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Evaluation of Land and Climate Suitability of Crop Yield in Auchi, Nigeria

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ABSTRACT

A crucial component of predicting crop yields is evaluating the suitability of the land. When estimating the potential yield of crops, it is especially important to analyse the land and climate suitability of a particular location. Auchi, Nigeria's crop yield is assessed in the study based on climate and land suitability. The study carried out a comprehensive examination of Auchi's terrain and weather, as well as any possible effects on crop yield. The findings indicate that there is still a sizable amount of suitable land available for agricultural activities and that Auchi's soil type is good for growing a variety of crops with a high potential for high yield. Auchi has a climate that is ideal for crop growth, with enough temperatures and precipitation. However, a few things, like the accessibility of water and the presence of pests, could have an impact on the region's crop yield. Overall, this research identifies areas that might need more attention to increase crop yield and offers insightful information about Auchi's climate and land potential for crop production. Farmers and policymakers can utilise the research's conclusions to make well-informed decisions about Auchi's crop production.

Key words: Crop yield, Land suitability, Potential, Policymakers, Auchi

1. INTRODUCTION

Farmer pressure to increase crop yields while maintaining sustainable agriculture is constant due to the growing global population and the need to feed more people. Using technology for remote sensing is one way to accomplish this. Using sensors on drones, satellites, and other platforms, remote sensing collects data about the earth's surface from a distance. After that, this data can be analysed to reveal insightful information about agricultural methods [1]. We will examine the uses of remote sensing in agriculture in this report, with an emphasis on how it can be applied to identify regions with the potential to produce more crops. Farmers can decide where to concentrate their resources for maximum yield by analysing a variety of data points, including crop health, soil moisture levels, and climatic conditions [2]. We will also go through a few case studies where crop yields and overall farm productivity have been successfully increased through the use of remote sensing technology. All things considered, the use of remote sensing technology presents a bright future for agriculture by providing farmers with a strong tool to maximise their productivity and increase food production for a growing population.

1.1 Application of remote sensing in agriculture

The aim of using remote sensing to detect areas of higher crop yield is to improve agricultural productivity and profitability. The applications of remote sensing are as follows:

i. Finding areas of a field or farm with a higher crop yield: remote sensing can assist in locating areas that regularly produce higher crop yields. Utilising this information will maximise crop yield by optimising planting and harvesting techniques [3].

ii. Monitoring crop health: remote sensing technologies can detect variations in crop health and identify stress factors such as nutrient deficiencies, pests, diseases, and water stress. By monitoring crop health, farmers can take proactive measures to address these issues and improve overall yield [3].

iii. Precision agriculture: remote sensing can support precision agriculture practices by providing detailed on soil fertility, moistures levels and crop growth. This data can be used to apply inputs as fertilizers and irrigation more efficiently, resulting in higher crop yields [4,5].
iv. Resource management: by utilizing remote sensing data, farmers can better manage their resources, including water, fertilizers and pesticides. This can result in cost savings and improved yield by ensuring that resources are applied where they are most needed.
v. Decision support: remote sensing can help farmers make more informed decisions by providing real-time and historical data on crop growth and environmental conditions. This information can be used to optimize planting dates, crop selection, and other management practices to maximize yield [6].

2. Research Methodology

The methodology for the definition of the crop/land suitability map for a given area is based on the processing and combination of a set of layers that are considered as the main drivers for land suitability:

i. Soil;
ii. Aspect;
iii. Precipitation;
iv. Topography (slope); and
v. Current Land use/cover.

The mentioned layers are the criteria addressing the suitability of the land for the crop cultivation in a given area. Different and/or additional criteria can be considered and generally this process can be done using the participatory approach by a group of experts from various disciplines. The combination procedure of the layers follows the conventional scheme for GIS-based MCDA [7,6]. It involves three main steps:
i. Criterion maps are standardized/reclassified using Spatial Analyst Reclassify tool. This step is necessary because the criterion maps contain the ordinal values (high, medium and low) that indicate the degree of land suitability with respect to a particular criterion (criteria standardization).
ii. Derivation of the of relative criterion importance using the pair wise comparison method. The criterion weights are automatically calculated once the pair wise comparison matrix is entered in Analytic Hierarchy Process (AHP) weight derivation module in Arc Map. [8]
iii. The criterion weights and the standardized criterion maps are combined /aggregated by means of weighted overlay technique and vector overlay analysis.
Taking into consideration of one crop (teff) at the defining a crop suitability map for a given watershed. The entire procedure is the following:

i. Data acquisition at watershed level;
ii. Definition of a table containing the crop requirement characteristics for teff;
iii. Criteria layers' creation of data preprocessing;
iv. Criteria maps reclassification;
v. Creation of the Soil suitability maps;
vi. Criteria weights assignment;
vii. Weighted overlay analysis;
viii. Creation of the Teff suitability map;
vix. Definition of weights land use/cover through AHP methodology [9,10]

Requirements are expressed by defining optimal, marginal and unsuitable conditions attributes that influence directly or indirectly plant growth, performance following table reports the environmental requirements at different suitability classes (FAO, 1984).
The methodology for the definition of the crop/land suitability map for a given area is based on the processing

2.2 Criteria layers' creation

2.2.1 Soil layer

The following procedures were used to map soil characteristics:
The scale of the original map (and the raster data is 5 x 5 arc-minute
• Clip by the study area boundary
• Preparation of a table containing for each Soil Mapping Unit (SMU) the attributes relative to organic matter, ph, depth and texture)
• Joining of the soil attribute table to the soil layer
• Creation of the raster layers
• Depth (rasterization: 5 depth classes)
• Crop/land suitability analysis by ArcGis tools

Suitability maps assignment by the AHP methodology Weighted overlay analysis Creation of the Teff suitability map Definition of weights for the criteria: soil suitability, precipitation, temperature, slope and through as described by FAO [11] and DSMW [12].

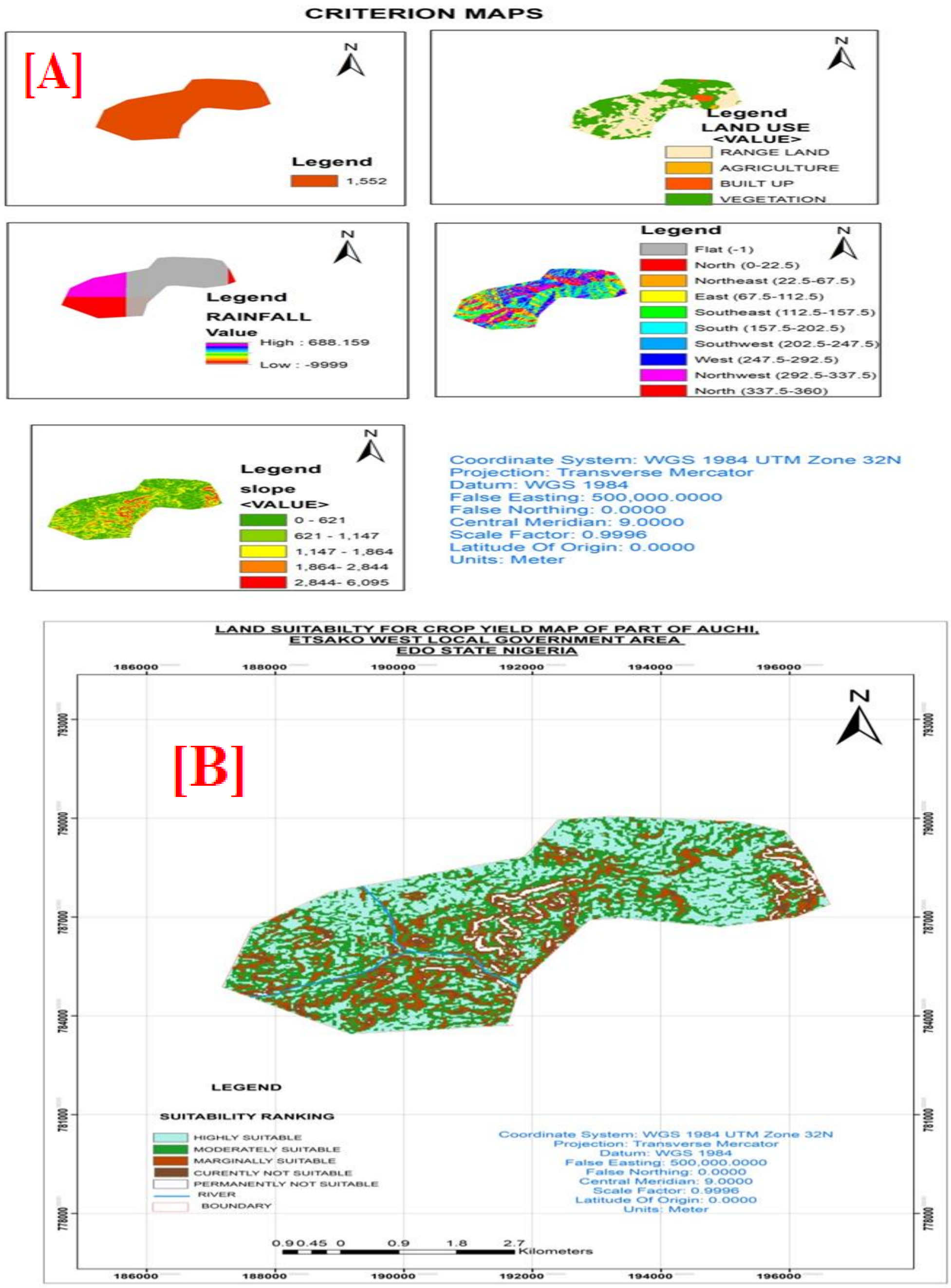

Figure 1: Classification of climatic suitability for crop production in Auchi (a), classification of soil suitability for crop production in Auchi, Edo State, Nigeria (b)

3. Result and Discussion

The crop and land suitability analysis using ArcGIS tools was applied to the soil, climate, and landscape variables of Auchi to produce a land suitability map for the crops. This process was repeated for all years up to 2023, and then the respective sets of maps for each crop were averaged to generate a map that represents the current predicted state of land suitability for a crop (Figures 1a and b). The purpose of weighting in land suitability analysis for agricultural crops is to express the importance or preference of each factor relative to other factors effects on crop yield and growth rate. In the MCDM process, the weights must add to 1. The weights can be defined through the Analytic Hierarchy Process (AHP) module in Arc Map. The AHP was introduced by 10,11] and is a very popular means to calculate the needed weighting factors with the help of a preference matrix where all identified relevant criteria are compared against each other with reproducible preference factors. All criteria or factors that are considered relevant for a decision are compared against each other in a pair-wise comparison matrix, which is a measure to express the relative preference among the factors. Therefore, numerical values expressing a judgement of the relative importance (or preference) of one factor against another have to be assigned to each factor.

Overall, Figure 1b's result indicates that Auchi, Edo State, Nigeria's stability can be classified as highly suitable, moderately suitable, marginally suitable, currently, or permanently not suitable. The study region's soil is moderately eroded and has less nourishing soil nutrients in the eastern and southern regions. By giving each factor or criterion a specific weight, the weighted overlay geo-processing tool can be used to create both the Teff suitability map and the soil suitability map. By using the AHP extension for Arc Map, weights can be defined directly by a pair-wise comparison of the factors and criteria, and the weighted overlay is also performed by the extension. Since it is known from psychological studies that an individual cannot simultaneously compare more than 7 ± 2 elements, [11] and [8,9] suggested a scale for comparison consisting of values ranging from 1 to 9, which describe the intensity of importance (preference or dominance). A value of 1 expresses "equal importance," and a value of 9 is given for those factors having "extreme importance" over another factor. It is interesting that the suitability maps in Fig. 1b predict this area as less suitable for all crops. Perhaps agriculture is avoided in the mentioned area due to its lack of suitability. The crop inventory can also be compared to the suitability maps of the SADs that were not used to generate the dataset to provide insights on how the model performs in northern regions that are outside the domain of the training data.

3.1 Conclusions

For the purpose of facilitating land-use management planning, Auchi's agricultural land needs to be assessed for suitability both now and down the road. We created the first data-driven model that, as far as we know, simultaneously forecasts the suitability of a piece of land for crop growth. Whereas the output is continuous rather than discrete land suitability classes, the model was trained using district-level crop yield data. In this study, we applied remote sensing (RS) and GIS techniques to identify suitable areas for the rice crop. The results obtained from this study indicate that the integration of RS-GIS and the application of multi-criteria evaluation using AHP could provide a superior database and guide map for decision-makers considering crop substitution in order to achieve better agricultural production. This approach has been used in some studies in other countries. The study clearly brought out the spatial distribution of rice crops derived from remote sensing data in conjunction with the evaluation of biophysical variables of soil and topographic information in a GIS context, which is helpful in crop management options for intensification or diversification. This investigation is a biophysical evaluation that provides information at a local level that could be used by farmers to select their cropping pattern. Additionally, the results of this study could be useful for other investigators who could use these results for diverse studies. This study has been done considering current land use and cover, topography, and soil properties that affect the suitability classification of land use types. Therefore, it gives primary results. For further study, we propose to select a larger number of factors, like soil, climate, irrigation facilities, and socio-economic factors, that influence the sustainable use of the land.

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