

Land Suitability Evaluation of Soils under Cashew (*Anacardium occidentale* L.) and Oil Palm (*Elaeis guineensis* Jacq.) Production in Iwo, Osun State, Nigeria

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Abstract
Agricultural productivity depends largely on the suitability of land for the intended use therefore, land suitability evaluation provides a scientific basis for matching land characteristics with crop requirements to ensure sustainable agricultural production and efficient land resource utilization. Despite the economic importance of cashew (*Anacardium occidentale* L.) and oil palm (*Elaeis guineensis* Jacq.) in southwestern Nigeria, information on the suitability of soils currently supporting these perennial plantations remains limited. This study was therefore conducted, to evaluate the suitability of soils under established cashew and oil palm plantations at Ile-Ogo, Iwo, Osun State, Nigeria.

Detailed field investigations involving auger observations, profile pit examination, and soil sampling were carried out adopting standard soil survey procedures. Representative soil samples were processed and analyzed for routine physical and chemical properties following standard laboratory procedures. The soils were characterized and classified adopting the USDA, WRB and Local Series systems of classification. Descriptive statistics was used. Parametric and non-parametric land suitability evaluation approaches were employed to place the soils into different suitability classes.

The soils were characterized mainly by sandy to loamy sand surface horizons, overlying sandy clay loam to clayey subsurface horizons. Soil pH ranged from moderately acidic to strongly acidic in most profiles, while cation exchange capacity was generally low, indicating low nutrient reserves in the study area. Stones and concretions were observed in several profiles, particularly within the cashew plantation, restricting effective rooting depth. The soils were classified as Alfisols, Lixisols, and Iwo Series at the USDA, WRB and Local Series systems, respectively. The Suitability evaluation using the parametric and non-parametric approach showed that the soils of the cashew plantation were marginally suitable (S3), with productivity indices of 41.57% and 48.00%, respectively, under current and potential assessment. Climatic factors and low cation exchange capacity, were the major limitations. Similarly, soils under the oil palm plantation were marginally suitable (S3) under the non-parametric approach, whereas the parametric method rated them as moderately suitable (S2) with productivity index of 53.67%, with climatic conditions, particularly rainfall, representing the dominant constraint.

Although the soils of the existing plantations are capable of sustaining production, improved soil fertility management, especially practices aimed at increasing nutrient retention, organic matter content and supplementary irrigation, will enhance productivity. This study validates the importance of site-specific soil suitability assessment for addressing sustainable management of perennial plantation crops in southwestern Nigeria.

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Keywords: Land evaluation, soil suitability, cashew, oil palm, soil limitations, sustainable land management

Introduction

Land is one of the most valuable natural resources supporting agricultural production, and its sustainable utilization depends largely on matching land characteristics with the ecological requirements of specific crops (Kumar *et al*., 2021) [11]. Increasing pressure on agricultural land arising from population growth, urban expansion, climate variability and competing land uses has

heightened the need for systematic land evaluation to guide appropriate land use decisions (Yaro *et al*., 2025) [27]. Land suitability evaluation provides a scientific basis for assessing the capacity of land to support specific agricultural enterprises and remains an indispensable tool for sustainable crop production and natural resource management (FAO, 2007) [6]. By identifying the opportunities and limitations of different land units, land evaluation facilitates optimum utilization of land resources while minimizing environmental degradation (Sys *et al*., 1993) [19].

Soil forms the foundation of agricultural productivity because it supplies water, nutrients, and anchorage required for plant growth. However, the productivity of any soil depends not only on its inherent fertility but also on its physical, chemical and morphological characteristics (Weil and Brady, 2017) [24]. Properties such as soil depth, texture, structure, drainage, effective rooting depth, soil reaction (pH), organic matter content, cation exchange capacity (CEC) and base saturation collectively influence crop performance and ultimately determine land productivity (Belay *et al*., 2025; Landon, 2014) [2, 12]. Deficiencies or limitations in any of these characteristics may restrict crop performance even where climatic conditions are favourable. Consequently, detailed soil survey and land suitability evaluation have become essential components of agricultural planning and sustainable land management (Soil Survey Staff, 2022) [16].

Amongst the important plantation crops in Nigeria, cashew (*Anacardium occidentale* L.) and oil palm (*Elaeis guineensis* Jacq.) contribute significantly to rural livelihoods, foreign exchange earnings, employment generation, and national economic development (Rossiter, 2018) [14]. Nigeria ranks among the leading producers of cashew in Africa, while oil palm remains one of the most important industrial food crops in the country (John-Martin *et al*., 2026) [10]. Cashew possesses the ability to thrive in marginal environments with moderate fertility and tolerates relatively drier conditions compared with many perennial tree crops (Azeez and Olabanji, 2024) [1]. Nevertheless, optimum nut yield and long-term plantation productivity depend on favourable soil conditions, including adequate rooting depth, good drainage, balanced nutrient supply and moderate moisture availability. Oil palm, on the other hand, requires deep, well-drained soils with adequate moisture supply, favourable soil structure, and relatively high nutrient availability for optimum growth and yield (Corley and Tinker, 2016) [4].

Although both crops are extensively cultivated in southwestern Nigeria, establishment of plantations has often been guided by availability of land rather than systematic evaluation of soil suitability. Consequently, many plantations are located on soils whose inherent limitations may constrain productivity (Ogunkunle, 1993; Fasina *et al*., 2015) [8, 13]. The mere presence of an established plantation should therefore not be interpreted as evidence of optimum land suitability. Perennial tree crops, particularly cashew, may survive and produce economically under marginal soil conditions because of their adaptive characteristics. However, such adaptation does not necessarily imply that the land possesses the characteristics required for maximum productivity (Habibu *et al*., 2021) [9]. This distinction between crop adaptability and land suitability is fundamental in land evaluation and provides the scientific basis for assessing the long-term sustainability of existing plantations. Consequently, detailed land suitability assessment is essential for identifying production constraints and developing site-specific management strategies capable of improving long-term productivity.

Despite the increasing cultivation of cashew and oil palm in the study area, comprehensive information on the suitability of these soils already supporting mature plantations for sustainable plantation development is limited. Such information is essential for guiding land-use planning, fertilizer management, crop selection, and investment decisions aimed at optimizing agricultural productivity while conserving soil properties. Most previous investigations have focused on soil characterization, fertility assessment or land evaluation for proposed agricultural development, with limited attention given to determining whether existing plantations occupy soils that are optimally suited to their ecological requirements. This study therefore seeks to evaluate the suitability of soils under established cashew and oil palm plantations in Ile-Ogo, Iwo, Osun State, the parametric and non-parametric land evaluation approaches.

Methodology

Study Area

The study was conducted at Favilus Peace Farms Limited, Ile-Ogo, within Ola-Oluwa Local Government Area of Iwo, Osun State, Southwestern Nigeria. The study area is located between latitude 7°47′09.5″N and 7°47′26.3″N and longitude 4°11′33.7″E and 4°11′39.0″E, with an average elevation of approximately 342 m above sea level. According to Sunmonu *et al*., 2018, the area lies within the tropical wet-and-dry (Guinea Savanna transition) climatic zone, characterized by distinct wet and dry seasons (Figure 1). Annual rainfall ranges between 1,200 and 1,500 mm, with most precipitation occurring from March to October, while the dry season extends from November to February. Mean annual temperature is approximately 29.7°C with relatively high humidity during the rainy season. The landscape consists of gently undulating terrain with varying degrees of soil depth, stoniness and drainage conditions, providing suitable conditions for comparative land suitability evaluation.

Geologically, the study area is underlain predominantly by Precambrian Basement Complex rocks, consisting mainly of granite gneiss, migmatite, and quartzite (Sunmonu *et al*., 2018) [18]. Weathering of these rocks has produced predominantly coarse-textured soils that are relatively deep, well-drained, and moderately to strongly weathered. Similar parent materials have been reported to produce soils characterized by sandy surface horizons over clay-enriched subsoils throughout southwestern Nigeria (Fasina *et al*., 2015) [8].

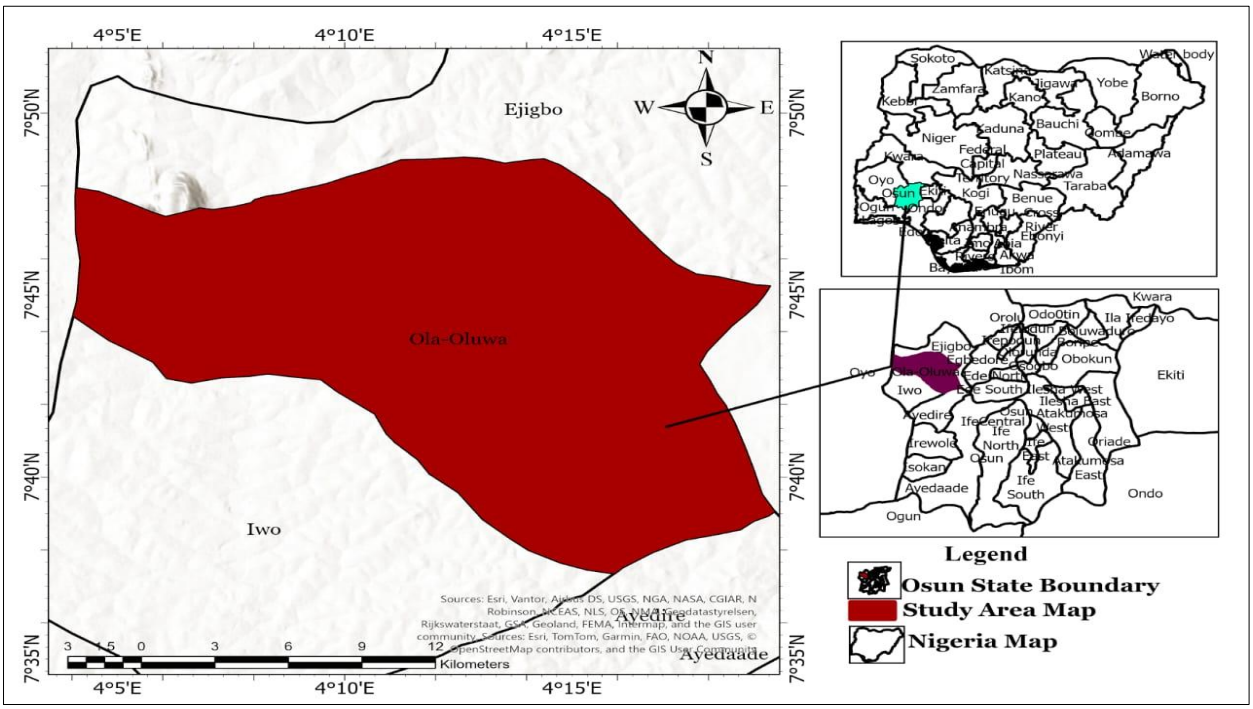


Fig 1: Map of the Study Area

Field Survey and Soil Sampling

A reconnaissance survey preceding the main soil investigation was carried out to identify major physiographic units and establish sampling locations within the perimeter of the plantations. The survey method was semi-detailed, involving systematic traverses across the plantations using existing access routes and predetermined sampling points on the Global Positioning System (GPS). Based on observable differences in topography, vegetation, soil characteristics, etc., within the cashew and oil palm plantations, representative profile pits (designated as FGB 01, FGB 02, on the cashew plantation; and OGO 01, OGO 02 and OGO 03, on the oil palm plantation), were dug and described following standard soil procedures (FAO, 2006) [5].

Soil samples were collected from each genetic horizon for routine analysis, while undisturbed soil samples were collected using a core sampler of known volume from all horizons for bulk density determination.

Laboratory Analysis

Soil samples collected were air-dried and processed for routine physical and chemical analysis following standard laboratory procedures recommended by Udo *et al*. (2009) [23]. The resulting soil properties were evaluated to determine the fertility status and suitability of the soils of the study area for cashew and oil palm production.

Soil Characterization and Classification

The soils were characterized using the data obtained from the morphological, physical and chemical analysis, and thereafter, classified adopting the three classification systems of USDA Soil Taxonomy (Soil Survey Staff, 2022) [16], World Reference Base for Soil Resources (WRB) (FAO, 2022) [7] and Local series (Smyth and Montgomery, 1962) [15].

Land Suitability Evaluation

Land suitability was evaluated by matching the measured land characteristics and qualities with the ecological requirements of cashew and oil palm following the principles of the FAO Framework for Land Evaluation (FAO, 1976) and the parametric procedures described by Sys *et al*. (1991) [20]. Both non-parametric and parametric approaches were employed to determine the actual and potential suitability of the soils.

The non-parametric approach involved matching individual land characteristics with crop requirements, whereby the most limiting factor determined the overall suitability class. The parametric approach involved numerical rating of individual land qualities and computation of an overall suitability index for each mapping unit. Suitability classes were interpreted according to the modified FAO classification system as: S1 – Highly suitable; S2 – Moderately suitable; S3 – Marginally suitable; N1 – Currently Not suitable; N2 – Permanently Not Suitable. The principal land qualities considered during the evaluation included climatic conditions (c), soil physical characteristics (s) (texture, effective soil depth), soil fertility (f), and topography (t). Tables 1 and 2 shows the land suitability requirements for cashew and oil palm respectively.

Table 1: Land Suitability Requirements for Cashew

Land Quality / Land Characteristics	Land Suitability Class			
	Highly Suitable (S1)	**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Not Suitable (N)**
Climate (c)				
Elevation (m)	<196	196–324	324–456	>456
Rainfall (mm)	987–2.247	827–987; 2,247–3,197	601–827; 3,197–4,926	<601; >4,926
Dry month (number)	5–10	4-5; 10-11	<4; 10-11	>11
Wet month (number)	1–3	<1; 3-5	5-8	>8
Soil Physical Properties (s)				
Texture	Clay loam, sandy clay loam, loam	Sandy clay, Sandy loam	Clay, silty clay, silty clay loam	heavy clay, silt, loamy sand, sand
Effective depth (cm)	>40	21–40	7–21	<7
Fertility (f)				
CEC (cmol kg^{-1})	>12.4	8.5–12.4	2.6–8.5	<2.6
pH (H_2O)	5.4–6.4	5.1–5.4; 6.4-6.9	4.6–5.1; 6.9-7.7	<4.6; >7.7
Organic C (%)	>0.8	0.5–0.8	0.1–0.5	<0.1
Base Saturation (%)	>66	<66		
Total N (%)	>0.07	0.05–0.07	0.03–0.05	<0.03
Available-P (mg/kg)	>40	11–40	1–11	<1
Exchangeable-K (cmolkg^{-1})	>0.37	0.27–0.37	0.10–0.27	<0.10
Topography (t)				
Slope (%)	<12	12–23	23–77	>77
Surface rock (%)	<15	15–29	29–76	>76

Source: (Widiatmaka *et al*., 2014)

Table 2: Land Suitability Requirements for Oil Palm

Land Quality / Land Characteristics	Land Suitability Classes				
	Highly Suitable (S1)	**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Currently Not Suitable (N)**	**Permanently Not Suitable (N2)**
Climate (c)					
Annual Rainfall (mm)	>1700	1450-1700	1250-1450	-	<1250
Mean Annual Temp. (°C)	>22	20-22	18-20	-	<18
Relative Humidity (%)	>70	65-70	60-65	-	<60
Topography (t)					
Slope (%)	0-8	8-16	16-30	>30	-
Wetness (w)					
Flooding	Fo	F1	F2	-	F3
Drainage	Perfect, well	Moderately well	Poor, aeric	Poor, Drainable	V. Poor, Not Drainable
Soil Physical Properties (s)					
Texture	Cl, SCL, L	SCL	SCL-LFS	Any	C,Cs
Structure	Blocky	-	-	-	Massive, Single grain
Depth (cm)	>100	50-100	25-50	-	<25
Fertility (f)					
ECEC (cmol/kg)	>80	5-8	<5	-	-
Base Sat. (%)	>35	20-35	<20	-	-
pH (H20)	6.5-7.0	5.5-6.0	<5.5; >7.0	<4.0; >7.0	<4.0; >7.0
OC (%)	>1.2	1.2-0.5	0.5-0.3	0-3-0.2	<0.2

Flooding: Fo, No flooding; F1, 1-2 flooding months in>10 yrs; F2, Not more than 2-3 months in 5 yrs out of 10 yrs; F3, 2-4 months almost every year; F4, >4 months in almost every. Texture: Cl, clay loam; Scl, Sandy clay loam; L, Loam; Lfs, Loamy fine sand; c, Clay; Cs, Clayey.
Source: (Sys *et al*., 1991)

Statistical Analysis and Data Interpretation

Descriptive statistics were used to summarize the physical and chemical properties of the soils. Mean values, ranges, standard deviations and coefficient of variation were computed where appropriate. Laboratory analysis results were therefore, interpreted using established critical limits for tropical agricultural soils (Chude *et al*., 2012) [3], and compared with the ecological requirements of cashew and oil palm, while land suitability ratings were assigned according to the recognized land suitability requirement tables.

Results

Morphological Characteristics of the Soils of the Study Area

The soils under both cashew and oil palm plantations exhibited distinct morphological variability, particularly in effective soil depth, gravel content, stoniness and horizon development associated with their landscape positions. Surface horizons were generally sandy to loamy sand, grading into sandy clay loam and clayey subsoil horizons with increasing depth. The increase in clay content down the

profile indicates active clay illuviation and the development of well-defined argillic (Bt) horizons, suggesting advanced weathering processes typical of tropical soils developed on Basement Complex rocks in southwestern Nigeria. The soils were generally well drained, although mottles observed in some horizons were pedogenic rather than indicative of poor drainage.

The cashew plantation was characterized by the frequent occurrence of gravels, ironstone concretions and stones beginning at approximately 20 cm below the surface. These coarse fragments became more abundant with depth, and consequently constituted one of the important physical limitations identified during land suitability evaluation. Root distribution was sparse below approximately 60 cm thereby, reducing the effective rooting depth of the soil. The reduced rooting depth observed in the cashew plantation therefore, may have contributed substantially to its classification as marginally suitable (S3).

In contrast, the oil palm plantation occupied relatively deeper soils with fewer physical restrictions to root penetration and appreciable clay accumulation in the subsurface horizons. These differences suggest more favourable rooting conditions for oil palm than for cashew. This observation probably explains why the oil palm soils attained a higher suitability index (53.67%) under the parametric evaluation despite experiencing similar climatic limitations.

Physical Properties of the Soils

Bulk density ranged from 1.30 to 1.64 g cm^{-3}, with values generally increasing with soil depth. Higher bulk density values (1.50–1.64 g cm^{-3}) were recorded predominantly in the cashew plantation, whereas the oil palm plantation generally exhibited lower values ranging from 1.30 to 1.55 g cm^{-3}. These observations indicate comparatively better soil structure and root penetration conditions under the oil palm plantation. Nevertheless, the relatively high bulk density recorded in portions of the cashew plantation may indicate localized compaction associated with gravelly subsoil horizons which may further restrict root development. Although the measured values were not sufficiently high to severely impede plant growth, but their interaction with reduced effective soil depth may have contributed to the lower suitability rating assigned to the cashew plantation.

Chemical Properties and Fertility Status

The soils have its pH to range from moderately acidic to strongly acidic, and generally decreased with profile depth. Organic carbon concentrations were highest within the surface horizons and declined progressively down the profile, reflecting the accumulation of organic residues near the soil surface. Similarly, total nitrogen followed the same trend because of its close association with soil organic matter.

Available phosphorus varied among the profile pits but was generally adequate in some surface horizons and comparatively lower in several subsurface horizons. Exchangeable calcium and magnesium ranged from low to moderate, while exchangeable potassium remained generally low across most sampling points. The soils also exhibited relatively low cation exchange capacity (CEC) especially those of the cashew plantation, indicating limited capacity for nutrient retention. Base saturation, however, remained relatively high in most horizons, suggesting that exchange sites were predominantly occupied by basic cations despite the generally low nutrient reserve.

Soil Classification

Following the results obtained from the morphological, physical and chemical properties of the soils of the study area, the soils were observed to be gravelly, moderately acidic with high base saturation. Few horizons were also observed to solidify on exposure showing properties of plinthization and therefore, were classified as Alfisols (Typic Kandiustalf and Plinthic Kandiustalf), Lixisols (Haplic Lixisols and Plinthic Lixisols) and Iwo Series in the USDA, WRB and Local Series system of classification respectively. Due to gravel and concretions dominant in their subsoil horizons.

Table 3: Land/Soil Characteristics of the Cashew and Oil Palm Plantations of the Study Site

Land Quality/ Land Characteristics	Cashew	Oil Palm
Climate (c)		
Elevation (m)	342	342
Rainfall (mm)	1,200-1,500	1,200-1,500
Dry month (number)	4-5	4-5
Wet month (number)	6-7	6-7
Temperature (°C)	29.7	29.7
Soil Physical Properties (s)		
Texture		
Sand (%)	81.62	76.37
Silt (%)	6.87	9.17
Clay (%)	11.51	14.47
Textural Class	LS	SL
Effective Depth (cm)	40	100
Fertility (f)		
CEC (cmol/kg)	5.97	7.33
pH (water)	5.68	5.53
OC (%)	1.80	1.18
B/Sat (%)	93.33	95.47
TN (%)	0.20	0.13
Avail. P (mg/kg)	12.19	12.61
Exch. K (cmol/kg)	0.29	0.45
Topography (t)		
Slope (%)	0-4	0-6

LS – Loamy Sand; SL – Sandy Loam; B/Sat – Base Saturation; OC – Organic Carbon; TN – Total Nitrogen; Avail. P – Available Phosphorus, Exch. K – Exchangeable Potassium.

Land Suitability Evaluation for Cashew

The non-parametric suitability evaluation classified the soils under the cashew plantation as marginally suitable (S3) for cashew cultivation under current conditions. The principal limitations identified were climatic factors, particularly elevation and the duration of wet months, together with fertility constraints arising from relatively low cation exchange capacity. Although improvement of soil fertility enhanced the potential productivity rating, the overall suitability class remained S3, indicating that climatic limitations could not be substantially altered through management practices.

Similarly, the parametric evaluation placed the soils within the marginally suitable (S3) category, with current and potential productivity indices of 41.57% and 48.00%, respectively. These findings suggest that while the soils can sustain cashew production, their inherent limitations reduce their capacity to support optimum yields, demonstrating the adaptive capacity of cashew to relatively marginal environments.

Table 4: Suitability Class Scores of the Soils Supporting Cashew and Oil Palm Plantations of the Study Site

Land Quality / Land Characteristics	Cashew	Oil Palm
Climate (c)		
Elevation	S3 (60)	-
Rainfall	S1 (100)	S3 (60)
Dry month (number)	S2 (80)	S2 (80)
Wet month (number)	S3 (60)	-
Temperature (°C)	-	S1 (100)
Soil Physical Properties (s)		
Texture	S1 (100)	S2 (80)
Effective Depth (cm)	S2 (80)	S1 (100)
Fertility (f)		
CEC	S3 (60)	S1 (100)
pH (water)	S1 (100)	S1 (100)
OC (%)	S1 (100)	S1 (100)
B/Sat	S1 (100)	S1 (100)
TN	S1 (100)	S1 (100)
Avail. P	S2 (80)	-
Exch. K	S2 (80)	-
Topography (t)		
Slope	S1 (100)	S1 (100)
PRODUCTIVITY INDEX		
Non-Parametric Method		
Current Actual Productivity	S3 cf	S3 c
Potential Productivity	S3 c	S3 c
Parametric Method		
Current Actual Productivity	S3 (41.57)	S2 (53.67)
Potential Productivity	S3 (48.00)	S2 (53.67)

Foot note: S1 – Highly Suitable; S2 – Moderately Suitable; S3 – Marginally Suitable; N – Not Suitable

Land Suitability Evaluation for Oil Palm

Unlike the cashew plantation, soils under the oil palm plantation exhibited comparatively better suitability characteristics. The non-parametric evaluation classified the soils as marginally suitable (S3), with climatic factors, particularly rainfall, constituting the principal limitation. However, the parametric approach rated the soils as moderately suitable (S2) for both current and potential productivity, each with a suitability index of 53.67%.

The relatively better performance of the oil palm soils may be attributed to their better effective soil depth, improved clay accumulation in the subsurface horizons and fewer physical restrictions to root penetration compared with the cashew plantation. Nevertheless, climatic conditions remained the dominant factor limiting further improvement in suitability. However, appropriate soil fertility management could further improve the productive capacity of the existing oil palm plantation.

Conclusion

The soils of the study area were marginally suitable for cashew and oil palm suggesting that the existence of mature plantations should not be interpreted as evidence of optimum land suitability, rather, the observed productivity reflects the adaptive capacity of these perennial crops under prevailing environmental conditions. This research therefore emphasizes the importance of land suitability evaluation as a prerequisite for sustainable plantation establishment and management.

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