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Articles

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Comparative Study on Carbon Sequestration Potentials of *Gmelina arborea* Roxb. and *Tectona grandis* L.f Seedlings

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Abstract

Deforestation and forest degradation are the main sources of greenhouse gas (GHG) emissions in most tropical regions which result in climate change. Tree crops play a significant role in mitigation of this dangerous phenomenon through CO_2 sequestration. The study therefore investigated carbon sequestration potentials of seedlings of *Gmelina arborea* and *Tectona grandis*.

Seeds of *G. arborea* and *T. grandis* were sown differently in germination boxes. Eighty seedlings of each tree species were selected and 5 seedlings from each species were harvested carefully and excised into roots, stem and leaves fortnightly for 10 weeks to determine sequestered carbon contents. The experimental design was Completely Randomized Design (CRD) with 2 and 5 replicates. Data was subjected to analysis of variance (ANOVA) and correlation analysis to determine the relationship between carbon content in leaves, stems and roots.

There was no significant difference in the carbon content of the roots of the two species ($P > 0.05$) while carbon contents in leaves, and stems were significantly different ($P < 0.05$). The fortnightly carbon sequestration by *G. arborea* and *T. grandis* increased with increase in number of weeks (age). The foliage carbon content of *G. arborea in the first* two weeks of study was higher (0.22g) than that of *T.grandis* (0.15g). This trend continued till 10th week with *G. arborea* (2.67g) and *T. grandis* (1.19g). At the end of the study period, stems of *G. arborea* had a higher carbon content (1.36g) while the stems of *T. grandis* had 0.45g. Roots of the seedlings of the two species had the least carbon contents at the end of the study (*G. arborea*: 0.93g and *T. grandis*: 0.66g) when compared to leaves and stem. The final carbon content of *G. arborea* seedling at the end of 10th week was 4.96g higher than *T. grandis* with 2.3g.

The assimilation rate of the seedlings bolstered the biomass of the two species of which carbon content is the main component.

Keywords: Forest degradation, Climate change, Biomass, Carbon dioxide, Sequestration

Introduction

Carbon dioxide (CO_2) is a major greenhouse gas among the principal gases causing global warming. The gas is released in excessive amounts via anthropogenic activities such as and including indiscriminate forest removal. CO_2 is trapped in the atmosphere, thereby raising the global temperatures (FAO, 1997). This poses a harmful challenge to humans as it increases the incidence of carcinogenic diseases, flooding as a result of ocean rise and melting of the polar ice

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in Polar Regions, aggravates drouts in the continental hinterland and loss of bio-resources of food and medicine (Label and Kane, 1989; Odjugo, 2009).

As consequent of various human activities such as deforestation and fossil fuel combustion Atmospheric CO_2 continues to increase. This has resulted into a phenomenon known as climate change, which is a contemporary harmful to the existence of man, livestock and environment generally. This is characterized by a consistent unfavorable climate exemplified in the rising earth temperature which is referred to as global warming. Deforestation and forest degradation account for between 15% - 20% of global carbon emissions, and most of that comes from tropical regions of the world (Odjugo, 2009). Approximately 60% of the carbon sequestered by forests is released into the atmosphere through deforestation (Gullison *et al.,* 2007). Deforestation of tropical forest releases about 1.5 Gt of carbon into the atmosphere every year (Gullison *et al.,* 2007). According to Gullison *et al.* (2007), deforestation and forest degradation are the main sources of greenhouse gas (GHG) emissions in most tropical regions and has a greater influence on the ecosystem generally.
Because the forests are estimated to store about 650 billion tons of carbon and absorb 8.5 billion tons of CO2 per year from the atmosphere (Nabuurs, 1998), forest ecosystems of the tropics therefore have a major role to play in the mitigation of this dangerous phenomenon. Forests store carbon and comprise about 80% of the entire above-ground organic carbon and 40% of the total below-ground organic carbon worldwide (FAO, 2011). They also contain one of the major carbon pools and have a substantial function in the global carbon cycle (FAO, 2011).

Trees use the carbon absorbed by leaves during photosynthesis to maintain cellular structures and grow new tissues. Maintenance of existing tissues requires an expenditure of carbon during respiration, which then reduces the carbon available for new growth (Bombelli et al., 2009). The net carbon available to a tree, along with required nutrients, is then allocated to the growth of leaves, roots stems, flowers and seeds (Bazzaz, 1996). All the same, tree seedlings utilize carbon from carbon dioxide in the process of photosynthesis towards attaining maturity. Sequestration of CO_2 occurs at every developmental stage of the forest and different plants store CO_2 at different rates and levels (Basuki *et al*., 2009). In order to ascertain how trees sequester CO_2, several studies have been carried out with different, destructive methods to directly measure the biomass by harvesting the tree and measuring the actual mass of each of its compartments, (e.g., roots, stem, branches and foliage) (Kangas and Maltamo, 2006). Indirect methods also attempt to estimate tree biomass by measuring variables that are more accessible and less time-consuming to assess (for instance, wood volume and gravity) (Peltier *et al*., 2007). More so, allometric equations have also been used for several forest estates with little or no effort on nursery-grown tree seedlings (Kettering *et al*., 2001). This study therefore investigated carbon sequestration potentials of seedlings of *Gmelina arborea* and *Tectona grandis*, endemic fast-growing tree species, with a view to determining the level with which they sequester CO_2.

Materials and Methods
The study was carried out at the Silviculture Nursery of the Department of Sustainable Forest Management (SFM), Forestry Research Institute of Nigeria (FRIN), Jericho Hill, and Ibadan,

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Nigeria. FRIN is located on the longitude $07^0$23'18"N to $07^0$23'43"N and latitude $03^0$51'20"E to $03^0$51'43"E.

Seeds of *Tectona grandis* and *Gmelina arborea,* which are fast growing tree species, were procured and sown differently in germination boxes. The germinated seedlings were pricked into polythene pots filled with topsoil. Pre-planting soil analysis of the topsoil was carried out in order to determine the initial carbon content and post-harvesting analysis was done after each harvest of tree seedlings.

Eighty seedlings of each tree species were selected and at the end of the 2nd week, 5 seedlings from each species were harvested carefully and excised into roots, stem and leaves. Fresh weight of each seedlings part was determined, using a sensitive weighing balance, after which they were oven-dried at 70^0C until they attain constant weight in order to estimate their biomass. The carbon content was determined by conversion of biomass to C through use of the coefficient (0.55). That is Carbon stock: C = 0.55 x Total biomass (MacDicken, 1997). The organic carbon in the soil after each harvest of the seedlings was determined through soil analysis to know exact carbon sequestered by the seedlings.

This was done fortnightly for 10 weeks. The ratio of carbon content in root, stem and leaves at each period of harvesting was determined.
The experimental design was Completely Randomized Design (CRD) with 2 species as treatments replicated 5 times. Data was subjected to analysis of variance (ANOVA) and correlation analysis was used to determine the relationship between carbon content in leaves, stems and roots of *Gmelina arborea* and *Tectona grandis* seedlings.

Results
The physico-chemical properties of the soil before and after study are presented in table 1. The organic carbon of the soil where *G. arborea* and *T. grandis* seedlings were planted relatively decreased after harvesting (*G. arborea:* 15.1cmol/kg and *T. grandis*: 15.8 cmol/kg). Other physico-chemical properties of the soil followed similar trend.
Table 2 shows Analysis of Variance among carbon contents sequestered by leaves, stems and roots of *G. arborea* and *T. grandis* seedling within 10 weeks of study. There was no significant difference in the carbon content of the roots of the two species ($P > 0.05$) while carbon contents in leaves, and stems were significantly different ($P < 0.05$). The total carbon contents in *G. arborea* and *T. grandis* seedlings within period of study were also significantly different.

Table: 1. Physico-Chemical Properties of Topsoil used for Raising Seedlings of *Gmelina arborea* and *Tectona grandis*

Nutrients	Pre- planting Quantity	Post-planting Quantity (Ga)	Post- planting Quantity (Tg)
O.C (cmol/kg)	17.8	15.1	15.8
O.M (cmol/kg)	30.6	21.3	23.7

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T.N (cmol/kg)	1.5	0.9	1.1
K (cmol/kg)	0.11	0.06	0.07
Na (cmol/kg)	1.27	0.98	1.2
Ca (cmol/kg)	5.19	3.07	3.43
Mg (cmol/kg)	2.34	1.89	2.0
Mn (mg/kg)	26.1	24.1	24.8
Cu (mg/kg)	0.8	0.7	0.6
Zn (mg/kg)	3.1	2.8	2.7
Fe (mg/kg)	36	29	31
P (mg/kg)	51.92	43.23	45.01
Sand%	86.5	86.5	86.5
Clay%	9	9	9
Silt%	4.5	4.5	4.5
pH (H_2O)	6.69	6.67	6.68

Table 2: Analysis of Variance (ANOVA) for Carbon Contents of leaves, stems and roots of *Gmelina arborea* and *Tectona grandis* seedling within 10 weeks of study

Parameters	SV	df	SS	MS	F-cal	P-Value
	Species	1	.222	.222	5.935	.041*
Leaves	Errors	8	.299	.037		
	Total	9	.521			
	Species	1	.083	.083	49.145	.000*
Stems	Errors	8	.013	.002		
	Total	9	.096			
	Species	1	.007	.007	2.581	.147ns
Roots	Errors	8	.023	.003		
	Total	9	.030			
	Species	1	.713	.713	11.858	.009*
Total	Errors	8	.481	.060		
Carbon	Total	9	1.194			

*****=significant at P<0.05
ns =not significant at P>0.05

The correlation analysis of carbon content in the roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings depict a positive and strong relationship (0.94g). This is followed by

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relationship between leaves (0.69g), stem (0.51) and the least correlation value was determined for the total carbon contents in Ga and Tg (Table 3)

Table 3: Relationship between Carbon content of leaves, stems and roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings

Variable	Species	Average C	St.dev	r-value
Leaves	Ga	0.2422	0.2149	
	Tg	0.1208	0.09211	0.69*
Stem	Ga	0.1322	0.160631	
	Tg	0.0378	0.04523	0.51*
Root	Ga	0.0834	0.074788	
	Tg	0.045	0.055	0.94*
Total	Ga	0.4324	0.368	
	Tg	0.197	0.1702	0.8*

* $P<0.05$

The fortnightly carbon sequestration by Ga and Tg are shown in figures 1- 4. Generally, carbon contents increased with an increase in the number of weeks (age). The foliage carbon content of Ga at first two weeks of study was higher (0.22g) than that of Tg (0.15g). This trend continued till 10^{th} week with Ga (2.67g) and Tg (1.19g) (Fig. 1)

At the end of the study period, stem of Ga had higher carbon content (1.36g) while Tg had 0.45g (Fig. 2). Roots of the seedlings of the two species had the least carbon contents at the end of the study (Ga: 0.93g and Tg: 0.66g), when compared to leaves and stem (Fig 3). The total carbon content in the two species is presented in figure 4. The carbon content of Ga at the end of 10th week was 4.96g, which is higher than Tg with 2.3g of carbon. The trend began from the second week of data collection.

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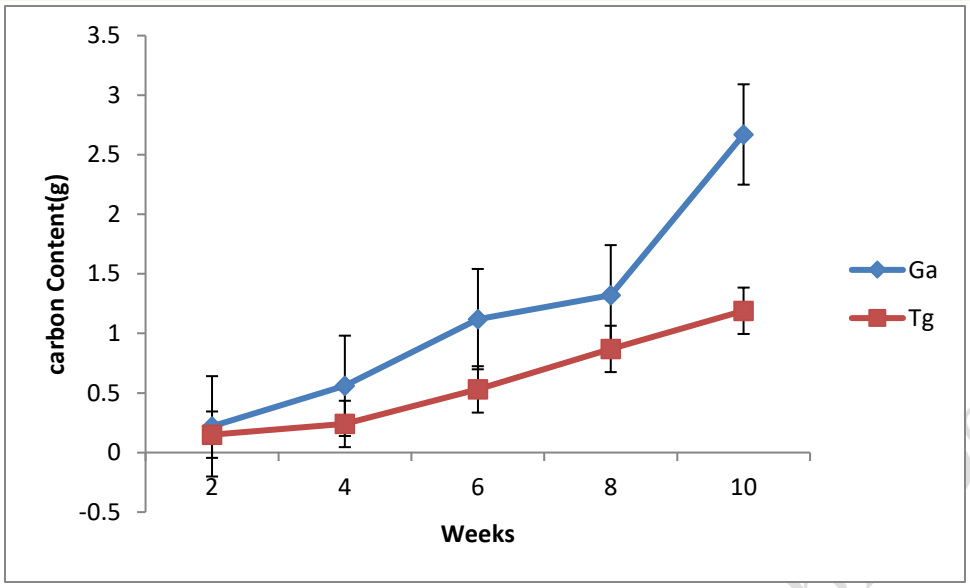

Figure 1: The estimated carbon sequestered by leaves of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

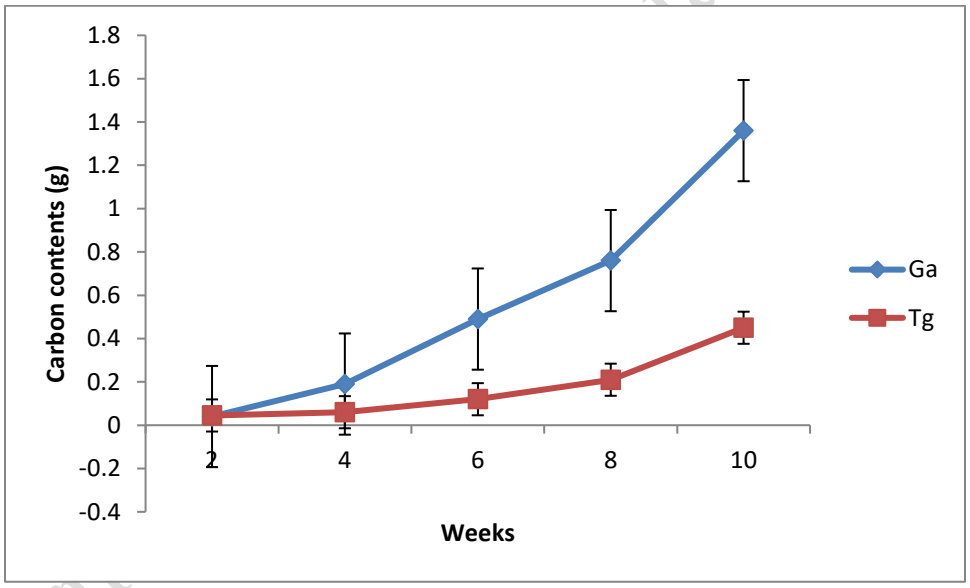

Figure 2: The estimated carbon sequestered by stem of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

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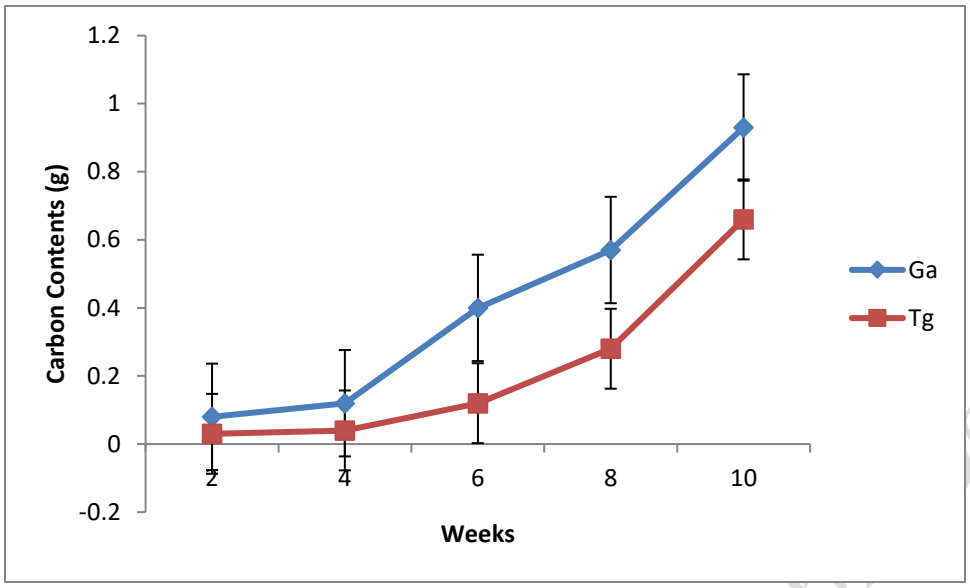

Figure 3: The estimated carbon sequestered by roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

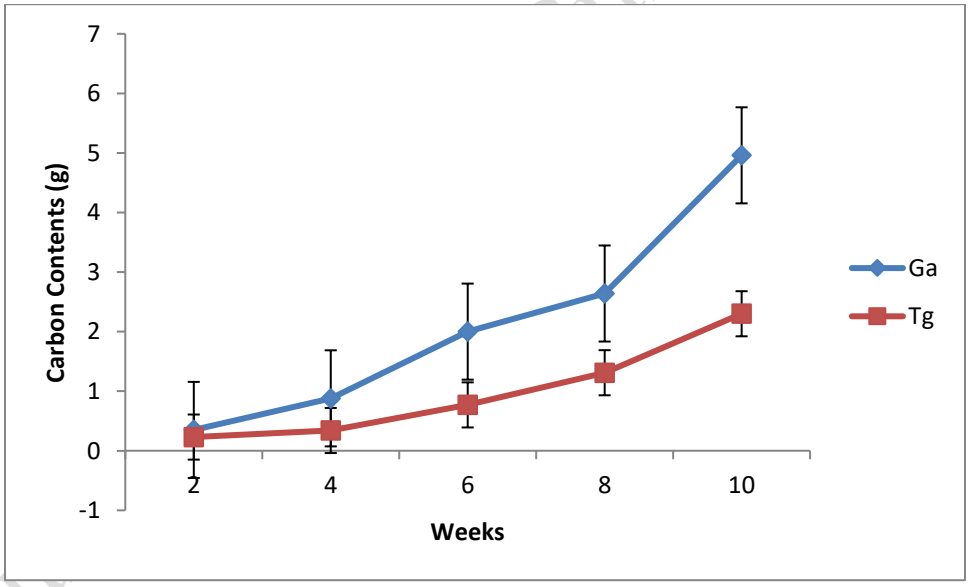

Figure 4: The estimated total carbon sequestered by *Gmelina arborea* (Ga) and *Tectona grandis*(Tg)seedlings within 10 weeks of study.

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Discussion

Growth and development of every part of the plant is subject to new tissue production, aided by meristems located at the tips of organs or between mature tissues. This phenomenon is the function of one or more factors, out of which carbon from CO2 plays a significant role, most especially during photosynthesis (Bäurle and Laux, 2003; Brand, et al., 2001). According to (Barlow, 2005), the role of carbon, whether from the air or organic carbon in soil, on plant growth is extremely valuable and, as a matter of fact, without this process, life as we know would not exist.

Different plant species exhibit natural variation in their forms, structures and growth rate, while some even exhibit an additional type of variation within a single individual. Variations do occur in different plant parts (Bäurle and Laux, 2003). Consequently, significant variation in carbon contents of leaves and stems of the Gmelina arborea and Tectona grandis seedlings depict differences in growth rate and development of the two species. The differences could be attributed to physiological processes and environmental effects. According to Conroy (1999), there is variation in metabolism and carbon sequestration among different parts of a plant and different species based on the relative position of the organ production. Leaves are the most important plant component, having a role in production. They play a major role in the flow of energy, matter and converting them between the land and atmosphere. Every year, trees produce new leaves to perform photosynthesis and thus, carbon sequestration transfers from the atmosphere increasing their biomass (Brandão and Levasseur, 2011). In fact, annual leaf production alone generates a large amount of biomass (Bird et al., 2011)

For instance, it was observed that along a new branch, the leaves may vary in a consistent pattern along the branch. The form of leaves produced near the base of the branch differs from leaves produced at the tip, and this difference is consistent from branch to branch on a given plant and in a given species. The variation consequently influences different sequestration ability of different plant parts (Eamus *et al.*, 1995).

Carbon assimilation and direct effects of CO_2 on tree seedling growth and biomass accumulation are compounded by soil nutrient input and foliar nutrition, which varies from species to species (Conroy, 1992). According to Wong *et al*., (1992); Conroy *et al.* (1990a) and Conroy *et al.*, (1990b) the carbon sequestration and nutrient intake by *Eucalyptus grandis* and *Eucalyptus. camaldulensis* differs, and also *Pinus ocarpa, Pinus radiata* and *Eucalyptus caribaea* varied in the study carried out on the species.

Carbon sequestration, which is enhanced by positive nutrient intake on young trees, can be attributed to compounding effects of increased leaf production and leaf area of the plants (Conroy *et al.*,1992). This also depends upon interception and utilization of sunlight, but subsequent use necessitates expenditure of metabolic energy (*Bäurle and Laux, 2003)*. The carbon content in the plant dry matter is subject to metabolic activities associated with growth and maintenance of plants and can be represented by biomass equivalents *(*Bäurle and Laux, 2003). The increase in carbon content with age in *Gmelina arborea* and *Tectona grandis* seedlings depicts that the biological energy derived from respiration sustains maintenance and growth as well as life support through supply of oxygen and environmental sustainability (Conroy *et al.,* 1992). Green plant respiration corresponds to suction of CO_2 associated with

production of energy for maintenance of chemical and electrochemical gradients across membranes, turnover of cellular constituents suc h as proteins and physiological acclimation to harsh environments (Nabuurs, 1998). Growth covers synthesis of new biomass, which chiefly constitutes carbon from photo assimilate and nutrients. Despite the increase in the carbon contents of the two species, the higher carbon in *G. arborea* seedlings in all growth parameters could be attributed to growth and assimilation rate in addition to the chemical composition of plant material, and by implication, the amount of energy capable to be produced by the species (Bombelli *et al*., 2009). Basuki *et al*. (2009) opined that the way in which new plant structures mature may be affected by the point in the plants life when they begin to develop or accumulate biological materials, as well as the environment to which the structures are exposed.

The higher carbon contents sequestered by the leaves of the two species throughout the period of the study corroborate the findings of (Basuki*et al*., 2009) that leaves produced during early growth tend to be larger with higher assimilation rate.

Conclusion

Seedlings of the two species; *Gmelina arborea* and *Tectona grandis* sequesters CO_2 from the atmosphere to accumulate biomass. As the seedlings of the species develop with time, the bio sequestration increases, and biomass accumulation is enhanced. The assimilation rate of the seedlings bolstered the biomass of the two species of which carbon contents is the main component. Though the carbon contents estimated from *Gmelina arborea* was higher than that of *Tectona grandis,* their sequestration potentials were correlated to one another. It can therefore be established that assorted seedlings in the nursery contribute immensely to the climate change amelioration through carbon sequestration.

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"Externality" of Fulani-Farmer Conflict in Ghana: A Critical Assessment of Existing Structures.

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Abstract

In the event where social marginal cost becomes greater than private marginal cost during production, social inefficiency (negative externality), amounting to both physical and non-physical costs occurs. This has become of the Fulani herdsmen in Northern Ghana, as farmers and members of the community incur a social cost from the pastoral activities of these herdsmen. Pastoralism and crop farming are ventures long established in Ghana and the share of common-pool resources is the ties that bind these two ventures. Conflict resulting from the share of common-pool resources between the Fulani herdsmen and farmers always leave devastating effects with at least a tripartite base of causes. This paper assessed all the existing structures of Fulani-farmer conflict in Ghana with a case study on the Gushiegu district and advocates for the re-consideration of property rights within the district for sustainable environment and development. The objective is to discuss the international economic, political, and cultural implications of these conflicts for

peacebuilding and to establish lasting resolution strategies among Fulani herdsmen and farmers for sustainable development.

Keywords: Common pool resources; Conflict; Environment; Fulani; Farmer; Negative externality

1 Introduction

Conflict resulting from the sharing of environmental resources is not a recent phenomenon in Ghana as there are a variety and sufficient amount of these resources with a high degree of importance. Taking gold, for example, Ghana earns a huge proportion of its foreign exchange from gold exports due to mineral industrialization, and mining contributes significantly to the gross domestic product of the country (Buaben 2012). Inasmuch as environmental resources generate government revenue, create jobs and other benefits, important characteristics such as utility, restricted supply and potential for depletion needs to be considered. The total measure of satisfaction received from the use of goods and services refers to *utility*. Natural or environmental resource depletion is of concern to sustainable development as it can degrade current state of environments and likewise its limited availability (Salvati and Marco, 2008). These characteristics of environmental resources underline the struggle for the maximum benefit of resources, hence the conflicts and potential of affecting the demands of future generations (Schilling and Chiang2011).

A fast-developing environmental crisis that has risen to prominence due to its devastating effect within the agricultural sector is the Fulani herdsmen-farmer conflict. Although this environmental problem is widespread within West Africa, Ghana has begun giving a lot of attention to the matter due to the multi-faceted nature of the causal factors. Agriculture is one of the main economic sectors of Ghana, employing 53.6 per cent of total labor in 2013, formally and informally more than half of the population and accounting for nearly half of GDP and export earnings (Clark 1994). Flowing across the country in eastern-western bands, dry savannah to wet forest zones, a range of crops are grown within these different climatic areas. Ghana's economy is focused on crops like yams, rice, cocoa, oil palms, cola nuts and timber (FAO 2016).

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Within the northern belt, the dominant form of agriculture is crop farming, such as yam, millet, sorghum and rearing of livestock. Ethnicity, ambiguous property rights, weak immigration laws, and policies have resulted in the influx of migrants to share in the limited resources of the area. An example is the Economic Community of West Africa States (ECOWAS) policy on migration which promotes free movement of people and goods within the ECOWAS community. This means nationals of any of the member countries are permitted to cross each other's borders and reside for a maximum of 90 days without a visa. Some people do extend the 90 days to illegally and permanently live and work in Ghana. Add to that Armah et al.'s 2014 assertion that the differences between farmers and herders in cultural values and the acceptance of modern and traditional laws exacerbate conflict. As the share of land, pasture, crop residues, livestock passages and water points between herdsmen and farmers, caused by population growth, migration and land degradation further escalates the conflict. The physical manifestation of the conflicts is the negative externalities incurred by farmers and community members (Armah et al. 2014). This paper sought to understand how the factors in the conflict system are interrelated giving rise to recurrent patterns of conflict, and at the same time, the externality of the Fulani-farmer conflict with current policy intervention.

1.1 Fulani-Farmer Conflict

In contextualizing Fulani herdsmen-farmer conflict, the Fulani's can be described as an ethnic group who are mostly shepherds and cattle herders located within the Northern part of Ghana and other West African countries. The Fulani are largely rural or pastoral, and they migrate from one area to another. However, crop farming is a business in which an Agri-Entrepreneur engages in crop production on a commercial scale. Originally, crop farming was usually only a small but essential part of the overall yield of a farm, whereas today, especially in developed countries, almost all crops are grown mainly for income.

The use of land for agricultural purposes is a fundamental practice in many parts of Africa. In Ghana, close to 80% of the land is kept under customary tenure regimes, since customary rules apply in both urban and rural settings, and the State officially has access to

20% of the land (Landlinks 2013). The main custodians of customary lands are chiefs and tribe leaders who oversee the use of it for purposes such as farming. This means of subsistence remains central to the economic survival of humanity, especially in Africa. Most communities in Africa have unequal access to land and land-use laws, leading to a fierce antagonism amidst non-agricultural user groups and their agricultural counterparts, and also among various agricultural user groups. Nomadic pastoralists and sedentary farmers are the two main classes of land-users for agricultural purposes who, through the demand to share resources, struggle with each other (Adisa 2012). The human security of these environmentally-conflicted countries continues to acquire national, religious and political form and consequently has a significant implication on development (Nwangwu and Enyiazu 2019). Fulani-farmer conflict or, in other words, herdsmen-farmer conflicts cannot be allowed to continue due to the adverse effect it brings on the community. Herdsmen–farmer disputes typically lead to more deadly group clashes, seriously affecting villages with associated loss of life and properties. A vivid example is at the beginning of 2018, when more than 76 people were killed in one village in Benue State, Nigeria, and, shortly afterwards, another 50 villages were burned in a reprisal attack, resulting in further loss of lives and property in retaliation for the first attack in the same Benue State (Doherty-Odueko 2019). It is therefore prudent for an effective implementation of policies that will ensure an effective measure in curtailing the externality resulting from the use or share of common pool resources.

1.2 Externality and Common pool resources

There are times where an individual or groups of people suffer consequences or enjoy benefits from a business establishment for which they are not part. Buchanan and Craig (1962) consider externality as the cost or benefit impacting a third party who has not opted to incur the cost or benefit (Buchanan and Craig1962). In situations of externality, the total cost or profit to society is defined as the amount of the imputed monetary value of the benefits and costs to all concerned parties (Arrow1969). This cost is borne by the people within a community, consumers, or an entire nation and poorly-defined property rights is one of the leading sources of externalities. The undefined ownership and use of

environmental resources may generate a situation when certain business participants start consuming or generating more when an unknown party covers or earns a portion of the expense or profit. In many parts of the world, examples of environmental resources with loosely-defined property rights include air, water and wildlife. Externalities generally are categorized into two, namely positive and negative externalities. On one hand, a positive externality, also known as an external benefit or in some cases, external economy, or beneficial externality, is the positive effect an activity inflicts on an extraneous third party (Varian 2010). Ultimately any economic activity which is benefited or experienced by an unrelated third-party is deemed to have a positive externality. On the other hand, if the output of a business affects the well-being of those who are not direct beneficiaries of the company, then such a condition may be considered a negative externality. Many negative externalities, including the various kinds of environmental pollution, are particularly dangerous because of their major adverse effects.

Common pool resources consist of a "core resource like water or fish, that measures the stock variable by providing a finite amount of extractable fringe units describing the flow variable. While a core resource must be secured so that it can be continuously used, the fringe units may be harvested or consumed" (Ostrom 1990). Environmental economics, as a discipline, interprets natural resources according to expectations regarding the protection of these resources in ways such as clearly identifying the sustainability of the resources. The definition of market failure with types such as include externalities, non-exclusiveness and non-rivalry are fundamental to environmental economics (Anderson 2019).

2 Materials and method

2.1 Demographic, cultural, and economic characteristics of the study area.

The Gushiegu district is situated about 105 kilometers northeast of Tamale, capital of Northern Region, Ghana. Gushiegu Township is the administrative center of the Gushiegu District, carved out of the former district of Eastern Dagomba. The district is one of 26 districts in the northern region and has borders with the districts of East Mamprusi

and Bunkpurugu / yunyoo in the north, Yendi in the south, Saboba and Chereponi in the east and Karaga in the west (Gushiegu District Assembly 2006). The total population of the district, as at the 2010 population and housing census, was 111,259 of which males constituted 48.7 percent while females were 51.3%. A little above three-quarters (76.0%) of the population in the district live in rural areas, and the remaining are in the urban areas. The working-age population (15-64 years) have more females (53.1%) than males (46.9 %) (Ghana Statistical Service 2014). The district is populated by six major ethnic groups: Dagoombas, Konkombas, Fulanis, Chacoshies, Bimobas, and Nanumbas (Gushiegu District Assembly 2006).

The 2010 population and housing census again showed evidence of migration to the district as the migrant population in the district is 14,966. The majority of people who migrated to the district have been residing there for a period between 1 to 4 years (26.5%). On the element of livelihood, about 88 percent of workers in the District are engaged as Skilled Agriculture, Forestry, and Fishery Workers. This is followed by Service and Sales Workers (4.4%) while Craft and Related Trade Workers are approximately three percent (Ghana Statistical Service2014). Agriculture activity commonly practiced is mainly crop farming and livestock rearing. Crop farming in urban and rural areas have proportions exceeding 90 percent of agricultural households. Animal-rearing is the second most important agricultural activity after crop farming. Among the ruminants, the top three are 20.2 percent of cattle with 15.3 percent of keepers, 19.4 percent of goat with 26 percent of keepers, and 18.3 percent of sheep with 22.5 percent of keepers. The average animal per keeper for cattle, goat, and sheep is 25, 14, and 15 respectively (Ghana Statistical Service 2014). This emphasizes the popularity of farming and livestock rearing within the district.

2.2 Case study design

A case study is a detailed analysis of a specific event, rather than a broad statistical survey. It is used as a tool to construct a very large field of study into one easily researchable subject and useful in evaluating whether the concepts and models of science function in the real world (Shuttleworth 2008). Case study research can mean single and

multiple case studies to include quantitative evidence that relies on numerous sources of data and aid from the theoretical proposals developed beforehand (Yin 2013). Case study research design is again useful in testing whether scientific theories and models work in the real world as in the case of how policies are working to resolve Fulani-farmer conflicts. The case study design is appropriate for this paper as it seeks to understand the reasons behind the externality of the use of the pool resources, which creates conflict within Ghana's Gushiegu district.

3 Results

3.1 Case study

The Konkomba-Fulani conflict was heightened in 2011 when two ethnic groups within the district clashed. The Konkombas are known farmers and the Fulanis are known herdsmen. Olaniyan (2015) recorded how on December 7, 2011, Konkomba farmers carried out a night raid in Damdaboli, Zamashigu, Batiga, and Naboya farming communities in the Gushiegu district of northern Ghana. By daybreak, 13 Fulani pastoralists had been killed; their houses burned, and their cattle rustled, as spoils of war. They were rendered homeless and had to be accommodated at the district headquarters for more than 3 months (Olaniyan 2015; Akosua-Dosu 2011; Zoure 2011). The twist to the problem is the fact that it had an international dimension as some of the affected herders were citizens of Burkina Faso. In conjunction with the above, the Konkomba ethnic group has a history of violent conflicts with neighboring groups. It began with an attack on the Dagomba village of Jagbel in 1940, in what is known as “cow war,” which resulted in the death of the chief, members of his family, as well as the burning of the village (Johnson2007). The Konkombas has been described as an acephalous group with no history of empire building (Oelbaum 2010). They have, however, had a long history of habitation at their present location in the Gushiegu district, unlike the Fulani ethnic group who are equally found in large numbers in some West African countries such as Togo, a product of colonial policy. A public referendum conducted in 1956 effectively made the British part of Togoland become part of the Northern Region of Britain’s Gold Coast, now Ghana, colony,

therefore it is the reason for the Fulani being found within the Northern Region of Ghana (Johnson 2007).

3.2 Policy implication- Free movement of persons within ECOWAS member states.

The concept of migration affects society in diverse ways as people or individuals move from one place to another in order to settle permanently or temporarily in a new location (World Migration Report 2020). Global figures suggest that 3% of the world's populations are migrants in search of work or economic opportunities or to escape conflict, terrorism, or human rights violations (United Nations 2006). The main reason is that the era of growing and intensive economic, political, and socio-cultural interdependence among states has been on the increase. The United Nations estimates once again that approximately 7 million of the 191 million refugees spread across the globe come from the sub-region of West Africa (United Nations 2006). In May 1979, the free movement of persons in ECOWAS member states began, with the first protocol on free movement of persons, residence and establishment adopted (Ecowas Protocol1979).

The provisions of the protocol state that citizens of ECOWAS have the right to join, live and develop economic activities in the territory of other Member States and proposed a five-year, three-step roadmap to achieve freedom of movement after a total of fifteen years. The first phase concerns the right of entry without visa, the second phase deals with the right of citizenship, and the third phase concerns the right of establishment in another Member State. The first phase of the protocol has been fully implemented, with the second phase being the right of residency, also implemented given that citizens can access an ECOWAS residence card (or permit) in fellow member states. The third phase, the right of establishment, is still under implementation in most member states (Adepoju et al. 2010).

Given the degree of progress achieved in the ECOWAS free movement protocol, the delay in implementing trade liberalization policies, such as reducing customs duties, has helped slow down attempts to incorporate and realize the free movement of citizens. Bolarinwa (2015) specifies that multiple memberships as ascribed of some member states who have joined other regional groups with overlapping interests are the reasons for the

inability to ensure full implementation of the protocol which poses serious problems when coordinating policies (Bolarinwa 2015).For example, the Nigerian Government in 1983 and 1985, respectively, abrogated Articles 4 and 27 of the Protocol and expelled around 1.5 million non-residents who were mainly Ghanaians (Adepoju and Wiel2007). Also, weak border control system within member countries encourages illegal entrance and has been one of the major causes of conflict among citizens and foreigners of the ECOWAS members. The manifestation of the unmatured implementation of the policies across several countries in West Africa is one of the major causes of the Fulani-farmer conflict experienced in Ghana.

4. Discussion

4.1 Negative Externality on farmers and community members

In the first place, the type of externality that sets in from the conflicts between the Fulani cattle herders and farmers within the Gushiegu district is a negative externality. The activities of the Fulani bring an unwanted, or external, cost to the farmers and community members. These negatives are seen in three broad areas: namely, destabilization of crop production, high rates of poverty and starvation, general loss of lives and properties, and polluted water bodies. The conflict identified between the Fulani herdsmen and farmers can be termed to be a low-intensity conflict. Conflicts of low intensity involve periods where aggression or disagreement exists at a more localized level and at a lower rate, typically less than 1,000 deaths in combat versus a civil war of full scale (Öberg, Möller and Wallensteen2009). The following are known negative externalities of the conflict.

First, the destabilization of crop production is a major effect or expense borne by farmers and community members as a result of the destruction by cattle, belonging to the Fulani, of crops and bodies of water. The reprisal attack by farmers leads to a non-peaceful coexistence between these two groups thereby causing a loss in food production within the district. The World Health Organization (WHO), for instance, values food security around the world and considers three pillars as a determinant of food security: food availability, food access, and food use & misuse (WHO 2013). Food insecurity affects the lives of

millions of people across the world and is increasingly concentrated in conflict-affected regions just like the Gushiegu district. All 19 countries the FAO currently classifies as being in a protracted food crisis are affected by conflict and violence (Martin-Shields and Stojetz 2018). Keeping an eye on food insecurity in conflict-affected areas to comprehend the connection between food insecurity and violent conflict is important in educating state, national, foreign practitioners and policy makers about evidence-based interventions.

Second, a negative form of externality is the high rate of poverty and hunger within the district caused by the conflict between Fulani herdsmen and farmers. Poverty and hunger go hand-in-hand with food insecurity; not everyone living in poverty faces chronic hunger, but almost everyone facing chronic hunger still lives in poverty (Hunger Project 2019). Millions suffer with hunger and malnutrition because they literally can't afford to buy enough food, they can't afford nutritious food, or they can't afford the resources they need to produce sufficiently healthy food for themselves. Hunger can be seen as an extreme poverty dimension, which is also considered the most serious and important form of poverty. The insecurity within the district, due to the conflict between farmers and herdsmen who are major elements of farming, has led to low production rates. As a consequence, Amanor-Boadu et al. (2013) observed that the districts in the Northern Region of Ghana with the highest poverty prevalence rates are in the northeastern parts of the region while those with the lowest are found in the southwestern parts. For example, Gushiegu district, Mamprusi East district and BunkpuruguYonyo in the northeastern part of the region has the highest poverty prevalence rates (Amanor-Boadu et al. 2013). Other factors, such as lower literacy rates, contributes to the poverty suffered in the region. The inability of both farmers and herdsmen to produce throughout the year, due to insecurity, contributes more however to the poverty in the district.

Third, one externality suffered by the community due to the Fulani-farmer conflict is the general loss of lives and property. The case study for this paper in which 13 lives were lost is just one out of several cases of lives and property being destroyed. Properties in the form of houses, farms, bicycles, and motorbikes are destroyed during such conflicts. There had been bottled up feelings of frustration among the Konkomba over the time

against the Fulani. These feelings border on allegations of raping, armed robbery, and destruction of farm crops, all allegedly attributed to the Fulani. Also, the issue of destruction of farms by cattle poses a major source of anger and frustration on the part of the Konkomba group (Olaniyan 2015). As argued, heretofore, the major preoccupation of the Konkomba is yam cultivation; and the herders were known to release their cattle to eat up and destroy yam farms, leading to loss of yield with serious consequences on accruable income. There is little or no compensation given to the farmers for their crops being destroyed, and this leads to reprisal attack on the herdsmen in the form of killing of the cattle.

Fourth, pollution of water bodies in the district has become both a cause and an indirect effect of the Fulani-farmer conflict. Cattle walk through water bodies and in the process rend many water sources not fit for consumption. Residents are exposed to all forms of contamination, and ineffective management of resources has made water bodies in the district a resource shared at the same time by humans and animals. In Ghana, around 60 percent of water bodies are contaminated and most are in a severe situation (Ampomah2017). The erroneous management of agricultural waste (manure) is responsible for contamination of the soil and groundwater. Animal production systems may result in direct surface or groundwater discharge, run off and/or flow of pollutants causing water pollution. Pollutants are sediments, minerals, chemicals, organic matter, salts and micro-organisms that can kill fish, cause odors, spread infectious bacteria and impede water-related activities. Water resources hold tremendous economic potential for forestry, tourism, irrigation, transportation and industry (Nsubuga and Namutebi 2014). This has been the reality on the ground as water bodies within the district are polluted from cattle droppings and from the cattle sharing drinking water with humans.

5 Recommendations

5.1 Proper definition of property rights

According to the Ministry of Food and Agriculture, within the Gushiegu district, there is communal ownership of land, and members of a family have a free and inalienable claim

to family land. The acquisition of land for farming by non-family members is subject to respect for tradition and payment of homage to the head of family or clan. No financial or in-kind charges are levied directly but it is often expected that a quantity of harvested produce is given to the landlord. The land tenure arrangement has a positive enabling environment for agricultural investment in the district. The fact that procedures for land acquisition are not cumbersome and that it is more or less freehold makes investment in the agricultural sector in the district very attractive. Despite the importance of communal ownership of land within the district, it is time for a re-look into the venture.

As defined by Bromley (1989) common property is owned by an identified group of people, invested with the right to exclude non-owners, and the duty of maintaining the property through constraints placed on use. There is the need or advocacy to convert the communal property rights into private property or the tightening of boundaries and rules concerning communal property rights to prevent encroachment and the clear protection of property. Movik (1994) notes that much of research on common property systems have centered on identifying the conditions under which such systems thrive and has consequently given rise to two major lines of arguments. Two conditions must be fulfilled for common property management systems to function – one is a clear demarcation of physical boundaries of resources, and the other is the presence of unambiguous social boundaries, i.e., group membership must be in place for common property arrangements to work (Movik 1994).

These two conditions are absent within the Gushiegu district because there is no proper physical demarcation of resources such as water bodies and farmlands. There is the existence of a multi-ethnic groups' composition within the district, including Dagoombas, Konkombas, Fulanis, Chacoshies, Bimobas, and Nanumbas. Inter-tribal marriages among the ethnic groups are allowed so, hence, the ambiguity in the definition of membership of the group. Private property of the lands within the district will best suit the situation of the negative externality. Private property – *res private* – assigns property to identifiable individuals, which guarantees them the control of access and the rights to socially acceptable use (Hanna and Munasinghe 1995). Harold Demsetz in 1967 wrote a paper

entitled 'Towards a Theory of Property Rights' where he argued forcefully that private property rights were superior to communal property rights because private property rights internalize externalities. Taking land title as an example, private ownership would internalize many of the externalities that come with community ownership. As an individual proprietor, one is entitled to exclude other possible users and the gains of a well-managed property could be achieved (Demsetz 1967). An accompanying argument is that private ownership greatly reduces the costs of negotiating remaining externalities – in other words, the expense of resolving contracts is that within the domain of the private property regime.

The main disadvantage of private ownership is the fact that it breeds inequality. Inequality here means the system creating a wide gap between the haves and have-nots and in the process, giving power to direct the lives of those who have no property. This goes a long way to serve as the basis of capitalism and the critics outlined by Karl Max in the Communist Manifesto. Despite the disadvantage of private property ownership and when compared to communal ownership of property, in context of the share of environmental resources, the former is suitable than the latter. Farmers with clear demarcation and ownership of land within the district will be able to effectively protect the land and seek redress from the court and authorities in the event of encroachment or destruction of crops from the Fulani herdsmen.

5.2 Implementation of compensation strategy

There should be the enactment and enforcement of the payment of compensation in the event where cattle belonging to the Fulani destroy farms and water bodies. Compensation for environmental damages is a phenomenon well-established in international standards. Within international and comparative environmental law, the notion of damage to the environment is gaining growing attention as liability and compensation laws come into the picture where administrative regulations have proven unsuccessful in preventing harm. If harm has occurred, attention is based on compensation, *inter alia* in the form of environmental re-establishment or, where this is not practicable or

is not economically feasible, by making financial compensation (Wetterstein1997). For instance, after a pollution incident, compensations could be in the form of restocking the waters with young fish, replanting new flora, and cleaning the banks. The Fulani are known polluters of water bodies and yet there are allegations of non-payment of compensation for pollution and destruction of people's farms.

The Fulani say none of their counterparts deliberately release cattle to destroy farms and that there could be some instances where cattle could stray and eat crops and that each time it happens, they always pay compensation to the farmers. There should a law specifically set up to support the enforcement of the compensation strategy to end the conflict between farmers and Fulani.

5.3 Establishment of grazing reserve: a possible solution to end the conflict

The demarcation of cattle routes and grazing reserves has been a desperate call from the Ghana National Association of Cattle Farmers (GNACAF), so that, they say, the incessant conflicts between farmers and herdsmen could be over. To come out with lasting solutions to the conflict, the government must set up public policy experts to find ways to solve the malingering crisis and, also, for the government to create a permanent settlement by establishing grazing reserves to ensure a regulated form of movement of the cattle and herdsmen. Pastoralism as a means of subsistence is under growing pressure in Africa, due to changes in social, cultural, political and environmental conditions. Before the 1950s, there was a symbiotic relationship between pastoralists, farmers and their climate with herders performing transhumance seasonal migrations (Ducrotoy et al. 2016).

The dry season compels pastoralists to move to the southern parts of Guinea's savannah zone, where there is pasture and lower crop density. Such areas are facing strong challenges from African animal try panosomias is, spread by tsetse flies during the wet season, while pastoralists will move to farmland in the Savannah region of northern Sudan and supply dairy products to the local farming community. Reciprocally, there was the provision of grains to the pastoralists by the agricultural community, and after the harvest, cattle were allowed to graze on crop residues in fields leaving valuable manure behind. The

creation of grazing reserves is a viable solution. It means shifting from the old system of animal husbandry to a modern method. This would overcome the problem of unavailability of cattle market and diseases control offices and at the same time ensuring the production of meat and cattle products throughout the year. Establishing grazing resources is a sure way to end the conflict.

6 Conclusions

For the prevention of conflict, there should be a rigorous establishment of a legislative instrument to enforce the prevention of the negative externality on community members. Finding a lasting solution to Fulani-farmer conflict in Ghana is a long shot at ensuring peaceful co-existence, prevention of hunger and poverty, and ensuring the production of food all year round. The conversion of the communal land ownership within the district to private-property ownership will ensure full security of properties and allow for the proper sale or rent of the property to a person. Failure of government to establish grazing reserves laws which among other things allows for the demarcation of the land for growing of pastures for grazing and passage routes for animals will do a lot of good. Further research is needed to be conducted on the causes and consequences of the conflict, and a sound conflict resolution mechanism is needed from the government which may include intensive research as the way forward to resolve the conflict by government policy-makers, and leaders of the parties involved in the conflict to come out with a policy that will end the conflict for the lasting peace of the country.

Disclosure statement

The authors declare no conflict of interest.

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Rethinking The Approach to Domestic Sewage Management in Nigerian Cities

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Abstract

This paper reviewed the current situation of domestic sewage management in Nigerian cities with the aim of suggesting more sustainable ways of improvement where necessary. Secondary data were largely explored through existing published and unpublished materials, reports, dissertations, and other related documents relevant to domestic sewage management, both in electronic copies (online or offline) and hard copies and are acknowledged in the references. The paper revealed that sewage management is one the key services in cities that largely influences its environmental performance and sustainability. Past studies have shown that developed nations are characterized by a robust sewerage system that encourages sustainability, unlike, the developing countries that are basically practicing onsite and non-sewerage systems. In Nigeria, only Abuja the Federal Capital Territory has an operational treatment plant for phase one and parts of phase two with 20-30% capacity due to technological gap. However, most of the laws and regulations, governance structure and research / studies within and outside Nigeria had focused on sewage management from the quality of the effluent released from industrial processes but neglected domestic sewage where waste water is also generated in cities and is a major contributor of municipal sewage. Therefore, this study concludes with the need to refocus interventions, and research by relevant stakeholders on sewage, and provision of sustainable frameworks that will enhance realization of Sustainable Development Goal 6.2 & 3 and 11 on reduction of the release of untreated domestic sewage to the environment, end open defecation in order to actualize sustainable and habitable cities.

Key words: Cities, Domestic sewage, Framework, Sewage management, Sustainability.

1.0 Introduction

Sewage management is amongst the key municipal services that determines the environmental performance and quality of cities. Societies with highly urbanised systems have their production and consumption activities, largely depending on the infrastructural resources, flow on energy, water, sanitation and sewage management for their existence and sustainability (Nigerian Advisory Infrastructural Facility, NAIF, 2012). When these service provision become inadequate or fail, the functionality and status of such cities drifts to a 'sorry state.' Nigeria is a

signatory to the Sustainable Development Goals on "achieving equitable sanitation, hygiene, end to open defecation and reduction of pollution through untreated sewage by year 2030" (Office of the Senior Special Assistant to the President on SDG's, National Bureau of Statistics and United Nations Development Program, 2017), yet its cities are experiencing challenges in domestic sewage management. Today, cities now house 55% of the global population and by the year 2050, they shall accommodate 68%, an increasing inflow of 2.5 billion urbanites with 35% contribution from Asia and Africa from years 2018-2050 (United Nations Department of Economics and Social Affairs, UNDESA, 2017). Therefore, as urban populations increase, consequential increases on sewage generation, quantity and services become inevitable (Asemota, Alkhadar, Sertyesilisik and Tunstall, 2011). In addition, most urban dwellers in developing nations live in slums and do not have adequate access to basic urban services, such as sewage management (UN-Habitat, 2016). By extension, without any significant intervention, more and more challenges associated with urbanisation including sewage management, shall abound in years to come.

Records of the past centuries have shown that across large parts of Europe, sewage was disposed on streets of living quarters with dense population, resulting in filthiness and source points for epidemics (Lucking, 1984; Sorcinelli, 1998; Brown, 2005; Human Development Report (HDR) 2006; and Aiello, Larson, and Sedlak, 2008). In response to the health problems that emanated from sewage borne diseases, modern cities evolved some management approaches for proper handling of sewage and provision of clean drinking water to help curb aforesaid menaces (Seeger, 1999; Schifrin, 2005; Brown, 2005; Vuorinen, Juuti, and Katko, 2007; Cooper, 2007).

In addition, agreements emerged on the use of appropriate, best available practices, and technological know-how in sewage handling (HDR, 2006). It is against this background that most developed and developing countries of the world established sewage governance, and technologies in order to ensure proper sewage handling to achieve good sanitation, environmental performance, and quality. Though, up till now, the extent to which the sewage is managed varies from one country to another depending on the enabling environment available for it to thrive.

Nigeria is a West African state that has remained a Federal republic since its amalgamation (North and southern parts) by the British colonialists in 1911 and currently has thirty-six states within six geo-political zones. It is located on longitude 3^0E and 15^0E degrees and latitude 4^0N and 14^0N as shown on figure 1.1, within the tropical region of sub-Saharan Africa (National Communication, 2003; Oguntunde *et.al*, 2011). The country covers a land mass of 923, 768 sq. km and a total coastline distance of 850 kilometres National Communication, 2003; Nwilo *et.al*, 2006), with a three predominant climatic regions of Highland climate Jos Plateau and Mambilla Plateau (Adamawa, Taraba and Obudu mountains of Cross rivers); Tropical savanna (North central, North East, and North West region); and Tropical rainforest/ Monsoon (South East, South-South, and South West) (Allu, 2014; Allu and Ochedi, 2015). Its land border includes, Niger to the North, Chad and Camero on to the east, Gulf of Guinea and Atlantic Ocean to the South and Benin to the West as shown in figure 1.1. It is amongst the most populous countries in Africa with a projected 2016 population size of 193, 392,517 (https://nigeria.opendataforafrica.org/hlvbkge/nigeria-population).

The topography is multifarious of plains in the north (Hausa plains), plateaus and hills and outcrops of inselbergs, mesa and butes in the North, central and southern parts is made up of the Basement complex, while the depressed areas such as the Lake chad, River Niger, Coastal areas, and Sokoto basin consists of Sedimentary basin. The south western parts of the country consisting of Cameroun and Adamawa highlands with highest points of 2,419 meters above sea level and Gotel and Dimlang mountains 2,042 meters (encyclopaedia britannica.com).

However, in spite of the aforementioned setting, Nigeria is still living with the quagmire of inappropriate onsite domestic sewage management that has the potential of polluting underground sources of water, the predominant water supply source for most households and a major cause of sewage borne diseases (Obada and Oladejo, 2013; UN-ESCAP, UN-HABITAT, and AIT, 2015). Without treatment plants and with many of open defecation and indiscriminate release of untreated sewage to the environment in urban areas, the issues are dire (Federal Government of Nigeria and UNICEF, 2016). This inspired the thrust of this paper with the aim of suggesting ways forward that may initiate reconsidering more sustainable ways of improvement, where necessary.

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Figure 1.1: Nigeria and its borders
Source: http://www.infoplease.com/atlas/country/nigeria.html

2.0 Conceptual issues on sewage

The British Department of Environment, Food and Rural Affairs (2010) and Corcoran, Nelleman, Baker, Osborn and Savelli (2010) define sewage as a liquid waste that occurs in the form of black water (toilet-used water and feacal sludge) and grey water (all other forms of used water from bath tubs, kitchen sinks, showers, and laundry). In some countries like the United States of America, sewage and sewerage are the same, while the British use the terms differently (Neilson William, Knott and Thomas, 1934; Wagnal, 1960; Flexner, Sturat, Hauck, Leonore, 1987). But in the technical sense, sewerage means the various wares (network of pipes) that aid the movement of sewage (Flexner, Sturat, Hauck, Leonore, 1987; Oxford Dictionaries.com). Metcalf and Eddy (1991) observed that sewage is an old term in use for liquid waste, but recently, waste water seems to be the most often used by scholars. In this light, the term *sewage* can be used interchangeably with waste water, being that they both are liquid waste and are municipal, domestic or industrially generated. Sewage can be classified based on their sources of generation, for instance, sewage generated from bathing, cooking, laundry in residences, car-washing services in commercial areas and abattoirs, and swimming pools in institutional facilities can be referred to as *domestic sewage* or *sanitary waste water*. *Industrial sewage* or

effuent emanate from processing, washing and water-cooling systems of industrial activities. Infiltration and Inflow sewage are usually the waste water that flows through leaking points and cracks in pipes/ sewerage or manholes that covers the sewerage networks. Storm water and runoff sewage are sourced from rainfall and snowmelt that flows on surfaces (https://cgi.tuharburg.de).

2.1 Global situation of sewage management.

Globally, about 9, 500, 900 m^3 of sewage (9.5 million m^3 of human feces and 900 m^3 of grey water) are generated daily in cities (Mateo-Sagasta, Raschid-Sally, and Thebo, 2015). The management of this huge quantity differs from one country or continent to another, largely influenced by the existing governance structure, guidelines for practice, and available technological options. Sewage management in developed and some developing nations is anchored by standards, guidelines and regulations on sewage management, with established agencies for regulation and enforcement of the provisions of the guidelines. In such cases, cities are served with well-designed waterborne sewerage systems that are linked to offsite sewage treatment plants.

2.1.1 Developed nations context

The European Union (EU) countries handle their sewage within the three pillars of sustainability the sanitation spheres of environmental, economic and social responsibility (Asemota, Alkhaddar, Sertyesilisik and Tunstall, 2011). They manage their sewage in accordance to the provisions of the EU council directive 91/271/EEC of the 21st of May 1991, as amended by Commission directive 98/15/EC of 27th February, 1988 (EU Council Directive, 1991; Stamou, 2014). For instance, the England and Wales public sewerage network collects approximately 10 billion litres of sewage from households and industries, and about 9,000 sewage treatment plants treat this sewage to permissible levels before discharge to inland water, estuaries and the sea (Department for Environment Food and Rural Affairs, DEFRA, 2010). However, before now, the World Health Organisation, WHO and UNICEF (2000) had reported that over 20 million EU citizens, mostly in Central and Eastern Europe, lacked access to safe sanitation. This manifests more in rural areas where financial resources are insufficient to

provide the requisite facilities for appropriate management. The simple explanation to the problem, was the undermining of the weakness of article 3 of the EU regulation on urban waste water which states that "...only localities with populations equivalent of more than 2,000 persons should be served with urban water collection systems and adequate biological treatment (https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1991L0271:20081211:EN:PDF) ". However, several approaches were imbibed to overcome the constraints to achieving a sustainable management practice, such as the decentralisation of the sewerage systems (Asemota, Alkhaddar, Sertyesilisik and Tunstall, 2011). Interestingly, the proportion of population that are connected to waste water treatment plants in European countries which was low before 1995, has now increased above 80% with 75% receiving tertiary treatments (www.eea.europe.eu)

The Environmental Protection Authority, EPA is a governance structure for the United States of America that provides the guidelines and framework for sewage management, and its cities are connected to an offsite central sewerage network (Burian, Nix, Robert, Pitt, and Durrans, 2000). In some American states, onsite waste water management is in use, while about 76 per cent to 100 percent sewage from residential areas are safely treated before release to surface water and environment (United Nations Water, World Health Organisation and UN Habitat 2018).

In the Kingdom of Saudi Arabia, sewage management is regulated and controlled by the Ministry of Water and Electricity (Ouda, 2015), and they regulate and guide the permissible level of organic pollutants such as nitrates, phosphorus, and ammonium just to mention a few. These pollutant levels are measured using certain techniques such as the alkalinity, conductivity, dissolved solids in sewage, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), just to mention a few. The sewerage systems are only available in large urban towns and waste water disposal is restricted to only a few cesspits in smaller towns and rural areas (Abu-Rizaiza, 1999).

In South Africa, the National Environmental Management Act 107 (1998) and the constitution of the Republic of South Africa (1996) guide the operations and regulation of the waste treatment plants in the country (Gopo, 2013). The central offsite sewerage system is predominantly in use in most cities of South Africa with about 824 treatment plants and only about 10% of the plants release treated or clean water, and about 50,000 liters of sewage is discharged every second (Kings, 2017). This means that most of the treatment plants are not operating in full capacity or are dysfunctional. This situation has negative implications on sewage management in the region.

The notable feature that is common amongst the aforesaid countries on sewage management is the presence of a strong sewage governance regime in terms of regulatory agency, guiding policy and regulation, and treatment plants that ensures the release of only treated waste water to the environment.

2.1.2 Some Developing nation's context

In most low-income developing nations, the onsite sewage management (pit latrines, septic tanks/vaults, soak way, pour flush) and significant incidences of open defecation are largely in use (Asemota, Alkhaddar, Sertyesilisik and Tunstall, 2011; Strande, Ronteltap, and Brdjanovic, 2014).It is also globally estimated that, 2.4 billion people do not have access to improved sanitary facility including one billion people who will resort to open defecation (Joint Monitoring Programme, JMP, 2015). The population of users of onsite sanitation systems are projected to double by the year 2030 (Strande, Ronteltap, and Brdjanovic, 2014). Looker (1998) adds that, in most cases the sewage collection systems in many cities of Asia, Africa and Latin America are mostly water-borne systems that lack treatment plants. A large population in most developing countries lack sewer network connections, and only 10% of populations of some sub-Saharan countries, for example, Cote d'Ivoire, Kenya, Lesotho, Madagascar, Malawi and Uganda, are connected to a sewer system (Banrjee and Morella, 2011). Most alarming is the release of about 80%-90% untreated waste water into flowing rivers and streams (Chung and Badiane, 2016).

Furthermore, reports of the UN Water, WHO and UNICEF (2014) highlighted that some households in middle and low-income developing countries had improved sanitary facilities, yet just a few have access to safe functioning toilets along the sewage management chain. For example, Tanzania in Dar Es Salam has about 97% of its urban population with an unsafe sewage management practice with regard to on-site feacal matter disposal (Jenkins, Cumming, and Cairncross, 2015).Therefore, it is obvious developing nations that are without adequate or weak sewage governance, technologies and adequate regulations will continue to dispose untreated sewage that pollutes streets, freshwater bodies and degradation of environment, undermining the goals and targets of the SDGs 6.2 and 3 on Water, Sanitation and Hygiene, WASH, which seek to end open defecation and halve the release of untreated waste water by the year 2030.

2.1.3 Sewage management situation in Nigeria

Studies by several scholars have revealed the status of sewage management practices in Nigeria, ranging from sewage governance to the non-existence of sewerage systems in cities. Adewumi and Oguntuase (2016) in their study on planning for waste water reuse programme in Nigeria revealed that most Nigerian cities do not treat their sewage before final release to the environment. Further, they recommended the reuse of waste water after treatment to avoid the negative effects it would have on ecosystems and humans.

Oji, Chukuma, Friday and Philip (2018) also carried out a perception study on reuse of urban waste water and the existence of urban waste water treatment plant in the Awka urban area of Anambra state. Their study revealed the absence of a treatment plant in the city, and about 53.4% of residents in Awka indicated low knowledge of waste water treatment, while 56.8% would not want to reuse waste water in any form. Their study corroborates the earlier findings of Idirs-Nda, Aliyu, and Dalil (2013) on Minna-Niger State, who ascertained the absence of municipal waste treatment plant and how most residents practice onsite vaulting management via septic tanks and pit latrines. Also, about 63% of residents of Minna town-Niger state are not aware of sewage treatment and the possibilities of waste water reuse and its consequences.

Studies by Ishaya (2016), Ogbonize, Adie, Igboro, and Giwa, (2016), Daya and Abbas (2016), Musa and Okonkwo (2017) revealed the presence of industrial wastewater treatment plants in Kaduna town. These treatment plants are owned by, and also domiciled in individual industries for the purpose of treating effluents from their production activities. It was observed that some of the treatment plants sometime fail and malfunction, thus leading to the release of untreated effluent to streams and the environment. This situation agrees with the reports of Asemota, Alkhaddar, Sertyesilisik and Tunstall, (2011), that in Nigeria, only a small fraction of urban sewage is treated with some wealthier and industrial neighbourhoods having offsite central sewerage and treatment plants, whereas, the low-income neighbourhoods have none.

In the Federal Capital Territory (FCT) Abuja, studies by Kadafa, Ayen, Idris, and Braimah (2018a & b) revealed the presence of a waste treatment plant in WUPA Phase III. This facility works at a 92-99% efficiency rate. Oluwadamisi (2013) also established the presence of some treatment plants in Phase I and II of the FCT such as the Wuye Lagoon, Gudu, Niger, Lungi, Mogadishu barracks, and Sheraton treatment plants. He ascertained a working capacity of about 20%-30% efficiency capacity, due to problems associated with population explosion that increases high sewage generation beyond the capacity of installed facilities and poor maintenance, as well. The FCT because of its model city plan philosophy has the aforesaid treatment plants because Abuja was envisaged to be a city free from sewage-borne diseases and to serve as an example to all Nigerian cities on sanitation and hygiene. Unfortunately, only Phase I and parts of Phase II is fully-served with treatment plants. Later parts of Phase III, IV and the Local Councils (satellite towns) are yet to be served, partly because the rate of urbanisation and leap frog development of the FCT undermines the urban services provision phasing of the city. The Federal Government of Nigeria and UNICEF (2016) and Obinna, (2019) reports that sustainable sewage management has continued to be a problem in Nigeria, with over 146 million people involved in open defecation, making the country rank second (2^{nd}) in the global ranking of countries with this ugly practice.

Lagos generates over 1.5 million m^3 of sewage per day, and just about 1-2% of the population is connected to an offsite treatment plant. Its black water is collected in septic tanks; soak-away onsite systems and their grey water discharged in open drainages; or gutters in some

cases flowing on streets (Anderson, et.al, 2016). Adekanbi, 1979, Adenuga, Ogujiuba and Ohuche, 2003, Aina, 1991; Orubu, (2006); Awomeso, Taiwo, Orebiyi, Orekoya and Odjegba (2010) justified the above assertion by their findings that sewage management in Lagos-Nigeria includes direct disposal of the sewage or release of by-products (sludge) of the minimally treated ones to the environment. This is associated with some problems such as the pollution of coastal waters, eutrophication of receiving water bodies (streams, lakes, and rivers), and disposal of sludge from wastewater treatment plants that causes siltation of surface water bodies and difficulty in flowing rates, flooding during storm events, and ultimately high pollution and depletion of underground water. Awomeso, Taiwo, Orebiyi, Orekoya and Odjegba (2010) and Asemota, Alkhaddar, Sertyesilisik and Tunstall (2011) corroborate the aforesaid findings that is, about 94 per cent of Lagos population have no access to sanitary toilets and the predominant management practice is the onsite sanitation systems such as the soaka way pit latrines, pit privies, pour flush latrines, and the septic and soak away pits.

Using the United States Environmental Protection Agency (USEPA) standards of 15 meters setback, Oladimeji, Shittu, and Amali (2016), in a study of on-site septic tanks proximity to water wells in Samaru, Zaria, found that out of 190 hand-dug wells studied in the area, 71% (134) were not located at the relatively safe setback of 15 meters from the nearest septic tanks. This shows the vulnerability of such populations to health risks associated with sanitary practices related to sewage management in our context.

It is noteworthy that poor sewage management practices can also have socio-environmental dimensions, as found in a study carried out by Oladimeji, Atere, Meshubi, Dauda and Ikpe (2015) in Zaria, Nigeria, where it was shown that social conflicts also occurred between residents living in unplanned neighbourhoods because of poor household wastewater management practices engaged in by some residents. This finding highlights the fact that poor wastewater management practices do not just impact on health and hygiene but can also impair peaceful coexistence between residents living in unplanned neighbourhoods especially in cases where neighbours carelessly dispose of wastewater into the property boundaries of other residents.

From the aforesaid studies and revelations, the sewage management practices in Nigeria can be said to have the following features: sewage management practice in Nigeria, is predominantly onsite non-sewerage systems. Urban dwellers dispose sewage, largely grey water, through open drains/ gutters and in some areas, it flows on the streets and through the vaulting of black water into septic tanks and soak away pits. There is an almost non-existent system of treatment plants for domestic sewage generated in urban areas. The presence of waste treatment plants, where found, are largely in the industrial areas of most cities and the central seat of government in the FCT. Formal regulations only exist for industrial effluent and none for domestic sewage. There is also poor knowledge of Nigerians on domestic sewage treatment plants and the integrated wastewater management approaches, for instance, reuse of treated waste water. Generally speaking, the sewage generated in Nigerian cities do not pass through any form of treatment and carries heavy loads of bacteria, viruses, protozoa that transmit infectious diseases, degrade environmental performance and quality and continue to pollute soils, surface and underground water sources through infiltration and seepage.

3.0 The way forward

Considering the findings of studies on the status of sewage management in Nigeria, it is obvious that we need a rethink on the approach to sewage management generally and particularly for the domestic situation. The current approach is not sustainable and makes the majority of our population vulnerable to sanitary risks. Sewage management needs a roadmap geared towards achieving the Sustainable Development Goals (SDG) 6.3 & 6.4 because of the huge gap that exists between industrial sewage handling in relation to domestic sewage. Most towns in Nigeria, with the exception of FCT, Abuja do not have domestic sewage treatment plan. Even the FCT, Abuja, only has 20-30% efficiency of the treatment facility in use within the Phase I and parts of phase II of the territory. There is therefore, the need to carry out additional studies on the predominant sewage management systems in Nigerian cities, in order to synthesise baseline data on the management practices currently in use. Such studies will help in developing models and strategies for improvement towards achieving the SDG's goal on Water, Sanitation and Hygiene, ending open defecation, and reducing the quantity of untreated sewage released into our environment. This may also help in mitigating other less obvious endemic consequences.

Domestic sewage (black water) contains methane gas (CH_4), which is good for energy generation. Perhaps, viewing sewage as a resource and the adoption of International Renewable Energy Agency, IRENA (2020) will move Nigeria towards generating renewable bio-energy as an alternative supply to cities in pursuit of sustainable development. So, to start, research might begin to focus on the quantity, quality and infrastructure as a way domestic sewage can be harnessed as an alternative source of power for cities. Also, there is the need for more public awareness on the threats posed by untreated sewage in our cities. In addition, integrated wastewater management systems should be promoted in our cities. Considering the prevalence of informal urban development of most neighbourhoods in our context, it is also important to promote safer practices in the location of water wells, particularly in relation to on-site septic/ soak away tanks. This will help in mitigating risks associated with maintaining hygienic potable water supply from such sources.

4.0 Conclusion

Sewage Management is critical in determining environmental performance, quality and aesthetics. Therefore, there is a need to rethink the approach to current practices and find more sustainable ways of managing the situation. This cannot be achieved by government and its agencies alone but will take the involvement of all stakeholders, including the private sector and households. There is a need to provide sustainable frameworks that can promote proper sewage management and make cities move towards the path of less sewage-borne diseases, creating more aesthetic living environments and a more sustainable urban ecosystem in general.

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