

A COMPARATIVE ECONOMIC ANALYSIS OF FURROW, SPRINKLER AND DRIP IRRIGATION METHODS FOR MAIZE (*Zea Mays, L.*) PRODUCTION IN MAIDUGURI SEMI-ARID REGION OF BORNO STATE, NIGERIA

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ABSTRACT

Maize production in the semi-arid region of Nigeria relies widely on irrigation. The irrigation method and schedule 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. The aim of this study was to determine economics of the irrigation methods and schedules in maize production for 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 experiments consisted of a factorial combination of irrigation methods and scheduling methods laid in a randomized complete block design that resulted in nine (9) treatments. Irrigation methods were at 3 levels namely; drip, sprinkler and furrow irrigation methods. Irrigation scheduling methods were also at three levels namely fixed irrigation interval (7days), soil moisture based schedule using tensiometer at trigger level of 30 cbar and climate based schedule based on the ratio of irrigation amount to cumulative pan evaporation of 1 (1.0 IW/CPE). The treatments were randomly assigned to plots and replicated 3 times. A total of 27 experimental plots were used for the study. The economic viability of maize production under the different irrigation and scheduling methods were determined. The results revealed that, the combination of drip irrigation and tensiometer schedule had the highest net farm income and benefit cost ratio of \$695.2 and 3.20 respectively compared to \$514.77 and 2.10 for sprinkler and \$545.8 and 2.84 for furrow irrigation method. It is recommended that farmers in the semi-arid region of Nigeria should all things being equal adopt the use of drip irrigation method for improved maize production.

Keywords: Economic Analysis, Furrow Irrigation, Sprinkler Irrigation and Drip Irrigation, Semi-Arid

1 INTRODUCTION

In the arid and semi-arid areas of Nigeria, water is the major constraint in crop production. Rainfall is extremely irregular, to the extent that the amount and distribution in space and time had not been ideal to optimally support crop production adequately [1]. The high temperature, high soil evaporation rate, poor water holding capacity of soils and the vagaries of climate change are among others responsible for reducing water availability to crops. Adequate amount of water in the soil is necessary for optimum growth and yield of crops [2]. Farmers in the region use furrow irrigation method and fixed irrigation interval schedule for maize production. The

irrigation method and schedule 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 in the region. The aim of this study was to determine the proper irrigation method and schedule in maize production for semi-arid environment of Nigeria. In Nigeria, the area under maize production was about 6million ha in 2013 with a production of 7million tonnes giving an average yield of 1.4 to 1.5 t/ha [3]. Maize accounts for about 43% of calorie intake in Nigeria [4]. Apart from being a food crop, maize has equally become a commercial crop on which many industries depend on for raw materials [5]. Maize contributes to about 80% of poultry feeds and this has great effect on the protein intake in Nigeria [6]. Therefore, maize can be considered very vital to the economic growth of the nation through its contribution to food security and poverty alleviation. Nigeria, Africa's most populated nation with an estimated population of about 150 million is overwhelmingly dependent on agriculture, where more than 70% of their population are involved [7]. Majority of farmers in Nigeria as in among other developing countries, are at subsistence level and hence cannot meet their food and fibre requirements. [8] reported that, food insecurity and poverty are still on the increase in many sub-Saharan countries, including Nigeria. The report revealed that the region recorded the highest prevalence of hunger compared to any other region with about 220 million hungry people between 2014 to 2015. The gap between the domestic food supply and demand in Nigeria is unfortunately an increasing one. The Human Development Report by United Nations [9] shows that about 84.5% of the population lives below \$2 per day. This economic condition is worse in the rural areas where over 70% of the people reside and earn their living through farming. Addressing the challenges of poverty and food insecurity calls for boosting agricultural production in Nigeria [10]. This will go a long way in increasing food production to meet the demand for the increasing population. Irrigation that had the highest contribution to increasing the global food production is the only alternative solution to this problem [7]. Currently, crop production in Nigeria is predominantly rain fed; the irrigated agriculture accounts for only 1% of cultivated area in the country [11]. This rain fed agriculture renders crop production in Nigeria vulnerable to climatic variability, both intra-annually and inter-annually. Irrigation has also greatly helped in stabilizing food production and prices over the years [12]. Today irrigated agriculture continues to make civilization less dependent on the vagaries of climate for food and fibre requirement to sustain life [13]. Irrigation methods are broadly classified into surface, sprinkler, trickle and subsurface irrigation on the basis of the modes of water application and their associated overall efficiencies [14, 15]. The general objective of this study is to examine the economics of irrigated maize production in Maiduguri, Borno State, Nigeria and specifically determine the costs associated with maize production and its profitability using Furrow, Drip and Sprinkler Irrigation methods.

2 MATERIALS AND METHODS

2.1 The 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 of the area is semi-arid or tropical grasslands vegetation which is known for its dryness. The area has a long dry season of 6 to 7 months spanning from November to March and a short wet season that last for about four months (July to October). The area has high temperatures which range from 20-43°C with an average annual precipitation of about 640 mm. The hottest months are usually April and May, while the cold and the dry periods of harmattan are from November to January. The texture of the soil is mostly sandy loam [16]. The meteorological data recorded during the period of the experiment showed that the maximum and minimum air temperatures were 42.2°C 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 overall field layout for the experimental farm used for the maize production using drip, sprinkler and furrow irrigation methods. The total area of the land used for the research was 5500 m² (0.55 hectares). The area occupied by the drip and furrow irrigated plots were

1000 m² each. While the sprinkler irrigated plots used an area of 3500 m² (0.35 hectares). The entire area was harrowed and the plots under the different irrigation methods were marked out.

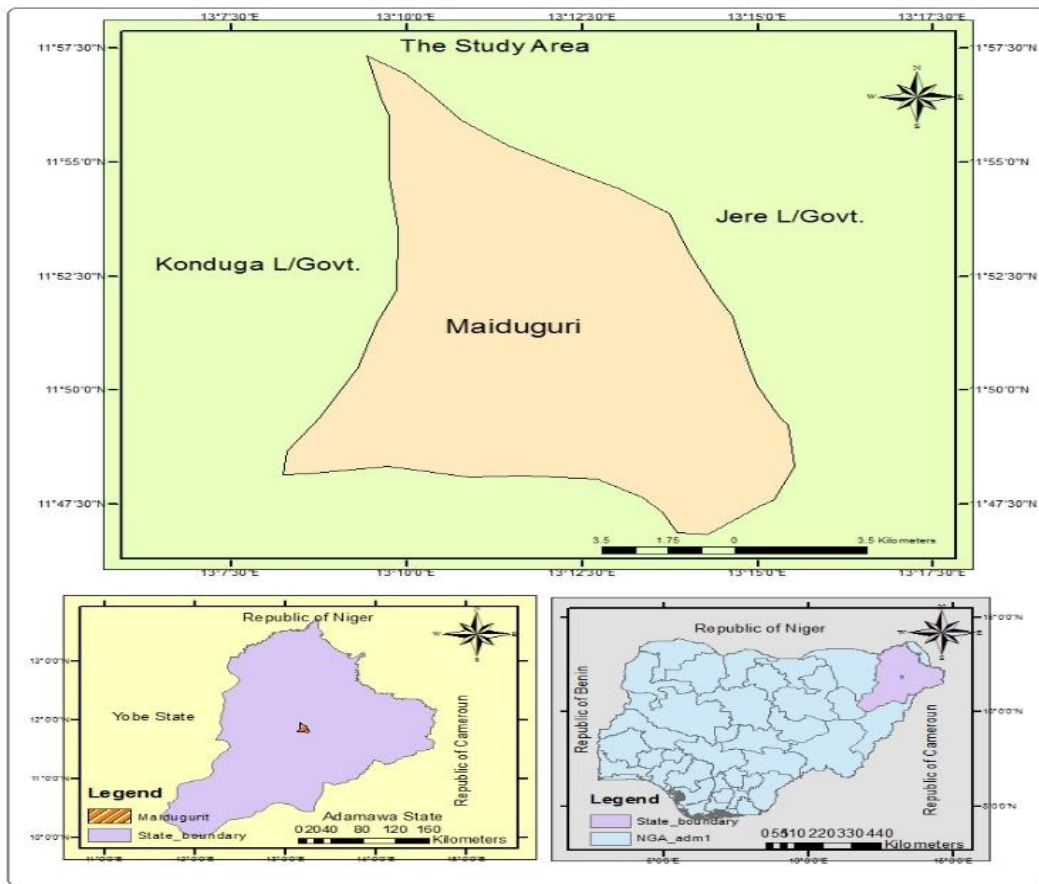


Figure 1. Map of the Study Area

2.2 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 to evaluate the performance of the production activities of the enterprise of the entire farm business. Performance indices such as profitability, gross margin, net farm income, the rate of returns to investments etc. are some 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 the 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 the farm business include farm profitability analysis, net farm income analysis, gross margin analysis and benefit cost ratio [17]. 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 the 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 as proposed by [18].

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

Where NFI = Net Farm Income from production per hectare, TR = Total Revenue/Returns from production per hectare, TC = Total Costs of production per hectare.

2.3 Benefit cost ratio

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).

$$BCR = \text{Benefit}/\text{Cost} \quad (2)$$

These were performed by identifying all costs incurred and the total revenue obtained from the production 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 were classified as fixed costs while costs that were incurred due to water application, planting, fertilizer application, weeding, harvesting and threshing were classified as a variable costs. The variable costs 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 of production 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 and benefit cost ratio and were determined using the procedures outlined by [17, 19, 20] as shown in equations 1 and 2 respectively.

2.4 Costs of Production

Costs of production are generally classified into fixed costs and variable costs. To facilitate 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 the maize cultivation under furrow irrigation method.

2.4.1 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 hectareage 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 hectares to arrive at its rent per hectare basis. The land rent per hectare therefore, was determined using equation (3).

$$LR = LP/FLS \quad (3)$$

Where LR = Land Rent per hectare, LP = Land Payments, FLS = Farm Land Size (Hectares).

2.4.2 Land Preparation

This involves clearing the land and then using farm tools or machines to harrow, 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 hectareage of the farm is the per hectare cost for land preparation. This was arrived at using equation (4).

$$LPC = TALP/FLS \quad (4)$$

Where LPC = Land Preparation cost per hectare, TALP = Total Amount Paid for the various Land Preparation activities, FLS = Farm Land Size (Ha).

2.4.3 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).

$$SC = TSC/FLS \quad (5)$$

Where SC = Seed Cost (Ha), TSC = Total Cost of Seed used, FLS = Farm Land Size (Ha).

2.4.4 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).

$$FC = TCF/FLS \quad (6)$$

Where FC = Fertilizer Cost per hectare, TCF = Total Cost of fertilizer used, FLS = Farm Land Size (Ha).

2.4.5 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 hectareage of maize farm to arrive at the fuel cost per hectare using equation (7).

$$FUC = TAF/FLS \quad (7)$$

Where FUC = Fuel Cost per hectare, TAF = Total Amount spent on fuel, FLS = Farm Land Size (Ha).

2.4.6 Rented pump

This is the amount paid for the use of 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 hectareage of the Maize farm using equation (8).

$$RP = TRC/FLS \quad (8)$$

Where RP = Rent of Pump per hectare, TRC = Total Rental Cost, FLS = Farm Land Size (Ha).

2.4.7 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 costed based on the average prevailing water rate using equation (9).

$$WCH = WUC/FLS \quad (9)$$

Where WUC = Total quantity of water used x average water rate, WUC = Total Cost of Water Used by the farmer, WCH = Cost of Water per hectare, FLS = Farm Land Size (Ha).

2.4.8 Rented Water Reservoir Cost

Water need 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).

$$RWR = TRC/FLS \quad (10)$$

Where RWR = Water Reservoir Rent per hectare, TRC = Total Rental Cost, FLS= Farm Land Size.

2.4.9 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 were calculated and divided by the size of the farm in hectares to get their per hectare values. For instance, water application cost per hectare is the total amount per water application divided 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

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 under the different irrigation methods and schedules are presented in Table 1. The result shows that the total cost of production for drip, sprinkler and furrow irrigation methods varied from 296.45 to 316.04, 404.11 to 468.05 and 259.51 to 297.31 \$/ha respectively. The total cost of production in sprinkler irrigation is comparatively higher than drip and furrow irrigation methods as shown in Table 1. This could be attributed to the higher initial cost of the sprinkler components and the costs involved in the maintenance of the system. The variable costs per hectare for the irrigation methods and schedules ranged from 46.90 to 66.49, 90.53 to 144.05 and 69.91 to 98.51 \$/ha for drip, sprinkler and furrow irrigation methods respectively. The variable costs of production are higher in sprinkler compared to drip and furrow irrigation methods. This is due to the capacity of the pump used by the sprinkler as well as the fuel consumption. The variable costs were also higher in pan and tensiometer irrigation techniques with shorter irrigation interval (4days) which resulted in higher cost of fuel and water application compared to the fixed irrigation interval of 7 days. 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 total revenue under the different irrigation schedules for drip, sprinkler and furrow irrigation methods ranged from 468.3 to 1011.2, 456 to 982.1 and 435.3 to 843.1 \$/ha respectively as shown in Table 2. Drip irrigation led the highest total revenue of \$1011.2 compared to \$982.1 from sprinkler and \$843.1 obtained using furrow irrigation methods as shown in Table 2. This could be due to the higher drip water application efficiency of 80%, which resulted in improved yield. 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).

Table 1. Total cost involved in maize production under the different irrigation methods and schedules

Items	Drip			Sprinkler			Furrow		
	Fixed	Tensiometer	IW/CPE	Fixed	Tensiometer \$/ha	IW/CPE	Fixed	Tensiometer	IW/CPE
Output									
Fixed inputs cost (FC)									
Land hiring	10.71(4.53)	10.71(4.19)	10.71(4.19)	10.71(3.65)	10.71(3.00)	10.71(3.00)	10.71(4.13)	10.71(3.60)	10.71(3.60)
Land preparation	17.86(7.56)	17.86(6.98)	17.86(6.98)	17.86(6.09)	17.86(5.00)	17.86(5.00)	17.86(6.88)	17.86(6.01)	17.86(6.01)
Seed	4.76(2.02)	4.76(1.86)	4.76(1.86)	4.76(1.62)	4.76(1.33)	4.76(1.33)	4.76(1.83)	4.76(1.60)	4.76(1.60)
Fertilizer	144.05(60.1)	144.05(56.3)	144.05(56.3)	144.05(49.1)	144.05(40.3)	144.05(40.3)	144.05(55.5)	144.05(48.5)	144.05(48.5)
Rented pump (1.5 hp)	-	-	-	-	-	-	5.32(2.05)	9.52(3.20)	9.52(3.20)
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	11.9	11.9	11.9	11.9	11.9	11.9
Sprinkler components	-	-	-	110.91	110.91	110.91	-	-	-
Drip components	60.27	60.27	60.27	-	-	-	-	-	-
Sub Total	249.55	249.55	249.55	313.58	324	324	194.6	198.8	198.8
Variable inputs cost (VC):									
Water application	21.43(9.07)	38.1(14.90)	38.1(14.90)	21.43(7.31)	38.1(10.7)	38.1(10.7)	26.79(10.3)	47.62(16.00)	47.62(16.00)
Weeding	4.46(1.89)	4.46(1.90)	4.46(1.74)	4.46(1.52)	4.46(1.25)	4.46(1.25)	4.46(1.72)	4.46(1.50)	4.46(1.50)
Fertilizer application	8.93(3.78)	8.93(3.49)	8.93(3.49)	8.93(3.05)	8.93(2.50)	8.93(2.50)	8.93(3.44)	8.93(3.44)	8.93(3.44)
Water Used	3.75(1.59)	6.67(2.61)	6.67(2.61)	4.52(1.54)	8.04(2.25)	8.04(2.25)	5.69(2.19)	10.12(3.40)	10.12(3.40)
Fuel	-	-	-	42.86(14.62)	76.19(21.33)	76.19(21.33)	10.71(4.13)	19.05(6.41)	19.05(6.41)
Harvesting	4.76(2.02)	4.76(1.86)	4.76(1.86)	4.76(1.62)	4.76(1.33)	4.76(1.33)	4.76(1.83)	4.76(1.60)	4.76(1.60)
Threshing	3.57(1.51)	3.57(1.40)	3.57(1.40)	3.57(1.22)	3.57(1.00)	3.57(1.00)	3.57(1.38)	3.57(1.20)	3.57(1.20)
Sub Total	46.9	66.49	66.49	90.53	144.05	144.05	69.91	98.51	98.51
Total Cost	296.45	316.04	316.04	404.11	468.05	468.05	259.51	297.31	297.31

The result further revealed that the highest net farm income and benefit cost ratio of \$695.2 and 3.2 respectively were obtained from the drip irrigation system compared to \$514.77 and 2.10 for

sprinkler and \$545.8 and 2.84 for furrow (Table 2). A relatively higher net returns but a lower benefit-cost ratio can be observed for the sprinkler system compared to furrow method of irrigation. This cannot be unconnected with the additional costs of installing and maintaining the sprinkler system which are not incurred in the furrow method thereby resulting in a lower benefit-cost ratio compared to the sprinkler system. The result of this study is similar to the findings of [21, 22, 23, 24].

Table 2. Net farm income for maize production under the different irrigation methods and schedules

Items	Drip			Sprinkler			Furrow		
	Fixed	Tensiometer	IW/CPE	Fixed	Tensiometer	IW/CPE	Fixed	Tensiometer	IW/CPE
Output	\$/ha								
Yield (kg)	2431.3	5056	5049.3	2281.3	4640.7	4635.7	2176.7	4215.3	4125.7
Unit price/100kg	20	20	20	20	20	20	20	20	20
Total revenue	468.3	1011.2	1009.8	456	982.1	927.1	435.3	843.1	825.1
Total Cost	296.45	316.04	316.04	404.11	468.05	468.05	259.51	297.31	297.31
Net farm income	171.8	695.2	693.8	52.61	514.77	459.77	176.1	545.8	527.3
Benefit cost ratio	1.58	3.2	3.2	1.13	2.1	1.98	1.68	2.84	2.78

4 CONCLUSIONS

Drip irrigation was found to be the most profitable irrigation method for maize production with higher net farm income of \$695.2 and benefit cost ratio of 3.2 compared to the net farm incomes of \$514.77 and benefit cost ratios of 2.10 obtained using sprinkler and \$545.8 and 2.84 from the furrow irrigated plots. It is recommended that, farmers in the semi-arid region of Nigeria should all things being equal adopt the use of drip irrigation method for improved maize production based on its proven performance and economic viability.

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