

AN ASSESSMENT OF SOIL FERTILITY CAPABILITY POTENTIALS OF WET GRASSLAND LANDSCAPES IN SOUTHERN NIGERIA

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Abstract

Population explosion and subsequent climate change are linked to the ongoing food crises in Africa. Several attempts have been made at ensuring food security, however with limited results. This situation has resulted in focus being drawn to the use of seemingly perceived marginal lands. In Nigeria, undue pressure on the forests, has resulted in redirected focus on the otherwise idle pockets of wet grassland occurring within the rainforest belt. However, studies on the underlying soil fertility capability status, with regards to sustainable agriculture, are sparse. This study therefore examined the fertility capability status of the underlying soils of wet grasslands in Delta state, Nigeria. The rainforest soils were served as the control site for this study. Thirty samples were taken at a depth of 0-15cm from each of the three senatorial districts of the study area, totaling ninety in all. Using standard procedures, the soil samples underwent laboratory analysis for sand, silt, clay, pH, organic carbon, total nitrogen, exchangeable hydrogen and aluminium, calcium, magnesium, potassium, and sodium. The Fertility Capability Classification (FCC) was used to ascertain the fertility capability of the various soil types. The FCC for the rainforest and grassland are Sanke and Sganke respectively. The basic constraints of the wet grasslands include high rate of infiltration and frequent denitrification. The study established potential for the grasslands in supporting sustainable arable farming. Adoption of a multidisciplinary strategy comprising both conservation and sustainability components, is recommended.

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**Related declarations are provided in the final section of this article.

Introduction

The nature and characteristics of any soil is determined, to a large extent, by activities and interactions occurring on or above the ground. Degradation emanating from urbanization and population explosion has been the plight of the global environment, with vegetation types being negatively impacted, and by extension the underlying soil. The implications for sustainability and food security have therefore become dire, on account of this. Affirming this, Babalola *et al.*, (2019) identified the resultant effect of population increase as being decline in soil fertility. Emerging issues have resulted in the adoption of perceived time and cost-efficient management options. They have, however proven to be environmentally unfriendly and unsustainable, in a number of cases.

It is a known fact that the choice of vegetation management options determines the character and potentials of the underlying soil. In view of the phenomenon of population explosion and associated urbanization, the necessity of the concept of sustainable development, as a subset of environmental sustainability cannot be over emphasized. This has placed increasing focus on the adoption of sustainable agricultural practices, such as agroforestry amongst others. The application of these concepts has however been limited, owing to the issues already enunciated. This situation has been further compounded by issues of land scarcity, resulting in the use of marginal lands. The categorization of these lands as marginal, is based on the level of productivity as evidenced by the vegetation and activities on the ground.

The focus of this study is on the wet grasslands located within the Niger Delta of southern Nigeria. Several literatures categorize these grasslands as derived savannas or simply do not recognize their uniqueness, stemming from their wetness almost all throughout the year. Jimoh et al (2020) in his categorizations of the savannas in Nigeria made no mention of the wet grassland, except for a mention of the Southern guinea savanna which does not do justice to the uniqueness of the wetland. The guinea savanna in the southern part of the country, depending on its location do not all experience flooding and wetness all throughout the year, as is specifically the case in these grasslands under focus. Obadoni et al (2009) acknowledged the waterlogged nature of these grasslands but noted that no notable scientific basis was available in literature for this situation. However, in a study carried out in the Urhobo plains of southern Nigeria, Aweto (1987) observed that these grasslands differ in tree species composition from the grasslands in the northern part of the country. This is in addition to the fact that these grasslands occur as discontinuous patches within the rainforest belt, which was corroborated and depicted in a

vegetation map of the area by Akpovwovwo (2007). Aweto (1987) traced the existence of these grasslands to anthropogenic factors ranging from bush burning sweeping across the forest, over exploitation of forest resources and other extreme natural factors. He further noted that these grasslands were adjudged to be in the secondary stage of succession. This, he attributed to the occurrence of a few resistant rainforest trees and shrubs. Joyce (2016) however noted that grasslands of this nature, are known to emerge usually from disturbances arising from waterlogging/flooding and particularly insect competition resulting in restraint in the process of plant colonization. She further noted that wet grasslands are considered a part of the wetland ecosystem, owing to their occurrence being generally between the hydrological gradients of waterlogged wetlands and water deficient lands. Casanova (2012) reported that wet grasslands are usually fragmented and isolated, agreeing with the nature of the grasslands of Southern Nigeria, which had been recognized by some researchers, as aforementioned. Joyce (2014) that the unique species occurring within these grasslands are characterized basically by their relative limitation in the abilities of dispersal and colonization. Russi *et al.* (2013) noted that these unique grassland types are rarely ever classified as wetland vegetation types. Furthermore, Fidelis *et al.* (2013) noted that wet grasslands function as a source of carbon sequestration and storage, particularly in below ground biomass. The soil, being a reservoir, provides the platform for nutrient cycling and several other location specific interactions within the environment. A better understanding of the wet grassland environment can therefore be obtained through the study of the soil and the imprints of the aforementioned activities within and above the soil. This is especially important, bearing in mind, its role in plant development and ecosystem sustainability. The paucity of research and information on these wetland grasslands is evident. In-depth understanding of the functioning, processes and interactions within the several aspects of the wetland grassland ecosystem is limited. It therefore becomes pertinent to examine the underlying soil of this grassland type, with the aim of categorization on the basis of capability, fertility and resourcefulness.

Ariyo (2015) defined soil capability as the ability of the soil to function within natural or managed ecosystem boundaries to sustain plant and animal production in order to enhance or maintain its fertility status for a conducive and healthy man and environmental interaction. On the other hand, soil fertility is the ability of soil to sustain plant growth (Adamu *et al.*, 2015). The fertility status of a particular soil is a major determinant of its suitability and productive capacity. Low soil fertility and capability indices often pose a general constraint to sustainable use of soil

resources. The need to ensure soil fertility maintenance through sustainable management practices cannot be over emphasized (Amaresh, 2015). For the adoption of more in depth and realistic approaches, the need to fully understand the associated limitations and constraints of the soil is extremely necessary. In literature however, emphasis has been placed on fertility, to the detriment of the soil's constraints or limitations. The Soil fertility capability classification (FCC), with the aid of a combination of criteria spanning through physical and chemical data, possess the capability of providing a realistic classification. According to Amaresh (2015), FCC is a classification system based on the quantification of factors linked to certain inherent conditions, which consequently expose the limitations and constraints of the soils in question. Adisa *et al.* (2016), noted that FCC is designed to technically classify agricultural soils based on potential draw backs experienced during the agricultural process. Fertility Capability Classification (FCC) was adopted for the classification of soil types on the basis of their limitations, and thereby ensuring optimal plant growth. The FCC was developed in response to the perceived underutilization of soil survey information. The need for a holistic spectrum of information pertaining to plant growth and sustainability inherent in the soil served as a driver for the emergence of the FCC. This classification is founded basically on both soil classification and soil fertility data. Information obtained serves as a decision support tool for appropriate fertilizer choice (Adisa et al, 2016). Awareness and corresponding knowledge of the soil's limitation present the possibility of insight into the appropriateness of crops or management strategies for the purpose of ensuring environmental sustainability. This study, therefore examined the fertility capability status of the soils of the wet grasslands of Southern Nigeria.

The Methods

The study was carried out in Delta State, located within Southern Nigeria. Delta State is located between latitudes $5^{\circ} 00' N$ and $6^{\circ} 00' N$ and longitudes $5^{\circ} 00' E$ and $6^{\circ} 00'E$ (Akpovwovwo and Gbadegesin, 2021). The predominant physical features of the area include swamps, creeks, rivers and coastlines extending from East to West for about 163 kilometers on the Atlantic Ocean (Delta State, 2014).

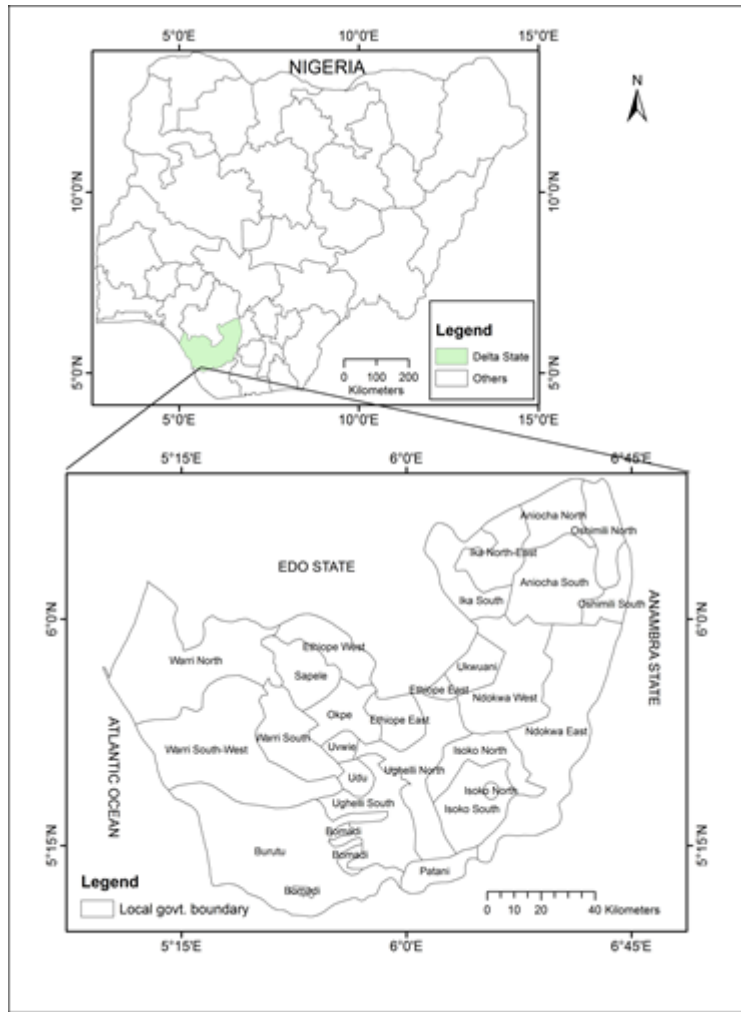


Fig 1: Map of study area

The study area has a wide coastal belt, inter-laced with complicated channels of water bodies such as rivulets, streams, and numerous tributaries which constitute part of the Niger Delta through which River Niger finds its way into the sea (Awaritefe, 2013). The area is underlain by sedimentary rocks consisting mainly of yellow, white, and sand with pebbles, clay and sandy soils (Peter, 2001). The naturally occurring vegetation in the area comprise of tropical lowland rainforest, freshwater swamp forest, mangrove forest and grasslands. The grasslands are unique because they are anomalous and discontinuous (Akpovwovwo, 2007).

The study was carried out within already established districts within Delta state comprising Delta North, Delta Central and Delta South. Within each of these districts respectively, samples were taken from the wet grasslands and the rainforests (control) landscapes. A total of sixty soil samples were obtained from a depth of 0-15cm, in each of the districts, with the aid of a core sampler. The soil samples were then subsequently analyzed for the following: Particle size

composition - Hydrometer method, soil pH - pH meter, Organic matter - Walkley Black method, Available Phosphorus, Exchangeable potassium, sodium, calcium - Flame photometry and Exchangeable magnesium - atomic absorption spectrophotometer. The Effective cation exchangeable capacity (ECEC) was obtained through the calculation method Edewor & Atubi (2021).

The FCC is comprised of Type/substrata and Modifiers categories. The Type/substrata gives an indication of top soil and subsoil textures. They are categorized in the following manner: S (Sandy top soils, loamy sands and sands), L (Loamy top soils: < 35% clay), C (Clayey top soil), O (organic soil->12% to a depth of 50cm or more). The Substrata type comprises of the following : S (Sandy subsoil), L (Loamy subsoil), C (clayey subsoil), R (rock or other hard root restricting layer), R⁻ (similar to R, but layer can be manipulated to increase rooting depth) (2003). The modifiers reflect the conditions and inherent potential limitations or restrictions to plant growth. The latest FCC version 4 was adopted for this study, comprising basically of soil physical properties, reaction, mineralogy and biological properties, as reflected by the individual modifiers in question. On the premise of the data obtained in this study, only the Type (top soil) category and corresponding modifiers were applied. The soils are therefore, classified based on the presence of the characteristics of corresponding outlined modifiers.

Results and Discussion

Table 1 shows the soil parameters for the three senatorial districts of Delta state. The mean soil parameters are presented in Table 2. Anova statistical test of the soils of the three different landscapes reveal significant difference in exchangeable acidity, exchangeable aluminium, exchangeable Hydrogen and effective cation exchangeable capacity, at the 0.05 sig level (Edewor & Atubi, 2021) (See Table 3 & 4). The pH is generally acidic, ranging from 4.18 to 5.22 across the wet grasslands and 4.94 to 5.31 across the rainforest landscape. Udo *et al.* (2009) noted that low pH indicating high level of acidity can be attributed to heavy rainfall, with leaching and soil fragility being a consequence. The phosphorus content of the soil of the study area falls within the high content class of >15 kg/mg classification. The content of the exchangeable bases for the different landscape soils were summarized thus: Rainforest: Ca=Mg>K=Na and Grassland: Mg>Ca>Na>K. The potassium content is seen to assume the lowest proportion of the exchangeable bases in the wet grassland landscape (Edewor & Atubi, 2021). According to Solarin (2000), low potassium content in soils can be attributed to heavy rainfall and increased weathering.

The Organic matter content for the wet grassland bordered around 2%, being comparable to that of the rainforest soils, with that of the wet grassland being slightly higher (see Table 2). Table 1, however shows some variations, with organic carbon content being above 2% in the wetland landscape in the Delta North district. This study disagrees with the assertion of Akpa *et al.*, (2016) stating that organic carbon contents were relatively lower in grasslands than other landscapes. This is evidenced by the fact that the organic carbon contents of the wet grassland did not significantly vary with that of the rainforest landscape. Organic carbon being a very important soil fertility parameter, as affirmed by Musinguzi *et al.*, (2013), stating that organic carbon is a major necessity for optimal plant growth, implies the possibility of wet grasslands in sustaining plant growth. Eshetu, Giesler & Hogberg (2004) noted that 2% organic carbon content was a standard value requirement for basis of the efficiency of cation exchange within soils. The organic carbon content in the study area is appropriate for sustainable plant growth, according to the aforementioned.

Soil texture is known to influence the nature and level of access to basic needs of any plant, being determined basically by the proportion of particle size composition. The textural class for the soils of the rainforest is sandy loam, while the grassland is categorized as loamy sand.

Table 1: Soil parameter values of the different landscapes in the various zones

Soil Parameters	Delta Central		Delta North		Delta South	
	Rain forest	Grassland	Rainforest	Grassland	Rainforest	Grassland
pH	5.31	5.22	4.12	4.48	4.94	4.18
OC (%)	2.43	2.17	2.11	4.29	3.40	2.41
Total Nitrogen (%)	0.26	0.24	0.23	0.48	0.37	0.27
Avail. Phosphorus (ppm)	6.11	7.25	58.53	7.64	13.44	33.98
Calcium (cmol/kg)	0.26	0.42	0.64	0.31	0.91	0.27
Sodium	1.36	1.57	1.90	1.60	1.79	1.93

(cmol/kg)						
Magnesium	0.52	0.46	1.09	0.36	0.58	0.55
(cmol/kg)						
Potassium	0.13	0.10	0.17	0.10	0.16	0.11
(cmol/kg)						
Sand (%)	74.8	78.2	84.20	84.80	74.40	77.20
	0	0				
Silt (%)	16.6	11.4	8.40	9.40	15.40	10.20
	0	0				
Clay (%)	8.60	10.4	7.40	5.80	10.20	12.60
		0				
ECEC	2.31	2.56	4.34	2.37	3.37	2.90

Source: Edewor & Atubi (2021)

Table 2: Soil parameter mean values for the wet grassland and rainforest landscapes

	Rainforest	Grassland
pH	4.79	4.63
OC (%)	2.64	2.96
Total Nitrogen (%)	0.29	0.32
Phosphorus	26.03	16.29
Calcium	0.74	0.33
Magnesium	0.74	0.45
Potassium	0.16	0.10
Sodium	0.16	0.17
ECEC	3.34	2.60
Sand	77.8	80.06
Silt	13.4	10.3
Clay	8.73	9.60

Source: Edewor & Atubi (2021).

Table 3: Summary of Anova test results of difference in the soils of the wet grasslands and the rain forest (control) landscapes in the study area.

Soil Parameter	Sig.
pH	0.160
Org. C	0.357
Total Nitrogen	0.286
Avail. Phosphorus	0.125

Exch. Acidity	0.264
Exch. H	0.368
Exch. ALH	*0.046
Calcium	*0.049
Magnesium	*0.009
Potassium	*0.050
Sodium	0.847
Sand	0.365
Silt	0.114
Clay	0.478
ECEC	*0.022

Source: Edewor & Atubi (2021).

*significant @0.05 sig level.

The FCC of the soils of the study area is presented in Table 4. The FCC of all the landscape soils is similar, except for a slight variation emanating from the water logging indicator (g) in the grassland soils (Table 3). This implies that the constraint of water logging for long periods of time is a critical. This is indicative of the inefficiency in drainage resulting in stagnation on the soil surface. This is attributed to the relatively higher mean proportion of sand content recorded in the grassland landscape, demonstrating its characteristic poor drainage. Adisa *et al.*, (2016) noted that this situation could be managed by the elevation of planting surfaces within farm lands. They further noted that nitrogen fixing plants could be employed in checking the action of denitrification occurring as a result of water logging. It is however surprising to note that the particle parameter percentages, show no indication of the aforementioned variation in the textural class. The variation observed in the mean sand content is observed to be insignificant. The water logging condition in the FCC, can therefore be basically linked in some way, to the Effective Cation Exchange Capacity (ECEC) (see Table 4). All the other significantly varying parameters observed, all form components of the ECEC, being derivative components of ECEC. This alludes to the linkage of the ECEC, with the physical condition of soil texture.

The Type categorization of the top soil for all the landscapes is categorized as S, signifying their predominant sandy nature. According to Sanchez *et al.*, (2003), the sandy Type is suggestive of high rate of infiltration as a result of poor drainage of sandy soils. Hogarth (2017) noted that limitation of oxygen in water served as a major limitation for plant growth in soils with the aforementioned characteristic. Corroborating this, Goud *et al.*, (2022) noted that oxygen dispersal within a waterlogged environment, was three hundred and twenty thousand times

slower than within a normal soil setting. One of the consequences of this attribute is the increased tendency for release of greenhouse gases, such as methane.

The “a” modifier is an indicator of aluminum toxicity. According to Sanchez *et al.*, (2003), a soil of less than 5.5 is indicative of this limitation. This limitation reflects low nutrient capital reserves. Rout *et al.*, (2001) linked aluminum toxicity to limitation in root development. Aluminum toxicity is indicative of respiration inhibition in plant roots, with the implication of reduced uptake of water and nutrients. Kochian *et al.*, (1995), also observed that aluminium toxicity had the potential of limiting root cell functions. This, he noted, could be effectively addressed by liming. Ojo and Bello (2010), reported that soya bean and other legumes, which are aluminium sensitive, will only adapt to aluminium toxicity in the soil through the adoption of liming. Growth of aluminum tolerant plants can however be adopted in situations of this nature. For instance, Sanchez *et al.*, (2003) noted that this limitation is actually of benefit to tea and rubber growth. Furthermore, Adeleke and Akinrinde (2011) noted that aluminium toxicity can be addressed effectively through the application of organic based fertilizers. This was further corroborated by Duruigbo *et al.*, (2007) and Adeleke and Akinrinde (2011), noting that organic manure application had the capability of reducing aluminum toxicity and consequently increasing crop yield. This strategy is both cost effective and environmentally friendly. The “n” modifier signifies high sodium content in soils, in excess of 15% of the Effective Cation Exchange Capacity. They therefore can be classified as alkaline or sodic soils. According to Zewd *et al.*, (2021), alkaline soils are likely to occur in coastal areas or irrigated areas. Mixture of sea water and naturally occurring carbonate within this environment, is a major component of this limitation.

Modifier “e” is suggestive of the limited ability of retaining nutrients. According to Sanchez (2003), the implication of this modifier is that the soil is highly leached. This is such that nutrients are transported to depths beyond the reach of the plants. This further translates to a low effective cation exchangeable capacity, thereby limiting plant growth. Modifier “k” is suggestive of the limitation of potassium supply for plant development. Confirming this, Udo *et al.*, (2009) observed that sandy soils had inherently low potassium reserves, resulting in low crop yield. Babalola *et al.*, (2019) and Fasusi (2019) noted that wetlands are characteristic of this limitation, stemming from excessively high rainfall and subsequent leaching.

Table 4: FCC of the various landscapes of the study area.

S/N	Landscape	Soil Fertility Capability
1	Rainforest	S, a, n, k, e
2	Grassland	S, g, a n̄, k, e
3	Fallow	S, a, n, k, e

Conclusion

The soils of the study area are relatively fertile as reflected by the organic carbon content which meets the standard of fertility. This is, in spite of the fact that significant differences were observed in the calcium, magnesium and potassium macronutrients. The detection of the water logging character of the soil as a limitation was revealed by the Fertility Capability Classification. This was however not detected in an earlier study carried out by Edewor & Atubi (2021), in their assessment of the soil fertility of the wetland grassland. This study, therefore confirms the importance of FCC as a critical combination of the attainment of both realistic and manageable solutions. This further reveals the inherent fertility potential of wet grasslands, on the condition that the waterlogging limitation is efficiently tackled. This study therefore establishes the suitability of the wet grassland soils for sustainable agriculture. Organic fertilizer use and adoption of sustainable environmentally friendly soil management options are being recommended.

This study was unable to incorporate the use of all the parameters in the Fertility Capability Classification, due to limitation in funding. Further studies, incorporating all the excluded parameters should be carried out. In addition, further studies, with a multidisciplinary approach, should be carried out to ascertain the origin and prevailing interactions within the wet grasslands of the Forest belt of Southern Nigeria. Based on the foregoing, this study recommends the application of a multidisciplinary approach into the effective management of wet grassland. It is expected that this will effectively tackle the issue of food insecurity and ensure the sustainability of the ecosystem services of the wet grasslands in the humid tropics. Singh (2015) affirmed the importance of sustainable use of wet grasslands, attributing the loss of 50 percent soil carbon to poor use of grasslands. The implication therefore, is that further studies on wet grasslands cannot be over emphasized as it will contribute to the efficiency in carbon sequestration. This in turn, will ensure the amelioration of the prevailing global issue of climate change.

CONFLICT OF INTEREST

We have no conflicting interest to declare.

COMPLIANCE OF ETHICAL STANDARDS

The nature of the work does not require approval by a bio (ethical) committee.

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