Journal of Agriculture and Ecology Research International

23(6): 190-198, 2022; Article no.JAERI.94671
ISSN: 2394-1073

Profitability Assessment of Sprinkler Irrigated Maize Production in Semi-Arid area of Maiduguri, Borno State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2022/v23i6510

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94671

Original Research Article

Received 06 October 2022
Accepted 12 December 2022
Published 13 December 2022

ABSTRACT

Water has been identified as one of the scarce inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed. Increasing the adoption of irrigation technology is an important requirement for increasing Nigeria's agricultural productivity. Farmers use the furrow irrigation method and fixed irrigation interval schedule for maize production in this region. The irrigation method used by the farmers has become unsustainable due to low yield, low water use efficiency, low quality of maize kernels and low net farm income. Thus, there is a growing gap between the demand for maize and its production to meet the food requirement for the growing population. The aim of this study was to determine the profitability of sprinkler irrigation method for maize production in semi-arid environment of Nigeria. Two field experiments were conducted in the 2014 and 2015 seasons at the Teaching and Research Farm of Ramat Polytechnic Maiduguri, Borno State which is located in the semi-arid region of Northern Nigeria. The sprinkler irrigation system used consisted of a reservoir, mainline and six laterals spaced 12 meters apart. Each treatment was irrigated using two laterals and each lateral has a control valve for

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regulating the flow of water. Each lateral consisted of three double nozzle sprinklers spaced 6 meters apart along the lateral. The diameters of the mainline and the laterals were 101.6 and 31.75mm respectively. The area irrigated by the sprinkler system was cleared and marked out into plots of sizes 12m^2. Scheduling was on the use of tensiometer, pan evaporation and fixed irrigation interval. Irrigation was conducted in the plots monitored by the tensiometer whenever the trigger level of 30cb is reached. The crops were irrigated at 1.0 IW/CPE ratio for optimum yield based on the evaporation pan method. The profitability analysis result revealed that Sprinkler irrigation was found to be a profitable irrigation method for maize production with net farm income of $460.8 and benefit cost ratio of 1.99. Based on the results, it is recommended that farmers in the semi-arid region of Nigeria should use the sprinkler irrigation method for improved maize production.

Keywords: Irrigation; profitability; semi-arid; sprinkler.

1. INTRODUCTION

Water has been identified as one of the scarce inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed [1]. It is a wide-ranging practice of using every drop of water for crop production through suitable irrigation practices. Irrigation practice across the world is vital to successful green revolution all year round to achieving sustainable development goals in food security, socio-economic and rural development [2]. Increasing adoption of irrigation technology is an important requirement for increasing Nigeria's agricultural productivity [3]. Irrigation systems can guarantee long-term production sustainability [4]. The investment in an irrigation system is influenced by two clusters of factors: the technical aspects of the irrigation systems, and the economics of the specific crop [5].

Nigeria is a net food-deficit nation and imports large amounts of grain [6]. And the exponential projection growth in the population has not translated to food sufficiency but rather agricultural production is on the decline Adelodun and Choi [2]. Inadequate supply of water is a major limiting factor in agriculture hence the need for irrigation in crop production. In Nigeria, crop production is heavily dependent on rainfall thus production suffers from the seasonality of rainfall in time for a given locality.

Several studies revealed that, there is much need to increase food output in order to: feed the increasing population; earn the needed foreign exchange to import non-food needs; to generate savings for investment; and to preserve and conserve the natural resource base to enhance its productivity [7,8]. Consequently, the approach to increasing agricultural production in a country through irrigation farming is a major panacea, if the problem of food shortage in the country is to be addressed [9].

Irrigation is the process of applying controlled amounts of water to plants at needed intervals. Irrigation helps to grow agricultural crops, maintain landscapes and re-vegetate disturbed soils in dry areas and during periods of less than average rainfall [10]. Different irrigation systems are suited to different soils, climates, crops and resources. There are three main types of irrigation systems: Surface, Sprinkler and Drip/trickle irrigation [11,12].

The sprinkler irrigation method is one of the modern methods of irrigation also known as the micro irrigation method. In the sprinkler system, water is sprinkled on the crop by using a pipe and nozzle system [10]. Sprinkler irrigation method is an easy and simple method of irrigation in present times. Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Sprinkler irrigation system not only saves water over the traditional method but also increases the yield and profitability of different crops and agroclimatic conditions [10].

Farmers use the furrow irrigation method and fixed irrigation interval (7 days) schedule for maize production in this region. The irrigation method and schedule used by the farmers have become unsustainable due to low yield, low water use efficiency, low quality of maize kernels and low net farm income [13]. Thus, there is a growing gap between the demand for maize and its production to meet the food requirement for the growing population in the region. The aim of this study was to determine profitability of the drip irrigation method for maize production in semi-arid environment of Nigeria.

According to Alabi and Esobhawan, [14] maize accounts for about 43% of calorie intake in Nigeria. Apart from being a food crop, maize has equally become a commercial crop which many industries depend for raw materials [15]. Maize contributes to about 80% of poultry feeds and this has a significant effect on the protein intake in Nigeria [16]. Therefore, maize can be considered very vital to the economic growth of the nation through its contribution to food security and poverty alleviation [17].

Addressing the challenges of poverty and food insecurity calls for boosting agricultural production in Nigeria [18]. Irrigation which had the highest contribution to increasing global food production is the only alternative solution to this problem [19]. Currently, crop production in Nigeria is rainfed; the irrigated agriculture accounts for only 1% of cultivated area in the country [20]. This rainfed agriculture makes crop production in Nigeria vulnerable to climatic variability intra-annually and inter-annually.

Irrigation has also greatly helped stabilize food production and prices over the years [21]. Today, irrigated agriculture continues to make civilization less dependent on the vagaries of climate for food and fiber requirement to sustain life.

The general objective of this study is to examine the economics of irrigated maize production in Maiduguri, Borno State, Nigeria.

Specific objectives were to:

i. determine the costs associated with maize production using sprinkler irrigation method under different irrigation schedules
ii. determine the profitability of maize production using sprinkler irrigation method under different irrigation schedules

2. MATERIALS AND METHODS

2.1 Study Area

Field experiments were carried out at the Teaching and Research Farm of Ramat Polytechnic Maiduguri, Borno State which is situated at latitudes 11° 46'18"N to 11° 53' 21"N and longitudes 13° 03' 23"E to 13° 14' 19"E in the semi-arid region of Northern Nigeria. Maiduguri lies within the Lake Chad Basin formation and is about 355m above sea level. The climate is semi-arid or tropical grassland vegetation which is known for its dryness. The area has a long dry season of 6 to 7 months spanning from November to Mach and a short wet season that lasts for about four months (July to October). The area has high temperatures which range from 20-43ºC with an average annual precipitation of about 640 mm. The hottest months are usually April and May, while the cold and dry periods of harmattan are from November to January. The texture of the soil is mostly sandy loam [22].

The meteorological data recorded during the period of the experiment showed that the maximum and minimum air temperatures were 42.2 to 43.5° C and 24.5 to 25° C respectively. The relative humidity ranged from 22.3 to 44.3%. The wind speed and evaporation rate were 123 to 135 km/h and 10 mm respectively.

The sprinkler irrigation system used consisted of a reservoir, mainline and six laterals spaced 12 meters apart. Each treatment was irrigated using two laterals and each lateral has a control valve for regulating the flow of water. Each lateral consisted of three double nozzle sprinklers spaced 6 meters apart along the lateral. The diameters of the mainline and the laterals were 101.6 and 31.75mm respectively. The area irrigated by the sprinkler system was cleared and marked out into plots of sizes $12m^2$.

2.2 Irrigation Schedule

The exact amount of water required by the maize crop was applied using different irrigation intervals based on the use of tensiometer, pan evaporation and fixed irrigation interval. Irrigation was conducted in the plots monitored by the tensiometer whenever the trigger level of 30cb is reached.

The evaporation pan used was the standard class A evaporation pan made from galvanized iron and is 120.5cm in diameter and 25 cm deep filled with water to a depth of 20cm. The crops were irrigated based on the ratio of irrigation amount (IW) to cumulative pan evaporation (CPE) that is IW/CPE ratio. Daily records of pan evaporation data were taken from the class A evaporation pan located in the research farm and irrigation was conducted at 1.0 IW/CPE ratio for optimum yield. The choice of the ratio of IW/CPE of 1 for scheduling maize in this work was based on the findings of earlier research which shows higher yield and water use efficiency values when irrigation was scheduled at the ratio of IW/CPE equals to 1 [23].

A fixed irrigation interval of 7 days was used for irrigating the maize crop under all the different irrigation systems based on the traditional irrigation cycle used by the farmers.

2.3 Determining the Performance of the Farm Enterprises

The rationale behind the estimations of the different costs and returns components associated with a production process is in order to evaluate the performance of the production activities of an enterprise or the entire farm business. Performance indices such as profitability, gross margin, net farm income, the rate of returns to investments etc. are some performance indicators that can be used to determine the optimal production process, enterprise selection, enterprise combination, make pricing decisions, marketing decisions as well as ascertaining the sustainability of investments. Comparisons of production costs structure between farms (in the same region or in different ones) could also lead to greater efficiency in the production process of individual farms as well as in the allocation of scarce resources.

The methods used in determining the performance of a farm business include farm profitability analysis, net farm income analysis, gross margin analysis and benefit-cost ratio [24]. Farm profitability involves subtracting from the total returns the total costs of production to arrive at the profitability index. A positive value indicates that some profits are realized from investments. The net farm income analysis is very similar to the profitability procedure with the major difference that it is used in cases of having a number of enterprises on the same farm with a common cost which cannot be easily allocated to a single enterprise. What is done in such a case is to calculate the gross returns from each enterprise and then get the net farm income by subtracting from the pooled gross returns. The net farm income was calculated using equation 1 used by Haruna et al. [25]:

$$NFI=TR-TC \quad (1)$$

Where:

NFI = Net farm income from production per hectare.
TR = Total revenue/returns from production per hectare.
TC = Total costs of production per hectare.

2.4 Benefit Cost Ratio (BCR)

The benefit-cost ratio (BCR) which is the ratio of the present value of benefit and the present value of cost was determined using equation 2:

$$BCR=Benefit/Cost \quad (2)$$

These were performed by identifying all costs incurred and the total revenue obtained from the production based on the irrigation methods and schedules used in the study. All costs were classified as either fixed or variable cost. Costs that were incurred due to land hiring, land preparation, seed, fertilizer, water used, fuel, rented pump, rented water reservoir, water application, planting, fertilizer application, weeding, harvesting and threshing were classified as a variable cost. While costs incurred from sprinkler and drip irrigation components were classified as a fixed cost. The variable and fixed costs were summed up to arrive at the total production cost for the research. The total revenue was obtained by quantifying the yield in monetary terms. The two costs-production cost and selling price (total revenue) were compared to evaluate the economic viability of different irrigation methods and techniques for maize production. The net farm income, benefit cost ratio and were determined using the procedures outlined by Rao [26], Brennan [27] and Srivastava [24] as shown in equations 3.41 and 3.42 respectively.

2.5 Costs of Production

Costs of production are generally classified into fixed costs and variable costs. To facilitative the calculation of net farm income and benefit cost ratio which were used to determine the profitability and economic viability of the different irrigation methods and schedules, the different cost items were identified, quantified and the amount involved in their use in the maize production were summed up and subtracted from the total returns. The following are the different costs and the various procedures used in getting the value of their worth in maize cultivation under the different irrigation methods.

2.6 Land Hiring

As most of the land used for irrigation by the farmers was rented, the average rent value per hectare was used. In some areas, the farms are not clearly divided into hectarages and so the value is not accordingly charged on per hectare

basis rather, for the whole farm land. In such cases, the total amount paid for the farm land is divided by the number of hectares to arrive at its rent per hectare basis. The land rent per hectare therefore, was determined using equation 3:

LR=LP/FLS..... 3

Where:

LR=Land rent per hectare.
LP= Land payments.
FLS= Farm land size (hectares)

2.7 Land Preparation

This involves clearing the land and then using farm tools or machines to harrow, and till as well as making the land suitable for irrigation purpose. For each particular farm operation, a specific amount is paid for carrying out such activities. The total amount paid for all of these activities divided by the total hectarage of the farm is the per hectare cost for land preparation that was calculated using equation 4:

LPC=TALP/FLS..... 4

Where:

LPC= land preparation cost per hectare.
TALP= Total amount paid for the various land preparation activities.
FLS= Farm land size (Ha)

2.8 Seed Cost

In order to arrive at the seed cost per hectare, the total quantity of seed used was multiplied by the seed rate. This total was then divided by the total hectares of land cultivated with maize to get the seed cost per hectare as shown in equation 5:

SC=TSC/FLS..... 5

Where:

SC= Seed cost (Ha)
TSC= Total cost of seed used.
FLS= Farm land size (Ha)

2.9 Cost of Fertilizer

Different types of fertilizer command different prices in the market and the total quantity used by a particular farmer influences his/her total cost of production. The total amount expended on fertilizer was divided by the total land size to arrive at the cost of fertilizer per hectare as shown in equation 6:

FC=TCF/FLS..... 6

Where:

FC = Fertilizer cost per hectare.
TCF = Total cost of fertilizer used.
FLS = Farm land size (Ha).

2.10 Cost of Fuel

This is the amount expended on the fuel used to run the water pump. It was calculated by summing all the amount of money spent on fuel which was then divided by the total hectarage with farmed maize to arrive at the fuel cost per hectare using equation 7:

FUC=TAF/FLS.....7

Where:

FUC= Fuel cost per hectare.
FLS= Farm land size (Ha).
TAF= Total amount spent on fuel.

2.11 Rented Pump

This is the amount paid for the use of a water pump to irrigate the farm under maize cultivation. The total amount paid as rent for the use of pump was summed and divided by the total hectare farmed using equation 8:

RP=TRC/FLS..... 8

Where:

RP= Pump rent per hectare.
TRC=Total rental cost.
FLS= Farm land size (Ha)

2.12 Water Used Cost

The area of study being in the semi-arid region of the country is an area with a scarcity of water. For this reason, the total quantity of water used was quantified and cost based on the average prevailing water rate using equation 9:

WCH=WUC/FLS..... 9

Where:

WCH = cost of water per hectare.
WUC = Total quantity of water used by the farmer (total quantity of water used x average water rate).
FLS = Farm Land Size (ha).

2.13 Rented Water Reservoir Cost

Pumped water had to be reserved in some type of container before ultimately being used for irrigating the maize crops. While some farmers purchase large plastic containers others use concrete water reservoirs. The reservoir is normally rented for the period of cultivation. The cost of renting the reservoir was arrived at by dividing the total cost of rented reservoir by the number of hectares cultivated to convert to per hectare basis using equation 10:

$$RWR=TRC/FLS \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

Where:

RWR = water reservoir rent per hectare
TRC= total rental cost
FLS= farm land size

2.14 Labour Cost

Labour costs were incurred for carrying out the different cultural practices such as planting; fertilizer application, weeding, harvesting, threshing etc. involved in the maize production activities. The total amount of money expended on each of these operations was calculated and divided by the size of the farm in hectares to get their per hectare basis. For instance, water application cost per hectare is the total amount per water application divided by farm size in hectares. For planting operation cost per hectare, it is the total cost of planting divided by farm size in hectares. For fertilizer application cost per hectare, it is the total cost for applying fertilizer divided by farm size in hectares. For weeding cost per hectare, it is total amount spent on weeding divided by farm size in hectares. For harvesting cost per hectare, it is total amount spent on harvesting divided by farm size in hectares. For threshing cost per hectare, it is total amount spent on threshing divided by farm size in hectares. The total for each of these activities on per hectare basis was the cost expended on labour for maize production per hectare.

3. RESULTS AND DISCUSSION

3.1 Economic Analysis of Maize Production Using Sprinkler Irrigation Method and Schedules

The process of choosing the most economically viable combination of irrigation method and schedule is one of the most important considerations in the development of irrigated agriculture, especially in arid and semi-arid areas.

The results of the total cost involved in maize production using sprinkler irrigation method and schedules are presented in Table 1. The result shows that the total cost of production varied from 403.39 to 467.33 $/ha. This was however, considered high and could be attributed to the higher cost of the sprinkler components including the costs involved in the maintenance of the sprinkler system. The sprinkler irrigation system fixed costs accounted for 23.73 to 27.49% of the total cost of production. The variable costs per hectare for the irrigation method and schedules were 293.20 to 367.8 $/ha.

The variable costs were higher in pan and tensiometer irrigation techniques with shorter irrigation intervals (4 days) which resulted in higher costs of fuel and water application compared to the fixed irrigation interval of 7 days. The total variable cost contributed 72.68% to 76.42% to the total cost. Fertilizer and water application costs accounted for 7.3% to 16.0% of the total variable cost.

The next limiting factor is the cost of fuel for the sprinkler irrigation system. The cost of fuel incurred for the sprinkler irrigation system was 19.09% of the average variable costs of production under this system of production. The implication of this finding is that for the optimum output of maize to be obtained adequate provision should be made to cater for these factors.

Land hiring, preparation, seeds, water used, weeding, harvesting and threshing contributed 5 to 7.56%, 3 to 4.53%, 1.33 to 2.02%, 1.54 to 3.40%, 1.25 to 1.90%, 1.33 to 2.02% and 1 to 1.51% of the total variable cost respectively. Fuel and rented pump accounted for 4.13 to 21.33% and 2.05 to 6.67% of the total variable cost respectively. A substantial proportion of the total variable cost was expended on fertilizer and water application. The total revenue under the different irrigation schedules ranged from 456 to 928.1 $/ha as shown in Table 2.

Table 1. Total cost involved in maize production under sprinkler irrigation method and schedules

Items		Sprinkler	
cost	**Fixed**	**Tensiometer**	**IW/CPE**
Output		**$/ha**	
Variable inputs cost (VC)			
Land hiring	10.71(3.65)	10.71(3.00)	10.71(3.00)
Land preparation	17.86(6.09)	17.86(5.00)	17.86(5.00)
Seed	4.76(1.62)	4.76(1.33)	4.76(1.33)
Fertilizer	144.05(49.1)	144.05(40.3)	144.05(40.3)
Water used	4.52(1.54)	8.04(2.25)	8.04(2.25)
Fuel	42.86(14.62)	76.19(21.33)	76.19(21.33)
Rented pump (6.5 hp)	13.39(4.57)	23.81(6.67)	23.81(6.67)
Rented water reservoir	11.9	11.9	11.9
Water application	21.43(7.31)	38.1(10.7))	38.1(10.7)
Fertilizer application	8.93(3.05)	8.93(2.50)	8.93(2.50)
Weeding	4.46(1.52)	4.46(1.25)	4.46(1.25)
Harvesting	4.76(1.62)	4.76(1.33)	4.76(1.33)
Threshing	3.57(1.22)	3.57(1.00)	3.57(1.00)
Sub Total	**293.20**	**357.14**	**357.14**
Fixed inputs cost (FC):			
Sprinkler components	110.91	110.91	110.91
Sub Total	110.91	110.91	110.91
Total Cost	**403.39**	**467.33**	**467.33**

IW/CPE stand for the ratio of irrigation amount (IW) to cumulative pan evaporation (CPE)
Source: Field experimental data 2014/2015

Table 2. Net farm income for maize production and schedules

Items		Sprinkler	
	Fixed	**Tensiometer**	**IW/CPE**
Output		**$/ha**	
Yield (kg)	2281.3	4640.7	4635.7
Unit price/100kg	20	20	20
Total revenue	456	982.1	927.1
Total Cost	403.39	467.33	467.33
Net farm income	52.6	460.8	459.8
Benefit cost ratio	1.13	1.99	1.98

Source: Field experimental data 2014/2015

Total revenue of $982.1 was obtained as shown in Table 2. The tensiometer and the ratio of irrigation amount to cumulative pan evaporation techniques also gave higher total revenue when compared with the fixed irrigation interval (7 days).

The result further revealed that the net farm income and benefit cost ratio were obtained $460.8 and 1.99, respectively.

4. CONCLUSION

Based on the research conducted to determine the proper irrigation method and schedule for maize production in the semi-arid environment of Nigeria, it can be concluded that Sprinkler irrigation was found to be a profitable irrigation method for maize production with net farm income of $460.8 and benefit cost ratio of 1.99.

5. RECOMMENDATION

Based on the findings of this study, it is recommended that farmers in the semi-arid region of Nigeria should all things being equal adopt the use of sprinkler irrigation method for improved maize production based on its proven performance and economic viability as shown in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/94671