

Impact of wood decay on carbon flux in the Niger Delta urban soil, Nigeria

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ABSTRACT

The use of unmatched trees for urban forestry is a critical issue causing increasing carbon accumulation in the soil through decaying. While the degradation of urban trees persists with pieces of evidence of roots and butts rotting, little is known about this process in Nigeria and particularly in the Niger Delta region where climatic characteristics favour activities of decaying agents. Soil contact tests were conducted on wood blocks of four introduced species (*Azadirachta indica*, *Gmelina arborea*, *Delonix regia*, and *Casuarina equisetifolia*) and two native species (*Musanga cecropioides* and *Ficus elastica*) at 15cm and 30cm depth for 16 weeks to investigate carbon flux into the soil at the University of Port Harcourt, Nigeria. Wood density, air and soil temperature, relative humidity, and the presence of termite infestation are among the factors considered that might affect decay rate and carbon fluctuations in the soil. *Delonix regia* recorded the highest weight loss and soil carbon at a depth of 15cm in week 12 ($98.69 \pm 1.64\%$) and ($1.40 \pm 0.01\%$) respectively. Weight loss increased exponentially with time for *Delonix regia* and *Ficus elastica* but other species had a weak linear trend. While the wood density significantly influenced the decay rate and soil carbon concentration, the use of *Delonix regia* in the Niger Delta should be completely discouraged.

Keywords: Soil carbon accumulation, urban trees, wood decay, carbon flux, decaying agents

INTRODUCTION

The soil is estimated to store about 1550GtC of carbon which is up to three times that of the volume of carbon in the atmosphere (Yousaf *et al.*, 2017). Soil serves as a carbon sink and is important in the carbon cycle making it key in addressing issues regarding climate change and the construction of global climate models (Amelung *et al.*, 2020). Two major inputs of carbon into the soil by plants are above-ground litter and root litter below the ground (Gougoulas *et al.*, 2014). Soil carbon (SC) can be released into the atmosphere through soil respiration by microbial/fauna – heterotrophic respiration and roots–autotrophic respiration (Jian *et al.*, 2021). The release of SC is affected by season and litter (Shi *et al.*, 2020), termite activities (Yamada *et al.*, 2005; De Gerenyu *et al.*, 2015), and temperature (Davidson and Janssens, 2006). Trees play significant roles culturally, environmentally, and economically

of which carbon sequestration is one, but the same tree could become a bane if not properly considered before planting (Shackleton *et al.*, 2016). Planting trees unmatched with environmental conditions are on the rise (Araujo and Austine, 2020) and this can expose these trees to conditions such as stress or decay agents leading to injury, property damage, and tree loss (Conway and Yip, 2016; Hasan *et al.*, 2017).

Wood decaying is considered one of the most important routes for the influx of carbon into the soil (Sarasija and Remadevi, 2012; Blonska *et al.*, 2019). Thus, wood decay represents a significant process transforming forests from carbon sinks to carbon sources in the soil (Sarasija and Remadevi, 2012). This process is affected by various agents such as fungi, bacteria, and insects (Greaves, 1971; Johnston *et al.*, 2016; Griffiths *et al.*, 2019), moisture (Brischke and Alfredson, 2020), rainfall,

temperature (Hossain *et al.*, 2011) and wood density (Owoyemi *et al.*, 2013).

The University of Port Harcourt (UNIPORT) established in 1975 is located within the Niger Delta region of Nigeria with a spatial land area extent of 4.61 km² (Eludoyin *et al.*, 2015). The UNIPORT environment is unique in climatic terms with humidity reaching 112.47% (Uko and Tamunobereton-Ari, 2013) and a high annual rainfall range of 2000mm to 2500mm occurs between April to October (Nwaerema and Edokpa, 2019). The soil type is of the Coastal Plain of the Eastern Niger Delta (Nghah and Abam, 2014) and it is always moisture saturated nearly throughout the year making it not favourable for species requiring lesser moisture and predisposing them to suffocation and rotting (Adedeji and Aiyeloja, 2017). The trees within the UNIPORT that have shown good vigour are mostly bark latex-containing species such as *Astonia bonnie*, *Milicia excelsa* and *Musanga cecropioides*, and *Ficus elastica* with outstanding prop roots which can make them breathe above the soil. While the use of unmatched trees for urban forestry is a critical issue causing increasing carbon accumulation in the soil through decaying, the impact of dying/declining introduced trees on carbon flux in the UNIPORT soil has not been reported. This study therefore examined the decay of four introduced species (*Azadirachta indica*, *Gmelina arborea*, *Casuarina equisetifolia*, *Delonix regia*) and two native species (*Musanga cecropioides* and *Ficus elastica*) and their impact on soil carbon in UNIPORT.

MATERIALS AND METHODS

Field experiment

The field experiment was laid out within the Professorial Quarters (longitude 4°54'12"N and latitude 6°54'26"E), Delta Park, University of Port Harcourt, Port Harcourt, Nigeria. Wood samples of selected species were processed into uniform sizes of 2cm x 5cm x 5cm and set up for the decay experiment. A total of 144 wood block samples were used for this experiment comprising 3 replicates of the six selected tree species at 4 times frames (t1 – t4) of 4 weeks intervals up to 16 weeks for ground soil contact at both 15cm and 30cm depth. 18 blocks representing 3 replicates for each species were also set aside for the measurement of wood density. Prior to wood burial, soil samples were drawn randomly within the experiment area at

15cm and 30cm depth for soil physicochemical analysis, soil micro-organism identification, and quantification. At the termination at various intervals, soil samples were collected from the base where wood samples were buried and each collection for each species was bulked in zip lock bags for soil carbon analysis.

Climate and soil characteristics

Air temperature and relative humidity at the study site were measured using a digital hygrometer (DC-103). This device also features a temperature probe which was inserted into the soil to measure soil temperature. Soil routine analysis including micronutrients (Cu, Mn, Fe, and Zn), exchangeable bases (Ca, Mg, K and Na), including available phosphorus, nitrogen, and acidity (pH) was carried out on soil samples prior to wood burial while soil carbon analysis was done at various termination intervals. Soil samples were air-dried and sieved and soil particle size distribution was done using the hydrometer method. Soil organic carbon was determined using the wet oxidation method (Sato *et al.*, 2014). Fungi isolation and quantification were done following procedures similar to Ramirez-Elias *et al.* (2014). Bacteria were isolated (Parvin *et al.*, 2016) and after incubation of bacteria, the colony formation unit was calculated (Sarayana *et al.*, 2013). Fungi identification was done after observing colonial morphology and microscopic morphology after 7 days of incubation while bacteria identification was performed using physical and biochemical test characterization.

Wood decay analysis

Wood blocks were conditioned by air drying and moisture content was measured using a wood moisture meter before burial and after exhumation. The weight of individual wood block samples was measured before burial and immediately after exhumation. Mass was measured using a digital weighing instrument. Failure to reach initial moisture content was corrected using the equation below;

$$\text{Moisture correction equation} = W_2 = W_1 - \left(\left(\frac{M_1}{100} \times W_1 \right) (M_0 - M_1) \right) \dots\dots\dots \text{Eq. 1}$$

Where;

W_2 is corrected weight, W is weight at M_1 , M_1 is final moisture and M_0 is initial moisture.

Weight loss calculated using the equation below;

$$\text{Weight loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (\text{Bakar et al., 2013}) \quad \text{Eq. 2}$$

Where;

W_1 = Initial weight of wood block sample

W_2 = Final weight of wood block sample

Wood samples density was estimated using the approach by Rodriguez *et al.* (2016). The samples were oven-dried at 100°C till constant weight, their volume was calculated and their mass measured using the formula thus:

$$WD = \frac{M}{V} \quad \text{Eq. 3}$$

Where;

WD is the wood density (g/cm^3), M is the dry mass of the wood (g) and V is the volume (cm^3).

The decay rate and half-life of each species were calculated using the decay rate or decay constant k model and half-life equation as used by Fravolini *et al.* (2016);

$$x_t = x_0 e^{-kt} \quad \text{Eq. 4}$$

Where;

x_t = Mass of deadwood at a given time (t),

x_0 = Initial mass

$$\text{Half-life } (t_{1/2}) = \frac{\ln(\frac{1}{2})}{-k} \quad \text{Eq. 5}$$

Where;

k = decay constant

Statistical analysis

Statistical analysis was performed using R version 4.1.2. The ggplot2 package version 3.3.5 was used for graphical representations. Mean comparison of decay rate amongst species and period intervals was conducted using Analysis of Variance and Least Significant Difference for post-hoc analysis using the Agricolae (v. 1.3-5) package and t test comparison using t-test function in R. Pearson correlation analysis was used to test for the linear relationship among variables using the cor function in R.

RESULTS

Microbial count and identification

Bacteria viable count averaged 2.38×10^5 cfu/g and 1.97×10^5 cfu/g, while mold and yeast count averaged 3.84×10^4 cfu/g and 1.85×10^4 cfu/g, for 15cm and 30cm depth respectively. Counts were significantly higher at 15cm than at 30cm (Table 1). Ten (10) bacteria species and five (5) fungi species were identified. Among the bacteria species identified, firmicutes were the most predominant phylum while Ascomycota was the most predominant phylum among the fungi species (Table 2).

Table 1: Viable Count of Micro-organisms at different Depths

Parameter	Depth	Count (cfu/g) (Mean±SD)	T-Test t	Sig.
Microbe Viable Count	15cm	2.38E5±1.12E4	15.50	0.004
	30cm	1.97E5±6.66E3		
Mould and Yeast Count	15cm	3.84E4±1.94E3 ^a	39.52	0.001
	30cm	1.85E4±2.82E3 ^b		

Means significantly different at sig. ≤ 0.05 ; cfu/g = colony-forming unit per gram

Table 2: Micro-organisms Identified in the Soil

S/N	Organism	Family	Phylum/Division
	Bacteria		
1	<i>Serratia marcescens</i>	Yersiniaceae	Proteobacteria
2	<i>Bacillus subtilis</i>	Bacillaceae	Firmicutes
3	<i>Pseudomonas fluorescens</i>	Pseudomonadaceae	Proteobacteria
4	<i>Enterococcus faecalis</i>	Enterococcaceae	Firmicutes
5	<i>Corynebacterium minutissimum</i>	Corynebacteriaceae	Actinobacteria
6	<i>Rathayibacter tritici</i>	Microbacteriaceae	Actinobacteria
7	<i>Clostridium pasteurianum</i>	Clostridiaceae	Firmicutes
9	<i>Microbacterium gubbeenense</i>	Microbacteriaceae	Actinobacteria

8	<i>Achromobacter xylosoxidas</i>	Alcaligenaceae	Proteobacteria
10	<i>Bacillus alcalophilus</i>	Bacillaceae	Firmicutes
	Fungi		
1	<i>Aspergillus fumigatus</i>	Trichocomaceae	Ascomycota
2	<i>Fusarium spp</i>	Nectriaceae	Ascomycota
3	<i>Aspergillus niger</i>	Trichocomaceae	Ascomycota
4	<i>Penicillium spp</i>	Trichocomaceae	Ascomycota
5	<i>Rhizopus spp</i>	Mucoraceae	Mucoromycota

Soil and climatic characteristics

Average soil temperature was observed to decrease from 29.21⁰C in week 4 to 27.15⁰C in week 8 then it increased to 28.70⁰C and 28.84⁰C in week 12 and week 16. The same trend was also observed for air temperature; 31.28⁰C, 27.46⁰C, 30.13⁰C, and 31.66⁰C from weeks 4 to 16 respectively. The highest humidity was observed in week 8 (84.00%) and the lowest in week 16 (75.00%) (Fig. 1). The

soil pH range is alkaline. There was no significant difference in most of the soil properties at the two depths with exception of sand, silt, Fe, Cu, and Zn. Significant correlation between soil property and depths was observed for sand, silt, Ca, Mg, ECEC, base saturation, organic carbon, available phosphorus, Mn, Fe, and Zn of which only Mn and available phosphorus were negatively correlated (Table 3).

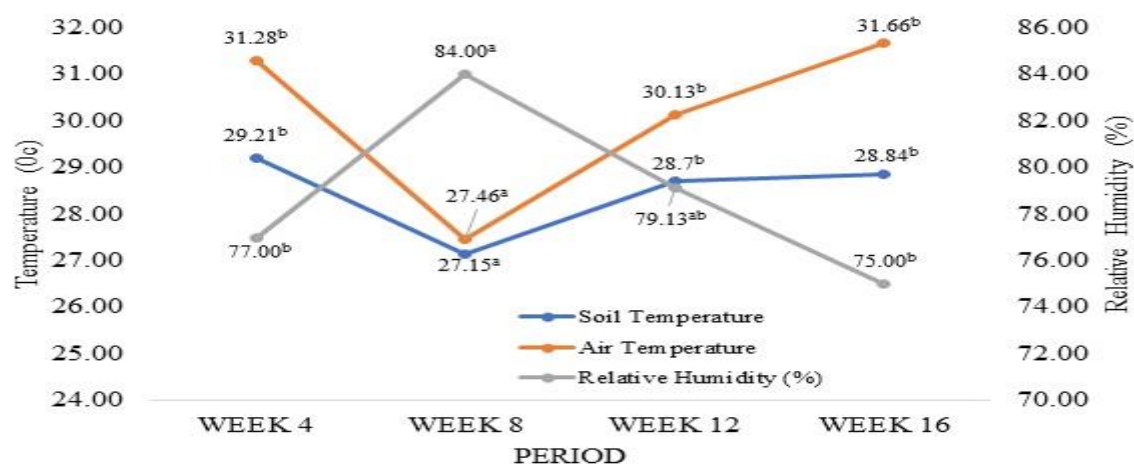


Fig. 1: Soil and air temperature, and relative humidity at various periods

Table 3: Soil Physico-chemical Properties at depths 15cm and 30cm

Properties	Depth		T-test		Correlation	
	15cm	30cm	t	Sig.	r	Sig.
pH	5.45±0.20	5.28±0.03	1.33	0.31	-0.99	0.07
Sand (%)	89.80±1.00	83.30±0.50	22.52	0.00*	-1.00	0.00*
Silt (%)	6.60±1.00	11.10±0.50	-15.59	0.00*	1.00	0.00*
Clay (%)	3.60±0.00	5.60±0.00	-	-	-	-
Ca (cmol)	5.38±0.33	5.78±0.08	-2.69	0.12	0.99	0.02*
Mg (cmol)	0.54±1.55	0.54±0.04	0.00	1.00	0.99	0.04*
K (cmol)	0.06±0.02	0.12±0.01	-3.90	0.06	-0.87	0.33
Na (cmol)	0.24±0.04	0.24±0.00	-0.16	0.89	-	-
Al+H (cmol)	0.11±0.01	0.10±0.01	-	-	-	-
ECEC (cmol)	6.32±0.54	6.65±0.22	-1.79	0.22	1.00	0.01*
Base Sat. (%)	98.32±0.22	98.64±0.05	-3.26	0.08	1.00	0.00*
Total N (%)	0.09±0.01	0.07±0.02	1.15	0.37	-0.24	0.85
Total Org. C (%)	0.72±0.10	0.83±0.21	-1.73	0.23	1.00	0.00*
Avail. P (mg/kg)	23.04±0.72	21.52±0.80	1.73	0.23	-1.00	0.00*
Mn (mg/kg)	63.98±42.03	61.77±2.22	0.09	0.94	-1.00	0.01*
Fe (mg/kg)	29.50±2.15	31.38±1.88	-11.82	0.01*	1.00	0.01*
Cu (mg/kg)	0.74±0.15	0.09±0.02	8.67	0.01*	0.99	0.11
Zn (mg/kg)	16.10±0.15	21.62±0.61	-21.00	0.00*	1.00	0.00*

* = significant at $p \leq 0.05$

Decay analysis of species and carbon fluxes

Among the species, no significant difference was seen in their weight loss until weeks 12 and 16. *D. regia* had the highest weight loss of $98.98 \pm 1.71\%$ at week 12 buried at 30cm depth. *A. indica* and *F. elastica* had the least minimum amount of weight loss ($21.18 \pm 5.98\%$ and 40.25 ± 24.11) occurring at week 16 depth of 15cm and week 16 depth of 30cm, respectively. The decay rate ranged from $0.016 \pm 0.01 \text{WK}^{-1}$ to $0.222 \pm 0.23 \text{WK}^{-1}$ being values for *A. indica* at 15cm depth and *D. regia* at 30cm depth. Similarly, *A. indica* at 15cm depth had the longest half-life while *D. regia* at 30cm depth had the shortest half-life (Table 4). At 15cm depth, *D. regia* recorded the highest spike of 1.40% at week 12 while *A. indica* resolved back to the initial concentration of 0.72% in the same week (Fig. 2). At 30cm depth, SC decreased below the initial mark for all species in the eightieth week. At the

termination period (week 16), *M. cecropioides* (1.20%) maintained its upward increase from week 12 while *F. elastica* (0.71%) declined below the baseline (Fig. 3). There was a significant positive relationship between weight loss of wood and carbon change ($r = 0.37$) at 15 cm depth but no significant relationship was observed within each species. *D. regia* ($r = 0.59$) and *F. elastica* ($r = 0.54$) were the top positive correlation while *G. arborea* ($r = -0.43$) and CE ($r = -0.41$) had greater negative correlation magnitude at 15cm depth. At 30cm depth, no significant correlation was observed overall but significant correlation existed for *M. cecropioides* ($r = 0.88$), *G. arborea* ($r = -0.93$) and *C. equisetifolia* ($r = 0.64$). The pooled weight loss and soil carbon change from both depths yield no significant correlation ($r = 0.10$) but significance was observed for *M. cecropioides* ($r = 0.67$) and *G. arborea* ($r = -0.75$) (Table 5).

Table 4: Weight Loss Trends and Decay of Selected Wood Species

Species	Mean Weight Loss (%) \pm SD				Mean \pm SD Decay (WK^{-1})	Half Life
	Week 4	Week 8	Week 12	Week 16		
15cm Depth						
A	12.41 \pm 2.76	3.32 \pm 2.70	13.62 \pm 3.72 ^c	21.18 \pm 5.98 ^b	0.016 \pm 0.01 ^b	119.41 \pm 212.23 ^a
B	23.86 \pm 7.20	34.56 \pm 6.61	47.13 \pm 10.03 ^b	30.87 \pm 7.39 ^b	0.050 \pm 0.02 ^b	17.37 \pm 9.58 ^b
C	9.34 \pm 5.78	12.91 \pm 4.04	23.56 \pm 11.40 ^c	23.82 \pm 4.84 ^b	0.021 \pm 0.01 ^b	40.47 \pm 17.31 ^b
D	14.87 \pm 12.70	35.86 \pm 30.97	98.69 \pm 1.64 ^a	81.88 \pm 24.90 ^a	0.195 \pm 0.21 ^a	19.15 \pm 30.10 ^b
E	13.17 \pm 5.99	29.18 \pm 16.25	61.07 \pm 27.56 ^b	87.05 \pm 8.88 ^a	0.080 \pm 0.06 ^b	15.19 \pm 11.72 ^b
F	12.54 \pm 0.68	16.73 \pm 4.58	19.58 \pm 4.34 ^c	11.98 \pm 1.82 ^b	0.021 \pm 0.01 ^b	45.21 \pm 28.35 ^b
30cm Depth						
A	13.07 \pm 5.49	6.38 \pm 1.25	16.53 \pm 3.45 ^b	17.42 \pm 1.84 ^c	0.018 \pm 0.01 ^b	53.99 \pm 25.99 ^a
B	19.55 \pm 1.01	20.48 \pm 1.88	32.61 \pm 1.74 ^b	48.72 \pm 2.80 ^b	0.040 \pm 0.01 ^b	18.73 \pm 4.78 ^{bc}
C	13.09 \pm 7.72	42.35 \pm 49.97	22.24 \pm 6.87 ^b	28.48 \pm 11.24 ^{bc}	0.101 \pm 0.26 ^{ab}	31.20 \pm 15.55 ^b
D	6.58 \pm 0.57	55.76 \pm 34.57	98.98 \pm 1.71 ^a	94.04 \pm 4.06 ^a	0.222 \pm 0.23 ^a	14.35 \pm 17.28 ^c
E	16.60 \pm 15.94	50.51 \pm 32.99	86.03 \pm 14.43 ^a	81.00 \pm 8.06 ^a	0.145 \pm 0.17 ^{ab}	12.50 \pm 12.99 ^c
F	13.35 \pm 1.65	21.29 \pm 6.64	30.72 \pm 19.17 ^b	40.25 \pm 24.11 ^b	0.034 \pm 0.02 ^b	26.96 \pm 16.77 ^{bc}

A = *Azadirachta indica*,

B = *Musanga cecropioides*,

C = *Gmelina arborea*,

D = *Delonix regia*,

E = *Ficus elastica*,

F = *Casuarina equisetifolia*

Means with same alphabet are not significantly different at $p \leq 0.05$

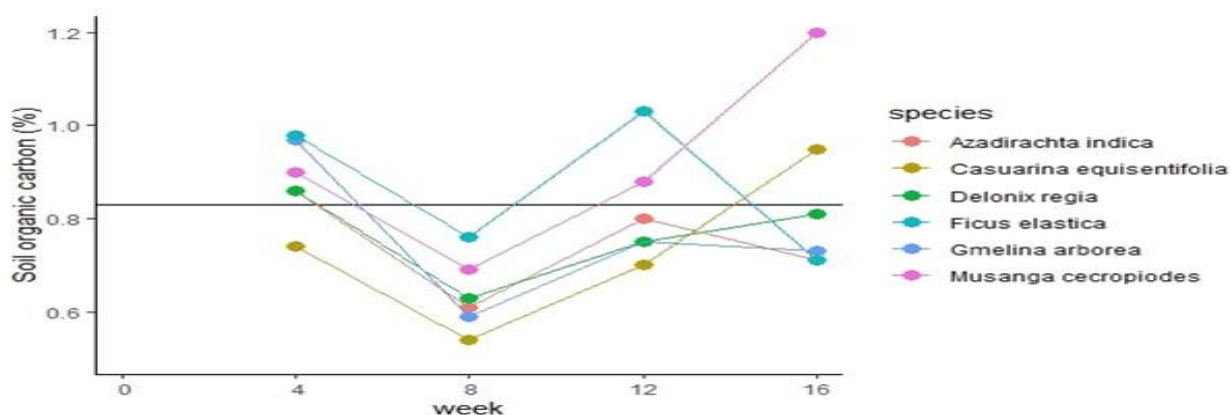


Fig. 2: Soil carbon fluctuations around control (Horizontal bar) at various weeks beneath wood species at 15cm depth

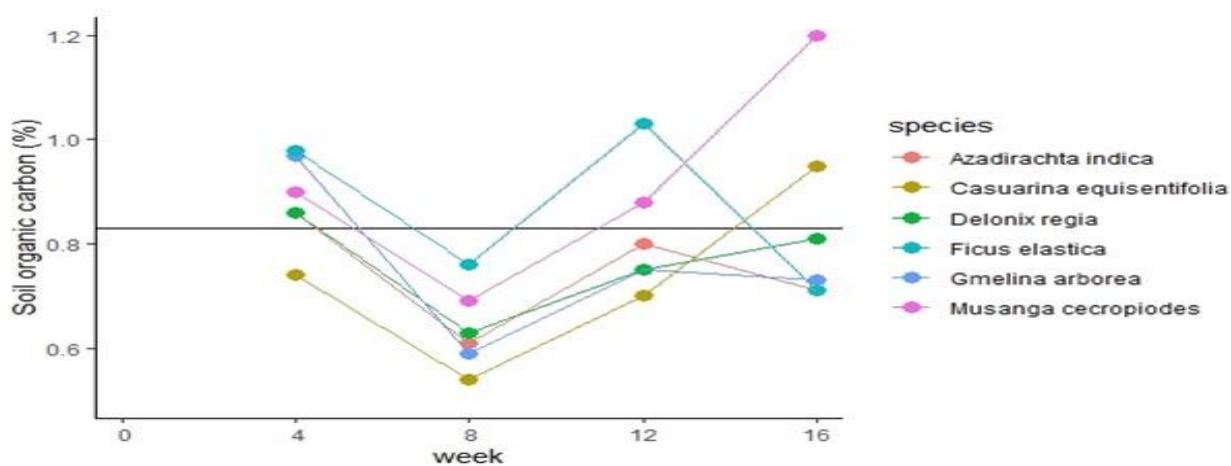


Fig. 3: Soil carbon fluctuations around control (Horizontal bar) at various weeks beneath wood species at 30cm depth

Table 5: Relationship between weight loss from wood decay and soil carbon change based on species

Species	15cm		30cm		Total	
	r	Sig.	r	Sig.	R	Sig.
<i>A. indica</i>	-0.37	0.36	0.59	0.13	-0.11	0.68
<i>M. cecropioides</i>	-0.06	0.89	0.88	0.00	0.67	0.01
<i>G. arborea</i>	-0.43	0.29	-0.93	0.01	-0.75	0.00
<i>D. regia</i>	0.59	0.12	-0.25	0.55	0.17	0.53
<i>F. elastica</i>	0.54	0.16	-0.19	0.65	-0.13	0.63
<i>C. equisetifolia</i>	-0.41	0.31	0.64	0.09	-0.23	0.39
Total	0.37	0.01	0.10	0.52	0.10	0.35

Significant at sig. < 0.05; r = correlation coefficient

Factors affecting the decay rate

A significant relationship was observed between the nature of degrading agent attack and the decay rate on the wood species with a higher decay rate associated with termite attack (Table 6). The decay rate at various weeks was significantly different with week 12 ($0.134 \pm 0.21 \text{ wk}^{-1}$) having the highest rate followed by week 8 ($0.071 \pm 0.16 \text{ wk}^{-1}$), week 16

($0.070 \pm 0.09 \text{ wk}^{-1}$) and lastly week 4 (0.039 wk^{-1}). Soil temperature, air temperature, relative humidity, and density had no significant relationship with the decay rate but were but differed statistically. The highest decay rate was observed in soil temperature of 28.70°C , air temperature of 30.13°C , relative humidity of 79.13%, and density of $0.41\text{--}0.60 \text{ g/cm}^3$ (Table 6).

Table 6: Comparison of decay rate of levels of various factors

Properties	Categories	Decay Rate (Mean \pm SD) (wk ⁻¹)	r	Sig
Soil temperature (⁰ C)	27.15 (Week 8)	0.071 \pm 0.16 ^{ab}	-0.023	0.785
	28.70 (Week 12)	0.134 \pm 0.21 ^a		
	28.84 (Week 16)	0.070 \pm 0.09 ^{ab}		
	29.21 (Week 4)	0.039 \pm 0.02 ^b		
Air temperature (⁰ C)	27.46 (Week 8)	0.071 \pm 0.16 ^{ab}	-0.042	0.617
	30.13 (Week 12)	0.134 \pm 0.21 ^a		
	31.28 (Week 4)	0.039 \pm 0.02 ^b		
	31.66 (Week 16)	0.070 \pm 0.09 ^{ab}		
Humidity (%)	75.00 (Week 16)	0.070 \pm 0.09 ^{ab}	0.044	0.600
	77.00 (Week 4)	0.039 \pm 0.02 ^b		
	79.13 (Week 12)	0.134 \pm 0.21 ^a		
	84.00 (Week 8)	0.071 \pm 0.16 ^{ab}		
Depth (cm)	15	0.064 \pm 0.11	0.103	0.218
	30	0.093 \pm 0.17		
Type of attack	No Termite	0.037 \pm 0.10 ^b	0.394	0.000
	Termite	0.154 \pm 0.18 ^a		
Density (g/cm ³)	0.20 – 0.40	0.05 \pm 0.13 ^b	-0.088	0.294
		0.16 \pm 0.18 ^a		
	0.41 – 0.60			
	> 0.61	0.02 \pm 0.01 ^b		

Means with same alphabet are not significantly different at $p \leq 0.05$

DISCUSSION

The results of microbial counts support higher a population of soil organisms at 15cm compared to 30cm depth. A higher population at this critical zone is expected as complex interactions involving soil components and microorganisms usually taken place near the surface environment (Bhattarai *et al.*, 205). These results are in congruent with previous studies indicating soil depth as a crucial determinant of soil micro-biome (Ko *et al.* (2017). Bacterial and fungi counts are higher but had similar species to those reported by Williams and Hakam (2016) in control soil samples in Port Harcourt. *Bacillus subtilis*, *Pseudomonas fluorescens* affects wood permeability by hydrolyzing pectin and hemicellulose (Greaves, 1971) which predisposes the wood to fungi attack. *Pseudomonas* spp, *Corynebacterium* spp have been reported to degrade xylan, which is a

hemicellulose compound (Deschamps and Lebeault, 1980). *Aspergillus niger*, *Penicillium corylophilum* and *Aspergillus fumigatus* were also reported by Risnasari *et al.* (2021) in the deterioration of wood exposed to mangrove ecosystem. Among this, *Clostridium xylanolyticum* of the same genus as *Clostridium pasteurianum* has been identified as causing tunneling decay (Rogers and Baecker, 1991).

Soil classification is sand to loamy using the United States Department of Agriculture (USDA) textural classification triangle (Garcia-Gaines and Frankenstein, 2015). Particle size distribution at 30cm depth was within the range of control values reported by Obianefo *et al.* (2017) with exception of silt which ranged from 5%-9% and 11.10%. Soil temperature was also within the range of optimum

temperature (25-30°C) for bacteria and fungi growth according to Pietikainen *et al.* (2005).

The interaction between microbial and insect attack clearly affected the rate of decay of the wood samples with the decay rate of wood species attacked solely by microbes being significantly lower than those which also had termite's infestation. *D. regia* and *F. elastica* were highly attacked by termites throughout the study which could be attributed to the higher weight loss of these species. The low decay rate observed in the early week could be a result of a delay in colonization by the degrading agents. At the early stages of decay, fungi activities are limited to those already present in the wood and the rate would speed up colonization from surrounding spores (Liu *et al.*, 2013).

The decay rate was significantly higher at the median temperatures and relative humidity and is similar to rates of litter decomposition reported by Cortez (1998). A positive correlation was reported by Hossain *et al.* (2011) between rainfall and temperature on litter decomposition of selected species including *A. indica* while Yatskov *et al.* (2003) reported no significant effect of climate on the decomposition of coarse woody debris. Density correlated negatively with weight loss which was in tandem with the trend reported by Owoyemi *et al.* (2013).

Depth and wood density was observed to have a negative impact on carbon influx as estimates predict less soil carbon influx with an increase in depth and density of wood species. Soil and litter respiration has been reported to increase with temperature (Pietikainen *et al.*, 2005; Xiao *et al.*, 2014). The inclusion of litter in the soil increases microbial activity and rhizosphere respiration which in turn increases respiration in the soil and soil carbon efflux (Xiao *et al.*, 2014).

CONCLUSIONS

Wood decay is affected by a variety of factors such as species, density, and the presence of macro-organisms as seen in this study. Intrinsic characteristics such as the density of the species significantly affected the degradation rate with lower decomposition in the highest and lowest density class. Both micro and macro-organisms were found degrading wood samples under the soil. The degradation rate of

the combined effect of micro-organisms and termite activity was significantly higher than the decay rate of those activities exclusive by micro-organisms. *D. regia* had the highest weight loss and also recorded the highest carbon levels in soil from its base at 15cm depth. Significant predictors of decay rate were weight loss, soil temperature, density, nature of the attack, and all linear combinations of them while depth and density were significant predictors of soil carbon influx. Though *F. elastica* tree is well adaptable species, its wood samples being one of the two most degraded is an indication that its debris if killed can cause a high influx of carbon to the soil. *Delonix regia* is not well adaptable and its use in the Niger Delta should be completely discouraged.

Authors' contributions: GAA conceptualize the idea for this work and FSE assisted in mapping out the methodology. ACE carried out the field experiment, data collection, and statistical analysis under the supervision of FSE and GAA. The manuscript was written by ACE and FSE with edits from GAA.

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