ASSESSMENT OF SPATIAL PATTERN OF NET SOLAR RADIATION AND SURFACE TEMPERATURE FOR SUSTAINABLE AGRICULTURE IN IBARAPA EAST LOCAL GOVERNMENT AREA, IBADAN, NIGERIA

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ABSTRACT

The study focused on the evaluation of the spatial distribution of net solar radiation and surface temperature in Ibarapa East local government area, Oyo State, Nigeria, using geospatial techniques. Variables were obtained from Landsat images of 2023 and Aster elevation data. To examine the impact in agriculture ecosystem, the study examined the response of temperature to spatial pattern of the net solar energy. Both variables were calculated using a machine learning algorithm called random forest. The results revealed northern part of the study area experienced more net solar energy, while the southern part experienced higher temperature. There was a strong study will help to ensuring sustainable food production in the area. Therefore, the local negative relationship of 84% between temperature and solar energy available on the earth's surface. The LGA experienced average of 32.7^{o}c and 221.2W m^{-2} net radiation in 2023. A striking finding of this study is the fact that net radiation decreased with increase in temperature. The findings of this authority and other relevant stakeholders should not jettison information about climate variables, rather prioritize investments in research and capacity-building initiatives in the field of climate science.

Keywords: Spatial distribution, net solar radiation, temperature, farmers and crop varieties.

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INTRODUCTION

Surface solar energy balance and temperature variability is one of the most pressing challenges facing humanity in the 21st century, with profound implications for agriculture ecosystems (IPCC, 2014). Understanding the spatial and dynamics of these climate variables and their effects on in agriculture system is crucial for accurately assessing the impacts of climate change and formulating effective adaptation and mitigation strategies (IPCC, 2014). In this context, the application of remote sensing has emerged as a powerful approach for analyzing climate variables at various spatial scales (Goodchild, 2015).

Satellites equipped with sensors capable of capturing data across multiple spectral bands enable the observation of various climate-related parameters, including land surface temperature, vegetation cover, precipitation, and atmospheric composition (Makinde *et al,* 2019). Remote sensing-derived datasets provide valuable input data for initializing and validating climate models, improving the accuracy of simulated climate projections (Makinde *et al*, 2019). The spatial analysis of climate variables using Geoinformatic techniques represents a cutting-edge approach for understanding the dynamics of earth's climate system. By harnessing the effectiveness of these techniques, this study provides insights into the spatial patterns of climate variability in Ibarapa East local government area. The area is known for its rich tradition of agriculture with limited resources to acquire expensive early warning devices such as agrometeorological stations. As climate change continues to exert profound impacts on our environment, and agriculture in particular, this study is set to use remote sensing to assess the spatial distribution of aforementioned climate variables in Ibarapa East area of Ibadan, and provide evidence-based decision-making for climate adaptation and mitigation strategies.

MATERIALS AND METHODS

Study Area

Ibarapa East falls within latitudes 70.15' N and 70.55' N and longitudes 30E and 30.3' E, and it is one of the local government areas in Oyo State, Nigeria. The area is approximately 706km² in geographical size, located in the western part of Oyo state and falls within the Forest-savanna Transition Zone.(Ogundele et al. 2012). Most of the land lies at elevations ranging between 120 and 200 meters above sea level. The predominant occupation of the people is farming. Soil type: Lateritic clay soil, loamy sand, and sandy loam. vegetation: Mixed deciduous and semi-deciduous forest, with grassland and shrubs in open areas. The region has a tropical climate with two distinct seasons, the rainy season and the dry season. This could be a good opportunity to assess the radiant flux in the region and its impact on agricultural productivity.

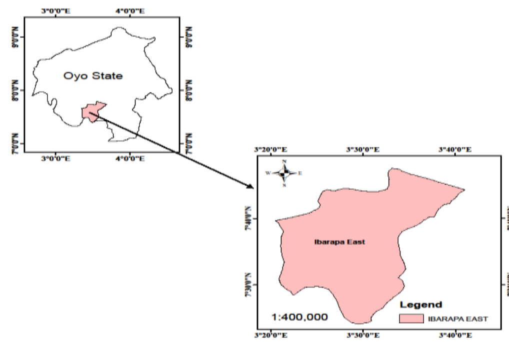

Fig. 1: The Study Area Map

Data collection and processing

Landsat satellite image of 2023 was obtained from US Geological Survey (USGS). The study area is within the Landsat path 191 and row 55 with pixel sizes of images 30m×30m with the exception for the thermal IR band 10, which has 100-m resolution bands (Chander, 2003). Table 1 describes the Landsat ETM+ and OLI images used, as well as the DEM of 30m resolution. Field data at various locations randomly selected were used to validate information derived from remote images. The satellite images used have been summarized in table 1. The study focused on the spatial dynamics of climate variables such as net solar radiation, and air surface temperature in 2023. The software systems used are random forest for image processing, excel for statistical analysis, and ArcGIS 10.5 for final map outputs.

Table 1: Satellite Images (source: USGS official website

Satellite Sensor	Spatial resolution	Acquisition years	Path	Row
Landsat 7 & 8	30m x 30m	2023	191	55
Asterdem	30m interval	2000	191	55

Estimation of climate variables

Net Solar Radiation: Net solar radiant flux distribution is crucial in climate modeling (Ryan *et al*, 2017). This was determined using Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC) model for calculating surface energy balance (SEBAL) (Richard *et al.* 2011. Ufoegbune *et al*, 2019; Ryan *et al*, 2017). It estimates the residual of energy at the terrain surface (Ryan et al, 2017) using shortwave and longwave radiation from satellite imagery, digital elevation model (DEM) (Richard *et al.* 2011). Net radiation (N_r) is computed by adding all incoming radiation and subtracting all outgoing radiation:

$N_r = (1 - \alpha)d_s + d_l - u_l - (1 - e_o)d_l \dots\dots\dots 1$

Where α is the surface albedo, d_s, d_l and u_l are the incoming and outgoing radiations respectively, and e_o as the surface emissivity.

The incoming shortwave d_s is calculated as in equation 2 (Ryan *et al*, 2017).

$d_s = tse_o cos_z$ ……… 2

where t *is* transmissivity of the atmosphere given as a function of the elevation above sea level h:

$t = 0.75 + (2 * 10^2 * h)$ …… 3;

s is the solar constant (1367W/m^2); θ is solar zenith angle, which is the sin of solar elevation. ε_o is the eccentricity correction factor of the earth's orbit about the sun calculated using equation 4.

$\varepsilon_o = 1 + 0.033\cos\left(\frac{2\pi dn}{365}\right)$ ………. 4

where dn is the Julian day of the year. The upwelling and incoming longwave energy were calculated in equations 5 and 6 (Ryan *et al*, 2017).
$u_l = e_s.\delta.T_s{}^4$ …….5
Where e_s is the surface emissivity, δ is the Stefan-Boltzmann constant (5.67*10^{-2}) and T_s is the surface temperature in Kelvin. The incoming long wave is given as:

$d_l = e_a.\delta.T_s{}^4$ …… 6
Where e_s is the surface emissivity, e_a is air emissivity, presented as
$e_a = \frac{N_r - G + \alpha + \sigma T_s{}^4}{\sigma Tar^4}$
*Land surface temperature(LST)***:** The surface temperature *LST* was estimated in equations 7.
$LST = \frac{T_a}{1 + \left(\frac{\lambda x T_a}{\rho}\right) \ln \varepsilon}$ ………7
where: λ is the wavelength of emitted radiance (11.345 for TM/ETM and 11.5 µm for OLI), ρ is $h \times c/\lambda$ (1.438 ×10^{-2} m K), σ the Boltzman constant (1.38 ×10^{-23} J/K), h the Planck's constant (6.626×10^{-34} J s), c is the speed of light (2.998 ×10^8 m/s) and **ε** denotes emissivity (Lillesand *et al*, 2008, Agbor et al, 2017 and Makinde et al, 2019)

RESULTS

Figures 2 and 3 show the spatial pattern net solar radiation and temperature of 2023, while figures 4 presents the relationships between the two variables. Table 2 shows mean distribution of surface temperature and net radiation across the northern and southern parts of the area. From figure 2, it is obvious that there was higher surface temperature in the northern part (33.8 ºC) and lower in the southern part of the area (31.6 ºC), while available surface energy distribution was in opposite direction (167.2 $W\ m^{-2}$s in the north and 275.2 $W\ m^{-2}$s in the south). The average temperature was 32.7ºC and that of net energy was about 221.2Wm^{-2}s for the entire area. Figures 4 presents the interactions between the climate variables in 2023. It explains a very strong negative relationship between temperature and net surface energy. It shows that increase in net solar radiation influences the surface temperature of the place negatively. The relationship between them is a strong negative one of about 84%.

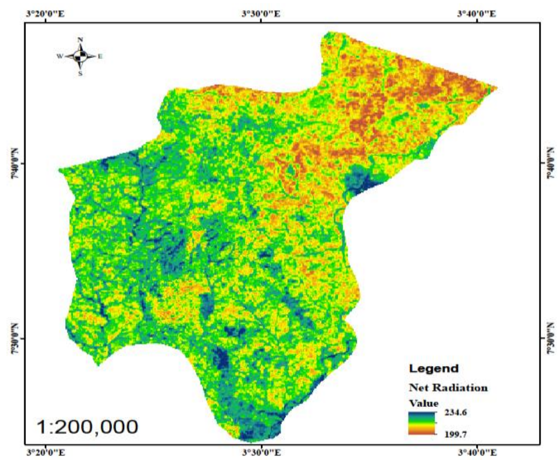

Fig. 2: Net Surface Energy of Ibarapa East LGA.

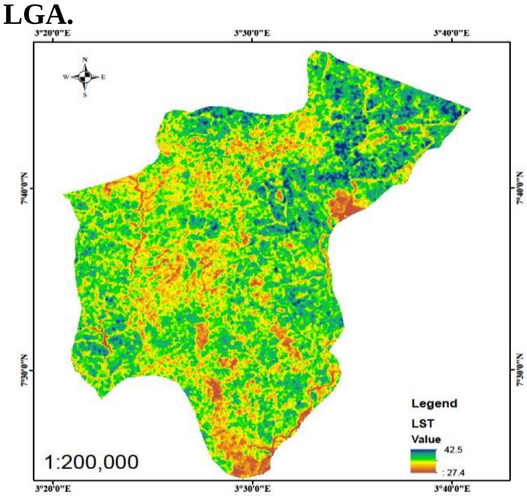

Fig 3: Surface temperature of Ibarapa East LGA.

Table 2. Mean distribution of surface temperature and net radiation of Ibarapa East LGA.

Regions	LST (ºC)	N_r $W\ m^{-2}$s.
North	33.8	167.2
South	31.6	275.2
Mean	32.7	221.2

$W\ m^{-2}$s represents net radiation in watts per square meter per second

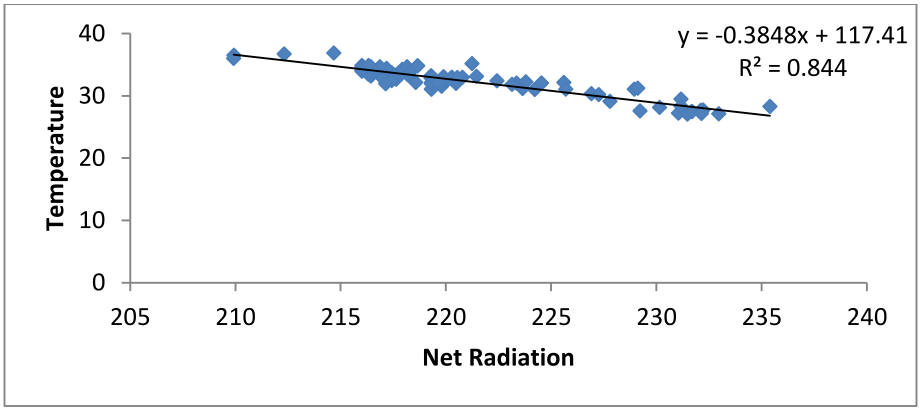

Fig 4: Relationship between N_r and LST in Ibarapa East LGA.

DISCUSSION

This study examined the spatial pattern of net solar radiation and temperature as well as the effects of their interaction in agriculture system. Results show significant impact of net radiation, on surface temperature. For instance, there was an increase in air temperature due to decrease in solar energy available on the earth's surface. Generally, one would expect to see a positive correlation between net radiation and air temperature, since an increase in net radiation would lead to an increase in air temperature (David, 2017, Pinde *et al*, 2002; Gabriela 2010). One possibility could be the effect of Vegetation cover. This can have a cooling effect on the atmosphere, which could explain why there is a negative relationship between net radiation and air temperature (Gabriela *et al*, 2010; IPCC. 2013). Vegetation releases water vapor into the air through transpiration, which increases the humidity and leads to lower air temperatures (Julia *et al*, 2006). This is really an important finding, because it shows that vegetation cover can play a role in regulating the earth's temperature. This could have implications for climate change, since changes in vegetation cover could affect the earth's ability to regulate its temperature (Aaron *et al*, 2014). This is important to farmers because, the primary effects of climate change on agriculture arise from changes in temperature and intensity of extreme weather events (Lobell et al, 2011). Thus, farmers may need to select crop varieties that are more resilient to the stress of higher or lower temperatures (Hatfield *et al*, 2015).

CONCLUSION

The assessment of spatial pattern of net solar radiation and surface temperature in Ibarapa East local government area offers invaluable insights into their impacts in agriculture ecosystem. Through the application of geospatial technologies, researchers can better understand the spatial patterns of these climatic variables among others. The results of this study revealed a negative response of temperature to increase in net solar radiation. It is quite intriguing and at the same time suggests the possible effect of vegetation cover on temperature and surface energy balance distribution pattern.

Recommendation

The study revealed interesting facts about the study area, such as the negative relationship between net radiation and surface temperature This is an important factor that should be monitored at regular interval. Therefore, it is imperative that stakeholders across various sectors prioritize investments in research in climate studies. Prioritizing this can enhance our capacity to effectively win the global fight against climate change, ultimately contributing to a more sustainable food production for all.

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