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FARMERS' PERCEPTIONS OF THE EFFECTS OF SOIL SALINITY ON AGRICULTURAL PRODUCTION IN THE LOWLANDS OF DALLOL FOGHA, NIGER

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Abstract

Soil degradation due to salinity/alkalinity is a major constraint on agricultural production, particularly in the dallols. The general objective of this study is to assess farmers' perceptions of the effects of soil salinity on agricultural production in the lowlands of the Fogha dallol in Niger. The study is based on individual surveys of 216 farmers in 8 villages in the commune of Yélou in the Dosso region. The main results of this study showed that the local indicators of soil salinity for the farmers surveyed were whitish efflorescence on the soil (22.5%), followed by black efflorescence on the soil (18.1%), plant death (14.8%) and sometimes no growth (11.4%). Capillary rise of groundwater (12.4%), naturally saline soils (17%) and naturally saline waters (17.4%) are the main sources of salinisation/alkalinisation of lowlands. The average area affected by salinity varies from 0.77 to 4.12 ha per farmer in Bara and N'Gaski respectively, with a total average of 2.36 ha per farmer. 42.4% of participants responded that salinity was leading to the relinquishment of cultivated plots. According to 71.8% of the surveyed farmers, yield losses for all crops could reach 90 to 100%. Furthermore, the use of manure (10.2%) and hulls and glumes (16%) are the management practices used by the surveyed farmers. However, 59% of farmers abandoned their plots in the event of contamination. Given this situation, it would be important to test species that can tolerate salinity in order to make this environment productive.

Introduction:-

Soil degradation is a complex phenomenon, involving several factors that contribute to the loss of fertility. Among these, salinization has become a major concern for farmers (Diatta et al., 2022). The scarcity of rainfall, high evaporation, irrigation with salt-laden water, the presence of a salty surface water table, poor natural drainage and unsuitable farming practices are all factors that contribute to soil salinization (Zarai, 2022)

Soil salinity is one of the world's greatest challenges in arid and semi-arid regions, severely affecting agricultural production. It affects 20% of total cultivated land and 33% of irrigated agricultural land worldwide (Sougueh, 2021). Around 1 billion hectares of the world's land surface are affected by salinization, representing around 7% of the planet's land surface. Worldwide, economic losses due to this phenomenon are estimated at 27.3 billion US dollars (Sougueh, 2021).

In West Africa, soil degradation through salinization and/or alkalinization is observed in irrigated perimeters on the edges of large valleys (Ado, 2017). It affects almost 40 million hectares, or nearly 2% of the total surface area (FAO., 2006, Dahli., 2019). This figure continues to rise from year to year due to poor farming practices (Karoune et al., 2017).

In Niger, the introduction and development of irrigated systems has enabled the development of arable land in the river valley. Irrigation has helped to increase yields and mitigate the effects of the food crisis. However, this irrigation is often accompanied by soil degradation linked to salinization (Adam, 2011). The latter influences many morphological, physiological and biochemical processes, including seed germination, plant growth and development, and causes a decline in stressed plant growth, productivity, yellowing and death (Kouadria et al., 2020; Alexis et al., 2012 and Chaibou, 2023)

Like other arid and semi-arid countries, Niger is not excepted to the phenomenon of soil salinization, with over 350 hectares of land abandoned due to high soil salinity. In addition, between 400 and 600 ha of land are thought to be affected by salinity (FAO, 2006; Ado et al., 2024). Several studies have been conducted in the Niger River valley to characterize soil salinization or alkalinization processes in terms of their origins and the types of salts involved (Barbiéro, 1995; Guéro, 2000; Marlet et al., 1996) as well as their spatial distribution (Adam, 2011; Michot et al., 2013; Ado, 2017). These studies have reported that salinization and alkalinization phenomena are accelerated above all by irrigation, which not only causes groundwater to rise, but also dissolves salty minerals in the soil. Ado et.al (2024) add that several constraints limit market garden crop production in the Tahoua region, including soil degradation due to salinization. According to growers, soil salinity is becoming increasingly apparent on market garden sites.

The Bosso, Fogha and Maouri dallols, in the process of fossilization, were the main left-bank tributaries of the River Niger. Today, they consist of strings of permanent or semi-permanent pools that receive intermittent runoff from secondary watersheds (Abdou, 2018). These valleys are areas with high potential for agricultural production, particularly horticultural crops, given the availability of water and relatively high soil fertility. However, the Dallol Fogha is characterized by a highly mineralized water table, which consequently limits agricultural production, particularly crops, given the presence of salts (Amadi, 2013).

At present, this salinity/alkalinity continues to spread, affecting the lowlands used by farmers. Salinization leads to the death of fruit trees, food and cash crops, and the abandonment of cultivated plots.

The aim of this study is to assess farmers' perceptions of the effects of soil salinity on agricultural production in the lowlands of the Dallol Fogha in Niger, in order to suggest ways of improving the situation.

I. Materials and methods

1.1 Presentation of the study area

The study was carried out in the Dallol Fogha, one of the three paleo-affluents of the River Niger on its left bank. It is located between geographic coordinates 12°4'60" north latitude and 3°31'33" east longitude (Figure 1). The dallol Fogha is a tributary of the dallol Maouri, which it joins at around latitude 11° 05' N after a north-south course. It extends over a length of 260 km and a width of up to 2 km in the southern part, with an alluvial fill of around 10 m. Altitudes vary between 170 and 200 m (Guero, 2003; Ango and Zangui, 2022).

The climate is Sudanian, with annual rainfall in excess of 800 mm. It is the wettest area in the country (Amadi, 2013). Average monthly temperatures range from 25.9°C to 33.8°C (Guero, 2003).

Generally speaking, there are three types of soil in the dallol zone (Amadi, 2013): (1) soils on the terraces and slopes at the base of the cliffs, (2) soils on the edges of the dallol consisting of sand of alluvial origin with a low content of fertilizing elements and (3) hydromorphic soils in the bottoms of the dallol and around the ponds.

Figure 1 shows the location of the commune of Yélou and the villages surveyed on a section of the Dallol Fogha.

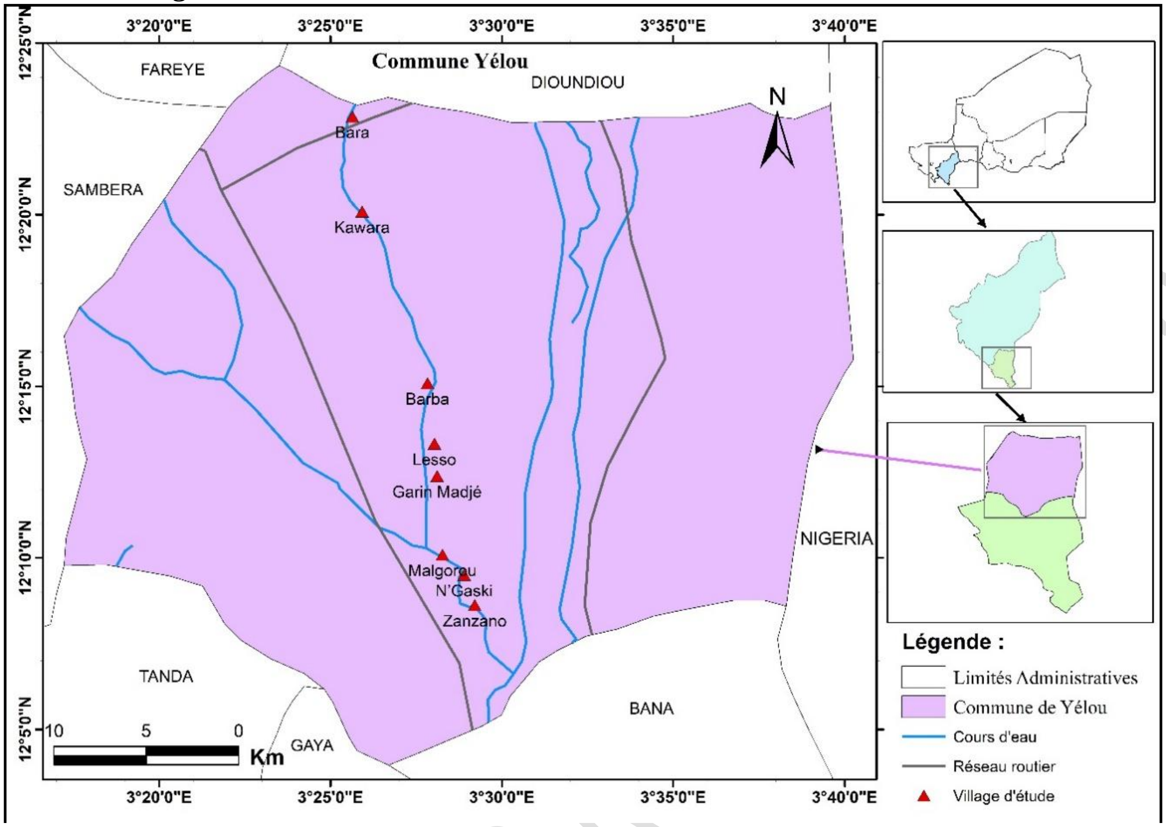


Figure 1: Location of study area and villages surveyed

1.2. Methods

To collect data on salinization in the dallol Fogha lowlands, field observations and individual and collective surveys of farmers in each village were carried out. The following methodology was used.

1.2.1 Choice of villages

The choice of villages began with targeting using Google Earth Pro version 2020, and was confirmed in the field in collaboration with the water and forestry officer from the commune of Yélou (field of study) and producers from the host village (Malgorou). Eight (8) villages were selected from upstream to downstream in the commune of Yélou (Bara; Kawara; Barba; Lesso; Garin Madjé; Malgorou; N'Gaski and Zanzano). The criteria for choosing these villages were based on their location on the bed of the Dallol Fogha valley and the extent of salinization/alkalinization.

1.2.2 Sampling and data collection

A sample of 216 farmers from the eight (8) villages was considered (Table 1). Producers aged 25 and over, selected at random, were considered on the basis of their experience in lowland farming. In each selected village, individual surveys were carried out using a semi-structured questionnaire.

The main points developed in the questionnaires are the identification of farmers, the characteristics of farming systems in the lowlands of Dallol Fogha, the history of soil and water salinity, the identification of surface conditions, crop constraints linked to soil and water salinity, farmers' salinity management practices, etc.

Table 1: Summary of the sample of farmers surveyed by village.

Village	Total population	Number of farmers surveyed	% Sampling	Village coordinates	
				Longitude	Latitude
Bara	625	22	3,52	003°25'598"	12°22'848"
Kawara	3557	31	0,87	003°25'890"	12°20'000"
Barba	710	24	3,38	003°27'834	12°15'093"
Lesso	803	29	3,61	003°28'056"	12°13'194"
Garin Madjé	413	30	7,26	003°27'768"	12°12'173"
Malgorou	4934	30	0,60	003°27'729"	12°10'202"
N'Gaski	189	20	10,58	003°28'901"	12°09'506"
Zanzano	527	30	5,69	003°29'207"	12°08'627"
Total	11750	216	35,51		

1.2.3 Data Analysis procedures

The data collected were entered and processed using Excel 2013 spreadsheet software and the Statistical Package for Social Sciences, IBM SPSS Statistics version 23. They were subjected to descriptive analyses (frequency, percentage and mean calculations) to determine producer characteristics. Analyses of variance (1-factor ANOVA) were also performed to determine the significance of variables between the villages surveyed.

2. Results

2.1 Socio-economic characteristics of surveyed farmers

The results presenting the socio-economic characteristics of the respondents (Table 2) show that the farmers surveyed are dominated by men (86.6%) versus 13.9% of women, over 50% of whom are polygamous spouses. 30.6% are young people aged between 25 and 30, while the oldest occupy 21.1%. Koranic school is the most common level of education (56.3%) among the operators surveyed, followed by primary school (15.1%). The average number of people cared for and the average number of farm workers are 10.12 and 3.63 respectively.

The surveyed farmers, most of whom were Hausa (95.4%), practiced agriculture as their main economic activity (85.6%), followed by trade (4.6%).

Table 2: Socio-economic characteristics of surveyed farmers.

Sections	Terms and conditions	Respondents	% of responses
Gender	Male	186	86,1
	Female	30	13,9

	Total	216	100
Ag	[25 ; 30 [years	66	30,6
	[31 ; 45 [years	62	28,7
	[46 ; 60 [years	42	19,4
	[60 years old ; more [	46	21,3
	Total	216	100
Education level	Primary school	37	15,1
	Secondary school	21	8,6
	Koranic school	138	56,3
	Literacy	19	7,8
	No	30	12,2
	Total	216	100
Marital status	Married Monogamous	95	44,0
	Married Polygamous	110	50,9
	Widowed	11	5,1
	Total	216	100
Ethnic groups	Haoussa	206	95,4
	Zarma	2	0,9
	Fulani	5	2,3
	Kanuri	3	1,4
	Total	216	100
Main activities	Agriculture	185	85,6
	Breeding	5	2,3
	Trade	10	4,6
	Transporter/Driver	2	0,9
	Hunting/fishing	1	0,5
	Salt extraction	9	4,2
	Other	4	1,9
	Total	216	100
Number of people cared for	**Minimum**	**Maximum**	**Average**
	0	32	10,12±5,603
Number of active farmers	0	12	3,63±2,55

2.2 Land ownership characteristics of surveyed farmers

2.2.1 Surveyed farmers' land acquisition methods

The different modes of access to land for farmers surveyed in the Dallol Fogha valley can be summarized as inheritance, pledge, loan, gift, lease and purchase (Fig. 2). This figure shows that inheritance is the most dominant mode of acquisition, with 56.6% of respondents accessing land through inheritance, compared with 20.4, 11.8 and 6.9% through purchase, loan and lease respectively. On the other hand, pledge and gift are the least common modes of acquisition in the area, with 2.3% and 0.6% respectively.

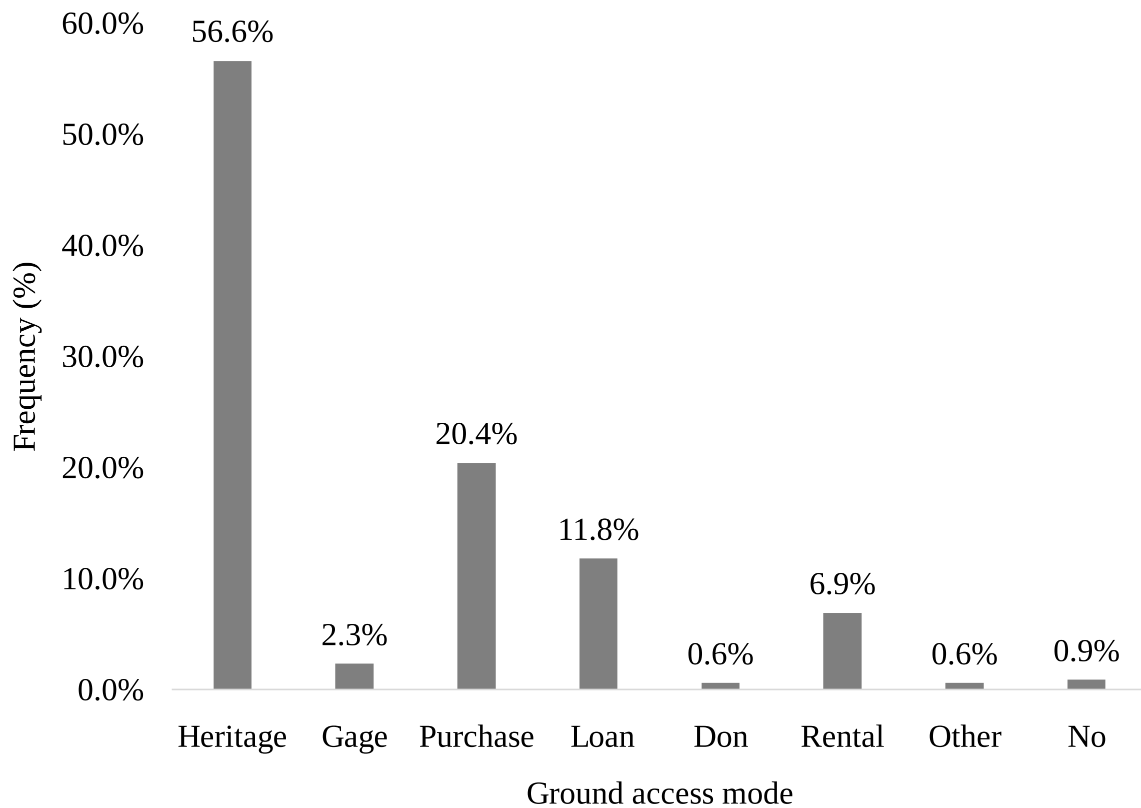


Figure 2: Land acquisition methods used by farmers surveyed in Dallol Fogha

2.2.2 Surface areas of dune soils and lowlands of surveyed village farmers

Farmers surveyed in the Dallol Fogha valley grow both rainfed and irrigated/deciduous crops (Table 3). Analysis of this table shows that the average rainfed area of farmers surveyed varies from 4.20 to 13.65 ha in Barba and N'Gaski respectively, with a total average of 7.53 ha. For irrigated/decreased crops, the average area varies from 0.60 to 3.43 ha in Bara and N'Gaski respectively, with a total average of 2.10 ha (Table 3).

Table 3: Areas of dune and lowland soils of farmers.

Villages	**Rainfed crops**		**Irrigated/unirrigated crops**	
	Total area (ha)	**Average area (ha)**	**Total area (ha)**	**Average area (ha)**
Bara	103,5	4,70±3,77	13,25	0,60±1,29
Kawar	252,5	8,15±10,77	1,25	1,09±33,75

Barba	100,75	4,20±3,07	69,5	2,90±3,32
Lesso	265,75	9,16±10,60	78,3	2,70±4,92
Garin Madjé	212,95	7,10±5,78	72,75	2,43±3,43
Malgorou	182,5	6,08±5,35	48,5	1,62±1,64
N'Gaski	273	13,65±16,95	68,5	3,43±3,55
Zanzano	235,5	7,85±4,95	69,5	2,32±1,71
Total	**1626,45**	**7.53± 8.75**	**454,05**	**2.10± 2.98**
P-value	0,012		0,014	
Significant	Yes		yes	

Area of dune fields : p-value = 0.012 < 0.05 : significant
Lowland area: p-value = 0.014 < 0.05: significant

2.2.3 Cropping systems

The surveyed farmers in the various villages of the Dallol Fogha zone practise several cropping systems (Figure 3), apart from salt extraction (salt production). Analysis of this figure shows that the most common cropping system is rainfed (58.3%), followed by fruit trees (19.1%). On the other hand, recession/irrigation cropping is the least practiced (6.4%) in the zone. This small proportion is explained by the occupation of lowlands by ponded water.

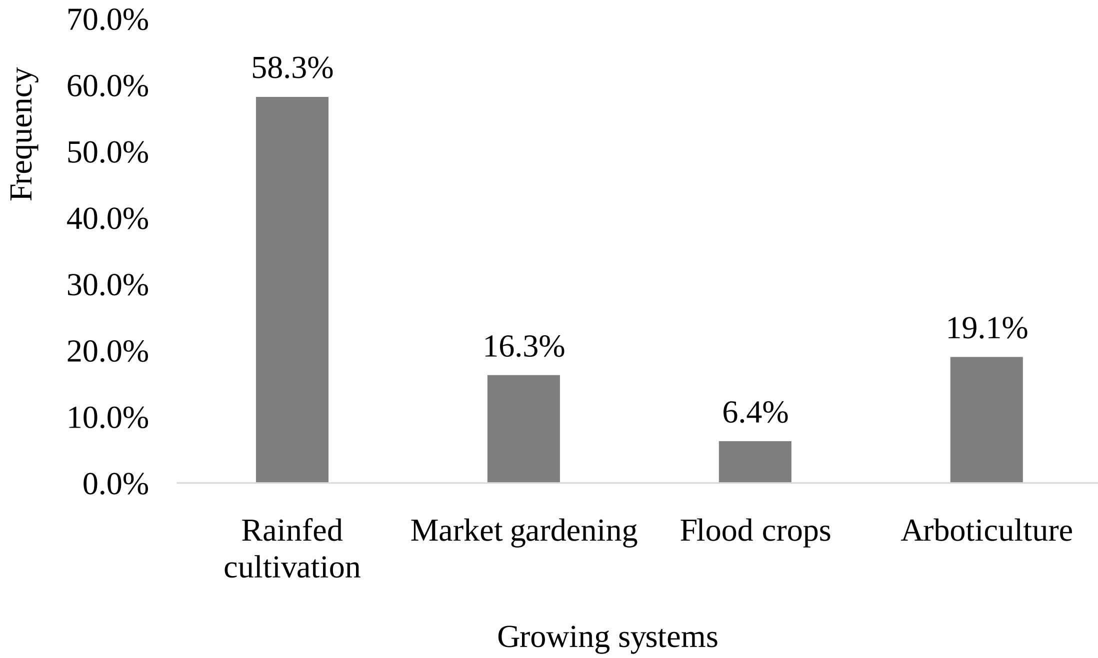


Figure 3: Main cropping systems in the Dallol Fogha valley

The main crops grown by the farmers surveyed according to cropping system are shown in table 4.

Table 4: Main crops grown in the lowlands during the rainy season

Rainfed crops	Irrigated/unirrigated crops	Arboriculture

Millet; Sorghum; Peanut; Cowpea; Squash; Fonio; Manioc; Sweet potato Sesame; Sorrel; Okra; Watermelon; Corn; Soya; Voandzou; Moringa; Green pepper	Sweet potato; Sugar cane; Rice; Melon; Squash; Sorrel; Okra; Tomato; Moringa; Maize; Lettuce; Cabbage; Onion; Rice; Watermelon; Cassava; Watermelon; Sweet potato; Cowpea; Rice; Lettuce; Cabbage; Maize; Pepper	Mango; Mahogany; Guava; Papaya; Banana

2.3 Farmers' perceptions of soil salinity in the lowlands of Dallol Fogha

2.3.1 Surveyed farmers' knowledge of salinity

Table 5 gives the percentages of responses concerning knowledge of soil and water salinity in the Dallol Fogha valley by the farmers surveyed. The table shows that 97.2% of farmers surveyed claimed to know about soil and water salinization, compared with 2.8% who did not.

Table 5 Distribution of respondents' knowledge of soil and water salinity.

		Knowledge of salinization/alkalinization		
		Yes	No	Total
Villages	Bara	21	1	22
	Kawara	30	1	31
	Barba	23	1	24
	Lesso	27	2	29
	Garin Madjé	30	0	30
	Malgorou	29	1	30
	N'Gaski	20	0	20
	Zanzano	30	0	30
Total		210	6	216
Percentage		97,2%	2,8%	100%

2.3.2 Indicators of salinity appreciation by surveyed farmers

The local indicators used by the farmers surveyed to assess soil salinity are numerous. Figure 4 shows the frequency with which the different indicators were cited and their meaning by the farmers surveyed. Analysis of this figure shows that whitish efflorescence on soils is the most frequent (22.5%) in the zone, followed by blackish efflorescence on soils (18.1%), plant death (14.8%) and sometimes nothing grows (11.4%). Figure 5 illustrates some photographs of the effects of salinity on soils and crops in the study area.

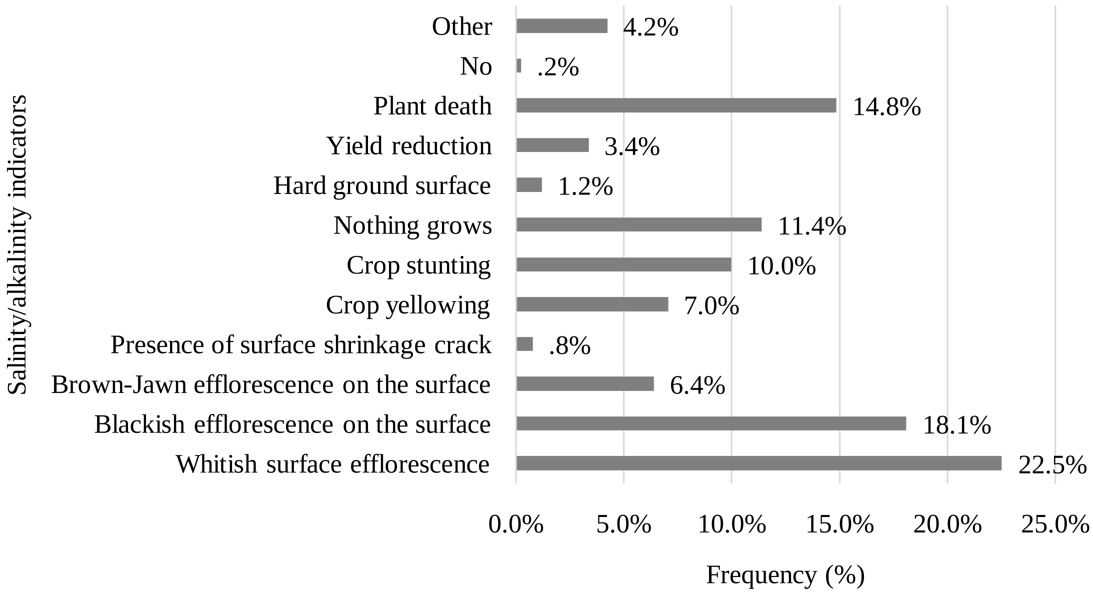
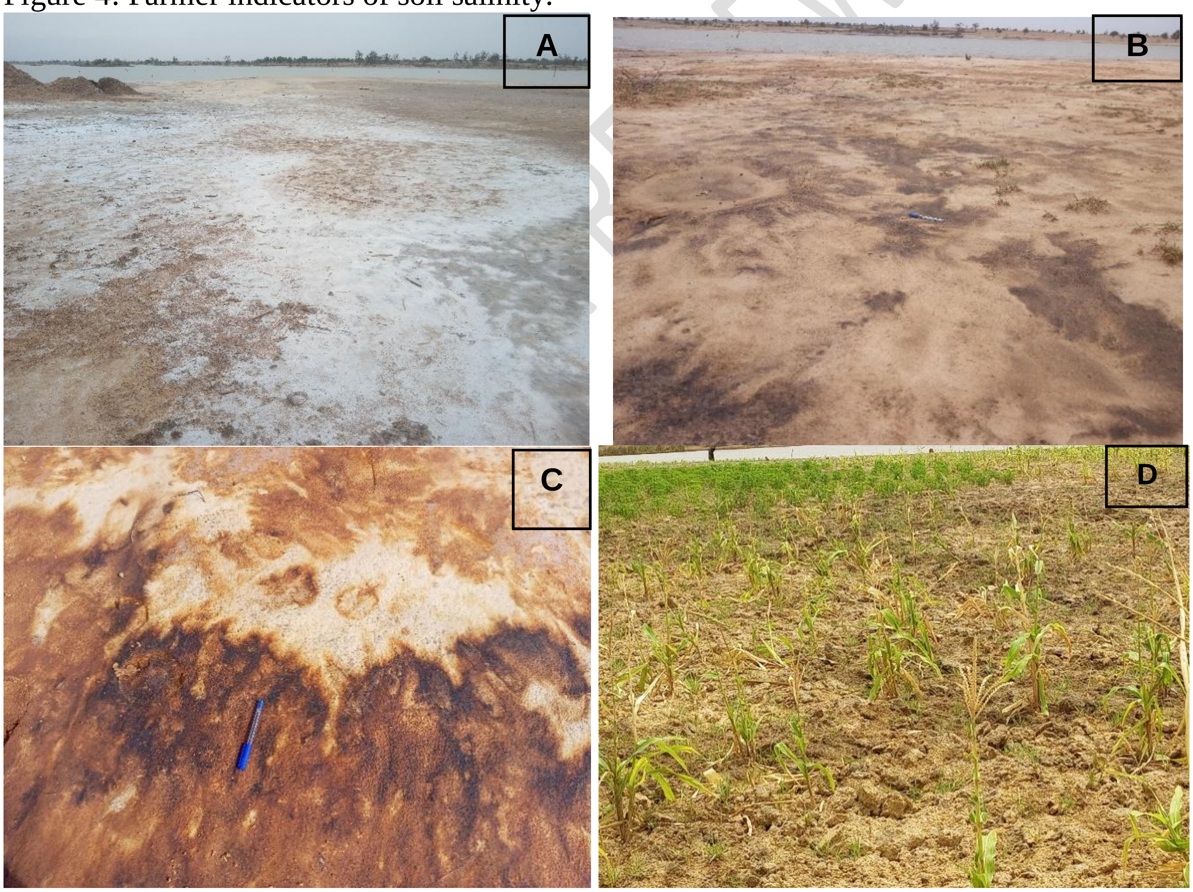


Figure 4: Farmer indicators of soil salinity.



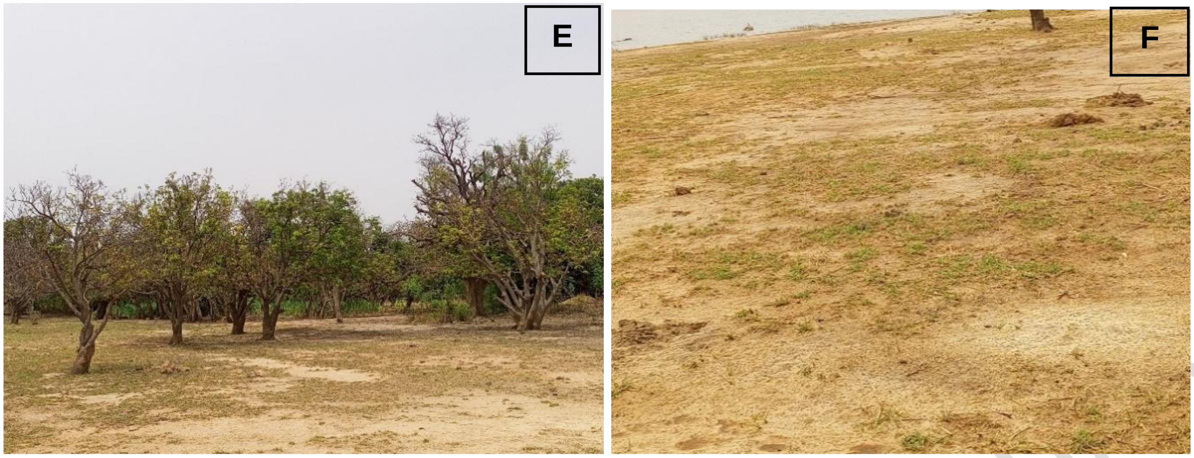


Figure 5: Photographs of surface conditions showing whitish efflorescences **in A**, blackish efflorescences **in B**, brownish-yellowish efflorescences in **C**, contaminated maize crops in **D** and diseased mango trees in **E**, as well as abandoned plots in **F**.

2.3.3 Origins of soil salinity according to farmers surveyed

The main sources of salinity and/or alkalinity in the soils and waters of the Fogha dallol lowlands are generally natural (Figure 6). Indeed, according to the farmers surveyed capillary rise of groundwater (12.4%), naturally saline soils (17%) and naturally saline water (17.4%) are the main sources of salinization/alkalinization in these lowlands. However, 48.2% of the surveyed farmers (Figure 6) stated that the main source of contamination in the lowlands they farmed was the continuous flow of water from naturally saline ponds during the rainy season.

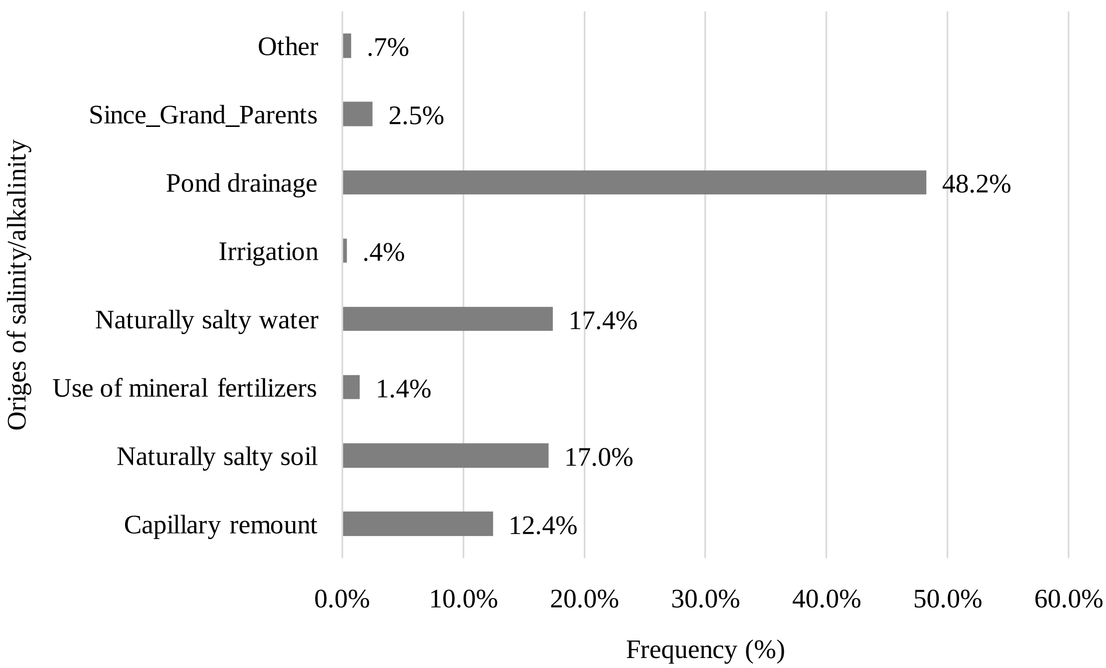


Figure 6: Origins of soil and water salinity

2.3.4. Surveyed farmers' areas affected by salinity

In the event of overflow, the salinity of pond water particularly affects the lowland land areas of the farmers surveyed (Table 6). Analysis of this table shows that the average area affected by salinity varies from 0.77 to 4.12 ha in Bara and N'Gaski respectively, with a total average of 2.36 ha.

Table 6: Area of land affected by salinity according to farmers surveyed

Villages	**Allocated areas (ha)**		
	Minimum	**Maximum**	**Average**
Bara	0,13	4	0.77± 1.22
Kawara	0,25	20	2.06± 3.61
Barba	0,5	10	4.12± 3.14
Lesso	0,5	30	2.89± 5.53
Garin Madjé	0,25	4	2.01± 2.08
Malgorou	0,5	9,5	2.03± 1.99
N'Gaski	1	10	3.10± 2.07
Zanzano	0,25	5	1.93± 1.50
Total	3,38	92,5	**2.36± 1.41**
P-value	0, 013		
Significant	yes		

2.3.5 Salinity-sensitive and salinity-tolerant crops according to respondents

Table 7 shows the distribution of salinity-sensitive and salinity-tolerant crops among the villages surveyed. Analysis of this table shows that all crops are sensitive to salinity in all villages surveyed, with the exception of Kawara and Malgorou, where farmers claim that rice, sweet potatoes, cassava and sugarcane are the most sensitive crops. As far as the most tolerant crops are concerned, we note that no crops are tolerant in all villages except Kawara and Malgorou, where farmers claim that sweet potatoes and sugar cane are somewhat tolerant of salinity.

Table 7: Main salinity-sensitive and salinity-tolerant crops according to farmers surveyed in different villages.

Villages	**The most sensitive crops**	**Most tolerant crops**
Bara	All crops	No crops except prosopis
Kawara	Rice; Sweet potatoes; Cassava; Sugar cane ;	Sweet potatoes; Sugar cane
Barba	All crops	No cultivation
Lesso	All crops	No cultivation
Garin Madjé	All crops	No cultivation
Malgorou	Corn; Rice; Sweet potatoes	Sweet potatoes; Sugar cane
N'Gaski	All crops	No cultivation
Zanzano	All crops	No cultivation

2.3.6 Crop stages influenced by salinity

Crop sensitivity to salinity varies not only by crop, but also by stage of the vegetative cycle. Indeed, according to the farmers surveyed, crops are most sensitive to salinity at the germination stage (39.5%), followed by the emergence and growth stages, with 28.1% and 26.3%

respectively (Figure 7). On the other hand, only 1.5% of farmers surveyed stated that certain crops are more sensitive at the fruiting stage.

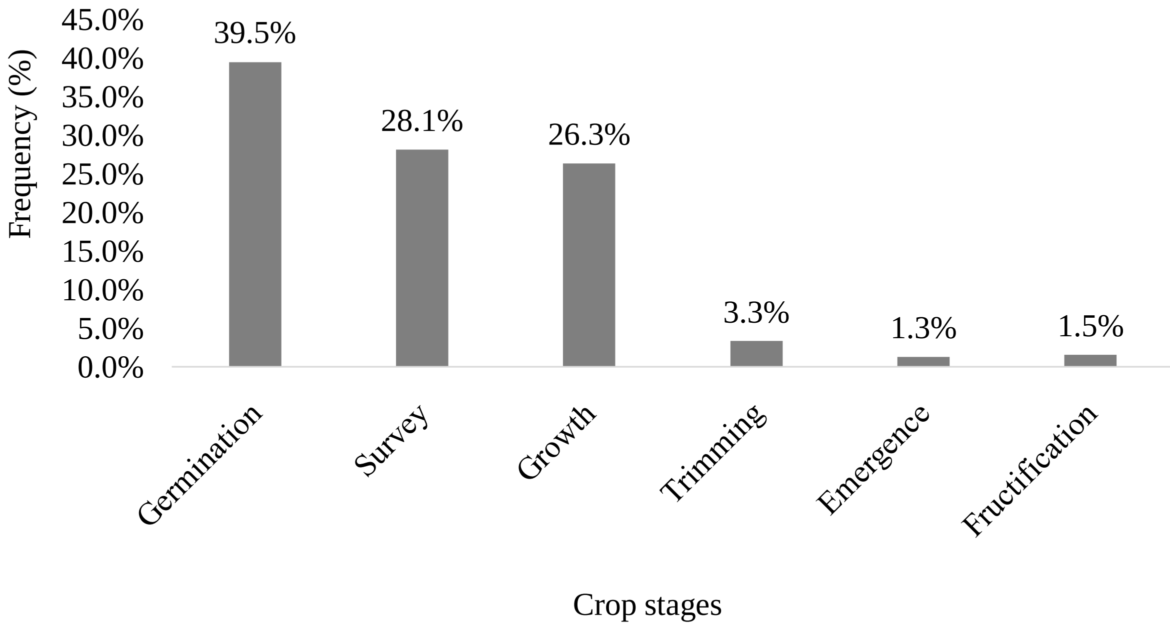


Figure 7: Stages of crop contamination by salinization according to farmers surveyed.

2.3.7 Consequences of soil salinity

Figure 8 shows how the farmers surveyed perceived the consequences of soil salinity in the lowlands of the Fogha dallol. Analysis of this figure shows that 42.4% of those surveyed said that salinity led to the abandonment of cultivated plots, while 25.5% thought that it resulted in poor water quality. 18.5% of farmers surveyed were unanimous that salinity led to lower yields, and 8.4% thought it reduced the production of certain crops.

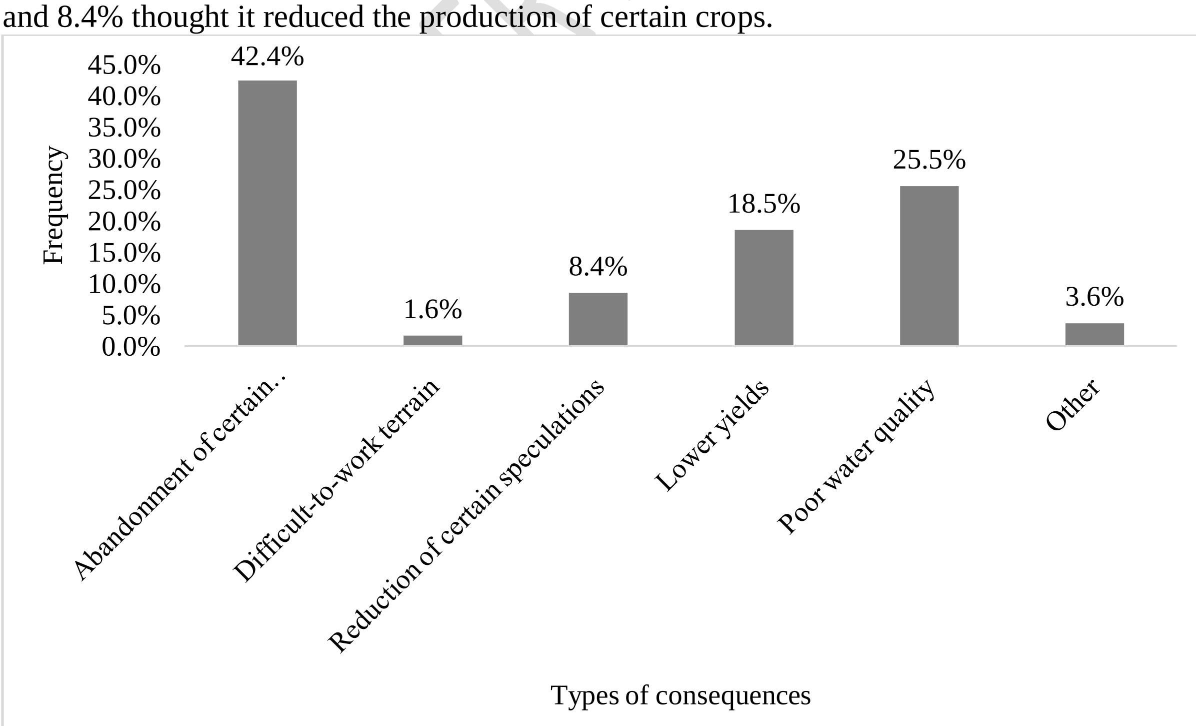


Figure 8: Consequences of soil and water salinity according to farmers surveyed

2.3.8 Crop yield losses on soil affected by salinity

Figure 9 shows the percentages of yield loss for crops grown in salinity-contaminated soil. According to 71.8% of farmers surveyed, yield loss for all crops could reach 90 to 100%. On the other hand, less than 1% of farmers surveyed stated that their salinity-affected soil could suffer a yield loss of less than 50%.

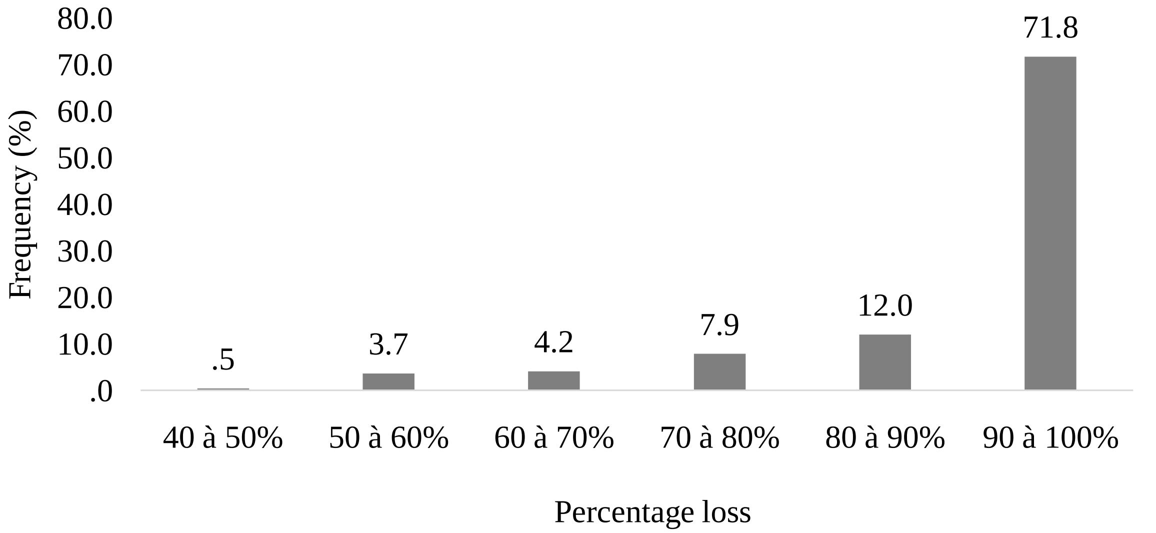


Figure 9: Distribution of yield loss percentages on salinity-affected soil.

2.3.9 Farming practices for salinity management

Figure 10 shows farmers' soil salinity management practices in the Dallol Fogha valley. Analysis of this figure shows that the use of manure (10.2%) and glumes and glumelles (16%) are the management practices most widely used by the farmers. Thus, 4.9% of surveyed farmers use mulching as a salinity management practice, while deep ploughing and chemical amendment are used by 3.3% and 2.5% respectively. On the other hand, 59% of respondents abandoned their plots in the event of contamination.

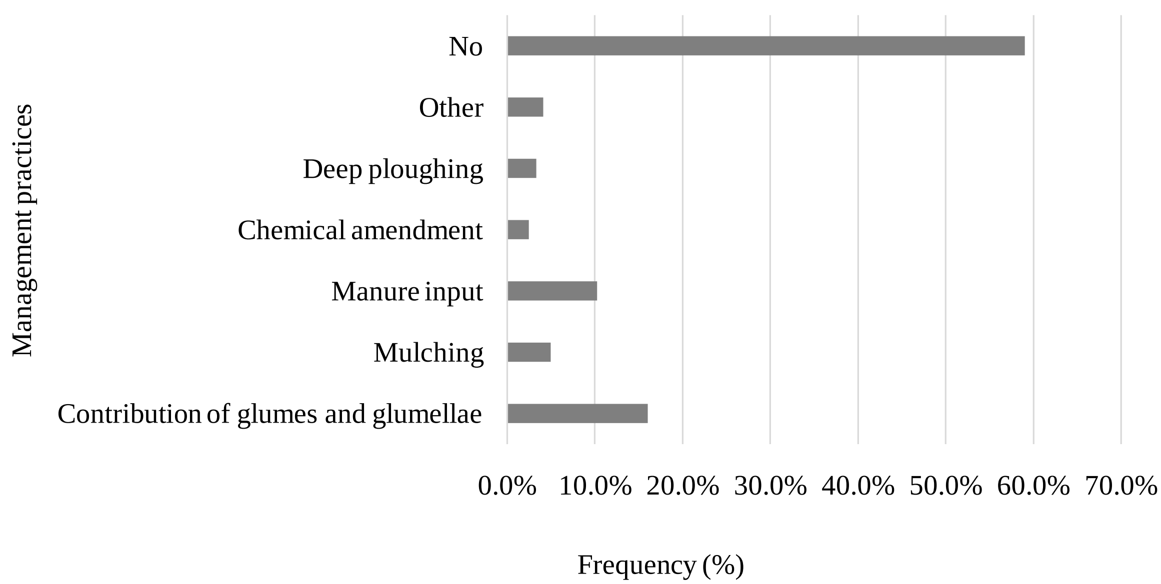


Figure 10: Farmers' salinity management practices in Dallol Fogha

III. Discussion

The results of this study show that the surveyed farmers in Dallol Fogha are aware of the salinity of the water and soil in the area, which they assess mainly by the whitish efflorescence and blackish crusts on the soil surface. These results corroborate those of Ado et al. (2024) in the Tahoua region, where growers noted the same signs on market garden sites affected by salinity. Diouf et al. (2022) also reported the same finding in the irrigated perimeters of Gorom-Lampsar, where farmers use a number of indicators to identify saline soils, with each indicator relating either to the soil or to crops, the combination of which enables saline soils to be classified.

According to the majority of farmers, soil salinity is due to natural causes and groundwater. These results confirm those found by Ado et al. (2024) in the Tahoua region, according to which farmers believe that soil salinity has a natural origin, irrigation water and capillary rise of groundwater. The work of Barbiéro (1995); Guéro (2000); Marlet et al. (1996) has also shown that salinization and alkalinization are accelerated by irrigation, which not only causes groundwater to rise, but also dissolves salty soil minerals. On the other hand, Marius (1985) and Sané (2008) have shown that changes in rainfall patterns, a shorter rainy season and higher temperatures are responsible for high soil salinization and acidification.

Salinity has affected the area of cultivated lowlands in the Dallol Fogha valley. According to surveys, around 504.34 ha of land in the study area is affected by salinization, confirming the FAO (2006) estimate that between 400 ha and 600 ha of land is affected by salinity, particularly in valleys used for irrigated agriculture.

All the farmers surveyed stated that salinity has a negative impact on agricultural production in the Dallol Fogha area. Salinity results in the abandonment of plots, poor quality pond water, lower yields and crop abandonment. This observation was made by Diatta et al. (2022) in the rice-growing valley of the Enampore commune, where the main consequence of salt on the environment, according to the producers surveyed, is the formation of a salt crust on the surface, which manifests itself on the rice through chlorosis and even mortality. Ado et al. (2024) also showed that growers reported a problem with market garden crops, notably stunted growth in plots affected by salinity, and that this stunted growth under the influence of soil salinity led to reduced yields and even the death of market garden crops in the plots.

According to the participants, salinity affects crop growth and development in Dallol Fogha. Indeed, crops are more sensitive to salinity at the germination stage; at the emergence stage and during growth, resulting in lower crop yields. According to the majority of growers surveyed, salinity leads to a 90-100% loss in crop yields. This finding by local growers has been confirmed by several authors (Munns and Tester, 2008; Hanana et al., 2011; Moussa 2018; Kpinkounet al., 2019; Ado et al., 2024) who have shown that soil salinity limits crop growth and development given i) the high soil osmotic pressure which limits the supply of water and nutrients to crops and ii) the toxicity of salty solutes which inhibits plant growth. Greeway and Munns (1980) confirmed that the growth of sensitive plants dropped sharply at EC levels of 3-4 dS/m (80% below potential growth).

The farmers use few practices (strategies) to manage the salinity of lowland land in the Dallol Fogha valley. In fact, the use of glumes and glumelles as well as manure are the management practices most commonly used by the farmers surveyed. Moreover, the majority of farmers surveyed do not fight against this salinity. These results differ from those reported by Diatta et al. (2022) in the rice-growing valley of the Enampore commune, where rice farmers set up anti-salt dykes and use organic fertilizers to improve yields. Diouf et al (2022) report that both chemical and organic amendments are used, and their impact, according to farmers, is real on salinity and crop yield. Organic amendments, in the form of manure or compost, are also applied to saline soils to improve soil structure, increase hydraulic conductivity and promote salt leaching (Wong et al., 2009; Prapagar et al., 2012; Abdel-Fattah, 2012; Wang et al., 2014; Meen et al., 2016; Ado et al., 2024).

Conclusion

At the end of this study, it should be noted that the farmers surveyed in the Dallol Fogha valley were well aware of the effects of soil salinity on agricultural production. The study revealed that 97.2% of the respondents were well aware of soil and water salinity through local recognition indicators, notably efflorescence on the soil surface, plant death (14.8%) and sometimes no growth (11.4%). This salinity, known since the 1800s, is due to rising groundwater (12.4%), naturally salty soils and waters, but also and above all to continuous runoff during the rainy season from naturally salty ponds (48.2%). According to the farmers surveyed, an average of 2.36± 1.41 ha per farmer are affected by this salinity, as all crops are sensitive except sweet potatoes and sugar cane, which also have low yields. All the farmers surveyed are aware of salinity, which not only leads to yield losses of up to 90-100%, but also, and above all, to the abandonment of plots. Regarding these perspectives, it would be important to conduct studies on plants or crops that can tolerate this salinity in order to make this environment productive.

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