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Land Salinization Effects on Farm Household Incomes and Coping Strategies. Case of the Keur Waly Ndiaye Village, Ndiaffate, Kaolack (Senegal)

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***Abstract* – Senegal is experiencing strong land salinization amplified by climate variability over the past decades and by human actions. To deal with this problem, this study was conducted on the evaluation of the land salinization effects on farm household incomes and coping strategies of the Keur Waly Ndiaye village, in the Ndiaffate commune, in Kaolack, one region located in the Groundnut Basin of Senegal. Following the literature review, we conducted quantitative and qualitative surveys of the 25 rural households of this village. Results showed that, before salinization, farm land was very fertile and very productive and crops were very diversified, with cereals such as millet, maize and sorghum, cash crops such as groundnuts and fruits like watermelon. However, salinization has caused the disappearance of cereals such as sorghum and fruits such as watermelon, reduced cereal production and led to a drop in producers agricultural income. Thus, strategies implemented by farmers to fight against this scourge, in particular by renting land in other villages have increased their number to 15% for groundnut producers and 11% for millet producers. Those coping strategies have also increased their production and income. In addition, women producers have converted to salt mining in salinized land in order to generate basic or additional income for their households.**

***Keywords* – salinization, coping strategies, income, rural households, Senegal.**

I. INTRODUCTION

The world has one and a half billion hectares of cultivated land (Legros, 2009) but loses, on average, 10 hectares of cultivable land per minute, including 3 ha, due to salinization (Yadaw, 1983). The latter is a major problem (Faye *et al.*, 2019). Indeed, it is estimated that around 400 million ha of land are affected by salinization (Bot *et al.*, 2000) which threatens, according to the FAO, an equivalent area. Salt lands are mainly located in the arid zones of Africa (Marlet and Job, 2006) where about 38 million ha, or 2% of the continent's surface area, are affected by salt. In Senegal, according to Leborgne (1988), cited by (Thiam *et al.*, 2015), this phenomenon has spread over the years and dates back to the 1920s, following periods of drought. In 2008, the National Institute of Pedology (INP) estimated the area of salt land at nearly one million ha. The Saloum estuary is the area most affected by this phenomenon because more than 50% of its cropland is threatened (Sadio, 1989) and the mangrove is gradually degrading, with 1.75 ha (i.e. 1.3%) disappeared in a decade, between 2001 and 2010 (Dieye *et al.*, 2013). However, the dynamics of salty lands seems to be poorly understood at the local scale, while its impacts can lead to dramatic environmental consequences at the national scale. Attempts to recover salty soils have very often come up against unpredictable problems of excessive salinity due to low rainfall, drought and the phenomena of intense evaporation and precipitation of salts on the surface by capillary

rise (Thiam *et al.* , 2015). In the commune of Ndiaffate, due to climate change, rainy seasons are shorter, dry periods longer and droughts are more frequent. Farmers must, therefore, deal with various stressful situations: falling water tables, flooding, coastal erosion, destruction of mangroves, and disturbance of fish stocks and, above all, salinity of vast areas of agricultural land by sea or rivers water (Sylla, 2015).

In agriculture, salinity can be defined as the amount of salt in the soil (Gorham, 1992) cited by (Fall, 2016). This is a serious problem for agricultural land development. In Saloum, particularly in Keur Waly Ndiaye, a village located 7 km from Ndiaffate, the capital of the commune, the phenomenon has resulted in the hypersalurity of the groundwater table which varies according to the slope of the flows and, above all, the texture of the soil that undergoes capillary infiltration. In Sine-Saloum, as flourishing as it is, the economy remains based on agriculture and fishing. This natural region of Senegal falls entirely within the groundnut basin which is the greater groundnut production area of the country.

This area is well endowed by nature, with a generally flat relief, rarely exceeding 20 m in altitude (Sylla, 2015). The village of Keur Waly Ndiaye has an agricultural economy but fishing is less and less practiced there. On the other hand, the collection of salt is gaining more and more ground and this growing salt production is causing a decrease in land productivity, affecting the waters of the estuary and causing the scarcity of fishery resources. All this affects the income of rural households of this area.

Will the salinization of the land not lead to the disappearance of agriculture, especially for all cash crops in Keur Wally Ndiaye?

Wouldn't it be an obstacle to gaining a decent income for all the producers living in this locality?

All these questions require in-depth research, hence the objective of our work, which is to contribute to the prevention of the living environment of the Keur Waly Ndiaye inhabitants.

Specifically, we will:

- Analyze the effects of land salinization on agricultural production;
- Assess the impact of salinization on household income;
- Identify adaptation’s strategies developed by agricultural producers to deal with this phenomenon.

II. MATERIAL AND METHODS

I.1. *Presentation of the Study Area*

The climate is of the Sudano-Sahelian type and marked by three types of winds:

- The maritime Alize (November-February): with temperatures varying between 12.5 and 14° C, it brings freshness and cold;
- The Harmattan: a very active agent in the erosion of the ecosystem, it is marked by sandstorms and temperatures that sometimes approach 45°C;
- The Monsoon (July-October): it crosses the Rural Community; rain factor, it is of particular interest to populations with high agricultural potential.

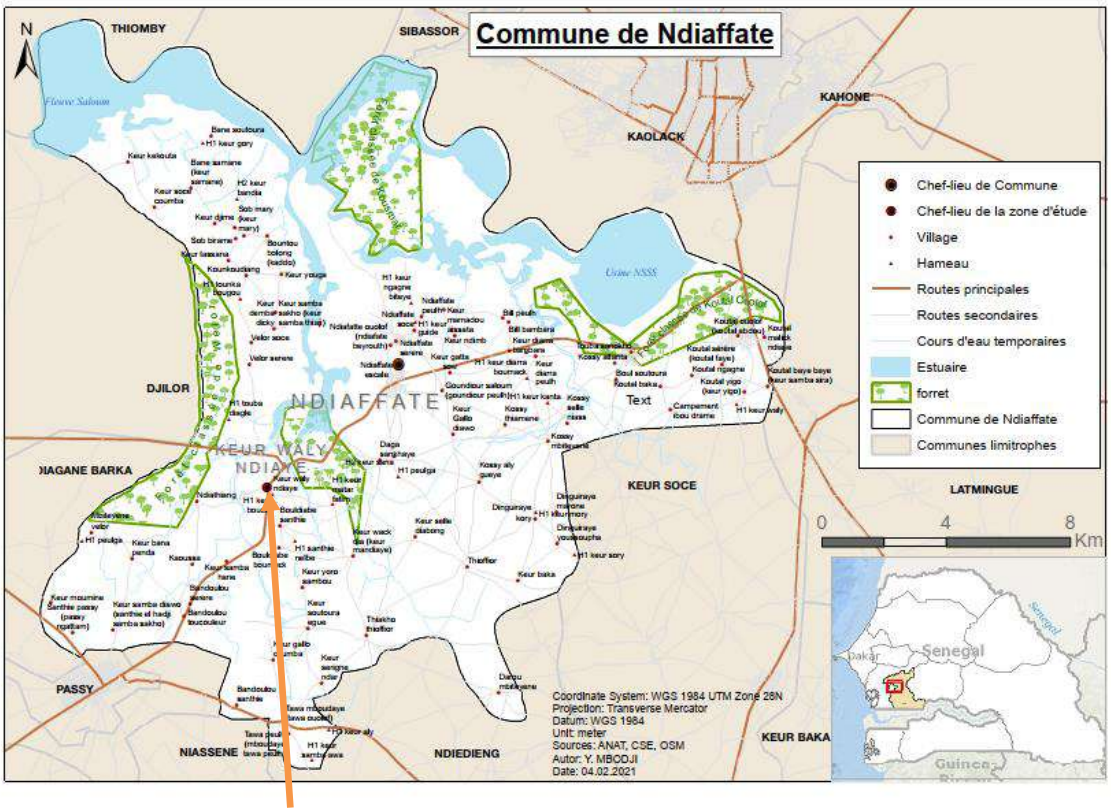
The commune has several natural water points which are among others ponds, backwaters, shallows, as for g-

-roundwater, several water tables cross the CR at variable depths between 10 and 20 m.

Due to the strong presence of salt, the water is most often brackish. Like the rest of the country, there are two seasons: the rainy season which lasts from June to October with heavy rains and the dry season for the rest of the year.

The rainfall for the year 2020 was 886.7 for 51 days of rain compared to the normal rainfall from 1981 to 2010 which was 555.3.

The main economic activities are: agriculture, breeding, arts and crafts and fishing.



Map 1. Location of the village of Keur Waly Ndiaye. Sources: ANAT, CSE, OSM.

I.2. *Material*

The equipment used to carry out the work consists of:

- Twenty-five (25) questionnaires to collect information from producers, with the possibility of comparing the weight of opinions expressed;
- Camera to take illustrative images;
- A motorcycle to move us to carry out the survey; and
- Small office equipment (pencil, eraser).

I.3. *Methods*

In addition to a documentary review which enabled us to collect secondary data, we carried out, following a prospecting visit which enabled us to address the local authorities to present our research to them, to test the

questionnaire and validate, quantitative and qualitative surveys to collect primary data through a questionnaire and interview guide. The survey results were analyzed using Excel software, version 2010.

To analyze the data collected from the 25 producers surveyed, including one per household in Keur Waly Ndiaye, which has 25 concessions, we broke them down by sex, age and marital status. Then, we calculated the income of each producer, before and after the salinization, through the receipts realized on each speculation.

II. RESULTS AND DISCUSSION

II.1. *Results*

II.1.1. *Distribution of Respondents According to Sex*

Figure 1 shows that out of 25 producers surveyed, 17 are men, including (68%) and 8 (32%) women.

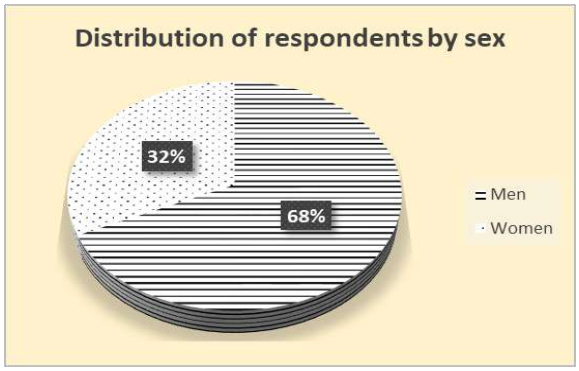


Fig. 1. Distribution of respondents by sex. Source: authors.

II.1.2. *Distribution of Respondents According to Age*

Figure 2 a shows that out of 25 producers surveyed, the 18-24 age group is not represented. However, 2 producers (8%) are 25 to 34 years old; 5 producers (20%) are 35 to 44 years old; 6 producers (24%) are 45 to 54 years old; 8 (32%) are 55 to 64 years old and 4 (16%) are 65 years old or over.

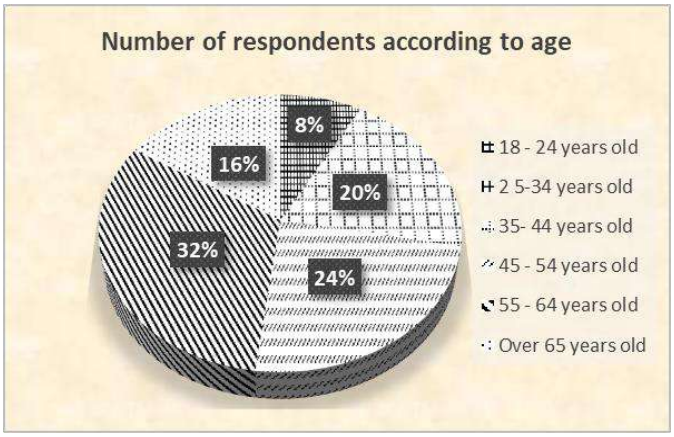


Fig. 2. Distribution of respondents according to age. Source: authors.

II.1.3. *Distribution of Respondents According to Their Marital Status*

Figure 3 shows that, out of 25 producers surveyed, 22 producers (88%) are married and 3 (12%) are single. None of the producers have divorced or been widowed.

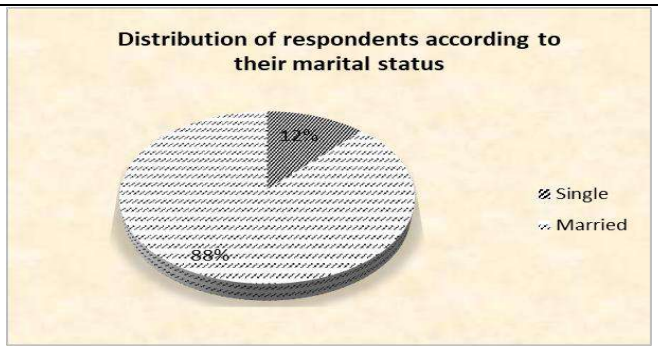


Fig. 3. Distribution of respondents according to their marital status. Source: authors.

II.1.4. *Distribution of Grown Crops before Salinization, According to Producers*

All the 25 producers surveyed produce groundnut, millet, maize, sorghum and some watermelon. Figure 4 shows that 25 producers (100%) cultivate millet and groundnuts, 20 (80%) cultivated sorghum; 15 (60%) produce maize and 2 (8%) cultivate watermelon. Millet has always been the staple food in the rural world and was not sold. It was intended for household consumption but the zakat was nevertheless taken out of it and sometimes the household takes a few kilograms of it for donations.

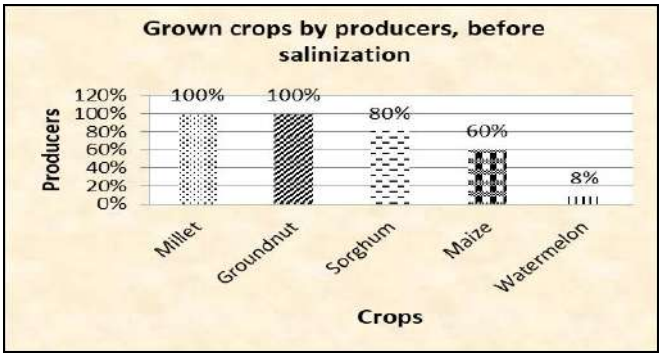


Fig. 4. Distribution of crops grown before salinization according to producers. Source: authors.

II.1.5. *Grown Crops Nowadays by Producers*

Figure 5 shows that nowadays certain speculations such as watermelon is no longer grown in the village of Keur Waly Ndiaye as well as sorghum. 24 producers (96%) grow groundnut, 22 (88%) produce millet and 9 (36%) cultivate maize.

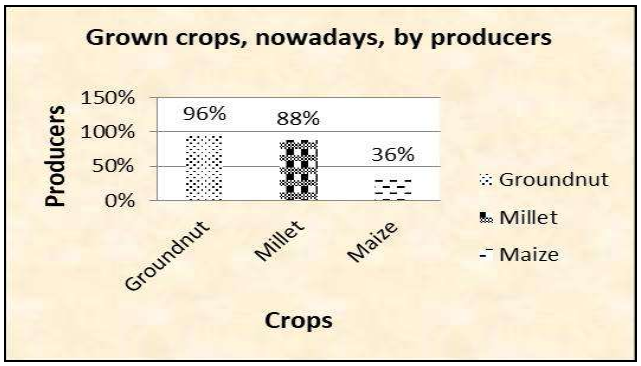


Fig. 5. Distribution of speculations cultivated nowadays by producers. Source: authors.

II.1.6. *Sorghum Production and Income, before Salinization*

Figures 6 and 7 show that, in the past, in Keur Waly NDIAYE, the production of sorghum sold was around 321 kg (figure 6) for an income of 27,285 FCFA (figure 7) and 2,102 kg (figure 6) for an income of 178,670 FCFA (figure 7). The price per kilogram was 85 FCFA.

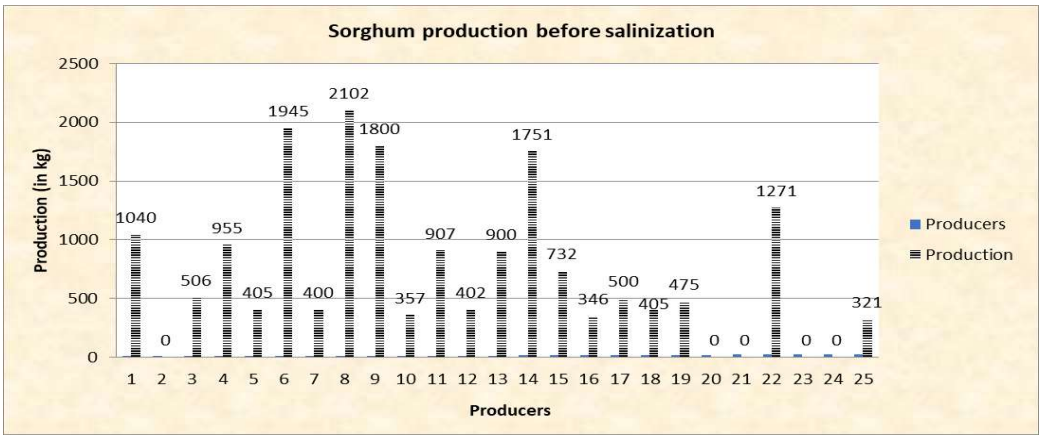


Fig. 6. Sorghum production, before salinization. Source: authors.

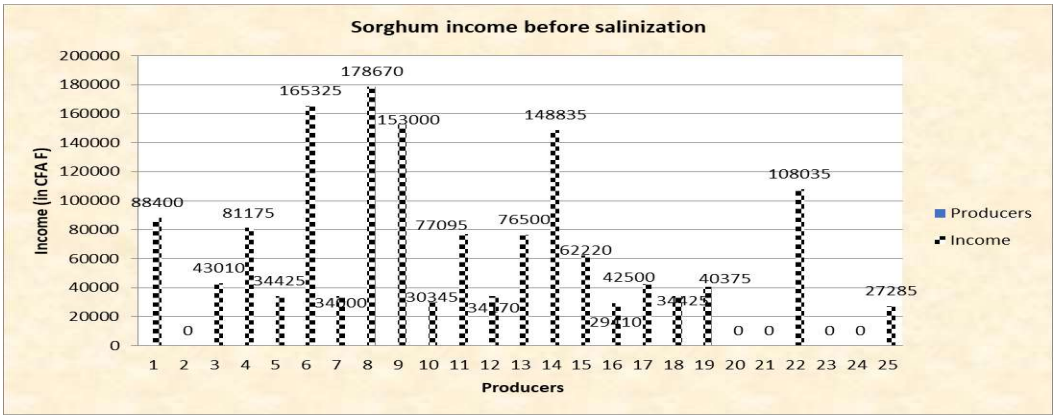


Fig. 7. Sorghum income, before salinization. Source : authors.

II.1.7. *Production and Income from Groundnut, before Salinization*

Figures 8 and 9 show that, previously, the income from groundnut production sold was around 53,475 FCFA (figure 9) for 465 kg (figure 8) and 255,300 FCFA (figure 9) for 2,220 kg (figure 8). The selling price per kilogram was around 110 to 120 FCFA.

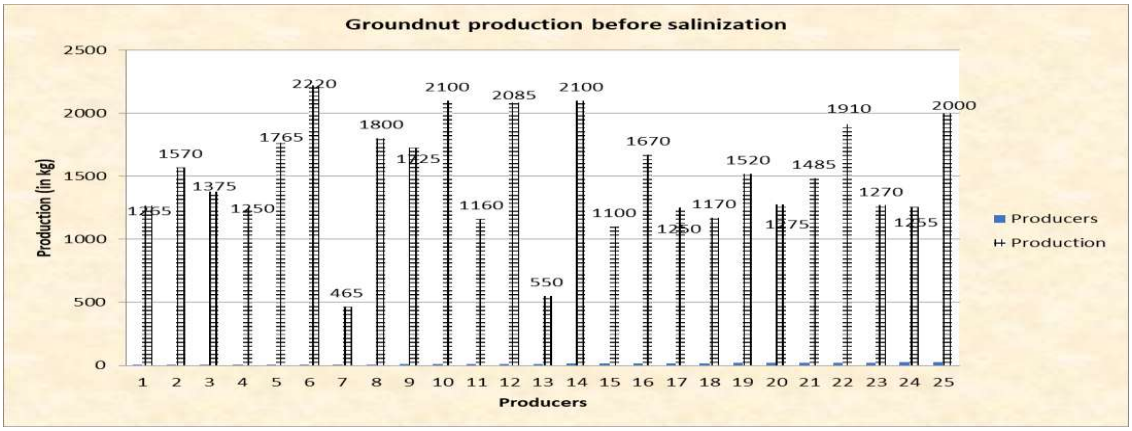


Fig. 8. Groundnut production before salinization. Source: authors.

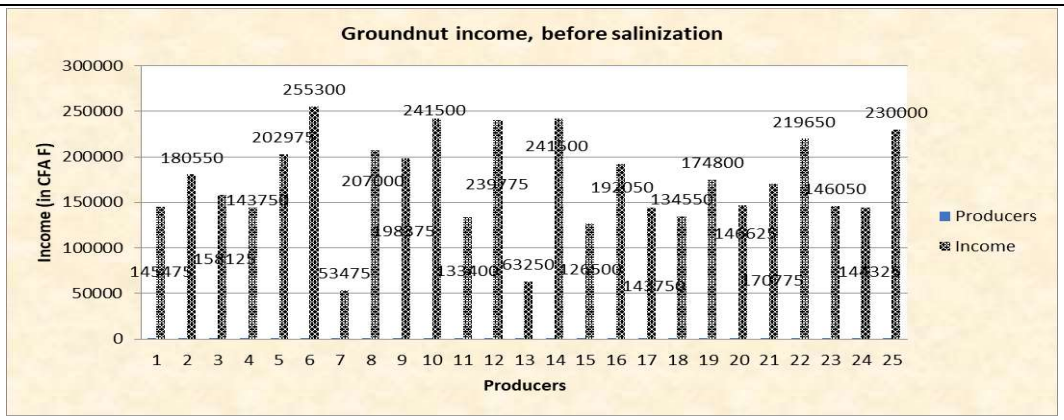


Fig. 9. Groundnut income before salinization. Source: authors.

II.1.8. *Groundnut Production and Income, after Salinization*

Figures 10 and 11 show that, nowadays, for a maximum production of 1,355 kg (figure 10) we have an amount of 424,115 FCFA (figure 11) and 25 Kg for a value of 6,260 FCFA in Keur Waly Ndiaye. The kilogram is sold between 300 and 325 FCFA.

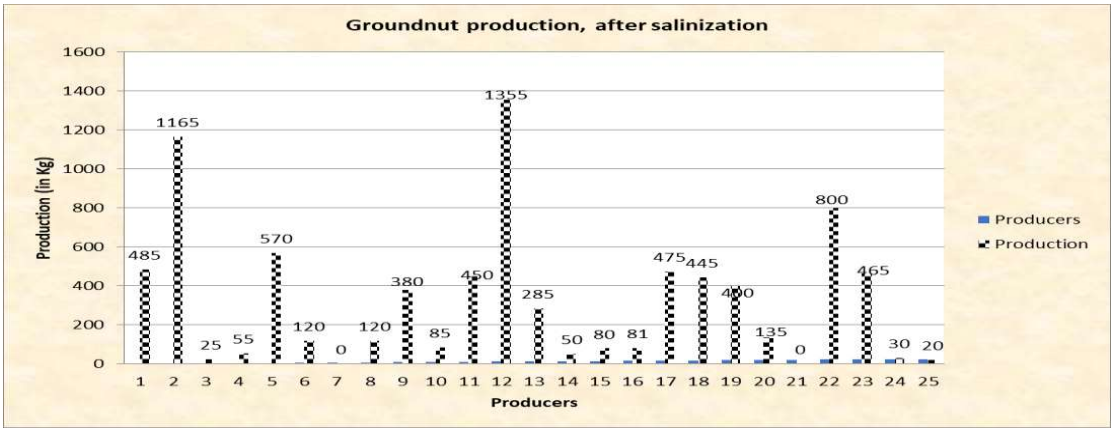


Fig. 10. Groundnut production, after salinization. Source: authors.

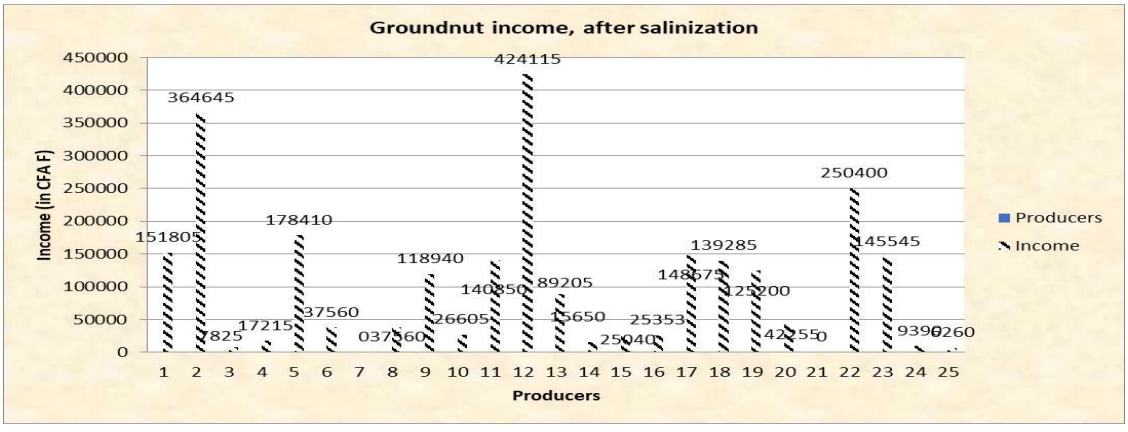


Fig. 11. Groundnut income, after salinization. Source: authors.

II.1.9. *Maize Production and Income, before Salinization*

Figures 12 and 13 show that, in the past, a few producers grew maize in Keur Waly Ndiaye and, among them, the best production sold was 3,830 kg (figure 12), for a value of 574,500 FCFA (figure 13). The lowest product-

-ion sold was 350 kg (figure 12) for 52,500 FCFA (figure 13). The selling price was 150 FCFA.

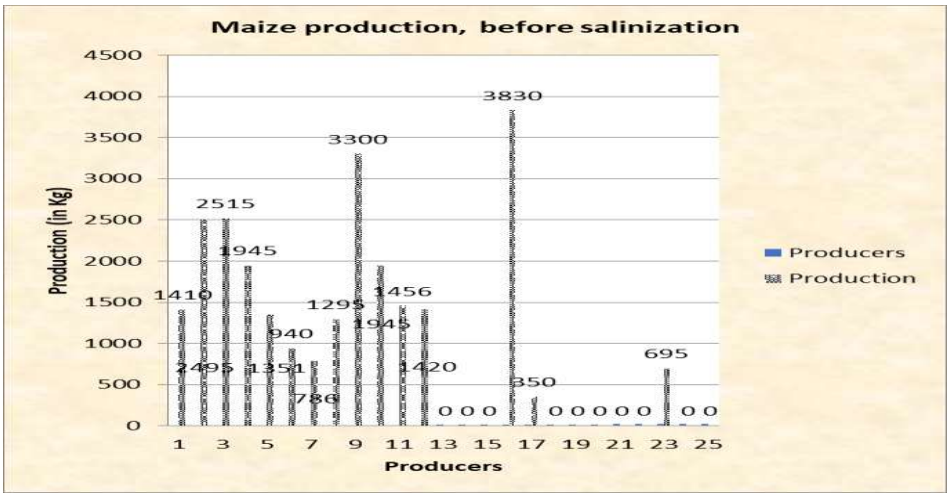


Fig. 12. Maize production, before salinization. Source: authors.

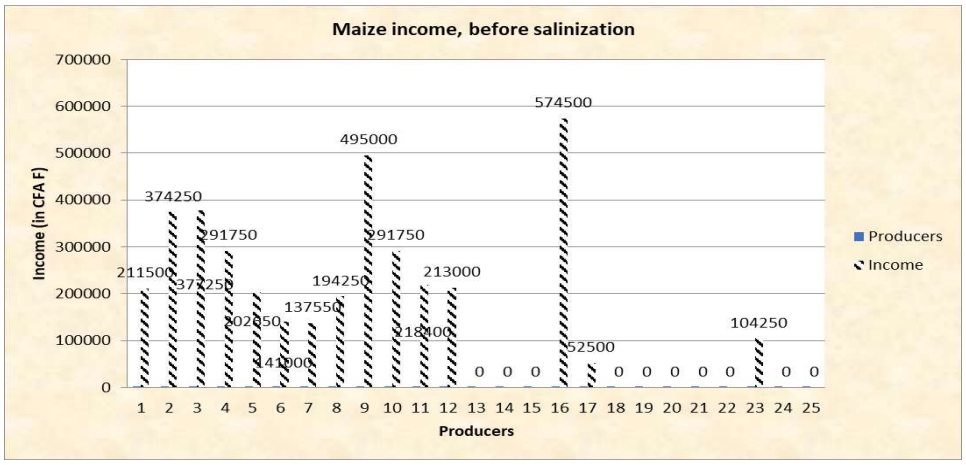


Fig. 13. Income from maize, before salinization. Source: authors.

II.1.10. *Income from Maize Production, after Salinization*

Figures 14 and 15 show that, nowadays, the best production sold is 1,320 kg (figure 14) for a value of 297,000 FCFA (figure 15). The lowest income is 10,125 FCFA (figure 15) for a production of 45 kg (figure 14). The selling price is around 200 - 250 FCFA.

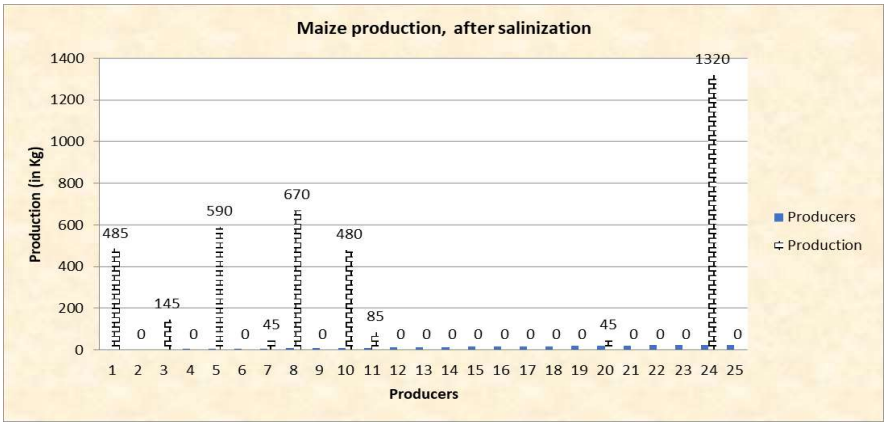


Fig. 14. Maize production, after salinization. Source: authors.

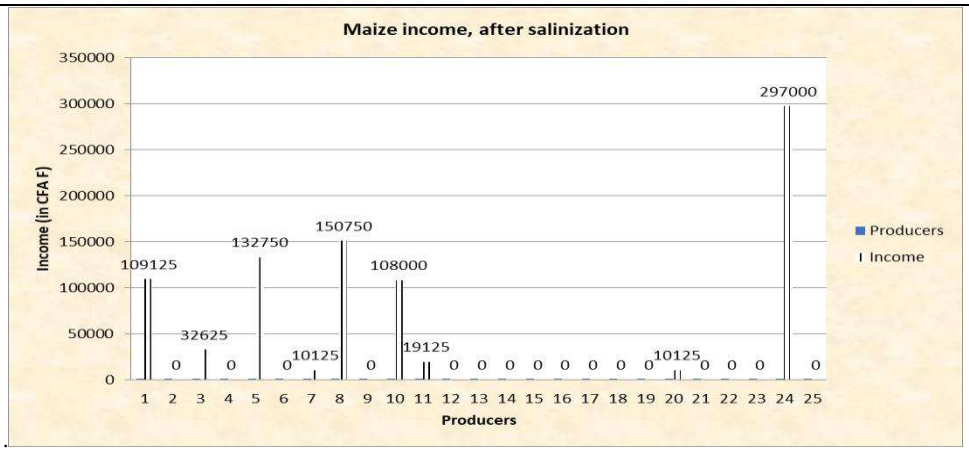


Fig. 15. Maize income, after salinization. Source: authors.

II.1.11. *Presence of Salinity in the Area, According to Producers*

Figure 16 shows the year in which salinity was noticed in the area, according to the 25 producers surveyed. This period is from 25 to 5 years, according to producers. Thus, 8 producers (32%) noticed the presence of salinity since 25 years ago, 7 (28%) noticed the presence of salinity since 10 years ago, 6 (24%) noticed the presence of salinity since 15 years ago, 3 (12%) noticed the presence of salinity since 20 years ago and 1 (4%) noticed the presence of salinity since 5 years ago.

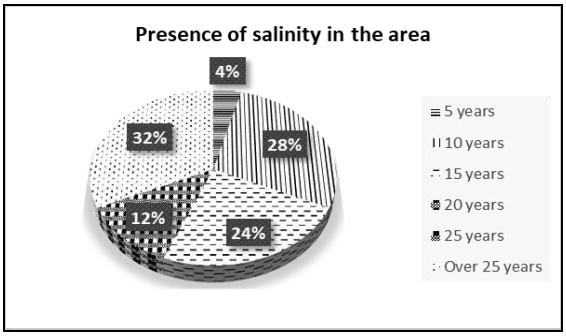


Fig. 16. Number of years of presence of salinity in the area, according to producers. Source: authors.

II.1.12. *Causes of Salinity in the Area, According to Producers*

Figure 17 shows us that 19 producers (76%) affirm that the cause of salinity in the area is due to an anthropogenic origin (exploitation of salt and dam) and 6 (24%) confirm that salinity is due to a natural cause (water table, climate, runoff and sea).

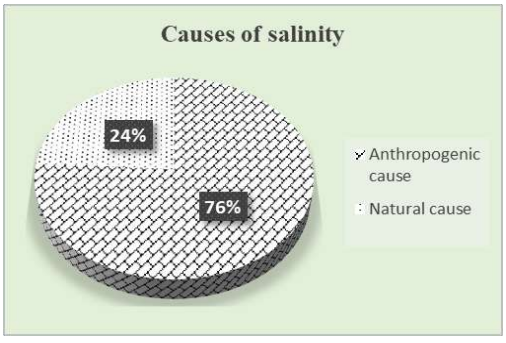


Fig. 17. Causes of salinity in the area, according to producers. Source : authors.

I.1.13. *Adaptation Strategies of Producers*

To fight against salinization, some producers can set up dikes to prevent the progression of salt tongue, while others sow in the nursery or use salinity-tolerant varieties. In Keur Waly Ndiaye, producers mobilized to buy a multipurpose atmospheric nitrogen-fixing forest species, *Prosopis juliflora* or "*Dakhar toubab*" in Wolof, which was provided by the National Center for Forestry Research of the Senegalese Institute of Agricultural Research to try to combat the salinization in this area. The choice of this species is based on its socio-economic importance in rural areas: production of fodder, firewood or charcoal, improvement of soil fertility and production of arabic gum.

Photo 5. A young *Prosopis juliflora* planted in Keur Waly Ndiaye. Source: authors.

Other adaptation strategies developed by the producers of Keur Waly Ndiaye are either crops rotation for two campaigns or more, or in order not to miss the rainy season, they rent other land to cultivate. Apart from all these methods, we have one which is totally practiced by women in Keur Waly Ndiaye: salt farming. Households diversify their activities by developing this activity to supplement income. They provide food salt to travellers, along the roads.

III. DISCUSSION

These surveys carried out in the village of Keur Waly NDIAYE have enabled us to highlight the production and income of producers before and after salinization but also the strategies that are implemented by them to combat this scourge. The best productions were not obtained in Keur Waly NDIAYE but rather in surrounding villages, either in Bouldiabe or Keur Boucar where the cultivated land is rented at 40,000 FCFA/Ha for one campaign. It should be noted that crops produced in this area are not only intended for sale, but also for self-consumption, zakat, gift and livestock food. Within the framework of this work, the priority was given to the sale of production because the objective of our study was to evaluate the effect of salinization on the income of the households in order to be able to make a comparative study of these incomes drawn from the production agriculture before and after salinization.

It emerged that, before salinization began to affect the land at Keur Waly Ndiaye Ndiaye, production was good compared to that obtained since the appearance of this phenomenon, especially for sorghum, groundnut and maize speculation. Market gardening was practiced by almost all the inhabitants but nowadays all the water reserves (wells) are salty, the same for the land. Productions have fallen in a really extreme way as well as arable land. Our comments agree with those of (Faye, 2019) for whom salinization leads to a drop in yield of

0.560 T/ha, i.e. more than half (54.79%). It is also noted a gradual reduction in plant cover and the appearance of whitish layers. According to producers, as long as there are salt mines in the village, the situation will get worser.

According to IRD (2017) to fight against land degradation, some villagers have set up dams, towards which rainwater is channeled. These results do not agree with ours which stipulate that the cause of the salinity according to 76% of the producers in the area is due to an anthropic origin (exploitation of salt, dam, saline etc.).

The origin of land salinity, according to 24% of Keur Waly Ndiaye producers, is due to natural causes. Our results invalidate those of Fall (2016) for whom nearly 80% of salinized soils have a natural origin and are qualified as "primary" salinization, which results from a progressive accumulation of the ions necessary for the formation of soluble salts. The intrusion of marine waters in coastal areas is also another source of ion accumulation. The released salts are transported by groundwater. They are accumulated on the surface of low areas where the rate of evapotranspiration is high. Primary salinization occurs naturally when the soil parent material is rich in soluble salts or in the presence of a shallow saline water table.

On the other hand, 76% of the producers attest that the salinity of the land is due to anthropogenic origins because according to some farmers, either it is linked to the salt exploitations, or to the dam which is in Tawa Mboudaye and is added to it. The rainfall which has become scarce in recent years. Our results do not confirm those of the FAO and IPTRID (2006), for whom nearly 20% of salinized land has an anthropogenic origin and is qualified as "secondary". It is the result of the accumulation of salts brought by human activities. But on the other hand validate those of IPTRID (2006) who say that irrigation with low quality water is the main anthropogenic cause of soil salinization. Affirm those of Ghassemi *et al.* (1995) and Marlet (2005) who attest that the quantities of water added over time lead to a cumulative deposit of salt in the soil and finally join those of Loyer (1991) who stipulate that secondary salinization can also be induced by the use of agricultural inputs and dams.

Households' access to basic foods presupposes that they can produce them or have the income to acquire them at any time. The opposite is noted in this area. In Keur Waly Ndiaye, all households are agricultural and food production is threatened from year to year, hence the impoverishment of agriculture leading to a drop in income. This confirms the words of Fall (2006) for whom agriculture occupies a preponderant place in the economy of Senegal and that more than 95% of households in rural areas are active in this sector which provides them with the first source of income. SDFG family farming needs financial resources for its intensification and modernization, but unfortunately the latter remains in vain. Salinization prevents them from carrying out their livelihood, an absence of income which is added to it paralyzes them more. As far as financial institutions are concerned, access to credit is difficult and very few people benefit from it. Our comments agree with those of Fall (2006) who assert that the mission of traditional commercial banks was not compatible with the objectives of access to credit for poor rural households who did not have the prerequisite guarantees.

The production of legumes, especially groundnut, is declining more than other crops in the area. Our results agree with those of Jouve (2010) for whom the regression of legumes, in particular groundnuts, in favor of cereals (millet, sorghum), has affected the economy of producers and the management of soil fertility.

Salinity presents a real problem, nowadays. Plant growth is declining more and more and it directly affects p-

-roduction, hence the drop in income. Our results are in line with those of Hanana *et al.* (2011) who noticed that the problem of salinity is multiple, because in addition to the toxicity of Na+ and Cl– ions (dissolved in irrigation water or present in the soil solution) and disturbance of mineral nutrition (as a result of interactions between ions), plants find it difficult to absorb water from the soil due to its high osmotic pressure, and this results in water stress, in addition to salt stress, complicating and altering, thus, exponentially, their physiological state. Regarding adaptation strategies for Keur Waly Ndiaye farmers, the means used are either crop rotation or the introduction of *Prosopis juliflora*. Our results confirm those of Hartani *et al.*, (2010) for whom the individual management methods of salinity are either the choice by the tenants of unsalted plots or the rotation of cereals.

IV. Conclusion and Perspectives

This study was carried out in the village of Keur Waly Ndiaye located 7 km from the town of Ndiaffate, in the Kaolack region, in Senegal. It allowed us to analyze the effects of salinization on the land, then see the income of producers before and after this scourge, in order to identify the adaptation strategies developed by producers.

Thus, we cannot conclude without highlighting the maintenance or disappearance of the profession of "peasant" which characterizes the socio-professional reconversion of farmers who abandon cereal and vegetables production because of the combination of drought, aridity constraints and, especially, salinization. The Groundnut Basin has experienced the opposite dynamic since the successive crises. Added to the groundnut crise of the 1990s and the rise of the salinization is the lack of employment and income. Very few producers have other income-generating activities. This pushes them, in Ndiaffate, more particularly in Keur Waly Ndiaye, to turn to the artisanal exploitation of salt, which is a threat that compromises the sustainability of food crops and groundnuts, already weakened by the progression of salinization and which grow peasants, especially young farmers, to try their luck in cities where urbanization and its corollaries, such as a more dynamic labor market, offer many more jobs.

Also, in the absence of an effective desalination policy led by the government, the *tannes* have widened towards the fields. The phenomenon has certainly physical origin, but through deforestation, salt production in particular, the populations have a part in it. In this context, the future of the cropping system based on mixed farming of millet and groundnut is increasingly compromised because the rate of land allocation by salt is very high, according to the producers. Even if millet is the staple food of the populations of this locality, the income from groundnuts and maize is used to supplement their other daily expenses. However, salinization has considerably reduced the size of farms. The lack of intensification and the decline in cultivated areas have conducted to a drop in production which explains the drop in income.

In Keur Waly Ndiaye, the agricultural sector is going through difficulties that aggravate the exodus of rural populations to cities in search of employment. In perspective, this study can be deepened and broadened in such a way as to:

- Carry out the study on all the villages of the municipality,
- Try to make a comparative study with villages that have no salinization problem,
- Measure the impact of this scourge on the scale of the municipality, and

- Carry out a study using satellite data.

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