

Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 22(1) January-April 2024]

Pantnagar Journal of Research

(Formerly International Journal of Basic and
Applied Agricultural Research ISSN : 2349-8765)



G.B. Pant University of Agriculture & Technology, Pantnagar



ADVISORYBOARD

Patron

Dr. Manmohan Singh Chauhan, Vice-Chancellor, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Members

Dr. A.S. Nain, Ph.D., Director Research, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Jitendra Kwatra, Ph.D., Director, Extension Education, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. S.K. Kashyap, Ph.D., Dean, College of Agriculture, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. S.P. Singh, Ph.D., Dean, College of Veterinary & Animal Sciences, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. K.P. Raverkar, Ph.D., Dean, College of Post Graduate Studies, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Sandeep Arora, Ph.D., Dean, College of Basic Sciences & Humanities, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alaknanda Ashok, Ph.D., Dean, College of Technology, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Alka Goel, Ph.D., Dean, College of Community Science, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. Avdesh Kumar, Ph.D., Dean, College of Fisheries, G.B. Pant University of Agri. & Tech., Pantnagar, India
Dr. R.S. Jadoun, Ph.D., Dean, College of Agribusiness Management, G.B. Pant University of Agri. & Tech., Pantnagar, India

EDITORIALBOARD

Members

Prof. A.K. Misra, Ph.D., Chairman, Agricultural Scientists Recruitment Board, Krishi Anusandhan Bhavan I, New Delhi, India
Dr. Anand Shukla, Director, Reefberry Foodex Pvt. Ltd., Veraval, Gujarat, India
Dr. Anil Kumar, Ph.D., Director, Education, Rani Lakshmi Bai Central Agricultural University, Jhansi, India
Dr. Ashok K. Mishra, Ph.D., Kemper and Ethel Marley Foundation Chair, W.P. Carey Business School, Arizona State University, U.S.A.
Dr. B.B. Singh, Ph.D., Visiting Professor and Senior Fellow, Dept. of Soil and Crop Sciences and Borlaug Institute for International Agriculture, Texas A&M University, U.S.A.
Prof. Binod Kumar Kanaujia, Ph.D., Professor, School of Computational and Integrative Sciences, Jawahar Lal Nehru University, New Delhi, India
Dr. D. Ratna Kumari, Ph.D., Associate Dean, College of Community / Home Science, PJTSAU, Hyderabad, India
Dr. Deepak Pant, Ph.D., Separation and Conversion Technology, Flemish Institute for Technological Research (VITO), Belgium
Dr. Desirazu N. Rao, Ph.D., Professor, Department of Biochemistry, Indian Institute of Science, Bangalore, India
Dr. G.K. Garg, Ph.D., Dean (Retired), College of Basic Sciences & Humanities, G.B. Pant University of Agric. & Tech., Pantnagar, India
Dr. Humnath Bhandari, Ph.D., IIRRI Representative for Bangladesh, Agricultural Economist, Agrifood Policy Platform, Philippines
Dr. Indu S Sawant, Ph.D., Director, ICAR - National Research Centre for Grapes, Pune, India
Dr. Kuldeep Singh, Ph.D., Director, ICAR - National Bureau of Plant Genetic Resources, New Delhi, India
Dr. M.P. Pandey, Ph.D., Ex. Vice Chancellor, BAU, Ranchi & IGKV, Raipur and Director General, IAT, Allahabad, India
Dr. Martin Mortimer, Ph.D., Professor, The Centre of Excellence for Sustainable Food Systems, University of Liverpool, United Kingdom
Dr. Muneshwar Singh, Ph.D., Project Coordinator AICRP- LTFE, ICAR - Indian Institute of Soil Science, Bhopal, India
Prof. Omkar, Ph.D., Professor, Department of Zoology, University of Lucknow, India
Dr. P.C. Srivastav, Ph.D., Professor, Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, India
Dr. Prashant Srivastava, Ph.D., Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, University of South Australia, Australia
Dr. Puneet Srivastava, Ph.D., Director, Water Resources Center, Butler-Cunningham Eminent Scholar, Professor, Biosystems Engineering, Auburn University, U.S.A.
Dr. R.C. Chaudhary, Ph.D., Chairman, Participatory Rural Development Foundation, Gorakhpur, India
Dr. R.K. Singh, Ph.D., Director & Vice Chancellor, ICAR-Indian Veterinary Research Institute, Izatnagar, U.P., India
Prof. Ramesh Kanwar, Ph.D., Charles F. Curtiss Distinguished Professor of Water Resources Engineering, Iowa State University, U.S.A.
Dr. S.N. Maurya, Ph.D., Professor (Retired), Department of Gynecology & Obstetrics, G.B. Pant University of Agric. & Tech., Pantnagar, India
Dr. Sham S. Goyal, Ph.D., Professor (Retired), Faculty of Agriculture and Environmental Sciences, University of California, Davis, U.S.A.
Prof. Umesh Varshney, Ph.D., Professor, Department of Microbiology and Cell Biology, Indian Institute of Science, Bangalore, India
Prof. V.D. Sharma, Ph.D., Dean Academics, SAI Group of Institutions, Dehradun, India
Dr. V.K. Singh, Ph.D., Head, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, India
Dr. Vijay P. Singh, Ph.D., Distinguished Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, Department of Biological Agricultural Engineering, Texas A&M University, U.S.A.
Dr. Vinay Mehrotra, Ph.D., President, Vinlax Canada Inc., Canada

Editor-in-Chief

Dr. Manoranjan Dutta, Head Crop Improvement Division (Retd.), National Bureau of Plant Genetic Resources, New Delhi, India

Managing Editor

Dr. S.N. Tiwari, Ph.D., Professor, Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Assistant Managing Editor

Dr. Jyotsna Yadav, Ph.D., Research Editor, Directorate of Research, G.B. Pant University of Agriculture and Technology, Pantnagar, India

Technical Manager

Dr. S.D. Samantray, Ph.D., Professor, Department of Computer Science and Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, India

CONTENTS

Productivity, nutrient uptake and economics of sweet corn (<i>Zea mays</i> L. var. <i>saccharata</i>) under different planting geometry and NPK levels	1-7
AMIT BHATNAGAR, SAILESH DEB KARJEE, GURVINDER SINGH and DINESH KUMAR SINGH	
Integrated effect of natural farming concoctions and organic farming practices with various NPK doses on quality of bread wheat	8-13
PRERNA NEGI, MOINUDDIN CHISTI and HIMANSHU VERMA	
Characterization and fertility capability classification of some soils in the rain forest zone of Edo state, Nigeria	14-25
OKUNSEBOR, F.E., OGBEMUDIA, I. and OKOLIE, S. I.	
Characterization and classification of guava growing soils of North-East Haryana according to frame work of land evaluation (FAO, 1993)	26-35
DHARAM PAL, MANOJ SHARMA, R.S. GARHWAL and DINESH	
Interactive impact of heavy metals and mycorrhizal fungi on growth and yield of pepper (<i>Capsicum annuum</i> Linn.)	36-47
SHARMILA CHAUHAN, MOHINDER SINGH, SNEHA DOBHAL, DEEKSHA SEMWAL and PRAVEEN	
Response of chilli (<i>Capsicum annuum</i> var. <i>annuum</i> L.) to different nutrient management practices	48-58
SHEETAL, K.C. SHARMA, SHIVAM SHARMA, NEHA SHARMA, D.R. CHAUDHARY, SANDEEP MANUJA and AKHILESH SHARMA	
Trend detection in weather parameters using Mann-Kendall test for Tarai region of Uttarakhand	59-67
SHUBHIKA GOEL and R.K. SINGH	
Comparative study of antioxidant potential of fresh peel from different citrus species	68-74
TARU NEGI, ANIL KUMAR, ARCHANA GANGWAR, SATISH KUMAR SHARMA, ANURADHA DUTTA, NAVIN CHAND SHAHI, OM PRAKASH and ASHUTOSH DUBEY	
Suitability of Quinoa Grains (<i>Chenopodium Quinoa</i> Willd.) for development of Low Glycemic Index Biscuits	75-84
RUSHDA ANAM MALIK, SARITA SRIVASTAVA and MEENAL	
A study on dietary intake among school-going adolescent girls of Udaipur, Rajasthan during COVID-19	85-92
JYOTI SINGH and NIKITA WADHAWAN	
Nutritional and sensory evaluation of gluten free chapatti developed using underutilised food sources	93-98
AYUSHI JOSHI, ARCHANA KUSHWAHA, ANURADHA DUTTA, ANIL KUMAR and NAVIN CHANDRA SHAHI	
Nutrient-enriched wheat chapatti with fresh pea shells (<i>Pisum sativum</i> L.): A comprehensive quality assessment	99-109
AMITA BENIWAL, SAVITA, VEENU SANGWAN and DARSHAN PUNIA	

Pearl Millet-Based Pasta and Noodles Incorporated with <i>Jamun</i> Seed Powder: Quality Analysis	110-121
SAVITA, AMITA BENIWAL, VEENU SANGWAN and ASHA KAWATRA	
Unlocking the biofortification potential of <i>Serratia marcescens</i> for enhanced zinc and iron content in wheat grains	122-131
BHARTI KUKRETI and AJAY VEER SINGH	
Antioxidant and anti-inflammatory properties of sun-dried leaves and fruits of wild <i>Pyracantha crenulata</i> (D. Don) M. Roem.	132-141
SUGANDHA PANT, PREETI CHATURVEDI, AAKANSHA VERMA, MANDEEP RAWAT, VAISHNAVI RAJWAR and KAVITA NEGI	
Studies on productive herd life, longevity, and selective value and their components in crossbred cattle	142-150
SHASHIKANT, C.V. SINGH and R.S. BARWAL	
Studies on replacement rate and its components in crossbred cattle	151-157
SHASHIKANT, C.V. SINGH, R.S. BARWAL and MANITA DANGI	
Principal component analysis in production and reproduction traits of Frieswal cattle under field progeny testing	158-163
OLYMPICA SARMA, R. S. BARWAL, C. V. SINGH, D. KUMAR, C. B. SINGH, A. K. GHOSH, B. N. SHAHI and S. K. SINGH	
Degenerative renal pathology in swine: A comprehensive histopathological investigation in Rajasthan, India	164-169
SHOBHA BURDAK, INDU VYAS, HEMANT DADHICH, MANISHA MATHUR, SHESH ASOPA, RENU	
Evaluation of histopathological changes on acute exposure of profenofos in Swiss albino mice	170-177
SONU DEVI, VINOD KUMAR, PREETI BAGRI and DEEPIKA LATHER	
Temporal and spatial performance of rapeseed and mustard oilseed in India: A study in the context of Technology Mission on Oilseeds¹	178-190
LEKHA KALRA and S. K. SRIVASTAVA	
Comparative economics of maize cultivation in major and minor maize producing districts of Karnataka – a study across farm size groups	191-203
GEETHA, R. S. and S. K. SRIVASTAVA	
A study on Usefulness of Participatory Newsletter for Potato growers in Udham Singh Nagar district of Uttarakhand	204–209
RAMESH NAUTIYAL and ARPITA SHARMA KANDPAL	
Training Needs of Hortipreneurs in Value Addition and fruit crop production in Kumaon Hills of Uttarakhand	210-215
KRITIKA PANT and ARPITA SHARMA KANDPAL	
Post-training Knowledge Assessment of the rural women about Mushroom Cultivation under TSP project, funded by ICAR	216-220
ARPITA SHARMA KANDPAL, S. K. MISHRA and OMVEER SINGH	
UAV Technology: Applications, economical reliance and feasibility in Indian Agriculture	221-229
A. AJAY and S. SAI MOHAN	

Characterization and fertility capability classification of some soils in the rain forest zone of Edo state, Nigeria

OKUNSEBOR, F.E.*, OGBEMUDIA, I. and OKOLIE, S. I.

Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin, PMB 1154, Benin City, Edo state, Nigeria

**Corresponding author's email id: faith.okunsebor@uniben.edu*

ABSTRACT: Characterization and Fertility capability classification was carried out on some soils in the rainforest zone of Edo state to assess the native fertility status of the soil. Different soil types were identified through rigid grid soil survey procedure that produced two mapping units in each of the site studied (Sites A and B). Each mapping unit was represented by a modal class profile, which was sunk, described, sampled and analyzed using standard laboratory methods. The results revealed that the entire study area had a sandy top soil (0 - 20cm) with sand fraction of particle size ranging from 660 to 960 gkg⁻¹, silt ranged from 10 to 44 gkg⁻¹ and clay had values ranging from 30 to 320 gkg⁻¹. Soil pH ranged from very strongly acidic (4.86) to slightly acidic (6.38); nutrient reserve was equally low as expressed by the low potassium values (K <0.2 cmolkg⁻¹) which ranged from 0.01 to 0.29 cmolkg⁻¹; and low Organic Carbon values (1.30 to 23.13 gkg⁻¹). The mean values ranged from 787gkg⁻¹- 886gkg⁻¹ for sand, 15 gkg⁻¹ - 26.8gkg⁻¹for silt and 88gkg⁻¹- 190gkg⁻¹for clay. The result of Fertility capability classification (FCC) showed that mapping units 1A (site A) and 1B (site B) were classified as FCC unit SSa'nKem; mapping units 2A (site A) and 2B (site B) were classified as SLa'nKem. This indicates that the soils of the study area are quite fertile and application of soil amendments, such as Organic fertilizers would enhance cation exchange capacity; biochar application would help to prevent high leaching rate of nutrients prevalent in the area and improve the inherent soil fertility.

Key words: Fertility capability classification, soil characterization, taxonomic classification, udic moisture regime

The characteristics of any soil and its ability to supply nutrients are determined by the dominant soil forming factor in the area under consideration, land use and management (Kefas *et al.*, 2022). Soil characterization refers to the in-depth study of soil characteristics which will provide baseline information on relevant soil properties for optimum use, while preserving the soil as a natural resource for the future (Okunsebor, 2023). The ever-increasing demand for food in third world countries like Nigeria, where most land use choices are based on discretion, rather than soil characteristics, requires that information on soil characteristics be made available to the average land user. Characterization provides the necessary basic information needed to create functional soil classification schemes, and assess soil fertility in order to reveal inherent limitations to crop production (Sharu *et al.*, 2013).

Fertility capability classification (FCC) is a technical system for grouping soils according to the kinds of

problems they present for agronomic management (Adisa *et al.*, 2016). FCC-classes indicate the main fertility-related soil constraints, which can be interpreted in relation to specific farming systems or land utilization types (Sanchez *et al.*, 2003; Udoh and Ibia., 2022). Fertility capability classification studies help to identify soil constraints that limit crop production (Adisa *et al.*, 2016; Fasusi *et al.*, 2019). This system also bridges the gap between natural soil classification systems and groups soils according to the specific kinds of problems that they present for managing their chemical and physical properties in a particular location (Udoh *et al.*, 2013).

Soils of the humid tropics are known to generally possess a low fertility status as a result of high mean temperatures and rainfall intensities (Osujieke *et al.*, 2018; Oko-oboh *et al.*, 2018). Moreover, they are known to suffer multiple deficiencies of nutrients due to high intensity of land cultivation and by implication have low productivity. Through knowledge of soil characteristics and FCC classes,

farmers and land users can identify fertility, rooting and moisture limitations of land to specific crops and plan their activities to circumvent the drawbacks (Sanchez *et al.*, 2003; Orimoloye, 2016). Thus, it is crucial to understand the state of soil fertility in order to make the right recommendations for managing soil nutrients, which defines specific soil conditions that affect plant growth. Therefore, this study was conducted to characterize some soils of the study area and establish their fertility capability classes.

MATERIALS AND METHODS

The study was conducted at Iguzama Community in Ovia North East Local Government area of Edo State, Nigeria. As shown in figures 1 and 3, the study area consists of two sites; Site A is a 4 hectare land lying within Latitude 6°24'40" N and 6°24'45"N; and Longitude 5°28'25"E and 5°28'35"E. Site B is a 12 hectare land which lies within latitude 6°24'30"N and 6°25'0"N; and Longitude 5°28'30"E and 5°29'0"E. The region is distinguished by a tropical climate with an annual average rainfall amount of 1900 mm, mean annual temperatures ranging from 23°C to 37°C and mean annual relative humidity ranging from 89% in the morning (10.00 am) to 75% in the evening (4 pm), recorded over a period of 18 years (NIFOR, 2018). The soils were developed from coastal plain sand parent material, a derivative of sedimentary rock that has undergone intense weathering process arising from high rainfall and temperature (Nigeria

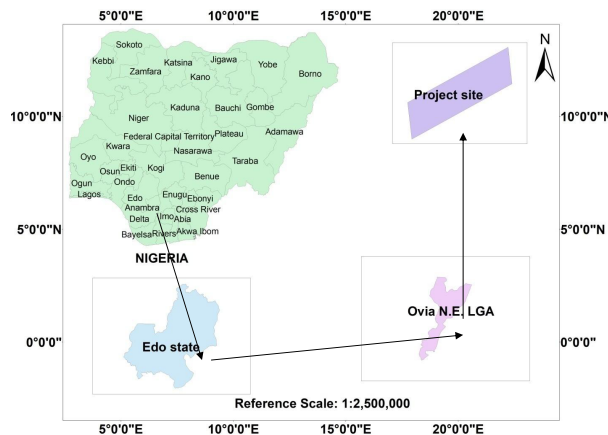


Fig. 1: Map of Site A

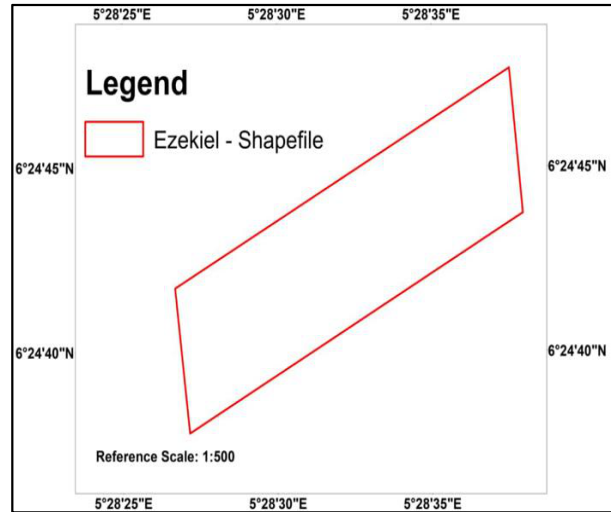


Fig.2: Shape file of Site A

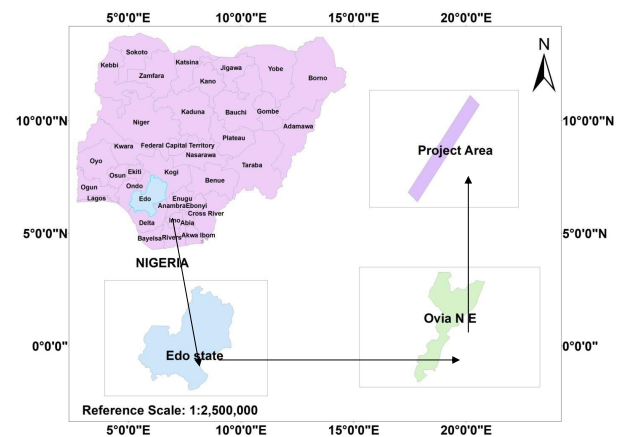


Fig. 3: Map of Site B

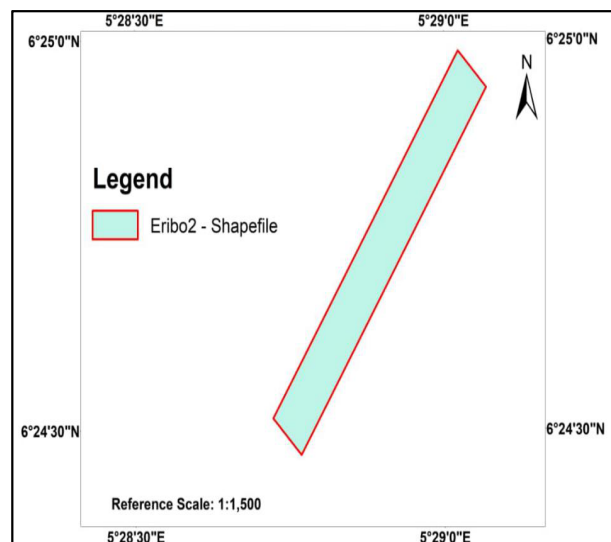


Fig.4: Shape file of Site B

Geological Survey Agency, 2008). The topography is a terrace, with a slope range of 2.59 - 6.09% in Site A; and 0.2 - 5.9% in Site B.

Field Studies

Soil survey was conducted on site A (4ha) and site B (12 ha) using the rigid grid systematic survey method at a detailed scale (Dent and Young, 1981). Traverses were cut at intervals of 100m apart; along the traverses, observation points (50 m apart for site A and 100 m apart for site B) were located using a GPS (global position system), Site A had eight observation points while Site B had twelve. Soil samples were examined at depth intervals of 30cm, 60cm, 90cm and 120cm respectively using a soil auger. The morphological properties which include texture by feel, colour, vegetation and slope position, were studied on the field and recorded on their respective proforma sheet. Mapping units were delineated based on similarities in properties and characteristics; two mapping units were delineated in each study site. Pedons measuring 2 m x 2 m x 2 m in dimension were sunk at representative points in each mapping unit, and described appropriately according to the guidelines of FAO (2006). The observed horizons were sampled from below to the top, collected in polythene bags and labeled properly for laboratory analysis.

Laboratory Analysis

The soil samples from each horizon were air-dried and passed through a 2mm sieve. The sieved samples were analysed for some physical and chemical properties. Particle size distribution was determined by the hydrometer method (Gee and Or, 2002) after the removal of organic matter content with hydrogen peroxide and dispersion with sodium hexametaphosphate (International Institute for Tropical Agriculture - IITA, 1979). Available P was determined by Bray-1 method (Olsen and Sommers, 1982). The pH was determined with glass electrode pH meter in soil: soil and water at ratio 1:1 (Maclean, 1982). Exchangeable Bases (Na, K, Ca and Mg) were extracted with neutral normal ammonium acetate (NH₄OAC at pH 7.0); Na and K were determined by flame photometer while Ca and Mg were determined by atomic absorption spectro photometer

(Thomas, 1982). Total N was determined by Macro Kjeldhal method (Bremner, 1996). Exchangeable Acidity was determined by titration method (Anderson and Ingram, 1993). Organic Carbon was determined by Walkley Black method (Page, 1982). Effective Cation Exchange Capacity (ECEC) was obtained by the summation of Exchangeable Bases and Exchangeable Acidity (Tan, 1996). Base Saturation was calculated by dividing the sum of Exchangeable Bases (Na, K, Ca and Mg) by the ECEC and multiplying the quotient by 100.

Aluminum saturation of the exchange complex was calculated using the formula

$$\% \text{Al Saturation} = \text{Al content (cmolkg}^{-1}) / \text{ECEC} * 100$$

Sodium saturation of the exchange complex was calculated using the formula

$$\% \text{Na Saturation} = \text{Na content (cmolkg}^{-1}) / \text{ECEC} * 100$$

Statistical Analysis

Data generated was analyzed statistically with Genstat (8.1 version). Variability of soil properties of horizons within the pedons was determined using coefficient of variation (cv). Coefficient of variation was ranked according to the procedure of Wilding *et al.* (1994) where:

$$\text{CV} < 15\% \quad = \text{Low Variation (LV)}$$

$$15\% \geq \text{CV} \leq 35\% \quad = \text{Moderate Variation (MV)}$$

$$\text{CV} > 35\% \quad = \text{High Variation (HV)}$$

Soil Map

Based on the field and laboratory results, a soil map was produced at a scale of 1: 1,500 for site A and 1 :< 5000 for site B.

Fertility capability classification

FCC version 4 (Sanchez *et al.*, 2003) was used to classify the soils on the basis of surface and sub-surface properties obtained from field studies and laboratory analysis.

RESULTS AND DISCUSSION

Morphological properties

Generally, the soils were deep, well drained and exhibited no sign of flooding. Soil colour varied from dark reddish brown (2.5YR3/3) to red (2.5YR4/6, 2.5YR4/8) in pedon 1A; dusky red (2.5YR5/2), dark

red (2.5YR3/6) to red (2.5YR4/6, 2.5YR4/8) in pedon 2A; very dusky red (2.5YR2.5/2), dark reddish brown (2.5YR3/4) to red (2.5YR4/6 2.5YR4/6) in pedon 1B; dusky red (2.5YR3/2) to red (2.5YR4/6, 2.5YR4/8) in pedon 2B (Munsell, 1994). The prevalence of red colour (2.5YR) in the study area could be attributed to good drainage condition and parent material of the soils; (Okunsebor and Umweni 2021; Okunsebor *et al.*, 2021). The soils had Sandy texture in Ap horizon; but ranged from Loamy Sand (pedons 1A and 2A) to Sandy Loam (pedons 2A and 1B) and Sandy Clay Loam (pedons 2A and 2B) in B horizon. The dominance of Sand fraction of particle size in all the pedons could be attributed to the nature of parent material (coastal plain sand), high rate of leaching and slope position of the soils (Osujieke *et al.*, 2018). Structure ranged from single grain crumb in Ap to fine/ Medium sub-angular blocky in B horizon. The prevalence of sub-angular blocky structure could be attributed to high rate of argilluviation in the study area. Root abundance in surface horizon was many but varied from many to very few in B horizon in all the pedons. Variation in root abundance across the soil profiles may suggest the degree of microbial activity in the soils. Boundary form ranged from smooth clear (Ap) to Smooth diffuse (B horizon) in all the pedons.

Some Physical and Chemical Properties

The physical and chemical properties of the soils (Table 2) showed that pH ranged from very strongly acidic (4.86) to slightly acidic (6.22) in pedon 1A; strongly acidic (5.18-5.26) to slightly acidic (6.14 – 6.38) in pedons 2A and 1B; and strongly acidic (5.26) to moderately acidic in pedon 2B according to the ratings of Chude *et al.*(2011), with mean values of 5.24, 5.58, 5.53 and 5.40 in pedons 1A, 2A, 1B and 2B respectively. The acidic pH of these soils could be attributed to the acidic nature of the parent material (coastal plain sands) from which the soils were derived, organic matter content of the soils, climatic condition of the study area and slope position (Weil and Brady, 2017; Abua, 2010; Osujieke *et al.*, 2018). Generally, organic carbon had high variation ($\geq 59.70\%$ to $\leq 110.10\%$) in all the pedons. This buttresses the fact that acid sands are low in organic matter content; the amount of plant

litter fall and differences in soil biodiversity across the mapping units could be responsible for high variability of Organic matter in soils. Total Nitrogen was deficient in all the pedons according to the rating of Chude *et al.* (2011), with means values of 0.66, 0.48, 0.40 and 0.58 gkg^{-1} in pedons 1A 2A, 1B and 2B respectively; variation was high ($\geq 58.60\%$ to $\leq 113.00\%$) in all the pedons. Low total Nitrogen may be attributed to crop harvest, bush and residue burning which increases the rate of volatilization of Nitrogen (Osujieke *et al.*, 2018).

Available Phosphorous ranged from 1.72 – 44.47 mgkg^{-1} in pedon 1A, 1.30-13.14 mgkg^{-1} in pedon 2A, 2.46 – 5.61 mgkg^{-1} in pedon 1B and 1.72 – 6.48 mgkg^{-1} in pedon 2B; which indicates that Phosphorus

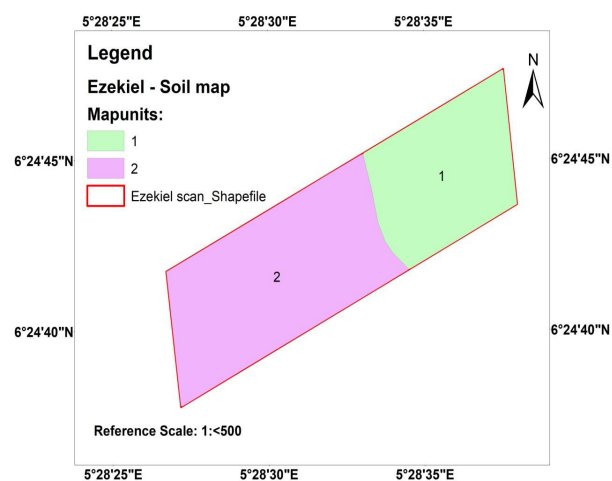


Fig. 5: Soil Map for Site A

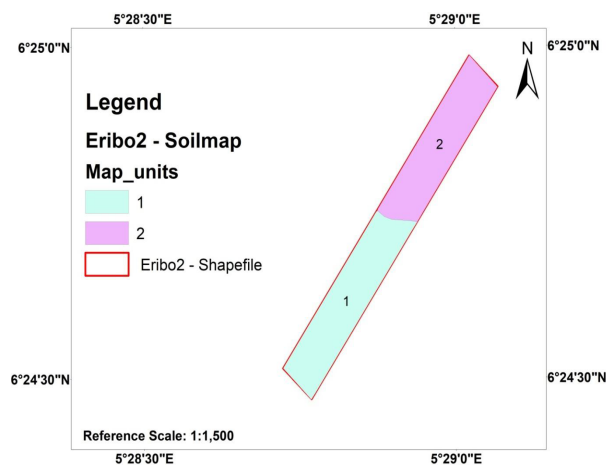


Fig. 6: Soil Map for Site B

Table 1: Some Morphological Properties of the Study Area

Pedon	Horizon	Desig.	Depth (cm)	Colour (moist)	Texture	Roots Abundance	Structure	Boundary form
SITE A								
1A	Ap		0-13	2.5YR3/3	Sand	Fine many	Very fine Single grain crumb	Smooth-Clear
	AB		13-33	2.5YR4/8	Loamy Sand	Medium many	Fine/Medium Sub-Angular blocky	Smooth-Diffuse
	BA		33-69	2.5YR4/6	Sandy Loam	Coarse very few	Medium Sub-Angular blocky	Smooth-Diffuse
	B1		69-121	2.5YR4/6	Sandy Clay Loam	Fine very few	Medium Sub-Angular blocky	Smooth-Clear
2A	B2		121-180	2.5YR4/6	Sandy Clay Loam	Fine very few	Medium Sub-Angular blocky	-
	Ap		0-15	2.5YR3/2	Sand	Fine many	fine Single grain crumb	Smooth-Clear
	Bt1		15-39	2.5YR3/6	Sandy Loam	Fine/Medium many	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt2		39-76	2.5YR4/6	Sandy Clay Loam	Coarse few	Fine Sub-Angular blocky	Smooth-Diffuse
1B	Bt3		76-127	2.5YR4/8	Sandy Clay	Medium very few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bt4		127-169	2.5YR4/8	Sandy Clay	-	Medium Sub-Angular blocky	-
	Ap		0-11	2.5YR2.5/2	Sand	Medium many	fine Single grain crumb	Smooth-Clear
	Bw1		11-27	2.5YR3/4	Loamy Sand	Medium many	Fine Sub-Angular blocky	Smooth-Diffuse
2B	Bw2		27-59	2.5YR4/6	Loamy Sand	Medium few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bw3		59-101	2.5YR4/6	Sandy Clay Loam	Medium very few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bw4		101-175	2.5YR4/8	Sandy Clay Loam	-	Medium Sub-Angular blocky	-
	Ap		0-17	2.5YR3/2	Loamy Sand	Medium many	Very fine Single grain crumb	Smooth-Clear
2B	Bt1		17-34	2.5YR4/8	Sandy Clay Loam	Medium many	Fine Sub-Angular blocky	Smooth-Diffuse
	Bt2		34-78	2.5YR4/6	Sandy Clay Loam	Medium few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bt3		78-116	2.5YR4/6	Sandy Clay Loam	Fine few	Medium Sub-Angular blocky	Smooth-Diffuse
	Bt4		116-183	2.5YR4/6	Sandy Clay	Fine very few	Medium Sub-Angular blocky	-

was very low to high in pedon 1A, ranged from very low to moderate in pedon 2A; very low to low in pedons 1B and 2B according to the ratings of Chude *et al.* (2011), Landon (1991). Variation for available P was high ($\geq 40.90\%$ to $\leq 156.20\%$) in all the pedons; high variation of available P could be as a result of erosion of soil particles due to surface run-off water, removal of biomass through harvest and fixation.

Results for exchangeable bases revealed that Calcium (Ca) was the predominant basic cation in the soils of the study area. Ca content ranged from 0.36 – 2.58 cmolkg⁻¹; Mg content ranged from 0.08 – 0.50 cmolkg⁻¹; Na content ranged from 0.10 – 0.43 cmolkg⁻¹; K content ranged from 0.01 – 0.29 cmolkg⁻¹ in all the pedons. Exchangeable bases were generally low in all the pedons according to the rating of Landon (1991) and Chude *et al.* (2011). Variation for Ca ($\geq 63.50\%$ to $\leq 97.40\%$) and K ($\geq 56\%$ to $\leq 142\%$) was high in all the pedons; variation for Mg was moderate in pedon 1B but high in other pedons ($\geq 19.80\%$ to $\leq 68.40\%$); variation for Na was moderate in pedons 1A and 1B, but high in pedons 2A and 2B ($\geq 26.10\%$ to $\leq 47.50\%$). Low content of exchangeable bases in the study area could be attributed to the parent material of the soils (coastal plain sands) and the high rainfall amount prevalent in the study area (Eze, 2015). It was also observed that exchangeable bases had an irregular trend with increase in depth; this could be as a result of translocation of materials down the profile.

Results for Exchangeable acidity (Table 2) showed that values for Hydrogen ranged from 0.04 - 0.26 cmolkg⁻¹ in all the pedons, with variation ranging from Moderate ($\geq 23.50\%$ to $\leq 34.10\%$) in pedons 1A, 2A and 2B, to high (45.05%) in pedon 1B. Aluminum had values ranging from 0.00 - 1.2 cmolkg⁻¹ in all the pedons. Variation for Al was high (≥ 51.89 to $\leq 59.40\%$) in all the pedons. Cation Exchange Capacity (CEC) had values ranging

Table 2: Some Physical and Chemical Properties of the Soils

Pedon ID	Horizon Design	Horizon Depth (cm)	Ph H ₂ O	EC μS/cm	Org. C g kg ⁻¹	Org. N g kg ⁻¹	Total Avail. matter N g kg ⁻¹	P mg kg ⁻¹	Ca mg kg ⁻¹	Mg mg kg ⁻¹	Na mg kg ⁻¹	K mg kg ⁻¹	H cmol kg ⁻¹	AI cmol kg ⁻¹	ECEC	CEC	ECEC/CLAY %	BS-CEC %	SAND	SILT	CLAY	TC	
																							MV
06.41313°N, 005.47692°E; 49 m ASL																							
1A	Ap	0-13	6.22	109.70	23.13	39.87	1.93	44.47	2.58	0.38	0.34	0.19	0.1	0.00	3.58	9.40	119.33	97.21	37.00	960.00	10.00	30.00	S
	AB	13-33	5.1	70.00	7.98	13.76	0.66	7.18	0.60	0.15	0.19	0.08	0.24	1.06	2.33	3.60	38.83	44.09	28.61	920.00	20.00	60.00	S
	BA	33-69	4.86	95.70	4.23	7.30	0.35	3.05	0.43	0.23	0.19	0.05	0.26	1.20	2.35	6.02	26.11	37.93	14.78	870.00	40.00	90.00	S
	B1	69-121	5.02	46.30	3.09	5.33	0.24	2.46	0.55	0.08	0.24	0.07	0.18	0.92	2.03	7.07	16.91	45.87	13.15	850.00	30.00	120.00	LS
	B2	121-180	5.02	65.10	1.30	2.25	0.10	1.72	0.55	0.08	0.29	0.17	0.16	0.82	2.06	7.45	14.71	52.52	14.49	830.00	30.00	140.00	LS
	MEAN		5.24	77.36	7.90	13.70	0.66	11.80	0.94	0.18	0.25	0.11	0.19	0.80	2.47	6.71	43.00	56.00	21.6	886.00	26.00	88.00	
	CV		10.50	32.60	111.20	111.10	113.00	156.20	97.40	68.40	26.10	56.60	34.10	58.70	25.80	21.30	101.00	43.00	49.20	6.00	43.90	50.40	
06.41168°N, 005.47450°E; 60 m ASL																							
2A	Ap	0-15	6.14	97.80	14.01	24.15	1.17	13.14	1.70	0.25	0.43	0.29	0.1	0.00	2.78	6.40	86.88	75.68	41.87	924.00	44.00	32.00	S
	Bt1	15-39	5.5	46.20	5.86	10.11	0.49	2.63	0.60	0.10	0.24	0.11	0.18	0.86	2.09	10.00	13.06	89.32	10.50	800.00	40.00	160.00	SL
	Bt2	39-76	5.34	34.80	3.58	6.18	0.30	1.30	0.50	0.10	0.14	0.02	0.18	1.00	1.94	10.74	10.21	84.22	7.08	790.00	20.00	190.00	SL
	Bt3	76-127	5.26	32.50	2.93	5.05	0.24	1.80	0.40	0.15	0.19	0.01	0.2	1.00	1.95	13.01	8.13	75.66	5.76	700.00	20.00	240.00	SCL
	Bt4	127-169	5.66	25.50	2.44	4.21	0.19	2.38	0.97	0.18	0.19	0.01	0.16	0.70	2.21	16.34	7.13	61.09	8.26	680.00	10.00	310.00	SCL
	MEAN		5.58	47.00	5.80	9.90	0.48	4.20	0.83	0.16	0.24	0.09	0.16	0.71	2.19	11.30	25.00	77.20	14.7	787.00	26.80	186.00	
	CV		6.20	61.60	833.10	83.10	84.40	117.60	63.50	40.20	47.50	136.90	23.50	58.50	15.80	32.60	138.00	13.90	103.9	11.50	54.20	55.40	
06.41097°N, 005.47964°E; 58m ASL																							
1B	Ap	0-11	6.38	61.90	9.12	15.72	0.76	5.61	1.60	0.20	0.24	0.08	0.04	0.08	2.24	7.14	28.00	94.64	29.70	900.00	20.00	80.00	S
	Bw1	11-27	5.58	47.70	5.86	10.11	0.49	2.55	0.75	0.30	0.14	0.03	0.16	0.52	1.90	8.00	15.83	64.25	15.25	860.00	20.00	120.00	LS
	Bw2	27-59	5.26	41.20	4.15	7.16	0.35	3.05	0.46	0.19	0.19	0.02	0.19	1.10	2.16	8.43	15.43	40.14	10.32	850.00	20.00	140.00	LS
	Bw3	59-101	5.18	39.10	3.09	5.33	0.26	2.63	0.42	0.28	0.10	0.02	0.23	1.00	2.04	10.32	11.03	39.79	7.85	800.00	15.00	185.00	SL
	Bw4	101-175	5.26	33.80	1.71	2.95	0.15	2.46	0.50	0.25	0.19	0.01	0.16	1.12	2.23	10.09	11.74	42.71	9.42	800.00	10.00	190.00	SL
	MEAN		5.53	44.70	4.80	8.30	0.40	3.26	0.75	0.24	0.17	0.03	0.16	0.76	2.11	8.80	16.40	56.00	14.5	842.00	15.00	143.00	
	CV		9.00	24.20	59.70	58.60	40.90	66.30	19.80	31.10	86.70	45.50	59.40	59.40	6.80	15.50	41.60	42.10	61.50	5.10	33.30	32.20	
06.41547°N, 005.48365°E; 96 m ASL																							
2B	Ap	0-17	5.82	63.20	19.22	33.13	1.64	6.48	1.50	0.50	0.24	0.12	0.08	0.10	2.54	10.13	36.28	92.92	23.30	900.00	30.00	70.00	S
	Bt1	17-34	5.26	36.50	5.70	9.83	0.47	2.71	0.46	0.19	0.10	0.02	0.22	0.98	1.96	8.47	15.08	38.87	8.97	850.00	20.00	130.00	SL
	Bt2	34-78	5.34	34.30	4.23	7.30	0.35	5.00	0.43	0.27	0.10	0.01	0.19	1.11	2.10	11.46	10.50	38.16	6.98	790.00	10.00	200.00	SCL
	Bt3	78-116	5.26	32.00	3.09	5.33	0.26	2.71	0.42	0.18	0.10	0.01	0.17	1.25	2.12	12.56	9.22	33.08	5.57	760.00	10.00	230.00	SCL
	Bt4	116-183	5.34	29.10	2.04	3.51	0.17	1.72	0.36	0.19	0.14	0.01	0.19	0.90	1.79	16.70	5.59	39.12	4.19	660.00	20.00	320.00	SCL
	MEAN		5.40	39.00	6.90	11.80	0.58	3.72	0.63	0.27	0.14	0.03	0.17	0.87	2.10	11.90	15.30	48.00	9.80	792.00	18.00	190.00	
	CV		4.40	35.30	102.70	102.70	104.50	52.50	76.60	51.00	44.60	142.00	31.40	51.80	13.20	26.20	79.50	51.60	78.80	11.60	46.50	50.30	
RANKING																							
			LV	MV	HV	HV	HV	HV	HV	HV	HV	HV	HV	HV	LV	MV	HV	LV	LV	LV	HV	HV	

from 3.60 - 16.70 cmolkg⁻¹ in all the pedons. Variation was moderate ($\geq 15.50\%$ $\leq 32.60\%$) in all the pedons. Effective Cation Exchange Capacity (ECEC) ranged from 1.39 - 3.58 cmolkg⁻¹ in all the pedons; and was below the critical value (12 cmolkg⁻¹) regarded to be suitable for crop production (Ekong and Uduak, 2015). Variation for ECEC ranged from low (≥ 6.80 to $\leq 25.80\%$) to moderate (15.80 to 25.80%).

Sand fraction was highest among particle size components, with mean values of 886, 787, 842 and 792 gkg⁻¹ respectively for all the pedons. Variation was low ($\geq 5.10\%$ to $\leq 11.60\%$), which could be as a result of homogeneity of parent material (coastal plain sand) in the study area (Osujieke, *et al.*, 2018; Okunsebor and Umweni, 2021). Silt fraction had means of 26, 26, 15 and 18 gkg⁻¹ respectively for all the pedons; the low silt content suggests high rate of eluviation in the study area; variation ranged from Moderate (33.30% - pedon 1B) to high ($\geq 43.90\%$ to $\leq 54.20\%$ - pedons 1A, 1B and 2B). Clay fraction had means ranging from (≥ 88.00 to ≤ 190.00 gkg⁻¹). Clay content increased with depth, which suggests the presence of an argillic / Cambic horizons in some of the pedons. Higher clay content in subsurface soils confirms active pedogenesis and argilluviation in the study area. Variation of clay ranged from moderate (32.20% - pedon 1B) to high (≥ 50.30 to $\leq 55.40\%$).

Taxonomic classification

Taxonomic Classification of the soils was according USDA Soil Taxonomy (Soil Survey Staff, 2014). The pedons were designated as 1A, 2A, 1B and 2B. Generally, the study area is characterized by an udic moisture regime and an isohyperthermic soil temperature regime. Pedons 2A and 2B had argillic horizon and a Base saturation value less than 35% at the appropriate depth, thus, they qualified as the order Ultisols; the presence of cambic B horizon in pedon 1B qualified the pedon as the order Inceptisols. However, Pedon 1A did not exhibit any genetic horizon nor morphological feature except colour; therefore, it was classified as Entisols.

At sub-order level, pedons 2A and 2B were classified as adults because of the presence an udic moisture

regime. At great group level, they qualified as Kandiuults, because of the presence of a kandic horizon at the appropriate depth in both pedons. They were classified as Rhodic kandiuults at subgroup level because they had a hue of 2.5YR.

Pedon 1A qualified as Psamments at the sub-order level because it had less than 35% (by volume) rock fragments and texture of Sand – Loamy sand in all the layers. At great group level, pedon 1A was classified as Udipsamments due to the presence of an udic moisture regime in the study area; and Typic Udipsamments at subgroup level, which indicates that there is no lithic contact, redox depletion, plaggan epipedon, and the pedon is not saturated with water. The soil classification results are in line with findings of Okunsebor and Umweni, (2021).

Fertility Capability Classification for Soils of the Study Area

Fertility Capability Classification (FCC) of the soils was according to the version IV (Sanchez, *et al.*, 2003). Pedons 1A (1.65 ha and 34% of site A) and 1B (6.4 ha and 53.3% of site B) were classified as SSaⁿkem; this implies that the pedons (1A and 1B) had Sandy texture in both top soil (within the top 0-20cm of the soil) and sub-strata (within 50cm). Pedons 2A (2.64 ha; 66% of site A) and 2B (5.69 ha; 47.4%) were classified as SLaⁿkem, indicating that the pedons had Sandy top soil (S) but Loamy (L) sub-strata.

Generally, fertility capability classification provides information on soil constraints that limit crop production (Moundjeu *et al.*, 2021). All the pedons had constraints of Aluminum toxicity (a⁻), because Al saturation of ECEC in the top 50 cm of the soil was within 10 - 60%. Al toxicity of the soils could be attributed to the high rate of leaching associated with the soils of rain forest zone (Osujieke, *et al.*,

Table 3: Summary of Taxonomic Classification

Pedon	USDA Soil Taxonomy	Size (ha)
1A	Typic Udipsamments	1.65ha
2A	Rhodic kandiuults	2.64ha
1B	Typic Dystrudepts	6.4ha
2B	Rhodic kandiuults	5.69ha

Table 4: Summary of Fertility Capability classification for all the Pedons

Land characteristics	Pedon 1A	Pedon 2A	Pedon 1B	Pedon 2B
Type; Texture for top soil	S	S	S	S
Substrata type	S	L	S	L
Condition	Modifier			
<i>Modifier related to soil physical properties</i>				
Slope	2.59- 6.09%	0.79 - 2.6%	0.2 - 2.1%	2-5.9%
<i>Modifier related to soil reaction/Altoxicity</i>				
Alkalinity	a ⁻	a ⁻	a ⁻	a ⁻
<i>Modifier related to soil mineralogy</i>				
Low nutrient capital reserve (Potassium deficiency)	K	K	K	K
High leaching potential (low buffering capacity, low ECEC)	e	e	e	E
<i>Modifier related to biological properties</i>				
Low soil organic carbon saturation	m	M	M	M
FCC CLASS/UNIT	SSa ⁿ Kem	SLa ⁿ Kem	SLa ⁿ Kem	SLa ⁿ Kem
Area extent of land	1.65ha	2.64ha	6.4ha	5.69ha
%Coverage	34%	66%	53.3%	47.4%

Fertility Capability Soil Classification System (Version IV)

FCC class and short description	Symbol	Definition and Interpretations
Type:	S	Sandy topsoil >35% sand, loamy sands and sands
Texture is the average of plow layer 0-20cm depth or which is shallower	L	Loamy topsoil <35% clay but not loamy sand or sand
	C	Clayey topsoil >35% clay
	O	organic soil >12% organic C to a depth of 50 cm or more (histosol and histic group)
Subtype: used if textural change is encountered within 50cm	S	Sandy Subsoil - texture as in type
	L	Loamy subsoil - texture as in type
	C	Clayey subsoil - texture as in type
	R	Rock or other hard root restrictions layer within 50cm
	R ⁻	As in above, but layer can be plowed to increase rooting depth

Condition modifiers: in plowed layer or top 20 cm, whichever is shallower, unless otherwise specified; grouped into modifiers related to soil physical properties, soil reaction (pH), soil mineralogy and soil biological properties.

Condition	Modifier	Identifying criteria (if more than one, they are listed in decreasing desirability)
<i>Modifiers related to soil physical properties</i>		
Waterlogging (gley): anaerobic condition, chemical reduction, denitrification; N ₂ O and CH ₄ emissions	G g ⁺	aquic soil moisture regime, mottles <2 chroma within 50 cm for surface and below all A horizon or soil saturated with water for >60 days in most years prolonged waterlogging: soil saturated with water either naturally or by irrigation for >200 days/year with no evidence of mottles indicative of Fe ³⁺ compounds in the top 50 cm; includes paddy rice soils in which an anaerobic crop cannot be grown without drainage; continuous chemical reduction can result in slower soil N mineralization and Zn deficient in rice
Strong dry season (dry): limits year-round cropping, interrupts pest cycles. Birch effect	D d ⁺	ustic or xeric soil moisture regime dry >60 consecutive days/year but moist >180 cumulative days/year within 20-60 cm depth aridic or torric soil moisture regime; too dry to grow a crop without irrigation
Low soil temperatures	T	cryic and frigid (<8°C mean annual), non-iso soil temperature regimes, where management practices can help warm top soils for short-term cereal production

<i>Modifier related to soil physical properties</i> Gravel	t ⁺	permafrost within 50 cm gelsols; no cropping possible
	r ⁺	r ⁺ = 10-35%
	r ⁺⁺	r ⁺⁺ > 35% (by volume) of gravel size coarse fragments (2 - 25
	r ⁺⁺⁺	cm in diameter) anywhere in the top 50 cm of the soil more than 15% rock outcroppings
Slope	%	where desirable place range in % slope (i.e., 0 - 15%; 15 - 30%; >30%)
High risk erosion	SC, LC CR, LR, SR, >30% C	soils with high erodibility due to sharp textural contrasts (SC, LC), shallow depth (R) or steep (>30%) slope pH < 3.5 after drying; jarosite mottles with hues, 2.5Y or yellower and chromas 6 or more within 60 cm sulfaquents, sulfaquepts, sulfudepts.
Aluminum toxicity for most common crops	a	>60% Al saturation within 50 cm, or < 33% base saturation of CEC (BS ₇) determined by sum of cations at pH 7 within 50 cm, or < 14% base saturation of CEC (BS _{8.2}) by sum of cations at pH 8.2 within 50 cm, or pH < 5.5 except in organic soils (O)
No major chemical limitations (includes former <i>h</i> modifier) Calcareous (basic reaction): common Fe and Zn deficiencies Salinity	a ⁻	10 - 60% Al saturation within 50 cm for extremely acid-sensitive crops such as cotton and alfalfa
	no symbol	< 60% Al saturation of ECEC within 50 cm and pH between 5.5 and 7.2
Alkalinity	B	free CaCO ₃ within 50 cm (fizzing with HCl), or pH > 7.3
	S	>0.4 S m ⁻¹ of saturated extract at 25°C within 1 m; salids and salic groups; salonchaks
	s ⁻	0.2 - 0.4 S m ⁻¹ of saturated extract at 25°C within 1 m (incipient salinity)
<i>Modifiers related to soil mineralogy</i> Low nutrient capital reserves (K deficiencies)	N	>15% Na saturation of ECEC within most solonch
	n ⁻	6 - 15% Na saturation of ECEC within 50 cm (incipient alkalinity)
High P fixation by Fe and Al oxides (>100 mg kg ⁻¹ P added to achieve adequate soil test levels); Ci soils have excellent structures but low water holding capacity <i>Modifier related to soil mineralogy</i>	K	< 10% weatherable minerals in silt and sand fraction within 50 cm, or siliceous, mineralogy or exchangeable K < 0.20 cmolc kg ⁻¹ soil, or exchangeable K < 2% of sum of base, if sum of bases is < 10 cmolc kg ⁻¹ soil
	I	dithionite-extractable free R ₂ O ₃ : clay ratio >0.2 or >4% citrate dithionite-extractable Fe in of topsoil, or oxisols and granular structure
Amorphous volcanic (X-ray amorphous); high P fixation by allophane (>200 mg kg ⁻¹ P added to achieve adequate soil test levels); low N mineralization rates	i ⁻	as above, but soils have been recapitalized with P fertilizers to supply long-term P to crop soil test >10 mg kg ⁻¹ P by Olsen method
	i ⁺	as above; potential Fe toxicity if soils waterlogged for long time (g ⁺) or adjacent uplands have i modifier
Cracking clays (vertic properties): (low buffering capacity, low ECEC)	x	within 50 cm pH > 10 (in 1 M NaF), or positive to field NaF test, or andisols and andic subgroup, except vitrands and vitric great groups and subgroups; other indirect evidences of allophane dominance in the clay size fraction or >90% P retention (Blakemore <i>et al.</i> , 1981 method)
	x ⁻	P retention between 30% and 90%; medium P fixers
<i>Modifier related to soil biological properties (new)</i> Low organic carbon saturation (soil organic matter depletion, C sequestration potential)	e	< 4 cmolc kg ⁻¹ soil as ECEC, or < 7 cmolc kg ⁻¹ soil by sum of cations at pH 7, or < 10 cmolc kg ⁻¹ soil by sum cations + Al ₃ ⁺ + H ⁺ at pH 8.2
	M	< 80% total organic C saturation in the topsoil (Van Noordwijk <i>et al.</i> , 1998) compared with a nearby undisturbed or productive site the same soil, which is equal to 100% or < 80% KMnO ₄ extractable topsoil organic carbon saturation (Blair <i>et al.</i> , 1997) compared with a nearby undisturbed or productive site of the same soil, which is equal to 100%

2018). It was observed that sodium saturation of ECEC in the top 50 cm of the soils fell within the range of 6 - 15%, indicating that the soils had limitations in Alkalinity (n), although this condition is rare in the rain forest zone, application of sodium based fertilizers in the study area over time may be responsible. The soils had low nutrient reserve (k), as expressed by the low values of exchangeable bases, especially exchangeable K ($0.08 - 0.19 \text{ cmolkg}^{-1}$) $< 0.20 \text{ cmolkg}^{-1}$. The soils had high leaching potential as revealed by low values of ECEC ($< 4 \text{ cmolkg}^{-1}$); soils of rain forest zone are low in soil nutrient reserve as a result of the high rainfall amount in this zone, thus resulting to high rate of leaching. Total Organic Carbon saturation was less than 80% in the soils, indicating that organic matter content was low (e). Acid sands are generally low in organic matter content and exchangeable bases (Okunsebor and Umweni, 2021).

Fertility Capability classification assesses the land on a general basis, however, information obtained from such assessment (fertility capability classes) provides insight on the native fertility status of soils and serves as a guide to fertilizer application and use.

CONCLUSION

Fertility limitations of the soils were assessed using Fertility Capability Classification (FCC). The study revealed that the agronomic constraints of the soils were sandy topsoil (S), slightly alkaline (potentially sodic), low nutrient reserve, high leaching potential and low organic carbon content and thus low organic matter content. These constraints could be managed by application of adding organic matter (soil amendment). Biochar can also be used to solve the problem of leaching of nutrients prevalent in the area to improve the inherent soil fertility.

REFERENCES

- Abua, M. A., Offiong, R. A., Iwara, A. I. and Ibor, U. W. (2010). Impact of newly constructed roads on adjoining soil properties in Tinapa Resort, South-Eastern Nigeria. *Annals of Humanities and Development Studies*, 1(1):176 - 184
- Adisa, K. F., Ojetade, J.O., Muda, S.A. and Amusan, A.A. (2016). Characterization and fertility capability classification of the soils of Shasha River floodplain, Osun state, Nigeria. *Ife Journal of Agriculture*, 28(1): 20-34
- Anderson, F and Ingram, I. (1993). *Tropical Soil Biology and Fertility: A Handbook of Methods* (2nd ed.). CAP International, 221p
- Brady, N. C. and Weil, R. R. (2017). *The Nature and Properties of Soils*. 15th Edition. Prentice Hall, Inco Publishers New Jersey, USA, 881 p.
- Bremner, J. M. (1996). Nitrogen-Total. In D. L. Sparks (Ed.), *Methods of Soil Analysis. Part 5, Chemical Methods* (2nd ed., SSSA Book Series No. 5, Pp. 1085-1125). SSSA. Madison, WI.
- Chude, V. O., Olayiwola, S. O., Osho, A. O. and Daudu, C. K. (2011). *Fertilizer Use and Management Practices for Crops in Nigeria* (4th edition). Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja, Pp 12 – 43.
- Dent, D and Young, A. (1981). *Soil Survey and Land Evaluation*. A standard handbook on soil survey and land evaluation
- Ekong, U. J. and Uduak, I. G. (2015). Fertility status of soils at the teaching and Research farm of Awkwalbom State university, ObioAkpa campus, South – East Nigeria. *International Journal of Science and Research*, 4(11):1434 – 1438.
- Eze, P. N. (2015). Spatial Variability and Classification of Soils on a Legon Hill Catena in the Accra Plains, Ghana. *Journal of Soil Science and Environmental Management*, 6(8): 204 – 214
- Fasusi, O. M., Amusan, A. A., Ojetade, J. O., and Muda, S. A. (2019). Fertility Capability Classification of Soils of Ogbese River Flood Plain, Southwest Nigeria. *Ife Journal of Agriculture*, 31(1): 75 – 90
- FAO (Food and Agriculture Organization) (2006). Guidelines for Soil Profile Description (5th edition). *AGLS, FAO Rome Soils Bull.*

- Gee, G. W and Or, G. (2002). Particle size. In J. H. Dane and G. C. Topp (Eds.), *Methods of Soil Analysis Part 4. Physical Methods*. Soil Science Society of America. Madison, WI. Book Series No. 5. ASA and SSSA, 225-293pp.
- IITA (1979). *International Institute for Tropical Agriculture. Selected Methods for Soil and Plant Analysis* (3rd ed., December). IITA, Ibadan, 34p.
- Kefas, P. K., Maniyunda, L. M., Shobayo, A. B., Garjila, Y. A., Philip, H. J. and Christopher, A. (2022). Fertility Capability Classification of Selected Soils on Basement complex of North – Eastern Nigeria. *Agro – Science*, 21(3):94 – 100.
- Landon, J. R. (Ed) (1991). *Booker Tropical soil manual: A hand book for soil survey and Agricultural Land Evaluation in the tropics and subtropics*. Longman Scientific and Technical, Essex, New York, 474 p.
- Maclean, E. O. (1982). *Soil pH and Lime Requirement*. In: Page, A. L. Ed., *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*, American Society of Agronomy, Soil Science Society of America, Madison, 199-224
- Moundjeu, E. D., Temgoua, E., Tamfuh, P. A., Vounang, J. G., Kabiwa, J. P. Y., Wouatong, A. S. L., and Bitom, D. (2021). Characteristics, Fertility Status and Fertility Capability Classification of Steep Slope Soils of the Dschang Cliff (Cameroon Western Highlands). *Journal of Geoscience and Environmental Protection*, 9:164 – 179.
- Munsell (1994). *Munsell colour charts*. Macbeth division of Kollmorgen instruments Corporation, New Windsor, New York, USA.
- Nigerian Institute for Oil Palm Research (NIFOR) (2018). *Weather data (Temperature, Rainfall, Relative Humidity): 1993-2018*. Nigerian Institute for Oil Palm Research Main Station, Benin-City, Nigeria.
- Nigeria Geological Survey Agency. (2008). *Regional and Geology Series, First Edition*
- Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In A. L. Page, R. H. Miller and D. R. Keeney (Eds.), *Methods of Analysis Part 2*. American Society of Agronomy. Madison, Wisconsin, Pp. 15-72.
- Okunsebor, F. E and Umweni, A. S. (2021). Soil mapping, classification, and morphological characteristics of the University of Benin land. *Nigerian Journal of Soil Science*, 31(2):32-40. <https://doi.org/10.36265/njss.2021.310205>
- Okunsebor, F. E, Umweni, A. S. and Agbogun, L. (2021). Land suitability evaluation for pawpaw (*Carica papaya*) and Plantain (*Musa parasidiaca*) cultivation in Iguzama community of Edo state, Nigeria. *The Nigerian Journal of Agriculture and Forestry*, 8(1):103 – 116.
- Okunsebor, F. E., (2023). Characterization of soils in Esan North East Local Government Area in Edo State, Nigeria. A Ph.D Thesis submitted to the school of postgraduate studies, University of Benin, Benin City, Nigeria, 290 p.
- Orimoloye, J. R. (2016). Fertility capability classification of some flood plain soils in Kogi State, Central Nigeria. *Life Science Journal*, 13(1): 48 – 55.
- Osujieke, D. N., Obasi, N. S., Imadojemu, P. E. Ekawa, M. and Angyu, M. D. (2018). Characterization and Classification of soils of Jalingo Metropolis, North-East, Nigeria. *Nigerian Journal of Soil Science*, 28(2): 72-80.
- Page, A. L., Miller, R. M and Kenny, D. R. (1982). *Methods of Soil Analysis. No 9, Part 2: Chemical and Microbial Properties*. American Society of Agronomy. Madison, WI, USA.
- Sanchez, P.A., Palma, C.A. and Buol, S.W. (2003). Fertility Capability Classification: A Tool to Assess Soil Quality in the Tropics. *Geoderma*, 114: 157-185.
- Sharu, M. B., Yakubu, M., Noma, S. S. and Tsafe, A. I. (2013). Characterization and Classification of Soils on an Agricultural Landscape in Dingyadi District, Sokoto State, Nigeria. *Nigerian Journal of Basic and*

- Applied Science, 21(2): 137 – 147.
- Soil Survey Staff (2014). *United States Department of Agriculture Keys to Soil Taxonomy 12th Edition*. Natural Resources Conservation Service, U.S. Department of Agriculture, Washington, D.C.
- Tan, K. H. (1996). *Soil Sampling, Preparation and Analysis*. Marcel Dekker Inc., 270 Madison Avenue, New York, NY 10016.
- Thomas, G. W. (1982). Exchangeable Cation. In A. L. Page *et al.* (Eds.), *Methods of Soil Analysis. Part 2, Agronomy Monograph, 9* (2nd ed., Pp. 159-165). ASA AND SSSA, Madison, Wisconsin.
- Udoh, B. T., Ogunkunle, A. O., and Akpan, U. S. (2013). Fertility Capability Classification of Acid Sands (Soils) as Influenced by Parent Materials In Akwa-Ibom State. *Nigerian Journal of Soil Science*, 23(1): 56 – 66.
- Udoh, B. T. and Ibia, T. O. (2022). Fertility Capability Classification for Agricultural Land Use Planning in the Beach Sand Area of Akwa – Ibom State, Nigeria. *Nigerian Journal of Tropical Agriculture, Food, Environment and Extension*, 12(2): 74 - 78
- Weil, R. R. and Brady, N. C. (2017). *The Nature and Properties of Soils*. 15th Edition, Pearson, New York.
- Wilding, L. P., Bouma, J. and Boss, D. W. (1994). *Impact of spatial variability on interpretative modelling*. In: Quantitative modelling of soil forming processes. Byrant, R. B. and Arnold, R. W. SSA Special publication. No., 39:61.

Received: January 10, 2024

Accepted: April 06, 2024