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Economic Viability for Reclaiming Irrigated Saline-Sodic Soil using Gypsum as an Amendment at Minjibir Irrigation Scheme, Kano

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ABSTRACT

This research was conducted to assess the cost implication in remediating salt-affected soils at Minjibir Irrigation Scheme due to the fact that cost effectiveness is very essential in determining the adoptability of a research to local environment. The experiment consisted of four plots treated with different levels of gypsum while a plot was left untreated to serve as control and the same variety and density of tomato crop was planted in each plot. The cost of amendment (gypsum) was computed from various levels applied in the experimental plots, labor cost which include; cost of land preparation, weeding, planting and harvesting were considered. The marketable value of tomato yields were obtained at the end of harvesting period. It was found that the total cost of amendment used in reclaiming the soil was N150/m^2, other cost of production was N95.63/m^2 and the total marketable yields of tomato as at period of harvesting was N270.53/m^{2}which amount to the profit realized as N25/m^2. The Net Present Value (NPV) and Internal Rate of Return (IRR) which are the indices of determining the viability of an investment were computed and found to be 21.53 % and 33.33 % respectively Also, it was noted that application of amendment could remind effective in the soil for two or three years depending on the nature and extent of the salt presence in the soil. Therefore, it is economically feasible to ameliorate the adverse effect ad harsh condition of saline-sodic soil that makes it unfavorable for crop to develop at Minjibir irrigation Scheme using appropriate amendment and achieve better yields.

Keywords; Gypsum, Saline-Sodic Soil, Economic Viability, Reclamation, Tomato

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INTRODUCTION

Background of the Study

Economic implication for reclaiming salt-affected soils seems to be impracticable due to the extent at which the soils could be deteriorated by gradual accumulation of salts that rendered them unproductive. Though it requires a huge capital to reclaim large hectare of land but practically feasible especially for producing cash crop. In Minjibir Irrigation Scheme which is known to have severely affected by salinity and sodicity problems as reported by [1]. Some of the cops that are commonly grown in the study area include; Tomato, pepper, onion, maize, rice, wheat etc. But crops that are sensitive to salt such as Tomato became very difficult to develop as a result of emergence of salt problem which surfaced almost everywhere. Under saline condition, nutrients toxicity and increasing osmotic pressure are common problems to plant [2]. The adsorption of sodium under sodic conditions usually manifests its destructive effects on the soil structure through reduced infiltration, permeability and increased surface crusting besides being toxic [3]. Note that the application of fertilizers and irrigation water continue to add salt to the system. A saline soil contains sufficient salt in the root zone that impair crop development; saline soils hinder soil productivity by increasing the osmotic pressure in the soil making it more difficult for the crop to extract water needed for evapotranspiration, such soil has an electrical conductivity of the saturated extract exceeding 4 dSm^{-1} at 25^oC and the exchangeable Sodium percentage (ESP) of less than 15% [4]. Also poor irrigation schedules can lead to the development of crop water deficit and result in reduced yield due to water and nutrients deficiency. Moreover, proper time of irrigation is essential to the production of quality of most vegetables. If water shortage occurs early in the crop development, maturity may be delayed which may reduce yields. The moisture shortage later in the growing season adversely

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affects the quality of produce even though total yields may not be affected.

Salt-Affected Soil and its Classification

Salt-affected soils contained excess water-soluble salts (saline soil), excess exchangeable sodium (sodic soils) or both excess of salts and exchangeable sodium (saline-sodic soils) [5]. Saline soils resulting from salinity hazard normally have pH value below 8.5 and are relatively low in sodium and contain principally sodium, calcium and magnesium chlorides and sulfates. These compounds cause the white crust which forms on the surface and the salt streaks along the furrows. The compounds that cause salinity of soils is very soluble in water therefore leaching with good quality water and improved drainage facilities are quite effective in reclaiming these types soil. Sodic soils resulting from sodium hazard generally have pH value between 8.5 and 10. The soils are characterized as “black alkali soils” due to their dark appearance and smooth, slick looking areas caused by the dispersed condition. In sodic soils, sodium has destroyed the soil structure which tends to make it impervious to water. Thus, leaching alone will not be effective unless the high salt dilution method or amendments are used. Sodic soils are classified as low to very high sodium hazard based on their sodium adsorption ration SAR. A soil that has SAR between 1 and 10 is said to have low sodium hazard. But when SAR is greater than 25, such soil has high sodium hazard and generally unsuitable for crop production.Several research works were conducted at Minjibir irrigation Scheme by IAR and other agencies aimed at improving irrigation water quality as well as cropping systems in Barwa-Minjibir Irrigation Scheme. The research work on salts problems in the scheme conducted by [6] showed that the Barwa–Minjibir irrigation water is saline and has contributed to sodicity problems in the area resulting in surface

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crusting and poor soil structural stability. The exchangeable sodium percentage (ESP) in surface and subsurface soils had the average value of 56.92%. The irrigation water had Electrical Conductivity (EC_i), sodium adsorption ratio (SAR) and adjusted SAR values of 0.65 dS/m, 13.0 and 12.17 respectively. These values of ESP and SAR were found to be above FAO standards of irrigation water [7].

MATERIALS AND METHOD

Study Location

The study was conducted at Barwa-Minjibir Irrigation Project Scheme Kano, Nigeria. The scheme lies between Longitude $8^0$30"E to $8^0$52"E and Latitude $12^0$5"N to $12^0$20"N at 414 m above mean sea level covering an area of about 1,200 hectares. The soil parent materials are derived from colluvial, alluvial and/or aerolian deposits over Basement Complex [8]. The climate of study area is a typical Sudan savannah ecological zone which is divided into three distinct periods. These were; cold and dry harmattan (October to February), the hot season (March – May) and warm rainy season (June – September) as reported by [8]. The mean annual rainfall is about 818 mm irregularly distributed within the rainy period of about 120 days. Potential evapotranspiration exceeds rainfall for greater part of the year. The mean daily temperature is 29^{o}C. The climate of the study area is gradually becoming drier [6] which favors salinization and/or sodification processes.

Agronomic Practice, Planting and Harvesting

The experimental area of 350 m^2 was harrowed to a depth of 40cm by using a hoe out of which 299 m^2 was marked for the experiment and plots were marked. The nursery stage for the tomato seedlings was carried out at International Institute of Tropical Agriculture (IITA, Minjibir Station) where seeds of tomato variety UC82B were planted and the seedlings were

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raised for about three weeks. Three days before transplanting, the experimental site was prepared by harrowing up to ensure proper and suitable environment for easy transplanting and germination. Sixteen seedlings were transplanted in each experimental plot at the space of 50 cm apart. A compound fertilizer NPK (15:15:15) was applied as basal application at the rate of 150 kg/ha and Urea was applied thereafter when plants started flowering at the rate of 200 kg/ha. Weeds control was carried out manually using hoe and hand picking where necessary. Fertilizer (CAN 26% Nitrogen) was applied at the rate of 65 kg/ha as top dressing just after second weeding. Harvesting was carried out by hand picking (manual) and last for five weeks. The yield obtained from each plot was separated and graded in to marketable quality right in the field. The same procedure was repeated up to the end of harvesting period which was later summed up to give total quantity of tomato obtained from experimental field.

Application of Gypsum (Amendment)

Gypsum ($CaSO_4.2H_2O$) as saline soil amendment was applied after land clearing prior to planting. Gypsum could be applied any time in a field without damaging the soil or crop [10]. Some producers prefer to incorporate it with their fall or spring water. Some of the benefits of using gypsum as amendment includes improvement of soil structure by replacing the excessive amount of sodium in the soil, supply of calcium, helps soil to breakdown plant residue into available nutrients in the root zone, and improve overall fertility of the soil .A proper application of gypsum was achieved by broadcasting a designed quantity of gypsum measured in the laboratory which was evenly distributed in the experimental unit and mixed-up with the soil to ensure the soil particles are in contact with gypsum. The experimental plots were left for

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about 24 hours to allow sufficient time for chemical reactions to take place and then followed by application of leaching water. The rate of gypsum application depends upon the nature and type of the soil as well as the degree of salinity or/and alkalinity of a particular soil. For averagely light to heavier soils, the rate of gypsum application is 2.5 to 5 tons per hectare for every two years or three [9]. From the soil analysis, it shows that the soil at Minjibir was slightly heavier and therefore the gypsum was applied at rate of 0 g/m^2, 200 g/m^2, 300g/m^2 and 400g/m^2.

Figure 1. Treated and Untreated Experimental Plots

Statistical Analysis

The results obtained from treated and untreated experimental plots were subjected to statistical analysis of variance (ANOVA). This will ascertain the significant differences between the treatments and know whether the application of gypsum could be

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encouraged. The analysis involved gypsum as a factor with four levels (G0, G1, G2, and G3 representing 0, 200, 300 and 400 g/m^2 respectively). Control (G0) served as a basis of comparison between treated and untreated plots. The experiment was replicated three times in order to minimize error and averages were taken.

RESULTS AND DISCUSSION

Cost of Production

The results showed the cost of production, cost of soil amendment and quantity of tomato harvested at Minjibir irrigation scheme during the experiment conducted in 2013/2014 dry season. Table 1presents the total cost of operations which include; land clearing, seeds, planting, weeding, fertilizer application, gypsum, insecticide and harvesting. It is clearly seen that only weeding and harvesting were carried out more than once. Weeding and harvesting were conducted three times and four times respectively. The aspects of the operation that consume more resources were land clearing and gypsum application with N5,500 and N5,400 respectively. The overall cost of input for the experiment was summed up to N29,912 used for production of tomato as a test crop in the reclaimed soil.

Table 1. Items/Task for Production of Tomato

Item/Task done	Qty	Price/Cost (N)	Total (N)
Land clearance	1	5,500	5,500
Seeds	1	2,200	2,200
Planting	1	1,400	1,400
Weeding	3	500	1500
Fertilizer application	1	1,200	1,200
Gypsum	3	5,400	16,200
Insecticide	1	1,500	1,500
Harvesting	4	400	1,600
		Grand Total =	**29,912**

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Marketable Yield of Tomato

The total yield of tomato was harvested on weekly basis and the result was presented in Table 2. The highest (26.94 ton/ha) and lowest (18.75 ton/ha) yields were obtained from the plot treated with 400 g/m^2 of gypsum and 200 g/m^2 of gypsum respectively. Zero yields were obtained from untreated plots despite the same number of tomato seedlings were transplanted (Fig. 1). This was because no plant (tomato) was able to withstand the current level of sodicity after two weeks of transplanting. The Table also shows treated and untreated experimental plots with their corresponding yield in ton/ha. It was observed that the total yields obtained from each plot were less than 30 ton/ha for the same variety under favorable conditions as reported by Institute of Agricultural Research Station Ahmadu Bello University Zaria [10]. All the plots could be regarded as under treated with amendment because does not give 30 ton/ha yields or above, likewise for the untreated plots where no yield was obtained at all as well as the control (local farmer practice). The total yield of tomato obtained the end of this experiment was 215.42 ton/ha (Table 2). Also, the percentage of plant survived in each plot was presented in the table noting that no single plant was able to survive in all the untreated plots (Fig. 1).

Table 2. Gypsum, Survived plant and Total yields in ton/ha

Gypsum Applied (g/m^2)	Survived Plants (%)	Total Yield (ton/ha)
0	0	0
0	0	0
0	0	0
200	52	18.75
200	58	22.43
200	56	23.32
300	79	22.76
300	77	24.76
300	69	25.83
400	90	26.94
400	85	25.65
400	85	24.98
	TOTAL =	**215.42**

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Table 3.Quantity of gypsum used for the experiment

Level & area of plot	Amount of gypsum used (g/m^2)				No. of Plot treated	Replication	Total (grams)
	0.0	200	300	400			
G0 (4m^2)	0.0	-	-	-	3	3	0.0
G1 (4m^2)	-	800	-	-	3	3	7,200
G2 (4m^2)	-	-	1200	-	3	3	10,800
G3 (4m^2)	-	-	-	1600	3	3	14,400
			Grand Total =		**12**	**12**	**32,400**

Where;G0,G1, G2, and G3 are the levels of gypsum applied to the experimental plots of 0g/m^2, 200g/m^2, 300 g/m^2, and 400 g/m^2 respectively.

Experimental Analysis

The results obtained from field experiment were subjected in statistical analysis using analysis of variance (ANOVA). Table 4 below presented the statistical means of tomato yields (ton/ha) obtained from experimental plots and percentage of plants in each plot as affected by the rate of gypsum application.

Table 4. Yields (ton/ha) and Survived Plants (%) as affected by gypsum application rate

Treatment	Yield (ton/ha)	Survived Plant (%)
Gypsum (GYP)		
G3	12.044a	87.111a
G2	22.356b	75.111b
G1	19.067c	55.556c
G0	0.000d	0.000d
Significance	**	**
LSD @ 5%	1.712	9.2291
R^2	0.9803	0.9541
CV	10.7159	17.339

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Means followed by the same letter (s) in a column of any treatment group are not significantly different at 5% level.

** = highly significant difference
* = significant difference
NS = No significant difference

The results showed that there was highly significant difference among the treatments in terms of both gypsum application at 1% level of significance. The statistically highest yield of 25.86 ton/ha was obtained from plots treated with 400 g/m^2. Similarly, the yield of 24.45 to/ha and 21.5 ton/ha of tomato were recovered from plots treated with 300 g/m^2 and 200 g/m^2 of gypsum respectively. However, there were no yield obtained from untreated plots due to the fact that all the tomato seedlings wereunable to grow in the present saline-sodic soil condition without prior treatment. This showed that to produce significant amount of tomato yields at Minjibir irrigation farmland, application of amendment (gypsum) is necessary and of correct quantityfollowed by optimum leaching water coupled with well-functioning drainage facility.

Similarly, the table 4 above showed that there was highly significant differences in percentage of survived tomato plants at 1% level of significance. About 87.11% of plants were survived when planted in the plot treated with 400 g/m^2 of gypsum, followed by 75.11% and 55.56 % of survived tomato plants from plots treated with 300 g/m^{2}and 200 g/m^{2}of gypsum respectively. Nevertheless, all the plants perished when planted in the untreated plots (control) as they could not withstand the soil sality level. This could simply show the level of necessity of applying an amendment at Minjibir irrigation farm where no tomato plant can be developed without prior treating the soil with amendment. Optimum gypsum application was not yet achieved since only 87.11% of plant survived even though the soil was treated with 400 g/m^2 of gypsum. Therefore, optimum amount of gypsum should be slightly above 400 g/m^2 to achieved 100% survival of tomato plants thereby increasing soil productivity potential through

Cost Benefit Ratio

Cost effectiveness is very essential in determining the adoptability of a research to local environment. The cost of gypsum, labor cost and marketable value of Tomato (yields) were taken into consideration as follows;

i. Total yields of Tomato collected from the three replicated plots = 236.1 Kg
ii. Total experimental area was 144 m^2 out of which 108 m^2 were treated with gypsum.
iii. Total amount of gypsum used = 32,400 g = 32.4 Kg (Table 3)
iv. Market price of gypsum = N500 /Kg

Hence, total cost of gypsum used = 32.4 Kg x N500 = N16, 200 only

But the market price of Tomato as per the period of harvest was N165/Kg (this price is subject to change depending on market demand)

Hence, the total market price of tomato obtained = 236.1Kg X total replacement of sodium ions and properly leached afterwards.

N165/Kg = N38, 956.5= N270.53/m^2

The summary of the cost of items/task for the production of tomato was presented (Table 1) including the cost of gypsum.

Also, the additional cost of water required for leaching was estimated as follows;

The administration charges of using the irrigation water = N1, 000/ha per session

The area for the experiment = 299 m^2 = 0.0299 ha

And, the cost of the irrigation water = N29.9 per session

Any additional use of the water normally charges the same. Therefore, the cost of water meant for leaching the salts was N29.9 per session.

This indicated the total amount of money spent on farm activities was N29, 971.8

In order to know whether the production tomato carried out in the reclaimed soil is economically feasible, the production cost was

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compared with marketable value of tomato yields harvested from the soil where the profit made was N38, 956.50 minus N29,971.8 = N8, 984.70 = N25/m^2

It has been reported that Gypsum as amendment remains effective in a soil up to three consecutive years depending on the level of the salinity and/or sodicity [9]. Therefore, farmers would save the cost of applying gypsum (N16, 200:00) for next two years for the production.

Now to find out the viability status of any investment, Net Present Value (NPV) and Internal Rate of Return (IRR) are usually deployed.

Net Present Value (NPV)

Net Present Value of this research can be compute using the following simple formular;

$$NPV = \sum (After - Tax\ cash\ flow/(1+r)\hat{}t) - Initial\ Investment$$

Or in more simpler terms,

$$NPV = \{\frac{C1}{(1+R)^1} + \frac{C2}{(1+R)^2} + \cdots + \frac{Cn}{(1+R)^n}\} - Initial\ Investment$$

Where; C is expected cash flow for the period 1, 2 …. n, R is the required rate of return and T is the number of time the project is expected to generate income

Since the efficacy of amendment is assumed to be three years as reported by [9], then T would have the values from 1 to three (i.e. T= 1,2 and 3)

Also, C= N 38,956.5 (the expected cash flow) and the R value is 0.33 (R= 33%)

Hence, the Present value of this investment of reclaiming saline sodic soil and producing crop in Minjibir Irrigation Scheme will be;

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$$NPV = \{\frac{38,956.5}{1.33} + \frac{12,855.65}{1.7689} + \frac{42,42.36}{2.353}\} - 29,971.8 = 8,388.94$$

Therefore, the Net Present Value of this investment was N 8, 388.94 (21.53%)

Internal Rate of Return (IRR)

IRR is the core component of capita budgeting and corporate finance. Businesses use it to identify which discount rate make the present value of future after tax cash flows equal to the initial cost of the capital investment. Or simply refers to what discount rate will cause the net present value (NPV) of a project to be zero. Also, IRR assumes you can always reinvest any incremental cash flow at the same rete

Considering the investment of this research work, the value of IRR (which will make the Present Value zero) within the period of three years was computed as follows;

IRR = (8,388.93/3) = 2796.31 (33.33%)

This shows that after every year the investment returns 33.33% of the initial capital invested.

CONCLUSION

The soil reclamation was successfully conducted and tested by planting tomato to ensure the profitable production is possible despite the high production input. The experiment shows the reasonable outcome as per the profit realized at the end of production taking into consideration the cost of all inputs including the cost of soil reclamation.Also, the Net Present Value (NPV) and Internal Rate of Return (IRR) were computed as 21.53 % and 33.33% respectively. This proved that it is possible to reclaimed saline/sodic soil and make economic production at the same time irrespective the cost inputs associated with the process.

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