MODELLING OF IRRIGATION INTERVALS AND TILLAGE METHODS ON SOIL MOISTURE DISTRIBUTION, GROWTH AND YIELD OF MAIZE (*Zea Mays* L.) IN SEMI-ARID REGION, BORNO STATE, NIGERIA

Maina, K.D.[1*], Tya, T.S.K.[2], Umaru, A.B.[2] and Zamdayu, W.J.[3]

[1]Department of Agricultural and Bio-Environmental Engineering technology, Ramat Polytechnic, Maiduguri Borno State, Nigeria

[2]Department of Agricultural and Environmental Engineering, Modibbo Adama University Yola

[3]Department of Agricultural and Bio-Engineering Technology, Adamawa State Polytechnic Yola. Adamawa State, Nigeria

*Corresponding email: kachmaina@gmail.com

ABSTRACT

The specific mechanisms by which varying irrigation intervals interact with different tillage systems to impact root development, vegetative growth, and ultimately, yield remain inadequately understood. Additionally, the implications of these interactions for sustainable agricultural practices and resource-efficient water use have not been fully explored. This study aim to model irrigation intervals and tillage methods on soil moisture distribution, growth and yield of maize (zea mays l.) in semi-arid region, Borno state, Nigeria, thereby providing insights into optimizing water management practices for sustainable maize cultivation. This study examined the modeling of irrigation intervals and tillage methods on soil moisture distribution, growth, and yield of maize (Zea mays L.) under semi-arid conditions. The research addressed a critical gap in knowledge by evaluating the interaction between irrigation scheduling and tillage systems, and their combined effects on soil moisture availability, crop growth, and yield performance. The experiment was conducted at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri (11°47.840'N; 13°12.021'E; 319 m above sea level), where the physico-chemical properties of the soil were determined prior to planting. The study involved five tillage methods: disc harrow (DH), disc plough (DP), double disc harrow (DDH), double disc plough (DDP), and a combination of disc harrow and disc plough (DH + DP), alongside three irrigation intervals of two, four, and six days, including a control. These treatments were factorially combined, replicated three times, and arranged in a Randomized Complete Block Design (RCBD), resulting in 54 treatment plots over two cropping seasons. Basins were prepared manually, and standard agronomic practices were followed throughout the experimental period. Data collected included plant height, stem girth, number of leaves per plant, days to 50% tasselling and silking, cob length, cob diameter, cob weight, 1000-seed weight, and seed weight per cob. The data were analyzed using Analysis of Variance (ANOVA) in Statistical Analysis Software (SAS), with treatment means separated using Duncan's Multiple Range Test (DMRT). Regression analysis was also applied to develop a predictive model for maize yield. Regression analysis identified 1000-seed weight, cob weight, and cob length as the most significant determinants of yield, collectively explaining over 91% of the variation in maize productivity, while cob diameter and seed weight per cob were less influential. The study further established that a two-day irrigation interval was the most effective for optimal maize growth and yield under semi-arid conditions. Among the tillage systems, double disc ploughing produced the highest yield, whereas zero tillage resulted in the lowest performance. A predictive model for maize yield was developed as follows: Yield = 0.7442CL + 0.01003CL + 0.00265CD + 0.0101CW + 0.01731000SW − 0.00349WSPC. Overall, the findings provide valuable insights into optimizing irrigation and tillage practices for sustainable maize production in semi-arid environments. This research is recommended to evaluate the effectiveness of these practices across different soil types, maize varieties, and irrigation scheduling methods. Similar studies should also be conducted in other agro-ecological zones of Nigeria to validate the applicability of the findings under varying environmental conditions and to support broader agricultural policy development.Findings from this study provides evidence-based recommendations for famers and policy makers to adopt the two days irrigation interval while the integration of appropriate agronomic principles provides a robust foundation for growth and yield parameters of maize, DDP, DDH, and DH+DP are most effective soil management practices for maximizing maize productivity under water limited conditions, particularly the semi-arid region.

Keywords: Irrigation Interval, Modeling, Tillage, Moisture Content, Yield, Growth, Bulk Density, Leaf Area, Disc Plough, Disc Harrow, Plant Height

1 INTRODUCTION

Irrigation is defined as the artificial application of water to the soil for the purpose of supplying moisture which is essential for plant growth [1]. Irrigation is a pivotal practice in regions with erratic rainfall patterns or limited water availability. Effective irrigation scheduling directly influences soil moisture dynamics, which in turn affects nutrient uptake, photosynthesis, and overall plant performance. Research by [2] underscores the significance of appropriate irrigation intervals in maintaining favorable soil moisture levels, preventing water stress, and promoting optimal maize growth and yield. In contrast, inadequate irrigation intervals can lead to physiological stress, reduced leaf area, and diminished grain yield [3]. Moisture distribution refers to the spatial and temporal variation of water content within soil layers and across landscapes. It plays an essential role in the hydrological cycle because it influences evapotranspiration, groundwater recharge, plant growth, and climate interactions. Understanding soil moisture distribution is therefore important for agriculture, irrigation management, and environmental sustainability. Several studies have shown that soil moisture distribution is controlled by soil physical properties such as texture, structure, porosity, and hydraulic conductivity. Coarse-textured soils like sandy soils allow rapid infiltration but have low water-holding capacity, whereas clay soils retain water for longer periods due to their fine pore structure [4]. Climate factors also influence moisture distribution. Rainfall provides the primary input of water into the soil system, while temperature, wind, and solar radiation regulate evaporation and evapotranspiration processes. Research indicates that soil moisture tends to increase with precipitation and decrease with higher temperature and sunshine duration [5]. Vegetation further affects moisture distribution through root water uptake. Plants extract water from different soil depths depending on their root systems, which creates vertical gradients in soil moisture within the root zone [6]. Agricultural practices such as irrigation can also modify soil moisture distribution patterns, particularly under drip irrigation systems where water spreads both vertically and horizontally from emitters [7]. Recent technological advances have improved the monitoring of soil moisture distribution. Traditional measurement methods such as gravimetric sampling and soil moisture sensors are now complemented by remote sensing techniques and hydrological models, which enable researchers to observe soil moisture dynamics over large spatial scales and longer time periods [8].Overall, understanding moisture distribution is important for improving irrigation efficiency, predicting drought conditions, and managing water resources sustainably. Efficient irrigation intervals and appropriate tillage systems play crucial roles in determining soil moisture distribution, crop growth, and ultimately, yield. Irrigation is a pivotal factor in modern agricultural practices, especially in areas where rainfall is inadequate or unpredictable. The timing and frequency of irrigation events significantly impact soil moisture levels, affecting nutrient availability, root development, and overall plant health. According to [9], improper irrigation intervals can lead to water stress, reduced photosynthesis, and lower grain yields in maize crops. Conversely, optimal irrigation scheduling enhances water use efficiency and promotes desirable growth patterns. [11] reported that water scarcity is an ever-increasing problem in irrigation schemes which requires improved water management that results in equitable and efficient distribution of the available water resources for irrigation supply. Efficient operation and management of an irrigation system play an important role in the sustainability of irrigated agriculture [10]. Thus, to determine the influence of irrigation intervals and tillage methods on soil moisture distribution growth and yield of crops cannot be over emphasized. Maize (*Zea mays* L.) is a crucial crop with global significance, providing sustenance and economic livelihood to millions of people. The successful cultivation of maize is heavily reliant on optimal water management practices, including irrigation intervals and tillage systems. However, there exists a knowledge gap concerning the intricate interactions between these factors and their combined effects on soil moisture distribution, crop growth, and yield. Despite the importance of irrigation intervals and tillage systems, there is limited empirical research that comprehensively investigates their synergistic influence on soil moisture dynamics and subsequent maize productivity. The specific mechanisms by which varying irrigation intervals interact with different tillage systems to impact root development, vegetative growth, and ultimately, yield remain inadequately understood. Additionally, the implications of these interactions for sustainable agricultural practices and resource-efficient water use have not been fully explored. This study seeks to address this critical knowledge gap by systematically examining the interplay between irrigation intervals and tillage systems and their cumulative impact on soil moisture availability, maize growth responses, and yield outcomes, in semi-arid regions. The aim of this study is to investigate the influence of different irrigation intervals and tillage systems on soil moisture distribution, growth, and yield of maize *(Zea mays* L.), thereby providing insights into optimizing water management practices for sustainable maize cultivation. The objectives of the study are to; assess the status of soil moisture under different irrigation intervals and tillage methods on soil physical properties and determine the influence of irrigation intervals and tillage methods on growth parameters of maize.

2 MATERIALS AND METHODS

2.1 Experimental Site

The study was carried out at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri, (11^{o}47.840’N; 13^{o}12.021’E; elevation 319 m above sea level), Borno State. Borno State is located in the northeastern sub-region of Nigeria. The map of Nigeria showing semi-arid region of Borno State is presented in Figure 1. The rainfall in Maiduguri starts in May/June with moisture regime reaching a peak in August and terminating in September/October each year. Mean annual rainfall in Maiduguri is less than 500mm all concentrated between June to September [12]. The rainy season is followed by a long dry season except during the short period of November to February when the harmattan blows. The period can be quite cool and temperature as low as 18^{o}C could be attained [12]. During the month of April to May, the temperature could be as high as 45^{o}C. However, during the harmattan period, the mean monthly temperature could be as low as 22^{o}C. The relative humidity of the area on average is low and August is the most humid (68%) on the average. March is the least humid (12%). The soil of the research farm had earlier been classified as Typic Upstisanment with Aeolian sand formation and weakly aggregated. The soil has a sandy loam texture and made up of 6% silt, 17% clay and 77% sand. The coldest month of the year in Maiduguri is January with average minimum and maximum temperature of 29^{o}C and 42^{0}C respectively [13]. Also, the air temperature ranges between 21^{0}C and 34^{0}C, and relative humidity ranges from 60% to 83% [14]. The major crops grown in the area are maize, guinea corn, millet and rice, while vegetables grown are tomato, onion, spinach, lettuce and okra [15].

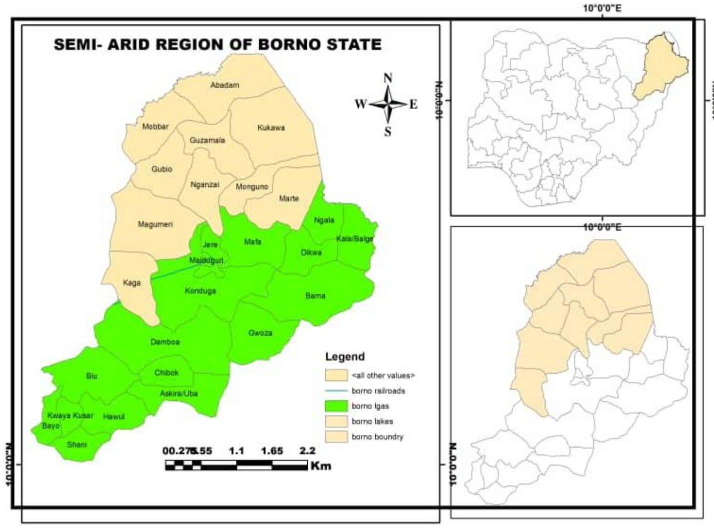

Figure 1. Map of Nigeria showing semi-arid region of Borno State

2.2 Determination of Physico-chemical Characteristics of Soil of the Experimental Sites

The soil of the experimental site was sampled randomly by auger borings in four places to a depth of 0-30cm [15]. The soil samples were bulked, air-dried and sieved through 2 mm sieve before Physico-chemical analysis was carried out in the Soil Science Laboratory of the Department of Soil Science, University of Maiduguri. The particle size analysis was carried out using the Hydrometer Methods described by. The textural class of the soil was obtained using Marshall's textural class triangle. According to [19] on good soils, maize can have a maximum rooting depth of 2.8m or deeper near the time of maturity.[20] reported that, the roots of plants well-watered throughout the experimental period penetrated the soil profile to a depth of 60cm while the greatest percentage of total root length was between 20 and 40cm. The pH was determined by using glass electrode pH meter as described by [21]. The organic carbon content of the soil was determined using the Dichromate Wet Oxidation Method described by [22]. Field capacity was determined in the laboratory using a pressure plate to apply a suction of -1/3 atmosphere to a saturated soil sample. When water is no longer leaving the soil sample, the soil moisture in the sample was determined gravimetrically and equated to field capacity. Wilting point was determined in the laboratory, by the retention curve method. Permanent wilting point: the permanent wilting point was estimated using the procedure outlined by [23]. A cylinder was filled with air dried sieved soil and placed on a plate. The sample was saturated with water and the plate with cylinder was transferred to a pressure chamber and a pressure of 15 bars was applied. The sample was removed after extraction, weighed and oven dried for 24 hours at a temperature of 105^0c. Soil sample was finally removed after drying and reweighed. The permanent wilting points (PWP) were calculated from the formula:

$$\mathrm{PwP} = \frac{\mathrm{Mw}}{\mathrm{Ms}} \tag{1}$$

Where; PwP= Permanent wilting point on weight basis, (Kpa), Mw= Mass of water, (g/mol), Ms= Mass of oven dried soil (Kg/m^3). Available water content was determined by the three essential parameters, apparent specific gravity of the soil(s), Depth of the Root zone of the plant (d) and water content (m). The formula for calculating depth of available water:

$$\mathrm{Dw} = \mathrm{s.d.m} \tag{2}$$

Where; d_w = Depth of available water (m), s = Depth of the root zone of the plant (m), m = water content (%). Bulk Density was determined by excavating a quantity of soil, drying and weighing it and the Bulk density was also determined with core sample [107] and calculated as:

$$\text{Bulk Density} = \frac{\mathrm{Md\ (g)}}{\mathrm{Vb(cm^3)}} \tag{3}$$

Where; M_d is mass of oven-dried soil (g) and V_b is Volume of bulk soil (cm^3).

2.3 Experimental Design and Treatments

The experimental factors considered in this study are tillage methods and irrigation intervals, each at three levels. The tillage methods are namely, disc harrow (DH), disc plough (DP), double disc harrow (DDH), double disc plough (DDP) and disc harrow (DH) + disc plough (DP) and the irrigation intervals are two days, four days, and six days respectively was considered and one control plot making total of nine factors [16]. These factors were combined and replicated three times to form a total of 54treatments, which was laid out in a Randomized Complete Block Design (RCBD) for the period of two years. The experimental field was 55m x 32.5mand was divided into 54 plots of 5m x 5m with alleys of 0.5m between the plots. The space was use to accommodate the tread width of 2.5m and the length of 4.80m of the tractor with implement and to allow the tractor gain speed before the tillage operation were carried out in line with [17]. The field was cleared and laid out before the treatments were applied. Maize (*Zea mays* L.) seeds of TZE yellow variety were planted [24]. Disc Ploughing was done at an average depth of 30cm with a 3-furrow mounted Disc Plough (DP) having 65cm disc diameter. Harrowing was done with an offset Disc Harrow (DH) at an average depth of 15 cm with 55cm diameter discs in line with [25]. Zero Tillage (ZT) involves planting on bare land with no soil disturbance, whereas the other treatments were carried out by Ploughing followed by Harrowing using the above implements.

2.4 Statistical Analysis

All data collected in the research was subjected to Analysis of Variance (ANOVA) as described by [34] using Statistical Analysis Software (SAS). Differences between treatments mean were separated using Duncan's Multiple Range Test (DMRT). Regression analysis was also employed for developing models.

ANOVA is a statistical method used to test for significant differences among the means of three or more groups while controlling the risk of type 1 error. It helps researchers identify sources of variation and analyze complex experimental designs, including interactions between variables. Overall, ANOVA enhances the validity and reliability of research findings [26, 27, 28]. Regression analysis is important in research because it enables the examination quantification of relationships between variables, allowing for prediction and control of confounding factors, thereby improving the accuracy of results [29]. It also supports hypothesis testing and modeling of complex real-world phenomena, enhancing the validity and generalizability of findings [30].

2.4.1 Multiple Regressions

Multiple regression analysis was employed for the model construction to sort out the effect of different tillage methods on maize in the study area over a period of two years. Maize yield was used as the dependent variable while the tillage methods (ZTcontrol, DH, DP, DDH, DDP and DH+DP) are the independent variables.

$$Y = \alpha + \beta 0x1 + \beta 1x2 + \beta 2x3 \ldots\ldots.. + \beta nxn + e \quad [33] \tag{4}$$

Where, Y= dependent variable, X= independent variable, α= constant variables, β=coefficient of independent variables, e=error. An excel computer package wasused to generate the predicted maize yields. The model was validated by using non-linear regression procedure in SAS Version 16.0 for windows. This procedure minimizes the error inherent in the data using interactive steps. It usually required that initial values of coefficients be provided. The initial values of the coefficients were obtained using the non-linear regression procedure for the various types of tillage methods.

2.5 Mathematical Model of Different Tillage Method on Plant Growth and leaf Area Index

2.5.1 Model Development

This model development was based on the following assumptions:(i)Yield increase linearly with increase in soil moisture content within the context of irrigation period in the recorded experimental area.(ii)Yield increases linearly with increase or decrease in different tillage method as observed throughout the period of experiment.(iii)Yield increases with increase in plant growth (height).(iv)Yield increases with increase in leaf area index.(v)Yield increases or decreases with method of tillage.(vi)The tillage methods ZT (Control), DH, DP, DDH, DDP and DH+DP are qualitative measurements. From the foregoing:

$$Y = f\,(ø, Pg, LAI, NLPP, \delta d, Pr) \tag{5}$$

Where;Y = maize yield (t/ha), ø = moisture content (%), Pg = Plant growth or plant height (cm), δd = Bulk density (kg/m^3), Pr = penetration resistance (Mpa), LAI = Leaf Area Index (c), NLPP = Number of leaves per plant. Sorting out the qualitative parameters, equation (6) becomes.

$$Y = f\,(Pg,\ LAI,\ NLPP) \tag{6}$$

Assuming that Y is a linear function of Pg, LAI, NLPP. Equation could be written as follows:

$$YPg = f\,(Pg) \tag{7}$$

$$YPg = C1 + a1Pg \tag{8}$$

$$YLAI = f\,(LAI) \tag{9}$$

$$YLAI = C2 + a2LAI \tag{10}$$

$$YNFPP = f\,(NLPP) \tag{11}$$

$$YNFPP = C3 + a3NLPP \tag{12}$$

$$Y = C1 + a1Pg - C2 + a2LAI + C3 + a3NLPP \tag{13}$$

Let,

$$C1 + C2 + C3 = C1 \quad (14)$$

Therefore,

$$Y = C1 + a1Pg - a2LAI + a3NLPP \quad (15)$$

Other extraneous factors that are uncounted for could be termed as error,

$$Y = C1 + a1Pg - a2LAI + a3NLPP + e \quad (16)$$

Model with the context of this study can be viewed as system which receives and translate set of input variables into set of output variable through number of processes. The input variables in NLPP are the different tillage methods. Multiple regression analysis was employed for the model construction to sort out the effect of different tillage methods on maize in the study area over a period of two years. Maize yield was used as the dependent variable while the tillage methods (ZT control, DH, DP, DDH, DDP and DH+DP) are the independent variables. The model equation is presented as:

$$NLPP = \propto + \beta x + e \quad (17)$$

Where = constant variables, β= coefficients of independent variables, X = ZT, DH, DP, DDH, DDP and DH+DP (independent variables), e =error, NLPP = maize yield (dependent variable).

2.5.2 Model Validation

The model was validated by plotting the predicted versus the observed yield. The model is said to be validated if the predicted values are in good agreement with the observed data. Predicted maize was obtained using the developed model**.**

3 RESULTS AND DISCUSSION

This paper presents the results and discussion of the study on the influence of irrigation intervals and tillage methods on the growth and yield performance of maize under semi-arid conditions. The analysis emphasizes key agronomic variables such as plant height, stem girth, leaf characteristics (number, length and width) and yield components, with the aim of evaluating the effectiveness of different tillage method and irrigation intervals practices in enhancing maize productivity. The experiment was conducted using a factorial design to capture both the individual and interactive effects of tillage methods (i.e. deep tillage, zero tillage and combined operations and disc ploughing and harrowing) and irrigation intervals (ranging from 2 to 6 days). This design allowed for a systematic assessment of tillage method and irrigation interval jointly influences maize growth. Statistical tools such as Analysis of Variance (ANOVA), descriptive statistics and least squares linear regression were employed to analyze the data. The results are presented in a structured manner: first examining the growth parameters across different treatments, then evaluating yield and yield components and finally identifying the agronomic traits most strongly associated with yield performance. The regression analysis provides further insights into the contribution of cob length, cob diameter, cob weight, 1000-seed weight and seed weight per cob to overall yield, supported by model diagnostics i.e. R^2, ANOVA and Variance Inflation Factors (VIF).

3.1 Least Squares Linear Regression of Yield

Least Squares Linear Regression analysis was conducted to identify the major agronomic traits influencing maize yield under different treatments. The regression model examines the relationship between yield (the dependent variable) and six predictor variables: Cob Length, Cob Diameter, Cob Weight, 1000-Seed Weight (1000SW), Weight of Seed per Cob and a constant term. By analyzing the coefficients, significance levels and model diagnostics such as R^2, ANOVA and Variance Inflation Factors (VIF), the analysis aims to determine which traits significantly contribute to variations in maize yield and evaluate the overall fit and reliability of the model.

Table 1. Analysis of Variance (ANOVA) and Model Significance

Sources of Variation	Df	SS	MS	F	p-value
Regression	5	15.9831	3.19662	53.55	0.00001
Residual	102	6.08825	0.05969		
Total	107	22.0714			

The ANOVA table confirms the overall significance of the regression model ($F = 53.55$, $p < 0.0001$) because the p-value is less than the level of significant, meaning at least one predictor significantly affects Yield. The Regression Sum of Squares (15.9831) and Residual Sum of Squares (6.08825) further validate the explanatory power of the model.

Table 2. Least Squares Linear Regression of Yield

S/N	**Predictor Variables**	**Coefficient**	**Std. Error**	**T**	**p-value**	**VIF**
1.	Constant	-0.74423	0.10048	-7.41	0.0000	0
2.	Cob Length	0.01003	0.00328	3.06	0.0029	1.3
3.	Cob Diameter	0.00265	0.00197	1.34	0.1828	2.3
4.	Cob Weight	0.0101	0.00263	3.84	0.0002	34.6
5.	1000 SW	0.01731	0.00569	3.05	0.0030	14.7
6.	Weight of Seed Per Cob	-0.00353	0.00528	-0.66	0.5094	52.3

Table 2 present the summary of the regression analysis. Results revealed that, among the predictor variables, Cob Length (coefficient = 0.01003, $p = 0.0029$) is statistically significant, which means it has a positive and significant effect on Yield. Similarly, Cob Weight (coefficient = 0.0101, $p = 0.0002$) shows a highly significant and positive influence on Yield. Furthermore, 1000 SW (coefficient = 0.01731, $p = 0.003$) is statistically significant and has the strongest positive effect on Yield among all variables, suggesting that increases in seed weight contribute significantly to higher Yield. In contrast, Cob Diameter (coefficient = 0.00265, $p = 0.1828$) is not statistically significant, implying that it does not have effect on Yield in this model. Likewise, Weight of Seed per Cob (coefficient = -0.00353, $p = 0.5094$) is not significant and has a negative relationship with Yield, indicating that variations in seed weight per cob do not significantly influence Yield.

Table 3. Model Fit and Goodness-of-Fit

S/N	Statistic	Value
1.	R^2	0.9103
2.	Adjusted R^2	0.9059
3.	AICc	-416.78
4.	PRESS	11.695
5.	Mean Square Error (MSE)	0.01941
6.	Standard Deviation	0.13932

The model fit and goodness-of-fit statistics indicate that the regression model provides an excellent fit to the data. The R^2 value of 0.9103 suggests that approximately 91.03% of the variability in Yield is explained by the predictor variables, demonstrating a very strong relationship between the predictors and Yield. The Adjusted R^2 of 0.9059, which adjusts for the number of predictors in the model, remains very high. This confirms that the model is robust and that the inclusion of additional predictors meaningfully contributes to explaining the variation in Yield. The AICc value of -416.78 indicates a good model fit, as lower AICc values generally reflect better model performance while penalizing unnecessary complexity. The Prediction Sum of Squares (PRESS) value of 11.695 further supports the model's predictive accuracy, with a relatively low error in predicting new observations. In addition, the Mean Square Error (MSE) of 0.01941 and the Standard Deviation of 0.13932 demonstrate that the residuals are small, indicating that the predictions of the model are close to the observed values. The regression equation is given in equation 18:

$$\text{Yield} = -0.7442\times CL + 0.01003\times CL + 0.00265\times CD + 0.0101\times CW + 0.0173\times 1000SW - 0.00349\times WSPC \quad (18)$$

Where: Yield is the predicted yield and CL, CD, CW, 1000 SW and WSPC are the predictor variables.

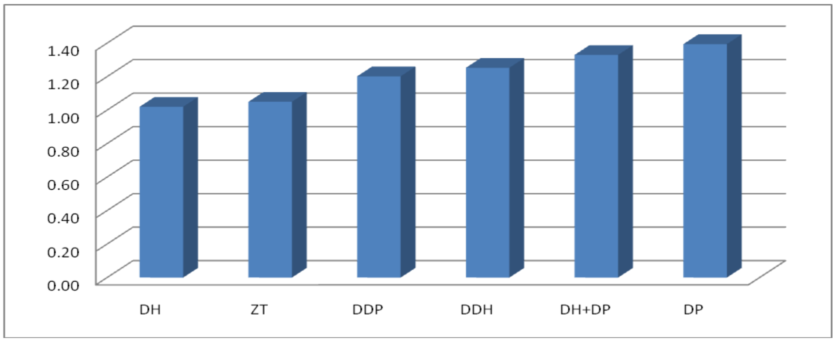

Figure 2. Maize Yield by different tillage method 2024

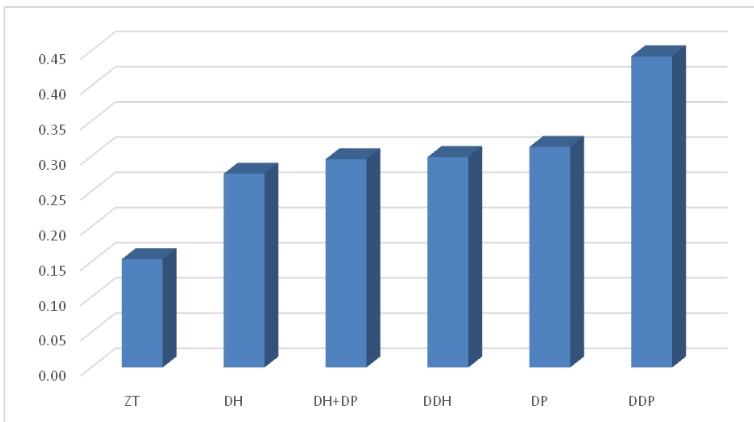

Figure 3. Maize Yield by different tillage method 2025

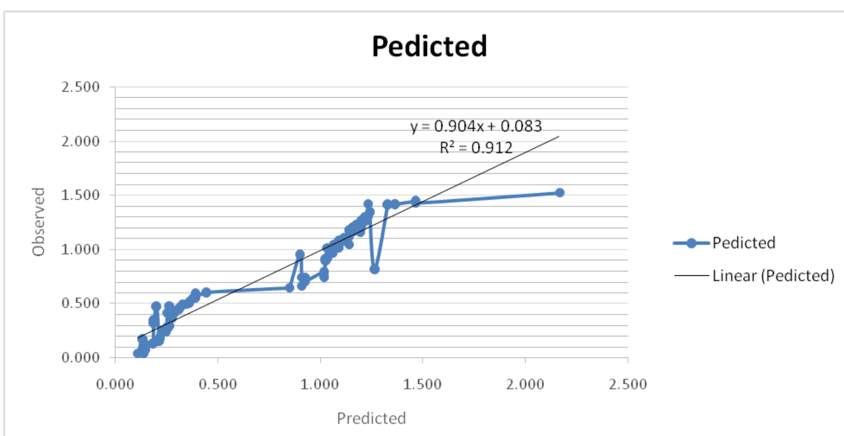

Figure 4. Observed vs. predicted

3.2 Temperature Before and After Irrigation

To evaluate the impact of different treatments on temperature variation before and after irrigation, a one-way analysis of variance (ANOVA) was conducted using temperature difference as the test variable. This statistical approach allowed us to compare mean temperature changes across multiple treatment groups. The results are presented below.

Table 4. Temperature Before and After Irrigation

	Years		
Treatments	2024	2025	Combined
DDH	3.2778^{a}	3.3000^{a}	3.3077^{a}
DH+DP	3.2500^{a}	3.3158^{a}	3.2759^{a}
DH	3.1667^{ab}	3.1765^{ab}	3.1923^{ab}
DDP	3.0556^{abc}	3.2941^{a}	3.1538^{ab}
ZT	2.7500^{bc}	2.9333^{ab}	2.8261^{bc}
DP	2.6667^{c}	2.7500^{b}	2.6923^{c}

Means followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test ($P \geq 0.05$). DDP = Double Disk Plough, DP = Disk Plough, DH + DP = Disk Harrow + Disk Plough, DDH = Double Disk Harrow, DH = Disk Harrow, ZT = Zero Tillage, PH = Plant Height, SG = Stem Girth, NLPP = Number of Leaves Per Plant, LL = Leaf Length, LW = Leaf Width *All geometrical values are measured in centimeters (cm). The data presented in Table 3.4 illustrates the variation in temperature before and after irrigation across different treatments over the years 2024 and 2025, along with their combined data. Treatments such as DDH and DH+DP recorded the highest temperatures difference before and after irrigation with values above 3.25°C in both years and in the combined analysis. These two treatments were statistically similar, as denoted by the superscript "a". DH and DDP showed moderately high temperatures difference, with DDP showing higher temperature difference in 2025 compared to 2024. ZT and DP on the other hand, exhibited the lowest temperature difference, particularly DP, which remained below 2.75°C across all years and was statistically distinct from the higher-temperature treatments. This could be due to the increased in moisture content which reduced the soil temperature, in DDP showing higher temperature difference in 2025, while ZT and DP in 2024 which has lowest temperature difference respectively. The results are similar to the findings of [14]. Knowledge of the agro ecology where crops are produced is among the suitability criteria for crop production. Climatic factors, mainly rainfall and temperature, affect the sustainable production of the crop, alter the planting date, and could cause a yield reduction. According to [31], temperature affects maize production from seed germination to grain filling, and it needs an optimal temperature range of 20°C to 22°C for the whole growing season. Climate change can reduce maize yield by 46% in semi-arid areas and may increase it by up to 59% in sub humid/ humid areas of Ethiopia in 2080 [32].

4 CONCLUSIONS

This study evaluated the modeling of irrigation intervals and tillage methods on soil moisture distribution, growth, and yield of maize (*Zea mays* L.) under the semi-arid conditions of Borno State, Nigeria. The findings clearly demonstrate that both irrigation scheduling and tillage practices play critical and interrelated roles in determining soil moisture dynamics, crop growth, and overall productivity. The assessment of soil moisture status revealed that irrigation interval significantly influenced the availability and distribution of moisture within the soil profile. Shorter irrigation intervals, particularly the two-day schedule, ensured more consistent soil moisture levels, thereby improving water availability to the crop. Tillage methods also affected soil physical properties, with intensive tillage systems enhancing soil structure, porosity, and moisture retention compared to less intensive or zero tillage practices. In terms of growth parameters, maize plants subjected to more frequent irrigation and intensive tillage exhibited superior vegetative performance, including increased plant height, stem girth, and number of leaves. These improvements can be attributed to better soil moisture conditions and enhanced root development, which facilitated efficient nutrient and water uptake. Furthermore, the validation of crop evapotranspiration (ETc) models confirmed their relevance and applicability in estimating crop water requirements within the study area. The models proved useful in supporting irrigation scheduling decisions, thereby enhancing water use efficiency. A model for predicting maize yield has been determined as follows; Overall, the study establishes that optimal maize production in semi-arid regions is highly dependent on the integration of appropriate irrigation intervals and effective tillage practices. The combination of a two-day irrigation interval with intensive tillage systems provides the most favorable conditions for soil moisture conservation, improved crop growth, and maximum yield. These findings contribute significantly to the development of sustainable agricultural practices aimed at improving food security and resource use efficiency in water-limited environments.

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