



Investigation of the Relationship between Land Surface Temperature and Radioactivity in Shira Hills, Bauchi State, Nigeria

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Abstract

Naturally occurring radioactive minerals in geologic formation within the rock matrix could lead to the conversion of the kinetic energy emitted from gamma rays into thermal energy. These results in generating high geothermal energy associated with radioactive rocks relative to non-radioactive formations. Excessive radiogenic heat formed due to high concentration of radioelement could affect the land surface temperature. Hence, the positive correlation between land surface temperature and radioactive dose is an indication for the effect of the radioactivity on the surface area. This study was carried out to investigate the relationship between land surface temperature and radioactivity of Shira hills, Bauchi state, Nigeria with the aim of assessing the impact of the gamma rays intensity on the surface of the studied area. Radiation alert inspector was used to measure the gamma rays intensity at different point (100 point) on the surface. The land surface temperature of the area was spatially mapped using Moderate Resolution Imaging Spectroradiometer Land Surface Temperature (MODIS LST) data. The correlation between the measured gamma ray intensity and the land surface temperature was obtained to be $R^2 = 0.007$, which indicates that the radioactivity of Shira hills, Bauchi state, Nigeria has less or no significant impact to the surfaced environment.

Keywords: Radioactivity, Land surface temperature, MODIS data, Arch GIS, radiation alert detector, Shira hills, Bauchi State, Nigeria

1. Introduction

Since the beginning of time, our earth has been radioactive. In nature, there are many radionuclides. Source that surrounds, which can be found in rocks, air, water, soil etc. We ingest/inhale nuclides every day through the air, food and water we consume. Radioactivity can be found in planet's rocks, soil, lakes, oceans, building materials and dwellings. Natural radioactivity can only be avoided in a few places on the planet (Ahmed *et al.*, 2011). The level of change in the natural background activity over time as a result of any radioactive discharge necessitates measurements and studies of natural radioactivity in rocks. Environmental protection necessitates monitoring of radioactivity in the environment (UNSCEAR, 2000).

The MODIS LST products are series of products that start with a swath (scene) and advance through spatial and temporal transformations to daily, eight-day, and monthly global gridded data. MODIS is a large-scale initiative that employs sensors on two satellites to offer daily coverage of the whole planet. Spectral, geographical, and temporal resolutions are all present in the data. Both the Terra and Aqua satellites have a MODIS sensor on board. For any given site, photos may generally be obtained in the morning (Terra) and afternoon (Aqua). In the thermal range of the spectrum, nighttime data is also available. When ordering a scenario for a given day, the time of day should be considered. While a daily scene for every specific date and location can be requested, MODIS data has been used to create a number of consolidated products, such as 8-day or 16-day composite images, a variety of indices, and a variety of additional global outputs with various time scales. MODIS data is available in a variety of

collections, versions, and processing levels. MODIS data Versions 4 have had their data confirmed and certified for scientific research.

The decay of radioactive isotopes such as uranium, thorium, and potassium within the rock matrix is known as radiogenic heat. The land surface temperature could be affected by excessive radiogenic heat caused by high radioelement concentrations. As a result, the positive association between land surface temperature and radioactive dosage indicates the impact of the area's radioactivity on the environment's surface. (Abbady *et al*, 2018).

The shira hill complex plays a significant role in the people's geographical and historical region, as so many activities take place around the area. The hill was not only a natural fortress but also a haven. The rocks are mined with simple tools like shovels and diggers, while industrial businesses are drilling and crushing of quartz/gravel into granite chips, which are sold as building and construction materials. Timber/wood and grazing grasses were found on the hills and in the surrounding area, which were used for domestic purpose.

Land Surface Temperature (LST) can reveal important details about the surface's physical qualities and climate, both of which are significant in variety of environmental processes (Dousset and Gourmelon, 2003; Weng, *et al.*, 2004). LST and most basic physical parameter of the earth's surface, has been examined for over a decade in order to track rapid and repeated changes in the global environment. Residents in Shira village, rely primarily on minerals extracted from rocks for building materials and road construction. Furthermore, there is a dearth of data on natural radioactivity concentrations in rock sources and MODIS measurements of land surface temperature.

This was the first time of carrying out a work using MODIS data to explore the relationship between land surface temperature and radioactivity in Shira Hills, Bauchi State, Nigeria, as no similar work was carried out in such area before. This will bring some alliance to academics follow-up and more in depth researches on such issues, and encourage the emergence of more conclusions beneficial to human survival and development.

2. Material and Methods

2.1 Study Area

The study samples are restricted to some rock samples in Shira local government area of Bauchi State. Shira is a Local Government Area of Bauchi State, Nigeria. Its headquarters are in the town of Yana. It has an area of 1,321 km² and a population of 234,014 at the 2006 census. The postal code of the area is 750. The area is mostly Hausa/Fulani spoken tribe. Its geographical coordinates are 11° 27' 0'' north, 10° 3' 0'' East and its original name (with diacritics) is Shira. The area is geologically located within eastern end of the cretaceous basement complex of northern Nigeria bordering the western end of the Chad basin (Figure. 2). It is characterized by extensive geologic features comprising the Mesozoic Younger granites ring complex (Obaje, 2009).



Figure 1: Goggle earth map showing study area

2.1.1 Geology of the area

Shira's geological foundation has been thoroughly investigated (Woolley, 2001). According to the aforementioned expert, the base is part of the West African carton's crystalline basement (Rocci *et al.*, 1991). The three exposed hill complexes, which consist of one main ridge and two smaller secondary ridges and cover an estimated 152 km² with the largest ridge, Sarkin na Dutse, reaching a height of 633.37m above sea level, are the most distinguishing features. The two lesser ridges, known as minor ridges, are less exposed to the elements than the main ridge. The geological composition varies from quartz syenite to granite, with Biotite granite dominating the central portion of the slope (Woolley, 2001). The Shira hill range is a significant aspect of human geography.

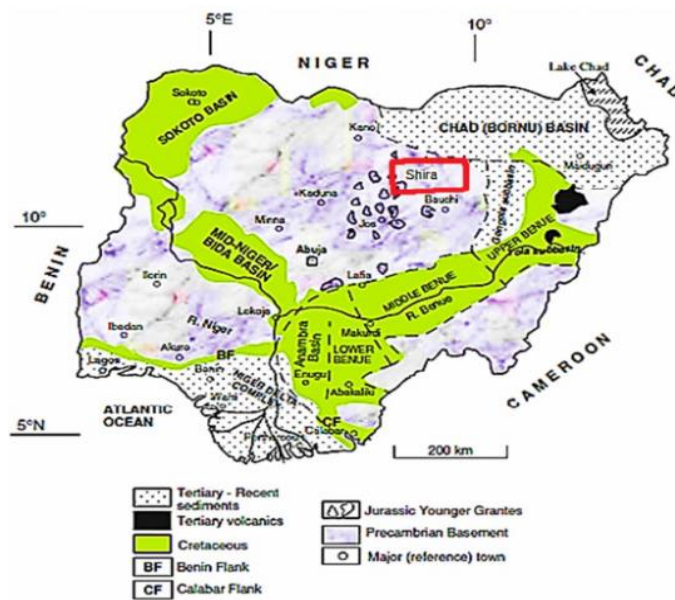


Figure 2: Geological map of Nigeria showing study area (Obaje, 2009)

2.2 Data Collection and Processing

About 100 points within the rocky surface were randomly selected as a sample points. A digital radiation meter known as Radiation Inspector Alert was used to measure the gamma dose rate in mR/hr. Handheld Global Positioning System (GPS) receiver was used to record the geographic coordinate of each sample location. To reduce the level of errors in the data, the readings were taken three times and the average of each data was obtained.

The recorded average Gamma Dose Rate (ADR) in mR/hr were converted to the Absorbed Dose Rate in Air (ADRA) in nGy/hr based on the relationship given by UNSCEAR (2000) as

$$ADRA (nGyhr^{-1}) = ADR(nRhr^{-1}) \times 2.778 \times 3600 \quad (1)$$

2.3 MODIS land surface temperature measurement

The first MODIS instrument was deployed aboard Terra in 1999, with an equatorial crossing time of 10:30 am.; the second MODIS instrument was flown aboard the Aqua platform in 2002, with an equatorial crossing time of 1:30 p.m. Every 1 to 2 days, the Terra- and Aqua-MODIS instruments scan the whole Earth's surface, collecting data in 36 spectral bands with wavelengths ranging from 0.4 m to 14.4 m. The twin-MODIS architecture was created

with the goal of achieving cloud-free imagery while limiting the optical impacts of shadows and glare that occur during morning and afternoon sunlight. MODIS data packages, which come in three resolutions of 250 m, 500 m, and 1 km, aid in our understanding of global environmental processes and dynamics that occur on land, in the oceans, and in the atmosphere. The MODIS data records assist in the extension of historical data such as NOAA's Advanced Very High Resolution Radiometer, maintaining the vital continuation of such collections to enable our research of both short- and long-term global environmental changes. MODIS-derived data sets continue to play an important role in assisting in the development and validation of global Earth system models with adequate predictive potential to inform and assist policymakers as they deal with global environmental change.

The daily data for Land Surface Temperature (LST) and Emissivity are extracted using the generalized split-window approach at 1 km pixel resolution and the day/night algorithm at 6km grids. Land cover types, atmospheric column water vapor, and lower boundary air surface temperature are used in the split-window algorithm to predict emissivities in bands 31 and 32. Figure: 3 are the global MODIS LST data from where the data for the study area was extracted.

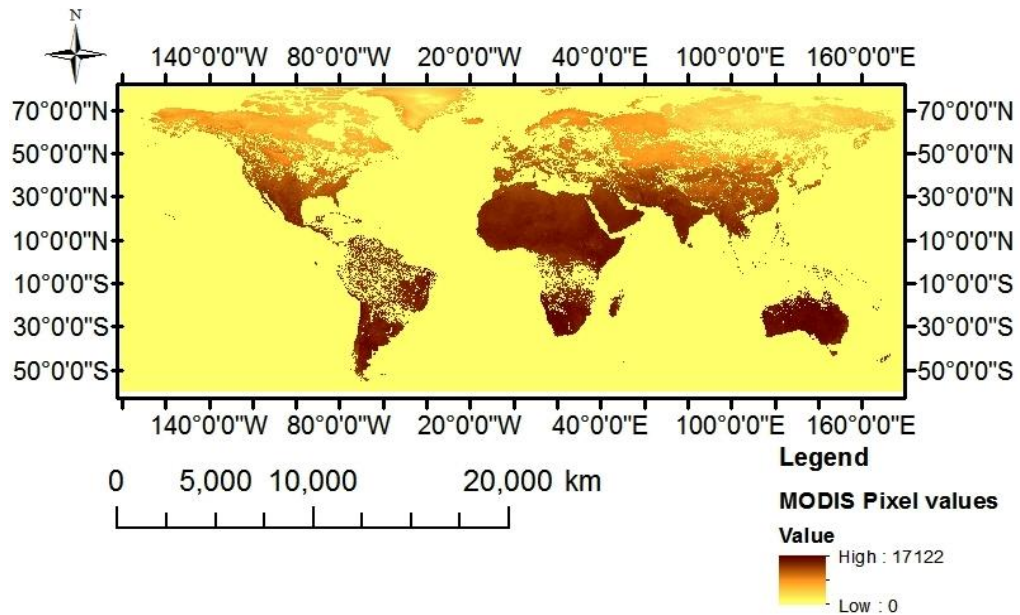


Figure 3: Global MODIS LST data (in pixel values) (NASA, 2020)

Daytime and overnight LSTs and surface emissivities are obtained from pairs of day and night MODIS data in seven Thermal Infrared (TIR) bands in the day/night algorithm. LSTs, quality assessment, observation time, view angles, and emissivities make up the product. The equation below (Wan, 2013) can be used to translate MODIS digital numbers into Land surface temperature (in °C).

$$LST (^\circ C) = (MODIS DN \times 0.02) - 273.15 \quad (2)$$

The sample points' coordinates were utilized to create a point picture of the study area. Using the ArcGIS software's extract values to point tool, the scattered points on the point picture were utilized to extract land surface temperature at the relevant sites from the LST map created based on equation (2).

3. Results and Discussion

The findings of measuring ambient radiation levels at several locations throughout the Shira rocks area of Bauchi State. Higher values are achievable as a result of the following factors: The rocks used for the building's foundation were mostly igneous rocks, which are thought to be rich in minerals like Zircon, Monazite, Uranite, Potassium, Feldspars, and Biotite (Solomon *et al*, 2002; Wentz, 1998), higher activity levels in radio-nuclides in the building materials (e.g. Soils, blocks, and tiles) used in the laboratories' construction (UNSCEAR, 1998), and the (Felix *et al*, 2015). Daytime MODIS images were also gathered, and the land surface temperature for the day (Day time Land surface temperature (DLST)) was calculated using the reference channel emissivity technique. Furthermore, during the day, the LST of syenogranite fluctuated from 36.11 to 42.73 °C. The average dose in the air was discovered to be 226.0535nGy/hr, and with a correlation between radioactivity and land surface temperature was obtained as $R^2 = 0.007$. When all of the results are compared, there is no clear link between radioactivity and LST.

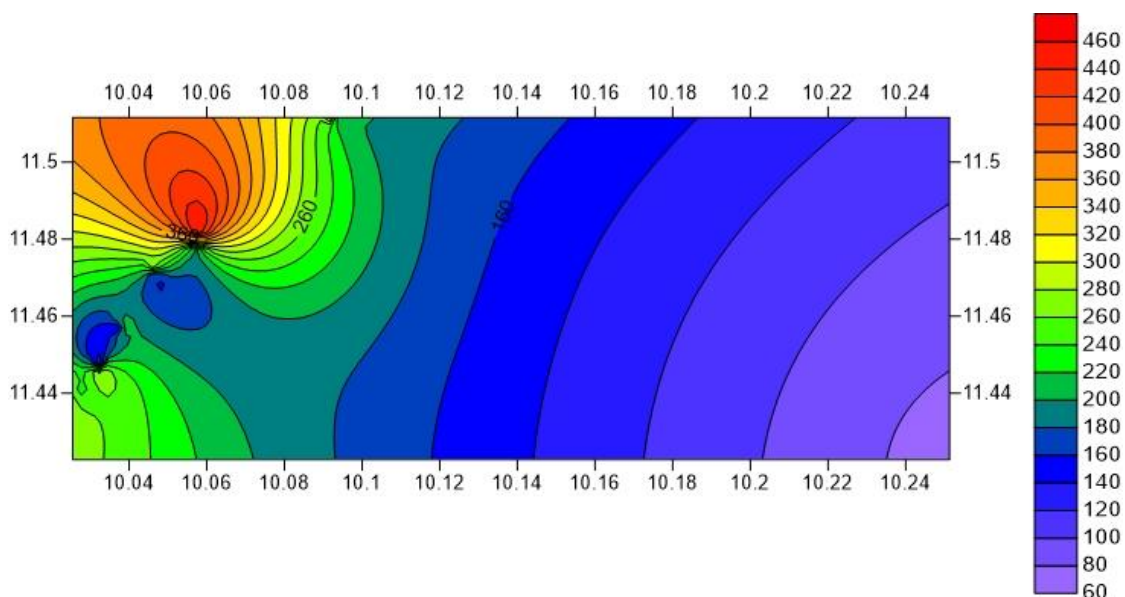


Figure 4: Map of the spatial distribution of average absorbed dose in air (nGy/hr)

The retrieved LST from the MODIS indicates that day-time LST of the study area ranges from 36.11 to 42.73 °C. Table 1 is the average data obtained for some selected point.

Table 1: Results obtained from field work using radiation alert and raster value obtained using MODIS data

POINT CODE	LATITUDE (deg)	LONGITUDE (deg)	ADRA (nGy/hr)	MODIS LST (deg C)
PC 1	10.09209	11.5116	251.02008	42.730011
PC 2	10.05705	11.4934	272.02176	41.829987
PC 3	10.047575	11.472683	280.0224	38.070007
PC 4	10.025131	11.42275	170.0056	39.649994
PC5	10.04637	11.47294	237.31065	38.070007
PC 6	10.03714	11.45665	210.0168	40.48999
PC 7	10.03215	11.44776	175.014	41.209991
PC 8	10.02574	11.4423	213.01704	41.48999

The plot of the spatial distribution of LST for the study derived from MODIS data is shown in Figure 5. Sample locations have been chosen to analyze the relationship between the two variables and are overlaid on the map. The map shows a lot of fluctuation in LST levels. The image's poor resolution (1km) limits the number of data points available for co relational analysis.

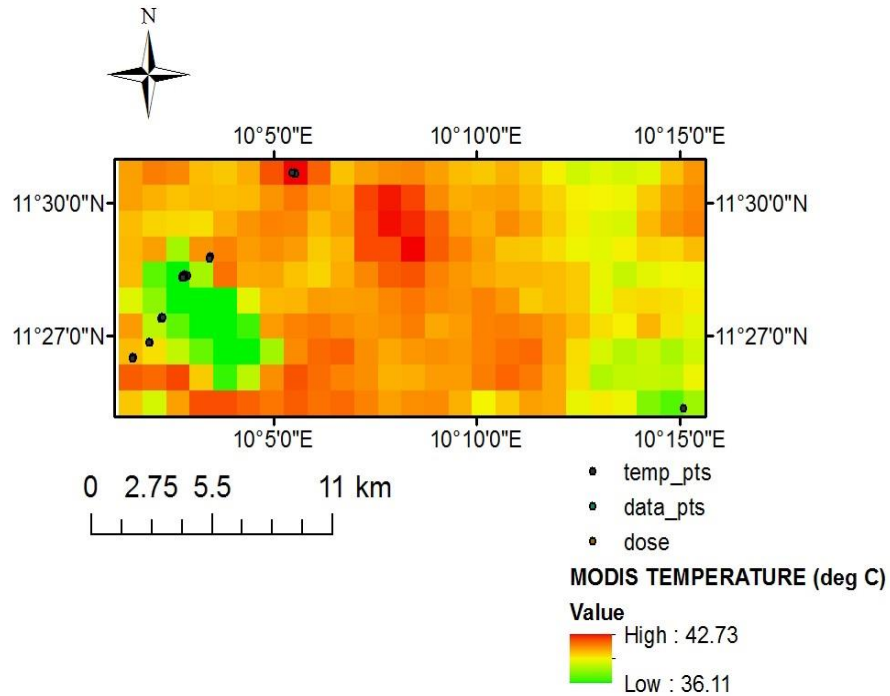


Figure 5: Map of the spatial variation of land surface temperature (deg C)

3.1 Relation between Radioactivity and LST

The relationship between the daytime land surface temperature (DLST) and radioactivity in Shira hills, Bauchi State, Nigeria was analyzed using spearman's correlation coefficient. This is accomplished by plotting the LST against the corresponding ADRA values for all respective sample points (Figure 6).

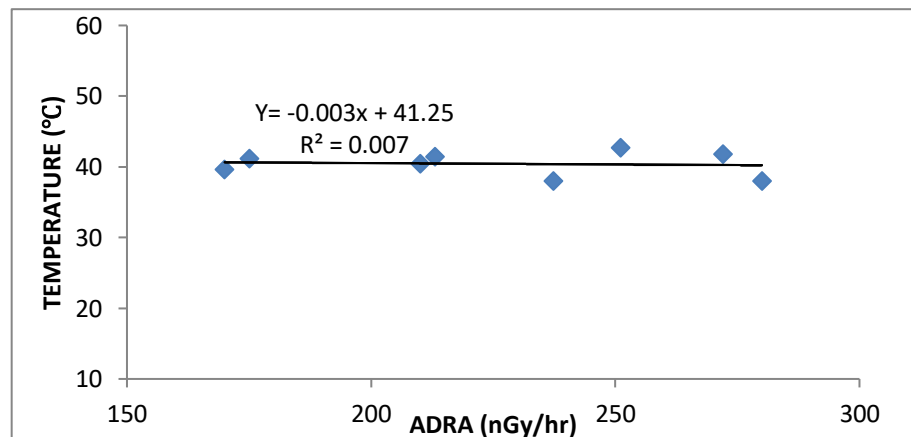


Figure 6: plot of the relationship between ADRA AND LST.



The plot gives a fitting equation of

$$LST(^{\circ}C) = -0.003 \times ADRA + 41.25 \quad (3)$$

With a fitting coefficient

$$R^2 = 0.007 \quad (4)$$

The extremely low fitting coefficient is an indication for insignificant relationship between the two variables. Thus; the plot exhibits weak positive correlation between radioactivity and daytime land surface temperature using MODIS data. This indicates that the level of radioactivity is low enough to influence the land surface temperature. Hence surface activities can be said to be relatively safe at Shira hills, Bauchi State, Nigeria.

4. Conclusion

Using day thermal bands from MODIS data, the current study attempted to identify a link between land surface temperature and radioactivity on Shira hills Nigeria. The syenogranite radioactivity and land surface temperatures were calculated. The average dose in air was found to be 226.0535 nGy/hr, with a correlation of $R^2=0.007$. The daytime land surface temperature was found to range between 36.11 and 42.73 °C, and the average dose in air was found to be 226.0535 nGy/hr. It has just a shaky relationship with radioactivity levels. The lack of a link between land surface temperature and radioactive dosage indicates that the area's radioactivity has little impact on the environment's surface. Other than radioactivity, a variety of factors can influence the temperature of the land surface, including Structures, terrain, geographic position, shadowing and scattering, moisture; rock thermal characteristics, rock color tone, and wind effect are among them. There is also a considerable difference in LST distribution between day and night data. When investigating the relationship between these two characteristics with the purpose of isolating the effect attributable to geothermal heat, all of these aspects should be considered. In addition to any technique that removes the effect owing to any component other than radiogenic, the use of night time data is recommended.

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