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Evaluation of the Impact of Seasonal Agroclimatic Information Used for Early Warning and Farmer Communities' Vulnerability Reduction in Southwestern Niger

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Abstract: In Niger (a fully Sahelian country), the use of climate information is one of the early warning strategies (EWSs) for reducing socio-economic vulnerabilities in farmer communities. It helps farmers to better anticipate risks and choose timely alternative options that can allow them to generate more profit. This study assesses the impacts of the use of climate information and services that benefit end-users. Individual surveys and focus groups were conducted with a sample of 368 people in eight communes in Southwestern Niger. The survey was conducted within the framework of the ANADIA project implemented by the National Meteorological Direction (NMD) of Niger. The survey aims to identify different types of climate services received by communities and evaluates the major benefits gained from their use. Mostly, the communities received climate (73.6%) and weather (99%) information on rainfall, temperature, dust, wind, clouds, and air humidity. Few producers in the area (10%) received information on seasonal forecasts of the agrometeorological characteristics of the rainy season. The information is not widely disseminated in the villages during the roving seminars conducted by the NMD. For most people, this information is highly relevant to their needs because of its practical advice for options to be deployed to mitigate disasters for agriculture, livestock, health, water resources, and food security. In those communities, 82% of farmers have (at least once) changed their routine practices as a result of the advice and awareness received according to the climate information. The information received enables farmers (64.4%) to adjust their investments according to the profile of the upcoming rainfall season. The use of climate information and related advice led to an increase of about 64 bunches (equivalent to 10 bags of 100 kg) in annual millet production, representing an income increase of about 73,000 FCFA from an average farmland of 3 ha per farmer. In addition, the use of climate information helps to reduce the risks of floods and droughts, which often cause massive losses to crop production, animal and human life, infrastructure, materials, and goods. It has also enabled communities to effectively manage seeds and animal foods and to plan social events, departures and returns to rural exodus. These analyses confirm that the use of climate information serves as an EWS that contributes to increasing the resilience of local populations in the Sahel.

Keywords: impact evaluation; seasonal agroclimatic information; early warning; vulnerability reduction; farmers communities; Southwestern Niger

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1. Introduction

Some studies have demonstrated the interest of African end-users in agroclimatic seasonal information to better manage their framework in order to improve their crop yields.

They have also shown that sea surface temperatures, such as the Southern Oscillation Index (SOI), correlate well with maize yields in Zimbabwe [1], and that crop models integrated with the seasonal forecasts of some identified agroclimatic parameters such as the cumulative rainfall during the season, the onset dates, the cessation dates, the duration of the season, and the duration of dry spells [2] are able to translate forecasts of climatic anomalies into predicted impacts on production and economic outcomes [3]. However, for [4], seasonal climate forecasts have no intrinsic value because they are derived from decisions to be taken to make improvements and are not direct climate solutions. The impacts derived from the system are relevant to the actions to be taken. It is therefore imperative to translate agroclimatic forecasts into useful information because, for them to be of value, they must be tailored to users' needs to generate objective or economic results. Ex-ante methods are, in most cases, the only way to estimate the benefits of the use of agroclimatic information in agriculture [3], and they are methods to assess the potential benefits of targeted support and interventions. This is a research action described as "climate-smart agriculture" by [5], and the Food and Agriculture Organization of the United Nations (FAO) since 2010. It is a "climate-services-decision" support tool that is part of the implementation of mitigation and adaptation strategies and the "Global Framework for Climate Services" actions. However, few studies highlight the benefits of climate information in West Africa and the Sahel, even though it is crucial for decision-support tool development. In some areas in Niger, using 2004/2007 data collected from the AMMA-CATCH project, it is reported that farmers tend to change their habits (choice of millet variety, sowing date, and fertilization application) according to agroclimatic information [6,7]. In Zimbabwe, using a seasonal climate forecast could increase the harvests by 9.4% [8], while in some areas in Niger an increase of about +6.9% of incomes was observed [6,7]. In Zimbabwe, the length of the wet seasons allows farmers to use long-cycle varieties and fertilizers to improve crop yields. In the same logic [8] indicate that the use of forecasts during wet years can increase harvest to about +18.7%. Therefore, the use of intra-seasonal and seasonal forecasts could be very helpful to farmers depending on the adaptation strategies used [7].

Typically, a tailored climate service is used to develop early warnings, policies, and strategies and to influence commodity prices in the market. For example, in the Sahelian regions that are prone to droughts leading to food insecurity, early warning systems based on agroclimatic monitoring allow the early detection of irregularities that can lead to food scarcity [9]. Therefore, early warning systems for food and nutritional security that anticipate climate variability from days to months in advance could bring a positive impact on the adaptation strategies of populations and can reduce the communities' vulnerability. Thus, agroclimatic information could guide short-term tactical (selection of varieties, sowing dates) and/or longer-term strategic (cropping system) choices to increase agricultural yields [10].

Through the ANADIA initiative (Adaptation to Climate Change, Disaster Prevention, and Agricultural Development for Food Security), the National Meteorological Directorate of Niger has made agroclimatic forecasts available at the community level. This action aims to reduce the negative impact of droughts and floods on agricultural activities, contribute in a sustainable way to food security, fight against poverty, and contribute to rural development and environmental quality. This study aims to assess the benefits that communities have derived from the use of the information provided to them.

2. Material and Methods

2.1. Material

Qualitative and quantitative data were collected in eight (8) municipalities (Ouro-Ouro-Ghéladjo, Gothèye, Namaro, Tounouga, Kiéché, Guéchémé, Tessa, and Falmèye) in Southwestern Niger. Three hundred and sixty-eight (368) producers were interviewed individually in the various communes, and focus group discussions were held with stakeholders in each municipality (local technical services such as agriculture, livestock, and community radio) to collect additional information on the use of climate information at the local level. The tools used to collect and analyze the information are the following:

- An individual survey form, containing questions about identification and socio-economic description, types of agroclimatic services received, benefits gained, and actions taken to reduce the communities' vulnerability. To facilitate the data collection, interview guidelines were designed for each type of interviewer.
- Sphinx Plus 2 software, used for the development of the questionnaire, the compilation of the answers, the processing and analysis of the survey data from the field, and the generation of outputs from the questionnaires.
- QGISv3.10.10, for the spatial mapping.
- Microsoft package (Excel, Word, etc.), for the graphical representation of some results.

2.2. Methods

2.2.1. Study Area

The surveys were conducted in the eight (8) municipalities of Tillabéri and Dosso regions in Southwestern Niger, namely, Tounouga, Namaro, Ouro-Ghéladjo, Kiéché, Gothèye, Guéchémé, Tessa, and Falmèye (Figure 1).

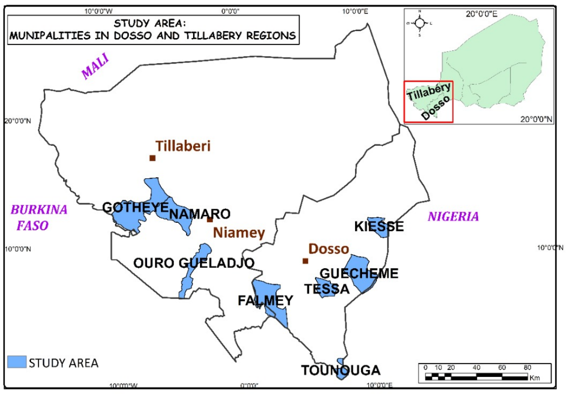

Figure 1. Study areas in Southwestern Niger (Tounouga, Namaro, Ouro-Ghéladjo, Kiéché, Gothèye, Guéchémé, Tessa, and Falmèye).

2.2.2. Optimal Sample Size and Survey Method

The sample was determined using the estimated population size (INS-Niger, 2020). The sampling unit is the household (Table 1). In order to calculate the representative sample of the population, the formula of [11] is used.

$$n_0 = \frac{Z^2 pq}{e^2} \quad (1)$$

where e = 5% is the desired level of precision (i.e., the margin of error), p is the (estimated) proportion of the population that has the attribute in question, and $q = 1 - p$. The value Z = 1.96 is found in the Z (95%) table.

Using the [11] formula, at least 368 householders representing the optimal sample size have to be interviewed (Table 1). To identify the people to be surveyed, the itinerary method, which consists of retaining households by using the main road of a village, was used and only people at least 18 years old were questioned. Similarly, groups of people who met in the chief's place, called "fada", were systematically interviewed. Then, flat sorting and cross-analysis were applied to the survey data to obtain the primary results in order to sketch out the findings.

Table 1. Estimated population and representative sample of the study area.

Estimated Population in 2020	Estimated Population between 18 to 60 Years Old	Proportion of Population (18 to 60 Years)/Total Population (p)	Level of Confidence $Z = 1.96$	Proportion $q = 1 - p$	Error $e = 5\%$	Estimated Households $n_0 = \frac{Z^2 pq}{e^2}$
640,004	254,302	0.40	1.96	0.60	0.05	368

Data Source: Institut National de la Statistique du Niger (web).

3. Results

3.1. Socio-Economic Characteristics of the Populations

Among the people interviewed in different households, 86.9% were men and 13.1% were women. Almost half of these people were married (48.9%), compared to 6.3% who were single, 5.7% who were divorced, 4.6% who were widowed, and 0.5% who did not answer the question. Most of them were heads of their household (83.7%) and were in charge of about eight (8) people. Among this fraction of the population, 46.3% were literate in French and 12.3% in Arabic (readers of the Holy Kur'an). The main activities of the people surveyed were agriculture (67.7%), livestock and agri-livestock (50.6%), and trade (24.2%). Cash income was mainly derived from the sale of agricultural products, accounting for 71.2% of the total income. The sale of livestock products represents 26.5% of the total income, while trade contributes only 14.8%.

The agrarian assets of the communities studied were mainly agricultural land (83%), with some gardens (19%) for off-season crops (Figure 2). The number of agricultural fields owned varied by household, but the average size of each farmer's field was about 3 Ha. Farming is primarily rain-fed, and few people use surface water (small temporary ponds) for irrigation. About 73.4% of producers owned at least 3 types of animals, mainly goats, sheep, and cattle. Generally, most of the interviewed people in these localities had means of communication and access to radio, television, and mobile services, according to more than 70% of the respondents (Figure 2).

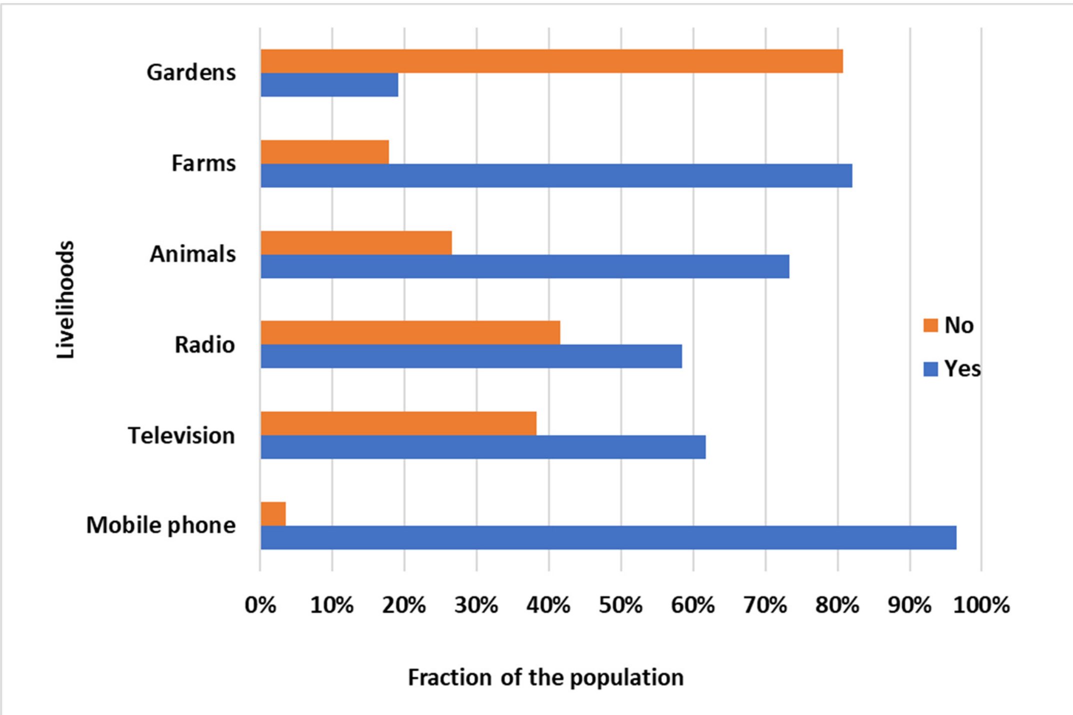

Figure 2. Livelihoods of surveyed communities in the height municipalities under study (Tounouga, Namaro, Ouro-Ghéladjo, Kiéché, Gothèye, Guéchémé, Tessa, and Falmèye).

The roads to access the main cities are mostly lateritic, asphalt, and rural tracks. The distances between the communities surveyed and the main cities are generally less than 10 km (77.7%), with available markets in the same order of radius.

The populations mainly grow cereals such as millet (85.3%), sorghum (31.3%), rice (15.5%), and corn (6.8%). These cereals are generally cultivated in association with vegetables such as cowpeas, peanuts, sesame, Sorrel, etc. In those areas, the farming of tubers and roots (mainly cassava, potatoes, and sweet potatoes) and fruits (mangoes, lemons, oranges, bananas, and guavas), are grown by, respectively, 15.5% and 6.8%) (Table 2).

Table 2. Production rate of speculations by the populations of the surveyed communities.

Speculation	Cereals					Vegetables		Tubers/Roots		Fruits
	Millet	Sorghum	Corn	Rice	Others	cowpeas	Others	Cassava	Others	
Proportion of population (%)	85.3	31.2	6.8	15.5	0.5	82.3	7.9	12.5	4.9	6.8

3.2. Climate Information Services

3.2.1. Types of Information

In the surveyed localities, 73.6% of the population receive climate information (such as year-to-year comparisons or anomalies, long-term trends, climate projections, and seasonal forecasts), while almost all (99%) receive meteorological information (hourly and weekly weather forecasts) (Figure 3a). This figure shows that information disseminated in the form of comparisons (or anomalies) of the situation at a given time of the current year, compared to the situation at the same time of the past year or to the average of a reference period (generally 5, 10, or 30 previous years), is the information most frequently received by the producers (51%). Regarding short-range weather forecasts, as shown in Figure 3b, those for 24 h are more received by producers (77%) than those for 48 h (31%) and for more than 72 h. The information is related to rainfall, temperature, dust, winds, clouds, and humidity. Unfortunately, fewer than 10% of the people received seasonal information on agroclimatic characteristics such as the onset and cessation of the season, dry spells, and runoff.

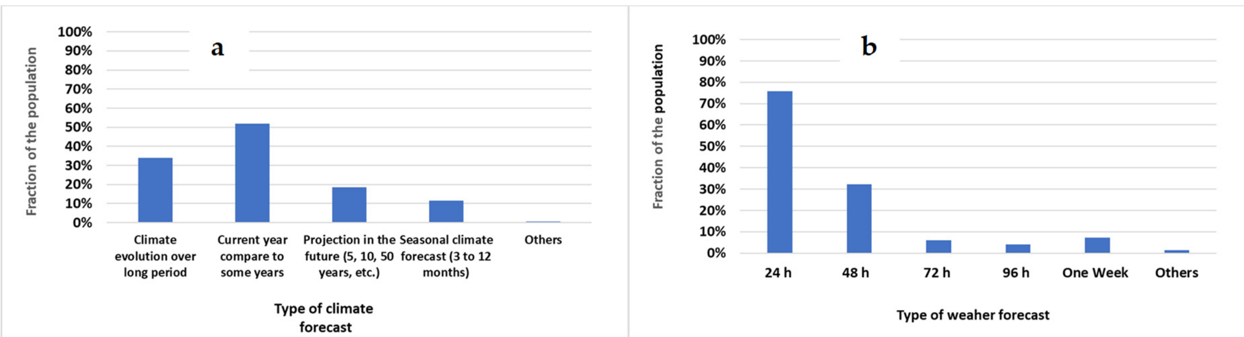

Figure 3. Types of climate (**a**) and weather (**b**) information received by producers in the communities surveyed in Western Niger.

The information is very relevant to the needs of the communities according to 94.3% of the respondents, but only 65.4% confirm that they are followed by useful advice. They are more focused on basic sectors such as agriculture and food security (77%), livestock (58%), health (49%), water resource management (44%), and disaster reduction (43%), according to most of the respondents (Figure 4).

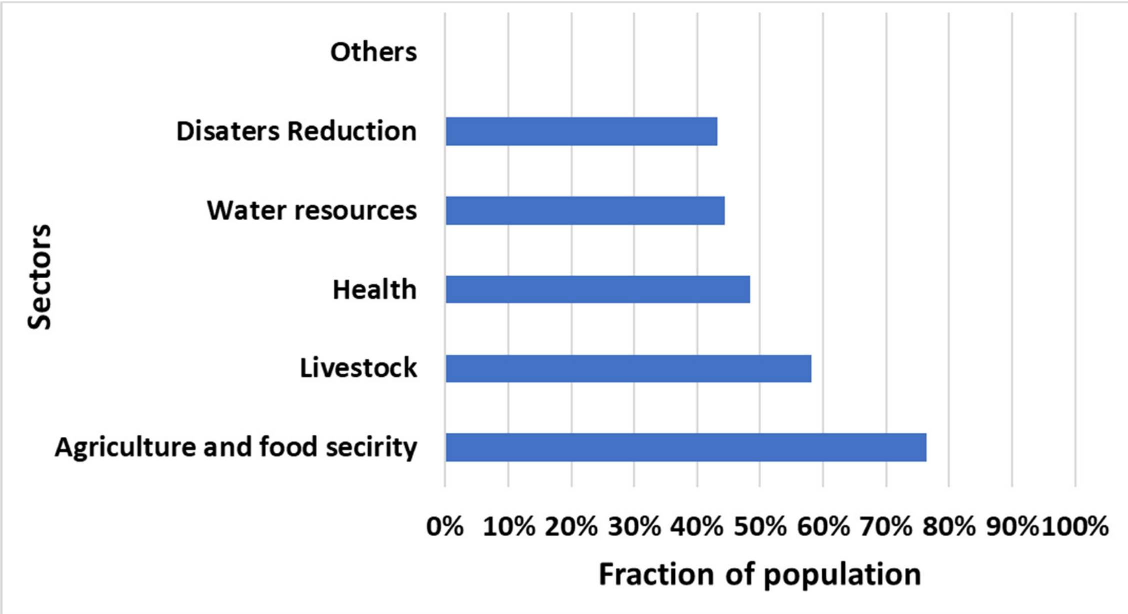

Figure 4. Use of agrohydroclimatic information by local producers according to sectors in the communes surveyed in Western Niger.

3.2.2. Dissemination of Climate Services

Most people have access to climate services through national and local radios (98.4%), televisions (72.8%), and mobile phones (96.5%). The proportion of those who use the internet is lower (51.8%), because of their low educational level and the costs involved. The radio and television available are mainly national media. As shown in Table 3, more than half of the people receive climate information through national radio (51.1%) and television (65.5%). Some people receive information through private and/or community radio (60.1%) and television (0.5%) stations (Table 3). The information is mainly communicated in French (according to 43.2% of respondents) but is also broadcasted in local languages (Hausa, Songhai/Djerma, and Fulfulde) depending on the ethnic configuration of the locality. The information is produced and communicated by the national meteorological department and local technical services (agriculture and livestock). It is mainly received on a daily and weekly basis as audio recordings.

Table 3. Proportions of people receiving agrohydroclimatic information according to the means of dissemination and communication available in the surveyed areas.

Means of Communication	Access (%)		Type (%)		
	Yes	No	National	Private	Community
Radio	98.4	1.6	51.1	17.9	60.1
Television	72.8	27.2	65.5	26.6	0.5
Mobile phone	96.5	3.5			
Internet	51.8	48.2			

3.3. Benefits of Climate Information

3.3.1. Agriculture and Livestock

The majority (82%) of the populations surveyed in the eight municipalities of the study area affirmed that they had changed their habits and practices after the community awareness workshops on the use of climatic information, while 18% continue their business as usual. Changes in agricultural practices are related to sowing dates, the types of seeds to be used, the cropping areas, and cultivation practices. The information received allows to adapt the practices and adjust the investments. For 64.4% of the communities, taking into account climatic information in their agricultural activities led to an increase in average yields of 64 bundles of millet (i.e., 10 bags of 100 kg), estimated at 73,000 FCFA per farmer with about 3 ha of farmland (Figure 5).

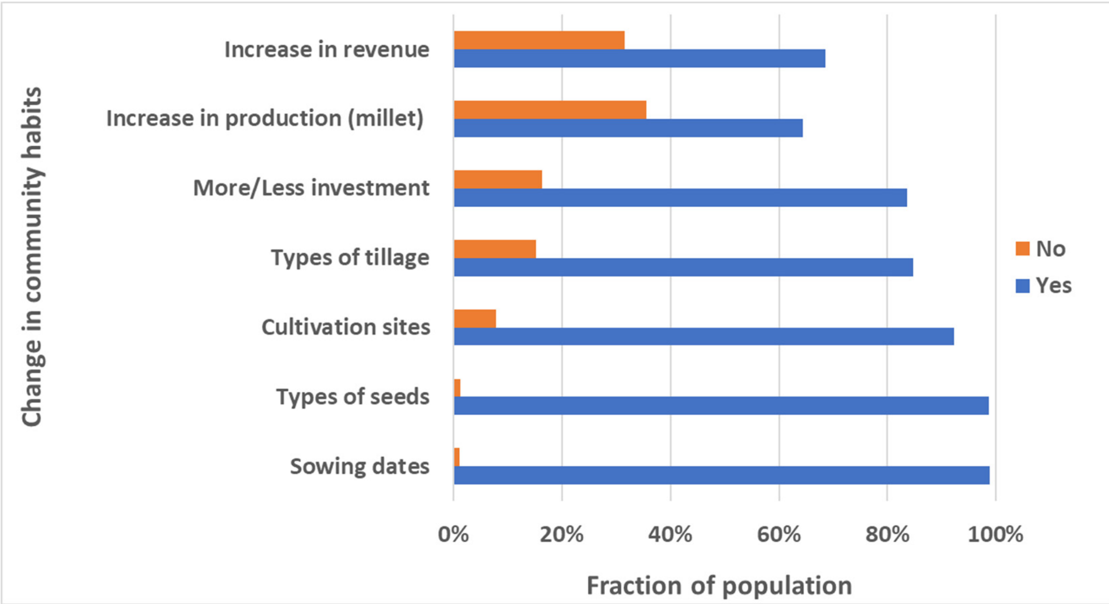

Figure 5. Proportion of people who changed their habits and practices in the surveyed areas.

In terms of livestock practices, about 32% of respondents have revised the departure and return dates for transhumance and have changed their grazing sites according to seasonal agroclimatic information. With respect to the prices of agricultural products and livestock, the release of agroclimatic information leads to market speculation. The information is generally followed by fluctuations in the prices of goods and animals, depending on the projected configuration, according to more than 60% of respondents (Figure 6).

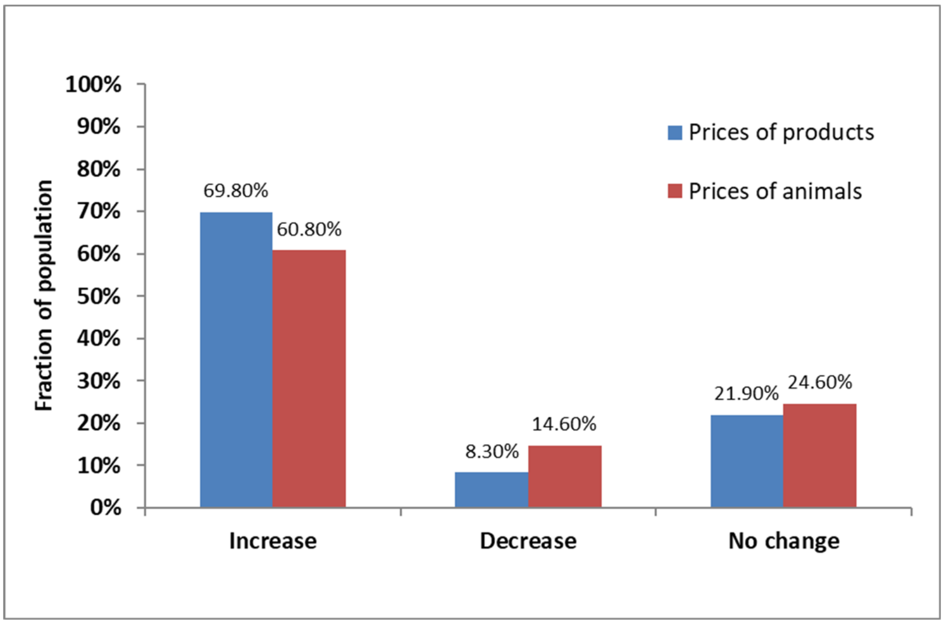

Figure 6. Changing livestock habits and practices in the surveyed areas.

3.3.2. Risk Reduction

The information received empowered the communities and led to a reduction in different forms of disaster, according to the participants in the survey. The risks avoided are mostly floods and droughts, according to 70.8% and 56.1% of respondents, respectively. According to the interviewees, reducing the risk of floods and droughts prevents losses of human (82.1%) and animal (58.1%) lives; prevents the unavailability of crop seeds (75%) and livestock feeding products (81.3%); minimizes the destruction of infrastructure according to 59.1% of respondents; and reduced harvest losses for 67.8% of respondents. According to this information, some social events (weddings, naming ceremonies, etc.) were planned, and decisions on whether/not to go/come back from exodus were made by 87% and 81.9% of respondents, respectively (Figure 7).

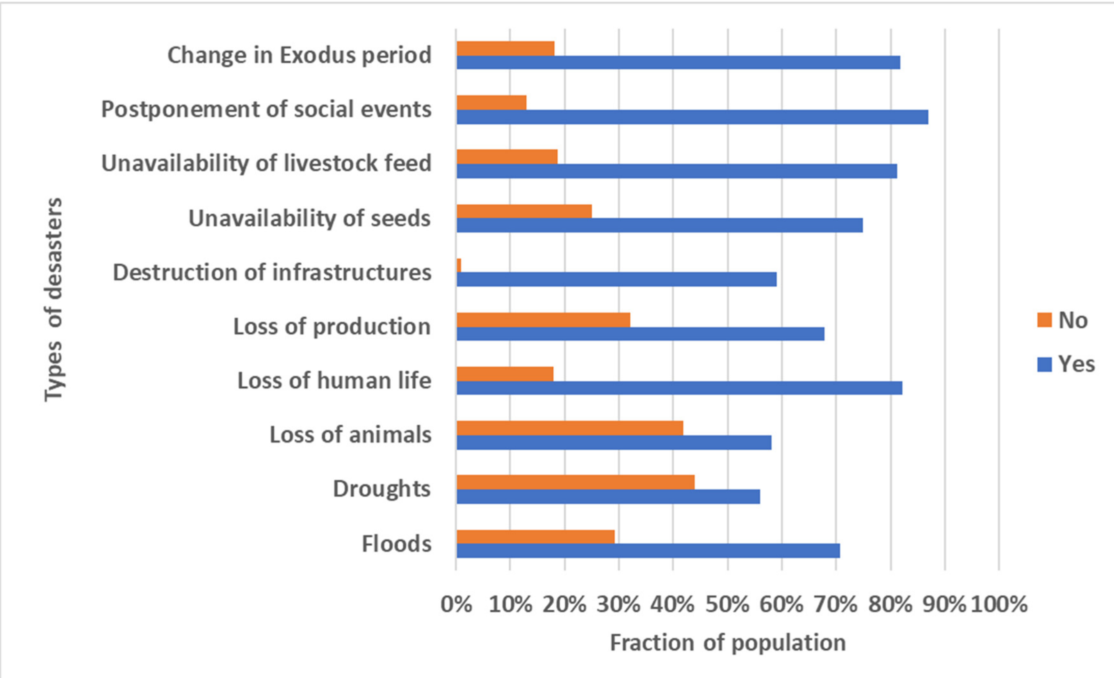

Figure 7. People's perceptions of disaster risk reduction by using agrohydroclimatic early warning information.

3.4. Perception of Seasonal Agroclimatic Characteristics and Coping Strategies

In the surveyed communities, the respondents to the questions mentioned that the agroclimatic indicators of a "good season", usually observed or projected, are equivalent to average rainfall (57%) or sometimes above-average rainfall (42.7%); a long-to-average length of the season (67.2%); a short-to-average length of dry spells (59.9%); early-to-average onset dates (52.2%) or equivalent to average (47.2%); late-to-average cessation dates of the season (72.8%); equivalent-to-higher-than-average intra-seasonal temperatures (58%); and average wind speed (70.8%) (Figure 8).

To maximize the benefits associated with the good climatic conditions of the cropping seasons, the populations of the surveyed zone use some coping strategies. The summary of the most applied strategies is listed in the table below in Table 4.

Inversely, according to communities in the study area, the agroclimatic parameters indicating a bad season are mainly seasonal rainfall deficits (65.7%) or excesses (33.7%), a short length of the season (97.6%), long dry spells (89.8%), late onset (90.4%), early cessation (94.8%), high or very low intra-seasonal temperatures (60.2% and 38.5% respectively), and strong winds (91.9%) (Figure 9).

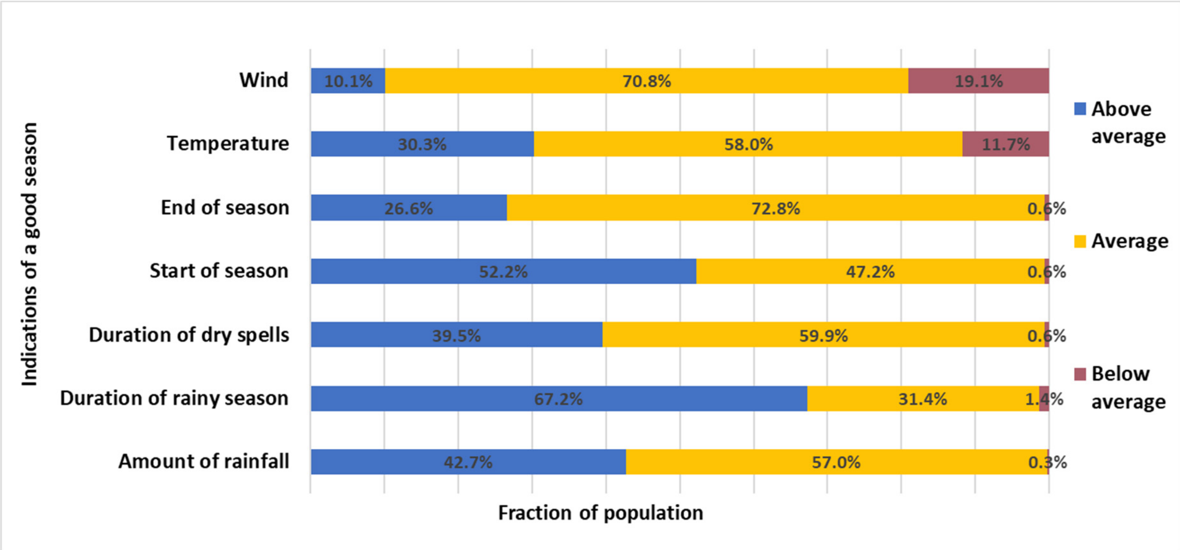

Figure 8. Community indicators of a good season (year): brown is above average, yellow is average, and blue is below average.

Table 4. Strategies to be implemented for good agropastoral season perspectives.

1	2	3	4	5	6	7
Rainfall Amounts	Start of the Season	End of the Season	Length of the Season	Length of Dry Spells	Temperatures	Winds
✓ Identification and preparation of farms ✓ Preparation of seeds ✓ Alternate crops	✓ Use improved/adapted seed varieties, etc. ✓ Prepare and maintain farms	✓ Harvest and store production on time	✓ Use adapted seed varieties	✓ Vegetable production/off-season crops	✓ Protect soil/farms/crops	✓ Protect soils/farms/crops

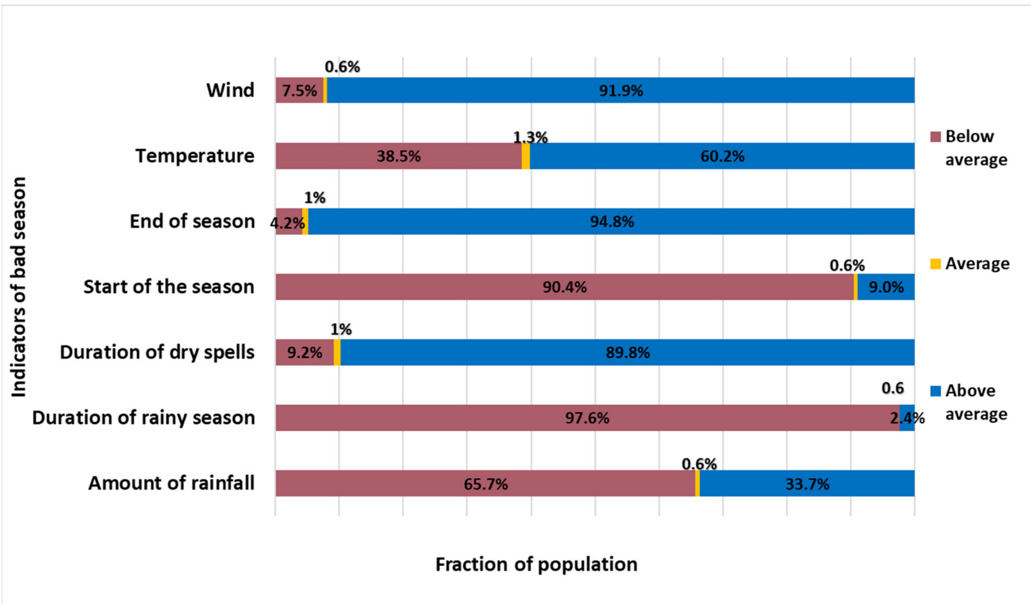

Figure 9. Community indicators of a bad season (year): brown = above average; yellow = average and Blue = Below average.

In the scenario that projects a bad season, based on the indicators described above, people took action in order to turn hazards into opportunities. These are adaptation strategies against climate adversities that are summarized in Table 5 below.

Table 5. Strategies to implement against a bad agropastoral season.

1	2	3	4	5	6	7
Rainfall Amounts	**Starts of the Season**	**End of the Season**	**Length of the Season**	**Length of Dry Spells**	**Temperatures**	**Winds**
✓ Choice of fields/crops	✓ Use improved seed varieties (short cycle/resistant) ✓ Prepare the fields	✓ Use improved seed varieties (short cycle/resistant) ✓ Harvest and store production early	✓ Use improved seed varieties (short cycle/resistant)	✓ Vegetable production/off-season crops	✓ Choice of crops/variety	✓ Market gardening and off-season cultivation

4. Discussion

In the areas visited, people's livelihoods are essentially based on farming, gardening, and animal husbandry. The average sizes of farmlands are around three hectares per person. These activities allow them to ensure part of their food needs and to have financial resources through the trading of their goods (agricultural, livestock). The agrarian inheritance permits them to have the confidence to face climatic hazards, but also to adapt according to situations imposed by the climate conditions. Due to weak agricultural policies and a lack of adequate support for the agricultural sector, agricultural activities are mainly rain-fed, with few uses of surface water (temporary ponds) for gardening during dry seasons. Given the sensitivity of these activities to climatic hazards, farmers have developed various adaptation strategies [12], including the use of seasonal agrohydroclimatic information [2], in order, to advise short-term applications (selection of crop varieties, identifying the best sowing date) and/or longer-term options (for strategic cropping systems) as described by [10] to reduce the unwanted impacts in order to increase agricultural yields and reduce food insecurity in the study area. In this regard, populations engage in crop association and a large proportion cultivates cereals such as millet (85.3%), sorghum (31.3%), rice (15.5%), and maize (6.8%), generally in combination with legumes such as cowpeas. Moreover, to have diverse activities and to be less vulnerable to climate variability, animal breeding is another activity, conducted as «hut-husbandry».

Most people receive climatological and meteorological information. Despite this, seasonal forecasts of the hydro and agroclimatic parameters, such as the onset and cessation of the agricultural season, dry spells, and river flows, were received by less than 10% of the population. This is due to the fact that the dissemination of this information, even if it is crucial for the planning of farming activities, is only done during the roving seminars organized by the National Meteorological Directorate in the study area. In these workshops, only selected individuals participate, but these participants do not disseminate the information received to others. To improve this, it is imperative to review this system by emphasizing national and community radios (popular within the communities). Adding to that, the national meteorological service has to disaggregate seasonal agroclimatic information at a lower administrative subdivision to allow community radio and mobile telephone users to disseminate them using the adapted language(s).

The disseminated information is in line with the needs of the communities and is much more oriented towards the basic socio-economic sectors (according to 43% of respondents), clustered into four priority sectors defined by the Global Framework for Climate Services (Agriculture and Food Security, Health, Water Resources, and Disaster Risk Management). A large proportion (82%) of the people have changed their habits and practices after the Early Warning seasonal agroclimatic information received. In agriculture, the adjustments (80%) regard the sowing dates, the types of seeds to be used, the areas to be cultivated, and the types of farming. This confirms the studies of [6,7] that evaluated the benefits of using agroclimatic information in Niger, where farmers would change their variety of millet, the date of sowing, and the level of fertilization according to the information on the onset and cessation of the rainy season, the amount of rainfall, and its distribution. It also allowed them to adjust their investments in terms of physical and financial efforts to be carried out in order to maximize profits. Therefore, when good agroclimatic conditions are expected, farmers mobilize more people for farm work, look for the best quality seeds, and protect the farmlands and crops against erosion and pests. However, 18% of people did not change their behavior due to a lack of means to implement the provided recommendations. The integration of seasonal agroclimatic information into activities, has for example, led to an increase in production of about 64 bunches (i.e., 10 bags of 100 kg) of millet in farms of about 3 ha, according to 64.4% of respondents, representing an estimated increase in income of 73,000 CFA francs. This confirms [8] and [6], whose results show a benefit of the seasonal forecast on harvests and farmers' incomes, with a positive impact of +18.7% and +6.9%, respectively. In animal rearing, only 32% of the respondents changed the departure and return dates of transhumance and the grazing areas according to the agroclimatic information. This low rate of change in livestock behavior can be explained by the fact that the area under investigation is predominantly agricultural, with farmers combining agriculture with "hut-breading". In addition, climate information leads to markets-speculations, such as increases/decreases in food prices according to bad/good perspectives of the upcoming rainy season. For example, the forecast of bad rainy season conditions is often followed by a drop in animal prices, as many herders try to sell some animals to obtain food. In general, a bad season leads to a drop in prices for the breeder who is obliged to destock his livestock to reduce the risk of loss. In addition, a bad season reduces the quality and especially the quantity of livestock products intended for sale (meat, milk, etc.). However, the forecast of a good season produces the opposite attitude, resulting in lower food prices and higher animal prices. In the same manner, [9] report that in the Sahel (where droughts are frequent), early warning systems based on the monitoring of agroclimatic parameters can perceive irregularities that can lead to future food deficits and monitor market commodities.

The information received helps to reduce different forms of disaster risk in the study areas, such as floods (according to 70.8% of respondents), drought (56.1%), loss of human life (82.1%) and livestock (58.1%), the unavailability of seeds (75) and animal feed (81.3%), damage to infrastructure (59.1%), and the loss of production (67.8%), while regulating the exodus process (81.9%). In addition to these profits at the local level, climate information, especially seasonal agroclimatic forecasts, are used as the input of the early warning system by humanitarian agencies to manage food insecurities. Thus, when a food crisis breaks out and requires external assistance, it takes several months to assist the affected population and can lead to temporary migration [13,14]. In order to reduce the time lag, organizations are interested in forecasts that allow them to anticipate assistance in the risk zones. Despite some difficulties in the use of seasonal agroclimatic information, many benefits can be derived from it. This answers the research question of this study, related to the socio-economic benefits of agroclimatic information for farmer communities, as mentioned by [15].

The present study was conducted based on agroclimatic parameters mostly communicated to farmer communities. The information is mostly on rainfall because it is the most crucial element for crop production in the Sahel. Despite the importance of the heat waves during the growing season and for yields [16], information on the behaviour of temperature has not been regularly given to farmers in the study area. To really analyze the impact of the temperature on crop production in the Sahel region, a future study could be conducted and perception analyses could be undertaken on that matter [16].

5. Conclusions

The use of climate information and services tailored to the needs of end-users is a relatively recent innovation referred to as "climate-smart agriculture" when applied to the agricultural sector. It consists of applying an early warning system that can help communities cope with the negative impacts of droughts and floods. It has potential benefits such as increased income that require impact assessment through field surveys of the socio-economic activities in areas under consideration. Thus, the integration of the seasonal agroclimatic information received in planning led to an increase in production and reduced many forms of disaster risks, including floods and droughts, which lead to the losses of goods (animals, seeds, production, livestock feed) and lives and force the rescheduling of social events and rural exodus. Furthermore, it appears that information on the seasonal forecasts of agroclimatic characteristics reaches only 10% of the population. This helps us to appeal for a review of the mechanism of the dissemination of climate information in this place. This is central to the resilience of communities to climate variability and change.

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