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MODELING THE IMPACT OF CLIMATE ON THE POTENTIAL YIELD OF MAIZE IN THE UPPER WEST REGION USING THE AQUACROP MODEL

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ABSTRACT

The potential yield of maize cultivated under rain-fed was simulated using the FAO AquaCrop model using climate data from the Wa Meteorological Station as a case study for the region. The potential maize yield was simulated by delineating the climate and the soil as a water storage reservoir to store the rainfall as the only limiting factors to the potential yield of maize. Hence the only limiting factors to the potential yield of maize were temperature stress and water stress which are climate driven. It's assumed that other factors such as access to certified viable high yielding seeds, soil fertility and productivity, pests and diseases control, weeds control and other economic and technological constraints are non-limiting and favourable for potential yield of maize. The results indicate that climate has a great impact on maize yield hence when to plant and which variety to plant is critical. The simulation was run on three most common maize varieties planted in the region (Obatanpa, Aburohima and Dodzi) cultivated on deep uniformly sandy loam soil. The simulated average potential yield of Obatanpa for the 2009, 2010 and 2011 farming seasons planted between late-May to mid-July which is the recommended planting period were; 12.61 ton/ha, 12.36 ton/ha and 12.48 ton/ha respectively. That of Aburohima for the same farming seasons planted between early-June to late-July were; 9.58 ton/ha, 8.97ton/ha and 9.62 ton/ha respectively. And that of Dodzi planted for the same seasons between early-June to early-August were; 8.82 ton/ha, 8.12 ton/ha and 8.63 ton/ha respectively.

I. INTRODUCTION

Maize is among the major grain crops produce in the region mainly by rain-fed and is mostly cultivated on small-scale by peasant farmers. Large commercial farmers are just a few in the region because of the low average yield of maize in the region about 1.59 tons/ha as presented by Statistics, Research and information Directorate (SRID), Ministry of Food and Agriculture (MoFA) [1] (see Table 1) and this does not encourage investment into large commercialisation of maize crop production.

TABLE .1. MAIZE PRODUCTIVITY IN THE UPPER WEST REGION

Year	Area(Ha)	Production (Mt)	Mt/Ha
2009	45,600	70,660	1.55
2010	56,370	96,018	1.70
2011	67,350	82,651	1.23
2012	50,655	92,700	1.83

(Source: SRID of MoFA, 2012)

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International Journal of Engineering Sciences & Management Research

Financial institutions therefore do not want to take the risk of supporting farmers. One obvious reason is the uncertainty of good yield due to popular opinion of the uncertainty of weather condition seasonally due to climate variability and climate change. The seasonal climate variability of the arid weather of the region is a major concern to farmers and investment alike. When to plant is therefore a critical decision to make since the weather condition during the rainy season is characterised by intermittent droughts and heavy down pours. This phenomenon affects crop growth, yield and quality of the yield. Building a robust decision support tool for crop production in the region using long-term climate data is of utmost importance even though climate variability and climate change dimension is highly unpredictable. It is therefore important to investigate the impact of only climate on the potential yield of maize by delineating climate which is not in the control of the investors and farmers from other factors which are deficiencies of technological and economical factors, which investors and farmers can improve to ensure high yields.

Due to seasonal climate variability and climate change, recommended cropping calendars have to be reviewed and updated continuously and also the yield responses to the climate variability and climate change have to be evaluated in other to improve the yield of crops by adapting to climate variability and climate change in other to build the confidence of farmers and investors to increase their production to combat the food insecurity situation in the region.

Crop potential yield is a direct response to the prevailing climatic condition, the soil condition and the cultivation practices to ensure the crop have the favourable unlimited environment for growth and for yield formation. Hence, to simulate the yield of crops, local climatic data are required to determine crop response to climate data. Climate influences the crop water requirement, the crop development and the growth stages and the yield. The soil type and its characteristics determines its' ability to provide favourable non-limiting soil environment for optimum crop growth such as soil water holding capacity, soil fertility and productivity. Cultural practices such as mulching, manure and fertilizer application, weeds control, pests and diseases control, irrigation also ensures that the crop have the favourable non-limiting environment for optimum growth and optimum yield.

For maximum crop yield, the crop must be a high yielding variety, grown in a favourable climatic condition, in a soil with non-limiting water availability and soil nutrient and diseased free with non-limiting economic environment to restrict proper cultural practices. The AquaCrop model used for the potential yield simulation, integrate all this factors expect that it does not include the effects of diseases and pests and weeds control it assumed that the crop is diseased free.

In simulating potential yield response to only climate, it's assumed that all other factors mentioned above are favourable and non-limiting and potential yield is only influence by climate. The soil is only considered as a storage reservoir to conserve the rainfall in the root zone and since the rainfall is climate factor, the soil water availability is dependent only on the rainfall and therefore a climate limiting factor. The major climatic parameters therefore required are: the air temperature, the relative humidity, the wind speed and the solar radiation or sunshine hour on daily time steps. These combined parameters affects the evapotranspiration rate which is directly proportional to the consumptive crop water use and hence directly affects the potential yield. Also, crops requires' the optimum air temperature for effective growth, above or below which crops will suffer from heat stress or cold stress and this affects the yield. The rainfall provides the soil moisture at the root zone to meet the consumptive crop water for optimum growth and yield. Therefore, in selecting model for simulating yield it is therefore important to select a model that factors the effects of the above parameters and demonstrates proper understanding of crops responses on daily time steps. The AquaCrop is preferred because of simplicity; robustness and accuracy (Fig. 1). The study considered the following objectives.

- To generate possible planting dates for three cropping rainy seasons in the region.

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International Journal of Engineering Sciences & Management Research

- To simulate impact of only climate on the potential yield of three common maize varieties cultivated under rain-fed in the region for the three cropping seasons.
- To provide enough information on the potential yield of the three maize varieties in the region and to recommend suitable cropping calendar.

II. MATERIALS AND METHODS

2.1. CLIMATE DATA

Climatic data was taken from the Wa Meteorological Station located at the Wa township on latitude 10.04°N, longitude 2.01°W and at altitude 322.7 m above sea level. The data comprises the rainfall, air temperature (maximum and minimum), the air relative humidity (maximum and minimum), the wind speed and the sunshine hours.

2.2. RAINFALL AND ETO DISTRIBUTIONS AND TRENDS ANALYSIS

The monthly and yearly rainfall and ETo distributions were displayed using time series sequential plots. To determine the monthly trends, the leading and lagging moving averages were employed to smooth the data. The linear trends were then determined using the smoothened data. The box plots were also employed to display the data ranges. The monthly rainfall histogram and the monthly sequential plot were displayed in the same graph to compare between the variables and to help determine when to plant to avoid water stress.

2.3. AQUACROP MODEL

Maize yield was simulated using the AquaCrop Model Version 3.1, the Food and Agriculture Organization (FAO) crop model to simulate yield response to water stress [2]. The AquaCrop Model environment consist of sub-model components that includes: the soil, with its water balance; the crop, with its development, growth and yield; the atmosphere, with its thermal regime, rainfall, evaporative demand and carbon dioxide concentration (CO_2); and the management, with its major agronomic practice such as irrigation and fertilization.

For potential yield simulation it is assumed that only the atmosphere (climate) is the limiting factor for crops growth, development and yield formation all other factors are non-limiting. Under the climate, five weather input parameters required to run the simulation were inputted. These are daily maximum and minimum air temperatures, daily reference crop evapotranspiration (ETo), daily rainfall and the mean carbon dioxide concentration. The mean carbon concentration data was taken from the Mauna Loa Observatory record in Hawaii which is included in the model structure, while others input variables were taken from the Wa Meteorological Station. The yield simulation was run for three cropping years (2009-2011). The statistical summary of the climate input variables are presented in Table 2.

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International Journal of Engineering Sciences & Management Research

The daily reference crop evapotranspiration (ETo) was determined using the ETo Calculator Version 3.1 software [3]. The ETo Calculator (EToCal) was developed by the FAO in 2009 and employ's the FAO Penman-Monteith (FAO-PM) method for calculating the ETo. In determining the ETo for the model input, using the FAO-PM method, measurable agro-meteorological weather input variables are required: the daily maximum and minimum air temperature, daily maximum and minimum air relative humidity, daily air wind speed and the daily sunshine hour. The station data such as the altitude, latitude and longitude and other location characteristics that are also required were inputted. The FAO-PM equation for the hypothetical reference crop evapotranspiration is expressed as below in (1), [4]. For detailed calculation steps, consult FAO Irrigation and Drainage Paper N^{o} 56 [4].

$$ETo_{FAO-PM} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where ETo_{FAO-PM} ET_o estimated by the FAO-PM [mm/day]; R_n net radiation at the crop surface [MJ m^2/day]; G soil heat flux density [MJ m^2/day]; T mean daily air temperature [^{o}C]; u_2 daily wind speed at 2 m height [m/s]; e_s saturation vapour pressure [kPa]; e_a actual vapour pressure [kPa]; $e_s - e_a$ vapour pressure deficit [kPa]; Δ slope of the saturation vapour pressure temperature curve [kPa/^{o}C]; and γ psychrometric constant [kPa/^{o}C].

Variables	Tmax	Tmin	ETo mm/day	Rainfall mm/day
2009				
Max	43.50	28.00	7.50	65.10
Min	25.00	16.30	2.00	0.00
Mean	33.87	22.65	4.65	3.09
Std	3.34	5.89	1.11	8.67
Cov	11.12	2.43	1.23	75.21
2010				
Max	42.00	30.50	9.60	88.20
Min	22.10	16.60	1.90	0.00
Mean	34.39	23.44	4.74	2.83
Std	3.49	2.48	1.20	9.80
Cov	12.19	6.16	1.45	96.07
2011				
Max	41.00	28.10	7.60	72.80
Min	25.00	17.00	2.00	0.00
Mean	34.12	23.13	4.79	2.64
Std	3.17	2.30	1.02	7.61
Cov	10.08	5.28	1.04	57.98

TABLE .2. STATISTICAL CHARACTERISTICS OF CLIMATE VARIABLES USED FOR MODEL SIMULATION (2009-2011)

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2.4. CONCEPTUAL FRAMEWORK OF AQUACROP MODEL

Crop responses to water deficits are simulated using empirical production functions as the most practical option to assess crop yield response to water. The empirical approach developed by Doorenbos and Kassam [5] presents an important source to determine the yield response to water of herbaceous crops (field, vegetable) and tree crops, through the expression (2) below.

$$\left(1-\frac{Y_a}{Y_m}\right)=k_y\left(1-\frac{ET_a}{ET_m}\right) \qquad (2)$$

Where Y_m and Y_a are the maximum (potential) and actual yield, $(1-Y_a/Y_m)$ the relative yield decline, ET_m (ETo) and ET_a are the maximum and actual evapotranspiration (dependent on soil moisture availability), $(1-ET_a/ET_m)$ the relative water stress and k_y is the proportionality factor between relative yield loss $(1-Y_a/Y_m)$ and relative reduction in evapotranspiration.

The AquaCrop model evolves from the expression (2) [6, 7]. AquaCrop model divides the ETa into soil evaporation (Es) and crop transpiration (Tr) as below in (3).

$$ET_a = Es + Tr \qquad (3)$$

The division of evapotranspiration (ET) into Es and Tr avoids the confounding effect of the non-productive consumptive use of water (Es). This is important for growing periods when canopy cover is incomplete.

The actual yield (Ya) is express as the product of biomass (B) and harvest index (HI).

$$Y_a = B \times HI \qquad (4)$$

The expression of yield (Ya) in terms of B and HI allows a distinction of the basic functional relations between environmental conditions and B, and environmental conditions and HI.

The biomass (B) is obtained from the product of water productivity (WP) and cumulated crop transpiration which is the core of the AquaCrop growth engine (5). The crop water productivity (WP), expresses the aboveground dry matter (g or kg) produced per unit land area (m^2 or ha) per unit of water transpired (mm).

$$B = WP \times \sum Tr \qquad (5)$$

The Tr is normalized with reference evapotranspiration (ETo). The normalization of Tr makes the B-Tr relationship general, applicable to different climatic regimes. The AquaCrop model (Fig. 1) focuses on the fundamental relation between B and Tr (5)

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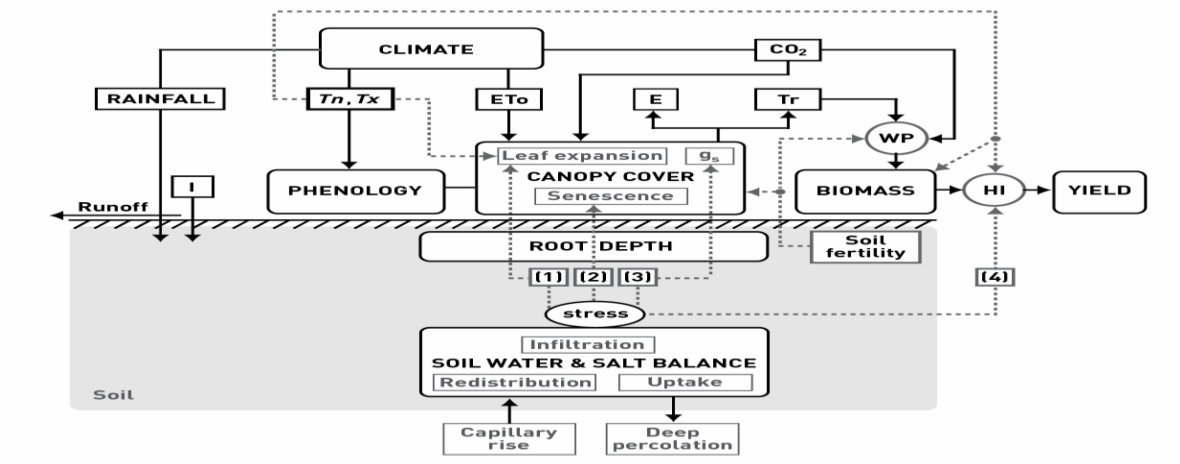
rather than yield (Y) and ET (2), relying on the conservative behaviour of WP. The expression in (2) and the AquaCrop (5) model is water-driven, meaning that the crop growth and production are driven by the amount of water consumptively used (Tr).

Fig. 1. AquaCrop flowchart indicating the main components of the soil-plant-atmosphere continuum



The simulation runs of AquaCrop are executed with daily time steps, using either calendar days or growing degree days (GDD). In this study the GDD was employed. The simulation of water use and production in daily time steps permits a more realistic accounting of the dynamic nature of water stress effects and crop responses.

2.5. GENERATION OF PLANTING DATES (PLANTING CALENDAR)

The modelling was done for three cropping years (2009-2011). The generation of the planting dates were done using the AquaCrop model. Once the climate data is provided, the software is able to generate the planting date using given selected generation criteria. Since the amount of soil moisture stored during rainfall is lost to the atmosphere to meet the environmental (climatic) demand through the ETo, the planting dates were generated using two criterion to generate enough planting dates for the simulations. The first criteria selected was that, planting should begin when rainfall in decade (10-day period) exceeds 0.5ETo in decade. This was to ensure that within that period there are not droughts and that there is enough soil moisture for good germination. The second criteria selected was that planting start when the rainfall in five successive days is at least 25 mm, since the average daily ETo during the rainy season is about 4.7 mm/day, and the emergence for maize is about 5 days with the required soil moisture temperature, the second criteria for the planting was found to be justified.

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International Journal of Engineering Sciences & Management Research

2.6. MODEL CALIBRATION FOR MAIZE VARIETIES

Maize crop parameters reported by [8] was adopted with some few adjustments for three common maize varieties (Obatanpa, Aburohima and Dodzi) commonly grown in the region. The dynamic growth and development of the three varieties were run under Growing Degree Day (GDD) (°C day) rather than on calendar month (days). The GDD allows for the effect of the temperature to effluence the growth and development of the crop dynamically. Different crop developmental stages are completed once a given number of GDD are reached. The GDD is determined by the expression in (6) below.

$$GDD = Tavg - Tbase \quad (6)$$

Where, $Tavg$ is the average temperature in °C and $Tbase$ is the based temperature in °C.

The temperature file which contains the minimum and maximum temperatures is required to calculate the GDD using the method for calculating the average temperature and hence GDD as presented by McMaster and Wilhelm [9] for maize. The base temperature is the temperature below which crop development does not progress. An upper threshold temperature (Tupper) which is the temperature above which crop development no longer increases with an increase in air temperature is also provided which forms the bases for determining the GDD. For all the maize varieties Tbase of 8°C and Tupper of 30°C were used.

Cultivar specific crop parameters and less-conservative crop parameters were adjusted for the three maize varieties such as the planting distances and growth periods. The planting spacing for Obatanpa, Aburohima and Dodzi were: 75 cm by 45 cm, 75 cm by 40cm and 75 cm by 35 cm respectively. The Obatanpa is a medium-maturity variety (105-110 calendar days), and in GDD ranges between 1946 -1988 GDD, using the air temperature of 2009-2011. The Aburohima is an early-maturity variety (90-95 calendar days) and in GDD ranges between 1661- 1712 GDD. The Dodzi is an extra-early-maturity variety (80-70 calendar days) and in GDD ranges between 1395-1487 GDD. Conservative crop parameters where maintained and used for the models simulations.

III. RESULTS AND DISCUSSIONS

3.1. THE CLIMATE OF UPPER WEST

The climate is one most important resource in crop production. The selection of the crop types and varieties for a particular locality are strictly based on first the suitability of the climate among other factors such as the soil requirement; the know-how, socio-economic constraints and just to mention but a few.

The climate of the Upper West Region using climatic data from the Wa Meteorological station is interesting in that based on the method of classification its can be either classified as arid, dry humid or tropical humid climatic zone. The annual rainfall ranges from 1961-2011 is presented using box plot (Fig. 2). The lowest annual rainfall depth from 1961-2011, was recorded in 1986 (523.5 mm/year) while the highest was recorded in 1963 (1542.8 mm/year). The average annual rainfall depth of Wa for the recorded period is 1045.70 mm/year. The average annual reference crop evapotranspiration computed using FAO Penman-Monteith method from 1986-2011 is 1756.97 mm/year (Fig. 3). Using therefore the average annual rainfall depth as the method of classification, the climate of Wa is arid climate zone. The wetness index ranges between 0.51 (1986) and 1.50 (1963) and the average is 1. Using the wetness

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index as the method of classification, the climate is tropical humid climate zone. These clearly show the seasonal variability of rainfall and the ETo in the region (Fig. 4 and Fig. 5).

Interestingly, the aridity index from 1986-2011, ranges from 0.30 to 0.78 and an average of 0.58. This is interesting indeed as the climate is a swing climate between arid climate and tropical humid climate. Even though it can be subject to debate, per the average aridity index the climate of Wa can also be classified as dry sub-humid. This is a clear indication of the seasonal climate variability and the uncertainty its presents in term of planning for agricultural production. But one thing that is clear is the trend over years has not shown any decline in the annual rainfall (Fig. 6) while the reference crop evapotranspiration experience a constant trend (Fig. 7).

Fig. 2. Box plot of annual rainfall distributions (1961-2011)

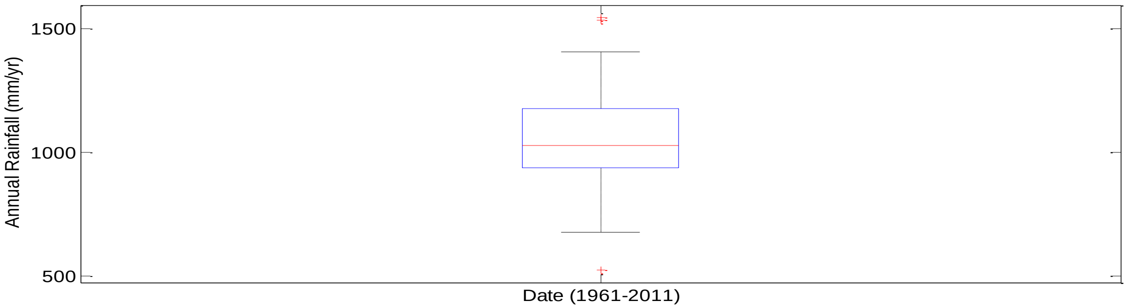

Fig. 3. Box plot of annual ETo mm/year (1986-211)

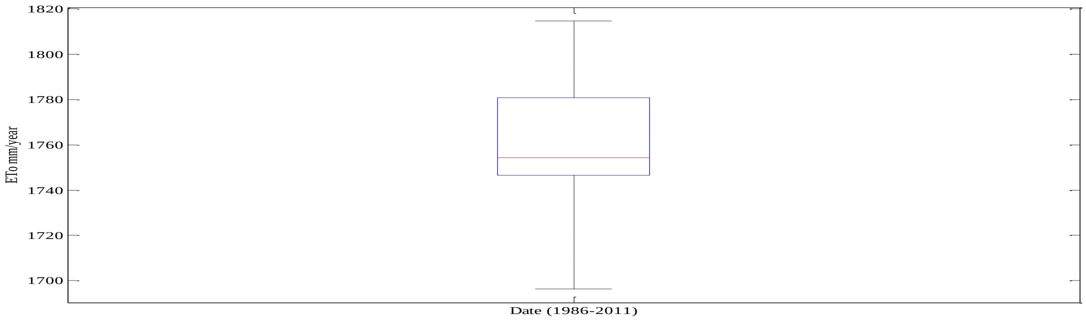

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Fig. 4. Time series plot of annual rainfall distributions (1986-2011)

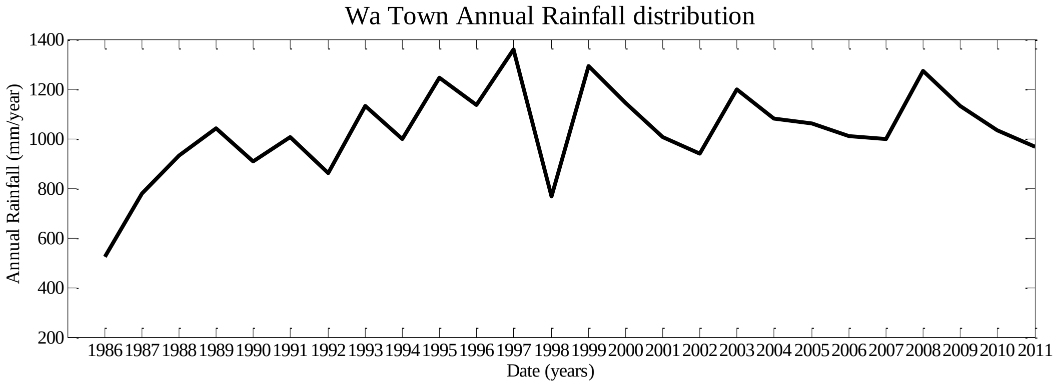
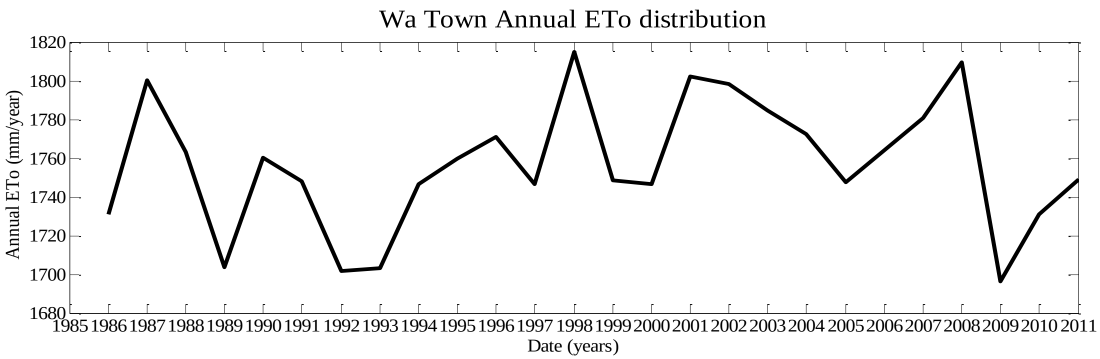


Fig. 5. Time series plot of annual ETo (1986-2011)



The monthly rainfall distribution presented in Fig. 6 indicates that seasonal variability exist which is typical of arid climate. The shape of the graph depict that the pattern of the variability is consistent making it possible to development a decision support tool for proper cropping calendar for the region. The trend shows a gradual increase in the rainfall pattern. It is therefore clear that climate variability and climate change in the region has increase the rainfall depth. Low-land crops may risk flooding if appropriate measures are not taken. Hence water scarcity is not a threat now for crop production in the region. With appropriate cropping calendar, crop production in the region will not be hampered because of inadequate rainfall.
The unimodal rainy season span from April to October, with high downpours recorded in August-September while droughts are also recorded in April and June in some years (Fig. 8a and 8b). The months in which 0.5ETo are higher than the rainfall are classified as

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drought months, but the generation of planting dates using decade (10 days) showed that intermittent drought could occur within the month followed by heavy downpour. That is why simulation using daily time steps is important than using monthly averages. Therefore the duration and frequency of drought is exposed using daily time steps. Sparse rainfall may be recorded in any of the remaining months, but this does not mark the beginning of the major raining season. Therefore planning when to plant is a major decision to be made to reduce water stress and it associated relative yield decline.

Fig. 6. Sequential monthly rainfall pattern and trend

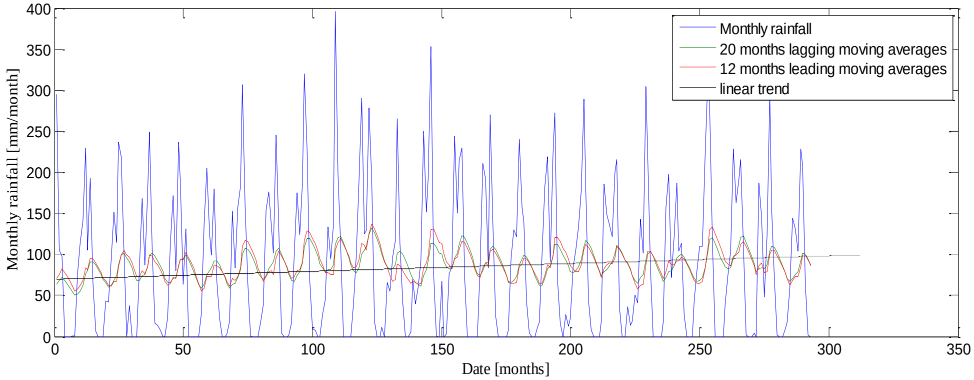

Fig. 7. Sequential monthly ETo pattern and trend

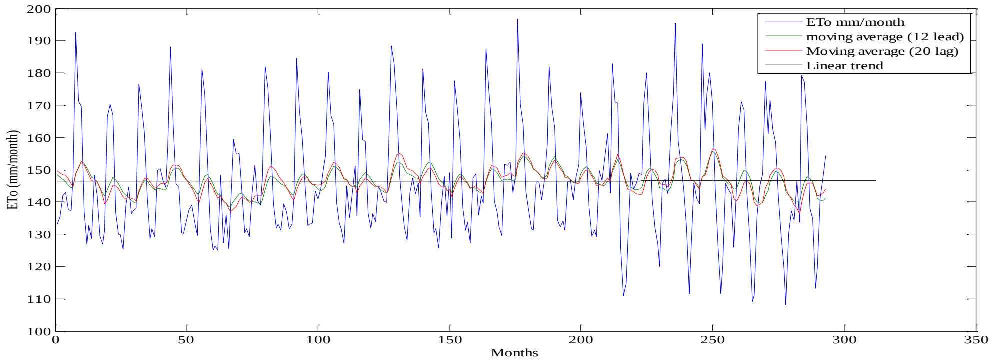

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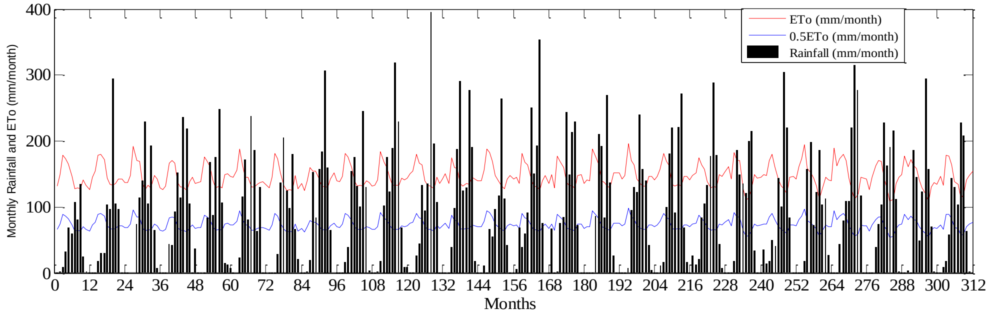
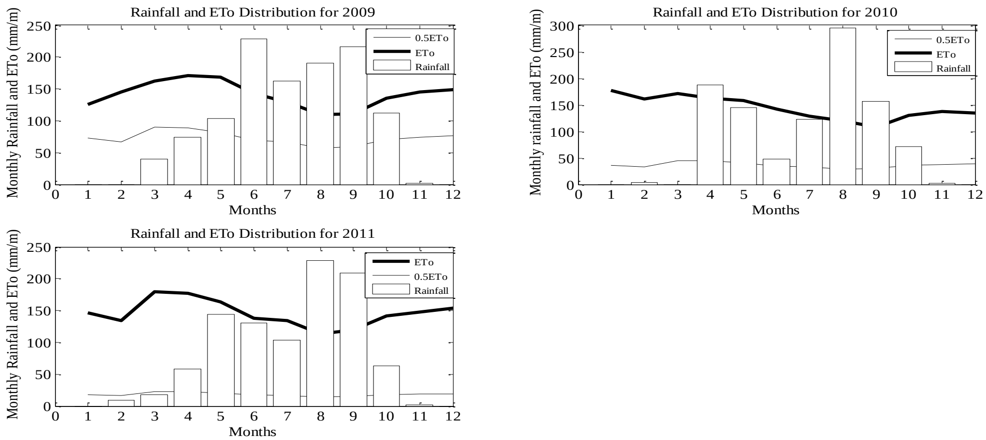
Fig. 8a and 8b. Comparsions of the monthly rainfall and ETo pattern



(a)



(b)

What is also clear is that in the major rainy season (May to October) the rainfall is higher than the 0.5ETo and hence with appropriate soil management, there is enough soil and atmospheric moisture to provide favourable environment for plant growth. Proper planning of when to plant requires an understanding of the physiological response of the crop to water stress, heat stress and the sensitivity to waterlogging or saturation, to ensure crops have the maximum evapotranspiration and hence produce maximum yield.

Research has shown that when half of the evapotranspiration is higher than the rainfall then that decade or month is experiencing drought. It is therefore clear that even though the rainfall starts in the month of April and sometimes earlier, planting in the month of April especially in the highlands is likely to suffer from water stress or poor germination or complete failure requiring filling and re-filling or complete replanting. Also in some years, the month of June also experiences slight drought and hence the need for proper planning. The AquaCrop model is therefore well structured to cater for these phenomena. It's therefore important to study the pattern of the climate and the crop physiology to determine when to sown. Planning of planting dates must avoid drought at the critical or

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peak period of the crop where the crop is highly sensitive to water stress. In maize production, the flowering stage (tasselling stage, silking and grain setting stage) is the peak period and therefore droughts during this period will significantly reduced yields.

3.2. GENERATED PLANTING DATES

The results of the planting dates generated for the three farming seasons, indicates that planting starts in early April and ends in either late July or early August in the region (Table 3). Even though the planting period spans for about 4 to 5 months, the effective planting days did not span for the total numbers of days in that period. This is as a result of the fact that intermittent drought period occurs in the rainy season. A total of twenty (20) planting occurrences were generated. For each criteria selected the software is able to generated only the 11th occurrence of planting from the onset of the rains or selective period, some dates were repeated and used only once. The result shows that, farmers that planted in April 2009 faced drought period (Table 3 and Fig. 8b). Also in April 2011 water deficit occurred even though the rainfall is higher than 0.5ETo, not all the rainfall is available in the root zone for plant used, some runoff, some deep percolate also the soil storage capacity is limited; hence the software takes care of the soil-water balance and on daily time steps. The effects of planting in such periods are poor germination hence low plant population per hectare, permanent wilting of young plants, stunted growth and delay in fertilizer application in some cases. In 2010 the rainfall in April was exceptional but in June there was intermittent drought by the generation criteria and the soil-water balance. Generating planting dates and using these planting dates to simulate yield provide enough information for decision support of when to plant and which variety to plant since the rainfall in the region ends in October (Fig. 8b).

Occurrences	2009		2010		2011	
1st	1	April	1	April	1	April
2nd	1	May	2	April	2	April
3rd	2	May	3	April	3	April
4th	3	May	4	April	4	April
5th	4	May	5	April	1	May
6th	21	May	11	April	2	May
7th	22	May	12	April	3	May
8th	23	May	13	April	4	May
9th	27	May	14	April	5	May
10th	1	June	15	April	6	May
11th	2	June	21	April	11	May
12th	3	June	22	April	20	May
13th	5	June	26	April	26	May
14th	7	June	23	May	4	June
15th	14	June	25	May	13	June
16th	19	June	5	July	20	June
17th	26	June	17	July	24	June
18th	30	June	23	July	13	July
19th	14	July	7	August	17	July
20st	17	July	10	August	20	July

TABLE .3.GENERATION OF PLANTING DATES (2009-2011)

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3.3. SIMULATED POTENTIAL YIELD OF OBATANPA MAIZE

The accumulated potential biomass for Obatanpa maize for unlimited soil fertility is about 26.5 tons/ha and the reference harvest index (HIo) was set at 48% for all the varieties with allowance for possible increase up to 15% (55% maximum HIo), therefore the expected potential yield is about 12.72 tons/ha and above. The actual yield simulated using the generated planting dates (Table 3) is presented in Fig. 9, 10 and 11 below. The actual simulated yields are the responses of the crop to water stress, heat stress and cold stress which are influence by the climate. The results for 2009 farming season (Fig. 9), shows that planting in April had the least yield (11.51 tons/ha) because as explained above, intermittent drought occurred in April causing water stress. Heat and cold stress had no influence on the yield. Even though the water stress occurred it occurred in the intial-growth stage, therefore yield loss was not drastic. In 2010 planting in April experience water stress in some part of June in the crop development stage and the mid-season stage (Fig. 10). In 2011, even though water stress occurred in April it occurred in the initial-growth stage and this did not had drastic effect on the yield (Fig. 11).

Fig. 9. Simulated yields of Obatanpa Maize 2009 rainy season

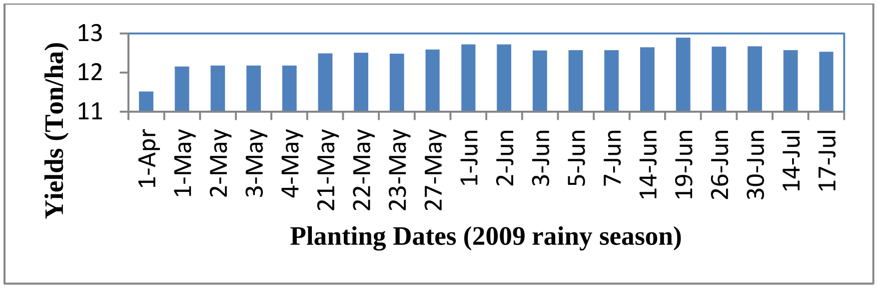

Fig. 10. Simulated yields of Obatanpa Maize 2010 rainy season

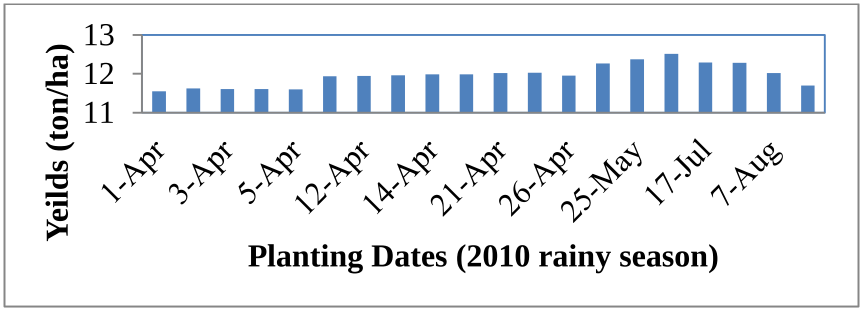

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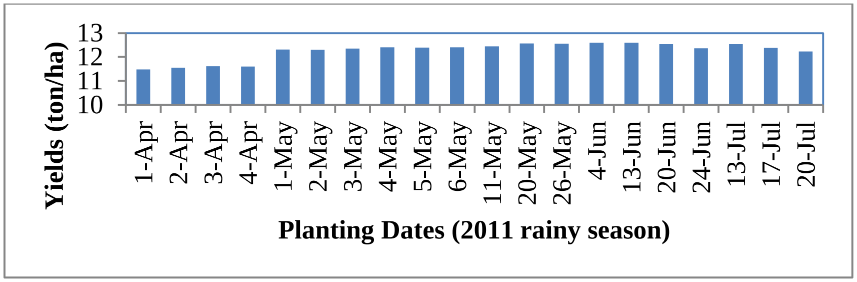
Fig. 11. Simulated yields of Obatanpa Maize 2011 rainy season



3.4. SIMULATED POTENTIAL YIELD OF ABUROHIMA

The actual simulated yield of Aburohima variety is presented in figures below in this section. The potential accumulated biomass is about 21.12 tons/ha. The expected yield therefore should be about 10.14 tons/ha. The result shows that all the planting date could not reach the maximum HI of 48% due to insufficient green canopy cover and hence could to reach the expected yield of about 10.14 tons/ha or above. This is typical of early-maturing varieties which are considered drought resistant varieties. In 2010, planting in late April experience drastic yield loss due to water stress in the mid-season (critical period) which occurred in June (Fig. 13). For example crops planted on 26th April 2010 experience water stress starting from 18th June to 3 July about two weeks of drought in the critical growth period, the relative water stress at the period range 23% to 90%. The result is limited pollination and hence relative yield loss of about 83%. This emphasized the early statement that water stress in the mid-season stage (critical period) causes severe loss and in extreme cases total yield failure.

Fig. 12. Simulated yields of Oburohima 2009 rainy season

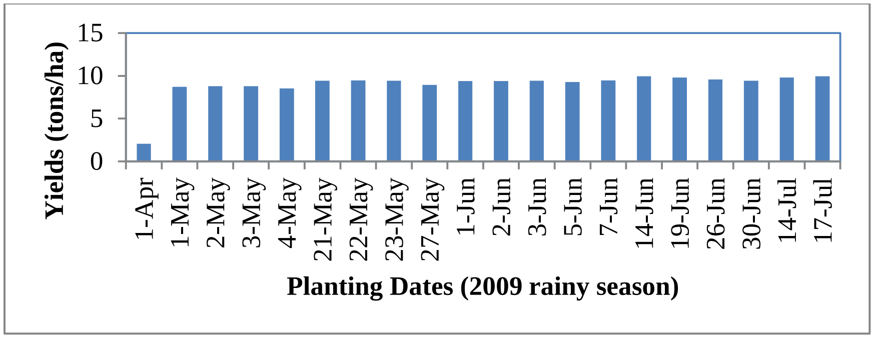


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Fig.13. Simulated yields of Oburohima 2010 rainy season

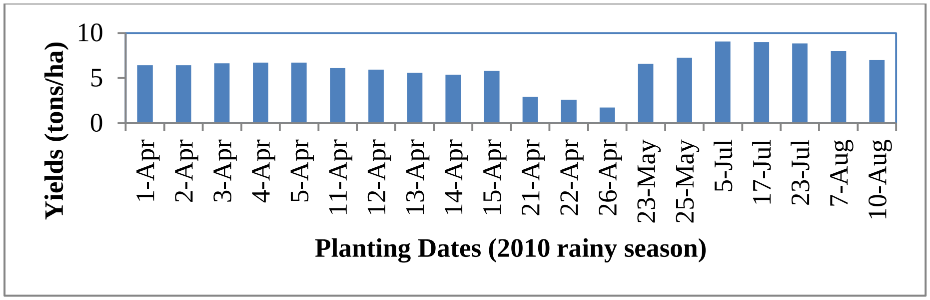
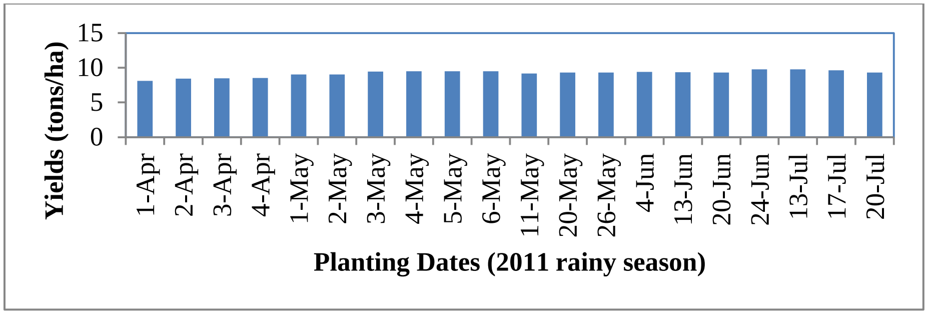


Fig.14. Simulated yields of Oburohima 2011 rainy season



3.5. SIMULATED POTENTIAL YIELD OF DODZI

The actual simulated yield of Dodzi variety is presented in figures below in this section. The potential accumulated biomass is about 19 tons/ha and the expected yield therefore should be about 9.12 tons/ha and above. The results shown similar behaviour as the Aburohima, the maximum HI of 48% could not be reached which is to be expected of extra-early maturity variety. The Dodzi did better on planting dates the Aburohima did not do well, this is because Dodzi is a more drought resistance crop (less water loving) than Aburohima due to fact that the physical growth characteristics such a number of leaves, leave area, height, canopy cover and so for, are reduced. The relative water stress was zero meaning there was no water stress in any of the growth stages. There were slight variations in the yields in all the planting dates making it more reliable in yield as compared to Aburohima in this scenario.

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Fig. 15. Simulated yields of Dodzi for 2009 rainy season

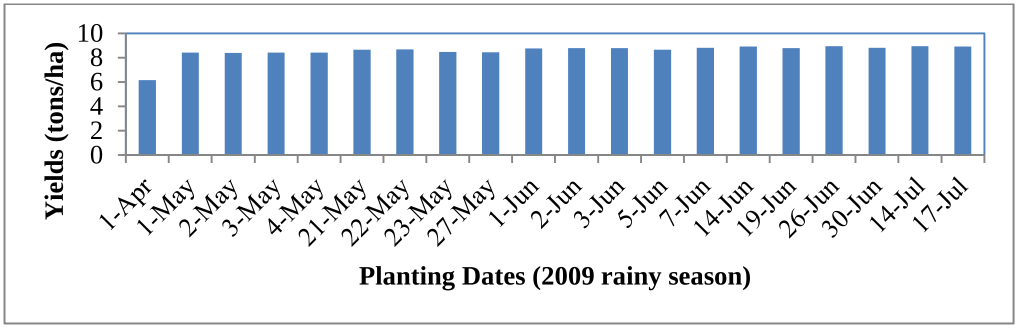


Fig. 16. Simulated yields of Dodzi for 2010 rainy season

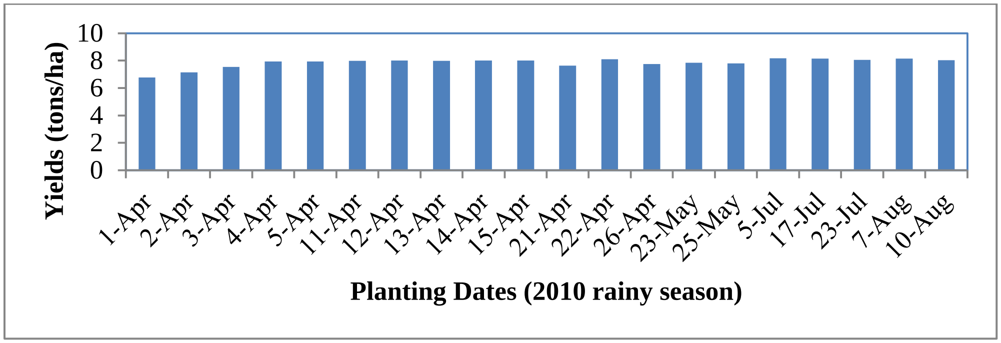
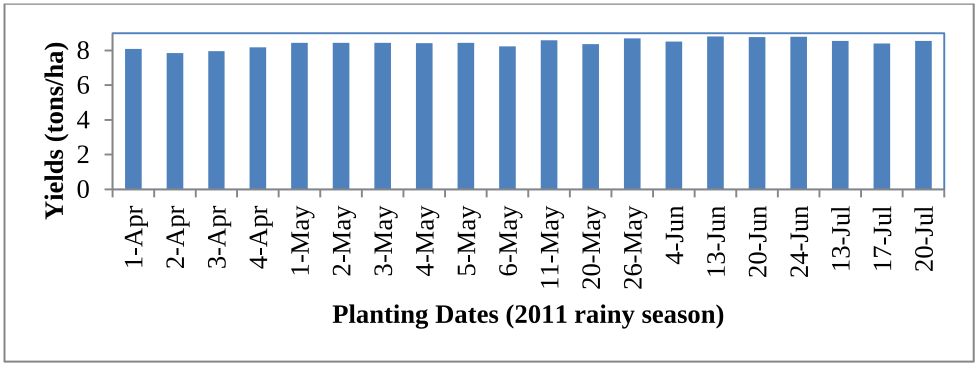


Fig. 17. Simulated yields of Dodzi for 2011 rainy season



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IV. CONCLUSIONS AND RECOMMENDATIONS

4.1. CONCLUSIONS

The climate of Upper West Region is suitable for maize production. Seasonal climate variability exist in the region which typical of arid climatic zone. The annual seasonal rainfall showed a gradual increase trend while the annual seasonal reference crop evapotranspiration showed a constant trend which is positive for crop production on the region. Climate variability and change is real in the region even though in the positive direction for crop production. The uncertainty of the climate showed a normal distribution and hence can be modelled using robust tools.

The results of the simulation of the potential yield of maize showed that when to plant and which variety to plant is an important decision to be made. Generating planting dates and modeling yield using local climate data is important in building decision support tool of when to plant and which variety to plant. Planting at the right planting calendar ensures that the agro-climate environment is favourable for optimum growth and development and hence optimum yield. Planting should avoid water stress, heat and cold stress which are climate influence assuming other factors are favourable. In general, water stresses during the mid-season (critical period) causes severe yield loss compared to the other growth stages.

Of the three maize varieties simulated for the three cropping seasons, the results showed that Obatanpa which is an intermediate-maturing variety generally did better, followed by the Aburohima which a early-maturing and the Dodzi which extra-early-maturing variety if planted at their recommended dates. The average yield of Obatanpa planted in late-May to mid-July which is the recommended growing period is about 12.48 ton/ha, 10.92 ton/ha and 12.61 ton/ha for the 2009, 2010 and 2011 farming seasons respectively. That of Aburohima for the same farming seasons planted between early-June to late-July were; 9.58 ton/ha, 8.97 ton/ha and 9.62 ton/ha respectively. And that of Dodzi planted for the same seasons between early-June to early-August were; 8.82 ton/ha, 8.12 ton/ha and 8.63 ton/ha respectively.

The region therefore has high potential in improving maize yield and to increase production with the right investment and technical support. Maize production in the region has the potential to alleviate poverty and improve the food security situation in the region and the country as a whole. It was clear that the current average yields of about 1.59 ton/ha recorded could not be as results of climate change even though seasonal climate variability exists, this was typical for semi-arid climates.

4.2. RECOMMENDATIONS

With the gradual increase of rainfall depth due to climate variability and change, adaptive measures should be made to conserve soil moisture for optimum yield. Also remote sensors and robust predictive tool should be built for predicting the uncertainties of climate change variability and change for yearly updating and planning of planting calendar if possible.

Planting should be done at the recommended planting periods if maximum yield is required. Results of the simulated yield should act a guide in planning planting calendar in the region. For high yield the Obatanpa variety is referred even though the other varieties can equally be grown. Efforts should be made to provide the favourable environment for optimum.

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Investors should be encouraged to go into commercial maize production in the region.

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