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Research Article

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Estimation of Groundnut Water Requirements using Arc-GIS Normalized Difference Vegetation Index

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Abstract The 83-day experimentation which covered four months (August-Aug., September-Sept., October-Oct., and November-Nov.) was conducted beside the mini-hydrological station at campus-one, Auchi Polytechnic to estimate the crop water requirements (CWR) of groundnut (*Arachis hypogaea* L.) using Normalized Difference Index (NDVI) on sandy loamy soil at Auchi, Edo State. The results showed that Normalized Difference Vegetation Index (NDVI) produced weak over a groundnut field of 10 m * 10 m. The result showed NDVI-CWR estimated values of 2.03 mm, 9.6 mm, 10.9 mm, and 6.5 mm for the months of Aug., Sept., Oct., and November. The poor performance of the NDVI technique could be attributed to the smaller size of the groundnut field, spatial resolution, and field coordinates. Therefore, green-seeker sensor is preferable to NDVI over a smaller field, while NDVI could be very effective on the large field.

Keywords Groundnut (Arachis hypogea L.), NDVI, Green seeker sensor, CWR, Large field

1. Introduction

Groundnut, with a botanical name called “Arachis hypogaea Linn”. it is derived from two Greek words, Arachis meaning a legume and hypogaea meaning below ground, referring to the formation of pods in the soil. The peanut, also known as the groundnut, goober (US) or monkey nut (UK), and taxonomically classified as Arachis hypogaea, is a legume crop grown mainly for its edible seeds [1]. It is widely grown in the tropics and subtropics, being important to both small and large commercial producers. It is classified as both a grain legume and, due to its high oil content, an oil crop. Groundnut, or peanut, is commonly called the poor man's nut. Today it is an important oilseed and food crop. This plant is native to South America and has never been found uncultivated [3]. The botanical name for groundnut, Arachis hypogaea Linn., is derived from two Greek words, Arachis meaning a legume and hypogaea meaning below ground, referring to the formation of pods in the soil. Groundnut is an upright or prostrate annual plant. It is generally distributed in the tropical, sub-tropical and warm temperate zones. Ethnological studies of the major Indian tribes of South America document the widespread culture of groundnut and provide indirect evidence for its domestication long before the Spanish Conquest. When the Spaniards returned to Europe, they took groundnuts with them. Later traders were responsible for spreading the groundnut to Asia and Africa where it is now is grown between the latitudes 40°N and 40°S.

The crop water need refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment. Crop water requirements (CWR) refer to the amount of water required to compensate the evapotranspiration losses from a cropped

growth during a specified period of time. Crop water requirements are expressed usually in mm/day, mm/month or mm/season and they are used for the management purposes: in the estimation of irrigation water requirements, irrigation scheduling and water delivery scheduling. The concept of crop water requirements is intimately connected with the crop evapotranspiration since both refer to the same amount of water. Nevertheless, there is some difference among them. While crop evapotranspiration represents the water losses that effectively occurs (i.e., a hydrological term), the crop water requirement indicates the amount of water that should be supplied accounting to these losses (i.e., an irrigation management term) [3]. In fact, this amount of water corresponds to the effective irrigation water supply necessary to reach the maximum growth parameter [4].

The agronomic parameter Normalized Difference Vegetation Index (NDVI) was proposed by Rouse *et al.* [5], which is a numeric indicator of the difference between the wavelengths of the red and near infrared bands divided by their sum. The Normalized Difference Vegetation Index (NDVI) shows good linear correlation with biomass compared to other vegetation index, and it is also expected to be less influenced by changes in atmospheric conditions, moreover, it is a good indicator of vegetation biomass when the terrain exhibits good vegetation cover [6], as is the case of the peanut crop whose shoots provide good cover. The Normalized Difference Vegetation Index (NDVI) is useful for obtaining growth data, such as photosynthetic efficiency and yield potential [1]. Also, it can be used to estimate groundnut crops water requirement. Based on this, determination of the Normalized Difference Vegetation Index (NDVI) may be an alternative and direct method for estimating the component of crop water requirement.

Conclusively, Normalized Different vegetation index (NDVI) was used to estimate crops water requirement for groundnut and this would be used to create a baseline result of crop water requirement in Auchi, Edo state.

2. Materials and Methods

2.1 The Study Area

Figure 1: Map of Africa showing Nigeria, Edo Sate and the study area Auchi at Etasko-West LGA
Source: Author's Arcmap 10.1 Production

Field experiments were carried out at the mini-Teaching and Demonstration Farm located beside Alumia Drawing Studio in Campus-One, Auchi Polytechnic at latitude 7.040N and longitude 6.27°E. Auchi is a tropical savanna with an average mean temperature and precipitation of 28.5°C and 1201.3 mm. February is the driest period average air temperature of 29.5°C, whereas the Months of July and September indicate a low mean temperature of 26.6°C and 27.8°C and average annual relative humidity of 65.9%. The study is shown in Fig. 1. The spatial location of the study area is shown in Fig. 2.

Groundnut was planted on sandy loamy soil on 24th August 2021 and 70% of the plant germinated at five (5) days after planting over a plot of 15 m * 15 m. A 40 cm * 40 cm spacing was used with a plant density of 2000 per hectare. Plate 1 a-d shows some of the field activities.

Plate 1: Initial groundnut crop growth (a), crop growth at developmental stage (b), crop at flowering stage (c), measurement of soil temperature and rainfall depth (d).

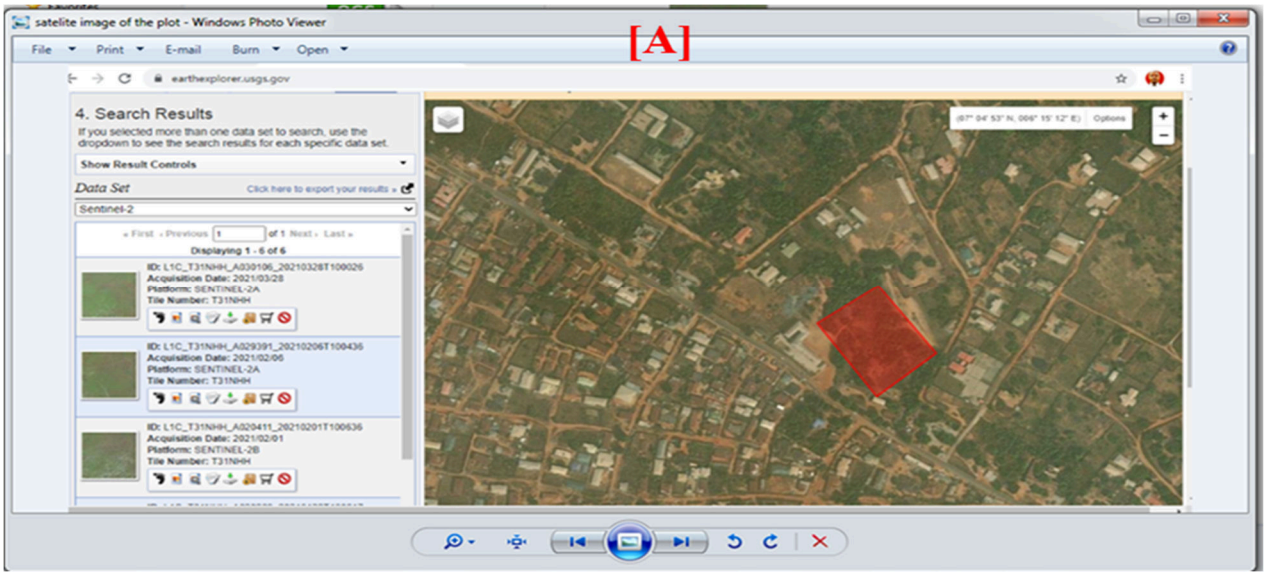

Figure 2a: Spatial map resolution of the study area

2.2 Normalized Difference Vegetation Index

Calculation of the Normalized Difference Vegetation Index (NDVI) is often used to monitor drought, forecast agricultural production, assist in forecasting fire zones and desert offensive maps. Farming application software such as Crop Monitoring, integrate NDVI to facilitate crop scouting and give precision to fertilizer application, irrigation, and estimation of crop water requirements. NDVI was calculated using equation (1). Groundnut crop water requirements (CWR) were estimated using the NDVI values as expressed in equation (2).

$$\text{NDVI} = \frac{\text{NIR}-\text{RED}}{\text{NIR}+\text{RED}} \quad (1)$$

Where;

NIR – reflection in the near-infrared spectrum

RED – reflection in the red range of the spectrum

According to this formula, the density of vegetation (NDVI) at a certain point of the image is equal to the difference in the intensities of reflected light in the red and infrared range divided by the sum of these intensities. This index defines values from -1.0 to 1.0, basically representing greens, where negative values are mainly formed from clouds, water and snow, and values close to zero are primarily formed from rocks and bare soil. Very small values (0.1 or less) of the NDVI function correspond to empty areas of rocks, sand or snow. Moderate values (from 0.2 to 0.3) represent shrubs and meadows, while large values (from 0.6 to 0.8) indicate temperate and tropical forests.

$$\text{CWR} = \text{NDVI} * \text{Kc} \quad (2)$$

Where,

Kc = Crop coefficient

2.3 Measurement of Egusi-melon Phenology and Field Management

Weed was controlled using a combination of manual and chemical operations. 5-day after planting (DAP), the Egusi-melon physiological growth was evaluated by measuring plant height from the soil surface to the emergence point of the youngest leaf, counting the number of living leaves, measuring the length and width of the youngest fully developed leaf.

2.4 Data Analysis

The relationship of plant phenological parameters such as plant height, leaf breath, number of leaf emergencies, and number of dead leaves was evaluated using statistical metrics such as mean, median, variance, regression coefficient, and T-test of SPSS software.

3. Results and Discussion

3.1 NDVI-CWR Computation

Fig.2a shows the mapped area of the study area using Arc-GIS software produced from Landsat images. Fig. 2b-c depicts the computed NDVI value of from the highest value of 0.12 to the lowest of 0.02 under groundnut plantation. Hence, the NDVI for vegetation, water, and bare soil is> 0.1, < 0, and 0 to 0.1 [7-9]. The reference evapotranspiration (ETo) values for the Months of August, September, October, and November of the groundnut crop were computed using the in-built mechanism as shown in Fig. 3a. The output of $NDVI_{kc}$ grid cell/pixel in Fig. 2b was multiplied by the ETo to obtain CWR. NDVI computed CWR is shown in Table 1:

Table 1: NDVI computed melon CWR-ETc

Period	NDVI-Kc(max)	NDVI-kc (min)	ETo (mm/day)	CWRmax (mm/day)	CWRmin (mm/day)
August	0.08	0.04	3.67	0.29	0.15
September	0.09	0.06	3.58	0.32	0.21
October	0.10	0.02	3.48	0.35	0.07
November	0.12	0.02	3.55	0.43	0.07

Hint: Computation of monthly CWR

Total CWR_{max} in August: 0.29 * 7 = 2.03 mm/month: Total CWR_{min} in August: 0.15 * 7 = **1.05** mm/ month

Total CWR_{max} in September: 0.32 * 30 = 9.6 mm/month Total CWR_{min} in September: 0.21 * 30 = **6.3** mm/ month

Total CWR_{max} in October: 0.35 * 31 = 10.9 mm/month Total CWR_{min} in October: 0.07 * 31 = **2.2** mm/ month

Total CWR_{max} in November: 0.43 * 15 = 6.5 mm/month: Total CWR_{min} in November 0.07*15= **1.05** mm/ month

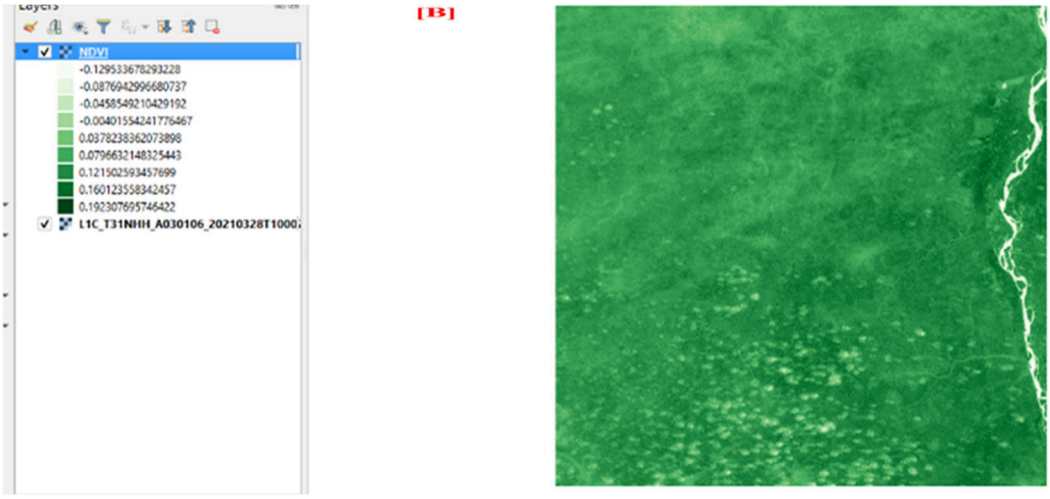

Figure 2b: The computed NDVI value

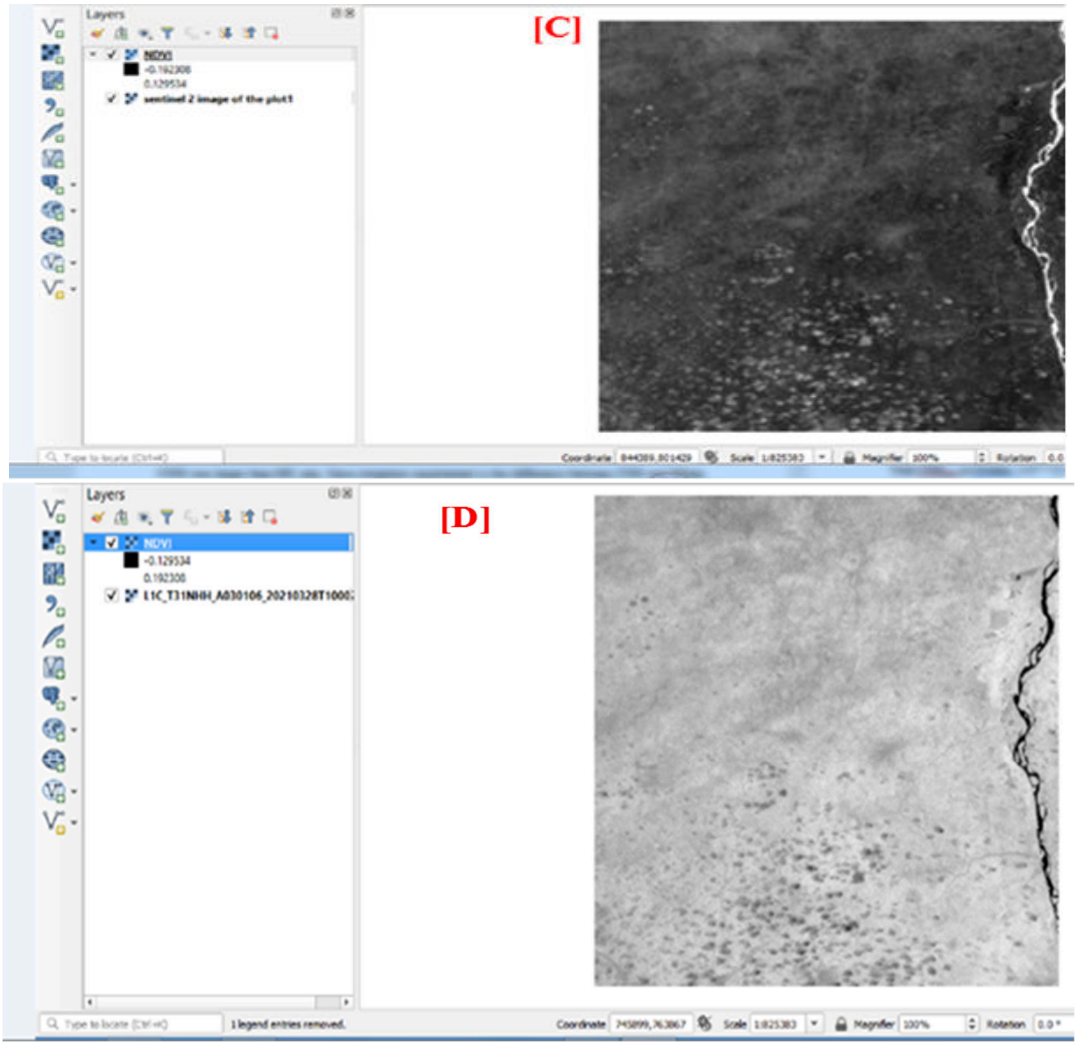

Figure 3: NDVI computed Max Kc-spatial map resolution of the study area (b), and NDVI computed Min Kc-spatial map resolution of the study area (c-d).

3.2 Groundnut Phenological Development

The growth parameters of groundnut were measured at 5 days after planting (DAP). A plant height (Ph) of 2.5 cm was recorded at the first measurement and increased steadily to the highest height of 34.2 cm at 83 DAP. The relationship between the groundnut height development in response to the DAP is highly significant at $P < 0.01$. The coefficient of determination $R^2 = 0.935$ indicated a strong and positive correlation of crop height and groundnut cycle in days. Hence, the development could be attributed to precise farm management practices such as weed control, fertilizer, and water application. The finding agrees with the study of Baker and Eaddy (2001) which explained the effect of temperature on muskmelon phenological development. Conversely, the study revealed a dynamic growth process of groundnut leaf width elongation in relation to the growing cycle length. The plant width of 1.2 cm was recorded at 5 DAP. However, we continuously observed daily leaf width elongation (WE) to a maximum length of 5.8 cm at exactly 60 DAP, and the WE was terminated at this value. The result indicated the difference between the maximum and minimum of melon width leaf. Fig. 3b shows the relationship of melon width length and plant cyclic period with $R^2 = 0.9544$. The finding agrees with the several studies [10-11]. The leaf emergency was immediately noticed on the 5DAP, and it continued to rapidly increase to a peak of about 60 leaves at 83 DAP. The increase in groundnut leaf emergency and other phenological development could be attributed to the health status of the crop under consideration. It was shown that the first dead plant at 18 DAP and the death rate of 2 plants per day continued till to 80 DAP. No death plant (dl) was recorded on 40-43 DAP. The death rate (LD) increased at 50 DAP and got to the peak of 14 dead plants per day at 60 DAP. A total number of 106 dead leaves was recorded during the 83-day of phenological measurement.

The result in Table 2 presents the statistical metrics of groundnut phenological development in response to the crop cyclic period under well-managed farming practices. All the growth parameters such as no of plant width (dl), leaf emergency (le), and plant height (Ph) and the number of dead leaves (dl) are significant at $P < 0.01$. This result shows similarity with the work of Patel *et al.* [12].

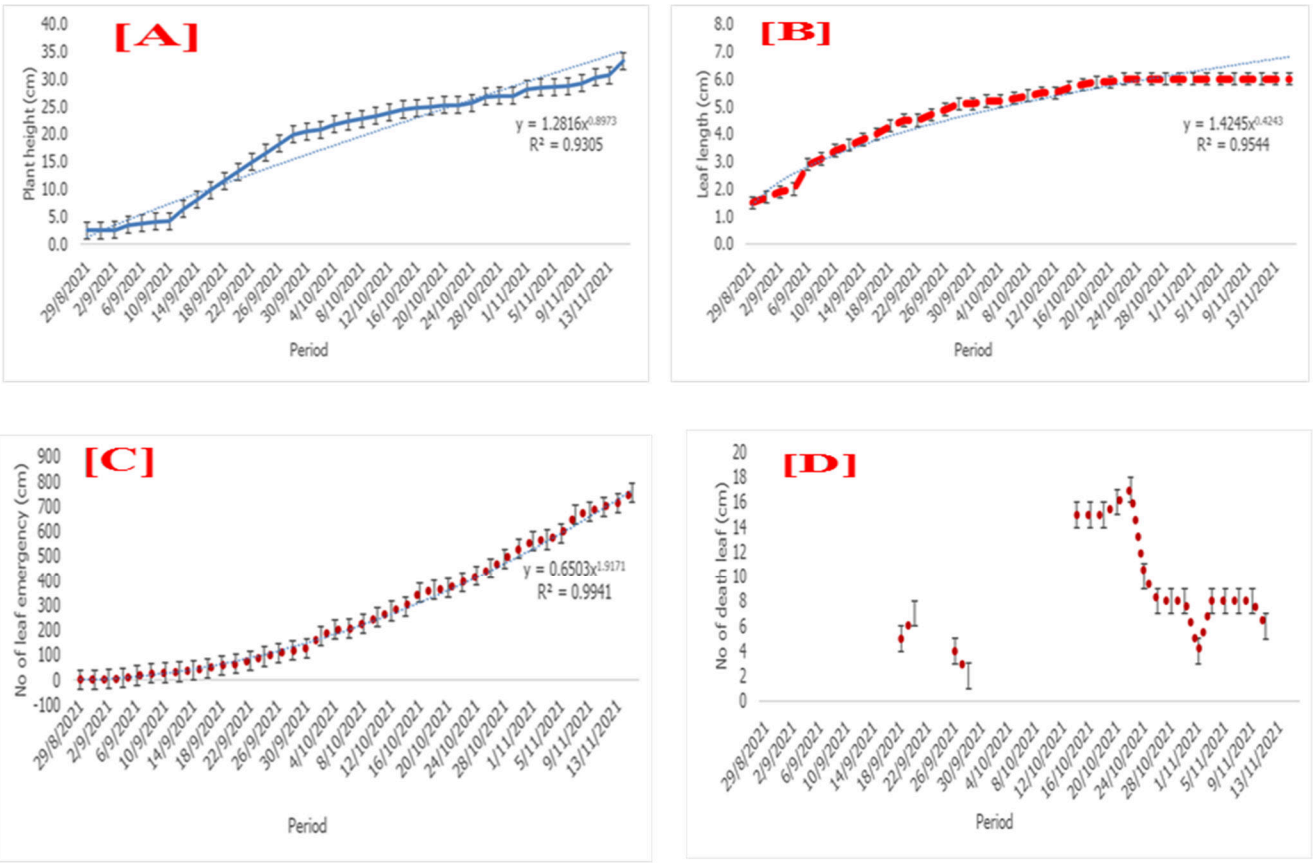

Figure 3: Plant phenology and growing cycle-plant height (a), plant length (b), number of leaf emergency (c), and no death leaves (d)

Table 2: Statistical metrics for experimental treatments

Treatments	Phenology	Mean	Median	Variance	Std. Dev.	Std. Error	T-Test	Sign
Groundnut	Plant height (Ph)	66.3	70	881.3	28.4	8.12	6.66	*0.001
	Plant width (Pw)	0.9	0.8	0.5	0.6	0.07	8.77	*0.001
	No of leaf emergency	33.6	34.6	180.4	13.2	3.77	8.23	*0.001
	No of death leaf	9.9	6.6	140.5	12.3	3	6	*0.001

* Significant at $P < 0.001$

3. Conclusion

In this study, groundnut crop water requirements (CWR) were estimated using Normalized Difference Vegetation Index (NDVI). The overall results showed that NDVI showed weak performance over of estimating CWR. In September, October, and November; maximum computed NDVI-CWR values of 9.6 mm, 10.9 mm, and 6.5 mm were estimated. The poor performance of NDVI could be associated with a small area of the field and spatial resolution of the experimental field. Conversely, a handheld green sensor is preferable to estimate the groundnut CWR and monitor the general health status of crops under small-sized cultivation, while NDVI is recommended for large farms.

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