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Land Suitability Analysis for the Commercial Cultivation of *Jatropha Curcas Linneaus* in Yobe State, Nigeria

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Abstract

This study assessed land suitability for the commercial cultivation of Jatropha curcas L. in Yobe State, Nigeria, using geospatial techniques and multi-criteria decision analysis (MCDA). Eight criteria were analyzed: rainfall, temperature, soil texture, soil pH, land use/land cover, slope, proximity to roads, and proximity to gas stations. Each criterion was mapped and standardized using the Analytical Hierarchy Process (AHP) and reclassified in ArcGIS 10.8 to identify optimal sites for cultivation and estimate potential biofuel and electricity output. Results showed that suitability levels varied across the state. Highly suitable areas covered approximately 11.15%–49.72% of the land depending on the factor considered. AHP weights revealed rainfall (21.1%), soil texture (14.9%), and temperature (14.5%) as the most influential factors, while road proximity (7.6%) had the least impact. Overlay analysis indicated that 23.32% of the southern region is highly suitable, 34.56% moderately suitable, and 42.12% marginally suitable for large-scale cultivation of J. curcas. The estimated energy generation potential from these areas was 689,726.05 m³ of biofuel which could be produced through transesterification, suitable for industrial lubricants, cosmetics, agro-biopesticides, and livestock feed supplements. Additionally, the fuel has the potential to generate approximately 7,138,664.6 kWh of electricity annually, offering an opportunity to power homes and devices, particularly in rural communities with limited access to energy. The findings underscore the economic and environmental importance of site selection for bioenergy projects. It recommends strategic investments in both small-and large-scale cultivation of J. curcas in identified suitable areas to support energy access, climate resilience, and rural development.

Keywords: Geospatial analysis, land suitability, *Jatropha curcas*, biofuel, energy potential, Yobe State

1. Introduction

Deforestation, carbon emissions from combustion engines, and the use of chlorofluorocarbons in agriculture are just a few of the harmful activities that the earth is currently experiencing.

These activities all put human survival at risk (Yahuza et al., 2020). In order to secure humanity's survival, it is imperative that sustainable and renewable energy sources be investigated. A potential option is the manufacturing of biofuel, which is a noteworthy advance in the quick conversion of biomass into sustainable energy. Biofuels, which are produced chemically or naturally from vegetable or animal fats, are becoming more and more popular as viable substitutes. Cassava, sugarcane, oil palm, and most significantly, the recently discovered *Jatropha curcas L*. (JCL) are a few possible sources of biofuel. It, because of its high energy content, has lately become a promising energy source (Halilu et al., 2011). JCL, also known as Physic nut, Barbados nut, and Poison nut, is a green plant that is native to the American tropics and is a member of the *Euphorbiaceae* family (Ojiako et al., 2016; Prandey et al., 2021). JCL grows widely in Nigeria, where it is referred to as "binidazugu" in Hausa and "lapalapa" in Yoruba. It requires little upkeep (Raufu et al., 2016). Interestingly, JCL seeds yield inedible oil, which makes them perfect for esterification in the production of biodiesel (Simpson & Peer, 2009). JCL is an adaptable and sustainable energy source since it also has a long lifespan of 40–50 years, it inhibits erosion, and grows on less fertile soil (Raufu et al., 2016).

In Nigeria, JCL is still underutilized despite its potential; it is mostly used as live fences or hedge plants rather than as a substantial energy source (Fairless, 2017). Comprehensive research is needed to optimize JCL cultivation in order to fully reap its benefits. The over dependence of Nigeria on crude oil for her energy source is alarming, owing to the established fact that the crude oil reserve will be depleted completely in the near future.(Cortez-Núñez et al., 2020; Wolde, 2017; Prandey et al., 2021).Also looking at the sudden decision by the Federal Government to remove the oil subsidy which has led to hike in the price of petroleum products in the country, this should be another motivation for the government to invest into another source of fuel for the benefit of her citizens The potential for biomass is highlighted by lessons learned from nations like Ethiopia, Uganda, India, and Mexico; studies in these countries have evaluated the agroecological compatibility of JCL as a potential plant for biomass energy production on abandoned or degraded lands using geographical information systems (GIS) and remote sensing techniques. (Cortez-Núñez et al., 2020; Wolde, 2017; Prandey et al., 2021). These studies encourage the need for extensive cultivation of JCL and other biomass energy sources. This is vital in attaining energy security and reducing the adverse effects on the environment.

Various studies by Halilu et al. (2011), Ojiako et al. (2016), Raufu et al. (2016), and Emeribe et al. (2017) have focused on different aspects of *Jatropha*, including farmers' awareness, biodiesel prospects, survey collection, and genetic modification of the germplasm. Ojiako et al. (2016) investigated methods to enhance *Jatropha curcas (Linnaeus*) cultivation and seed yield among farmers, revealing findings on seed emergence rates, nursery practices, and multiplication techniques. Emeribe et al. (2017) utilized GIS-based suitability analysis to identify favourable areas for Jatropha cultivation in Edo State, highlighting highly suitable regions with good soil and drainage characteristics. Similarly, Raufu et al. (2016) in his study has identified Yobe State as a promising environment for Jatropha cultivation. However, this study used GIS based Multi Criteria Decision Analysis approach coupled with Analytical Hierarchy Process (AHP) to analyse the land suitability for *Jatropha* commercial cultivation in Yobe state Nigeria. And this is achieved by fulfilling the following objectives: characterizing the criteria for the cultivation of JCL in the study area; determining the most suitable lands for large-scale cultivation of JCL in the study area and estimating the potential biofuel energy production from JCL in the study area.

2. Materials and Method

2.1. Study Area

Yobe State is in north-eastern Nigeria, between Latitudes 11°30'20" and 13°22'25" North of the Equator and Longitudes 9°40'45" and 12°30'50" East of the Greenwich meridian (fig 1). It is bordered by Borno, Jigawa, Bauchi, and Gombe states, with Niger Republic to the north. Its capital is Damaturu, with major towns like Potiskum, Gashua, and Nguru. Covering approximately 45,502 square kilometres, the state experiences a tropical continental climate characterized by distinct wet and dry seasons, with rainfall lasting about four months from June to September, but irregular in time and space. Predominantly hot and dry for around eight months from April to October, temperatures peak at 42°C in April and drop to about 30°C in December. Geologically, Yobe comprises crystalline and sedimentary rock, predominantly the Chad Formation, with soil types mainly silt-clay or clayey, influencing *Jatropha curcas* production. The state is home to five major ethnic groups - Kanuri, Fulani, Kare-kare, Bade, and Hausa - with English as the official language and Hausa widely spoken. According to the 2006 national census, Yobe state has a population of 2,321,591 (Nigeria - Administrative Division" - City Population website, 2023; Mamman et al., 2002; Ileoje, 1977; Price, 1990; Openshaw, 2000

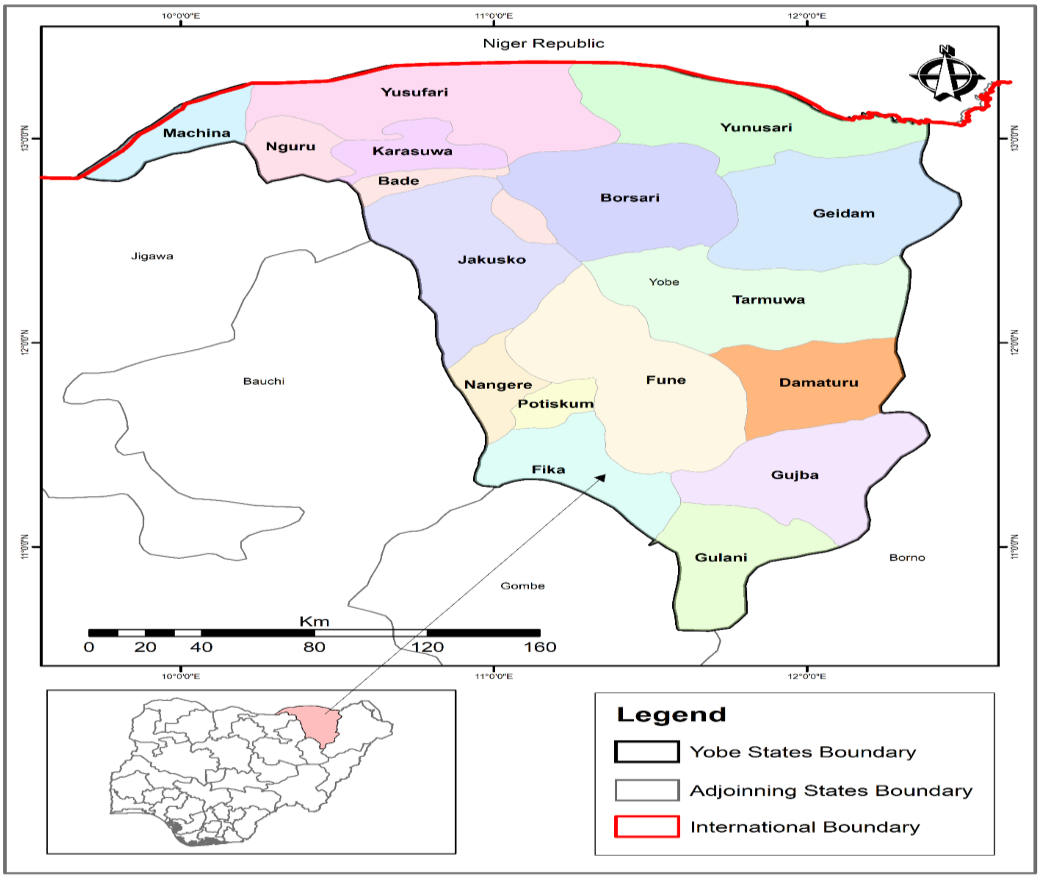

Figure 1: Yobe State; The Study Area Map

Source: Modified from the Administrative Map of Yobe State

3. Data Collection Methods

The types of data used and their various sources are summarized in Table 1

Table 1: Types and sources of data

S/No	Type of Data	Source	Purpose
1.	Administrative map of Yobe state	Ministry of Lands and Survey, Yobe state	To identify spatial infrastructure like road, pipelines, railway, and facilities like fuel stations.
2.	SRTM	US Geological Survey (USGS) website	For DEM creation, Topography and Slope map.
3.	Landsat 8	USGS website	Production of Land use/land cover map.
4.	Rainfall and Temperature data	Nigerian Meteorological Agency (NiMet).	Production of rainfall and temperature distribution map.
5.	Soil Data (Soil ph and Texture)	Digital soil map and database for Nigeria was retrieved from Mendely data (2021).	Production of soil Ph and Texture map of the study area.

3.1. Research Methods

Landsat 8 images were processed and stacked using ERDAS Imagine software, with a subset of the study area obtained through the subset tool. Supervised pixel-based classification using the Maximum Likelihood classifier was employed to generate a raster land-use/land cover map. Ground checks for soil pH and texture characteristics involved sampling at various locations and laboratory analysis against the digital soil map for Nigeria retrieved from Mendely data (2021). Suitability criteria for *Jatropha curcas* cultivation, drawn from various studies, encompassed factors like soil properties, climate, topography, hydrology, and socio-economic variables such as proximity to infrastructure like gas stations and roads (Ravi and Gowthami, 2019). Integrating these criteria enabled the identification of suitable cultivation areas.

Table 2: Criteria for *Jatropha curcas* Suitability analysis

Criteria	Measurement Range	Suitability Level	Source
Rainfall (mm)	838.94 - 972.66	Highly Suitable	Emeribe et al. (2017) Grass 2009; Heller (1996b)
Slope (^{O})	<5	Highly suitable	Emeribe et al. (2017)
Soil Texture	Loamy sand	Highly Suitable	Ouwens et al. 2007; Brittaine and Lutaladio 2010; Achten et al. 2008
Soil pH	> 7.5	Highly suitable	Rathore et al., (2014)
Average Temperature (^{o}C)	26.2 - 26.97	Highly suitable	Cortez-Núñez, et al., (2020) Achten et al. 2008; Gour 2006
LULC (classes)	Vegetation Farmland	High suitable	Cortez-Núñez, et al., (2020)
Distance to roads (Km)	<5	Highly suitable	Cortez-Núñez, et al., (2020)
Distance to gas stations (Km)	< 5	Highly suitable	Cortez-Núñez, et al., (2020)

In processing thematic maps, the study utilized various tools and techniques in ArcGIS 10.8. The Digital Elevation Model (DEM) from SRTM data was employed to generate a slope raster map, crucial for solar and wind energy facility siting. Additionally, supervised classification of

Landsat 8 imagery produced the land use/land cover map, depicting built-up areas, vegetation, bare land, agricultural zones, and water bodies. Euclidean distance analysis was conducted to assess accessibility to infrastructure like roads, water bodies, railway, and pipelines, considering socio-economic factors crucial for the study's feasibility (Adhikari and Gupta, 2012; Sarker and Uddin, 2015). Suitability criteria were mapped by reclassifying criteria into GIS-compatible formats and standardizing them using the score range method to ensure comparability (Lukokoa and Mundiab, 2016; Saaty, 1980). Multicriteria Decision Analysis (MCDA) and Analytical Hierarchical Procedures (AHP) were employed to assign weights to each criterion, facilitating pairwise comparisons to determine their relative importance (Anurag et al., 2010; Maczewski and Rinner, 2015; Saaty, 1980*).*

Table 3 AHP criteria weight as introduced by (Saaty, 1980)

Scale	Degree of Importance	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judge slightly favour one element over another
5	Strong or essential importance	Experience and judgment strongly favour one element another
7	Very strong important	One element is favoured very strongly over. Its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation,
2,4,6,8	Values for inverse comparison	Can be used to express intermediate values

Source: Saaty and Vargas (1991).

In determining site suitability for *Jatropha curcas* cultivation, criteria weights were calculated through the normalization of eigenvectors and mean values to ensure consistency, with a threshold consistency ratio (CR) set at 0.1 (Saaty, 1980). The weighted layers were overlaid in ArcGIS to identify suitable cultivation sites, with higher weights indicating greater influencing factors (Saaty, 1980). The overlay analysis employed the weighted sum method, multiplying each input raster layer by assigned weights and summing the results to generate a final suitability map (Adhikari and Gupta, 2012). Reclassification into suitability classes followed using ArcGIS tools (Lukokoa and Mundiab, 2016). Additionally, potential biofuel energy production from *Jatropha curcas* was estimated considering various parameters like seed yield, oil content, extraction efficiency, and biodiesel energy content, with calculations based on established formulas (Islam et al., 2014; Ivanova et al., 2018; Tosin and Kolios, 2017)

4. Results and Discussions

The site suitability analysis for *Jatropha curcas* cultivation considered eight factors: average rainfall, average temperature, soil pH, soil texture, land use/land cover (LULC), slope, distance to road network, and distance to gas stations. Each criterion was mapped and reclassified as presented in the figures as follows:

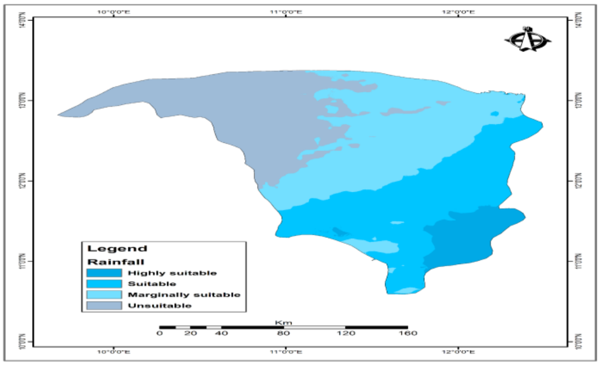

Fig 2: Rainfall

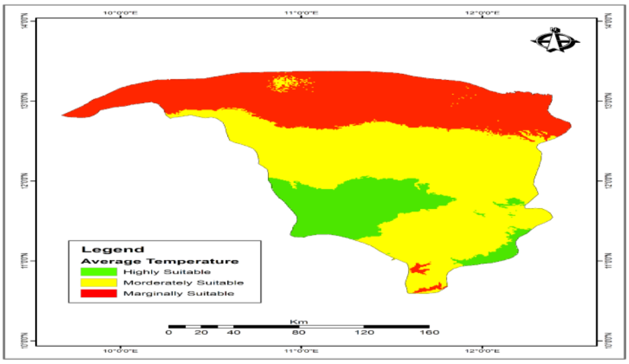

Fig 3: Annual Average Temperature

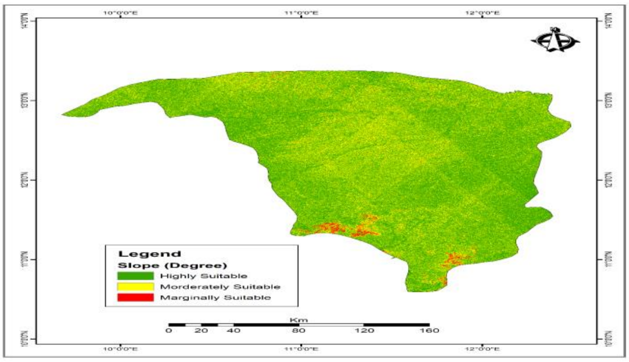

Fig 4: Slope

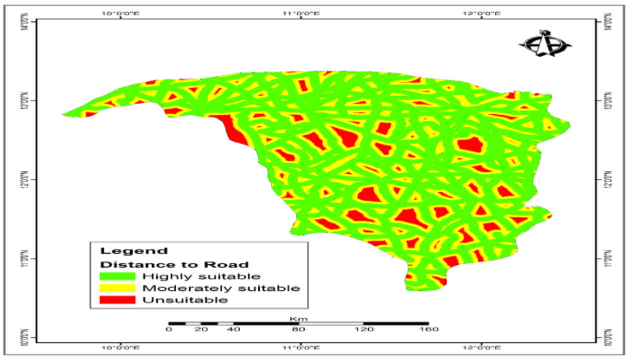

Fig 5: Distance to Road

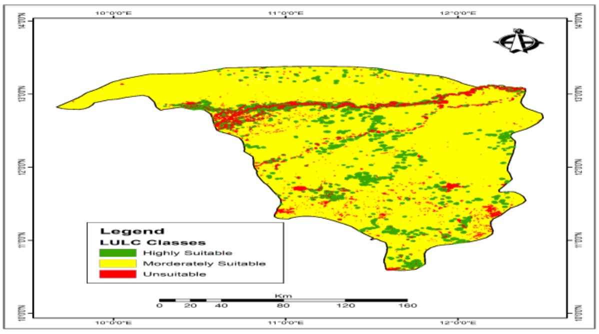

Fig 6: LULC Classes

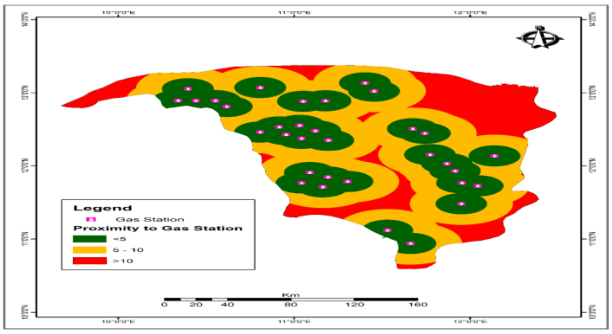

Fig 7: Proximit to gas stations

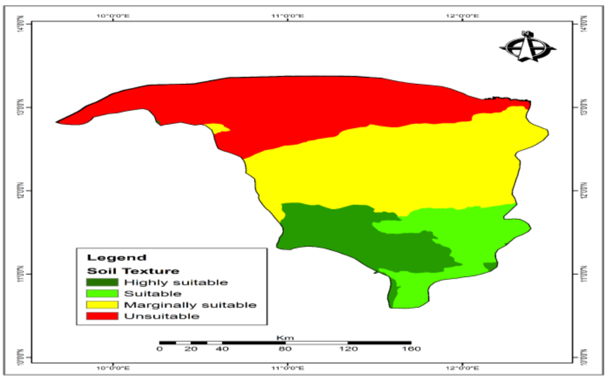

Fig 8: Soil Texture

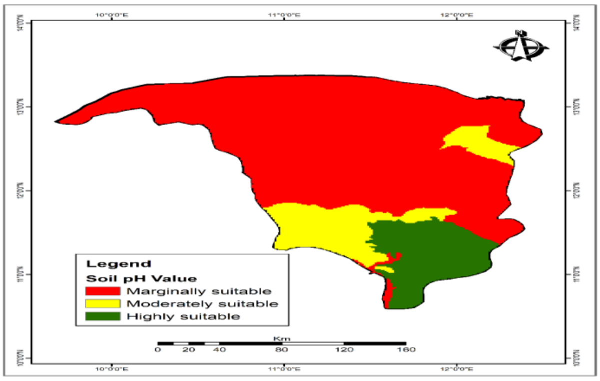

Fig 9: Soil pH

Rainfall Distribution

The reclassified rainfall distribution map (Figure 2) illustrates that approximately 43.58% of the study area, primarily in the south and southeast, is highly suitable or suitable for *Jatropha curcas* cultivation, while 56.42% in the north and north-central regions is marginally or unsuitable due to lower and sporadic rainfall. This contrasts with Emeribe et al.'s (2017) study in Edo State, which found rainfall ranging from 936mm to 1770mm without significant restrictions on *Jatropha curcas* cultivation, likely influenced by differing climatic zones.

Average Temperature

Figure 3is showing the visual representation of the suitability levels based on the average temperature values of the study area. Results shows that locations with average temperature range of 26.2° to 26.97° are highly suitable for cultivating JCL plants, this amount to a total of about 22.61% of the study area. It is mostly located in the western and the south-eastern part of the study area as shown in Figure 3. while locations with higher temperature values greater than 27.75° which are predominant at the northern part and at some elevated points in the southern part accounted for about 31.46% of the study area were deemed less suitable for JCL plants. Figure 3 illustrates the graphical presentation of the suitability classes of annual average temperature for JCL cultivation. This finding agrees with Mimien et al. (2013) Who stated that when planting *Jatropha curcas* seeds, a temperature of around 25-30°C (77-86°F) is ideal for germination. Once the plant has established, it can tolerate higher temperatures. It is therefore, important to provide adequate moisture and shade during extreme heat conditions.

Slope

Results revealed that locations with high suitability for large-scale cultivation JCL plants are found on gentle slopes with slope values ranging from 0 to 5 degrees which make up about

49.25% of the study area. This area is highly effective and offers the optimal conditions for the successful cultivation of JCL in areas while presenting the best conditions for high yield. Slope of 5 to 10 degrees accounted for 33.72% and are considered as moderately suitable for the commercial cultivation of JCL plant; this may be due to the high risk of soil erosion and instability of the plant's root system associated with this degree of slope. Areas with slope value greater than 10 degrees accounted for about 17.03% of the study area. Based on this Criterion, it is obvious that a greater part of the study area is highly suitable for large scale establishment of JCL farms. These findings disagree with that of Emeribe et al., (2017) which only classified the slope of Edo state into only two classes and observed that 95% of areas investigated area may be considered highly suitable for *Jatropha curcas* cultivation based on their slope value. Figure 4.3 show the map presentation of slope values of the study area.

Proximity to road

Result of the analysis shows about 49.72% of the study area falls within a distance of less than 5Km away from a major road which is considered as highly suitable for implementing JCL farms in the area. This means that a good percentage of the study area is accessible. It was also revealed that a further 23.12% falls within 5 to 10Km away which is moderately suitable while the remaining 27.16% is greater than 10km away and are deemed as marginally suitable for JCL cultivation (Fig 5).

Landuse and Landcover

The LULC result was reclassified into three based on their level suitability for the commercial cultivation of JCL, the result shows that vegetation and farmland are highly suitable for the commercial cultivation of JCL and occupy about 26.76% of the total extent of the study area. Bare surfaces which are barren land devoid of vegetation were categorized as moderately suitable and occupy the largest portion 60.15% of the study area. Finally, water surfaces and built-up area are considered as marginally suitable and cover a total area of about 13.15% of the area. Land use and land cover analysis provide valuable insights into the suitability, sustainability, and environmental impacts of *Jatropha curcas* cultivation. This result agrees with the works of Fersi et al. (2013) and that of Adepoju and Oloyede (2018) that landuse and landcover analysis provide valuable insights into the suitability, sustainability, and environmental impacts of *Jatropha curcas* cultivation (Figure 6).

Proximity to Gas Stations

Coordinates of gas station were collected and analysed in the ArcGIS environment by creating a buffer around them. Findings from field survey identified about 58 gas stations in the study area. Findings revealed that about 26.72% of the study area share close proximity to gas stations making it highly suitable for the cultivation and processing of JCL plants for biofuel extraction and for energy generation. Furthermore, 42.12% of the area is moderately suitable while the remaining 31.16% are marginally suitable. This result shows that the study area is viable for JCL production and is in line with the position of Adepoju and Oloyede (2018) who noted that *Jatropha curcas* is, which contain oil that can be converted into biodiesel and that proximity to gas stations is significant because it ensures easy access and availability of fuel which is the end product to the public for consumption (Figure 7).

Soil Types

Soil sample were collected from the quadrants created in the area; the samples were analysed to determine the soil particle size distribution of the study area. The result shows that 19.81% of the study area has loamy sand which are categorized as highly suitable for JCL plant (FAO, 2006). Areas such as Geidam, Bade, Jakusko and Borsari are most suitable location for cultivating JCL based on this criterion and are mostly found in the south western axis of the study area. Sandy loam soil which can be found in the opposite direction (south eastern axis) occupied about 21.05% and are classified as suitable, sandy clay also took about 23.21% and are considered as marginally suitable while the remaining 36.02% went to clay loam soils which categorized as unsuitable for JCL cultivation in the study area. It was revealed the sand clay and clay loam which are generally less suitable for JCL cultivation occupied the north central axis as well as the northern part of the study area. This resulted corroborates with that of Taddese (2014) whose finding revealed that soil with water logging conditions such as clay and sand clay soil area less suitable for JCL cultivation while the well-drained soils like loamy sand and sandy loam soil are the most suitable for JCL cultivation. Figure 4.7 shows the reclassified soil texture map of Yobe State.

Soil pH

The soil analysis that was conducted was also used to categorize the different soil pH and the result shows that in about 63.65% of the study areas, the soil pH was observed to be slightly acidic, ranging from soil pH with a mean of about 5.5 to 6.5 and are classified as marginally suitable for JCL cultivation. This pH range is relatively common in soils with low organic matter content and susceptible to weathering processes. This was commonly found in the northern part down to the central part of the study area. The lower end of this range indicates slightly more acidic soil conditions. In other areas, especially where alkaline soils are present, the soil pH ranges from neutral (around pH 7) to slightly alkaline (up to pH 8) these occupied about 19.22% of the area and are regarded as highly suitable for JCL cultivation in the area. Figure 4.8 shows the map of soil pH distribution in the study area.

4.1 Weighting of the Criteria

The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The rule of thumb states that, the higher the weight: the more important the corresponding criterion and vice versa. Table 4.9 presents the Analytical Hierarchy Process (AHP) pair-wise comparison matrix for the weighting for all the eight criteria influencing the commercial cultivation of JCL plant in the study area. The consistency ratio (CR) was calculated to be 0.042. which is less than 0.1, hence, the result indicates a high level of consistency.

Table 4 AHP Pairwise Comparison Matrix of Criteria

Criteria	R	Avg. T	S	LULC	PGS	DR	ST	S pH
R	1	2	5/2	3/2	3	5/2	3/2	2
Avg. T	1/2	1	3/2	5/3	3	2	2/3	3/2
S	2/5	2/3	1	2	5/3	2	4/5	2/1
LULC	2/3	3/5	1/2	1	2/1	3/2	2/5	2/3
PGS	1/3	1/3	3/5	1/2	1	3/2	3	2
DR	2/5	1/2	1/2	3/2	2/3	1	3/4	2/3
ST	2/3	3/2	5/4	5/2	1/3	4/3	1	3
S pH	1/2	2/3	1/2	3/2	1/2	3/2	1/3	1
Total	**4.47**	**7.27**	**8.35**	**12.17**	**12.17**	**13.33**	**8.45**	**12.83**

R = Rainfall, Avg. T = Average temperature, S = Slope, LULC = Landuse/Landcover, PGS = proximity to gas station, DR = Distance to Road, ST = Soil Texture, S pH = Soil pH

The weights of the pairwise comparison matrix was normalized by dividing each value by the sum of the values in each column, and the weight of each criterion was calculated by averaging each row and was summed up to 1; indicating the proportionate importance of each criterion. Table 5 presents the results.

Table 5 Normalized AHP Pairwise Comparison Matrix

Criteria	**R**	**Avg. T**	**S**	**LULC**	**PGS**	**DR**	**ST**	**S pH**	**Wi**	**%**
R	0.22	0.28	0.30	0.12	0.25	0.19	0.18	0.16	1.69	21.1
Avg. T	0.11	0.14	0.18	0.14	0.25	0.15	0.08	0.12	1.16	14.5

S	0.09	0.09	0.12	0.16	0.14	0.15	0.09	0.16	1.00	12.5
LULC	0.15	0.08	0.06	0.08	0.16	0.11	0.05	0.05	0.75	9.4
PGS	0.07	0.05	0.07	0.04	0.08	0.11	0.36	0.16	0.94	11.7
DR	0.09	0.07	0.06	0.12	0.05	0.08	0.09	0.05	0.61	7.6
ST	0.15	0.21	0.15	0.21	0.03	0.10	0.12	0.23	1.19	14.9
S pH	0.11	0.09	0.06	0.12	0.04	0.11	0.04	0.08	0.66	8.2
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**8.00**	**100.0**

R = Rainfall, Avg. T = Average temperature, S = Slope, LULC = Land Use/Landcover, PGS = proximity to gas station, DR = Distance to Road, ST = Soil Texture, S pH = Soil pH

According to findings presented in Table 4.10, rainfall is the most influencing factor in the selection of suitable land for the commercial cultivation of JCL in the study area, having the highest weight of about 1.69 (21.1%) followed by soil texture with a weight of about 1.19 (14.9%) and closely followed by average temperature with 1.16 (14.5%) weight. On the other hand, distance to road and soil pH have the least weight of 0.61 (7.6%) and 0.66 (8.2%) respectively and are therefore, considered as the least factors influencing the selection of suitable sites for JCL cultivation in the study area.

4.2 Potential sites for the Commercial Cultivation of JCL

A suitability map for commercial cultivation of JCL in the study area was developed using ArcGIS 10.8 software. The weighted overlay tool, available in the Spatial Analyst extension, was utilized to perform overlay analysis and the results are shown in Table 6 The obtained values were classified into three suitability levels: Highly Suitable, Moderately Suitable, and Marginally Suitable. These levels were assigned areas in km2, and percentages of the total area. To calculate the values for each suitability level, the raster calculator in ArcGIS 10.8 was employed. The resulting suitability map is illustrated in Figure 10.

Table 6 Land Suitability Classification for Jatropha Cultivation

Suitability Level	Area (Km^2)	Percentage (%)
Highly Suitable	10611.17134	23.32
Moderately suitable	15725.64672	34.56
Marginally Suitable	19165.63194	42.12
Total	**45502.45**	**100.00**

Table 6 revealed that the most suitable sites for the cultivation of JCL plants occupy a total of about 23.32% of the state and as shown in Figure 4.9 are located at the southernmost part of the study area. The highly suitable area extends to about 6 LGAs in the state including Nangere, Potiskum, Fika, Gulani, Gujba and Fune. This shows that these Local Government areas have a combination of favourable climatic and environmental conditions to support the growth of

JCL and economic feasibility for the commercial cultivation of the crop in the study area. Approximately 34.56% of the total area of the state possess moderately suitable conditions and are mostly found in Fune, Damaturu and Nangere LGAs. The remaining 42.12% comprised marginally suitable zones in the study area cover Yusufari, Ngiru, Bade, Borsari, Yunusari, Geidam and part of Machina LGAs.

According to Figure 10, the northern part of the study area does not provide favourable conditions for the commercial cultivation of JCL. This is due to insufficient rainfall, which is a crucial factor for JCL cultivation. Additionally, the northern axis has unfavourable annual average temperatures, poorly drained soil, and a pH value below the required standard, rendering it unsuitable for JCL cultivation in that area. This finding varies from that of Taddese (2014) who analysed land suitability for Jatropha production in Ethiopia, using 6 criteria (rainfall, temperature, soils, slope elevation and landcover). His result showed that 15.07%, 76.57% and 8.36% of the land as highly suitable, moderately suitable and not suitable for Jatropha production, respectively. The variation may be due to the number of criteria considered for both studies. This present study further considered economic feasibility such as proximity to road and gas station which are important for suitability analysis. Another reason for the variation might be attributed to the differences in atmospheric conditions where the studies were conducted as climatic conditions are rated as the most influencing factors for the commercial cultivation JCL plant. (Figure 10) presents the final suitability map for JCL cultivation in Yobe, Nigeria.

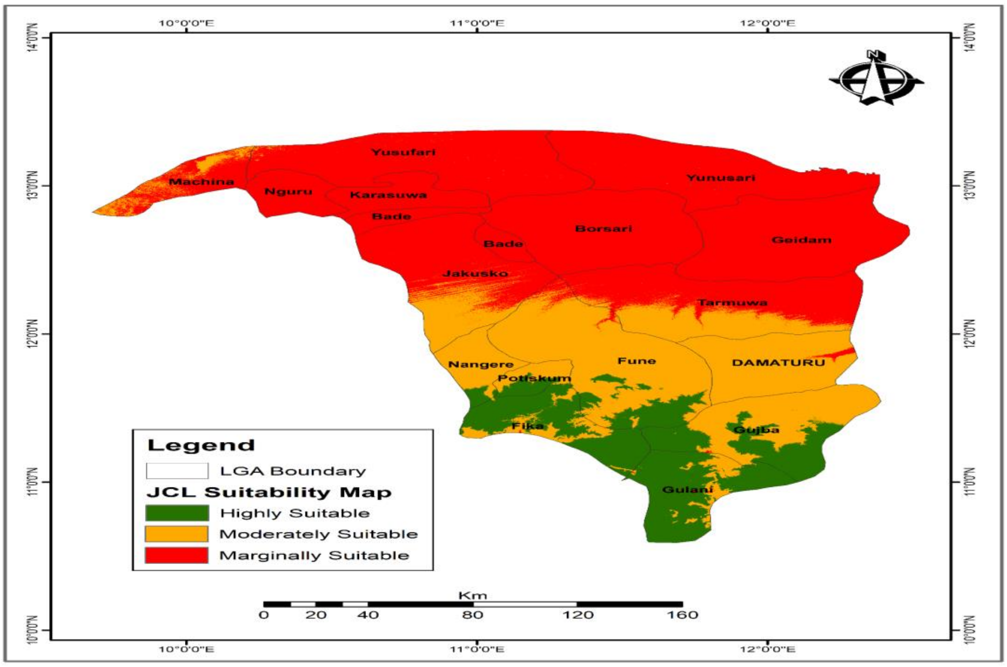

Figure 10: JCL Suitability Map of Yobe State

4.3: Potential Biofuel Energy Production from JCL in the Study Area

This study estimated the potential energy production that can be generated from the yield of JCL in the identified suitable sites. The estimated potential of energy production from JCL in the identified suitable sites was based on equation 1.

Potential of JCL for Biofuel production

To calculate JCL yield in the identified high suitability sites, the estimated biomass per plant was multiplied by the number of plants per area to obtain the biomass yield. The estimated yield per individual *Jatropha curcas* plant is 2 kg and the estimated number of plants per hectare is 1000 (Fersi et al. 2013; Somorin and Kolios 2017). Hence, the biomass yield is expressed as:

Biomass Yield = 2 kg/plant * 1000 plants/ha = 2000 kg/ha/yr. ………….. Equation 1

1061117 ha * 1000 kg/ha = 2,122,234,000 kg which is = 2,122,234 m3/yr.

Therefore, the potential biomass yield of the study area is estimated at approximately 2,122,234 m3 per year.

The oil content from JCL is estimated at 32.5% per seed (Somorin and Kolios,2017), thus, the formula for estimating the oil content is expressed as:

Oil content (%) = (Mass of extracted oil / Initial mass of sample) x 100

Oil content = (32.5 / 2122234) x 100 = 689726.05m3/yr.

The findings revealed that about 689726.05m3 per annum of biofuel can be produced from the identified suitable sites in the study area through a process of transesterification. Biodiesel produced from Jatropha oil can be used as a substitute for diesel fuel in transportation and can help reduce greenhouse gas emissions. This finding disagrees with that of Isaac et al., (2016) which focused on the various considerations for both oil and by-product usage. The variation may be as a result of the different methods used for estimation.

Converting potential oil extracted to kWh of electricity

According to international conventions, one metric tonne of JCL oil is equivalent to or is capable of producing 10.35 kWh of electricity (Somorin and Kolios 2017) therefore;

689726.05m3/yr. * 10.35kWh = 7,138,664.6kWh/yr.

Thus, 689726.05m3/yr of JCL biofuel has the potential to produce electricity of about 19,557.9kWh daily, 594,888.7kWh monthly, and 7,138,664.6kWh annually

These findings suggest that 689726.05 cubic meters per year of JCL biofuel has the potential to generate a significant amount of electricity. Breaking it down would translate to a daily electricity production of 19,557.9 kWh and a monthly electricity production of about 594,888.7kWh. This highlights the potential of JCL biofuel as a sustainable and renewable energy source for generating electricity. It shows that with the right infrastructure and utilization, a significant amount of energy can be harnessed from biofuels like JCL. The rural electrification scheme currently ongoing in rural areas in Nigeria can key into this technology for sustainability of the project in order to provide access to electricity which can facilitate the establishment and operation of small businesses and cottage industries in rural areas. This result varies from that of Cortez-Núñez et al. (2020) whose findings revealed that approximately 15.3% of Mexican territory was suitable for JCL production, with a projected biodiesel yield of 9.683 Mm3/year.

Conclusion

Selecting appropriate lands for the commercial cultivation of *Jatropha curcas Linneaus* is a crucial step due to its economic and environmental implications. The study has successfully revealed that GIS based MCDA using AHP is highly effective in the determination of suitable lands for the commercial cultivation of JCL in the study area. It was revealed that the eight criteria analysed in this study are all important in the determination of suitable land for the commercial cultivation of JCL plants as they all influence its suitability at different rate. The study found that large acres of land exist in the southern part of the study area and are highly suitable for the commercial cultivation of Jatropha. If developed, the land has the potential to produce about 689726.05m3 of biofuel annually and generate electricity of about 7,138,664.6 kWh per annum to provide lighting and power devices and appliances in households, improving the living conditions and quality of life in the state especially for the rural communities.

Recommendation

In the production and cultivation of *Jatropha curcas* there is need for substantial government and private investments. Awareness campaigns, policy amendments, and funding for farmers should be implemented. Small and large-scale farming should be encouraged to benefit farmers and promote JCL oil production. The federal and state governments should focus on rural electrification projects using *Jatropha curcas*. Further research is needed to estimate the technical and economic potential of JCL energy production. This will help mitigate the negative impacts of fossil fuels, promote sustainable energy development, and diversify Nigeria's energy sources.

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