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RESEARCH ARTICLE

EXTREME RAINFALL WINTER OF 2020 AND IMPACTS ON AGRICULTURAL ACTIVITIES IN THE DEPARTMENT OF OUSSOUYE IN LOWER CASAMANCE

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ABSTRACT

The 2020 rainy season was surplus in most of Senegal. In the department of Oussouye, it was described as "extreme" because some stations recorded annual rainfall totals (over 2000 mm) well above the average for these stations. In addition, these stations received intense or even extreme daily rainfall, which had a major impact on the agricultural calendar. The aim of this study is to show how the extreme rainfall of the winter of 2020 affected the cropping calendar in the department of Oussouye. From a statistical point of view, this study analyses the extreme rainfall recorded during the 2020 rainy season, comparing this situation with data from the 1971-2020 period. Next, the maximum daily rainfall for the 2020 winter season was analysed. Finally, the agro-climatic parameters were also analysed. These analyses showed that total annual rainfall increased over the period 1971-2020. The year 2020 was characterised by an increase in the number of rainy days above 50 mm, which was statistically higher than the 1971-2020 average. The duration of the rainy season showed a general trend towards normal over the period 1971-2020. However, the extreme rainfall during the 2020 rainy season flooded rice fields and disrupted the cropping calendar. On the other hand, the results of the 2020 agricultural season were considered high for all crops in the department of Oussouye. Faced with this situation, adaptation strategies have been developed by the state authorities with the support of their partners and farmers. But today, with the resurgence of these extreme climatic phenomena, the strategies developed are ineffective.

INTRODUCTION

In Senegal, agriculture plays an important role in the national economy. According to the World Bank, it will account for 17% of GDP by 2020. The impact of global warming poses serious risks for agriculture, which is highly dependent on rainfall, water resources and the fragile coastline. The agricultural sector is highly vulnerable to climatic hazards and has suffered greatly from rainfall fluctuations, particularly the droughts of the 1970s and 1980s. The unfavourable rainfall trends observed since the 1970s in the Sahel have not spared the Sudanian part of Senegal (Ndong, 1995; Sagna 1995 and 2007). This climatic and ecological crisis has compromised Senegal's economic and social development. The repercussions of rainfall deficits can be seen in the fall in yields and seed quality (Diop et al., 2016). Agricultural production has fallen considerably, making life difficult for the population. However, since the 1990s, normal rainfall conditions have returned to Senegal (Sène and Ozer, 2002; Sarr and Lona 2009; Faye, 2015). Intense and extreme rainfall events are becoming increasingly common in Senegal in general, and in the department of Oussouye in particular, often resulting in flooding of urban centres and agricultural plots.

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The department of Oussouye is part of the coastal South Sudan region, which is characterised by very abundant rainfall. The winter of 2020 was very rainy over most of Senegal. It was even described as "extreme" in some parts of the country, particularly in the south, where localities such as Ziguinchor, Oussouye and Enampore recorded annual rainfall totals in excess of 2,000mm. Cumulative rainfall in 2020 in the department of Oussouye was higher than the 1981-2010 normal. The 2020 rainy season was surplus in the north, north-west and south-west of the country, and normal over the rest of the country, compared with the 1981-2010 normal. In addition, the rainy season got off to a normal to early start over much of the country, and ended late over most of the country. In the department of Oussouye, the 2020 rainy season is marked by episodes of extreme rain, with rainfall spread out from June to October, peaking in August. Intense rainfall is one of the factors influencing agricultural production. Extreme rainfall events in September can flood plants. In this area, the 2020 rainy season lasted until early November. This extension of the rainy season into this month (harvest time for certain crops) could lead to problems with the storage of agricultural production. This can disrupt the harvesting of produce. The aim of this study is to show how the extreme rainfall of the 2020 winter season affected agricultural activities in the department of Oussouye.

Data and methods : For this study we used rainfall data, agronomic data and field survey data. The rainfall data are daily and relate to four (04) stations, namely Oussouye (1971-2020), Loudia Ouolof (1981-2020), Cabrousse (1986-2020) and Diémbéring (2020). Agricultural data are collected by the Service Départemental de développement Rural d'Oussouye and concern agricultural production, crop yields and arable land in the department of Oussouye from 2010 to 2020. Field surveys were carried out using a questionnaire and an interview guide. The aim was to obtain a broad overview of agricultural activities and the impacts of the extreme rains of 2020. Six (06) localities were selected for the surveys. The choice was motivated on the one hand by the importance of the agricultural activity in these localities, in this case rice-growing, and on the other hand by their position on the toposequence. The sample was drawn with a sampling rate of 15%. As a result, 142 households were surveyed. We adopted random sampling in which each person has a chance of being surveyed. Our sampling unit was the household. Figure 1 shows the location and distribution of the localities surveyed in the department.

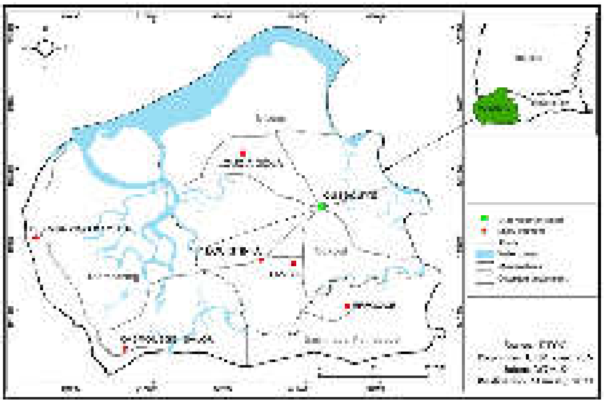

Fig .1. Location and distribution of localities surveyed in the study area

We began by presenting the transition from a drier to a wetter climate, focusing on changes in extreme rainfall. We then highlighted the extreme nature of the 2020 winter. To do this, we analysed the decadal evolution of daily rainfall and that of maximum daily rainfall for the 2020 winter season. Rainfall is considered intense when it is greater than or equal to 50mm, very intense when it reaches 75mm and extreme when it is greater than or equal to 100mm. Thirdly, we determined the duration of the 2020 rainy season. There are several criteria for determining the duration of the rainy season. The criterion used in this study is the agronomic criterion of Sivakumar (1988), which considers the start date to be the date from 1er May when a cumulative rainfall of at least 20 mm over 3 consecutive days is recorded without a dry spell of more than a week in the following 30 days. The end of the rainy season corresponds to the date after 1er September when there is no rain for two consecutive decades, i.e. when the plant's water consumption exhausts the soil's water reserves. The length of the wintering period is the difference between the start date and the end date of the wintering period. We then determined the rainfall breaks (breaks of 1 to 3 days, 4 to 7 days and 8 to 14 days) for the 2020 winter season for each of the stations selected for this study. After the agro-climatological data, we focused on the agricultural impacts of the 2020 rainy season in the zone. We showed the impact of these extreme rains on arable land and crops, and on yields and agricultural production. At the end, we highlighted the measures and strategies implemented in the area to combat drought, as well as community adaptation strategies in the face of extreme rainfall.

RESULTS AND DISCUSSION

Trends in extreme rainfall in Oussouye department: Figure 2 shows the inter-annual trend in the number of days with daily rainfall greater than or equal to 50 mm at the Oussouye, Cabrousse and Loudia Ouolof stations. The analysis shows a slight upward trend in the number of days with daily rainfall ≥ 50mm for all stations. The average number of rainy days ≥ 50mm was 5 days at Oussouye, 6 at Kabrousse and Loudia Ouolof. The maximum is 14 days (2020) for the first two stations and 12 days (1999) for the third station.

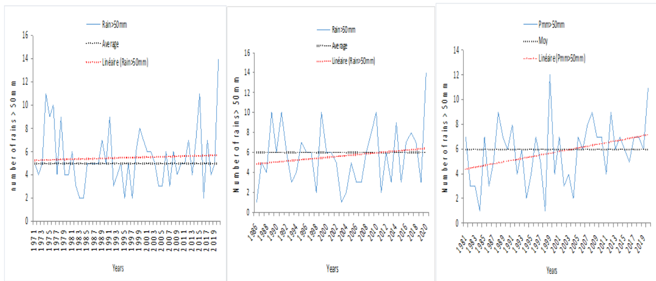

Fig.2. Annual change in the number of days with rainfall ≥ 50mm at the Oussouye, Cabrousse and Loudia Ouolof stations (from left to right)

The observations reveal two phases for each station. A first phase (1971-1997 at Oussouye; 1986-2008 at Cabrousse and 1981-2004 at Loudia Ouolof) in which the annual average of the number of days with daily rainfall ≥ 50mm was mostly below the series average, at 19/23 at Oussouye and Cabrousse and 16/24 at Loudia Ouolof respectively. A second phase (1998-2020 in Oussouye, 2009-2020 in Kabrousse and 2005 to 2020 in Loudia Ouolof) was characterised by an increase in the average annual number of days with daily rainfall ≥ 50mm. ≥ 50mm. The figures are 12/19 in Oussouye, 7/12 in Kabrousse and 10/16 in Loudia Ouolof.

The extreme nature of the 2020 winter season

Decadal trends in precipitation: Analysis of Figure 3 shows that the rainy season did not really get underway in the area until the second dekad of June, with 4 days of rain in Oussouye and Diémbéring and 5 days in Loudia Ouolof and Cabrousse. All the stations recorded 3 days of rain each in the third dekad. In July, the second dekad had the highest number of rainy days in the area, with the exception of Diémbéring.

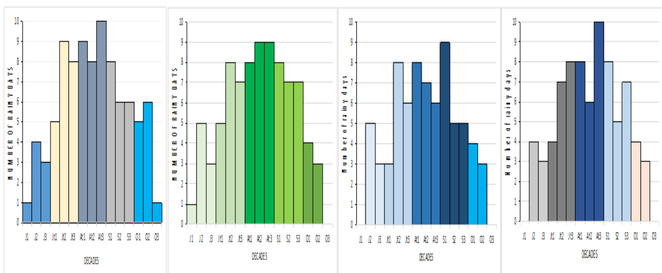

Fig. 3. Decadal change in the number of rainy days in the zone (from left to right: Oussouye, Loudia Ouolof, Kabrousse and Diémbéring) in 2020

In August, all dekads reached 08 days of rain in Oussouye and Loudia, while it rained every day of the third dekad in Oussouye and Diémbéring. In Loudia, the last two dekads had the same number of rainy days, 9 days. In September, the dekads did not exceed 08 days of rain for all stations, except Cabrousse where the first dekad had 10 days of rain. In the last dekad of October, only the Oussouye station recorded one day of rain.

Analysis of maximum daily rainfall: The various stations received very intense and even extreme daily rainfall totals during the winter of 2020. Most of the maximum daily rainfall occurred between July and September, with peaks in August (Figure 4).

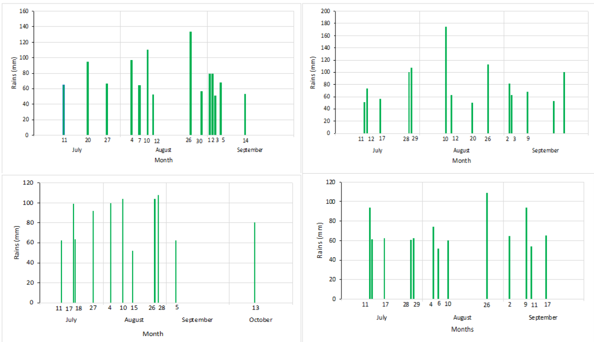

Fig. 4. Maximum daily rainfall ≥ 50 mm at Oussouye station, Cabrousse, Loudia Ouolof and Diémbéring in 2020

The 2020 rainy season was marked by a total of 14 days of intense to extreme rainfall at the Oussouye station (3 in July, 6 days in August and 5 days in September). The maximum daily total was recorded on 26 August with 133.8mm. Seven (07) days of heavy rainfall were recorded prior to 26 August: 11 July (64.5mm), 20 July (94.5mm), 27 July (66.9mm), 4 July (97mm), 7 July (64.4mm), 10 July (110.7mm) (52.8mm) and 30 July (56.6mm). In September, during the first dekad, four (04) consecutive days of heavy rain were recorded, on 1^{er} (79.3mm), 2 (79.7mm) and 3 (50.7mm). In 72 hours, 209.7mm of rain fell, 60% of the ten-day total and 38% of the monthly total. After a one-day break, the 5th saw 68mm. Finally, the 14th saw the last heavy rainfall of the year in Oussouye, with 53.2mm. The situation remains similar throughout the zone, as shown by the results from the other stations. For example, in July, the Cabrousse and Diémbéring stations recorded 124mm and 154.8mm respectively in 48 hours, on the 11th (51mm and 93.6mm) and 12th (73mm and 62.3mm). In the same dekad, between the 17th (with 99.2mm) and 18th (with 63.7mm), the Loudia Ouolof station received cumulative rainfall of 162.9mm, followed by a daily total of 92mm on the 27th of the same month. Whatever the station, the maximum daily total was recorded in August (on the 10th with 174.2mm at Cabrousse, on the 28th with 108mm at Loudia Ouolof and on the 26th with 109.1mm at Diémbéring). Isn't it important to stress the cumulative rainfall on consecutive days? Between 26 and 28 August, the Loudia station accumulated 222.2mm of rain, while between 28 and 29 August, the Cabrousse station recorded 207.6mm.

Rainfall duration and breaks: Knowledge of the agro-climatic parameters (start and end dates of the rainy season) is important for setting up a cropping calendar. The choice of suitable crop varieties and cultivable areas depends on information about the start and end of the rainy season (Camberlin*et al.*, 2003; Traboulsi, 2012). The 2020 rainy season began normally in the department of Oussouye, in the second dekad of June, more precisely on 12 June for all the stations selected. It ended on 14 October for the Kabrousse, Loudia and Diémbéring stations, and on 22 October for the Oussouye station. The duration of the 2020 rainy season is sufficient for crops to complete their vegetative cycle properly. With the first rains recorded, sowing began in some areas in the first half of June, particularly for groundnuts and upland rice. Figure 5 shows the duration of the 2020 rainy season according to farmers. In fact, 63.38% of the farmers questioned thought that the 2020 rainy season was long, while 11.97% thought it was normal. For them, the success of the 2020 agricultural season depended on the length of the rainy season.

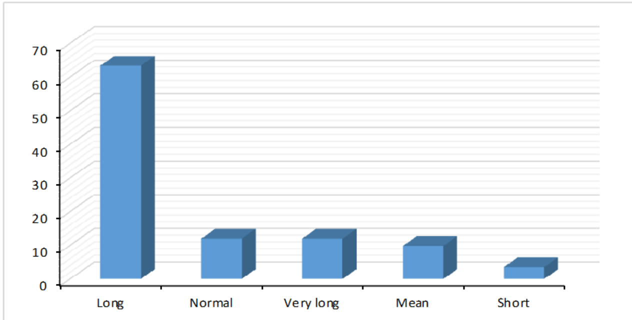

Fig. 5. Population perception of the duration of the 2020 wintering period

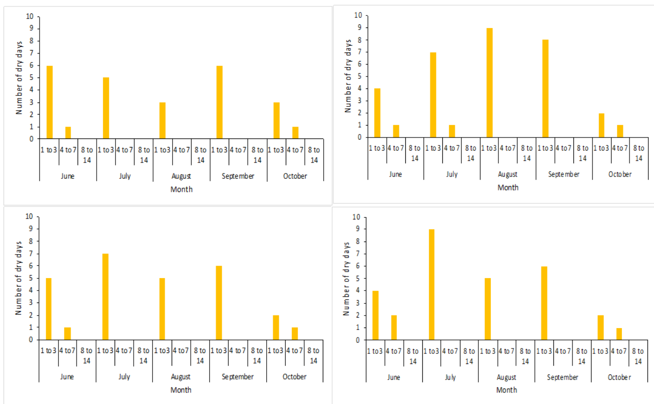

Fig. 6. Monthly change in rainfall breaks in Oussouye department in 2020

The analysis of breaks is crucial for an agro-climatic study in that, depending on their frequency and duration, they can reduce crop yields (Diallo, Faye and Nacro, 2022). Analysis of Figure 6 shows that in 2020, for all the stations included in this study, breaks of 1 to 3 days were the most frequent. They represent 92% at Oussouye, 91% at Cabrousse, 93% at Loudia and 89% at Diémbéring of the total number of breaks per station. This shows the regularity and good temporal distribution of rainfall during this rainy season. Breaks of 4 to 7 days were only noted in June and October for all stations and in July for the Cabrousse station alone, whereas no break of more than 7 days was recorded in the area during the 2020 wintering season. All these results clearly demonstrate the special nature of the 2020 wintering season in this south-western part of the country.

Agricultural impacts of extreme rainfall in the 2020 winter season in the zone

Impact on arable land and crops: In the department of Oussouye, crops are generally grown on individual plots. Farmers rarely cultivate more than one hectare. As a result, cultivated areas are small for crops such as groundnuts, maize and millet. The period 2010-2020 is marked in the department of Oussouye by a general upward trend in the area sown, especially to rice. Rice is the crop with the largest area sown, as it is grown in two different areas: on the plateau and in the valleys. In the 2020 crop year, the area sown was higher than the average (2010-2020) for all crops (Table 1). For rice, the area sown rose to 14,008.8 ha, compared with 9,612 ha (2010-2020 average). For groundnuts, the 2020 figure is 1,418.1 ha compared with 1,342 ha. For maize, the figure is 580 ha in 2020, compared with 113 ha. Over the 2010-2020 period, only 2020 has an above-average arable area. Finally, millet has increased from 455 ha to 698 ha in 2020.

Table 1. Area sown to each crop in the department of Oussouye in 2020 and 2010-2020

Years	Area (Ha)			
	Rice	Corn	Millet	Peanut
Average 2010-2020	9612	113	455	1342
2020	14008.8	580	698	1418.1

Heavy rain has both positive and negative consequences for crops. The extreme rainfall recorded between July-August-September in the department caused rice fields that were already full to overflow their banks. Indeed, 93% of respondents said that flooding of rice fields was caused by the extreme rains (Figure 7). The heavy rains slowed down farming operations in the valleys, and some deep rice fields were impassable and abandoned. With the extreme rainfall recorded in the department, the level of the river rose. The river overflowed its banks and invaded the low (deep) rice fields, i.e. the rice fields close to the river. This phenomenon has been noted in Cabrousse, where rice fields have been abandoned because of the invasion of the river's waters. This causes salinisation of the low-lying rice fields, which is a limiting factor for rice growing.

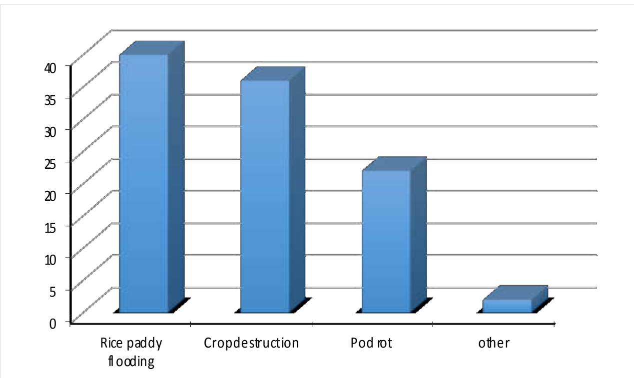

Fig.7. Impact of extreme rainfall on crops

On the plateau, harvesting of the first groundnut and maize seedlings got underway, and upland rice was fully ripening between September and October, while it was still raining. As a result, the rains in September and October caused some of the harvested seeds to germinate. In addition, the heavy rains caused erosion in the plateau areas and silting of the rice fields (Figure 8).

Fig. 8. Rice bunches protected with canvas in Cabrousse (left); Water erosion in Cabrousse (right)

Impact on agricultural yields and production: The 2020 rainy season was very wet in the department of Oussouye, with rainfall in excess of 2,000mm recorded in some localities. Yields followed the same trend as cultivated areas. In fact, there is a general upward trend in agricultural yields from 2010 to 2020 in the department of Oussouye. In 2020, the yields of the various crops selected exceeded their 2010-2020 averages (table 2).

Table 2. Yields for the various crops in 2020 compared with the 2010-2020 average

Speculations	2020 agricultural yield (Kg/ha)	Average 2010-2020 (Kg/ha)
Rice	2950	2194.5
Corn	934.5	701.7
Millet	897	573
Peanut	1005.6	795.3

In 2020, rice had the highest yield over the 2010-2020 period. It reached 2,950 kg/ha, 755.5 kg/ha higher than the average. Groundnut, maize and millet yields have also risen considerably compared with the 2010-2020 average. Rice remains the most widely grown cereal in the department of Oussouye. Its production is estimated at 247,703 tonnes between 2010 and 2020. Groundnuts, maize and millet each produced less than 15,000 tonnes over the same period (Table 3). These crops are marginalised in the department of Oussouye, and the areas allocated to them are relatively small.

Table 3. Production of various crops in 2020 compared with the average for 2010-2020

Speculations	Agricultural production 2020 (Tonnes)	Average 2010-2020 (Tonnes)
Rice	41326.1	22518
Corn	542.0	103
Millet	626.1	279
Peanut	1426.1	1215

Although rainfall is an essential determinant of agricultural production in sub-Saharan Africa (Diop, 2003, 2007; Ndong, 2003, Seck et al., 2005; Adomefa, 2006; Sambou, 2015), cumulative annual rainfall alone does not determine agricultural yields (Faye et al., 2018). In the department of Oussouye, the winter of 2020 had an impact on agricultural production due to the large amount of rainfall associated with its good temporal distribution and the short duration of rainfall breaks. This finding confirms that of Bathièry and Ndiaye (2001), who state that "the characteristic of a poor agricultural season is therefore a rainy season with a deficit, poor spatial and temporal distribution of rainfall and long rainfall breaks". The final production results for the 2020 agricultural season have been judged to be high for all crops in the department of Oussouye. Rice production is estimated at 41,326.1 tonnes, up 18,808.1 tonnes on average.

This is the best agricultural production for the period 2010-2020. Groundnut production in 2020 will be 1,426.1 tonnes. At the same time, maize production is estimated at 542 tonnes, and millet at 626.1 tonnes.

Measures and strategies to combat drought: In Senegal, most of the policies designed to protect agriculture from the effects of climate variability have focused on strengthening the resistance and resilience of agriculture to drought. To this end, major hydro-agricultural development projects and programmes were launched in Lower Casamance in the 1980s with the aim of combating the degradation of farmland, particularly rice-growing land. These included the Guidel and Affiniam dams (Figure 9). In addition, many other facilities such as anti-salt dykes and mini-dams equipped with flood evacuation structures have been built, particularly in the department of Oussouye, by NGOs and development projects with support from state structures such as the Direction Régionale du Développement Rural (DRDR) and the Service Départemental du Développement Rural SDDR.

Fig. 9. The Guidel dam (left) and Affiniam dam (right)

In the department of Oussouye, the projects and programmes involved in hydro-agricultural development, such as the Casamance Development Pole Programme (PPDC), focus on setting up mini-dams and dykes equipped with rainwater drainage structures (Figure 10). These structures perform several functions.

Fig. 10. Dam equipped with gates at Loudia Diola (left); Mini dam at Effoque (right)

On the one hand, they help to combat salinisation of the land by preventing the intrusion of sea water into the rice fields and, on the other, they help to retain water during extreme rainfall. They are fitted with sluices that can be opened or closed at the right moment. The sluices are closed at the start of the rainy season, then opened once the plots are flooded to evacuate the salt. This type of arrangement facilitates land leaching and better control of water levels (Sané, 2017 and Diédhiou *et al*, 2021). One of the consequences of the drought has also been the abandonment of a number of cultivated areas. Programmes have been set up to implement strategies, including the construction of dykes such as the one at Heir in Cabrousse (Figure 11) by the Projet de Valorisation des Eaux pour le Développement des Chaîne de Valeur (PROVAL-CV), which has made it possible to recover several hectares of abandoned rice fields.

Fig.11. Heir dam at Cabrousse under construction

Community adaptation strategies in the face of extreme rainfall: Against this backdrop of climatic variability, farmers in the department of Oussouye have developed strategies to adapt to extreme rainfall events, including the construction of traditional dykes, the implementation of drainage systems and the diversification of rain-fed crops. While these techniques are effective, they are not sustainable, as they require financial and human resources.

Traditional dykes and bunds: In the department of Oussouye, farmers prefer to grow crops on ridges. The construction of dykes is effective in protecting rice fields from saltwater intrusion, and bunds for better water management in the basins. The rice-growing plots are separated by bunds about 60 cm high (Figure 12).

Fig.12. A traditional dyke at Kabrousse

This traditional technique consists of retaining water in the basins for as long as possible, while also slowing the speed of run-off water in the fields during extreme rainfall. Although this technique is effective and appropriate, the construction and maintenance of these structures require a large workforce, which can sometimes be a constraint when it comes to monitoring and renewing them.

Traditional rainwater drainage system: In the department of Oussouye, abundant rainfall is a real problem for farmers. In the winter of 2020, more than 2,000 mm of rain fell in the area, and the rice fields were full from August onwards, beginning to overflow as a result of the extreme rains. Faced with this situation, the farmers adopted a drainage system using bunds fitted with nozzles made from hollowed-out palm trunks placed in the lower areas (Figure 13). These nozzles allow excess water to be evacuated from the basins, where submersion threatens plant development. These drains also facilitate the desalination of the plots and allow better control of the water level in the traps. This structure needs to be monitored and maintained during the rainy season to cope with the threat of destabilisation of the drains, which can be caused by the increased river flow caused by these extreme rainfall events.

Fig.13. Traditional drainage system

CONCLUSION

The winter of 2020 was characterised by very high levels of rainfall in the department of Oussouye. Annual rainfall totals exceeded 2,000 mm. August recorded all the monthly rainfall maxima, as well as the highest daily rainfall peaks of the year at the four stations included in this study. Rainfall breaks were tolerable for crops in terms of their impact, as they were generally of short duration. Analysis of the rainfall during the 2020 rainy season enabled us to understand the behaviour of the crops during the growing season. The study revealed positive impacts on production and yields for the various crops. The final results for the 2020 crop year show an increase in agricultural production and yields compared with the previous crop year and the 2021-2020 average, especially for rice, which is the most widely grown crop in the department. The area sown is also up. On the other hand, the heavy rains of the 2020 winter season also had a negative impact on crops, with flooding of rice fields, the invasion of river water due to excess rainfall, and a slowdown in farming operations. In Lower Casamance in general, and in the department of Oussouye in particular, strategies have always been implemented, either by the state authorities with the support of their partners and farmers, or by the communities themselves, both to combat droughts and to cope with extreme rainfall events. These strategies involve both the construction of modern structures (anti-salt dykes and mini-dams equipped with rainwater evacuation structures) and traditional methods (traditional dykes and bunds, traditional rainwater drainage systems). However, while these community-based adaptation strategies have proved effective, particularly in the face of extreme rainfall, they require both regular monitoring and annual renewal, which in turn requires considerable financial resources and, above all, a large workforce, leading to serious problems with the durability of these structures.

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