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# TREND CONFIDENCE INTERVALS OF PARAMETERS REQUIRED FOR CROP GROWTH MODEL (AQUACROP) OF EPE LAGOS STATE NIGERIA

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***ABSTRACT***

***The development of various models such as Aquacrop gives clue to climate smart agriculture. Climatic daily data used include radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation, and they were sourced from the archive of NASA/POWER SRB/ FLASH flux from 1982 to 2018. All the parameters considered have 99 % and 95 % positive confidence intervals and significance levels with Sen's estimates of 16.92 MJ/M$^2$.day, 28.90 $^o$ C, 23.53 $^o$ C, 1.55 m/s, 85.11 % and 1559.81 mm for radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation with the mean values of 16.90 MJ/M$^2$.day, 28.13 $^o$ C, 22.91 $^o$ C, 1.51 m/s, 82.74 % and 1558.31 mm respectively. Radiation, maximum temperature and wind speed had 44 %, 91 % and 9 % negative down ward trends respectively, while minimum temperature, relative humidity and precipitation have 9 %, 23 % and 139 % positive upward trends respectively as well. Findings show that increase in precipitation over the years keep the water level relatively stable and provides good natural habitat for fishes, aquatic lives and exotic forestry species. The slope gradients were greater than the mean values for all the parameters which signifies strength and fair weather for agricultural activities. The trend patterns show while agricultural activities such as fishing activity and crop production thrive in the study area.***

**Keywords:** AquaCrop, Climatic Parameters, Confidence Intervals, FAO, Sen's slope and Trend Statistics

## INTRODUCTION

Agricultural production is often characterized by risk and uncertainty in an environment where water supply to crops from rainfall is inadequate such as in arid and semi-arid region. Also areas where irrigation water is scarce and yields are often affected, therefore procedures and tools are needed to predict the crop response to a supply of water, so as to reduce uncertainty and manage risk. Aquacrop is a model that is thoroughly designed to solve water and soil related stresses in crop production in such a manner to have a holistic climate smart approach to agricultural activities.

Aquacrop has some inherent comparative advantages over few other models that are available in the areas of number of parameters required, and in this case Aquacrop has a smaller numbers; Aquacrop is simple, accurate, robust and users' friendly (Hsiao, *et al.*, 2009; Steduto *et al.*, 2012). Since the essence of the model is to enhance effective water use at the crop root zone, hence attention is paid to in and out movement of water fluxes in order to simulate root zone water content.

Among various researches carried out globally, none was focused on the trend confidence intervals and statistics of the climatic parameters required by Aquacrop. Such previous research works included assessment of the limitations and potential uses of Aquacrop for the prediction of crop failure (Minella *et al.*, 2014; Toumi *et al.*, 2016); study of the Aquacrop's parameterization and validation of sugar cane (Allen *et al.*, 2006); Comparative study of aquacrop with similar models (Battisti *et al* 2017; Raes *et al.*, 2009). Meanwhile, Salami *et al.*, (2011) emphasized on soil- water balance. Also, emphases were made on the quality of physical models as

relates to the accuracy of the input values, and parameter selection criteria (Benke *et al*., 2008; Hame and Guswa., 2015). The objective of this study was to simulate yields response to water usage using aquacrop.

## MATERIALS AND METHODS

### Study Area

The research location is at Epe Lagos State Nigeria. Epe lies on the latitudes $6^0$. 29'N and $6^o$.58' N and longitudes $3^0$.30' and $3^o$.96' E and it is 3.98 metres above the sea level. It is located at the bank of Lagoon, on the north side of Lekki Lagoon in Lagos State. The major occupations of the people are fishing, farming, logging and other forestry activities.

### Data Sourcing and processing

Daily Data from 1982 to 2018 on radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation were obtained from http:// power/arc.nasa.gov/data-access-viewer (NASA/POWER SRB/ FLASHflux/ MERRA 2/ GEOS 5.12.4 (FT-IT) 0.5 X0.5 Degree at location of Latitude 5.5845 N and longitude 3.9755 E and elevation of 55.68 metres, and Microsoft excel was used to processed data from daily to annual basis.

### Required Data for Aquacrop

The data required by aquacrop are shown in the table 1 below with their possible units

**Table 1: Climatic Parameters and Units Recognized by AquaCrop for Import**

| S/No. | Parameters | Units |
|---|---|---|
| 1 | Maximum Temperature (T max) | $^o$C |
| 2 | Minimum Temperature (T min) | $^o$C |
| 3 | Mean Relative Humidity | % |
| 4 | Wind Speed | m/sec |
| 5 | Solar or Shortwave Radiation | MJ/M$^2$. Day |
| 6 | Rainfall | mm |
| | others | |
| 7 | Eto, reference Crop Evaporation | mm/day |
| 8 | Actual Vapour Pressure | K pa |
| 9 | Temperature of dry bulb (T dry) | $^o$C |
| 10 | Temperature of wet bulb (T wet) | $^o$C |
| 11 | Relative Sunshine in a day | Hour |
| 12 | Maximum and Minimum relative Humidity | mm |

The following data are required by Aquacrop as thus:

i. Reference evapo-transpiration (ETo) was needed to determine the evaporative demand of the atmosphere, and the rate of the crop transpiration and soil evaporation.

ii. Minimum (T min) and maximum (T max) air temperature are required calculate amongst; growing degree days which determine crop development and phenology; adjustments in crop transpiration during cold periods; and determine heat and cold stresses as affect pollination.

iii. Rainfall data was required to bring the soil water up to field capacity; update the soil water balance and to calculate soil water stresses affecting crop growth and production processes.

iv. Mean annual atmospheric $CO_2$ concentration ($CO_2$)**.** Aquacrop has some $CO_2$ adopted from different scenario like Manualloa $CO_2$ which is universal and

capable to test the crop response for climate change scenarios. The MaunaLoa CO2' file contains observed mean annual [$CO_2$] for the period 1902 till today with projected atmospheric composition for the future.

v. Air temperature involves both minimum and maximum temperature is required to calculate ETo, which is to handle heat transfer and heat loss around the crops.

vi. Air humidity is required to calculate ETo: The difference between the saturation (es) and actual (ea) vapour pressure, called

vii. Radiation data is required to calculate ETo which is the amount of energy available to make water to be vaporized. It can also be estimated from the actual duration of sunshine which is measured with a Campbell-Stokes sunshine recorder. In absence of any measurement, solar radiation (Rs) can be estimated from the difference between maximum and minimum temperature.

Meanwhile, in the absence of daily data Aquacrop invokes built-in procedures to estimate the required daily data (time step of the simulation) based on the 10-day or monthly means. Cases of missing or missed data were taken care or accounted for in Aquacrop with the computation of number -999.

**Description of the Model And Template Used**
**Calculation of Trend Statistics**
An excel template application Makensens (Timo *et al*., 2002) was used to calculate the trend statistic of the parameters required for aquacrop in Epe Lagos State Nigeria. It contains time series for radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation. The number of annual values in the calculation template is the difference between the first (1982) and the last year (2018).

**Aqua crop model**
Aquacrop describes the relationship between the plant and the soil from the root zone and how water and nutrients can be extracted by the plant. The major components included environment, climate, crop, management, simulation and run. The run button is to carry out simulation after when necessary parameters are input. Climate entails the climatic parameters mentioned above i.e radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation, while management entails both field (soil fertility) and irrigation.

**Import Climatic data**
The climatic data were prepared and copied as text file. The text files are imported from the directory of Aquacrop. The data were saved as thus; precipitation is saved in PLU file; maximum and minimum temperature in Txn file; and ETo (Http.www.fao.org).

**Data Analysis**
Microsoft excel was used to convert 38 years daily data into annual for parameters under study.

**RESULTS**
Table 2 shows the descriptive analysis of parameters required for aquacrop in Epe, South West Nigeria with the mean values of 16.90 $MJ/M^2$.day, 28.13 $^{o}$C, 22.91 $^{o}$C, 1.51 m/s , 82.74 % and 1558.31 mm for radiation, Maximum temperature, minimum temperature wind speed, relative humidity and precipitation respectively. Mean deviation and standard deviation values for radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation are 0.008 $MJ/ M^2$.day and 0.047 $MJ/M^2$.day, 0.765 $^{o}$C and 4.652 $^{o}$C, 0.609 $^{o}$C and 3.704 $^{o}$C, 0.044 m/s and 0.270 m/s, 2.290 % and 13.928 %, and 47.471 mm and 288.757 mm respectively. Meanwhile, median and coefficient of skewness for radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitations are 17.20 $MJ/M^2$.day and 19.149 $MJ/M^2$.day, 29.17 $^{o}$C and 0.224 $^{o}$C, 23.39 $^{o}$C and 0.390 $^{o}$C, 1.53 m/s and 0.222 m/s, 82.9 % and 0.037 %, and 992.40 mm and 5.879 mm respectively.

**Table 2. Descriptive Statistics of climatic parameters of Epe Lagos State Nigeria**

| Parameters | Solar Radiation $MJ/M^2$.Day | Max Temp 0 $^oC$ | Min Temp 0 $^oC$ | Wind speed (m/s) | Relative Humidity | Precipitation mm |
|---|---|---|---|---|---|---|
| Mean | 16.90 | 28.13 | 22.91 | 1.51 | 82.74 | 1558.31 |
| Mean Deviation | 0.01 | 0.77 | 0.61 | 0.04 | 2.29 | 47.47 |
| Standard Deviation | 0.05 | 4.65 | 3.70 | 0.27 | 13.93 | 288.76 |
| Median | 17.20 | 29.17 | 23.39 | 1.53 | 82.91 | 992.40 |
| Coefficient of skewness | 19.15 | 0.22 | 0.39 | 0.22 | 0.04 | 5.88 |

Table 3 shows that there was an increase in the trend of minimum temperature, relative humidity and precipitation at slope magnitude of 2.5 %, 14.4 % and 946 % respectively while radiation, maximum temperature and wind speed decrease in trend at slope magnitude of 2.3 %, 0.8 % and 0.3 % respectively. It shows also that radiation decreased at no significance level while maximum temperature and wind speed decreased at significance levels 0.1 and 0.001 respectively. The minimum temperature, relative humidity and precipitation increased significantly at 0.001, 0.001 and 0.1 levels respectively.

**Table 3. Trend Statistics of Climatic Parameters of Epe Lagos Nigeria**

| Parameters | Solar Radiation $MJ/M^2$.Day | Max Temp 0 $^oC$ | Min Temp 0 $^oC$ | Wind speed (m/s) | Relative Humidity | Precipitation mm |
|---|---|---|---|---|---|---|
| Test Z | -1.54 | -1.70 | 4.23 | -3.58 | 5.30 | 1.77 |
| Significance | Nil | + | *** | *** | *** | + |
| Slope Magnitude | -0.023 | -0.008 | 0.025 | -0.003 | 0.144 | 9.461 |
| Trials | 37 | 37 | 37 | 37 | 37 | 37 |
| Last Year | 2018 | 2018 | 2018 | 2018 | 2018 | 2018 |
| First Year | 1982 | 1982 | 1982 | 1982 | 1982 | 1982 |

*Note: *** 0.001, ** 0.01, * 0.05, + 0.1 levels of significance*

Table 4 shows the values at which each parameter is constant in trend. At slope magnitude of 99 % maximum significance level, radiation, maximum temperature, minimum temperature, relative humidity and precipitation were experiencing upward trend at constant values of 16.94 $MJ/M^2$.day, 28.79 $^o$C, 22.80 $^o$C, 81.30 %, 1163.08 mm respectively while wind speed experienced downward trend at constant value of 1.56 m/s. At slope magnitude of 99 % minimum significance level, radiation, maximum and minimum temperature, wind speed, relative humidity and precipitation experienced upward trend at constant values of 17.87 $MJ/M^2$.day, 29.18 $^o$C and 23.39 $^o$C, 1.65 m/s, 83.74 % and 1711.41 mm.

At slope magnitude of 95 % maximum significance level, radiation, maximum and minimum temperature, relative humidity and precipitation experienced upward trends at the constant values of 17.02 $MJ/M^2$.day, 28.83 $^o$C, 22.84 $^o$C, 81.70 %, and 1238.58 mm respectively while wind speed for both maximum and minimum 95 % significance levels experienced down ward trends at constant values of 1.58 m/s and 1.64 m/s respectively. The 95% minimum significance level for radiation, maximum and minimum temperature, relative humidity and precipitation experienced upward trends at the constant values of 17.72$MJ/M^2$.day, 29.15 $^o$C and 23.30 $^o$C, 83.58 % and 1603.52 mm respectively.

**Table 4. Confidence Intervals and Constant B for Climatic Parameters of Epe Lagos Nigeria**

| Parameters | Solar Radiation MJ/M$^2$.Day | Max Temp 0 $^{o}$C | Min Temp 0 $^{o}$C | Wind speed (m/s) | Relative Humidity | Precipitation mm |
|---|---|---|---|---|---|---|
| Q Max 99 | 0.012 | 0.004 | 0.039 | -0.001 | 0.203 | 21.117 |
| Q Min 99 | 0.056 | 0.020 | 0.011 | 0.005 | 0.085 | 4.454 |
| Q Max 95 | 0.006 | 0.001 | 0.036 | -0.002 | 0.186 | 17.791 |
| Q Min 95 | -0.049 | 0.018 | 0.014 | -0.005 | 0.095 | -0.959 |
| B Max 99 | 16.94 | 28.79 | 22.80 | 1.56 | 81.30 | 1163.08 |
| B Min 99 | 17.87 | 29.18 | 23.39 | 1.65 | 83.74 | 1711.41 |
| B Max 95 | 17.02 | 28.83 | 22.84 | 1.58 | 81.70 | 1238.58 |
| B Min 95 | 17.72 | 29.15 | 23.30 | 1.64 | 83.58 | 1603.52 |
| B | 17.34 | 29.04 | 23 | 1.60 | 82.51 | 1419.52 |

*B and Q are constant and Slope at 95% and 99% Confidence Intervals*

Table 5 shows that all the parameters have positive confidence intervals at both 99 % and 95 % minimum and maximum significance levels with Sen's estimates of 16.92 MJ/M$^2$.day, 28.90 $^{o}$ C, 23.53 $^{o}$ C , 1.55 m/s, 85.11 % and 1559.81 mm for radiation, maximum temperature, minimum temperature, wind speed, relative humidity and precipitation respectively.

**Table 5. Mean Annual Confidence Intervals of Climatic Parameters of Epe Lagos Nigeria**

| Parameters | Solar Radiation MJ/M$^2$.Day | Max Temperature 0 $^{o}$C | Min Temperature 0$^{o}$C | Wind speed (m/s) | Relative Humidity | Precipitation mm |
|---|---|---|---|---|---|---|
| Sen's estimate | 16.92 | 28.90 | 23.53 | 1.55 | 85.11 | 1559.81 |
| 99% Max Confidence interval | 17.16 | 28.87 | 23.50 | 1.54 | 84.96 | 1543.18 |
| 99% Minimum Confidence Interval | 16.86 | 28.82 | 23.58 | 1.56 | 85.26 | 1631.24 |
| 95 % Max Confidence interval | 17.12 | 28.85 | 23.49 | 1.55 | 85.04 | 1558.82 |
| 95% Minimum Confidence Interval | 16.85 | 28.82 | 23.55 | 1.55 | 85.29 | 1586.26 |

Table 6 shows the relationship that exists among the true slope, the mean value of data under study, the trends and the constant at which the trends were recorded. Radiation, maximum temperature and wind speed decreased in trends at the rate of 44 %, 91% and 9 % departure from the mean values respectively. The records simply mean that radiation, maximum temperature and wind speed have 44 %, 91 % and 9 % negativity of down ward trends respectively. In other hands, minimum temperature, relative humidity and precipitation have 9 %, 23 % and 139 % positivity of upward trends respectively. The slope is greater than the mean values for all the parameters which signify strength and fear weather for agricultural activities in Epe over the years.

**Table 6. Summary of Trends Statistics of Climatic Parameters of Epe Lagos Nigeria**

| Parameters | Solar Radiation $MJ/M^2$.Day | Maximum Temp $^oC$ | Minimum Temp $^oC$ | Wind Speed m/s | Relative Humidity % | Precipitation mm |
|---|---|---|---|---|---|---|
| Sen's estimates | 16.92 | 28.90 | 23.53 | 1.55 | 85.11 | 1559.81 |
| Mean | 16.90 | 28.13 | 22.91 | 1.51 | 82.74 | 1558.31 |
| Constant B | 17.34 | 29.04 | 23 | 1.60 | 82.51 | 1419.52 |
| Trends | Negative | Negative | Positive | Negative | Positive | positive |

## DISCUSSION

The trend statistic shows that if radiation, maximum temperature and wind speed are decreasing, though at insignificant or low significant level and precipitation is increasing at the same time, it shows while the relative humidity must increase as well. This trend probably gives reason while fishing activities is fairly stable and thrive in Epe. However, other agricultural activities also do thrive in Epe with moderate increase in minimum temperature and no significant increase in maximum temperature. Rafael (2012) reported that moderate temperate of thermal regimen of temperature of 30 $^o$ C in the day and 25$^o$ C in the night support plant growths. The mean temperature of Epe is 28.13 $^o$ C maximum and 22.91 $^o$ C minimum and this generally informed while the production of vegetables like cucumber (cucumis sativus), tomato, okro etc is viable in Epe. Meanwhile, on a global scale, temperature has been on the increase (Omofunmi *et al*., 2019) which actually contributed to the 0.8 % decrease in maximum temperature and 2.5 % increase in minimum temperature. Radiation decreased at no significance level while maximum temperature and wind speed decreased at significance levels 0.1 and 0.001 respectively. The minimum temperature, relative humidity and precipitation increased significantly at 0.001, 0.001 and 0.1 levels respectively.

At difference significance levels, slope magnitude experienced variation such as thus; at 99 % maximum significance level, radiation, maximum temperature, minimum temperature, relative humidity and precipitation were experiencing upward trend at constant values of 16.94 $MJ/M^2$.day, 28.79 $^o$ C, 22.80 $^o$ C, 81.30 %, 1163.08 mm respectively while wind speed experienced downward trend at constant value of 1.56 m/s. At 99 % minimum significance level, radiation, maximum and minimum temperature, wind speed, relative humidity and precipitation experienced upward trend at constant values of 17.87 $MJ/M^2$.day, 29.18 $^o$ C and 23.39 $^o$ C, 1.65 m/s, 83.74 % and 1711.41 mm. The findings show that the slope magnitude and trend patterns of required parameters are dependent of other factors that give adequate information on agricultural activities of the study area. More also, the slope magnitude and trend of data used show that data are statistically relevant for aquacrop to give appropriate insight into the climate of Epe.

Precipitation experienced the strongest positive trend with 946 % and minimum temperature experienced least positive trend with 2.5 %. In other hand, maximum temperature experienced the least negative trend of 0.8 % and solar radiation experienced the highest negative trend of 2.3 %. The increase in precipitation and decrease wind speed will invariably constitute increase in relative humidity. The steady increase in precipitation over the years will reasonably keep the water level relatively stable and as such provides good natural habitat for fishes in the rivers.

## CONCLUSION

With the kind of parameters acquired by Aquacrop model, and their results of trend statistic analysis displayed in this study, aquacrop model could be used to carry out comprehensive analysis and simulation on responses of water stress to crops, canopy behaviours, canopy and root senescence, water deficit etc of the research location.Three out of the six parameters considered in this study namely solar radiation, maximum and minimum temperature, wind speed, relative humidity and precipitation experienced upward trends such as minimum temperature, relative humidity and precipitation, while solar radiation, maximum temperature and wind speed experienced down ward trends.

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