



Mapping and Modelling the Status of the Gujba Grazing Reserve Using Satellite Remote Sensing

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ABSTRACT

Grazing reserves are the main source of livestock feeds, and thus the quantity of foliage in a grazing reserve will determine its sustainability for livestock grazing. Over the years, growth in the population, increased in commercialized agricultural production, and climatic changes have resulted in shifts in vegetation species distribution, decreased grazing land biodiversity, lower production of foliage, and increase plant cover erosion. This resulted in low foliage productivity that can sustain grazing livestock in most parts of Africa. Many studies associated Earth Observation (EO) data with ground-measured biomass to quantify the amount of foliage in a particular area. However, few studies were conducted in African savannahs to investigate the sustainability of their grazing lands in terms of foliage availability. This study uses satellite remote sensing to investigate the status of the Gujba grazing reserve in the Savannah region and its level of sustainability for grazing. From the result, it was found that the total quantity of foliage calculated was 2,581,788,982kg, while, the recommended livestock intake was 22,523,869,644kg. This clearly indicates that the grazing reserve was seriously overgrazed and is not sustainable. The findings of the study will contribute to decision-making for proper management of grazing reserves by relevant ministries and other government agencies, thereby minimizing the persistent crop farmers and herders' conflicts in Nigeria and boosting livestock productivity.

Keywords: Mapping, Status, Grazing-land, Satellite Remote Sensing

1.0. Introduction

Grazing-reserves are still the primary source of livestock feeds in Nigeria, and thus the quantity of foliage in a grazing reserve determine its sustainability for grazing livestock for a certain period. Determining the quantity of foliage in a gazing land is very important more specifically to the farmers that depends on livestock grazing for their sustenance as well as ministries of livestock production. This information will guide them in planning and decision-making processes for sustainable livestock management.

Over the years, growth in population, technological development, increased commercialized agricultural production, and climatic changes in African savannah have resulted in shifts in vegetation species distribution, decreased grazing land biodiversity, lower production of biomass, and increase plant cover erosion (Porqueddu *et al.*, 2016). These variables had a dramatic impact on both the primary productivity of the pastureland ecosystem and livestock farming (Pritchard *et al.*, 2018; Chiwara, *et al.*, 2018). In Nigeria, these factors have led to an increase in clashes between the herders and crop farmers that resulted in the loss of lives and properties. Recently, it has led to cattle rustling, banditry, and kidnappings for ransom.

A growing body of literature illustrates that the common approach for estimating biomass, based on Earth Observation (EO) data, has been to examine the possible association between the ground-measured biomass and the EO data since biomass quantities cannot be directly derived from remotely sensed data (Lu, 2006). Many remote sensing approaches were used worldwide to measure grazing land biophysical parameters such as grass quantities (Ali *et al.*, 2016, Pfeiffer *et al.*, 2019), and the rate of pasture growth and productivity (El-Tantawi, *et al.*, 2019). Spectral indices are a strong indicator of the production of above-ground biomass in several regions and are often used as a method for estimating available forage (Fajji *et al.*, 2018; Oumar *et al.* 2017). It was also used to indicate the vigor or development of the canopy (Wang *et al.*, 2019; Dlamini *et al.*, 2019). The most common VIs used include the Normalized Distribution of Vegetation Index (NDVI), Vegetation Index Number (VIN), Normalized Difference Index (NDI), and Ratio Vegetation Index (RVI). Many studies use these four common VIs for vegetation studies. Scholars use such VIs for modeling vegetation biomass (Zumo *et al.*, 2021, Zumo and Hashim 2020) and density (Meshesha *et al.*, 2019, Yuyun *et al.*, 2019).

This study used the model derived from VIN by Zumo *et al.*, (2021) to calculate the quantity of foliage in a grazing land. This was because the two sites have the same geographical region with the same vegetation species. The calculated foliage quantity was compared with the recommended foliage quantity to evaluate the sustainability of the grazing site. The recommended livestock intake was derived from the daily intake of the livestock.

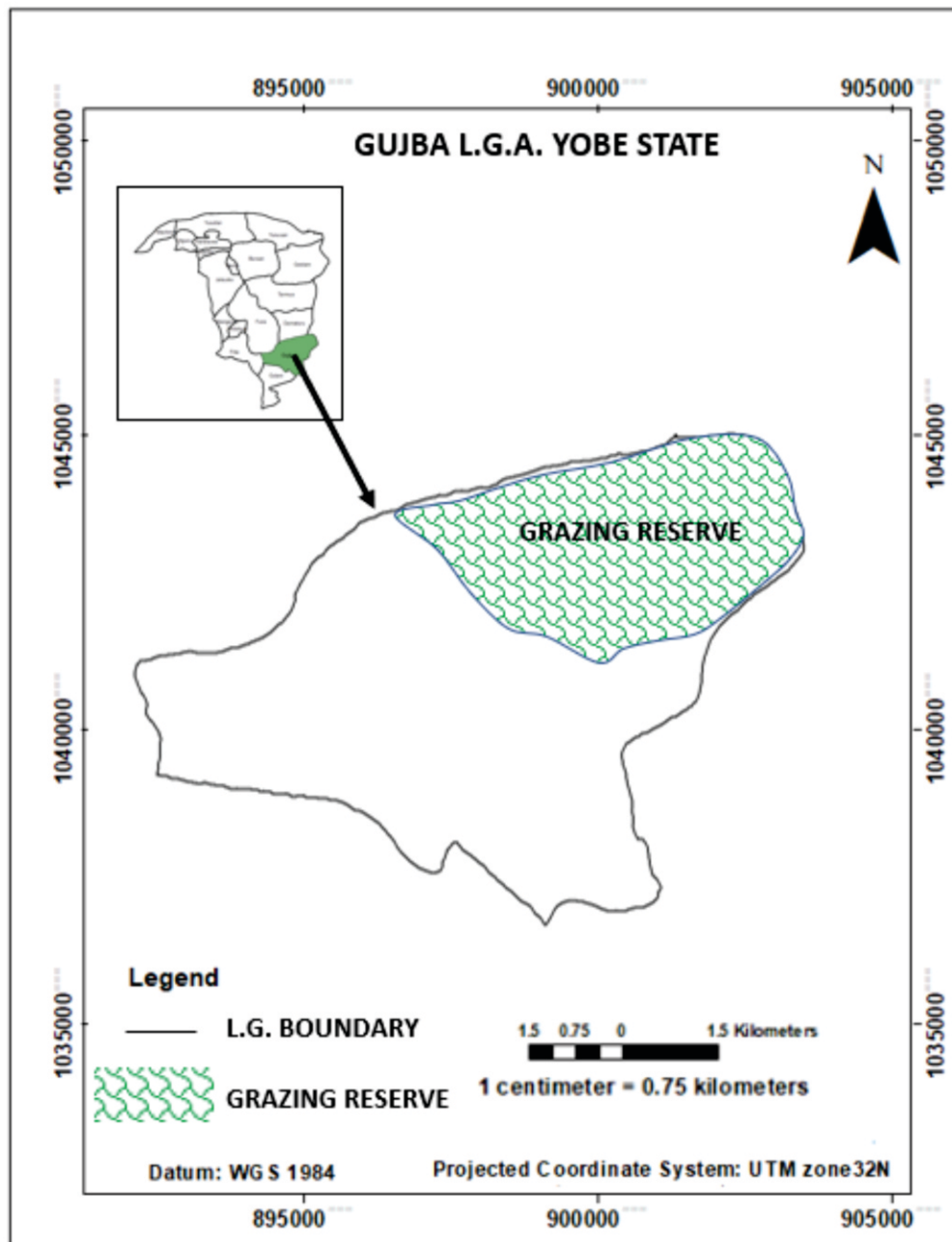
Literature reveals that the daily feed intake for a 250kg live weight of a cow was 2.5% of its weight (Meshesha, 2019; Sserunkuuma and Olso, 1998). However, some findings suggest that the daily dry matter intake for a cow that weighs 421.77 ± 28.60 kg is 18.89 ± 3.21 kg per day (Astuti *et al.*, 2019). The average daily intake of ruminants that weighs 39.4 ± 1.8 kg and 48.2 ± 1.3 kg consume 85.6 ± 2.3 and 104.0 ± 3.5 g of grass and take 662 ± 35 ml and 875 ± 34 ml of water per day (Squires and Wilson, 1971). Sheep, goats, and other ruminant animals share this characteristic. Using the intake of cattle, sheep, and goats, the recommended intake was calculated. The existing foliage quantity calculated from satellite data and the recommended were compared to see whether they are at the point of equilibrium, over production (over-grazed) or under production (under-grazed).

The study concluded that the Gujba grazing reserve was seriously under-grazed. This finding will contribute to the decision-making for proper management of grazing reserves by relevant ministries and other government agencies, thereby minimizing the persistent crop farmers and herders' conflicts in Nigeria and increasing livestock productivity.

2.0. Methodology

2.1. Study Area

The proposed study area is the Gujba grazing reserve, in Gujba Local Government Area (LGA) of Yobe State, Northeast part of Nigeria. The reserve has a bounding coordinate of 895203.264mE to 904503.252mE and 1041053.453mN to 1045017.921mN on WGS 1984 UTM projection (Figure 1). The measured annual average Temperature for the 2021/22 grazing season was 35 ° C. February is the warmest month with an average of 44 ° C. September is the coldest, with average temperatures of 26 ° C. The Precipitation ranges from the driest month in March 815mm to the wettest month in August 415,281 mm.



2.2. Materials

The materials used in this work were in three categories. Satellite data, topographical map, and livestock data. These three were acquired from different sources and used for the analysis for determining the sustainability of the grazing land.

Satellite data has been widely used in the study of the natural environment as an effective method to monitor the large-scale surface of vegetation dynamics. In this work, Landsat 8 OLI satellite data that covers the entire grazing site was downloaded and used for estimating the quantity of foliage in the grazing site. The World-Wide Reference System 2 has divided the world's land mass into 57,784 scenes, each measuring 183 km by 170 km, and this is how the Landsat satellite gathers data. The Operational

Land Imager (OLI) and the Thermal Infrared Sensor make up the payload of the Landsat 8 satellite (TIRS). With a spatial resolution of 30 meters (visible, NIR, and SWIR), 100 meters (thermal), and 15 meters, these two sensors give seasonal coverage of the world's continent (panchromatic). In comparison to Landsat 7, which acquired 438 scenes per day, Landsat 8 has been consistently capturing 725 scenes per day. Table 1 below lists the mapping uses for the Landsat 8 spectral bands.

Table 1. OLI Spectral Bands and Applications

Spectral Band	Wavelength	Application for Mapping
Band 1 - coastal aerosol	0.43-0.45	Coastal and aerosol studies
Band 2 - blue	0.45-0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53-0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - red	0.64-0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.85-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57-1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11-2.29	The improved moisture content of soil and vegetation; penetrates thin clouds
Band 8 - Panchromatic	0.50-0.68	The 15-meter resolution, sharper image definition
Band 9 - Cirrus	1.36-1.38	Improved detection of cirrus cloud contamination
Band 10 - TIRS 1	10.60-11.19	The 100-meter resolution, thermal mapping, and estimated soil moisture
Band 11 - TIRS 2	11.50-12.51	The 100-meter resolution, improved thermal mapping, and estimated soil moisture

Our study concentrates on bands 4 and 5. These two bands were good for discriminating vegetation slopes and evaluating the foliage quantity in an area of interest.

Topographical maps provide detailed, comprehensive, and accurate information on the graphical representation of any natural or artificial geographical feature that occurs on the surface of the Earth. Detailed information on the topographical map that was used in this work includes the settlements within the site, the road network, and vegetation cover.

The livestock data used in this study are the livestock population and livestock intake. These two sets of data were used to determine the quantity of foliage needed in the grazing site. The intake for cattle, sheep, and goats was obtained from existing literature while the livestock population was from the Yobe State Ministry of Agriculture.

2.2. Methods

The method involves three major components: (a) Foliage quantity estimation from satellite data, (b) analysing the acquired data with the livestock intake, and (c) evaluation of the status of the grazing reserve. The estimated foliage and the livestock population were used to evaluate the sustainability of the grazing land. The workflow of the overall methods was illustrated in figure 2.

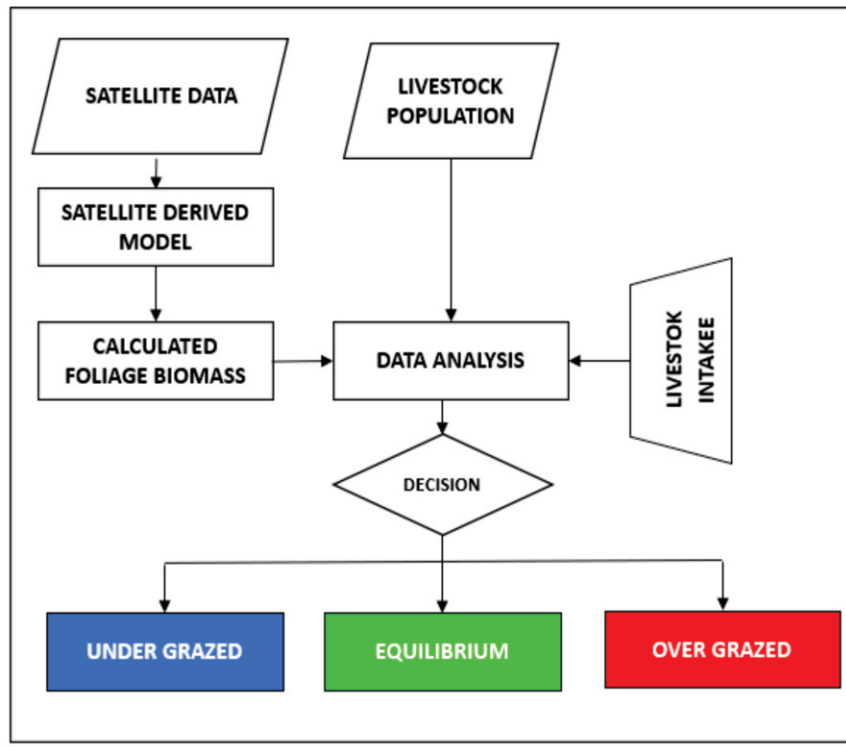


Figure 2: Workflow of the methodology

2.3.1 Data Collection

Three sets of data were collected in this study. Site plan of the grazing reserve, satellite data, and livestock data.

i. Site Plan of the Grazing Reserve.

The gazetted plan of the grazing site was not available from all the sources we contacted. However, we were guided by the staff from the Department of Livestock Management, Yobe State Ministry of Agriculture to trace the boundary of the grazing reserve on a topographical map. The site was bordering Gujba from the north, Buni from the south, and Dallari from the east. Figure 3 is the boundary of the reserve.

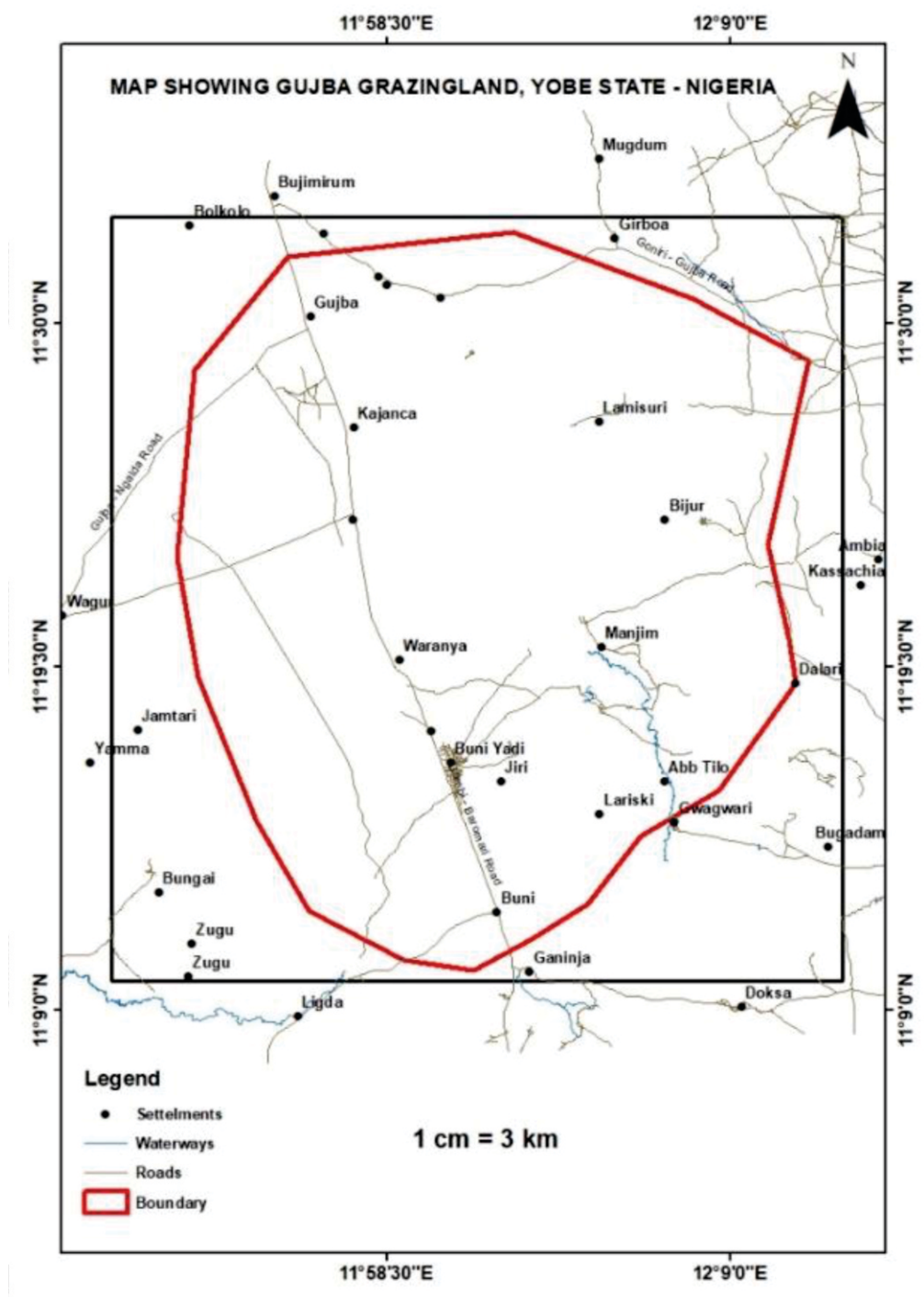


Figure 3. Site of Gujba Grazing Reserve

ii. Landsat 8 Satellite Data

Landsat 8 data was accessed via the Earth Explorer (EE) user interfaces online. The area of interest was selected via the google map interface. The range of dates was selected from 1st September 2022 to 30th September 2022. This is the period when vegetation reaches its peak of maturity. Cloud cover of less than 10% was considered. The dataset selected was Landsat 8 OLI/TIRS C2 L2 under the Landsat collection 2 level 2. Since only 2 bands were needed, the band 3 and 4 image data within the visible and NIR were downloaded. The world reference system (WRS) path and row were 186 and 052 under collection number 2. The images were LC08_L2SP_186052_20210916_20210925_02_T1_SR_B4 and LC08_L2SP_186052_20210916_20210925_02_T1_SR_B5.TIF.

iii. Livestock Population

The livestock population data was collected from the Department of Livestock Management, Yobe State Ministry of Agriculture. The population for cattle was 2,764,200, sheep was 3,774,432, and goats 2;988,970. This population was based on the projection of the 2009 livestock census in Nigeria.

2.3.2 Data Analysis

i. Satellite Data Modelling

The wavelengths that are absorbed and reflected by a green canopy are collected and used in remote sensing phenology. The optical region of the Electro-Magnetic Spectrum (EMS) includes wavelengths of near-infrared light, which are reflected and heavily absorbed by certain pigments in leaves (EMS). In order to determine the amount of foliage in the grazing area, a mathematical formula was created using the ratio of the red and near-infrared bands. The most widely used and practiced Vegetation Indices (VIs) are the Normalized Distribution of Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Normalized Difference Index (NDI), and Vegetation Index Number (VIN), which are evaluated as a standard ratio with red and near-infrared spectral bands depending on multispectral data. Table 1 shows the most common vegetation indices and their description.

Table 1. Commonly used vegetation indices

Vegetation index	Acronym	Formula	Description	Citation
Normalized Distribution of Vegetation Index	NDVI	$\frac{(NIR - R)}{(NIR + R)}$	This differentiates green grasses from the soil background with values varying from -1 to +1. 1 For heavily vegetation areas and -1 for non-vegetation areas.	Rouse <i>et al.</i> , (1974)
Vegetation Index Number or Simple Ratio	VIN	$\frac{NIR}{R}$	This spectral coefficient is the wavelength ratio with the maximum vegetation reflection and the lowest chlorophyll absorption wavelength. In dense vegetation, NDVI will saturate when LAI is very high.	Pearson and Miller, (1972)
Normalized Difference Index	NDI	$NIR - R$	It estimates non-photosynthetic local biomass	McNairn and Protz, (1993)
Ratio Vegetation Index	RVI	$\frac{R}{NIR}$	It's about the fact that green vegetation absorbs a lot more red than infrared.	Pipatsitee <i>et al.</i> , 2019

ii. Foliage Quantity calculation

VIN values vary from 1.5 to 0.5 for all the features in the studied area. However, foliage has a VIN between 0.85 and 0.99. In order to obtain the portions of the satellite data that were covered as pasture, input value of less than 0.9 and more than 1.0 was employed.

$$\text{[Grass]} \text{ map} = 0.9 \leq \text{VIN} \leq 1.0 \quad (1)$$

Equation 1 gives a map that was covered with only foliage. This map was later used in equation 2 to get the quantity of foliage in the grazing land. Equation is the model for calculating the foliage above ground biomass.

$$FAB = 2817.9 \left[0.877 \left(\frac{NIR}{Red} \right) + 0.458 \right] - 2373.4 \quad (2)$$

Where FAB = Foliage Aboveground Biomass

iii. Recommended Foliage Quantity

The recommended Foliage Quantity was calculated based on the findings from existing literature. The study used 20kg as an average intake for cattle per day and 0.95kg for sheep and goats. Since the total livestock population is known, the recommended quantity of foliage needed to sustain the livestock in a year will be easily calculated.

iv. Evaluating the Sustainability of the Grazing Land.

For the grazing land to be sustainable, the total livestock intake must not be less than the quantity of foliage in the grazing area. To get the recommended total intake for a year, the livestock intake per day was multiplied by the livestock population and again multiplied by 365 days. Table 2 is the summary of the livestock intake for one grazing season.

Table 2. Livestock intake for one year

Livestock	Intake/day	Intake/year	Total intake for each class of livestock
Cattle	20kg	20kg * 365	2,764,200 * 20kg * 365 = 20,178,660,000kg
Sheep	0.95kg	0.95kg * 365	3,774,432 * 0.95kg * 365 = 1,308,784,296kg
Goat	0.95	0.95kg * 365	2,988,970 * 0.95kg * 365 = 1,036,425,348kg
Total intake			22,523,869,644kg

The total intake is the recommended and sustainable intake for the whole livestock grazing in the site for one grazing calendar.

3.0. Results and Discussion

3.1. Results

The results were the VIN map of the study area derived from the satellite imagery, and the quantity of foliage in tons derived from the VIN map. The recommended foliage quantity was already calculated in 2.3.2. (iv).

i. Vegetation Index Map

The Red and the NIR values was extracted from the Landsat 8 OLI satellite imagery. It was used to get the Vegetation Index Number (VIN) of the site. This was presented in figure 4.

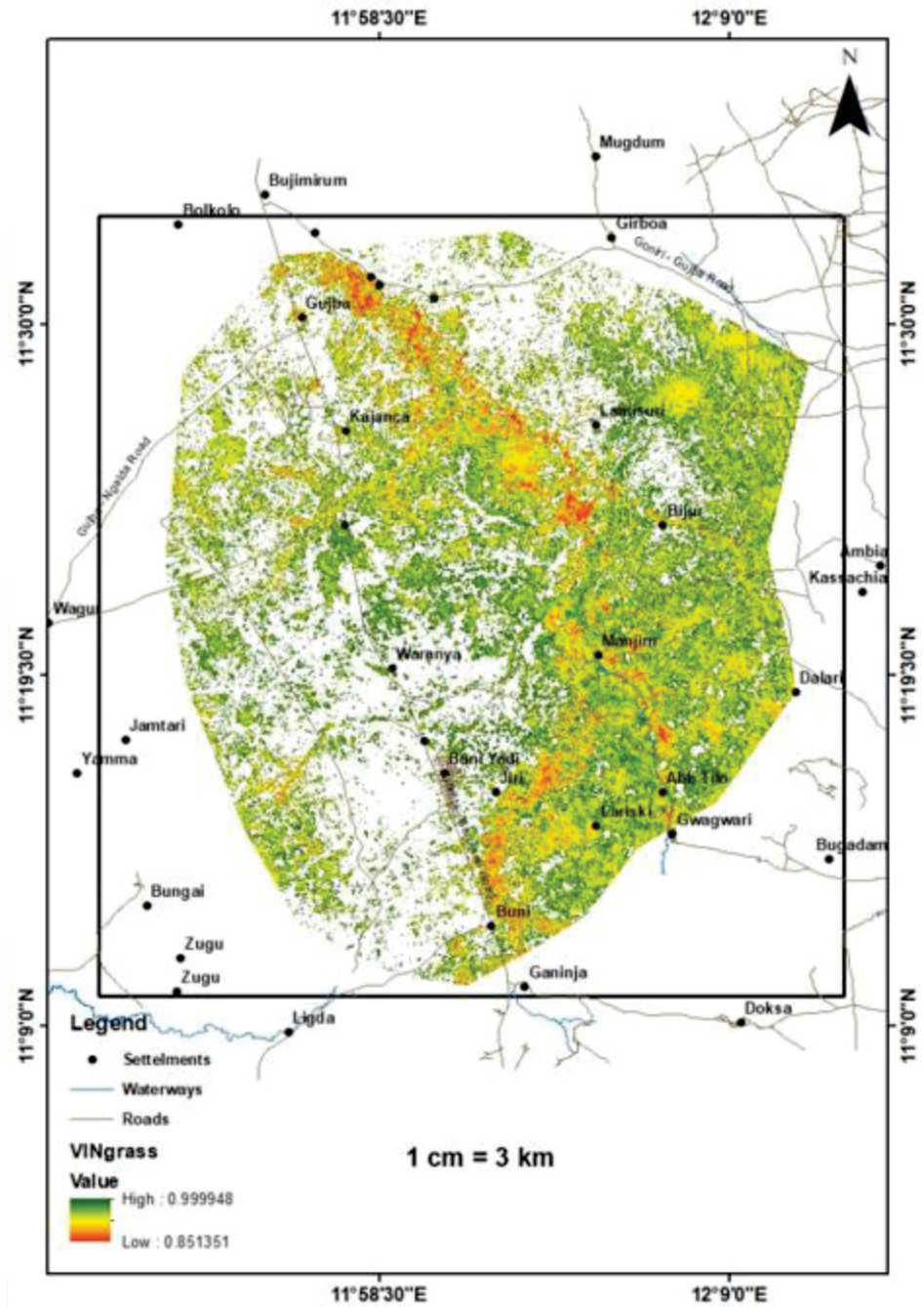


Figure 4: VIN map of the study area.

From the map, it could be seen that the highest value of VIN was 0.999948 while the least was 0.851361. this map was used to calculate the quantity of foliage in the grazing land.

ii. Foliage Quantity Calculation

ArcGIS 10.3 has the facilities of raster spatial analysis that can calculate the quantity of foliage in a specific area. There are many options from the Arctoolbox that can perform different operations. This work used a raster calculator from the spatial analyst tool. The quantity of foliage as Foliage above ground Biomass was calculated using equation (3) in the raster calculator. The result was 2,581,788,982 kg of foliage in the grazing site. This result was the available foliage that was expected to sustain the livestock population in the site. The statistical presentation of the result was in figure 5 having minimum pixel as 3.063kg of foliage and the maximum was 4.165kg.

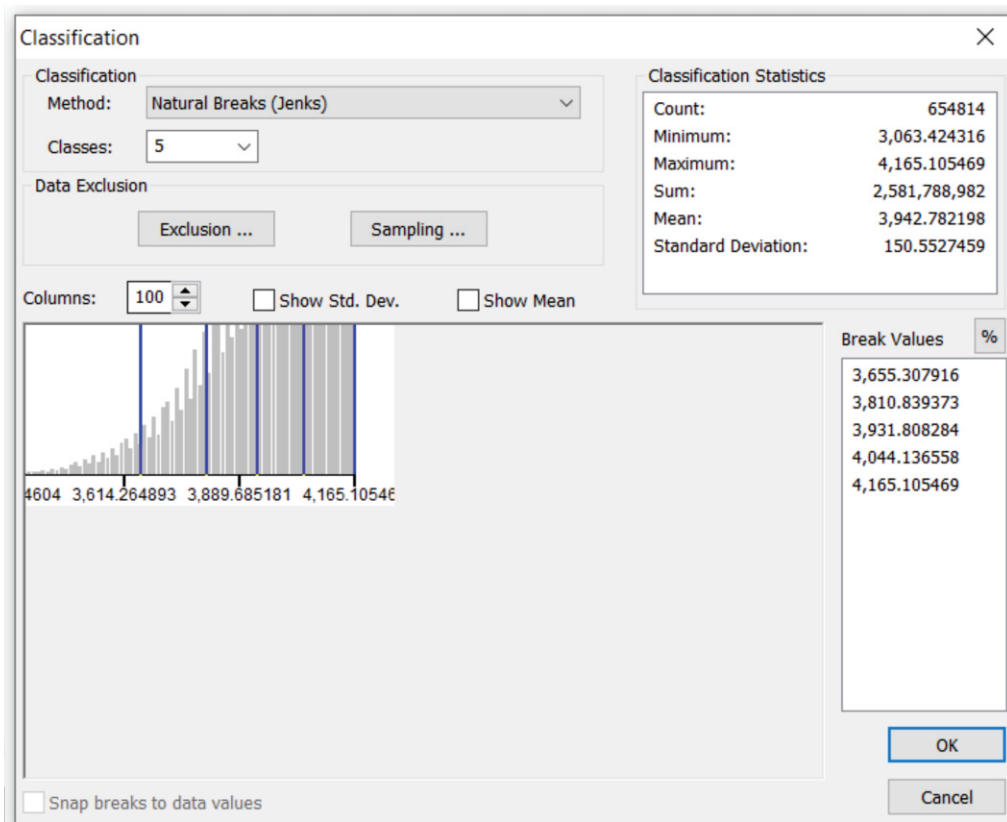


Figure 5. Statistical Presentation of Foliage Quantity in Grammes.

The map showing the spatial distribution of the foliage was presented as figure 6. From the figure, the 4165kg and 3063kg are the maximum and minimum values.

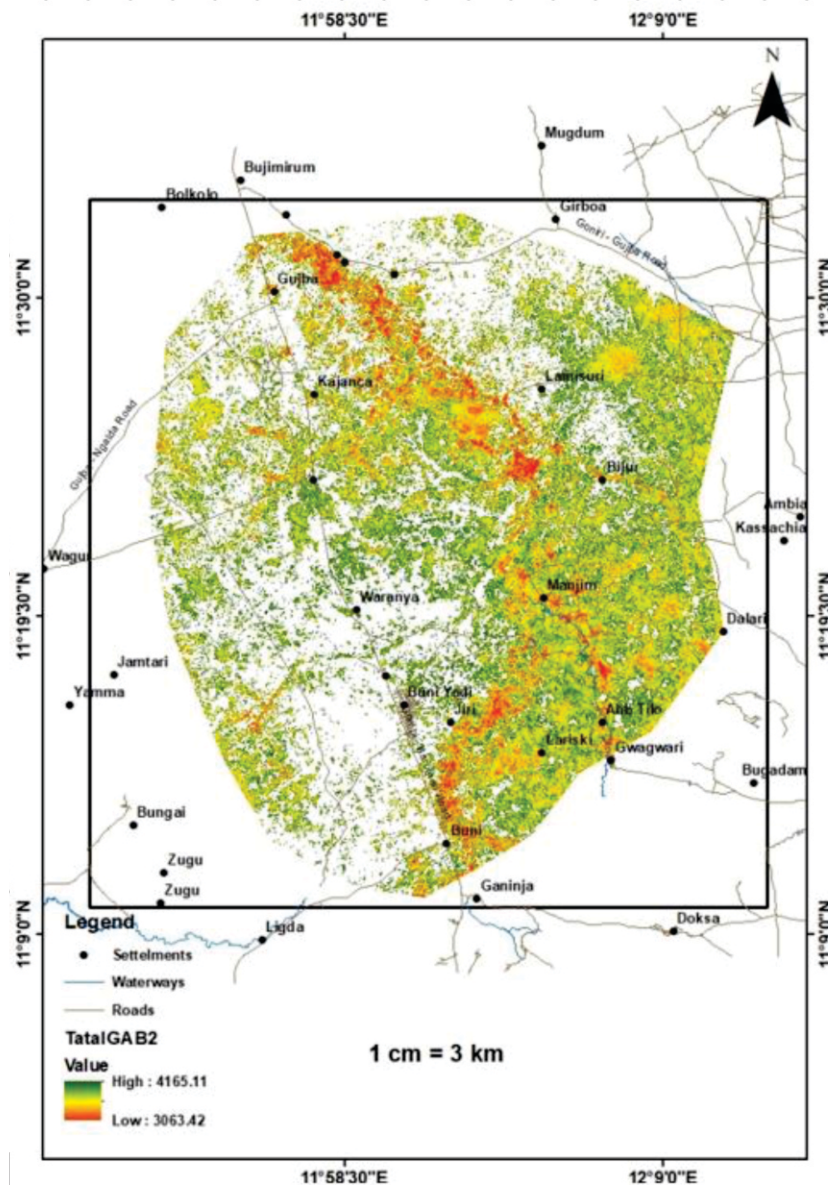


Figure 6. Spatial Distribution of Foliage Within the Grazing Land.

iii. Evaluating the Sustainability of the Grazing Land

For the grazing site to sustainable, the calculated foliage quantity must be equal with the recommended. However, the total quantity of foliage as calculated when the plants are at the peak of maturity was 2,581,788,982kg, and the recommended livestock intake of the study area was 22,523,869,644kg. This clearly indicates that the grazing reserve was seriously overgrazed and is not sustainable. Figure 7 below shows the existing amount of foliage and the recommended. It can be seen that the existing foliage is much less than the recommended. The result show that the grazing reserve has not enough quantity of foliage that can sustain the current livestock population.

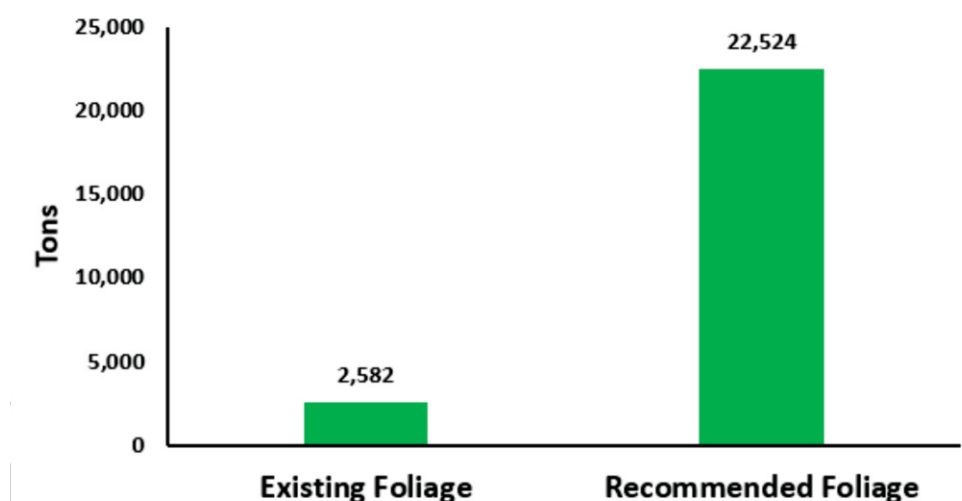


Figure 7. Existing and Recommended amount of foliage in the Gujba grazing reserve.

3.2. Discussion

Foliage maps is vital when enacting policies regarding the management of grazing lands and monitoring pastoral projects, infrastructure, and equipment in the livestock domain. Farm animals, as they help to improve the earnings and well-being of the farming community, play an important financial, cultural, and social role in rural communities. Therefore, there is a need to determine the required number of farm animals for each grazing land depending on the foliage availability.

Thematic maps such as the maps that show the quantity of grasses in grazing land will aid farmers in grazing management. Cattle, goats, sheep, poultry, and other animals make up the livestock population which primarily depends on grass for survival. The farmers' livestock system is characterized by a conventional system of production. Nigeria's cattle industry accounts for the bulk of the country's overall livestock cash production. It has contributed an average of 12% of total Nigerian livestock cash production over the last decade (National Bureau of Statistics, 2010). Livestock contributes directly to the economy by generating jobs, increasing savings and investment, and earning foreign exchange. The contribution of livestock production to Nigeria's GDP increased by 2.38 percent in the fourth quarter of 2020 compared to the same time the previous year. Agriculture accounts for a large portion of the country's GDP. It is, after crude, Nigeria's most significant economic activity. Agricultural operations, on the other hand, provide a source of income for many Nigerians, while oil wealth only reaches a limited percentage of the population. Despite this, the management of grazing lands has not been taken seriously as a contributor to the livestock sector, resulting in this study.

Globally, intensively maintained grasslands are valued for their high biodiversity as well as their social and cultural significance. However, when compared to other production systems, their ability to provide multiple Ecosystem Services (ES) as part of agricultural systems is relatively understudied. Just a few grasses land maps (if any) that were obtained and used as a contributor to ES have been performed in Nigeria (Nodza et al., 2021; Akintoye et al., 2016). In the multiple ES paradigm, mapping grasslands have received significantly less attention than other production systems such as forest (Gamfeldt et al.

2013) and other crop production. Grassland maps have also been widely ignored in international policy debates about ES (Diaz et al. 2015, Pascual et al. 2017). Grasslands maps are important not only on a local level for biodiversity and food production, but they also influence ecological processes at the landscape (pollination), regional (water regulation, recreation), and global levels (climate regulation).

4.0. Conclusions

This study uses satellite remote sensing to investigate the status of the Gujba grazing reserve and its level of sustainability for grazing. It was found that the existing foliage quantity was far less than the required and recommended quantity of foliage to sustain the current livestock population grazing in the reserve. This indicates that the reserve was seriously over stretched by overgrazing. This finding will contribute to the decision-making for proper management of the grazing reserve by the relevant ministry and other government agencies, thereby improving livestock productivity and minimizing the persistent crop farmers and herders' conflicts in Nigeria and Yobe state in particular. It will also contribute towards the realization of the Sustainability Development Goal (SDG) Target 2.3: Achieving food security and promoting sustainable agriculture and Target 16.1: Reducing all forms of violence and related deaths.

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