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AMELIORATIVE ACTIVITIES OF *Vernonia amygdalina* Delile METHANOLIC LEAF EXTRACT IN ALLOXAN-INDUCED DIABETIC WISTAR RATS

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ABSTRACT

There is an increasing prevalence of diabetes mellitus (DM) in Africa. It is estimated that by 2030, people living with this condition would increase to 33 million in the African region alone. This study evaluated the ameliorative effects of *Vernonia amygdalina* on alloxan-induced diabetes mellitus in male rats. Thirty adult male rats were randomly assigned into five groups (n=6). Diabetes mellitus was induced in animals allotted to groups A-D. Groups A and B were treated with 100 and 200 mg/kg of *V. amygdalina* extract while C and D were treated with 5mg/kg glibenclamide and 10 mg/kg propylene glycol respectively. Group E (non-diabetic control) was treated with 10 mg/kg propylene glycol. All treatments were administered orally once daily for 21 days. Blood samples were obtained from the tail of the rats daily on days 1 – 7, days 14 and 21 for determination of fasting blood glucose using a glucometer. On day 21, five milliliters of blood was collected for haematology and serum biochemistry. Tissues were harvested for histopathology. There was a significant loss in weight in extract-treated groups. Similarly, blood glucose concentration was significantly lower ($p \leq 0.05$) in group B than in D. Haematology and protein profile values across the groups showed no significant difference ($p > 0.05$). Low-density lipoprotein was higher significantly ($p \leq 0.05$) in group B than in group C. The cytoarchitecture of pancreatic islets and kidneys was maintained in the extract-treated groups in contrast to group C. *V. amygdalina* leaves extract possess anti-diabetic potential.

Keyword: Diabetes, *Vernonia amygdalina*, Haematology, Histopathology, Ameliorative

DOI:

INTRODUCTION

Diabetes mellitus (DM) is fast becoming a threat to global health because of its increasingly high prevalence. According to WHO (2021), persons with DM rose from 108 million in 1980 to 422 million in 2014. In Africa, it is estimated that about 33 million persons would be diabetic by 2030 (International Diabetes Federation, 2021). Diabetes mellitus refers to hyperglycemia that results from deficiency of insulin hormone or impaired effectiveness of its action (Magliano *et al.,* 2015).

In Nigeria, the exact prevalence of DM is unknown, but estimates put it in the region of 8-10% which is an increase of more than 2.6 folds over the past 25 years (Ogbera and Ekpebegh, 2014; Uloko *et al.,* 2018). In Veterinary Medicine, DM is one of the most frequently diagnosed endocrinopathies in dogs and cats, with a reported hospital prevalence rate of 0.4-1.2% in the United States of America (Nelson and Reusch, 2014) and 0.22% in Nigeria (Gani and Ihedioha, 2015). Till date, the management of DM involves controlling blood glucose levels through adoption of dietary alterations, exercise, and the use of antidiabetic drugs such as intravenous insulin injection, sulfonylureas - tolbutamide, glibenclamide and the biguanides - metformin, phenformin (Nelson and Cox, 2005).

There are recommendations for the use of alternative therapy such as medicinal plants, especially in countries where access to conventional management procedures for DM is inadequate. Plant parts such as leaves, fruits, seeds, barks, roots and flowers have been used to cure various diseases of humans and animals (Phyllistin and James, 2000). It is believed that the consumption of green leafy vegetables (GLVs) plays a significant role in the prevention and management of certain degenerative health conditions, such as cancer and DM (Montonen *et al.,* 2004; Dasgupta and De, 2007). Since oxidative stress is known to play a vital role in the aetiology and/or progression of DM (Sarma *et al.,* 2010), the rich antioxidant components of GLVs can combat or mitigate the disease by reducing the generation of reactive oxygen species (ROS), scavenging the ROS or interfering with ROS-induced alterations (Yang *et al.,* 2004; Vassort and Turan, 2010).

Vernonia amygdalina Delile (Bitter leaf) (Family: Asteraceae), is a widely grown shrub plant in Africa, a GLV consumed in many households and has gained wide application in the treatment and management of various diseases (Oyeyemi *et al.,* 2017). Secondary metabolites in the plant confers on it some pharmacological activities [such as vernodalin (antiplasmodial), vemonioside B1 (antiplasmodial and antischistosomal) and luteolin (powerful antioxidant and anticancer)] (Muraina *et al.,* 2010). Although considerable research has been done to evaluate the hypoglycemic and hypolipidemic properties of *V. amygdalina* (Adeoye *et al.,* 2017; Okoduwa *et al.,* 2017, Katemo *et al.,* 2018), there is still a dearth of information on the ameliorative potential of the plant. This study, therefore seeks to examine the ameliorative effects of *V. amygdalina* methanolic leaf extract on the haematology, oxidative stress markers, serum biochemistry profiles, some organ functions and histology of the pancreas, kidney and liver of alloxan-induced diabetic rats.

MATERIALS AND METHODS

Ethical consideration

Ethical approval was obtained from the College of Veterinary Medicine Research Ethics Committee of the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria. Approval number: FUNAAB/COLVET/CREC/2020/09/01.

Collection of plant sample

Fresh leaves of *V. amygdalina* were collected from the natural habitat in Abeokuta, Ogun State. Botanical identification was carried out at the Department of Botany, College of Biological Sciences, FUNAAB and voucher number FHA-3724 was assigned.

Preparation of plant extract

Vernonia amygdalina leaves were washed with distilled water to remove debris, dust particles and other contaminants. The leaves were thereafter air dried at room temperature and milled to coarse powder and extracted with methanol (90%) for 72 hours. The filtrate was poured through a muslin cloth into a beaker, heated in a water bath at 40^{O}C to evaporate the methanol, and the extract stored at 4^{o}C until use.

Experimental design

Thirty adult, male Wistar rats were used for this study. They were divided into five groups (A-E) consisting of six animals per group. Bodyweight and fasting blood glucose levels of all the rats were determined before the start of the experiment. Groups A-D were administered 158 mg/kg alloxan (KEM Light A05790B10) by intraperitoneal injection. Diabetes mellitus was confirmed in the rats by elevation of fasting blood glucose levels (above 180 mg/dl) 72 hours post -administration using a glucometer (Accu-Chek®, Germany). Groups A, B, C and D diabetic rats were administered 100 mg/kg *V. amygdalina,* 200 mg/kg *V. amygdalina,* 5 mg/kg glibenclamide and 10 mg/kg propylene glycol respectively, while Group E (Non -diabetic rats) were administered 10 mg/kg propylene glycol (Kao *et al.*, 2021). The administration of test samples was by oral intubation from 9:00 - 11:00 a.m. daily for 21 days.

Sample analyses

At the end of the experimental period, 5 ml of blood was collected from each rat via the medial canthus of the eye into Ethylenediamine tetraacetic acid (EDTA) and plain bottles for hematology and serum biochemistry respectively. Thereafter, rats were euthanized via cervical dislocation (Carborne *et al.,* 2012) and some tissue samples (pancreas, liver and kidney) were harvested for histopathology.

The packed cell volume (PCV), haemoglobin concentration (Hb), red blood cell (RBC) count, mean corpuscular haemoglobin concentration (MCHC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), white blood cell (WBC) count and differential WBC counts were determined as described by Jain (1993).

Total protein, albumin, globulin, blood urea nitrogen (BUN), creatinine, total and conjugated bilirubin, alanine transaminase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), superoxide dismutase (SOD) and hydrogen peroxide (H_2O_2) were analyzed using commercial kits (Randox Laboratories Ltd, UK), following standard procedures as outlined by the manufacturer. Also, total cholesterol, triglycerides, phospholipids, high-density lipoproteins (HDL), low-density lipoproteins (LDL), very low-density lipoproteins (VLDL), were evaluated using standard procedures.

The pancreas, liver and kidney tissue samples were fixed in 10% buffered formalin for histopathology. The fixed tissues were dehydrated in graded levels of alcohol (40, 50, 70, 80 and 100%) and thereafter embedded in paraffin wax; sectioned with a microtome at 5μm and stained with Haematoxylin and Eosin stains. The sections were put in a medium to harden and produce a clear binder between the slide and cover slip, labeled and examined under a light microscope (Hawsley®, England) and viewed at ×400 magnification (Llewellyn, 2009).

Data analysis

Results were presented as Mean ± Standard error of mean (SEM). Data were subjected to statistical analyses using the Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Corp, 2011). Mean values were compared using a one-way analysis of variance (ANOVA). The post Hoc test was done using the Tukey HSD test. *P*-value ≤ 0.05 was considered to be statistically significant.

RESULTS

Effect of Vernonia amygdalina methanolic leaf extract on the body weights of alloxan-induced diabetic male Wistar rats

There was no significant difference between the means of the rats' initial and final weights in all the groups. However, the weight change for group C was significantly higher than that of the other groups (Table 1).

Table 1: Effect of Vernonia Amygdalina Methanolic Leaf Extract on Body Weights of Alloxan-induced Diabetic Male Rats

Group	Initial weight	Final weight	Weight Change
Mean ± SEM (kg)			
A (100 mg/kg *Vernonia amygdalina*)	0.16±0.00	0.14±0.01	-0.02±0.01^{b}
B (200 mg/kg *Vernonia amygdalina*)	0.15±0.00	0.13±0.01	-0.02±0.01^{b}
C (5 mg/kg Glibenclamide)	0.14±0.00	0.15±0.01	0.01±0.01^{a}
D (Positive control)	0.18±0.01	0.15±0.01	-0.03±0.02^{b}
E (Non-diabetic control)	0.16±0.00	0.19±0.02	0.03±0.02^{a}

Mean values bearing different superscripts a,b are considered significantly ($p<0.05$) different

3.2 Effect of *Vernonia amygdalina* methanolic leaf extract on blood glucose of alloxan-induced diabetic male rats

Results from the extract treated groups A and B showed a decrease in blood glucose values on day 7 when compared with group D (Figure 1). There was a significant decline in the blood glucose of rats in groups A, B, and C in the first seven days of administration of the test samples. On day 21, an increase in blood glucose level was noticed in group A while group B rats had a continuous decrease. Group C maintained the level of blood glucose between day 7 and 14 followed with a slight increase by 21 (Figure 1).

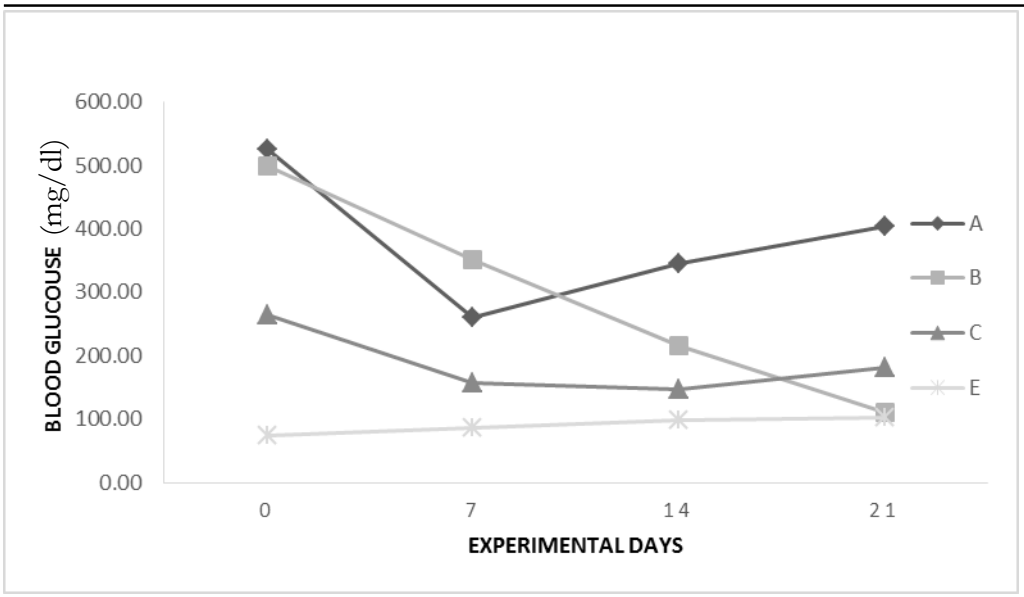

Figure 1: The effect of *Vernonia amygdalina* methanolic leaf extract on the blood glucose of alloxan-induced diabetic Wistar rats
A= 100 mg/kg *Vernonia amygdalina* methanolic leaf extract; B= 200 mg/kg *Vernonia amygdalina* methanolic leaf extract; C= 5 mg/kg glibenclamide; D= Positive control; E= Non diabetic control

Effect of Vernonia amygdalina methanolic leaf extract on the haematology, serum proteins and oxidative stress markers of alloxan-induced diabetic male rats

The PCV and Hb values of rats treated with 100 mg/kg *V. amygdalina* (Group A) were significantly lower than the other groups (Table 2). There was however no significant difference in the other haematological parameters.

Total protein values were significantly higher in Group D (8.50±0.28). However, there was no difference among the other Groups A, B and C (7.10±0.17, 6.77±0.67, and 6.30±0.26 respectively), while Group E was least (5.97±0.35). The differences in albumin values in Groups B, D and E were significantly different (3.63±0.33, 3.83±0.21 and 3.85±0.60 respectively). Globulin values were least in Groups C and E (2.90 ±0.26 and 2.27±0.31 respectively) - Table 3. For the serum enzymes (liver injury markers), the aspartate transaminase (AST) values were not statistically different between Groups B and D, although Group D had the highest value (106.33±5.61) while alanine transaminase (ALT) values were lower in Groups A, B, C and E but highest in group D (58.00 ±3.00). The alkaline phosphatase (ALP) value was least in Group C and E, although values were not significantly different (Table 3).

The blood urea nitrogen (BUN) values were higher in Group D (20.54±0.75), similar in Groups A and B (17.79±0.81 and 17.16±0.50 respectively) and between Groups C and E (13.24±1.31 and 13.25±1.21 respectively), total bilirubin values were higher in Group E (3.42±0.20)

when compared with values for Groups B and C, with Group D being the least (0.76±0.16). Values for direct bilirubin differed slightly, with Group B being higher (3.95±0.26). Creatinine values varied significantly, with value from Group E being statistically higher (0.70±0.66) from Group D (Table 4).

The Superoxide dismutase (SOD) and H_2O_2 values across the groups were not significant different. However, the SOD value was least from Group C (0.03±0.01) and highest from Group A (0.07±0.02). The H_2O_2 value amongst the group was highest from Group A (52.80± 3.10) and similar values were obtained from Groups B and C (42.47±3.64 and 42.10±2.87 respectively) -Table 5.

Table 2: Effect of *Vernonia amygdalina* methanolic leaf extract on the haematology of alloxan-induced diabetic male Wistar rats

Parameter	A (100mg/kg *Vernonia amygdalina*)	B (200mg/kg *Vernonia amygdalina*)	C (5mg/kg Glibenclamide) (Mean ± SEM)	D (Positive control)	E (Non-diabetic control)
PCV (%)	40.33±2.72[b]	50.00±2.44[a]	48.25±1.46[a]	48.50±1.19[a]	47.00±0.91[a]
Hb. (g/dL)	13.60±0.86[b]	16.95±0.86[a]	16.15±0.50[a]	16.30±0.29[a]	15.85±0.24[a]
RBC count ($\times10^{12}$/L)	6.73±0.48	8.40±0.43	8.15±0.27	8.08±0.19	7.95±0.21[a]
MCV (fl)	59.93±0.23	59.55±0.25	59.23±0.32	60.05±0.09	59.13±0.42
MCH(pg)	20.23±0.17	20.18±0.11	19.83±0.16	20.20±0.18	19.98±0.29
MCHC (g/dL)	33.73±0.17	33.90±0.26	33.48±0.16	33.63±0.27	33.78±0.33
WBC count ($\times10^{9}$/L)	11.47±0.84	11.18±0.53	10.80±0.57	11.43±0.59	10.05±0.15
Neutrophils	2.99±0.27	2.91±0.15	3.07±0.28	3.11±0.15	3.19±0.21
Lymphocytes	8.17±0.57	7.96±0.57	7.53±0.64	7.92±0.62	6.54±0.26
Eosinophils	0.11±0.06	0.11±0.07	0.02±0.02	0.20±0.07	0.13±0.05
Basophils	0.03±0.03	0.11±0.05	0.13±0.06	0.08±0.03	0.05±0.05
Monocytes	0.16±0.08	0.11±0.08	0.16±0.08	0.11±0.05	0.15±0.03

Mean values with different superscripts [a], [b] across the same row are significantly different ($p \leq 0.05$)

SEM = Standard error of mean; PCV= Packed cell volume; RBC= Red blood cell; Hb.= Hemoglobin concentration; MCV= Mean corpuscular volume; MCH= Mean corpuscular hemoglobin; MCHC= Mean corpuscular hemoglobin concentration; WBC= White blood cell

Table 3: Effect of Vernonia Amygdalina Methanolic Leaf Extract on some Serum Proteins and Markers of Hepatic Injury in Alloxan-induced Diabetic Male Rats

	A (100 mg/kg *Vernonia amygdalina*)	B (200 mg/kg *Vernonia amygdalina*)	C (5 mg/kg Glibenclamide)	D (Positive Control)	E (Non-diabetic control)
	Mean ± SEM				
Total protein (g/dl)	7.10±0.10[b]	6.77±0.38[b]	6.30±0.15[b]	8.50±0.20[a]	5.97±0.20[c]
Albumin (g/dl)	2.70±0.21[b]	3.63±0.17[a]	3.37±0.28[b]	3.83±0.12[a]	3.85±0.30[a]
Globulin (g/dl)	4.40±0.15[a]	3.73±0.55[a]	2.90±0.15[b]	4.20±0.59[a]	2.27±0.18[b]
AST (µ/L)	59.50±12.50[c]	104.33±7.17[a]	68.50±5.50[b]	106.33±5.61[a]	67.50±3.50[b]
ALT (µ/L)	31.50±4.50[b]	38.67±3.84[b]	28.00±3.00[b]	58.00±3.00[a]	33.33±4.26[b]
ALP (µ/L)	44.13±2.77[a]	42.30±2.44[a]	38.60±0.00[a]	42.30±4.60[a]	37.25±4.15[a]

Mean values bearing different superscripts [a], [b] are considered significantly different ($p<0.05$)

ALP: Alkaline phosphatase
ALT: Alanine transaminase
AST: Aspartate transaminase

Table 4: The Effect of Vernonia Amygdalina Methanolic Leaf Extract on some Kidney Function Parameters of Alloxan-induced Diabetic Male Rats

Parameter	A (100 mg/kg *Vernonia amygdalina*)	B (200 mg/kg *Vernonia amygdalina*)	C (5 mg/kg Glibenclamide)	D (Positive Control)	E (Non-diabetic control)
Mean ± SEM					
BUN (mg/dl)	17.79±0.81[b]	17.16±0.50[b]	13.24±1.31[c]	20.54±0.75[a]	13.25±1.21[c]
Total bilirubin (mg/dl)	1.37±0.14[b]	2.71±0.40[a]	1.67±0.37[b]	0.76±0.16[c]	3.42±0.20[a]
Direct bilirubin (mg/dl)	1.82±0.73[b]	3.95±0.26[a]	1.06±0.20[b]	3.22±0.58[a]	0.77±0.04[b]
Creatinine (mg/dl)	0.30±0.12[b]	0.30±0.06[b]	0.50±0.00[a]	0.67±0.09[a]	0.70±0.06[a]

Mean values bearing different superscripts [a], [b], [c] are considered significantly different ($p<0.05$)

Table 5: Effect of *Vernonia amygdalina* methanolic leaf extract on serum oxidative stress markers of alloxan-induced diabetic male rats

Parameter	A (100 mg/kg *Vernonia amygdalina*)	B (200 mg/kg *Vernonia amygdalina*)	C (5 mg/kg Glibenclamide)	D (Positive control)	E (Non-diabetic control)
			Mean ± SEM		
SOD (µ/L)	0.07±0.02	0.04±0.00	0.03±0.01	0.07±0.00	0.06±0.02
H_2O_2 (µM)	52.80±3.10	42.47±3.64	42.10±2.87	47.03±1.24	40.28±2.16

SEM : Standard error of mean; SOD: Superoxide dismustase; H_2O_2 :Hydrogen peroxide

Effect of Vernonia amygdalina methanolic leaf extract on the serum lipids of alloxan-induced diabetic male Wistar rats

Serum triglyceride values were significantly higher (p<0.05) in Groups A, B and C (70.97±4.27, 66.10±12.30, and 66.10±12.30 respectively) when compared with Group D (23.40±3.50) and E (10.13±1.03). Cholesterol values were significantly higher in Groups B and D (70.55±7.55 and 65.93±5.12 respectively) while Group E was lowest (25.88±2.98). Serum phospholipid level was significantly higher in Group B (150.33±0.88) when compared with Group C (119.13±2.86) - Table 6.

The high density lipoprotein (HDL) values were significantly higher in Group B (30.35±0.15) when compared with Group C (23.47±1.78), D (18.52±1.50) and E (15.30±3.29). However, the VLDL value was higher in Group D (20.00±4.30) when compared with Groups A, B, C and E (14.17±0.87, 18.47±1.43, 12.30±0.80 and 2.00±0.21 respectively) - Table 6.

Table 6: Effect of Vernonia Amygdalina Methanolic Leaf Extract on some Serum Lipids of Alloxan-induced Diabetic Male Rats

Parameter	A (100 mg/kg *Vernonia amygdalina*)	B (200 mg/kg *Vernonia amygdalina*)	C (5 mg/kg Glibenclamide)	D (Positive control)	E (Non-diabetic control)
			Mean ± SEM		
Triglycerides	70.97±4.27^a	66.10±12.30^a	49.90±11.74^a	19.30±0.60^b	10.13±1.03^b
Cholesterol	43.80±5.61^b	70.55±7.55^a	43.33±2.66^b	65.93±5.12^a	25.88±2.98^b
Phospholipids	125.41±3.87^b	150.33±0.88^a	119.13±2.86^c	134.60±2.12^b	108.89±2.18^d
HDL	15.70±4.10^b	30.35±0.15^a	23.47±1.78^a	24.97±1.30^a	15.30±3.29^b
LDL	9.97±0.27^c	27.47±3.01^a	10.19±0.60^c	18.52±1.50^b	9.47±0.95^c
VLDL	14.19±0.85^a	19.81±0.65^a	12.28±0.82^a	20.00±4.32^a	2.03±0.21^b

HDL: High density lipoprotein; LDL: Low density lipoprotein, VLDL= Very low density lipoprotein
Mean with different superscripts a,b,c,d across the row are statistically significantly different (p<0.05)

Effect of Vernonia amygdalina methanolic leaf extract on the histopathology of the pancreas, kidney and liver of alloxan-induced diabetic male rats

In rats treated with 100 mg/kg of *V. amygdalina* (Group A), there were areas of mild vacuolar degeneration of the islet of Langerhans of the pancreas, though maintaining their anatomical architecture (Plate 1). The kidneys showed areas with multiple foci of tubular dilatation, mild glomerular atrophy and mild vacuolar degeneration of the tubular epithelial cells (Plate 2). In contrast, rats in Group B showed areas with diffuse interstitial oedema of the islets of Langerhans with varying vacuolar degeneration of the cells (Plate 3). Histopathology of the kidneys revealed diffuse areas of tubular dilatation with the presence of protein cast in the lumen (Plate 4).

Kidneys of the rats in Group C showed areas with moderate diffuse vacuolar degeneration and necrosis of the tubular epithelial cell (Plate 5). There was also diffuse tubular dilatation with mild protein cast in the lumen. In the Group D rats, there were areas of dilated tubular lumen with vacuolar degeneration and necrosis. Across all groups, there were no hepatic pathologies seen morphologically (Plate 6).

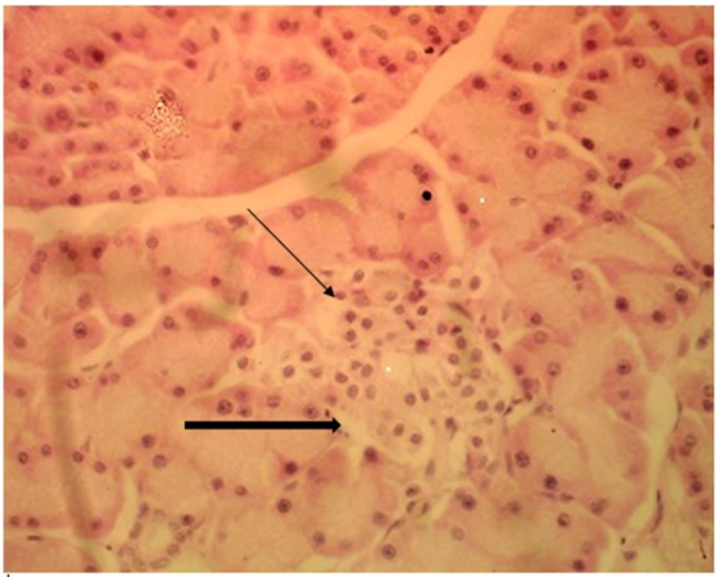

Plate 1: Histopathology of the pancreas of alloxan-induced diabetic male rat treated with 100 mg/kg Vernonia amygdalina methanolic leaf extract (Group A) showing very mild vacuolar degeneration (thick arrow) of the islet of Langerhans with the cells maintaining cellular architecture (thin arrow) (H&E stain ×400) scale bar: 25µM

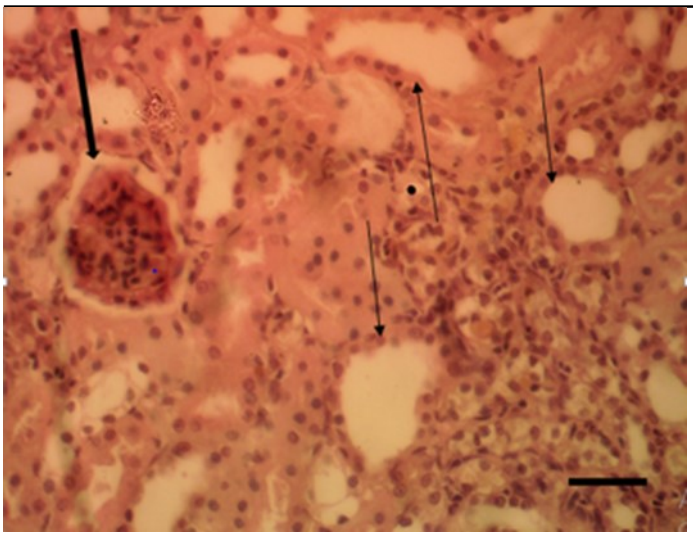

Plate 2: Histopathology of the kidney of alloxan-induced diabetic male rats treated with 100mg/kg V. amygdalina extract (Group A) with multiple foci of tubular dilatation (thin arrows), mild glomerular atrophy (thick arrow) and mild vacuolar degeneration of the tubular epithelial cells (H&E stain ×400) Scale bar: 20µM

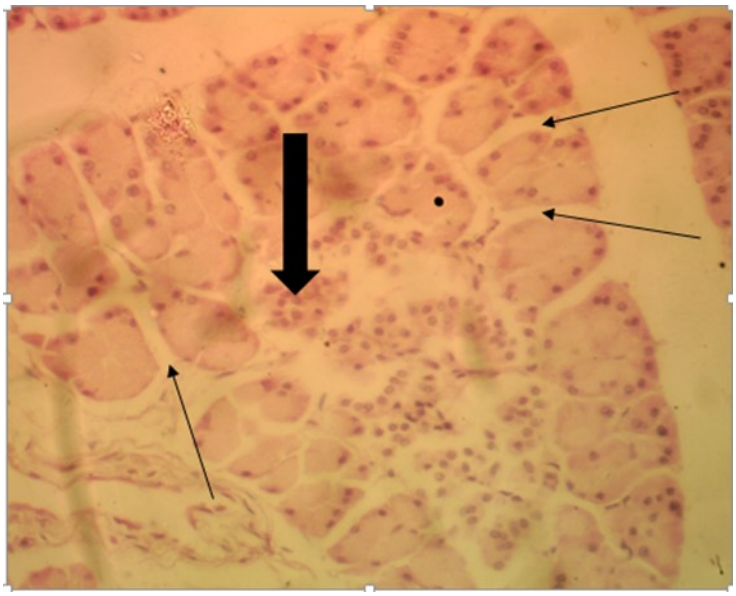

Plate 3: Histopathology of the pancreas showing areas of diffuse interstitial oedema of the islets of Langerhans (thin arrow) with varying vacuolar degeneration of the cells (thick arrow) in alloxan-induced diabetic male rats treated with 200 mg/kg Vernonia amygdalina methanolic leaf extract (Group B) (H&E ×400) Scale bar: 25µM

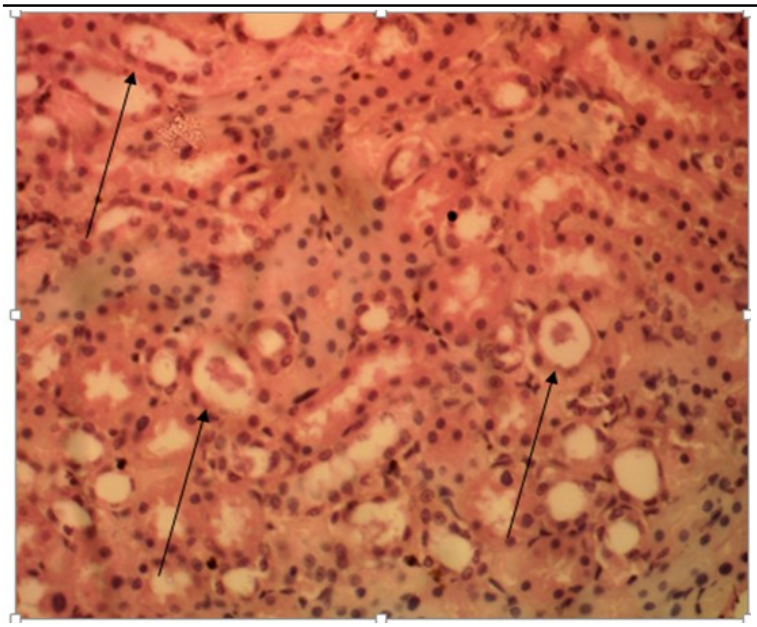

Plate 4: Histopathology of the kidney showing diffuse areas of tubular dilatation with protein cast in the lumen of alloxan-induced diabetic male Wistar rats treated with 200 mg/kg Vernonia amygdalina methanolic leaf extract (Group B) (H&E ×400) Scale bar: 20µM

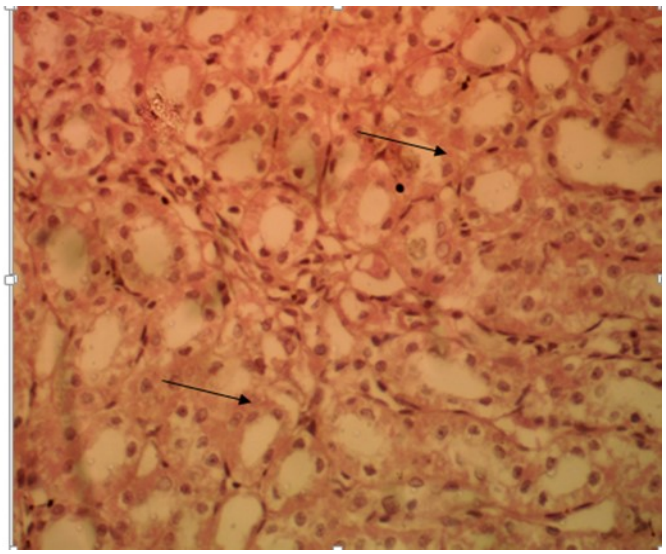

Plate 5: Histopathology of the kidney of alloxan-induced diabetic male Wistar rats treated with 5 mg/kg glibenclamide (Group C) showing areas with moderate diffuse vacuolar degeneration and necrosis of the tubular epithelial cell. There was also diffuse tubular dilatation with mild protein cast in the lumen (H&E ×400) Scale bar: 20µM

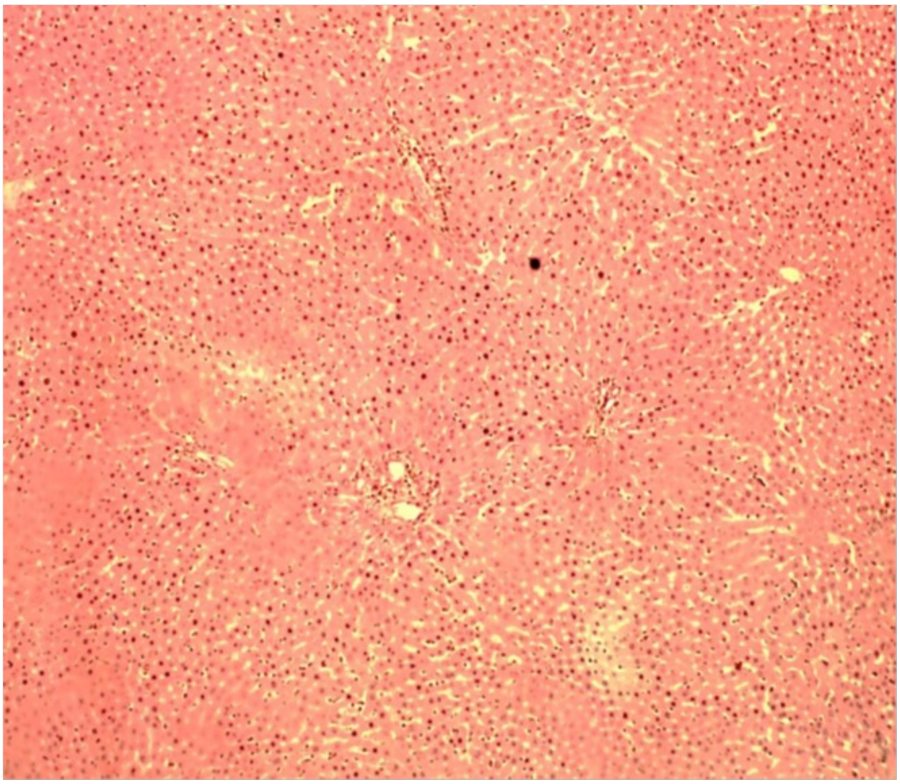

Plate 6: Photomicrograph of the liver in alloxan-induced diabetic male Wistar rats treated with 100mg/kg *Vernonia amygdalina* methanolic leaf extract (Group A) with no visible lesion observed (H&E stain ×400)

DISCUSSION

Diabetes mellitus is a debilitating health condition and is one of the leading causes of death, especially in medium and low income countries (WHO, 2022). There is global agreed target to halt the rise in diabetes and obesity by 2025 (WHO, 2022). This study was aimed at proffering solution to a global health disorder in human and pets.

The weight losses were recorded in the *V. amygdalina* extract-treated groups in this study. This aligns with the findings of Atangwho *et al.* (2012), demostrated that *V. amygdalina* leaves can induces weight loss, thereby suggesting that it may ameliorate the potential risk of glucose intolerance associated with diabetes mellitus.

Moreso, the hypoglycemic effect of *V. amygdalina* methanolic leaf extract in alloxan-induced diabetic male rats at dosages of 100 mg/kg and 200 mg/kg were outlined. At the 100mg/kg dosage, this extract demonstrated a probable biphasic hypoglycemic property. Other researchers have documented the hypoglycemic effects of the aqueous extract (Michael *et al.,* 2010), ethanolic extract (Effiong *et al.,* 2013), and chloroform fraction (Atangwho *et al.,* 2013; 2014) of *V. amygdalina* streptozotocin-induced diabetic rats. This suggests that the active blood sugar lowering principles in the plant may be extracted by both polar and non-polar solvents.

Uncontrolled hyperglycemia has been noted to affect certain haematological parameters such as glycated Hb levels, platelet volume, WBC counts (Biadgo *et al.,* 2016). These may serve as pointers to certain systemic events (markers) occurring in a body as seen in cases of diabetes mellitus. The present study showed increased PCV and Hb concentration in the 200 mg/kg *V. amygdalina* leaf extract-treated group when compared with the controls. The findings in this study agreed with the report of Asante *et al.* (2016) in Ghana, who observed that a dose-dependent increase in PCV values of Sprague Dawley rats treated with lower doses (10 and 30 mg/kg) of ethanolic extract of *V. amygdalina*. The results from this study however, differ from the findings of Chike *et al.* (2018) and Airaodion *et al.* (2019), whose studies revealed significantly lowered PCV and Hb concentrations after treatment with ethanolic extract of *V. amygdalina* leaves, and suggested that the extract of *V. amygdalina* had the potential of adversely affecting haematological indices.

Serum enzymes have been used to demonstrate hepatic and renal injury related to liver disease and hyperglycemia (Zafar and Navqi, 2010; Ajiboye *et al.,* 2016). Abnormal increases in aminotransferases specifically ALT generally reflect liver cell damage (hepatotoxicity), while that of ALP is more specific for cholestasis-hepatobiliary damage (Atangwho *et al.,* 2007). In this study, ALT values were decreased significantly in extract-treated groups, an indication that there was no hepatic injury resulting from the methanolic extract of *V. amygdalina*. This result could be due to the antioxidative activities of sequesterpene lactone in *V. amygdalina* (Arhoghro *et al.*, 2009). A review according to Kaur *et al.* (2019) documents the hepatoprotective effects of this plant which was demonstrated in this study. A study by Ekam and Udosen (2012), using the benzene, chloroform, ethyl acetate, butanol, and methanol fractions of *V. amygdalina*, on acetaminophen-induced hepatotoxicity also reported hepatic protection of this plant. Hepatoprotective effect of some other plants in related families such as the aqueous extracts of *Rosmarinus officinalis* and *Moringa oleifera* has also been reported (Ramadan *et al.,* 2013; Abakpa *et al.,* 2017). In addition, total bilirubin and creatinine values in the extract treated group were not significantly different from the non-diabetic control and can be inferred that there was no hepatobiliary damage as well as kidney damage relating to the use of the extract. Oxidative damage in various tissues may be controlled or prevented by enzymic and nonenzymic antioxidant defense systems such as SOD (Aksoy *et al.,* 2003). Studies have shown antioxidant enzymes activities are decreased in DM causing an increase in the level of H_2O_2 in serum (Shen *et al.*, 2009). The serious imbalance between reactive oxygen species (ROS) production and the decline of antioxidative ability leads to the enhancement of oxidative stress seen in DM. Several sesquiterpene lactones such as vernolide, vernodalol, vernolepin, vernodalin and hydroxyvernolide; flavonoids such as luteolin, luteolin 7-O-βglucoroniside and luteolin 7-O-β-glucoside, and stigmastane-type steroid saponins isolated from *V. amygdalina* leaves have been observed to possess antioxidant properties (Ong *et al.,* 2011; Adeoye *et al.,* 2018; Bashir *et al.,* 2020; Alara *et al.,* 2020; Zhao *et al.,* 2021). These phytochemicals have the ability to scavenge for free radicals which are increasingly produced in cells of diabetic subjects (Malik *et al.,* 2010). In this study however, serum antioxidant marker (SOD) was not significantly altered by DM but the decrease in H_2O_2 level in *V. amygdalina* treat-

ed group (200 mg/kg) could be due to the presence of radical scavenging compounds in leaves.

Dyslipidemia associated with DM is characterized by increase in total cholesterol, LDL, VLDL, triglycerides and a fall in HDL. In this study, the levels of total cholesterol and triglycerides were markedly increased in diabetic control following induction of DM with alloxan confirming that the dyslipidemia associated with DM can give useful information on lipid metabolism (Oyedemi *et al.,* 2010). There was also an increase in the good cholesterol (HDL) and bad cholesterol (LDL) in the *V. amygdalina* treated groups. Nwanjo (2005) observed that the aqueous extract of the plant reduced triacylglycerol levels and normalized cholesterol concentrations in the serum of diabetic rats. The ethanolic extracts of the plant have also been reported to keep the lipid profile of rats within the normal range (taken as that of the control rats) when doses of 100-1000 mg/kg body weight were administered (Atangwho *et al.,* 2012). The methanolic extracts of *V. amygdalina* have also been shown to have lipid-lowering effects in rats fed on a high cholesterol diet for nine weeks (Adaramoye *et al.,* 2008). These reports suggest that the plant may play very important roles in the future management of chronic diseases.

From the histopathology, *V. amygdalina* extract dosed at 100 mg/kg and 200 mg/kg caused an architectural maintenance of the pancreatic islets cells as well as in the kidneys, hence mitigating the effect of diabetes mellitus on the tissues in these groups. This is buttressed by Akinola *et al.* (2010), with the demonstration of the presence of viable cells of the pancreatic islets after treatment using *V. amygdalina* at 400mg/kg. In glibenclamide treatment, there was loss in the cellular architecture of the pancreatic islets as well as diffuse areas of necrotic lesions in the tubular epithelial cells and distention of the tubular lumen with presence of protein casts. The absence of morphological lesions in the livers of the rats across the groups could be due to the short duration of the study. According to Kini *et al.* (2016), steatosis, lobular inflammation, portal inflammation, nuclear glycogenation, and fibrosis are the characteristic histopathological changes seen in the liver due to DM.

In conclusion, this study evaluated the ameliorative effect of *V. amygdalina* on alloxan-induced diabetic male rats and showed favourable protective effect that was more pronounced in the 200 mg/kg treatment group. It is believed that the ameliorative signs associated with the extract is due to rich presence of flavonoids and polyphenols. Further studies should be focused on characterizing the active principle(s) responsible for this effect and the possible mechanism(s) of action.

Authors' contributions

OAA conducted the project and drafted the manuscript; OTA and JOO conceptualized designed the project; OLA read the histopathology slides; OAA did the statistical analysis; OTA and OJA revised the manuscript critically for important intellectual content. All authors read and approved the final version of the manuscript.

Conflict of interest

All authors declare that there is no conflict of interest.

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CRYSTALLINE AND AMORPHOUS FORMS OF IRON (Fe) OXIDES IN HYDROMORPHIC SOILS OF DADIN KOWA, GOMBE STATE, NIGERIA

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ABSTRACT

The content and distribution of different forms of Iron oxides are important indicators used in describing soils. This study was conducted with the aim of evaluating the crystalline and the amorphous forms of Iron oxides distribution in hydromorphic soils across five different land uses (amaranth, millet, mango, rice and tomato) at Dadin Kowa, Gombe State. Two soil profile pits were dug in each of the identified land uses, and soil samples collected from identified genetic horizons. All soil samples collected were analyzed using standard laboratory procedures. The textural classes of the soils revealed loamy sand to sandy loam. Bulk density, particle density, total porosity and silt/clay ratio varied between 1.60 to1.67 g/cm^3, 2.57 to 2.71 g/cm^3, 35.82 to 40.41% and 0.92 to 1.86, respectively. The soil reaction was slightly acidic to neutral (pH 6.39 – 6.68). Soil electrical conductivity (EC) for all the soil mapping units was below the critical limits of 4 d/Sm EC, an indication of the non-saline nature of the studied soils. The values for OC, TN and AP contents of the soils across land use and horizons was substantial > 10 g/kg, and is rated medium to high, 1.1 to 1.40 g/kg, rated low to medium and 8.03 to 9.35 mg/kg, rated low, respectively, while the exchangeable bases were generally rated medium to high. The mean distribution of forms of Fe oxides, extracted by different extracting reagents revealed the dominance of diotonite extractable iron (Fed) over oxalate extractable iron (Feox) and pyrophosphate extractable iron (Fep), while the active iron ratios was generally <0.4 but > 0.1, confirming a moderate stage of soil development, and the dominance of crystalline forms of Fe oxide as against the amorphous forms across the study area. The direction of soil development with age followed the trend; amaranth < mango < millet < tomato <rice.

Keywords: Active iron ratio, Amorphous, Crystalline, Hydromorphic, Iron

DOI:

INTRODUCTION

Content and distribution of the different forms of iron oxides in soils are important indicators used in describing soils, not just the direction, but also the intensity of weathering or soil development. A larger proportion of irons in soils exist as oxides. These oxides are found as iron concretions as well as coatings on the soil minerals or bind the different soil particles (Akinbola *et al.*, 2013). Particle size with free iron oxides has been exclusively studied at both small and large scales (Agbenin, 2003). Their distribution and amount in the soil are known to influence some soil properties such as anion adsorption, surface charges, specific surface area, nutrient transformation, swelling and aggregate formation and pollutant reten-

tion in soils (Enya *et al.*, 2011). Percentages of free iron have long been used as aids in distinguishing soil types, differentiating soil horizons and determining soil age or degree of soil development (Akinbola *et al.*, 2013).

According to Walker (1983), the origin of free iron oxides in soils is free iron released during weathering of rocks. The released free irons are subsequently precipitated as crystalline and amorphous forms of iron oxides. Ogunkunle and Onasanya (1992) indicated that the crystalline form of iron and aluminum oxides are the dominant oxy-hydroxides in the basement complex soils of western Nigeria. The predominance of the crystalline forms of sesquioxides represents a more advanced stage of soil development than the presence of amorphous forms that is mobile in the soil and could be associated with organic matter (Ogunkunle and Onasanya, 1992). Ojanuga (1985) also reported that the crystalline forms of Fe were goethite and hematite and occur either singly or in association within the hard nodules and concretions in the soil environment. The level of the crystalline form of Fe can thus serve as an estimate of the degree of soil development and formation of hard nodules and concretions. Obi *et al.* (2009) concluded that the dominance of higher proportion of the crystalline form of Fe will lead to structural distortions with implication for anion retention which affects the surface area and leads to hardness of the soil. Higher crystalline Fe content will affect both the physical and chemical properties of soils as well as their management and land use. This study is important because the study area covers a large expanse of irrigable land in Gombe State. Therefore, this research was conducted with the aim of evaluating the disposition of both crystalline and amorphous forms of iron oxides in hydromorphic soils of Dadin Kowa, Gombe State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study area is at Dadin Kowa in Yamaltu Deba Local Government Area of Gombe State. It is located between latitudes, 10° 29' 00" N and latitude 10° 30' 12" E and longitude 11° 50' 35" N and latitude 11° 53' 07" E, within the Northern Guinea Savannah ecological zone of the country (Klinkenberg and Higgins, 1968). It lies at an elevation ranging from 184-351m above sea level (Ikusemoran *et al.*, 2016), situated about 40 km along Gombe – Biu road in the Northern Guinea Savanna Zone of Nigeria. According to Ikusemoran *et al.*, (2018), the geological succession of the Dadin Kowa area, is underlain by the upper cretaceous rocks of marine sediments. The sediments are predominantly argillaceous and consist of alternating shale and limestone with sandy mudstones, siltstones and sandstones respectively (Ikusemoran *et al.*, 2018). The remnants of these included materials form the major components of the resultant soils. These inclusions are either decreased or increased with depths or are uniformly distributed. The climate of the area is that of the semi-arid type characterized by wide seasonal and diurnal temperature ranges with two main seasons: rainy season (April-October) and dry season (November to March) (Abubakar, 2013). Average annual rainfall is put at about 1000 mm, with the greater part falling between July and October (UBRDA, 2018). April is usually the hottest month (maximum temperature being 39°C) while December and January have the lowest temperature, averaging 16°C (UBRDA, 2018).

Field Methods

Five (5) extensively cultivated farms/

orchards were identified and mapped as soil mapping units; they are tomato (TMT), amaranth (AMR), mango (MNG), millet (MLT) and rice (RCE). To achieve the objectives of the study, two soil profile pits were dug on each of the 5 mapping units identified, and soil samples from each recognizable pedogenic horizon from each of the dug profile pits were collected, stored, and tagged in polythene bags for laboratory analysis.

Laboratory Analysis

Particle-size fractions were determined using the Bouyoucos hydrometer method (Gee and Bauder, 1986). Soil pH was determined in 1:2 water ratio using a glass electrode pH metre (Page *et al*., 1982). Determination of Organic carbon, and Total nitrogen were done by the wet oxidation method and regular micro-kjeldal method respectively. Available phosphorus was determined using the Bray 1 method. Extraction of DCB extractable Fe (Fed) was carried out according to the procedure of Mehra and Jacson (1960) while the oxalate extractable iron (Feox) were extracted with Oxalic acid according to the procedure of Mckeague (1966).

Data Analysis

The data obtained from the study were subjected to descriptive statistics to assess the soil properties. Mean differences in properties between soils developed across different land use systems (LUS) and between horizons were analyzed using two-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Physical Properties

The total mean sand content across LUS and depths ranged from 73.38-84.8%, and is the predominant soil particle (Table 1). This observation of sand fraction predominance in this study is consistent with the findings of Askira *et al*. (2019). Onweremadu *et al*. (2011) attributed the high sand content to the nature of parent material. The highly significant ($p<0.01$) variation in mean sand distribution across land use could be related to the secondary products of weathering (Brady and Weil, 2013).

The significantly ($p<0.01$) higher variation in mean sand fraction in the surface soil over the subsurface soil might be attributed to pedogenic processes such as lessivage, eluviations and illuviation (Ojetade *et al*., 2014). Silt particle mean values ranged from 7.8-14.04% across the different LUS and depths (Table 1). A notable feature in all the soils studied is their high silt content. Nsor and Uhie (2016) and Askira *et al*. (2019) reported higher silt content in their various studies. The high silt content obtained in this study could be attributed to the nature of parent material and stage of soil development (Maniyunda, 1999). There was a highly significant ($p<0.001$) difference in silt content between the different land uses. The high mean content of silt recorded in soils under rice, tomato and amaranth, could be attributed to the received fine colluvial and alluvial sediments from the upper slope positions through erosion and deposition (Maniyunda and Gwari, 2014). There was no significant ($P>0.05$) variation in mean silt content with depth. Clay mean content ranged from 6.58-9.91% across LUS and depths. The result for particle size distribution showed that percentage clay content was lowest when compared to sand and silt, in all the studied soils. Such low values of clay content as obtained in this study, agrees with the findings of Akintoye *et al*. (2012) and Akpan *et al*. (2017), from similar soils. The value of mean clay content differed significantly ($p<0.05$) across

Table 1: Physical properties of soils across the different land uses and horizons

	Sand (%)	Silt (%)	Clay (%)	Soil Texture	BD (g/cm³)	PD (g/cm³)	TP (g/cm³)	Silt/ Clay (%)
Land Uses								
Amaranth	77.36^{bc}	14.00^{a}	8.64^{ab}	Sandy loam	1.61^{b}	2.71^{a}	40.41^{a}	1.66^{a}
Millet	83.12^{ab}	7.80^{b}	9.07^{a}	Loamy sand	1.61^{b}	2.57^{ab}	37.14^{ab}	0.92^{b}
Mango	84.80^{a}	8.62^{b}	6.58^{c}	Loamy sand	1.67^{a}	2.64^{a}	36.76^{ab}	1.45^{a}
Rice	73.38^{c}	16.70^{a}	9.91^{a}	Sandy loam	1.60^{b}	2.48^{b}	35.82^{b}	1.68^{a}
Tomato	78.36^{bc}	14.04^{a}	7.60^{ab}	Loamy sand	1.63^{b}	2.66^{a}	38.70^{ab}	1.86^{a}
LSD ($p<0.05$)	5.23	4.07	1.95		0.04	0.12	2.72	0.46
LOS	**	***	*		*	*	*	**
Soil Horizon								
Surface	81.78^{a}	11.04	7.18^{b}	Loamy sand	1.64^{a}	2.61	37.03	1.54
Subsurface	77.03^{b}	13.42	9.54^{a}	Sandy loam	1.60^{b}	2.61	38.50	1.49
LSD ($p<0.05$)	3.31	2.57	1.23		0.02	0.08	1.72	0.29
LOS	**	NS	***		**	NS	NS	NS

LOS (Level of significant) (p): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.001, BD= bulk density, PD= particle density, TP= total porosity

Note: Means followed by the same letters in the column are not significantly different at 5% LOS

the different land uses (Table 1). The significant variation in clay distribution obtained could be related to the pedogenic processes such as lessivage, eluviations and illuviation (Ojetade *et al.*, 2014).

There was a highly significant ($p<0.001$) difference in mean clay content between the horizons, which increased with increasing depth. This trend was in conformity with earlier reports of Ojetade *et al.* (2014) and Fekadu, *et al.* (2018), Brady and Weil (2013)

attributed the increase in clay content with depth, to the fact that some of the clay particles in the top soil may have been removed by run-offs, and some still move downwards through other processes such as illuviation or a combination of both processes while Yitbarek *et al.* (2016) and Kebede *et al.* (2017) noted that higher clay content in the B horizon of soils is as a result of predominant in situ pedogenetic formation of clay in the subsoil, and destruction of clay in the surface horizon. Soil texture across mapping units revealed occurrence of loamy sand and sandy loam particles, which corroborated earlier report by Salem *et al.* (2017). Soil texture is an important soil physical property which affects water holding capacity, nutrient retention capacity, organic matter content and soil aeration (Kefas *et al.*, 2016). Several researches have linked soil texture to the nature of parent materials from which the soils were derived and also to the rate and nature of some weathering processes (Ahukaemere *et al.*, 2012). The mean data in bulk density (BD) values across the different land use systems (LUS) and depths ranged from 1.60-1.67 g/cm^3. The values for bulk density obtained in this study are within the range reported in earlier studies by Ande *et al.* (2016) with values of 1.11 to 1.98 g/cm^3 from floodplain soils in Southern Guinea Savanna of North Central Nigeria. There was an observed significant variation ($p<0.05$) in mean bulk density values, between the land uses (Table 1). The highest value for BD recorded for soils under mango cultivation could be attributed to high intensity of livestock grazing (Raji *et al.*, 1996). There was also a highly significant variation ($p<0.01$) across soil depths, with the surface horizons having a higher value. Findings by Zata *et al.* (2010) following a detailed soil survey and characterization of some Usterts in Northeastern Nigeria, also corroborate this finding. The relatively high mean values of the bulk density on the surface horizon could be attributed to compaction due to high intensity of livestock grazing (Raji *et al.*, 1996). The mean BD values obtained in these studies are considered to be generally safe for plants' root penetration as this might be hindered in soils having a bulk density value >1.75 g/cm^3 (Ashenafi *et al.*, 2010). Donahue *et al.* (1990) pointed out that plant growth is best at soil bulk densities below 1.40 g/cm^3 for Clay, and 1.60 g/cm^3 for Sandy soils. Results (Table 1) show that mean particle density (PD) values ranged from 2.57 -2.71 g/cm^3 indicating that quartz, feldspar, micas and the colloidal silicates with densities between 2.60- 2.75 g/cm^3 forms the major portion of minerals in the study area (Brady and Weil, 2013). The mean value of PD differed significantly ($p<0.05$) across the different land uses, while there was no significant ($p>0.05$) difference in mean particle density with depth. Generally, the values of particle density recorded in this study (< 2.75 g/cm^3) were considered satisfactory (Kachinskii, 1965) for plant growth. The mean value for Total Porosity (TP) values of the studied soils across land uses and depths ranged from 35.82 to 40.41%, indicating that the values recorded are low. Similar low porosity values were reported by Ogban and Utin (2015) and Akpan *et al.* (2017) for some soils while working on wetland and coastal plain soils, respectively, in Calabar, Cross River State, Nigeria. Therefore, porosity is a limiting factor in the present study (Kachinskii, 1965). There was a significant ($p<0.05$) variation in mean porosity values with respect to land use. The significantly ($p<0.05$) higher mean porosity value recorded for the Amaranth land use may be attributed to loosening of soil materials by plant roots and during cultivation of the soil (Ahukaemere and Ak-

pan, 2012). Brady and Weil (2008) stated that optimum total pore space value for crop production is >50%. The subsurface horizon (38.50%) is not significantly ($p>0.05$) different from the surface horizon (37.03%). Incorporation of organic manure to the soils will decrease the soil bulk density and ultimately increase the percentage pore distribution, thereby enhancing the soil physical condition for optimum crop production and food security (Hassan and Shuaibu, 2006). The mean range in values for silt to clay ratio across LUS and depths ranged from 0.92-1.86 in the studied soils. The silt/clay ratio (SCR) is an index for extent of weathering as noted by Olehge and Chokor, (2014). "Old" parent materials usually have a silt/clay ratio below 0.15 while silt/clay ratios above 0.15 are indicative of "young" parent materials (Van Wambeke, 1962). Results in this study show that, all the soils have silt/clay ratio above 0.15 indicating that the soils are relatively young with high weathering potential, which is similar to reports by Ajiboye *et al.* (2015) and Osujieke, *et al.* (2017). There was a highly significant ($p<0.01$) variation in mean silt/clay ratios across land uses. The land under millet cultivation recorded the lowest value of 0.92, which is an indication that the soil is older, compared to other land uses. There was no significant ($p>0.05$) variation in mean Silt/clay ratio across soil depths.

Chemical properties

Generally, soil pH is a major driver of soil fertility (Brady and Weil, 2013). The mean soil pH values determined in water [pH (H_2O)] across land uses and horizons ranged from 6.39 to 6.68 (Table 2) which is rated as slightly acidic to neutral in reaction (Malgwi, 2007). The low pH values recorded in this study are similar to those earlier reported (Abagyeh *et al.*, 2017; Okoli *et al.*, 2017; Fekadu *et al.*, 2018). The acidic condition of the soils under study could be attributable to higher leaching process (Brady and Weil, 2013). There was no observed significant ($p>0.05$) variation in mean pH values across the different land uses. However, there was an observed significant ($p<0.05$) variation in mean pH values across depth. The increased pH values with soil depth might be due to less H^+ ions released from low organic matter (OM) decomposition, which is due to decreased OM content with depth (Abay and Sheleme, 2012). However, Akpan *et al.* (2017) attributed this finding to excessive leaching of basic cations from the surface to the subsurface horizons (Table 2). The electrical conductivity (EC) of a soil solution is a good indicator of the degree of salinity of the soil (Brady and Weil, 2013). The mean EC values across LUS and depths ranged from EC 0.12 -0.22 d/sm, which were found to be below the critical limits of 4 d/sm to be described saline soils (FAO, 1993).

Table 1: Physical properties of soils across the different land uses and horizons

	pH (1:2)	EC (d/sm)	OC (g/kg)	TN (g/kg)	AP (mg/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	K (cmol/kg)
Land Uses									
Amaranth	6.68	0.22^{a}	16.02^{a}	1.4^{a}	9.35^{a}	2.79	1.40	0.55^{a}	0.52
Millet	6.39	0.12^{b}	12.25^{b}	1.1^{b}	8.86^{ab}	2.54	1.23	0.52^{a}	0.53
Mango	6.47	0.20^{a}	12.57^{b}	1.1^{b}	8.36^{bc}	2.81	1.38	0.49^{a}	0.49
Rice	6.53	0.15^{ab}	15.20^{ab}	1.3^{ab}	8.03^{c}	3.30	1.71	0.29^{b}	0.51
Tomato	6.64	0.18^{ab}	13.55^{ab}	1.2^{ab}	8.43^{bc}	2.84	1.31	0.55^{a}	0.50
LSD ($p<0.05$)	0.22	0.05	0.24	0.02	0.50	1.21	0.73	0.14	0.03
LOS	NS	*	*	*	***	NS	NS	**	NS
Soil Horizon									
Surface	6.47^{b}	0.16	15.01^{a}	1.3^{a}	9.03^{a}	2.41^{b}	1.14^{b}	0.50	0.52^{a}
Subsurface	6.61^{a}	0.19	12.83^{b}	1.1^{b}	8.19^{b}	3.31^{a}	1.67^{a}	0.47	0.50^{b}
LSD ($p<0.05$)	0.14	0.03	0.15	0.01	0.32	0.77	0.46	0.09	0.02
LOS	*	NS	**	**	***	*	*	NS	*

LOS (Level of significant) (p): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.001, EC=electrical conductivity, OC=organic carbon, TN=total nitrogen, AP=available phosphorus, Ca=calcium, Mg=magnesium, Na=sodium, K=potassium
Note: Means followed by the same letters in the column are not significantly different at 5% LOS

The entire soil mapping units recorded low EC values which are an indication of the non-saline nature of the studied soils (Malgwi, 2007). Such low EC values obtained in this study is in line with the earlier findings by Egwu *et al.* (2018) and Imadojemu *et al.* (2018). The low electrical conductivity (EC) values recorded in the study area might be attributed to the sandy nature of the parent materials (Imadojemu *et al.*, 2018). The EC mean values recorded for the studied soils indicated that soils under amaranth

and mango cultivation had significantly ($p<0.05$) higher values compared to the other land uses. However, there was no significant ($p>0.05$) variation between the soil horizons. The mean organic carbon (OC) content across LUS and soil horizons ranged from 12.25-16.02 g/kg (Table 2). The mean values of the OC content of soils across land use and horizons is substantial (> 10g/kg) and is rated medium to high (Malgwi, 2007). This finding is contrary to earlier report of low OC content for soils in the Savanna zones of Nigeria (Salem, *et al.*, 2018). Soils under amaranth cultivation, in comparisons to others was observed to be statistically ($p<0.05$) higher in mean OC content. The high content of organic matter in the soil mapping unit of amaranth may be attributed to short growing season and regular addition of farm yard manure which causes a relative accumulation of organic matter, reduced microbial activities and less frequent and less severe translocation of mineralized products at the start of the rains (Esu, 1982). The organic carbon content of soils obtained across horizons was highly ($p<0.01$) different indicating a consistent decrease with increased soil depth. This trend corroborates earlier findings of (Abagyeh *et al.* (2017) and Fekadu *et al.* (2018). The decrease in OC content with soil depth may be attributed to immobilization of organic matter by the clay in the surface horizons in forms of organo-clay-complexes (Shobayo, 2010). The mean total nitrogen values for the studied soils, across the various land uses and horizons ranged from 1.1 to 1.4 g/kg (Table 2) and are rated low to medium in accordance with Malgwi (2007). Similar values have been reported for soils in the Northern Guinea Savanna Zone of Nigeria (Egwu *et al.*, 2018). Also, low total nitrogen (TN) in soils has been reported by Salem *et al.* (2017). The low to medium level of TN obtained in this study could be attributed to its' mobile nature in soils. As a result its losses through various mechanism like ammonia volatilization, succeeding denitrification, chemical and microbial fixation, leaching and runoffs, all result in low residual/available N in soils (Awanish *et al.*, 2014 and Akpan *et al.*, 2017). Soils under amaranth cultivation was significantly ($p<0.05$) higher in mean TN content compared to other land uses and this may be related to the higher level of OC in the land use system. Lawal *et al.* (2012) had reported that organic matter content accounts for between 90 and 98 % of soil nitrogen. There was also a significant ($p<0.01$) higher TN at the surface than the subsurface horizons. Such finding was similar to earlier reports of Abagyeh *et al.* (2017), Okoli *et al.* (2017) and Fekadu *et al.* (2018). The higher TN recorded in the surface soil of the floodplain may be related to the relatively higher organic carbon content on the surface in the studied soils. The mean available phosphorus (AP) content of the soils across land uses and profile depths, ranged from 8.03 to 9.35 mg/kg and was substantially found to be low (Malgwi, 2007). Such low AP values were earlier reported by Osujieke *et al.*, (2017) and could be due to fixation, as a result of the acidic condition of the soils under study (Fekadu *et al.*, 2018). The mean value of AP recorded for the soil under amaranth cultivation was highly significantly higher ($p<0.001$) than under millet, mango, rice and tomato cultivations. The higher AP values recorded for the soil under amaranth cultivation could be attributed to addition of phosphorous containing fertilizers to boost crop yields and high organic matter that subsequently accrue to the soil (Sai Kumar *et al.*, 2013). The exchangeable bases in the soils occurred in the order Ca>Mg>Na>K (Table 2), which is in line with earlier reports for soils under irriga-

tion (Esu, 1982). The mean values of calcium (Ca) across the different sampling units and depth ranged from 2.41 to 3.31 cmol (+)/kg and is rated medium to high according to Malgwi, (2007) rating scale. This rating may be attributed to the inherent Ca content of the soil dictated by the parent material (Havlin *et al*., 1999). Even though, there was no significant ($p>0.05$) difference in mean Ca content between the different land uses, the subsurface horizon recorded a significantly ($p<0.05$) higher value than the surface horizon; this result was similar to the earlier findings of Shobayo (2010). Fekadu, *et al.* (2018) attributed the accumulation of Ca with soil depth to leaching and might also be attributed to mining of Ca by plants from the rooting zone. Magnesium (Mg) is the second most dominant extractable cation on the exchange complex of the studied profiles. The mean values of exchangeable Mg content in the soils across the various sampling units and depth ranged from 1.14 to 1.71 cmol (+)/kg soil, and was rated medium to high (Malgwi, 2007). Ogbodo, (2011), also encountered high Mg soil content in his assessment of some soil fertility characteristics of Abakaliki Urban Floodplains in South-Eastern Nigeria. The seeming medium to high value of Mg content could be related to the calcareous nature of the parent material (Havlin *et al*., 1999). The soils in the study area showed no significant ($p>0.05$) difference in Mg content across the different land uses. However, the subsurface horizon was significantly ($p<0.05$) higher in mean Mg content, which might be due to higher leaching losses from this horizon (Brady and Weil, 2013). The mean values for exchangeable sodium (Na) in the soils ranged from 0.29 to 0.55 cmol (+)/kg soil and were substantially rated high as per rating scale by Malgwi (2007). Similar values had earlier been reported by Ogbodo (2011) who also, attributed this high value to deposition of salts on the soil as the flood water receded, leaving salt crusts and crystals upon evaporation. Babalola *et al.* (2011) however, attributed it to the nature of parent material (colluvia and alluvia) and use of low quality water for irrigation. Soils under rice cultivation recorded a highly significantly ($p<0.01$) lower Na content which could be attributed to higher leaching losses. However, there was no significant ($p>0.05$) variation in mean sodium content across the soil depth. The mean exchangeable potassium (K) values between sampling units and soil horizons ranged from 0.49 to 0.53 cmol (+)/kg and were rated high (Malgwi, 2007). Salem, *et al.* (2018) also reported high K values while assessing variations in the soil exchangeable bases along toposequences, in Gombe State, Nigeria. There was no observed significant ($p>0.05$) difference in mean K content between the various land uses. However, the surface horizon recorded a significantly ($p<0.05$) higher mean K content across depth which was similar to the findings of Adisa *et al.* (2016), and attributed to more intense weathering, release of labile K from organic residue and application of chemical fertilizers containing K (Sai Kumar *et al*., 2013).

Pedogenic forms of Iron (Fe) oxides

The values of the amorphous form of iron oxide (Feox) across land uses and horizons ranged from 2.07 to 3.82 g/kg (Table 3). These values were higher than those reported by Maniyunda and Raji, (2017), even though they are generally regarded as low. Osayande *et al.* (2016) attributed low values of Feox in soils to less weathered soils as the parent materials contain very high weatherable minerals. It is also observed in this study that, both land use and soil depth did not

significantly ($p>0.05$) influence the variability of the mean Feox distribution (Table 3). Osodeke *et al.* (2005) also reported similar observation while assessing the Sesquioxides distribution along a toposequence in Umudike area of Southeastern Nigeria. However, the crystalline form of iron oxide (Fed) mean content for the studied soils across land uses and horizons ranged from 10.25 to 13.98 g/kg, which falls within the values earlier reported by Ajiboye *et al.* (2015) and Maniyunda and Raji (2017).

Table 3: Pedological forms of iron oxides, across different land uses and horizons

	Feox (g/kg)	Fed (g/kg)	Fep (g/kg)	Feox/Fed (g/kg)
Land Uses				
Amaranth	3.82	10.84[c]	0.76	0.36
Millet	2.07	10.25[c]	0.76	0.21
Mango	3.29	12.76[b]	0.58	0.26
Rice	2.42	13.98[a]	0.71	0.18
Tomato	3.33	12.77[b]	0.43	0.24
LSD ($p<0.05$)	*2.23*	*0.88*	*0.30*	*0.19*
LOS	NS	***	NS	NS
Soil Horizon				
Surface	3.32	12.38	0.64	0.28
Subsurface	2.65	11.86	0.65	0.22
LSD ($p<0.05$)	*1.41*	*0.55*	*0.19*	*0.12*
LOS	NS	NS	NS	NS

LOS (Level of significant) (p): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.001, Feox=oxalate extractable iron, Fed=diotonite extractable iron, Fep=pyrophosphate extractable iron

Note: Means followed by the same letters in the column are not significantly different at 5% LOS

Soils under rice cultivation recorded a higher ($p<0.001$) soil content of Fed and this might be attributed to abundance of ferromagnesian minerals (Maniyunda and Raji, 2017) or an advanced stage of pedological process. There was an observed increase in soil mean Fed content with depth which was similar to the trend that was also observed by Ajiboye *et al.* (2015) and Maniyunda and Raji (2017). This trend could be attributed to co - translocation of Fe with clay from surface to subsoil horizons through elluviation-illuviation processes (Jelic *et al.*, 2011). Maniyunda and Raji (2017) had re-

ported a significant positive correlation between Fed and clay which further affirm this process.The values for crystalline form of Fe (Fed) obtained in this study was higher than the amorphous form (Feox) in the studied soils; an observation corroborated by the findings of Osayande *et al.* (2016) and Maniyunda and Raji (2017) while assessing the profile distribution of crystalline and amorphous sesquioxides in their various studies. The higher values of Fed compared to Feox was an indication that a considerable fraction of Fe may be present in crystalline form. According to Seal, *et al.* (2006), high temperature condition and the prolonged dry season as is characteristic of the study area, may be responsible for higher amount of crystalline Fe fraction in soils. The mean values for soil Fep content recorded across land uses and horizons for the studied soils ranged from 0.43 to 0.76 g/kg (Table 3). The values of Fep obtained in this study were lower than the range earlier reported in established forest in the Southern Guinea Savanna zone of Nigeria (Samndi *et al.*, 2006). The general low extractable values of Fep might be attributed to well drained condition of the soils which had been noted to promote strong weathering and crystallization of Fep in soils (Hassan *et al.*, 2004).

Active iron ratio (Feox/Fed)

Active iron ratio is defined as the amorphous form divided by the crystalline form of iron oxide (Feox/Fed), and has been used in evaluating soil development and weathering (Omenihu *et al.*, 1994). It indicates the reactivity of sesquioxides and the relative amounts of the amorphous and the crystalline oxides in a soil (Omenihu *et al.*, 1994) and classifying soils into well drained and poorly drained conditions (Stonehouse and Amaud, 1971). The mean data for active iron ratio across land uses and horizons ranged from 0.18 to 0.36 (Table 3). The values obtained in this study are within the range earlier reported (Camêlo *et al.*, 2017). The obtained range of active iron ratios was found to be low (<0.4) across all the land use systems, an indication that the soils of the study area were generally young soils. According to Mahaney *et al.*, (1991), soils with high ratios were younger soils, whereas low ratios are indicative of older soils. The higher mean active Fe ratio of 0.36 and 0.28 recorded in soils under amaranth production and the surface horizon, respectively, suggest that the soils were relatively less weathered when compared to other land uses and the subsurface horizon. Active iron ratio is also an index used in describing the proportion of the amorphous and crystalline iron contents of soils (Obi *et al.*, 2009). The values of active iron ratios (Feox/Fed) (<0.4) obtained confirmed that most of the Fe in the soils in this study was in the crystalline rather than the amorphous forms. The values further suggest that the degree of crystallinity of the Fe fraction is higher than those reported by Obi *et al.* (2009) for some basement complex soils in Southeastern Nigeria.

As for drainage condition, the soils under amaranth cultivation with 0.36 active iron ratio is classified as poorly drained, while soils under mango, tomato, millet and rice cultivation which recorded 0.26, 0.24, 0.21 and 0.18 active iron ratios, respectively are well drained. According to Stonehouse and Amaud (1971), soils with active iron ratio of higher than 0.35 are poorly drained, while well drained soils have values lower than 0.35.

CONCLUSION AND RECOMMENDATIONS

Based on the above results the silt/clay ratio, different forms of iron oxides, Feox/Fed

and the disposition of crystalline and amorphous forms of Fe all gave a consistent information on the the stage of development of the studied soils. The higher values of Fed as compared to Feox and Fep and the generally low active iron ratios of (<0.4) obtained is an indication of the predominance of the crystalline forms as against the amorphous forms of Fe, which is indicative of an early stage of development of the soils, while the direction of soil development with increase in age followed the trend; amaranth < mango < millet < tomato <rice. The general agronomic constraints of the soils were low nutrient reserve, acidic reaction and high P fixation conditions. Effective management practices such as periodic monitoring of soil quality, addition of organic manure and guided inorganic fertilizer use are recommended for sustainable agricultural productivity of the soils.

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ARTIFICIAL NEURAL NETWORK MODELLING OF ABOVEGROUND BIOMASS FROM TROPICAL RAIN FORESTS IN NIGERIA

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ABSTRACT

This study investigated the impact of applying artificial neural networks (ANNs) with different input variables and different architectures to estimate aboveground biomass (AGB) using allometric data from tropical forests in Southwestern Nigeria. The study also compared the result of ANNs with linear regression. Three fully connected feed-forward neural networks (all four-layer) with backpropagation of error were used in this study. They had two hidden layers: the first two had topography [2, 3, 3, 1], and the third had topography [3, 5, 5, 1]. Rectified Linear Unit (ReLU) activation function was used for all networks; Mean Squared Error (MSE) was used as the loss function. A learning rate of 1e-06 and 1000 iterations was used to run the first two ANNs, and a learning rate of 1e-06 and 1850 iterations was used to run the third. Maximum loss for each neural network was 12.8393, 12.0371, and 0.2078, respectively, while minimum loss was 0.0391, 0.0408, and 0.1559, respectively. Accuracy was measured using Root Mean Squared Error (RMSE) with the training for each neural network RMSE's being 0.1997, 0.2113 and 0.3949 while test RMSE's was 0.2199, 0.2284, and 0.3812 for each neural network.

Keywords: Aboveground Biomass, Neural Network, Regression, ReLU, RMSE

DOI:

INTRODUCTION

Forests play an important role in global carbon cycling because they act as carbon sinks and sources for atmospheric CO2 (Pan *et al.* 2011; Chave *et al.* 2014). Forest aboveground biomass (AGB) is an indicator for assessing forest ecosystem productivity and health as well as an indicator for determining the potential for carbon storage and carbon sink, as well as an important parameter for estimating carbon emissions and disturbances caused by land use and climate change (Baccini *et al.*, 2017 and Rodríguez-Soalleiro *et al.*, 2018). More accurate estimation of trees aboveground biomass (AGB) in forests is needed to determine commercial use of forest production, stand density, fuel and bio-energy contribution, and the role of forest biomass in the global carbon cycle. Currently, the most accurate methods for obtaining forest AGB are the use of the site- and species-specific allometric equations based on measured forest biometric parameters, such as the diameter at breast height

(DBH), height, crown closure, and stem density (Chave *et al.* 2014; Ali *et al.* 2015; Paul *et al.* 2015).

There are major concerns with selecting the best regression model to estimate tree AGB in natural forests. Stevens, (2009) declared that because many growth data empirically turned out to align along a straight line when plotted in log-transformed scales, power models have played a substantial role in allometry. In contrast, others opined that allometry should go beyond power-law models because the growth data do not exactly align along a straight line in log-log plots (Bernacci *et al.*, 2000 and Picard *et al.*, 2015). However, Sileshi, (2014) argued that some allometric equations are dubious due to lack of taking into consideration some validation indicators like collinearity among the predictors and reliability of parameters estimate.

To reexamine the issue of whether or not power-law models are the best predictors for biomass estimation, an artificial neural network (ANN) based system was used to be compared to a traditional allometric method (regression analysis). There has been a substantial increase in the interest in artificial neural networks (ANNs) during the last 15 years (Kumar *et al.*, 2015). Considering the complexity of relationships between the response and explanatory variables and of different views and major concerns associated with allometric equations application for prediction of trees AGB, ANN may be the best alternative to decrease the obscurity of biomass estimation.

MATERIALS AND METHODS

Data Collection

A Forest inventory-based approach was adopted to estimate above-ground tree biomass in the study areas. Transects were distributed over the entire forest, using a systematic segmented grid (Buckland *et al.*, 2004) randomly superimposed onto the area. There were 5111 plots of 30 × 30m in Omo Biosphere Reserve. The forest inventory was conducted in 50 plots of 30 × 30m sample plots which was 1% sample intensity. All the trees in each sample plot were labelled with the use of paper tape and markers to avoid leaving out any tree and also for easy identification. Data were also collected for model validation on 9 plots of 30 × 30 m in Akure Forest Reserve. Field measurements of tree variables were carried out using relascope, Haga altimeter, increment borer, scale weight, measuring tape, ranging pole, and Global Positioning System (GPS).

Determination of Biomass and Carbon Stock in the Study Area

Measurement of total height

This is the vertical distance between the ground level and the tip of a tree. It is obtained by taking the reading at the top (RT) and reading at the base (RB) which is usually negative (when on an elevated ground) and positive (when in a depressed ground or valley). It was measured with the aid of Spiegel Relaskop.

Total height (H), using the metric scale was obtained by:

$$H = RT\text{-}RB \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where is the height, is the reading at the top, and is the reading at the base.

Measurement of tree diameter at Breast height (DBH)

This is the diameter measurement taken for a standing tree at height 1.30 m above the ground level. This tree parameter was taken for trees within the permanent sample plots.

This measurement is generally accepted in forest inventory (Elzinga *et al.*, 2005). It is the easiest measurable parameter in forest inventory with high degree of accuracy where guiding rules are followed. It was measured with the aid of diameter tape in centimetres (cm).

Diameter at middle (Dm) and Diameter at the top (Dt) were also measured at various positions on the standing tree using Spiegel relaskop. Readings for Dm and Dt were taken in terms of numbers of bands of the relaskop occupied by the stem of the trees both at the middle and the top. These bands of relaskop are of two types: dark bands which are one unit each and big white bands which are four units each.

Wood Density

To determine the specific wood density, core samples were collected for each species at breast height. The specific wood density is the arithmetic average value of all samples of a species and were calculated as oven dry weight divided by fresh volume of each sample. The inner diameter of the bit of the increment borer device was 0.5 cm leading to a diameter of the sample of 0.5 cm. The length L of the sample was measured after its extraction. The oven dry density (ϱ) in terms of dry mass per fresh volume (g/cm^3) of all collected wood samples was estimated using

$$\rho = \frac{4dMSi}{\pi d^2 Li} \qquad \ldots\ldots\ldots (2)$$

Where $dMSi$ is the dry mass of wood sample i obtained by the increment borer, d is the diameter of the bit, and Li is the length of the sample i.

Data Processing and Analysis

Basal Area Estimation

Tree Basal Area (TBA) is the cross-sectional area (over the bark) at breast height (1.3 metres above the ground) measured in metres squared (m^2). The TBA can be used to estimate tree volumes and stand competition. The Tree Basal Area was determined by measuring the diameter at breast height in centimetres and the basal area (m^2) was calculated using an equation based on the formula for the area of a circle (area = πr^2 where r = radius and π = 3.142) and the formula for radius (r =diameter/2 = DBH/2).

$$BA(m^2) = \pi r^2 * DBH(cm)^2 /4 \qquad \ldots(3)$$

Volume Estimation

Volume for each tree was estimated using the Newton's formula

$$V = \pi H \left(\frac{Db^2 + 4Dm^2 + Dt^2}{24} \right) \qquad \ldots\ldots\ldots(4)$$

Where V is the stem volume (m^3), H is the total height (m), Db is the diameter at base (cm), Dm is the diameter at the middle (cm), and Dt is the Diameter at the top (cm).

Above-Ground Biomass (AGB) Calculation

The above ground biomass (AGB) for each tree was estimated using the formula:

$$AGB = V \times \rho \times B_{ef} \qquad \ldots\ldots\ldots(5)$$

Where AGB (t/ha) measured in tonne per hectare is the aboveground biomass of the tree, V is the volume of tree (m^3/ha) measured in cubic metre per hectare, ρ is the specific wood density (t/m^3), and B_{ef} is the biomass expansion factor.

Regression Model Development

Based on the data collected, three equations were developed. Prior to the establishing of the allometric equation, scatter plots were used to ascertain that the relationship between independent and dependent variables was linear. Furthermore, several allometric relationships between independent and dependent variables were tested. The independent variables included DBH (D), height (H) and wood density (W), whereas, the dependent variable was AGB (A).

$$\ln(A) = \alpha + \beta(DH) \quad \ldots\ldots(6)$$

$$\ln(A) = \alpha + \beta(D^2H) \quad \ldots\ldots(7)$$

$$\ln(A) = \alpha + \beta(D^2HW) \quad \ldots\ldots(8)$$

Where: ln is the natural logarithm; α is the intercept; β and is the slope.

Model Development for Artificial Neural Networks

Three fully connected feed forward neural networks (all four–layer) with backpropagation of error were used in this study. They had two hidden layers: the first two had topography 2, 3, 3, 1, and the third had topography 3, 5, 5, 1. Rectified Linear Unit (ReLU) activation function was used for all networks, and half of the Mean Squared Error (HMSE) was used as the loss function.

Let W_i and b_i be the vector of weights and biases for layer i of the neural network. The weights and biases for all layers of the neural networks were randomly initialized from a normal distribution with arbitrary minimum and maximum values.

Forward Propagation

Let Z_1 be the sum of the vector of biases for the first layer b_1 , and the dot product of the input vector X_{OAV} and the weight of the first layer W_1 such that:

$$Z_1 = b_1 + X_{OAV} \cdot W_1 \quad \ldots\ldots\ldots\ldots(9)$$

Let z be an element of Z_i for layer i, the input vector for layer i + 1 denoted by A_i is derived by the application of the activation function (Rectified Linear Unit or ReLU) (Fukushima, 1980; Nair & Hilton, 2010; and Schmidhbuer, 2014) on each element of Z_i such that:

$$A_i = ReLU(Z_i) \quad \ldots\ldots\ldots\ldots(10)$$

Where ReLU performs a threshold operation to each input element where values less than zero are set to zero, such that:

$$f(z) = \max(0, z) \quad \ldots\ldots(11)$$

Generalizing (11) above subsequently for layer i of the neural network, we have:

$$Z_i = b_i + A_{i-1} \cdot W_i \quad \ldots.(12)$$

The output vector of the neural network is given as:

$$\hat{Y}_{AGB} = ReLU(Z_f) \quad \ldots..(13)$$

Where $\hat{Y}_{AGB}$ is the vector of the predicted output variable; and Z_f is the sum of the bias vector and the dot product between the input vector and weight vector of the final layer.

Loss Function

The loss function used is the Mean Squared Error (MSE) and is defined as:

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_{AGB} - \hat{Y}_{AGB}\right)^2 \quad \ldots\ldots(14)$$

Back Propagation

Differentiating the Loss Function MSE in (14) with respect to $\hat{Y}_{AGB}$, results in:

$$\frac{\partial MSE}{\partial \hat{Y}_{AGB}} = \frac{2}{n}\sum_{i=1}^{n}\left(Y_{AGB} - \hat{Y}_{AGB}\right) \tag{15}$$

From (13) above, differentiating the output vector of the neural network $\hat{Y}_{AGB}$ with respect to Z_f is given by:

$$\frac{\partial \hat{Y}_{AGB}}{\partial Z_f} = \partial ReLU(Z_f) \tag{16}$$

Where $\partial ReLU(Z_f)$ is defined by

$$f(z) = \begin{cases} 0 \; if \; z < 0 \\ 1 \; if \; z > 0 \end{cases} \tag{17}$$

Differentiating the Loss Function MSE with respect to Z_f is given by:

$$\frac{\partial MSE}{\partial Z_f} = \frac{\partial MSE}{\partial \hat{Y}_{AGB}} \times \frac{\partial \hat{Y}_{AGB}}{\partial Z_f}$$

$$= \frac{2}{n}\sum_{i=1}^{n}\left(Y_{AGB} - \hat{Y}_{AGB}\right) \times \partial ReLU(Z_f) \tag{18}$$

From (12) above, differentiating Z_i with respect to Z_{i-1} is given by:

$$\frac{\partial Z_i}{\partial Z_{i-1}} = \frac{\partial Z_i}{\partial A_{i-1}} \times \frac{\partial A_{i-1}}{\partial Z_{i-1}}$$

$$= \frac{\partial Z_{i+1}}{\partial Z_i} \times \partial ReLU(Z_{i-1}) \tag{19}$$

Differentiating Z_i in (12) with respect to W_i results in:

$$\frac{\partial Z_i}{\partial W_i} = {A_{i-1}}^{T} \cdot \frac{\partial A_i}{\partial Z_i} \tag{20}$$

Differentiating Z_i in (12) with respect to b_i results in:

$$\frac{\partial Z_i}{\partial b_i} = \sum_{j=1}^{n}\frac{\partial Z_i}{\partial W_i} \tag{21}$$

Let τ be the learning rate of the neural network. The vector of weight W_i and bias b_i for each layer i are updated by the following equations:

$$W_i = W_i - \tau * \frac{\partial Z_i}{\partial W_i} \tag{22}$$

$$b_i = b_i - \tau * \frac{\partial Z_i}{\partial b_i} \tag{23}$$

Accuracy

Accuracy was measured using Root Mean Square Error (RMSE) defined as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Y_{AGB} - \hat{Y}_{AGB}\right)^2} \quad (24)$$

Analysis

Analysis was carried out using Python Programming Language version 3.8 (Van Rossum & Drake, 2009). Packages used include NumPy (Oliphant, 2006; van der Walt *et al.*, 2011), Matplotlib (Hunter, 2007), Pandas (McKinney & others, 2010), SciPy (Virtanen *et al.*, 2020), and Scikit-learn (Pedregosa *et al.*, 2011). Data were split into two parts: training set (80%) and validation set (20%).

Regression analysis was first carried out on the data, using the allometric models in equations 6, 7 and 8 above to estimate parameters α and β. The resulting estimated parameters were thereafter used to create regression models between the dependent variable (In (AGB)) and the independent variable (In(DH), In(D^2H), In(D^2HW)) of each allometric models. The input data from the validation set is then inputted in the regression model to predict $\widehat{ln\ (AGB)}$. For the ANN models, a learning rate of 1e-06 and 1000 iterations was used to run the first two ANNs, and a learning rate of 1e-06 and 1850 iterations was used to run the third. The predicted values for both the regression and ANN models were compared with the test values and accuracy was measured with Root Mean Square Error (RMSE).

RESULTS AND DISCUSSION

The output variable In(A) had a mean of 4.135 and a standard deviation of 0.679. It also had a strong correlation concerning all input variables used in this study. With a mean of 6.524 and standard deviation of 0.689, the first explanatory In(DH) variable had a covariance of 0.382041 and a correlation of 0.815684 with respect to the output variable In(A). In(D^2H) had a mean of 10.119 and standard deviation of 1.136, and it had a covariance of 0.624536 and correlation of 0.808669 concerning In(A). In (D^2HW) had a covariance of 0.629540 and correlation of 0.850021, with a mean of 9.605 and standard deviation of 1.089.

Table 1: Summary of Explanatory Variables and Regression Model Details

Explanatory Variable	Covariance	Correlation	Mean	Standard Deviation	Rsq	Intercept (α)	Slope (β)
$\ln(DH)$	0.382041	0.815684	6.524	0.689	0.646596	-1.1174	0.8066
$\ln(D^2H)$	0.624536	0.808669	10.119	1.136	0.63298	-0.7326	0.4817
$\ln(D^2HW)$	0.629540	0.850021	9.605	1.089	0.6937	-0.9025	0.5250

Linear Regression Models

The regression models were all good fit for their respective variables (Table 1; Figure 1). The intercept and slope for the regression models were -1.1174 and 0.8066 for In (DH), -0.7326 and 0.4817 for In(D^2H), and -0.9025 and 0.5250 for In(D^2HW) (Figure 1). The R-squared values were 0.646596, 0.63298, and 0.6937 for In(DH), In(D^2H), and In(D^2HW) respectively (Table 1).

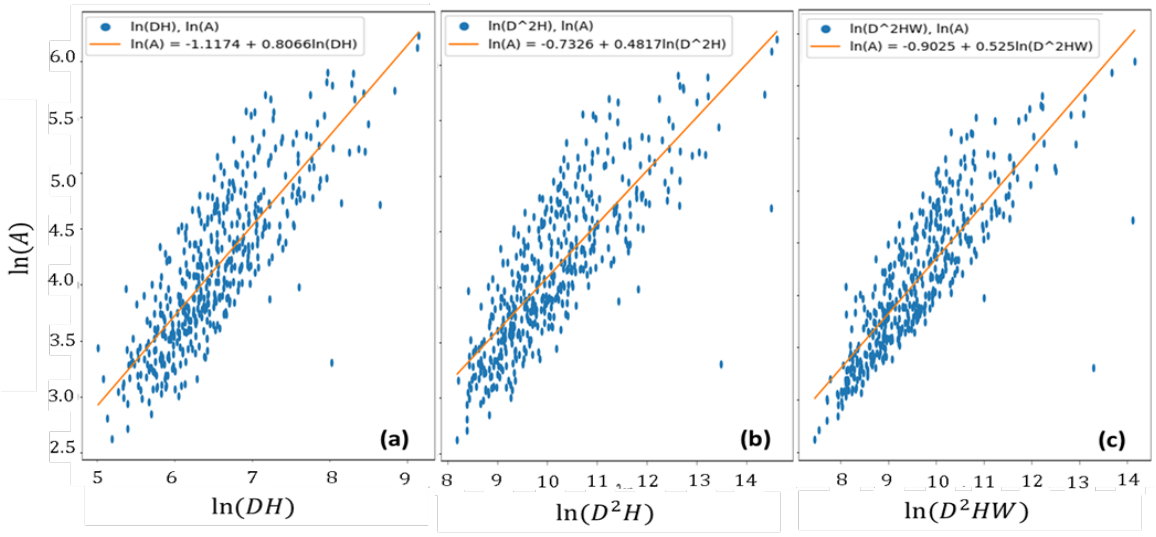

Figure 1: Scatter plot of the variables under Study with Regression Line

Artificial Neural Networks

The input variables used in the linear regression modelling were slightly altered for the ANNs to be able to accommodate them. From the laws of logarithm, the input variables in equations 6, 7, and 8 can each be rewritten as a linear combination of the natural logarithm of the individual allometric measurements that make up the variable.

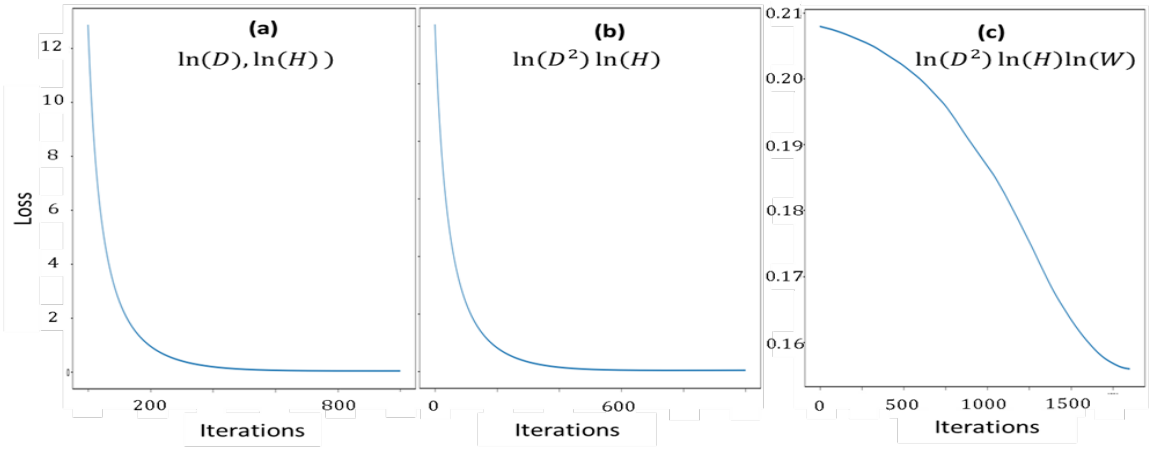

Figure 2: Graphs Training Loss against number of Iterations for each Neural Network

$$\ln(DH) = \ln(D) + \ln(DH) \tag{25}$$

$$\ln(D^2H) = \ln(D^2) + \ln(H) \tag{26}$$

$$\ln(D^2HW) = \ln(D^2) + \ln(H) + \ln(D^2HW) \tag{27}$$

The values on the right-hand side of equations 25, 26, and 27 make up the input variables for the respective ANNs under study (Table 2, Table 3, and Table 4). The first and second ANNs (Figure 3, Figure 4) showed a rapid decline rate of training loss with fewer iterations, while the third ANN (Figure 5) showed a less steep decline with more iterations (Figure 2).

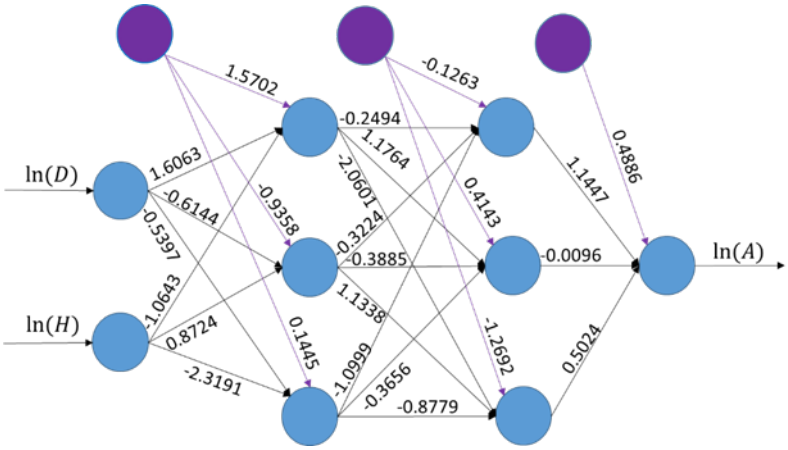

Figure 3: Architecture of the First Neural Network

Table 2: Weights and Biases of the First Neural Network

Layer 1	**Bias**	$\ln(D)$	$\ln(H)$	
Node 1	1.5702	1.6064	-1.0643	
Node 2	-0.9358	-0.6143	0.8724	
Node 3	0.1445	-0.5397	-2.3192	
Layer 2	**Bias**	**Layer 1**	**Layer 1**	**Layer 1**
		Node 1	**Node 2**	**Node 3**
Node 1	-0.1263	-0.2494	-0.3224	-1.0999
Node 2	0.4143	1.1764	-0.3885	-0.3656
Node 3	-1.2692	-2.0601	1.1338	-0.8779
Layer 3	**Bias**	**Layer 2**	**Layer 2**	**Layer 2**
		Node 1	**Node 2**	**Node 3**
$\ln(A)$	0.4886	1.1447	-0.0096	0.5025

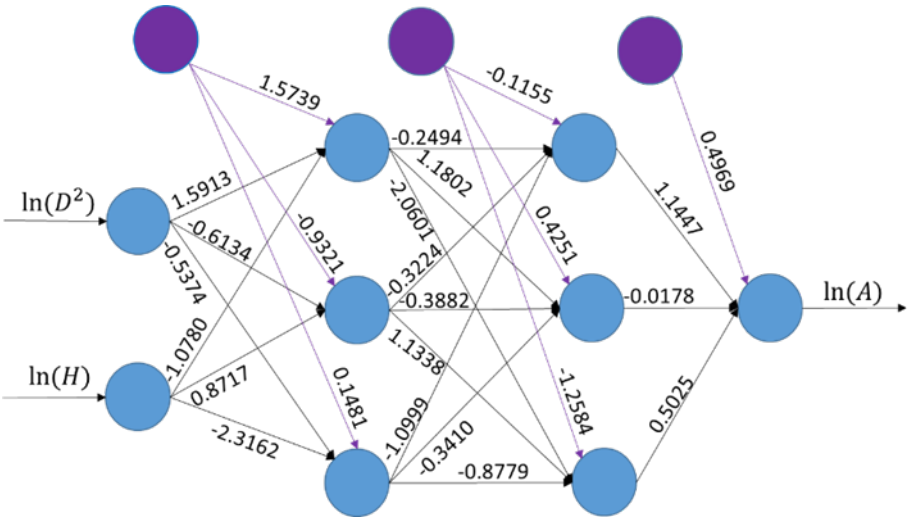

Figure 4: Architecture of the Second Neural Network

Table 3: Weights and Biases of the Second Neural Network

Layer 1	**Bias**	$\ln(D^2)$	$\ln(H)$	
Node 1	1.5739	1.5913	-1.0780	
Node 2	-0.9321	-0.6134	0.8718	
Node 3	0.1481	-0.5374	-2.3163	
Layer 2	**Bias**	**Layer 1**	**Layer 1**	**Layer 1**
Node 1	-0.1155	-0.2494	-0.3224	-1.0999
Node 2	0.4251	1.1802	-0.3882	-0.3410
Node 3	-1.2584	-2.0601	1.1338	-0.8778
Layer 3	**Bias**	**Layer 2**	**Layer 2**	**Layer 2**
$\ln(A)$	0.4969	1.1447	-0.0178	0.5025

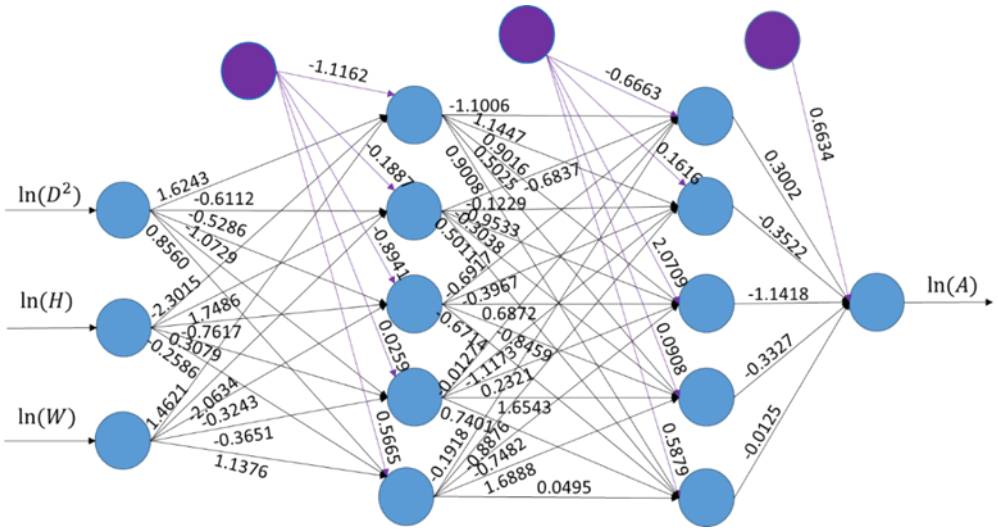

Figure 5: Architecture of the Third Neural Network

Table 4: Weights and Biases of the Third Neural Network

Layer 1	**Bias**	$\ln(D^2)$	$\ln(H)$	$\ln(W)$		
Node 1	-1.1162	1.6244	-2.3015	1.4621		
Node 2	-0.1887	-0.6113	1.7486	-2.0634		
Node 3	-0.8941	-0.5287	-0.7617	-0.3244		
Node 4	0.0260	-1.0730	0.3080	-0.3651		
Node 5	0.5666	0.8560	-0.2586	1.1377		
Layer 2	**Bias**	**Layer 1 Node 1**	**Layer 1 Node 2**	**Layer 1 Node 3**	**Layer 1 Node 4**	**Layer 1 Node 5**
Node 1	-0.6663	-1.1006	-0.6837	-0.6917	-0.0127	-0.1918
Node 2	0.1616	1.1447	-0.1229	-0.3968	-1.1173	-0.8876
Node 3	2.0709	0.9016	-0.9533	-0.6872	0.2321	-0.7482
Node 4	0.0909	0.5025	-0.3038	-0.8459	1.6543	1.6888
Node 5	0.5879	0.9009	0.5011	-0.6714	0.7401	0.0495
Layer 3	**Bias**	**Layer 2 Node 1**	**Layer 2 Node 2**	**Layer 2 Node 3**	**Layer 2 Node 4**	**Layer 2 Node 5**
$\ln(A)$	0.6634	0.3002	-0.3523	-1.1418	-0.3327	-0.0125

Comparative Accuracy Analysis

The training RMSE's for the linear regression models were 0.3967, 0.4043, and 0.3693 while the test RMSE's were 0.3761, 0.3784, and 0.3060 (Table 5).

Table 5: Model Accuracy Measurement

Model Type	Explanatory Variables	RMSE	
		Training	Test
Linear Regression	$\ln(DH)$	0.3967	0.3761
	$\ln(D^2H)$	0.4043	0.3784
	$\ln(D^2HW)$	0.3693	0.3060
Neural Network	$\ln(D)$, $\ln(H)$	0.1997	0.2199
	$\ln(D^2)$, $\ln(H)$	0.2113	0.2284
	$\ln(D^2)$, $\ln(H)$, $\ln(W)$	0.3949	0.3812

Maximum loss for each neural network was 12.8393, 12.0371, and 0.2078, while minimum loss were 0.0391; 0.0408; and 0.1559. Accuracy was measured using Root Mean Squared Error (RMSE) with the training RMSE' as 0.1997, 0.2113 and 0.3949, while test RMSE's was 0.2199, 0.2284, and 0.3812 for each neural network.

This study investigated the impact of applying ANNs with different input variables and different architectures to estimate AGB using allometric data from tropical forests in Southwestern Nigeria. The study also compared the result of ANNs with linear regression and found out that the ANN models performed better than the linear regression models. Two things were a factor in the accuracy of the models. The first was the number of input variables. The models with more input variables performed better than other models within the same category. In conclusion, the architecture of the neural network, and the nature and number of the input variables are significant factors in the accuracy of the ANN models. Also, ANNs are a valuable way of modeling AGBs.

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EVALUATION OF HEAVY METAL CONCENTRATION IN BODY FLUID OF THE INHABITANTS LIVING ALONG ABA RIVER, ABIA STATE, NIGERIA

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ABSTRACT

River pollution and its health effects has been one of the main issues in urban water management in Nigeria and globally due to the ever increasing population and developmental activities. Aba River is being polluted by a number of domestic, industrial and commercial activities. The aim of the study was to evaluate the concentrations of some heavy metals in body fluids of the inhabitants living along Aba River, Abia State, Nigeria, using water and blood samples. Water samples were collected from locations along the river within the six selected communities. The communities were purposely targeted for medical outreach. Convenience sampling was used to select people for blood samples test. Water and blood samples collected were analysed in the laboratory for heavy metals. The water results were compared with national standards. Two-way ANOVA and Pearson correlation co-efficient were used to determine significant differences among the communities and seasons, relationships between metals in water and metals in blood. The results identified 8 heavy metals of varying concentrations in the water and blood samples collected. The dominant metals were: Zinc, Manganese, Iron and Lead recorded in higher concentrations in water in the downstream stations and dry season as well as in blood samples in the communities. Some of the heavy metals in water exceeded acceptable limits while the blood levels though high, were still within cut off levels. High levels of Zn, Mn, Fe and Pb recorded in the bloods portends potential public health risk. A drastic action must be taken to stem the trend.

Keyword: Blood, Diseases, Heavy Metals, Permissible Limit, Population, Water

DOI:

INTRODUCTION

Water quality has become a major challenge in the world today; as it is being polluted by industrial and urban wastes generated largely by human activities (Ojutiku and Okojevoh, 2017). The main anthropogenic sources of heavy metals contamination of water, sediment and aquatic animals are industrial activities, mining, agriculture and disposal of untreated and partially treated effluents containing toxic metals (Huang *et al.*, 2020; Desiree *et al.*, 2021; Anyanwu *et al.*, 2022a and b). Heavy metal contamination has become a global problem due to inherent

bioaccumulation and biomagnification potentials and their long-term persistence in environmental compartments (Wang *et al*., 2014; Dhar *et al*., 2020 Gao *et al*., 2020; Zeng *et al*., 2020) warrants constant monitoring. Heavy metal contamination of rivers (like Aba River) flowing through cities is a major problem in the developing countries (Maigari *et al*., 2016; Amah-Jerry *et al*., 2017). Heavy metals were found in body fluids of inhabitants living along the river channels and using the water for various purposes (Gupta *et al*., 2022). Body fluids are liquids within the human body, that help transport nutrients or expel waste from cells (New Health Guide, 2016) and the most common is the blood. Due to uncontrolled pollution levels driven by causative factors like industrial growth and heavy increase in traffic using petroleum fuels (Egbuonu *et al*.,2018), the blood system of most inhabitants living along or using water from heavily polluted rivers are contaminated (Nouri, *et al*., 2008; Gupta *et al*., 2022).

Aba River is the main source of water for the residents and the numerous industries and commercial establishments in the Aba metropolis. The river has been consistently and extensively used for drinking, laundering, bathing, swimming, livestock watering and irrigation, especially during the dry season. With wastes from industries and commercial establishments being discharged into the river, the water quality has deteriorated drastically. (Amadi, 2012; Amah-Jerry *et al*. 2017; Nwankwoala and Ekpewerechi 2017; Egbuonu *et al*., 2018). After the introduction, heavy metals may accumulate in aquatic life, enter the food chain and cause serious harm to human health where contamination and exposure are significant (Maigari, *et al*., 2016). Accumulation of heavy metals in humans can result in a number of health conditions - skin diseases, abdominal cramps, acute abdominal pain, diarrhoea, cold, fever, cough and headache (NORD, 2006). Consequently, most heavy metals (Zinc, Mercury, Iron, Copper, Manganese, Chromium, Lead, Nickel, Cadmium and Arsine) have been listed as metals that can cause diseases by the United States Environmental Protection Authority (USEPA) based on their potential for human exposure and health risks (Birungi *et al*., 2007). The degree of environmental contamination depends on type of heavy metal, aquatic species, trophic level and feeding pattern (Asuquo *et al*., 2004).

Aba River has been extensively studied by researchers over the years (Ezeama and Nwamkpa, 2002; Amadi, 2012; Mgbemena, 2014; Amah –Jerry *et al*., 2017; Nwankwoala and Ekpewerechi, 2017; Egbuonu, 2018). However, there is limited knowledge on the effect of heavy metal contamination of Aba River on the inhabitants of the area. Hence, this study is aimed at evaluating the heavy metal concentration in body fluid of the inhabitants living along Aba River.

Study Area

Aba River, a tributary of Imo River is the major river flowing through Aba town (Figure1). It is located between latitudes 5° 05'N to 5°30'N and Longitudes 7°15'E to 7° 40'E (Figure1) and is characterized by relatively low elevation and near flat topography (Uma, 1989) which enhances its runoff. The River flows in North-South direction and joins the Imo River (Ezigbo, 1989). The river is recharged by precipitation and groundwater (Uma, 1989; Amadi *et al*., 2010). Aba town is within the sub-equatorial climate zone; characterized by high temperatures and heavy rainfall. The area is characterized by the wet season (May to October) and dry

season (November to April); a double maxima rainfall with peaks in July and October with "August break" (short period of dryness) usually occurring in August in between the peaks.

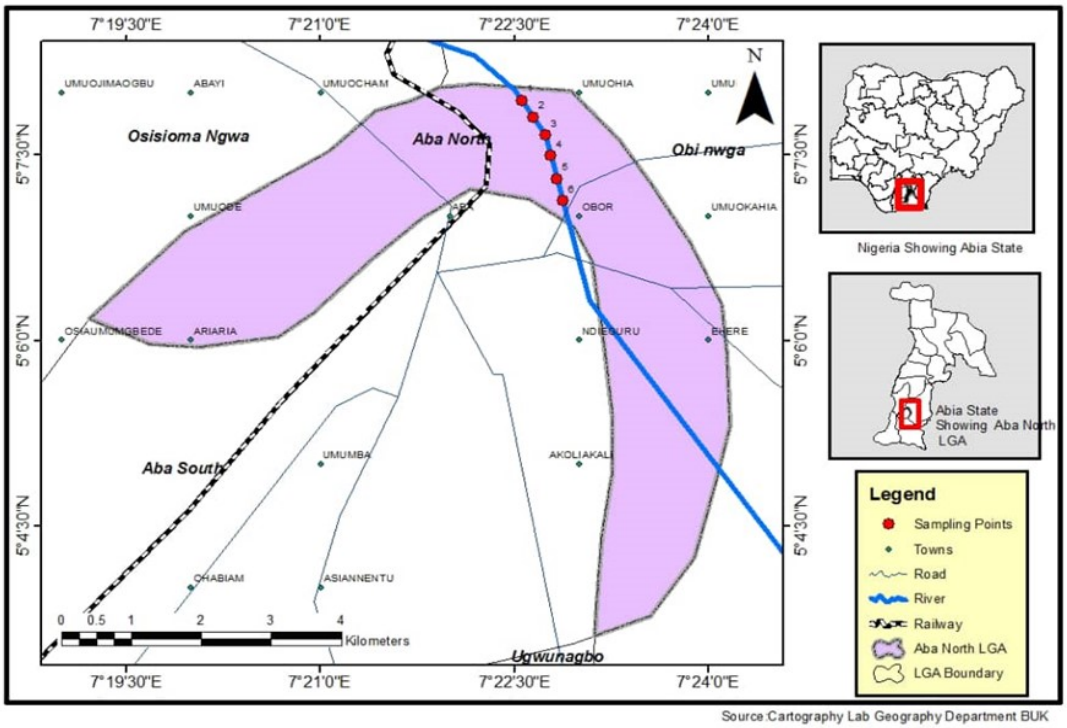

Figure 1: Map of Aba, Abia State, Nigeria showing the sampling stations of Aba River.

Anthropogenic Activities in the study area

Landuse pattern shows that in station 1, landuse is used for both animal and crop farming while key water uses are for irrigation and laundry (Table 1). Stations 2,3,4,5 and 6 have common land uses of commercial and residential. Stations 1 and 2 have land uses covering industrial land use (Table 1). Stations 5 and 6 have a key water usage for domestic uses while station 3 has a key water usage for abattoir (Table 1).

Table 1: Summary of Human Activities carried out at the Sampling Sites

S/ NO	Sampling Site	Land use	Key Uses of Water	River water colour	Type of crops Cultivated	Other activities
1	OkpourUmuobu	Piggery, industries and farming	Irrigation and for Piggery	Light brown	cassava, maize and vegetables	Fishing, Car workshops, dredging and Battery charging, piggery.
2	Emmanuel Ave.	Residential	Laundry	Light brown	Plantain, Bananas and Cassava	Laundry, Swimming, and Car workshops
3	Umuoba Road	Residential	Laundry and Swimming	Greenish	Maize and Vegetables	Laundry, Swimming, dredging activity, abattoir, fetching water for domestic uses and Car workshops
4	AhiaUdele	Industrial, residential and commercial (Abattoir)	Abattoir activities	Greenish and reddish in some area		Swimming,dredging activity, car wash, laundry, open defecation, and electroplating and battery charging.
5	Peoples Road 1	commercial, residential and industrial	Domestic uses	Greenish and reddish in some area	-	Refuse dump, swimming, dredging activity, fetching water for domestic uses, electroplating and battery charging.
6	Peoples Road 2	Commercial and residential	Domestic uses	Greenish	Cassava and maize	Laundry, dredging activity, defecation, swimming, electroplating, car workshops and car washing.

Source: Field work 2020

METHODOLOGY

Water sample collection, analysis and quality control

Six water samples were collected using 1-L plastic bottles, at a depth of 1 meter below the surface of the river. The samples were collected on the 24th of August 2019 and 24th January 2020 between 7am and 12 noon. The samples were collected from Okpolour Umuobu, Emmanuel Ave., Umuoba Road, Ahia Udele, Peoples Roads 1 and Peoples Roads 2 along the river course. The sampling points were selected based on accessibility and nearness to the selected communities along the river. The samples were fixed immediately acidified with Nitric acid (HNO_3) to pH 2 and taken to the laboratory for analysis. The water samples were digested using concentrated Analar nitric acid according to Zhang (2007) and analysed for nickel, zinc, copper, iron, lead, mercury, cadmium, manganese and arsenic. UNICAM 969

Atomic Absorption Spectrophotometer (AAS) that uses air acetylene flame with the appropriate wavelengths of the various elements was used for the heavy metal analysis. Standard curves were obtained by running a prepared standard solution of the various metals. The absorbance values of the metals present in the water samples were determined and by comparing with the standard absorbance of the various heavy metals, the concentrations were determined. This was done in triplicate for each sample and the mean concentration was taken as the actual level of concentration of the heavy metal in mg/L. Background corrections were activated in the analysis of Hg. Quality of the analysis was ensured through replicate analysis, analysis of blank, pre-digestion spikes and analysis of certified reference materials.

Blood sample collection and testing

Six communities that were within Aba River catchment area were selected for the medical outreach.They include Okpolour Umuobu, Emmanuel Ave, Umuoba Road, AhiaUdele, People Road 1 and Peoples Road 2. Aba- Owerri road settlement was used as a control because it is outside the Aba river watershed. The sampling methods were purposive and convenient. Purposive sampling method was used because it is based on communities where the sampling site fell on (Robinson, 2014) while the convenient sampling method was also used because it is only the people that were willing to submit themselves for blood tests that were used (Dörnyei, 2007).

Free medical outreaches were conducted in each of the 6 communities and one community outside as a control. The sampling was conducted on the river bank for each settlement on 7th and 14th March 2020 (Saturdays) when more people visit the river for different purposes. A total of 90 persons from the 6 communities participated and they were interviewed to get their medical history. A semi-structured questionnaire was used and the eligibility of respondents was determined by age (18 years and above).

Seventy-seven (77) persons voluntarily submitted themselves for blood sampling. Sensitization and publicity for the outreach were made in the communities through their various town criers and in churches. The free medical outreach was organized by the researcher and his team in collaboration with some churches. The medical team was made up of three doctors and a medical laboratory scientist. The participants were administered with some basic drugs donated by the churches.

The blood samples were collected as described by Ali and Abduallahi (2017). Blood samples were collected between 7am and 12 noon; when the participants must have taken their breakfasts and have not engaged in any stressful activities. A written informed consent was obtained from each of the participants before a venous blood sample was collected.

Blood samples were collected through venipuncture, 5ml of blood sample was collected by the medical laboratory scientist using pyrogen free sterile disposable syringes. The collection spot on the participant was first cleaned with alcohol (70%) swab. The blood samples were put in well-labelled 5ml capacity EDTA plastic bottles containing K, EDTA as anticoagulant and mixed carefully by shaking. All blood samples collected were immediately stored in a medical cooler box with ice blocks at 4°C in the field, to prevent deterioration before the analysis and taken to the laboratory for analysis. The

blood concentrations of nickel, zinc, lead, copper, manganese, cadmium, arsenic, iron and mercury were determined by LC – tandem mass spectrometry.

Data Analysis

The results were summarized using the statistical measures of central tendency and presented as means±SE. Two-way ANOVA without replicate was used to ascertain if there were significant differences of the heavy metals in water and blood in communities and seasons while correlation coefficient was used to determine the relationship between the heavy metal in water and blood. The statistical significance value was set at $p < 0.05$.

RESULTS

Heavy metal content in water

Relatively higher values of the heavy metal concentrations were recorded in the downstream stations (4 – 6) and dry season (Table 2). Zinc (Zn) values ranged between 0.06 and 6.25 mg/l. The lowest and highest values were recorded in stations 1 and 6 in the dry season. The seasonal mean values were 2.56±0.59 mg/l (wet season) and 2.41±0.87 mg/l (dry season). There were significant differences among the stations ($F = 11.61$, $p < 0.05$) while there was no significant difference within the seasons ($F = 0.13$, $p > 0.05$). All the values exceeded 3 mg/l set by SON (2015) except in stations 2 and 6 (wet season) and station 6 in the (dry season).

Manganese (Mn) values ranged between 0.02 and 1.15 mg/l. The lowest values were recorded in stations 2 and 3 while the highest was recorded in station 6 all in the dry season. The seasonal mean values were 0.11±0.01 mg/l (wet season) and 0.25±0.18 mg/l (dry season). There was no significant difference in the stations ($F = 1.15$, $p > 0.05$) and seasons ($F = 0.63$, $p > 0.05$). All the values were lower than 0.2 mg/l set by SON (2015) except in station 6 in the dry season (Table 2).

Mercury (Hg) values ranged between 0.001 and 1.03 mg/l. The lowest and highest values were recorded in stations 3 and 6 in the dry season. The seasonal mean values were 0.02±0.00 mg/l (wet season) and 0.20±0.17 mg/l (dry season). There was no significant difference in the stations ($F = 1.06$, $p > 0.05$) and seasons ($F = 1.20$, $p > 0.05$). All the values were higher than 0.006 mg/l set by WHO (2017) except for stations 1 – 3 in the dry season (Table 2).

Cadmium (Cd) values ranged between 0.003 and 1.12 mg/l. The lowest and highest values were also recorded in stations 3 and 6 in the dry season. The seasonal mean values were 0.06±0.01 mg/l (wet season) and 0.22±0.18 mg/l (dry season). There was no significant difference in the stations ($F = 1.23$, $p > 0.05$) and seasons ($F = 0.84$, $p > 0.05$). All the values were higher than 0.003 mg/l set by SON (2015) except for station 3 in the dry season (Table 2).

Nickel (Ni) values ranged between 0.001 and 0.08 mg/l. The lowest values were recorded in stations 2 and 3 while highest was recorded in station 5 all in the dry season. The seasonal mean values were 0.02±0.00 mg/l (wet season) and 0.03±0.01 mg/l (dry season). There was no significant difference in the stations ($F = 1.55$, $p > 0.05$) and seasons ($F = 0.56$, $p > 0.05$). Stations 2, 5 and 6 (wet season) and stations 5 and 6 (dry season) had values higher than 0.02 mg/l set by SON (2015).

Lead (Pb) values ranged between 0.03 and

1.65 mg/l. The lowest value was recorded in station 1 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.45±0.09 mg/l (wet season) and 0.79±0.25 mg/l (dry season). There was no significant difference in the stations ($F = 2.14$, $p > 0.05$) and seasons ($F = 2.52$, $p > 0.05$). Stations 1, 4 and 5 (wet season) and stations 4 - 6 (dry season) had values higher than 0.02 mg/l set by SON (2015).

Arsenic (As) values ranged between 0.001 and 1.12 mg/l. The lowest value was recorded in station 1 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.07±0.01 mg/l (wet season) and 0.34±0.20 mg/l (dry season). There was no significant difference in the stations ($F = 2.05$, $p > 0.05$) and seasons ($F = 1.15$, $p > 0.05$). All the values exceeded 0.01 mg/l set by SON (2015); relatively higher values were recorded in stations 2, 5 and 6 (wet season) and 3, 5 and 6 (dry season).

Copper (Cu) values ranged between 0.02 and 0.57 mg/l. The lowest value was recorded in station 3 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.24±0.05 mg/l (wet season) and 0.25±0.09 mg/l (dry season). There was no significant difference in the stations ($F = 1.15$, $p > 0.05$) and seasons ($F = 0.00$, $p > 0.05$). All the values lower than 1 mg/l set by SON (2015); though stations 1 – 3 were relatively higher during the wet season while stations 4 – 6 were relatively higher during the dry season (Table 2).

Iron (Fe) values ranged between 0.38and 2.78mg/l. The lowest value was recorded in station 4 (wet season) while highest was recorded in station 6 (dry season). The seasonal mean values were 0.72±0.12 (wet season) and 1.13±±0.45 mg/l (dry season). There was no significant difference in the stations ($F = 2.47$, $p > 0.05$) and seasons ($F = 1.17$, $p > 0.05$). Stations 1 and 3 were within 0.3 mg/l set by SON (2015). Other exceeded the limit with stations 5 and 6 having relatively higher values in both seasons (Table 2).

Table 2: Spatial and seasonal values of the heavy metals concentrations in waters of Aba River

Heavy Metal	Season	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	mean±SE	Station F-value	Season F-value	SON (2015)
Zinc	Wet	1.262	3.160	2.110	1.462	2.208	5.160	2.56±0.59	11.61	0.13	3
(mg/L)	Dry	0.062	2.180	1.103	1.862	2.989	6.250	2.40±0.87	P<0.05	P >0.05	
Manganese	Wet	0.081	0.106	0.120	0.100	0.122	0.143	0.11±0.01	1.15	0.63	0.2
(mg/L)	Dry	0.031	0.016	0.020	0.132	0.157	1.148	0.25±0.18	P >0.05	P >0.05	
Mercury	Wet	0.016	0.024	0.014	0.032	0.014	0.033	0.02±0.00	1.06	1.2	0.001
(mg/L)	Dry	0.006	0.004	0.001	0.082	0.091	1.033	0.20±0.17	P >0.05	P >0.05	
Cadmium	Wet	0.046	0.088	0.046	0.058	0.052	0.114	0.06±0.01	1.23	0.84	0.003
(mg/L)	Dry	0.020	0.021	0.003	0.089	0.091	1.124	0.22±0.18	P >0.05	P >0.05	
Nickel	Wet	0.026	0.012	0.011	0.024	0.022	0.018	0.02±0.00	1.55	0.56	0.02
(mg/L)	Dry	0.018	0.001	0.001	0.034	0.084	0.026	0.03±0.01	P >0.05	P >0.05	
Lead	Wet	0.163	0.655	0.481	0.226	0.448	0.704	0.45±0.09	2.14	2.52	0.01
(mg/L)	Dry	0.026	0.255	1.041	0.526	1.221	1.654	0.79±0.25	P >0.05	P >0.05	
Arsenic	Wet	0.021	0.060	0.066	0.053	0.083	0.112	0.07±0.01	2.05	1.15	0.01
(mg/L)	Dry	0.001	0.025	0.012	0.781	0.101	1.121	0.34±0.20	P >0.05	P >0.05	
Copper	Wet	0.412	0.310	0.106	0.226	0.114	0.281	0.24±0.05	1.15	0.00	1
(mg/L)	Dry	0.112	0.110	0.016	0.449	0.229	0.572	0.25±0.09	P >0.05	P >0.05	
Iron	Wet	0.661	0.760	0.553	0.380	0.982	1.180	0.72±0.12	2.47	1.17	0.3
(mg/L)	Dry	0.221	0.660	0.153	0.790	2.182	2.780	1.13±±0.45	P >0.05	P >0.05	

Source: Field work 2020

Assessment of Metallic Element in blood

Heavy metals were detected in the bloods of the participants from the communities and control of Aba - Owerri Road participants (Table 3). Four (4) metals - Zn, Mn, Fe and Pb - out of nine (9) evaluated were detected in the blood samples from the upstream stations - station 1 (Okpolour Umuobu), station 2 (Emmanuel Ave), station 3 (Umuoba Road) and control (Aba-Owerri Road). However, between five (5) and eight (8) metals were recorded in the blood samples collected from the downstream stations - station 4 (Ahia Udele), station 5 (Peoples Road 1) and station 6 (Peoples Road 2). Generally, the prevalence of metalsin the blood was more among the female (51.6%) than the male (48.4%) though not significantly different (Table 3).

Table 3: Summary of people with heavy metals in their blood in the stations and control.

Stations	Communities	Heavy Metals	Gender		Total %
			Male (%)	Female (%)	
1	Okpolour Umuobu	Zn	64	27	91
		Mn	45	18	63
		Fe	64	36	100
		Pb	27	18	45
2	Emmanuel Ave	Zn	27	55	82
		Mn	9	55	64
		Fe	27	64	91
		Pb	27	64	91
3	Umuoba Road	Zn	73	27	100
		Mn	27	27	54
		Fe	64	27	91
		Pb	45	45	90
4	Ahia Udele	Zn	64	34	100
		Mn	45	36	81
		Fe	64	27	91
		Pb	55	36	91
		Ni	18	9	27
5	Peoples Road 1	Zn	27	45	72
		Mn	45	55	100
		Fe	36	64	100
		Pb	64	27	91
		Hg	18	27	45
		Cd	9	9	18
		Ni	18	9	27
		Cu	9	9	18
6	Peoples Road 2	Zn	27	64	91
		Mn	18	45	63
		Fe	27	54	91
		Pb	27	64	91
		Hg	9	27	36
		Cd	9	9	18
		Ni	9	9	18
		Cu	9	9	18

Control	Aba Owerri Road	Zn	54	27	81
		Mn	27	36	63
		Fe	27	64	91
		Pb	36	45	81

Source: Field work 2020

The mean concentration of Zn in the blood ranged between 4.70±2.54 and 1.25±1.67 µg/L (Table 4). The lowest value was recorded in station 1 while the highest was in station 5.Stations 4 – 6 were significantly higher ($p<0.05$) than the other stations and control.

Table 4: Concentrations of metallic elements (heavy metals) in the blood of people in communities having contacts with Aba River

Communities	Zn (µg/L)	Mn (µg/L)	Hg (µg/L)	Cd (µg/L)	Fe (µg/L)	Ni (µg/L)	Pb (µg/L)	Cu (µg/L)
Okpolour Umuobu	4.70^{c}± 2.54	0.023^{c} ±02	ND	ND	0.12^{c}± 0.01	ND	2.80^{a}± 0.84	ND
Emmanuel Avenue	5.33^{bc}± 2.29	0.037^{c} ±0.02	ND	ND	0.48^{b}± 0.38	ND	0.47^{b}± 0.30	ND
Umuoba Road	7.18^{b}± 1.78	0.350^{b} ±0.16	ND	ND	0.83^{a}± 0.19	ND	0.97^{b}± 0.21	ND
AhiaUdele	9.27^{a}± 2.05	0.667^{a} ±0.19	ND	ND	0.95^{a}± 0.40	0.0080^{a} ±0.00	0.89^{b}± 0.13	ND
Peoples Road 1	11.25^{a} ±1.67	0.791^{a} ±0.13	0.003^{a} ±0.00	0.0050^{a} ±0.00	0.87^{a}± 0.10	0.0070^{a} ±0.00	1.05^{b}± 0.25	0.070^{a} ±0.03
Peoples Road 2	10.33^{a} ±2.78	0.783^{a} ±0.08	0.003^{a} ±0.00	0.0045^{a} ±0.00	0.85^{a}± 0.11	ND	1.02^{b}± 0.21	0.055^{a} ±0.01
Aba-Owerri Road	6.33^{bc}± 1.12	0.066^{c} ±0.03	ND	ND	0.60^{b}± 0.18	ND	2.33^{a}± 1.22	ND

ND - Not Detected

Values are mean± standard deviation of replicated determinations (n=11). Means in the same column followed by different superscripts are significantly different ($p<0.05$).

Source: Field work, 2020

Manganese mean concentration ranged between 0.023±0.20 7.91±0.13 μg/L (Table 4). The lowest and highest values were also recorded in stations 1 and 5 respectively. Stations 3 – 6 were significantly higher ($p<0.05$) than stations 1, 2 and control. Fe ranged between 0.12±0.01 and 0.95±0.40 μg/L. The lowest value was recorded in station 1 while the highest was recorded in station 3. Stations 3 – 6 were significantly higher ($p<0.05$) than the others. Pb ranged between 0.47±0.30 and 2.80±0.84 μg/L. The lowest value was recorded in station 2 while the highest was recorded in station 1. Station 1 and control were significantly higher ($p<0.05$) than the others. Hg, Cd and Cu were only recorded in stations 4 and 5. Hg recorded the same value (0.003 μg/L) in both stations while Cd was 0.0045±0.00 μg/L (station 5) and 0.0050a±0.00 μg/L (station 4) and Cu – 0.055±0.01 μg/L (station 5) and 0.070±0.03 (station 4). On the other hand, Ni was recorded only in stations 4 (0.0070±0.00 μg/L) and 3 (0.0080a±0.00 μg/L). Generally, lower values were recorded in station 1 while higher values were recorded in station 5 with a few exceptions.

The values observed were however lower than the blood metal cutoff levels reported by Cusick et al. (2018) Table 5.

Table 5: Cutoffs for blood metal levels

Heavy Metal	Cutoff Point	Source
Arsenic	3.12 μg/L	Goullé*et al.,* 2015
Cadmium	0.15 μg/L	CDC, 2017
Copper	1495 μg/L	Goullé*et al.,* 2015
	20 μg/L	
Lead	50 μg/L	CDC, 2017
	100 μg/L	
Manganese	18.3 μg/L	CDC, 2017
Nickel	2.62 μg/L	Goullé*et al.,* 2015
Zinc	5234 μg/L	Goullé*et al.,* 2015

Correlation coefficient ($r0.01(2)14 = 0.623$) showed some significant positive correlations within the different media (water and blood respectively) and in between the media (Table 6). However, two significant negative correlations were recorded in between the media. In water, Zn correlated with Mn (0.747), Hg (0.704), Cd (0.742), Pb (0.715) and Fe (0.809);Mn correlated Hg (0.994), Cd (0.997), Pb (0.716), As (0.833), Cu (0.671) and Fe (0.802); Hg correlated with Cd (0.997), Pb (0.713), As (0.841), Cu (0.659) and Fe (0.782); Cd correlated with Pb (0.704), As (0.829), Cu (0.670) and Fe (0.781); Pb correlated only with Fe(0.789) and As correlated with Cu (0.772) and Fe (0.648). In the blood, Zn correlated with Mn (0.989), Hg (0.799), Cd (0.805), Ni (0.626), Cu (0.806) and Fe (0.837) (Table 6).

Table 6: Correlation between heavy metals in water and in the blood of people in communities having contacts with Aba River

	Zn-Water	Mn-Water	Hg-Water	Cd-Water	Ni-Water	Pb-Water	As-Water	Cu-Water	Fe-Water	Zn-Blood	Mn-Blood	Hg-Blood	Cd-Blood	Ni-Blood	Pb-Blood	Cu-Blood	Fe-Blood
Zn-Water	1																
Mn-Water	**0.747**	1															
Hg-Water	**0.704**	**0.994**	1														
Cd-Water	**0.742**	**0.997**	**0.997**	1													
Ni-Water	0.154	0.140	0.127	0.097	1												
Pb-Water	**0.715**	**0.716**	**0.713**	**0.704**	0.349	1											
As-Water	0.581	**0.833**	**0.841**	**0.829**	0.177	0.586	1										
Cu-Water	0.571	**0.671**	**0.659**	**0.670**	0.309	0.363	**0.772**	1									
Fe-Water	**0.809**	**0.802**	**0.782**	**0.781**	0.592	**0.789**	**0.648**	0.605	1								
Zn-Blood	0.339	**0.702**	0.281	0.214	0.188	0.229	**0.757**	-0.612	0.438	1							
Mn-Blood	0.335	**0.686**	0.359	0.222	0.221	0.179	**0.736**	-0.573	0.377	**0.989**	1						
Hg-Blood	0.605	**0.746**	0.117	0.438	0.144	0.459	**0.806**	-0.288	**0.875**	**0.799**	**0.749**	1					
Cd-Blood	0.562	**0.724**	0.073	0.392	0.157	0.434	**0.785**	-0.316	**0.859**	**0.805**	**0.748**	**0.998**	1				
Ni-Blood	-0.403	-0.063	0.125	-0.338	0.521	-0.411	0.030	-0.442	-0.244	**0.626**	0.612	0.199	0.236	1			
Pb-Blood	-0.426	-0.583	-0.366	-0.422	**0.641**	**-0.666**	-0.602	0.563	-0.086	-0.406	-0.371	-0.157	-0.156	-0.224	1		
Cu-Blood	0.505	**0.693**	0.017	0.330	0.172	0.400	**0.753**	-0.349	**0.834**	**0.806**	**0.742**	**0.989**	**0.997**	0.280	-0.154	1	
Fe-Blood	0.268	**0.694**	0.340	0.160	-0.196	0.304	**0.695**	**-0.796**	0.076	**0.837**	**0.851**	0.427	0.427	0.552	-0.712	0.425	1

Boldface Correlationsare significant at the 0.01 level (2-tailed), DF = 14 = 0.623

Mn correlated with Hg (0.749), Cd (0.748), Cu (0.742) and Fe (0851); Hg with Cd (0.998) and Cu (0.989) while Cu correlated only with Cu (0.997). Across the media, Mn (water) correlated with Zn (0.702), Mn (0.686), Hg (0.746), Cd (0.693) and Fe (0.694) in blood. Ni (water) correlated only with Pb (0.641) in Blood. As (water) correlated with Zn (0.757), Mn (0.736), Hg (0.806), Cd (0.785), Cu (0.753) and Fe (0.695) in blood and iron (water) correlated with Hg (0.875), Cd (0.859) and Cu (0.834) in blood.The two negative correlations were Pb (water) correlated significantly with Pb(-0.666)in blood and Cu (water) correlated significantly with Fe (-0.796) in blood (Table 6).

DISCUSSION

The four (4) metals recorded in the blood samples from the upstream stations and control is a reflection of minimal anthropogenic activities in the areas while the downstream stations located in the hub of the city recorded between five (5) and eight (8) metals in the blood samples. This could be attributed to nature and intensity of human activities in the area compared with the upstream stations and control. Minimal pollution of any environmental media can occur through geogenic contamination (Davraz, 2015; Deniz and Çalık, 2016) but most cases of high level pollution are from anthropogenic sources - domestic, industrial, and agricultural sources (Huang et al., 2020; Desiree et al., 2021; Anyanwu et al., 2022 a, b). Some of the activities observed in and around the river during the study are potential sources of heavy metals (abattoir waste disposal, refuse disposal, dredging, electroplating, car workshops and car washing, etc.). Amah-Jerry et al., 2017. The presence of heavy metals in the blood of participants from the control station could be attributed to sources other than contact with the river (ingestion and dermal contact). Inhalation could be a possibility and has been reported as one of the major sources of human heavy metal contamination (Faisal et al., 2021) because the area usually experience heavy vehicular traffic and build up for greater part of each day.

The heavy metals in water totally or partially exceeded limits set by SON (2015) except manganese and copper. All recorded relatively higher values in the downstream stations which could be attributed to the intensity of anthropogenic activities in the stations. This has also collaborated the high number of people with metals in their blood from those stations compared with the upstream stations. Lowest and highest values generally occurred in some upstream stations and downstream stations respectively during the dry season. This is season influencing the concentrations of water quality parameters (Ling et al., 2017). Low values can be recorded in dry season due no allochthonous input or high values due concentration occasioned by little or no precipitation, low flow velocity, high temperatures and high evaporation (Haque *et al*., 2019;Anyanwu *et al*. 2022a, b).

The heavy metal mean concentrations in the blood followed same trend observed in water. Generally, lower values were recorded in the upstream stations while higher values were recorded in downstream stations (especially in station 5) with a few exceptions which are not unconnected with the prevailing anthropogenic activities. For instance, Hg, Cd and Cu were only recorded in stations 4 and 5. On the other hand, significantly high lead values recorded in station 1 and control could be due to its availability and ease of entering into environmental compartments; which has made lead poisoning

common in Nigeria (Orisakwe et al., 2014). However, the heavy metal values recorded were lower than the blood metal cutoff levels reported in Cusick et al. (2018).

A high negative or positive correlation coefficient value between two indexes is an indication of stronger correlations between them (Mukaka, 2012). Correlation coefficient showed some significant positive correlations within the different media (water and blood respectively) and in between the media. This is an indication that changes in the concentrations of the heavy metals within one medium or between the media affect each other in the same direction (Majhi and Biswal, 2016). In order words, as one metal is increasing within or between media, a correlated metal is also increasing; indicating common source or influence. On the other hand, the two negative correlations recorded between Pb (water) and Pb (blood) and Cu (water) and Fe (blood) indicated that change in Pb and Cu in water was predicated by change in Pb and Fe in blood in the opposite direction (Majhi and Biswal, 2016). In order words, as Pb and Cu are increasing in water, Pb and Fe are decreasing in blood. It is a clear indication that the concentration of Pb in the water did not influence the concentration in the blood but the relationship between Cu and Fe can be attributed to inhibition. Studies have shown the copper plays a major role in iron metabolism; high concentration of copper can inhibit iron uptake (Chanand Rennert, 1980; Arredondo et al., 2006).

CONCLUSIONS

The study has established that Aba River was polluted with heavy metals among others; which reflected in level of heavy metals in the body fluid (blood) of people who live around and use it for their daily domestic and other activities. The water of the river is contaminated due to high concentrations of Zn, Mn, Fe and Pb which were largely from anthropogenic sources. High concentrations were high in dry season and downstream stations where the anthropogenic activities were intense. The high levels of Zn, Mn, Fe and Pb recorded in the bloods of the participants from this study communities portends potential public health risk. A drastic action must be taken to stem the trend.

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COMPUTATIONAL MODEL FOR MEASURING THE INFROMATION AND COMMUNICATION MATURITY INDEX OF NIGERIA ECONOMY

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ABSTRACT

The Information and Communication Technology maturity of an enterprise is a strong foundation for successful implementation of knowledge management. The fundamental issue within the Nigeria economy that has resulted in skewed ICT planning is the uncertainty surrounding the stage or level of ICT maturity. This paper therefore, evaluates and measures the level of ICT maturity of selected firms in all the sectors listed in the Nigerian Stock Exchange (NSE) using the ICT maturity model of Small- and -Medium Enterprises (SMEs). This model was based on a 5-stage road map of ICT development in SME: Inactive, Basic, Substantial, Web-based and Knowledge-oriented, in which knowledge-oriented is the highest development stage. The result has shown that the Nigeria economy is web-based in ICT maturity, with an index of 0.67; an indication that the ICT maturity of the Nigerian economy has not grown to the fullest level. This could give SMEs knowledge of their current situation and strengthen their competitive capability for effective management of knowledge resources for their improvement in this knowledge economy.

Keywords: Nigeria economy, NSE, ICT Maturity, SMEs

DOI:

INTRODUCTION

Though, during the past years, information and communications technology (ICT) had increased rapidly in terms of adoption and diffusion process, varying degrees in the level of access, use and skills of ICT can be determined, both among countries as well as within them. Decision and policy makers had opined that, these differences among countries are key causes limiting the ICT penetration and thus requires strategies at targeting the development and deployment of ICT which can be applied to many countries. Researchers and managers are majorly concerned about the benefits from digital age among countries and also concerned about how, these benefits, could be measured and evaluated. Their primary focus, is to get the understanding of the causes which increase ICT adoption, which eventually accelerate ICT deployment. A good number of studies have revealed some hindrances and some driving factors on this deployment. Factors such as income level, investment level and education level could either be aids or hindrances, to ICT deployment increase (Weber et al., 2011).

Furthermore, some researchers have queried whether a positive correlation exists between ICT value and its corporate result, in particular for a short period. Some of those researchers are: Roach (1991) and Carr (2003). Brynjolfsson and Hitt (2000) submitted that, the benefits from ICT adoption in an organization are not usually seen at the beginning but needs some certain period when technology integration and penetration had taken place – a period within which certain changes in the company's organizational structure have taken place and even staff had undergone a good number of trainings before any positive effect of the ICT adoption could be seen in such an organization. Hong and Zulkifli (2011) however submitted that, "companies have had no choice but to incorporate ICTs in response to internal and external pressure from either their clients or competitors, contributing to their survival but not to their growth from a reactive perspective". There are lots of arguments across the literatures as to the huge amount of investments on ICT (i.e. ICT maturity) as against the value derivable from ICT and its eventual competitive advantage on the society at large, which have not led to absolutely indisputable positions.

The general assertion is that, "information and communication technologies (ICTs) have positive influence on the economic, social, and political enhancement of a country, region, or community". While it is simple to conclude on that assertion,"it is far from easy to quantify it in a way that results in an explanatory and predictive theoretical understanding which can be applied to information policies". This is considered by many organizations and economies as a major back-bone for functional information policy-making (Richard and Bin, 2007), and improved benefits of ICT.

In-order to reap the benefits of ICTs, governments and private sectors are spending huge amounts of valuable money on ICT and this is being done across the globe. They are also ensuring universal access to the ICT facilities and their services but could not ascertain if what they are getting in return in form of value equals what they are spending because "their level of empirically-based indicator in form of policy guidance is low" (Richard and Bin, 2007). However, for organizations, societies or countries that are not aware of the stage they belong (i.e. in terms of ICT maturity), it is hard to decide where to go and also hard to know, the actual value they are getting, let alone thinking about how to improve. Therefore, service scientists have vital function(s) to perform by assisting key policy makers and business stakeholders on ways of improving the benefit from ICT so that, nation's potentials can be harnessed which can later result to an enhanced economic growth.

The misgiving surrounding the arguments across the literatures as to the huge amount of investments on ICT as against the value derivable from ICT and its eventual competitive advantage which have not led to absolutely indisputable positions requires further exploration, especially in the formal sector of the Nigeria stock exchange (NSE) which is the major regulating body of the companies/firms across the Nigeria economy.

Putting the required regulations in place as well as guiding policies as to the ways both public and private establishments are to invest in ICT innovations, is a right step that has to be taken in a right direction. Such regulations must be backed up with empirical data within the Nigeria economy, which is

however lacking. Therefore, the problem the study stands to address is that of ICT mis-planning bedevilling emerging service dominant (digital) economy like Nigeria due to the dearth of understanding of how investments on ICT relates to the benefits from ICT.

To this end, this paper measured the ICT maturity of all the sectors in the NSE as a possible panacea towards unravelling the uncertainty of the level or stage of the ICT maturity in order to effectively harness the potentials of ICT for sustainable improved economy. The most common reason for measuring is to improve internal performance, i.e. management control. The idea is founded on one of the most quoted management slogans; what is not measured, cannot be effectively managed (Skyrme et al., 2003).

LITERATURE REVIEW

This research noted the work of Raef et al. (2019) which was carried out in Saudi Arabia, titled "Impact of Information and Communication Technology on Economic Growth: Evidence from Developing Countries" that was motivated by the question: what is ICT's impact on economic growth? The aim of their study was to "evaluate the impact of ICT on the economic growth of some selected developing countries in the Middle East and North Africa (MENA) region and the Sub-Saharan Africa (SSA) region. The panel Generalized Method of Moment (GMM) growth model was used for methodology". According to their findings, mobile phone, Internet usage and broadband adoption were the main drivers of economic growth in MENA and SSA developing countries.

Also, the work of Virginia et al. (2018) carried out in Spain entitled "A study of the value of ICT in improving corporate performance: a corporate competitiveness view" was motivated by the economic crises and strong healthy competition among companies in their country. It was hoped that, proper management of information and knowledge could be a panacea to the crisis. The work was aimed at "analysing the impact that the intensity of firms' adoption of information and communications technologies (ICT) and industry attractiveness has, on corporate performance". Ordered Logistic Regression and principal axis factoring analysis were adopted for their methodology and the results showed that there was a significant positive relationship between ICT intensity of use and corporate performance.

The work of Oladimeji et al. (2018) which focuedon Nigeria and entitled "ICT and its Impact on National Development in Nigeria: An Overview", explored the growth benefits that ICT sector has provided and its impacts on the Nigeria economy. According to their findings, the work showed that, "ICT services have helped in some economic areas like, improving on the markets, reduction in transaction cost and increased productivity". Most contentious is the work of Ekuobase and Olutayo (2016), entitled Study of Information and Communication Technology (ICT) maturity and value: The relationship motivated by the challenge within the service industry which centres on how the benefits from the ICT adoption and diffusion (ICT value) relate to the degree of adoption and diffusion of ICT (ICT maturity). The main purpose of their study" was to determine whether a relationship exists between ICT maturity and value for some selected service firms and to determine the type of such relationship. In their study, the quasi-experimental research method was used for

methodology. The empirical results according to their findings show that, there is a negative-weak correlation between ICT maturity and ICT value in the service industry, which shows that the benefit from ICT adoption and diffusion is not traceable to the degree of ICT adoption and diffusion in the service industry". They also submitted that, the work could be extended to all the formal sectors of a country in-order to assess the level of ICT adoption and ICT value of the nation.

The researches by Raef et al. (2019) and Virginia, et al. (2018) made use of secondary data that could contain some sort of bias at the point of collection which could no longer be verified. Their view about ICT maturity definition appear faulty, they were equating ICT maturity to be ICT investment and ICT value to be economic benefit. Their concerns were only centered on economic benefits which is the tangible value while both tangible value and non-tangible value are the main concerns of the service scientist. None of these works made reference to ICT maturity and value models, let alone using them. However, these ICT models are critical to measuring ICT maturity and ICT value in any organization, sector or economy. In-fact, Oladimeji, et al., (2018) only carried out a review of the impact of ICT on national development and did not make use of any data. However, in the work of Ekuobase and Olutayo (2016), the gaps in the work are: sample size of the work was small, with only 23 service firms willing to complete their questionnaires. Very importantly, the work only focused on service sector, out of other several sectors of the companies listed in Nigeria Stock Exchange (NSE).

MATERIALS AND METHODS

Research design

Research design is a plan or blue print which specifies how data relating to a given problem should be collected and analysed. Research design that was adopted in this study was quasi-experimental research method, because it allows both the use of a model and a questionnaire survey method. Also, it does not allow the manipulation of the independent variables by the researcher.

Population and Sample size

The target populations of this study were the firms listed in NSE. There are eleven (11) sectors in the NSE and one hundred and seventy-two (172) firms. Of these 172 firms a total of 61 firms across the eleven sectors of NSE were investigated. Thus, the sample size of this study is about 35% of the total population which exceeds that of similar studies by Ekuobase and Olutayo (2016) and Chan et al. (2012) whose population samples were about 32% and 25% of their total population respectively. Out of these sectors; agriculture had 2 firms, ranging from F1 to F2, conglomerate had 3 firms, ranging from F3 to F5, Consruction had 3 firms, ranging from F6 to F8, Consumer_goods had 7 firms, ranging from F9 to F15, financial_services had 18 firms, ranging from F16 to F33, health_care had 5 firms, ranging from F34 to F38, ICT had 3 firms, ranging from F39 to F41, industrial _goods had 6 firms, ranging from F42 to F47, natural _resources had 2 firms, ranging from F48 to F49, oil_ and_gas had 4 firms, ranging from F50 to F53, services had 8 firms, ranging from F54 to F61 (Table 1). The firms were specifically instructed that the nine questionnaires should be distributed three each per levels of management namely operational, middle and top management levels. This is to avoid a possible pitfall of position prejudice observed in Chan et al.

(2012) for companies in mainland China where one questionnaire per firm was administered. Distributing three questionnaires per managerial level did not only degrade the effect of position prejudice but also weakened bias within a managerial level.

Table 1: Types of sector, Firms name and their code

Type of Sector	Firms Name	Firm Code	NO OF FIRMS
AGRICULTURE	FTN COCOA PROCESSORS PLC	F1	2
	LIVESTOCK FEEDS PLC	F2	
CONGLOMERATE	JOHN HOLT PLC	F3	3
	SCOA NIGERIA PLC	F4	
	TRANSNATIOAL CORPORATION PLC	F5	
CONSTRUCTION	ARBICO PLC	F6	3
	JULIUS BERGER PLC	F7	
	SMART PRODUCTS NIGERIA PLC	F8	
CONSUMER_GOODS	7UP BOTTLING PLC	F9	7
	CADBURY NIGERIA PLC	F10	
	DANGOTE FLOUR MILLS PLC	F11	
	GUINESS PLC	F12	
	HONEYWELL FLOUR MILLS PLC	F13	
	NESTLE NIGERIA PLC	F14	
	PZ PLC	F15	
FINANCIAL_SERVICES	ACCESS BANK	F16	18
	BANK OF INDUSTRY	F17	
	DIAMOUND BANK PLC	F18	
	ECO BANK	F19	
	FBN INSURANCE	F20	
	FCMB	F21	
	FIDELITY BANK	F22	
	FIRST BANK	F23	
	GTB	F24	
	NEM INSURANCE	F25	
	NPF BANK	F26	
	SKYE BANK	F27	
	STACO INSURANCE	F28	
	STERLING BANK	F29	
	UBA	F30	
	UNITY BANK	F31	
	WEMA BANK	F32	
	ZENITH BANK	F33	

HEALTH CARE	EKO CORP	F34	5
	EVANS MEDICAL	F35	
	FIDSON	F36	
	GLAXO	F37	
	PHARMADEKO	F38	
ICT	CHAMS	F39	3
	CWG	F40	
	E-TRANSACT	F41	
INDUSTRIAL_GOODS	AFRICAN PAINTS	F42	6
	AUSTIN LAZ	F43	
	AVON	F44	
	BERGER PAINTS	F45	
	BETA GLASSS	F46	
	CAP	F47	
NATURAL_RESOURCES	ALUNMINIUM	F48	2
	BOC GASES	F49	
OIL_AND_GAS	BECO	F50	4
	CAPITAL OIL	F51	
	MOBIL_OIL	F52	
	SEPLAT	F53	
SERVICES	ACADEMY_PRESS_PLC	F54	8
	AIRLINE SERVICES	F55	
	ASSOCIATED BUS COMPANY	F56	
	CAPITAL HOTEL	F57	
	CAVERTON OFFSHORE SUPPORT PLC	F58	
	DAAR COMMUNICATION	F59	
	IKEJA HOTEL	F60	
	INTERLINK TECHNOLOGY_PLC	F61	

Instrumentation

The field work exercise was a questionnaire survey meant to capture the necessary data to measure the ICT maturity of these firms. The questionnaire modelled after the ICT Maturity Model of SMEs (Pham, 2010) is a three-part document. The first part introduced the questionnaire and contained demographic data (name and type) of firms and respondents' managerial position. The second part consisted of 50 indicator questions grouped under the four major factors of observable capabilities of SMEs: Infrastructure (eleven indicator questions), Application (thirteen indicator questions), Human Resource (twelve indicator questions) and Policy (fourteen indicator questions). The third part captured the respondents contact (mobile phone and e-mail address). Questionnaires with similar connotations and indicator value had been used by Pham (2010), Pham et al. (2013), and Ekuobase and Olutayo, (2016), as survey instrument for research purpose.

Method of Data Analysis

The questionnaires were then sorted and coded using the indicator stage value as proposed by Pham (2010). The ICT maturity index (ICTMI) was calculated using the for-

ICTMI = αI + βA + γH +θP …… (1)
Where 0 ≤ I, A, H, P, ICTMI ≤ 1 and α + β + γ + θ = 1; and

$$I = \frac{\sum_{t=1}^{4}\left(\frac{\sum_{t=1}^{nl} Ilt}{nl}\right)}{4} \qquad A = \frac{\sum_{t=1}^{4}\left(\frac{\sum_{t=1}^{ml} Alt}{ml}\right)}{4}$$

$$H = \frac{\sum_{t=1}^{4}\left(\frac{\sum_{t=1}^{pl} Hlt}{pl}\right)}{4} \qquad P = \frac{\sum_{t=1}^{4}\left(\frac{\sum_{t=1}^{ql} Plt}{ql}\right)}{4} \qquad \text{.....(2)}$$

Where Ilt, Alt, Hlt and Plt are indicators of stage l; nl, ml, pl and ql are number of respective indicators of stage l.

The ICT maturity data were then extracted and processed to realize the ICT maturity indexes of the selected firms and sectors in NSE using a visual C++ program designed and implemented. Thereafter, the results of ICTMIs were mapped to the ICT maturity levels using the following stratification proposed by Pham (2010): Inactive (0.0 – 0.2), Basic (0.2 – 0.4), Substantial (0.4 – 0.6), Web based (0.6 – 0.8) and Knowledge oriented (0.8 – 1.0).

This study made use of ICT maturity model of SMEs not only because it has been improved to be able to handle any category of enterprises but because it is simple, generic, quantifiable, popular, strongly aligned with modern business enterprises and yet powerful (Pham, 2010; Chan et al., 2012).

The model was designed by Australian Communication Authority in 2008. It is based on four main factors: Infrastructure, Application, Human Resource and Policy. It originally consists of four phases namely: (i) Inactive; (ii) Basic; (iii) Substantial and; (iv) Sophisticated. However, based on the above classification of ICT development in SMEs, Pham (2010) in consideration of recent development trends as well as conditions for knowledge management maturity, the 'Sophisticated' phase is suggested to be divided into two stages: Web-based and Knowledge-oriented. Thus, we now describe this model as consisting of five phases:

1. Inactive – no current use of ICT in company.
2. Basic – including word processing and other desktop packages.
3. Substantial – extending into the networking of PCs and several applications.
4. Web-based – extending to e-commerce with many web-based services.
5 Knowledge-oriented – integration of applications and using ICT tools for innovation and knowledge management.

Each of the maturity levels is characterized by certain observable capabilities of four major factors: Policy, Infrastructure, Application and Human Resource, with maturity level ranging from level 1 to level 5 which is the highest level (Table 2).

Table 2: ICT Maturity Stages and Its Features

	Maturity level	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	Development Trend	**Inactive**	**Basic**	**Substantial**	**Web based**	**Knowledge Oriented**
Infrastructure	Connectivity & Mobility	Telephone	PC, laptop	Network	Internet	Wireless
ICT HR	Sophisticated & Innovation	Unskilled	Business skills	Technology skills	MIS skills	Learning skills
Application	Integrated applications	No application	Office, E-mail	MIS applications	E-commerce	E-business
Policy	Flexibility & Mobility	No policy	Standardize	Modernize	Cooperation	Outsourcing

In general, it is very difficult for an enterprise to build up a knowledge system without appropriate ICT infrastructure and previous ICT applications. Moreover, to strengthen the competitive capability of SMEs, it is very important to apply appropriate ICT applications at the right time rather than adopting latest information systems. Therefore, the SMEs model will be useful to generate information needed for effectively improving companies' ICT maturity knowledge-oriented business outfits.

RESULTS AND DISCUSSIONS

The respondents gave a fair distribution across the managerial levels where middle management level had 50.49% (Table 3). The majority of the respondents were from financial services sector with 29.77% and operational level had the least percentage with 29.45%.

All the sectors appeared to be in the same ICT maturity level i.e., web based, also consumer goods sector had the highest ICTMI with 0.723975 followed by ICT sector while Industrial Goods had the lowest ICTMI with 0.621107 (Table 4).

Table 3: Management Levels of the Respondents

Sector Type	No of firms in sector	Operational management	Middle management	Senior Management	Total Type	% Type
AGRICULTURE	2	3	7	2	12	3.88
CONGLOMERATES	3	3	9	2	14	4.53
CONSTRUCTION	3	3	12	4	19	6.15
CONSUMER GOODS	7	9	21	5	35	11.33
FINANCIAL SERVICES	18	33	48	11	92	29.77

HEALTH CARE	5	4	12	7	23	7.44
ICT	3	10	8	1	19	6.15
INDUSTRIAL GOODS	6	9	9	7	25	8.09
NATURAL RESOURCES	2	2	6	2	10	3.24
OIL AND GAS	4	4	8	10	22	7.12
SERVICES	8	11	16	11	38	12.3
Total	61	91	156	62	309	100
% of managerial Level		29.45%	50.49%	20.06%	100.00%	

Table 4: The ICTMI and Quantized ICTMI of all the Sectors in Nigeria

SECTOR NAME	I	P	H	A	ICTMI	QUANTIZED ICTMI
AGRICULTURE	1.693576	2.043403	1.333333	1.575149	1.661365	0.664546
CONGLOMERATES	2.00372	2.096726	1.456845	1.662628	1.80498	0.721992
CONSTRUCTION	1.711075	2.141447	1.202851	1.59187	1.661811	0.664724
CONSUMER GOODS	2.01369	2.110119	1.528571	1.587372	1.809938	0.723975
FINANCIAL SERVICES	1.689312	2.017889	1.460485	1.657269	1.706239	0.682495
HEALTH CARE	1.775815	2.004529	1.344656	1.597244	1.680561	0.672224
ICT	1.850877	2.003289	1.396382	1.589051	1.7099	0.68396
INDUSTRIAL GOODS	1.573333	2.003333	1.214583	1.419821	1.552768	0.621107
NATURAL RESOURCES	1.64375	1.977083	1.216667	1.525	1.590625	0.63625
OIL AND GAS	1.833807	2.022727	1.339489	1.561688	1.689428	0.675771
SERVICES	1.831963	1.889803	1.334156	1.487312	1.635808	0.654323

Table 5: ICT Maturity of Sectors in NSE

SECTOR	ICT MATURITY INDEX
AGRICULTURE	0.664546
CONGLOMERATE	0.721992
CONSTRUCTION	0.664724
CONSUMER_GOODS	0.723975
FINANCIAL_SERVICES	0.682495
HEALTH	0.672224
ICT	0.68396
INDUSTRIAL_GOODS	0.621107
NATURAL_RESOURCES	0.63625
OIL_AND_GAS	0.675771
SERVICES	0.654323
Nigeria Economy (Average)	0.672852
Standard Deviation	0.03122

DISCUSSION

The ICT maturity of the various sectors of the Nigeria economy presently converges at 0.67 which by Pham (2013) classification is web based. The implication of this is that the various sectors of the Nigeria economy have attained about same level of ICT maturity. The various sectors now know their current situation, which is the first step for them to make a plan for improving their ICT maturity. This would help them to strengthen their competitive capability and lead to effective management of resources for their development in the age of knowledge economy.

CONCLUSION

Nigerian Economy is Web based in ICT maturity. Therefore, managers of the Nigerian Economy are now better positioned towards a sustainable improvement of ICT based service delivery in Nigeria. Also, this paper contributes to practical aspect of building a knowledge system by doing the first step, which is measuring the ICT maturity. Based on this result, Managers of the Nigeria Economy can start making a plan for improving their ICT maturity towards Knowledge-oriented in order to use their knowledge resource effectively for development in the future.

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ON WEAK AMENABILITY OF RESTRICTED SEMI-GROUP ALGEBRA AND SEMIGROUP ALGEBRA ON RE-STRICTED SEMIGROUP

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ABSTRACT

We studied weak amenability of restricted semigroup algebra $l_r^1(S)$ and semigroup algebra $l^1(S_r)$, on restricted semigroup S_r. We give condition for the restricted semigroup algebra to be commutative for every inverse semigroup S. Some classes of inverse semigroups such as semilattice, Clifford and Brandt semigroup are used to characterize a weakly amenable restricted semigroup algebra. In particular, we show that for a Clifford semigroup $S = \bigcup_{i=1}^{n} G_i$ and the Brandt semigroup $S = M^0(G, I, n)$, the weak amenability of semi- group algebra $l^1(S)$, restricted semigroup algebra $l^1(S)$, and semigroup algebra $l^1(S_r)$, on restricted semigroup S_r are equivalent. In general, the necessary and sufficient conditions for weak amenability of restricted semigroup algebra and semigroup algebra $l^1(S_r)$, on restricted semigroup S_r are given.

Keywords: semigroup, restricted semigroup, semigroup algebra, weakly amenable.
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INTRODUCTION

Bade et al. (1987) introduced the notion of weak amenability for commutative Banach algebras while Johnson (1988) considered the same notion for arbitrary Banach algebra and in (Johnson 1991) showed that the group algebra $L^1(G)$ of a locally compact group G is always weakly amenable. The authors in (Bade et al. 1987) defined a weakly amenable Banach algebra A as one in which every continuous derivation from it into a commutative Banach A-bimodule is necessarily zero. This definition was extended by the author in (Gronbaek 1989) by giving some characterizations of weakly amenable Banach algebra in terms of the splitting of an admissible sequence. Blackmore (1997) particularly showed that if S is a completely regular semigroup, then the semigroup algebra, $l^1(S)$ is weakly amenable and that if S is commutative, then the weak amenability of $l^1(S, \omega)$ for any weight ω implies the weak amenability of $l^1(S)$. He further gave some conditions for which the semigroup algebra $l^1(S)$ is weakly amenable. Haagerup (1983) showed that C*-algebra is always weakly amenable.

Massoud Amini and Alireza Medghalchi (2006) introduced a class of Banach algebra called the restricted semigroup algebra and the authors in (Mewomo and Ogunsola 2016), Mohammad and Massoud (2010) and Sahleh and Grailo (2015) respectively studied

the character amenability, amenability and module amenability of this class of Banach algebra. This study is motivated by the introduction of this class of Banach algebra and the need to investigate the notion of weak amenability that has not been studied on this class of Banach algebra. In this work, we investigate both the commutativity and non-commutativity of different classes of discrete inverse semigroup to establish the weak amenability of restricted semigroup algebra and that of the semigroup algebra l^1S_r on restricted semigroup S_r .

PRELIMINARIES AND DEFINITIONS

First we recall some standard notions. For further details see (Dales 2000).

Let A be an algebra and let X be an A-bimodule. A linear map D : A → X is called a derivation if:

D(ab) = D(a).b + a.D(b) (a, b ∈ A).

This derivation is inner if for x ∈ X, there is a map δx : A → X such that

$\delta_x(a)$: a.x − x.a (a ∈ A).

Clearly, every inner derivation is a derivation.

Let A be a Banach algebra and let X be a Banach A-bimodule. The Banach algebra A is amenable if the first cohomology group of A with coefficient in dual module X', of X is trivial i.e $H^1(A, X') = \{0\}$.

If A' = X', then the Banach algebra A is said to be weakly amenable as $H^1(A, A') = \{0\}$.

We recall from (Johnson 1972) that the first cohomology group of A with coefficients in X is the quotient space: $H^1(A, X) = Z^1(A, X)/N^1(A, X)$, where $Z^1(A, X)$ is the space of all continuous derivations from A into X and $N^1(A, X)$ is the space of all inner derivations from A into X.

The Banach algebra A is n-weakly amenable if $H^1(A, A^{(n)}) = \{0\}$ where n ∈ N and $A^{(n)}$ is the nth conjugate space of A.

A is permanently weakly amenable if A is n-weakly amenable for every n ∈ N. See (Dales et al. 1998).

Let S be a semigroup.

Let s ϵ S. An element s* ∈ S is called an inverse of s if ss*s = s and s*ss* = s*.

An element s ∈ S is called regular if there exists t ∈S with sts = s.

An element s ∈ S is called completely regular if there exists t ∈ S with sts = s and ts = st.

S is called regular if each s ∈ S is a regular element.

S is called completely regular if each s ∈ S is a completely regular element. Completely regular semigroups are those which can be regarded as the disjoint unions of their maximal subgroups (Blackmore 1997).

S is called an inverse semigroup if S is regular and every element in S has a unique inverse.

An element p ∈ S is called an idempotent if $p^2 = p$; the set of idempotents of S is denoted by E(S). E(S) is also defined as a commutative subsemigroup of an inverse semigroup S.

S is called a semilattice if it commutes and E (S) = S.

An inverse semigroup S is called a Clifford semigroup if $ss^{-1} = s^{-1}s$ for each s ∈ S.

Let S be a Clifford semigroup and let s ∈ S. Then s ∈ G_{ss-1} and hence S is a disjoint union of the groups G_p (p ∈ E(S)). That is S = Up ∈ E(S)G_p where G_ps are the maximal subgroups of S.

GENERAL RESULTS

In this section, we prove some general results which are useful in establishing our main results on restricted semigroup algebra and semigroup algebra, l^1S_r on restricted semigroup Sr.

Proposition 3.1
Let S be an inverse semigroup which is a union of groups. Then the following are equivalent:
(i)Every idempotent in S is commutative.
(ii) $l^1(S)$is weakly amenable.
Proof:
(i) This follows from [Clifford and Preston (1961), Theorem 4.11].
(ii) If S is commutative, then by [Gronbaek (1989), Corollary 2.8], $l^1(S)$ is weakly amenable. We recall that a Banach algebra A is said to be graded over a semigroup S if we have closed subspaces A_s for each $s \in S$ such that $A = l^1 - \bigoplus s \in S\ A_s$; $A_sA_t \subset A_{st}$ (s,t ∈ S).
For the case in which S is a finite semilattice, each A_s is a closed subspace of A.

Proposition 3.2
Let S be a finite semilattice and let A be a Banach algebra graded over S. Then A is weakly amenable if and only if each A_s is weakly amenable.
Proof:
The result clearly follows from [Gronbaek (1989), Theorem 2.7].
Let A be a Banach algebra and let *I* be a non-empty set. Let the set of $I \times I$ matrices (a_{ij}) with entries in A be denoted by $M_I(A)$ such that $||(a_{ij})|| = \sum_{i,j \in I} ||a_{ij}|| < \infty$. Then $M_I(A)$ with the usual matrix multiplication is a Banach algebra that belongs to the class of l^1-Munn algebras. It is an easy verification that the map $\theta : M_I(A) \rightarrow M_I(C) \otimes A$ defined by $\theta((a_{ij})) = \sum_{i,j \in I} E_{ij} \otimes a_{ij}$ $((a_{ij}) M_I(A))$, is an isometric isomorphism of Banach algebras, where (E_{ij}) are the matrix units in $M_I(C)$.

Proposition 3.3
Let A be a weakly amenable Banach algebra and J a non-empty set. Then Mj(A) ~=A⊗Mj(C) is weakly amenable if and only if Mj(C) is weakly amenable.
Proof:
It is well known that Mj(A) ~= A ⊗Mj(C). If Mj(C) is weakly amenable, then by Proposition 2.6 (Gronbaek 1989), Mj(A) is weakly amenable. Conversely, if Mj(A) is isomorphic to A ⊗ Mj(C) and Mj(A) is weakly amenable, then A ⊗ Mj(C) is weakly amenable and so Mj(C) is weakly amenable.

Let η be a relation on a commutative inverse semigroup S defined as aηb (a, b ∈ S) if and only each of the elements a and b divides some power of the other. More details are given in [14]. Clearly the relation η on S is a congruence relation and by Theorem 4.12 (Mohammad and Massoud 2010), S/η is the maximal semilattice homomorphic image of S.
Let S be an inverse semigroup and p ∈ E(S). We set $G_p = \{s \in S : ss^{-1} = s^{-1}s = p\}$.
where s^{-1} denotes the inverse of s. Then G_p is a group with identity p and G_p contains other subgroup of S with identity p. Thus G_p is called maximal subgroup of S at p.
If S is a semilattice, it then suffice to say that S/η is isomorphic to G_p.

Proposition 3.4
Let $S = U_p \in E(S) G_p$ be a Clifford semigroup. Then $l^1(S)$ is weakly amenable if and only if $l^1(G)$ is weakly amenable.
Proof:
Clearly $l^1(S) = l^1(G)$ ($G_p = G$). If $l^1(G)$ is weakly amenable, then it is immediate from Proposition 3.1 that $l^1(S)$ is weakly amenable. Conversely, suppose $l^1(S)$ is weakly amenable. From $l^1(G) \subset l^1(G_p)$ $l^1(S)$ we can conclude that $l^1(G)$ is weakly amenable.

MAIN RESULTS

In this section, we shall consider the weak amenability properties of restricted semigroup algebra $l^1(S)$ and semigroup algebras,

l^1S_r on restricted semigroup Sr using different characterizations. For details on restricted semigroups and restricted semigroup algebras see (Johnson 1991) and Mewomo 2011). For any inverse semigroup S, the restricted product of elements s and t of S is st if s*s = tt* and undefined, otherwise. The set S with this product forms a discrete groupoid and if we adjoin a zero element 0 to this groupoid with 0* = 0, we get an inverse semigroup denoted by Sr, with the multiplication:

$$s \bullet t = \begin{cases} st = s*s = tt* \\ 0 \quad otherwise, \end{cases}$$

(s, t ∈ S ∪ {0}) which is called the **restricted semigroup** of an inverse semigroup S.
It is clear that E(Sr) = E(S) ∪ {0}.
Suppose S is a ∗-semigroup, given a Banach space $l^1(S)$ with the usual l^1- norm, we set f˜ (x) = $\overline{f(x)}$ and define the following multiplication on $l^1(S)$.

$$(f \bullet g)(s) = \sum_{s*s=tt*} f(st)g(t*) \qquad (s \in S)$$

Then ($l^1(S)$, •,) with the l^1-norm is a Banach ∗-algebra denoted by $l^1_r(S)$ called the restricted semigroup algebra of S.
Since S is discrete, $l^1_r(S)$ is a discrete semigroup algebra.
$l^1_r(S)$ = {f : S → C : $\sum_{s\in S} |f(s)| < \infty$}, | | = $f||_1 = \sum_{s\in S} |f(s)|$
The module action of on is shown as follows:
(f, g.λ) = (f.g, λ) , (f, λ.g) = (g.f, λ) (f, g ∈ l^1S_r λ ∈ $l^\infty_r(S)$).

Clearly, $l^\infty_r(S)$ is a Banach-$l^1_r(S)$ bimodule.
For a restricted semigroup S_r of an inverse semigroup S, l^1S_r is called the semigroup algebra on restricted semigroup S_r.

In the following Lemma, we show the commutativity of restricted semigroup algebra.

Lemma 4.1
Let S be an inverse semigroup. Then the restricted semigroup algebra $l^1_r(S)$ on an inverse semigroup S, is commutative if and only if S is a semilattice.

Proof :
By the definition of restricted semigroup algebra $l^1_r(S)$, we have for each f, g ∈ $l^1_r(S)$ f • g(u)= $\sum f(ut)g(t*)$, if u*u=tt* and 0 otherwise.
Let S contain idempotent elements which commute i.e for s = ut then su* =t, t*=s*u. So $\sum f(s)g(s*u)$ = f • g(u).
Similarly, g • f(u)= $\sum g(ut)f(t*)$ if u*u=tt* and 0 otherwise.
With s = ut, $\sum g(s)f(s*u)$ = g • f(u). This shows that $l^1_r(S)$, •) is a commutative Banach algebra.
Conversely, suppose ($l^1_r(S)$, •) is commutative, then for f, g ∈ ($l^1_r(S)$ •), (f • g)s = (g • f)s (s ∈ S).
By definition of the restricted product on ($l^1_r(S)$, •), (f • g)s = $\sum f(st)g(t*)$ if s*s = tt* otherwise it is zero.
Similarly, (g • f)s = $\sum g(st)f(t*)$ with the same condition. This implies that $\sum f(st)g(t*) = \sum f(t*)g(st)$.
Hence we have st = t* (i)
Now suppose t* = s*u and substituting in (i) gives st = s*u.
Thus s = s*ut* = s*ust = s*sut. This implies that s = ut. and hence S is a semilattice.

Example 4.2
Let (S, +) be an abelian semigroup such that s + s = t + t = s + t = s = t for all s, t ∈ S. Clearly S is a semilattice. Then by Lemma 4.1, $l^1(S)$ is weakly amenable.

Corollary 4.3
Let S be a finite semilattice . Then the following are equivalent:
(i)$l^1(S)$ is commutative.
(ii) l^1S_r is weakly amenable.

Proof :
(i) This is Example 4.2.
(ii) Suppose $l^1(S)$ is commutative. We recall that $S_r = S \cup \{0\}$ and $S \subset S_r$. Clearly $l_1(S) \subset l^1S_r$. Since $l^1(S)$ can be embedded in l^1S_r, it then follows from [Gronbaek (1989), Corollary 2.9] that l^1S_r is weakly amenable.
In the following theorem, we characterize restricted semigroup algebras using the concept of derivation.

Theorem 4.4
Let $A = l_r^1(S)$ be a commutative restricted semigroup algebra on an inverse semigroup S and let A' be the dual space of Banach algebra A. Then A is weakly amenable if every continuous derivation $D : l_r^1(S) \rightarrow A'$ is inner for every commutative Banach -$l_r^1(S)$ -bimodule.

Proof :
Let $D : l_r^1(S) \rightarrow A'$ be a continuous derivation for every Banach -A-bimodule.
Clearly D is a bounded linear map. To show that D is an inner derivation, let $f, g \in l_r^1(S)$ and $u \in S$, we have

$$D(f \bullet g)(u) = D\left(\sum f(ut)g(t*)\right) = D\left(\left(\sum f(ut).\left(\sum g(t*)\right)\right)\right)$$
$$= \sum f(ut)D\left(\sum g(t*)\right) + D\left(\sum f(ut)\right)\left(\sum g(t*)\right)$$

Suppose S contains idempotent elements which commute. By Lemma 4.1, then we have

$$= \sum f(s)D\left(\sum g(us*)\right) + D\left(\sum f(s)\right)\left(\sum g(s*u)\right)$$
$$= \sum f(s)D\left(\sum g(uu*t)\right) + D\left(\sum f(s)\right)\left(\sum g(u*t*u)\right)$$
$$= \sum f(s)D\left(\sum g(t*)\right) + D\left(\sum f(s)\right)\left(\sum g(t*)\right)$$
$$= f\,D(g) + D(f)g.$$

Clearly D is a derivation. Now to show that D is inner.
Let $D(f) = \delta_\lambda f = f.\lambda - \lambda.f$ for each $\lambda \in l^\infty(S)$.
Thus we have :

$$(f.g, \lambda) = (f, D(g)) + (g, D(f))$$
$$= (f, g.\lambda - \lambda.g) + (g, f.\lambda - \lambda.f) = 0.$$

It then follows that $D = \delta_\lambda = 0$ and so we conclude that D is an inner derivation. The proof is complete.

Let G be a group, a Brandt semigroup S over a group G with index set J is the semigroup consisting of elementary $J \times J$ over $G \cup \{0\}$ and a zero matrix $\{0\}$.
We write $S = \{(g)_{ij} : g \in G, i,j \in J\} \cup \{\{0\}\}$, with multiplication given by:
$(g)_{ij}\,(h)_{kl} = (gh)_{il}$ if j=k and 0 if $j \neq k$.
The Brandt semigroup is an inverse semigroup.
For an inverse semigroup S, it was shown in [9] that the restricted semigroup $S_r = S_i \cup_{i \in I}$ for Brandt semigroup S_i with $S_i \cap S_j = S_iS_j = \{0\}$, if $i \neq j$.
The next result shows weak amenability of Brandt semigroup algebras while the subsequent ones give the necessary and sufficient conditions for $l_r^1(S)$ and $l^1(S_r)$.

Theorem 4.5
Let $S = M^o(G, I, n)$ be a Brandt semigroup. Then the semigroup algebra, $l^1(S_r)$ on a restricted semigroup S_r , is weakly amenable if and only if the semigroup algebra $l^1(S)$ on a Brandt semigroup S is weakly amenable.

Proof :
For a Brandt semigroup S_i of finite index, $S_r = \cup_{i\in I} S_i$. It then suffice to say that $l^1(S_r) = \cup l^1(S_i) = l^1(S)$. Thus if $l^1(S)$ is weakly amenable, $l^1(S_r)$ is also weakly amenable. The converse follows easily.

Proposition 4.6
If S is an inverse semigroup, then $C\delta_0$ is an essential closed ideal of $l^1(S_r)$.

Proof :
By [Mohammad and Massoud (2010), Lemma 2.5], $C\delta_0$ is a closed ideal of $l^1(S_r)$ Let $I = C\delta_0$ and $A = l^1(S_r)$
Let $[I : A] = span\{s.f - f.s | s \in I, f \in A\}$. Clearly, $[I : A] = I$. Since $[I : A] = I = \bar{I}^2$ [4, Theorem 3.2], then $C\delta_0$ is an essential ideal of $l^1(S_r)$.

Theorem 4.7
Let $l^1(S_r)$ be a weakly amenable Banach algebra. Then $l^1_r(S)$ is weakly amenable if and only if $l^1(S_r)$ has an essential closed ideal.

Proof :
Suppose $C\delta_0$ is an essential closed ideal of $l^1(S_r)$. By Proposition 2.2 (Gronbaek 1989), $C\delta_0$ is weakly amenable. By [Massoud and Alireza (2006), Theorem 3.7], the restricted semigroup algebra $l^1(S)$ is isomorphic to the quotient space, $l^1(S_r)/C\delta_0$. Then it clearly follows that $l^1_r(S)$ is weakly amenable.

Corollary 4.8
Let $l^1_r(S)$ be a restricted semigroup algebra on an inverse semigroup S. Then $l^1_r(S)$ is weakly amenable if and only if $l^1(S_r)$ is weakly amenable.

Proof :
By Proposition 4.6, $C\delta_0$ is an essential ideal of $l^1(S_r)$. Using Theorem 4.7, the result clearly follows.

Proposition 4.9
Let $S = \cup_{i=1}^{n} G_i$ be a Cliford semigroup. Then the following are equivalent.
(i) $l^1_r(S)$ is weakly amenable.
(ii) $l^1(S_r)$ is weakly amenable.
(iii) $l^1(S)$ is weakly amenable.

Proof :
$\Rightarrow$ (*ii*) By Corollary 4.8, if $l^1_r(S)$ is weakly amenable so is $l^1(S_r)$.
$\Rightarrow$ (*iii*) $S_r = S \cup \{0\}$. Let $S_i = G_i \cup \{0\}$, *i=1,2,…n, then* S_i is a Brandt semigroup with group G_i. Thus $S_r = \cup n\ S_i$ with $S_i \cap S_j = S_iS_j = \{0\}$.

If $l^1 S_r$ is weakly amenable, then by Theorem 4.5, $l^1(S)$ is weakly amenable.
$\Rightarrow$ (*i*) The result follows from Theorem 4.5 and Corollary 4.8.
We recall that $S_r = S \cup \{0\}$. We have $l^1(E_r) = (l^1(E \cup \{0\})^\bullet)$ as a subalgebra of $l^1(S_r)$. Hence $l^1(E_r) \subseteq l^1(S_r)$. Now suppose S_r is a finite semilattice. Let $A = l^1(S_r)$ and let $A_{sr} = l^1(E_r)$. Hence $A = l^1 \bigoplus A_{sr} : A_{sr} A_{tr} \subset A_{str}$, s_r, $t_r \in S_r$. Clearly, each A_{sr} is a closed subalgebra of A.
The following result is an analogue to Proposition 3.2.

Proposition 4.10
Let S_r be a finite semilattice and let A be a Banach algebra graded over S_r. Then A is weakly amenable if and only if each A_{sr} is weakly amenable.

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