nature, although severe to extreme droughts do occur in some months on different time scales. While droughts were moderate over the period 1970-2000, they will worsen over the period 2010-2018.

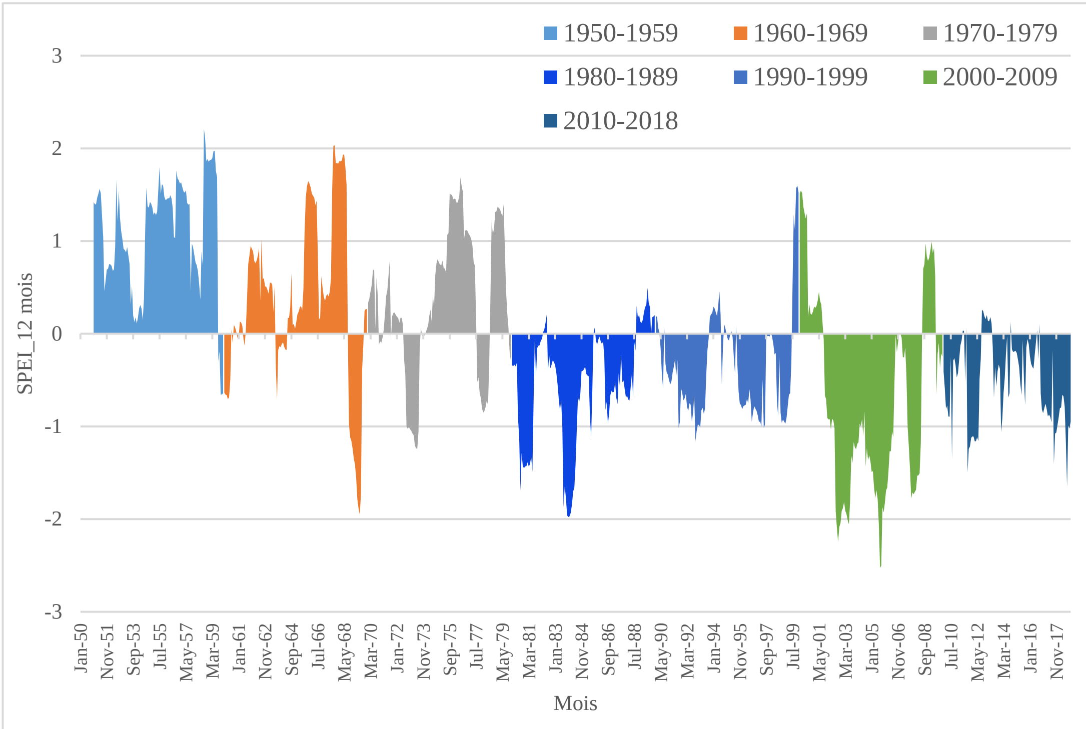

Figure 4. Monthly evolution of SPEI values on the 12-month time scale from 1950 to 2018 for the Ziguinchor zone

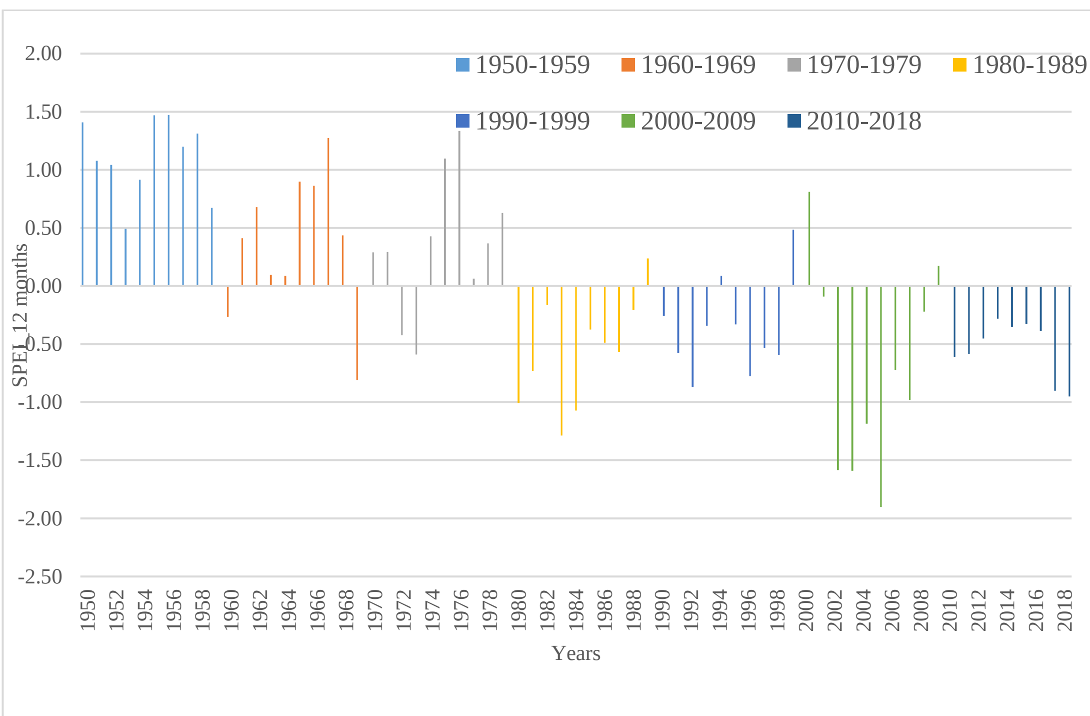

Figure 5. Annual evolution of SPEI values on the 12-month time scale from 1950 to 2018 for the Ziguinchor zone

[Table 2], which shows the mean values of EPSI with different time scales from 1950 to 2018 in the Ziguinchor area, clearly shows that while the periods 1950-1959, 1960-1969, and 1970-1979 are wet, those from 1980 to 2018 are rather dry. While the period 1950-1959 remains the wettest on the different time scales, the period 2000-2009 remains the driest. Thus, the last period (2010-2018), although dry, is less dry than the previous period (2000-2009), which attests to a decrease in drought in the Ziguinchor area with the increase in rainfall noted over the recent period. This improvement in rainfall conditions is in line with the work of some authors [40][41][42] who suggest the end of the Sahelian drought during the 1990s.

Table 2. Mean SPEI values on time scales of 1, 3, 6, 12, and 24 months from 1950 to 2018 for the Ziguinchor zone

Periods	SPEI 1	SPEI 3	SPEI 6	SPEI 12	SPEI 24
1950-2018	-0,08	-0,08	-0,06	-0,05	-0,06
1950-1959	0,17	0,36	0,63	1,07	1,34
1960-1969	0,09	0,18	0,24	0,37	0,58
1970-1979	0,53	0,54	0,46	0,35	0,34
1980-1989	0,01	-0,09	-0,28	-0,57	-0,67
1990-1999	-0,20	-0,21	-0,25	-0,37	-0,47
2000-2009	-0,55	-0,71	-0,74	-0,73	-0,86
2010-2019	-0,61	-0,70	-0,65	-0,54	-0,61

If the standardized rainfall indices become positive over the period 2010-2018 (in line with the increase in rainfall), indicating significant wet sequences even if the 1960s optimum is not yet reached [43][44][45][46][47], the SPEI continue to be negative. This is probably related to the reported increase in temperature with climate change [2]. This increase in temperature improved the PET, which made the water deficit high and thus lowered the SPEI value [48]. This global warming would likely lead to intensification of the hydrological cycle [49], leading to changes in water resource availability and the frequency and intensity of droughts [45] as well as amplification of warming through water vapor feedback [50].

3.2. Public perception of climate change

Although the cognitive dimension of climate change remains little invested, an analysis of people's representations and perceptions of climate change and the risks associated with it should make it possible to strengthen the capacity of territories and societies to adapt to this phenomenon. A better understanding of how social representations of climate change are constructed will help to raise citizens' awareness.

3.2.1. Perception of the signs of climate change

The results of people's perception of the change in temperature and precipitation in recent years are shown in [Figure 6]. The majority of respondents (65.4% strongly agreed and 26.6% somewhat agreed) indicated that there was indeed an increase in temperature on both the annual and seasonal scales. However, some of the respondents (5.2%) tend to disagree that temperatures have been increasing on an annual scale in recent years and a small number of people (2.7%) strongly disagree that temperatures have been increasing.

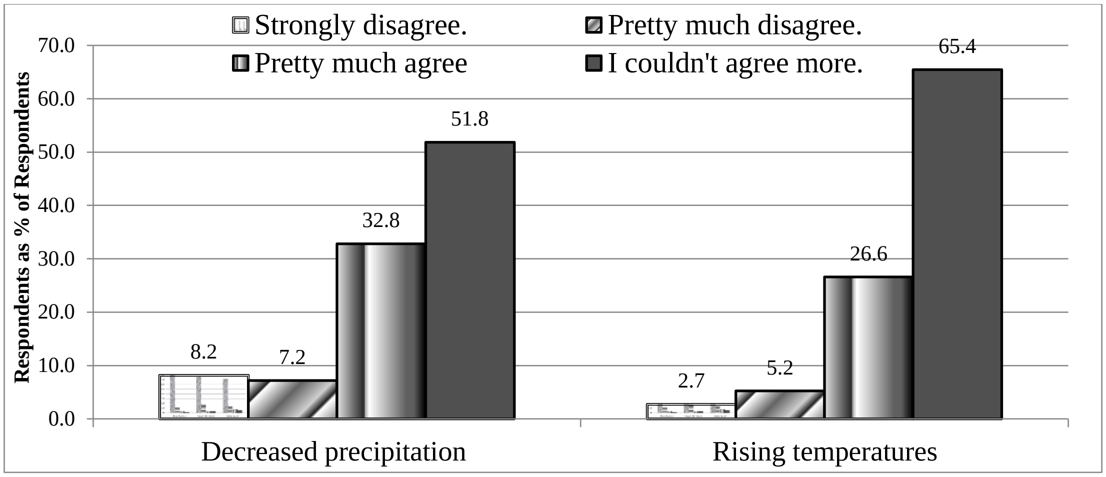

Figure 6. People's perception of the signs of climate change

Of those surveyed, 84.6% of respondents strongly agreed that there has been a decrease in rainfall over the past few decades (with 51.8% strongly agreeing and 32.8% somewhat agreeing). On the other hand, about 15.4% of respondents (including 8.2% who strongly disagree and 7.2% who somewhat disagree) disagree that rainfall is decreasing and indicate an increase. Thus, there is often a large discrepancy between the observed rainfall trend and the perception of the population of this trend. In [Figure 1], it is clear that there is a clear downward trend in precipitation during these years, while 15.4% of respondents think the opposite. These would certainly indicate the return of years with excess rainfall compared to drought years (the 1970s and 1980s). Many respondents also noted a change in the onset of the rainy season in recent years, often indicating a late start to the rainy season.

3.2.2. Perception on the effects of climate change

Rural populations in sub-Saharan Africa have an acute perception of the consequences of climate change. The latter has an impact on the environment and socio-economic activities [Figure 7] and [Figure 8].

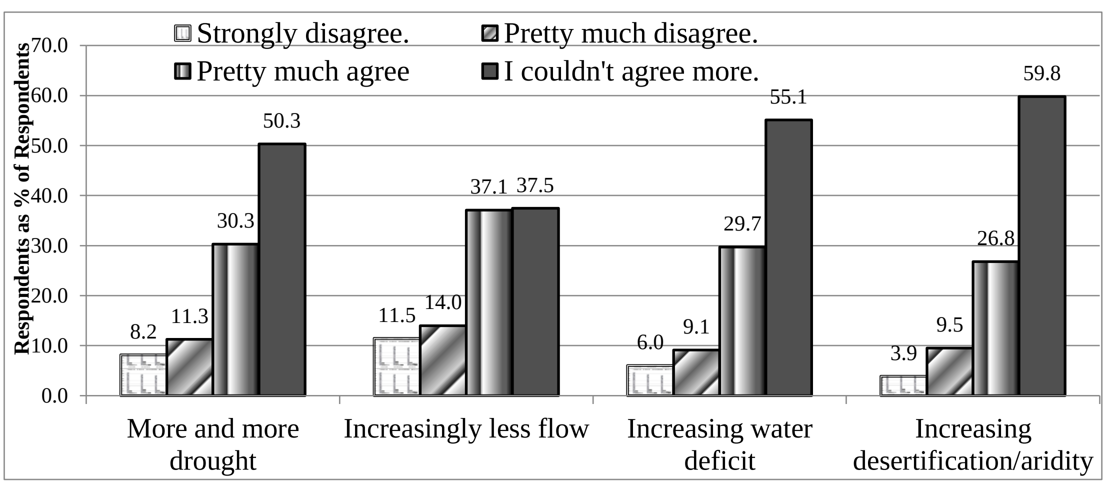

Figure 7. People's perception of the signs of climate change on the environment

The populations surveyed base their perception of climate change on experienced climatic events (abundant rainfall, drought, floods, etc.). This perception of the climate by the population is therefore based on the observation of annual punctual situations and not on systematic monitoring of climatic factors over a given time interval. They perceive this climate change through the adverse effects on their agricultural work. Thus, they can distinguish changes in climatic events through the frequency of rainfall and high temperatures, but they do not have the equipment to accurately quantify the changes perceived (rainfall height, thermal amplitude). [Figure 7] presents people's perception of the signs of climate change on the environment. Thus, the populations questioned note that there is more and more drought (with 50.3% who strongly agree and 30.3% who rather agree), a decrease in runoff (with 37.5% who strongly agree and 37,1% who rather agree), water deficit (with 55.1% who strongly agree and 29.7% who rather agree), desertification or aridity (with 59.8% who strongly agree and 26.8% who rather agree).

There is therefore a diversity of environmental impacts of climate change to which populations are subject and which influence socio-economic activities. Fig. 8 shows the public's perception of the effects of climate change. These effects of climate change are noted on access to water (according to 79.0% of the populations surveyed, of which 47.7% strongly agree and 31.3% somewhat agree), agriculture (according to 89.9% of the populations surveyed, of which 64,5% strongly agree and 25.4% agree), livestock farming (according to 82.7% of the populations surveyed, of which 46.6% strongly agree and 36.1% agree), human health (according to 83.3% of the populations surveyed, of which 52.0% agree), and the health of humans (according to 83.3% of the populations surveyed, of which 52.0% agree),2% strongly agree and 31.1% somewhat agree), energy resources (according to 61.2% of the populations surveyed, of which 24.3% strongly agree and 36.9% somewhat agree), migration (according to 62.9% of the populations surveyed, of which 36.9% strongly agree and 26.0% somewhat agree) and farmers' incomes (according to 88.9% of the populations surveyed, of which 56.9% strongly agree and 32.0% somewhat agree).

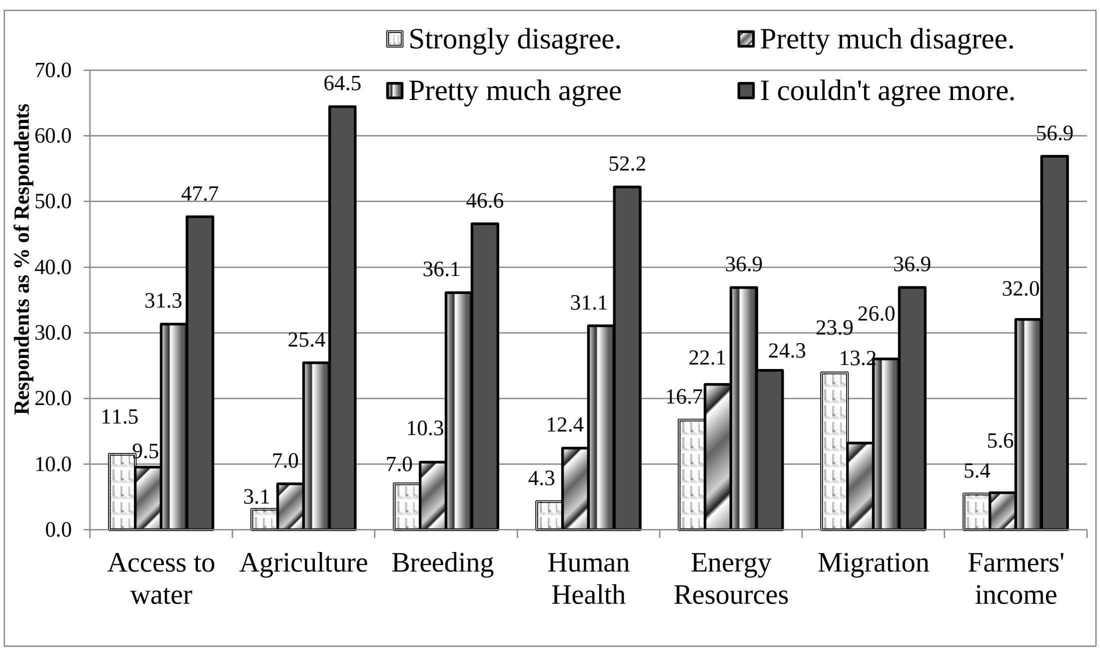

Figure 8. People's perception of the effects of climate change on the socio-economic environment

The populations surveyed, therefore, express the consequences of climate change through the harmful effects felt on their agricultural activities, their health, and their living environments. Crops such as maize, cowpeas, groundnuts, and rice are subject to substantial crop losses that threaten the food self-sufficiency of people living in the vicious circle of poverty. The resurgence of diseases is undermining the health of populations as well as that of farm animals, which pay a heavy price for climate change.

3.2.3. Perception on measures to address climate change

To cope with the adverse effects of climate change, there are various adaptation strategies developed by local populations, either individually or collectively, based on endogenous knowledge. Fig. 9 shows the perception of the surveyed populations on measures (innovations) to deal with climate change. The populations interviewed proposed several adaptation measures such as investment in a rich and quality education (according to 80.0% of the populations surveyed, of which 51.7% strongly agree and 28.3% agree); poverty reduction through the development of new crops (according to 85.2% of the populations surveyed, of which 54.7% strongly agree and 30.5% agree); the implementation of much more efficient irrigation methods (according to 91.3% of the populations surveyed, of which 61.6% strongly agree and 29.7% agree); soil improvement (according to 93.8% of the populations questioned, of which 69.8% strongly agree and 23.9% somewhat agree); increasing the use of new agricultural tools (according to 97.7% of the populations questioned, of which 75.5% strongly agree and 22.2% somewhat agree); developing forest protection techniques (according to 92.6% of the populations questioned, of which 60.1% strongly agree and 32.5% somewhat agree).

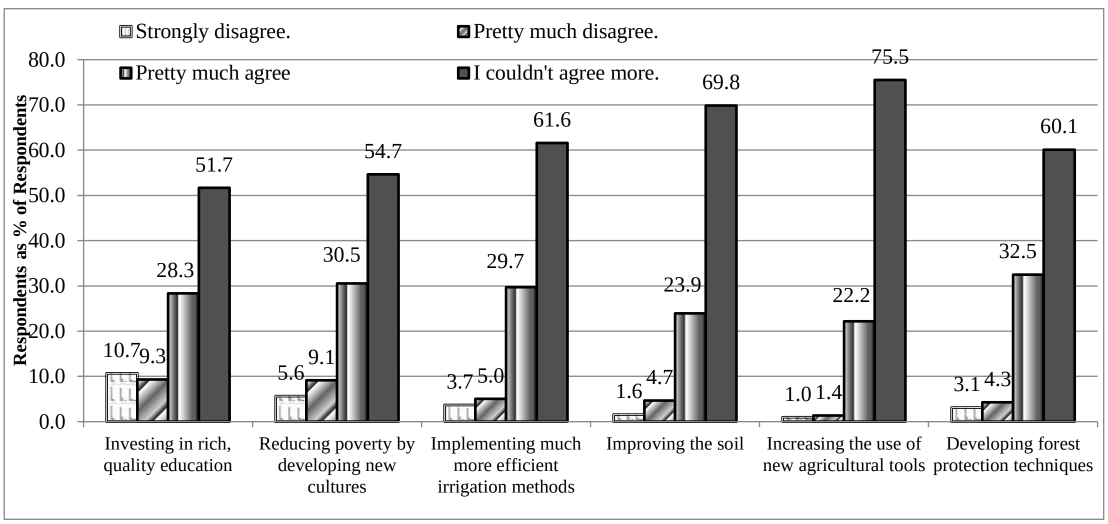

Figure 9. People's perception of measures (innovations) to deal with climate change

To establish innovative agriculture, the populations surveyed have different views on the measures or objectives that stakeholders should pursue to address climate change [Figure 10]. These measures (innovations) to be taken for innovative agriculture, capable of resisting the impacts of climate change, are among others: the promotion of education (according to 81.4% of the surveyed populations), the promotion of social capital (according to 79.4% of the surveyed populations), the promotion of economic activity (according to 85.4% of the surveyed populations), the increase of technical capacity (according to 89.9% of the surveyed populations), the promotion of sustainable agriculture (according to 95.7% of the surveyed populations), the protection of the ecosystem (according to 95.3% of the surveyed populations).

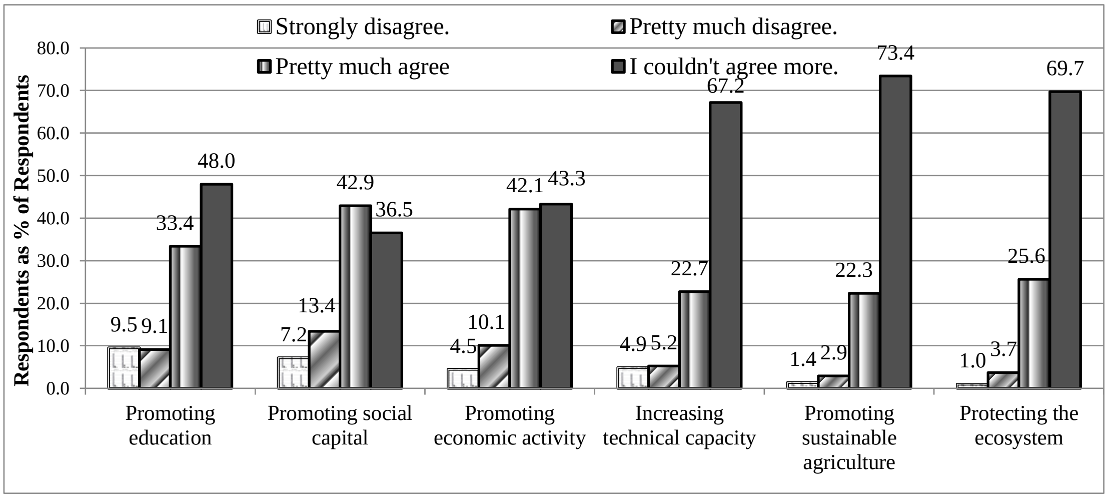

Figure 10. People's perception of the measures (innovations) to be taken for innovative agriculture

The adoption of new crops or varieties (such as rainfed rice and early maize), the modification of land use and the change of technical itineraries such as dry plowing for early sowing, the application of high doses of fertilizers even to leguminous crops, and finally the modification of rotations leading to a gradual change in the usual cropping calendar are also measures reported to address climate change. There is also diversification, which means the development of other activities parallel to agricultural production.

According to the respondents, to better adapt to climate change, farmers should now grow organic products (according to 80.8% of the populations surveyed, of which 45.6% strongly agree and 35.1% somewhat agree) and fair products for their fair remuneration (according to 82.9% of the populations surveyed, of which 42.7% strongly agree and 40.2% somewhat agree) [Figure 11].

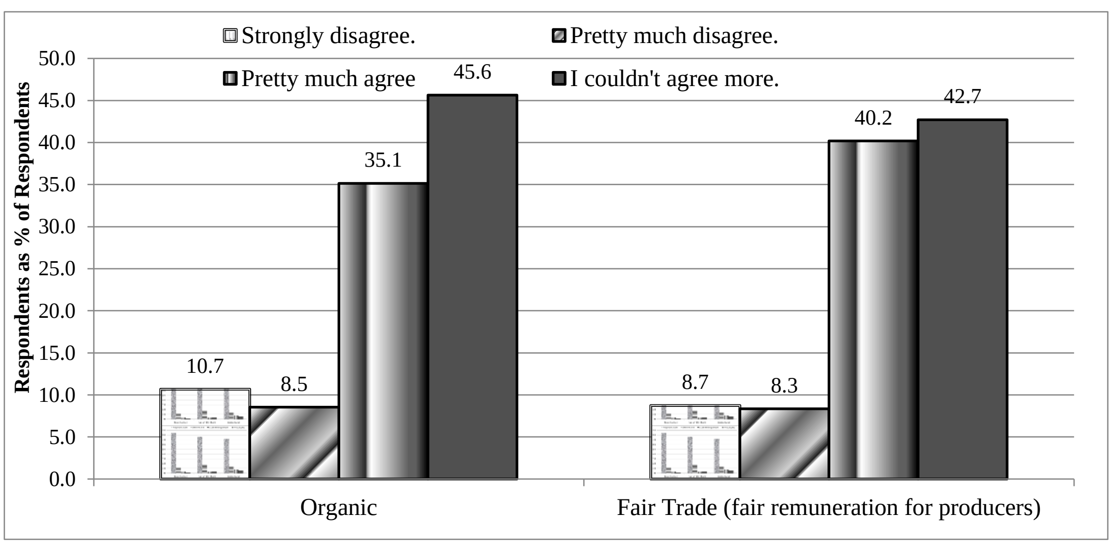

Figure 11. People's perception of the types of agriculture that need to respond to climate change

4. Discussion

The analysis of temperature trends showed the increasing annual trend in minimum and maximum temperatures. The trend is 0.61°C/year for maximum temperatures and 0.70°C/year for minimum temperatures. Average temperatures in the study area increased by 0.74°C/year, which is similar to the results of previous studies by CILSS [51] and IPCC [1] which mentioned the temperature increase in Senegal. For CILSS [51], the increase is greater for minimum temperatures (up to more than +1°C) than for maximum temperatures (up to +0.5°C). As for the IPCC [1], it appears that Africa has experienced a temperature increase of the order of 1.5°C, which, as noted in this study, is faster than the global average, which has risen in the range of 0.6+/-0.2°C [52]. In Senegal, research conducted by Gaye et al [53] and Malou *et al* [54], based on GHG emission scenarios, predict a warming of the order of 2 to 4°C.

Other studies [47][55][56][57] have also highlighted the context of global warming and also reported a temperature increase in most parts of Africa. These results are in concert with those of Sarr [58] for whom the current period 1990-2007 has been particularly hot *in Africa*. By analyzing both the annual mean minimum and maximum temperature over the period 1990-2007, Sarr [58] found that the annual mean maximum temperature increased at a higher rate (0.53°C) than the annual mean minimum temperature (1.44°C). Similar trends have also been found in other regions of the world. For example, Cuccia [59] and Leroy et *al* [60] 2012) have indicated very rapid warming of average air temperatures in territories in France and a climate shift towards warmer influences, of the order of 1.1°C on an annual scale. The warming values noted in Casamance are very close to those of the trends in annual mean surface temperature for the whole world (of the order of 0.011 to 0.022°C/year) and for the Northern Hemisphere (of the order of 018 to 0.031°C/year) over the period 1976-2000 as reported by the IPCC [1] IPCC, [39].

The conclusion of the temperature increase was consistent with the perception of the populations. Compared to 20 years ago, populations perceived an increase in minimum and maximum temperatures on both annual and seasonal scales. Similar results have been found by other researchers [61] around the world. Local people have perceived that the coldest days are decreasing and extremely hot days are more pronounced than 20 to 30 years ago. In conclusion, temperatures in Casamance are increasing at a faster rate than the global average. This increase in temperature harms both agriculture and livestock farming. These results are in line with those of Ogouwalé [62] who confirm farmers' perceptions that climate change is manifest through late onset and/or poor distribution and decrease in rainfall amounts (decrease in the number of rainy days, scarcity, or fairly rapid disappearance of flood periods and more intense and overwhelming heat).

The observed rainfall trend has been analyzed throughout the year and the annual rainfall has decreased significantly by -0.08 mm/year over the year. This result has been supported by previous studies [47][55][57]. These studies have shown a decrease in rainfall. People's perception of climate change has revealed that most believe that there is a change in temperature and rainfall as noted by Mertz *et al* [63], Ofuoku [64], Ajibefun and Fatuase [65], Fosa-Mensah et al [66], Ozer et *al* [41].

The perception of the populations is quite similar to the downward trend observed on rainfall as noted by other researchers in West Africa [67], but also in Senegal [47][55][57]. It should also be noted that the trend observed and the perception of the populations at the start of the rainy season were similar.

Although the majority of respondents agreed with the decrease in annual and seasonal precipitation compared to wet years, some respondents indicated an increase in annual totals in recent years that has led to increased flooding. Average annual precipitation, measured at Ziguinchor, has been increasing since the late 1990s. This improvement in rainfall has led some to estimate the end of the drought [68][69][70][71] which does not seem to be the case elsewhere in the Sahel. This improvement in rainfall contrasts with previous years of drought rainfall. The statistical reality of the series also breaks with the commonly accepted idea of a future decline in rainfall on the African continent [72], which leads others **to** talk about the persistence of the drought that has changed little since the late 1960s and a dramatically deficient Sahel [73].

A mixed nature of the responses on the characteristics of rainfall about the observed trends, especially in the context of increased flooding, is noted. It is very difficult to identify the specific causes of climate change-induced flood risks, but these events are partly the result of climatic factors [45][55][74]. Therefore, the trend between the recorded data and the perceptions of local populations is the same. The results of this research reaffirm the phases of *climate evolution* (change and variability) mainly in the context of climate change, hence the need to implement a national adaptation program to climate change in Senegal.

The populations surveyed base their perception of climate change on experienced climatic events (abundant rainfall, drought, floods, etc.). This perception of the climate by the population is therefore based on the observation of annual specific situations and not on systematic monitoring of climatic factors over a given time interval. They perceive this climate change through the adverse effects on their agricultural work.

The strategies developed vary by sector. This observation is explained by the heterogeneity of socio-economic situations that characterizes the Casamance environment, like any society of men. This heterogeneity is a function of the level of access of populations to capital (social, human, natural, physical, and financial) and of the institutional environment that prevails in the area and, of course, of the individual perception of each person. However, strategies such as crop abandonment, or crop varieties, changing the technical itinerary (changing the agricultural calendar) do not vary from one category to another. These adaptation measures do not specifically require resource mobilization but are in response to the common perception of climate change among respondents. While it is true that most people are engaged in erosion control activities, their capacity alone would be insufficient given the state of degradation of their environment, especially as the trend is upward. So, are the strategies developed effective? Anything that suggests that there is a need for closer government involvement to best achieve the desired results.

5. Conclusion

This article analyzed the trend and the perception of populations on the evolution of temperature and precipitation. The results of the analysis confirm a climatic shift from the 1970s (for precipitation) and the 1990s (for temperature). The effects of climate change, which is a major challenge for present and future generations, are increasing the vulnerability of societies around the world. The temperature is rising at a faster rate in the Casamance Basin than in the world. Similarly, the intensity and magnitude of rainfall have declined on annual and seasonal scales, although in recent years the return of years of excess rainfall has triggered extreme events such as floods. Moreover, the current trend observed was confirmed and justified by the perceptions of the populations surveyed. The floods affect the city and cause significant damage to the lives of the population and their economic activities. The analysis presented here shows that combining scientific facts with people's opinions provides more dependent and relevant investigations of climate change. It also allows for better-planned adaptations. The results of this study may be useful for the implementation of an effective flood management policy and strategy in Casamance.

Government policies should therefore ensure that farmers have easy access to credit to increase their capacity and flexibility to change production strategies in response to expected climatic conditions. Since access to water for irrigation increases farmers' resilience to climate variability, irrigation investment needs should be reconsidered to allow for increased access to water by farmers to counteract and change adverse impacts of climate variability. However, to promote water efficiency, priority should be given to reforms: the clear and precise definition of property rights, as well as to strengthening management capacity and methods for the efficient and sustainable use of water resources. The increasing access of populations to extension services is a great need for the emergence of Africa in the face of global warming. In addition, the government should improve incomes from activities vulnerable to climate change and opportunities to increase earnings.

The importance of this work to the well-being of people or the scientific literature comes down to the fact that it provides results that could be exploited in improvement programs in the agricultural sector for the creation of more varieties. adapted to changing environments. These results must then be exploited to facilitate the adoption of virtuous behaviors, thus reducing the unobservable costs of migration to new behavioral patterns. This means, for example, providing information to agents when they show some desire for a paradigm shift. This endogenous knowledge could be used to support the resilience strategies adopted by rural farmers to cope with these climate changes.

A good part of the questionnaire being done online, several advantages were noted: low cost, speed of data collection, reduction of errors during data entry, greater freedom of the respondent, etc. On the side of the limits, there are the difficulties related to the control of the sampling and those which are inherent to it (representativeness, confidentiality, anonymity, self-selection bias, etc.).

As for recommendations for future research, it is essential to innovate current agricultural practices or to seek new adaptation practices for producers in this region. Endogenous seasonal climate forecasting indicators should be further promoted, as they allow agricultural producers to forecast the course of the rainy season and guide them better in the implementation of their strategies and practices for adaptation to climate change.

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