Innovations

Effect of Scattered-Hevea Trees Agroforestry system on Cassava (Manihotesculenta) in Ebedei Gas Flaring Community, Delta State, Nigeria

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Abstract
Gas flaring presents associated thermal, obnoxious and black flakes issues that interferes with critical physiological pathways in agricultural conurbations for sustained yield. Field experiment was therefore conducted at Ebedei gas flare community to ascertain the effects of Heveabrasillensisagroforestrytype, as anti-thermal and edaphic-reflux system for the morphological adaptation ofcassava cultivation and its enhanced nutrient-use efficiency. Thirty (30) sqm cassava plots were established infarmlands at 90, 120, 150, 180 (Hevea agroforestry) and 210metres (control) respectivelyfrom the flare station. Soil samples collected at 0-15cm depthwere analyzed for bulk density, moisture content, effective cation exchange capacity (ECEC), oil film thickness while Cassava leaves were analyzed for organic carbon ©, nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and yield. Data were subjected to analysis of variance and mean separated with Duncan multiple range test. Results showed significant differences (p>0.05) withCassava yield at 210m (4.13kg/stand) = 180m (4.01kg/stand) > 150m (1.25kg/stand) > 120m (1.10kg/stand) > 90m (0.93kg/stand). Nutrient contents was180m > 210m (organic C, N, Ca and Mg) and least N, P, K, Ca and Mg at 90m from the gas flare station as probable volatilization trend along thermal gradient with low ECEC range of 3.19-4.16cmol/kg between 90-150m. These underpinned the capacity of Heveabrasillensis scattered trees in agroforestry as probable ecological and edaphicshields for theinterception and neutralizationofgas flare particles as well as viable source of moisture at field capacity for better cassava yield.

Keywords*: 1.Gas flare, 2.black flakes, 3.agroforestry, 4.nutrient volatilization, 5.cassava, 6.effective cation exchange capacity*

Introduction

Agroforestry systems have been largely reported as conflict resolution tool in land-hunger conurbations to accommodate arable agricultureand forestry interests, meeting needs of food, fodder and fuel as well as enhance income of smallholders (ICRAF, 2017; FAO, 2016). The relative interactioncomponents of agroforestry have equally been tied to biological significance of nutrient enrichment through the soil by the forest tree component, even though compatibility ofarable crops is critical to averting allelochemical concerns especially as changes in utility of tree species form unique measures for mitigation of greenhouse gas budgets (Kakar et al, 2021;Larson and Nielsen, 2007) especially as critical environmental infrastructure to buffer economic projects with visible challenges.Hence, variation in agroforestry system has been reported to account for critical differences in microbial

synthesis, communities and soil physicochemical properties that implicate especially N and C inputs (Man Shi *et al*, 2022).
Crude oil prospecting and exploration has continued to encroach into arable lands to create significant challenges of oil spill and gas flaring on both soil and air. There are over 180 wellheads and 10 flow stations in Delta State with operational activities that impinge on socio-economic livelihood support systems of host communities. The lowland rainforest ecological zone has over four (4) new gas flaring sites established in the last seven (7) years to facilitate crude oil production in the State(MOE,2019). Increase in temperature, sulphur dioxides, nitrous oxides, black soot and other crude oil particulates have been reported as obnoxious products of gas flaring (Ekeke, 2017) with varying degrees of impact on ecosystem components.

Arable crops on farmlands in host communities of gas flaring fields have reportedly witnessed poor harvest depending on the proximity to flare sites. Unfortunately, most flare fieldsare located in open areas in the surrounding farmlandsleading toreportedly suppressed growth and poor yield to farmers. Thermal influence as a result of temperature change have been observed to reduce biological process while increasing demand for CO_2 due to reactions in the air with nitrates and oxides of sulphur to produce radical compounds (Oseji, 2012; Ojeh, 2012). Furthermore, leaves of arable crops have been reported to undergo severe stress that encouraged wilt conditions to reduce vigor which alters the natural inclination of individual leaves on the stem for adequate sunlight and increased food manufacture (Rai, *et al*, 2010).

The quick reaction of un-intersected gas vapor with available atmospheric oxygen generates black flakes (soot)that on contact with arable crops and underlying soil constitutes different degrees of disruptions and damage on physiological pathways and production respectively. Hot black flakes on arable crops, especially the leaves have potentials of producing leaf coloration and bore holes after a longer period on repeatedly fallen spot on the leaf surface.

However, literatures have been bereft on the engagement of agroforestry system as probable environmental shield in gas flare localities except for erosion control at contours to stabilize soil structure by braking percolation energy, windbreak and shelter belts at right angles to the direction of prevailing winds to reduce wind velocity near the ground and watershed management in managing ground water degradation (Panitnok*et al*, 2013; Oku *et al*., 2011; Forman, 2010).The recombinantpotential of standing trees species in agroforestry system presents significant relationship with the arboreal and edaphic environments to generate sufficient interactions that produce palpable changes within the micro-environment to relatively ameliorate critical challenges.Specialized bacteria that use O_2 and NO_2^- as electron acceptors to enhance CH_4uptake that is strongly influenced by N-availability has been reportedly linked to agroforestry system (Lie *et al*, 2021; Shen*et al*, 2019).

AlthoughCassava (*Manihotspp*) has been reported as potentially resistant to harsh climatic condition that affect yield (Obasi*et al*, 2011), the impact of gas flare under constant thermal and obnoxious gas environment presents an altogether a more precarious situation for this root tuber crop that is source of daily carbohydrate and sustainable livelihood with domestic as well as industrial implication in the tropics. As a staple food in the tropics, Cassava farming constitutes 56-70% of crops on farmlands annually due to the use for local “garri”, industrial starch production and other ancillary export productsthat account for income generation and gross domestic product.

Therefore, this study investigated the scattered *Heveabrasillensis*trees species on cassava farmland asan agroforestry model for probable ecological antidote and shield to enhancing the yield of this economic tropical crop amidst increasing threats from abounding gas flaring stations in arable agricultural communities of Delta State, in the Niger Delta region of Nigeria.

Materials and methods

Description of study area

Ebedei is situated in the lowland rainforest ecological zone of Delta State in the Niger Delta oil and gas rich region of Nigeria. It lies between latitude 6.20 and 6.34°N and longitude 5.86 and 5.90°E of Ukwuani Local Government Area of Delta State in Nigeria. The climate is of the tropical equatorial climate with mean annual temperature of 27-32°C average relative humidity of approximately 60-80% and annual rainfall of 4205mm (NIMET, 2019).

It lies in the tropical rainforest belt and characterized by dense vegetation of tall forest trees with undergrowth of climbing plants particularly entangled together along the streams and creek channels of primary vegetation. The presence sparse patches of secondary vegetation within the vegetation belt that consists of shrubs due to anthropogenic activities in search of arable farmlands. The retention of shrubs on farmlands appears to be a traditional ecological knowledge for the cooling of arable crops.

Mean temperature around the flare station range between 27-52°C and 38-57°Cduring the wet and dry seasons respectively as a result of radiation from the station and composite energy of related activities associated with gas lifting (Anomohanran, 2012). Estimated anthropogenic activity ratiowas 60:40, 70:30, 80:20 and 50:50 for farmland to built-up spaces in the south, north, east and western respectively around the flare station.

The main occupation in Ebedei community is farming. The soils of Ebedei have high composition of sand in relation to the running stream and land filling by relative coarse soil.

Experimental plots and soil collection

Five experiment sites were systematically selected around the flare site at of 90m, 120m, 150m and 180m cassava farm plots with the control farm at 210m from the flare site.The first farmland is located directly opposite gas flare station has an area of 281.26m^2 while the second farmland towards the West-gate has area of 554.48m^2.The third farmland with an area of 353.38m^2 is located beside the lateral site opposite the flare vertical station. The forth farmland close to the lateral gas flare point but perpendicular to the flare line measured 417.97m^2 while the fifth farmland was located in the East-gate with an area of863.29m^2.

The farmland at 180m site is an agro-forest of scattered *Heveabrazillensis*and *Manihotesculenta* tree crop species. The trees and leaves are still green at the control site with relatively abundant biodiversity, sounds of birds, low flying bird species around unlike at the flare site. There is an increase in temperature both along the site and at Ebedei community as a whole, accompanied by an irritating sound from the flare station.

Five (5) experimental plots measuring 30m^2 were marked outusing the Global Positioning System (GPS) in selected four weeks established cassava farmlandslocated at 90, 120, 150, 180 and 210m respectively from the gas flaring station. Thensix (6)soil sampleswere collected systematically from laterally and horizontally gridded points in the middle and edge at 3 samples per point (0-15cm depth)with the Dutch handaugar. A total of thirty (30) soil samples was collected from these experimental plots to determine the relevant physical and chemical properties.

The soil pH was determined using a pye-unican pH meter with a glass electrode in 1:1 soil water suspensions (JUO, 1979). Bulk density by (Exchangeable cations were extracted with neutral normal sodium acetate (NH_4OAc at pH 7.0) and cation exchange capacity and the exchangeable acidity determined according to the procedure of Hossner (1970). Effective cation exchange capacity (ECEC) was calculated as the summation of total exchangeable bases (TEB) and the exchangeable acidity (EA)as described by Ingram(1998).

Plant and yield analysis

Cassava leaves were collected at 5months after cultivation from the established 30m^{2}experimental plotsand oven dried for 24hours at 70°C before grounding. Leaf N was determined using Micro-Kjedahl digestion. Samples were dried to ash at 500°C for 6hours before extraction with nitric-perchloric acid for determination of P, K, Ca and Mg. The P was determined by Vanadomolybdate method while the K, Ca and Mg by EDTA titration (Faithful,2002).

Yield of cassava per experimental plot from each farmland was estimated as the mean weight of harvested cassava tuber per stem per 30m^2 using spring balance.

Estimation of oil-film thickness

Soil samples were collected from 0-15cm depth using the Dutch man augar in the middle and edges of each farmland at five different points. These were bulked beforespreading on trays and allowed to stand under greenhouse conditions for 24hours and loaded 30g of each soil sample to different 50ml glass beaker. Thirty (30) ml of distilled water was added and then allowed to stand overnight. The oil film was examined along the side of each beaker at four different points marked with on the beaker with graduated transparent cellulose tape in mm. Oil film thicknesses were estimated by taking the readings on graduated cellulose points with the aid of magnifying hand lens at the four points. The oil thickness per sample was taken as average value computed.

Source: Delta State Ministry of Urban Renewal, Asaba (2020)

Results

There were significant differences in the mean cassava yield in the various farmlands around the gas flaring station (Table 1). There was no significant difference ($p > 0.05$) between the yield at 180m (Hevea-agroforestry farmland) and 210m at the middle farmland plots. The highest and lowest yield of 4.13 and 0.93kg/stand was recorded at 210m and 90m respectively. There was no significant difference in yield at 120 and 150m farm plots at the middle and edges but differed significantly with farmlands that are 90m from flaring station.

Table 1: Mean Cassava yield (kg/stand)in farm plots around the gas flare station

Location within farm	**90m**	**120m**	**150m**	**180m**	**210m**
Edge	$8.60x10^{-1}\pm1.01^{e}$	1.08 ± 0.12^{cd}	1.18 ± 0.15^{c}	3.88 ± 0.33^{b}	4.00 ± 0.21^{a}
Middle	$9.30x10^{-1}\pm1.11^{d}$	1.10 ± 1.10^{bc}	1.25 ± 0.31^{b}	4.01 ± 0.11^{a}	4.13 ± 0.23^{a}

Means± standard in the same row with the same superscript are not significantly different (p>0.05)

Soil physical and chemical properties

The pH ranged from 5.08-6.70 and significantly differed ($p>0.05$) as shown in Table 2. There was no significant difference between farmlands at 180m (Hevea-agroforestry farmland) and 210m as well as between farmlands at 90-150m from the gas flaring station.

Moisture contents varied significantly with no significant difference between farmlands at180m and 210m farmlandsas well as among 90,120 and150m farmlands. The highest MC (15.34%) was recorded in 210m farmlands but was not significantly different from the farmland at 180m (Hevea agroforestry).

There were significant differences in the effective cation exchange capacity (ECEC) of farmlands along the study gradient of 90-210m. The highest (10.83cmol/kg)and least (3.19cmol/kg) ECEC were recorded at 210m and 90m farmlands respectively.The 180m-Hevea agroforestry farmland was not significantly different from the 210m farmland.There was no significant difference in the thickness of oil films between farmlands at 120 and 150m as well as 180 and 210m. Butthere were significant differences between farmlands at 90m and all the other farmlands. The thickest oil film (1.80mm) was at farmland that is 90m away from the flaring station while the least (0.80mm) was at the 210m farmland which was not significantly different from the 180m Hevea agroforestry farmland.

Table 2: Physicochemical properties of farmland soils around gas flare station

Distance of farm (m)	**pH (H_2O)**	**Bulk density (g/m^3)**	**Moisture content (%)**	**TEB (cmol/kg)**	**EA (cmol/kg)**	**ECEC (cmol/kg)**	**Oil-film thickness (mm)**
90.0	5.08^{b}	2.88^{a}	12.50^{b}	2.43^{e}	0.76^{a}	3.19^{e}	1.80^{a}
120.0	5.26^{b}	2.25^{b}	12.95^{b}	2.80^{d}	0.68^{ab}	3.48^{d}	1.54^{b}
150.0	5.24^{b}	2.35^{b}	12.76^{b}	3.64^{c}	0.52^{c}	4.16^{c}	1.50^{b}
180.0	6.70^{a}	1.33^{c}	14.59^{a}	10.11^{b}	0.34^{d}	10.45^{ab}	1.00^{c}
210.0	6.60^{a}	1.24^{c}	15.34^{a}	10.58^{a}	0.25^{d}	10.83^{a}	0.85^{c}

Means in the same column with the same superscript are not significantly different (p>0.05)

Nutrient composition

There were significant differences in the mean concentration of nutrients in the leaves of cassava (Figure 1). The presence of nutrient elements within the region of gas flaring was not appreciable but there was drastic increase in the agroforestry farmlands especially for C, N, Ca and Mg. The highest organic C (8.32±0.77%) was recorded by farmland at 180m (Hevea agroforestry) and differed significantly from the others. There was no significant difference between the organic carbon of farmland at 90 and 120m.

The highest N content (1.98±0.11%) was recorded in the Hevea agroforestry farmland and was significantly different from others. The least N (0.83±0.40%) was recorded at farmland 90m from the flare station.

Apart from P, the Hevea scattered agroforestry farmland recorded the highest mean nutrient concentration, although only the control farmland at 210m had a higher P (0.25 ± 0.17%). There was no significant difference in the mean P-value at 90, 120 and 150m.

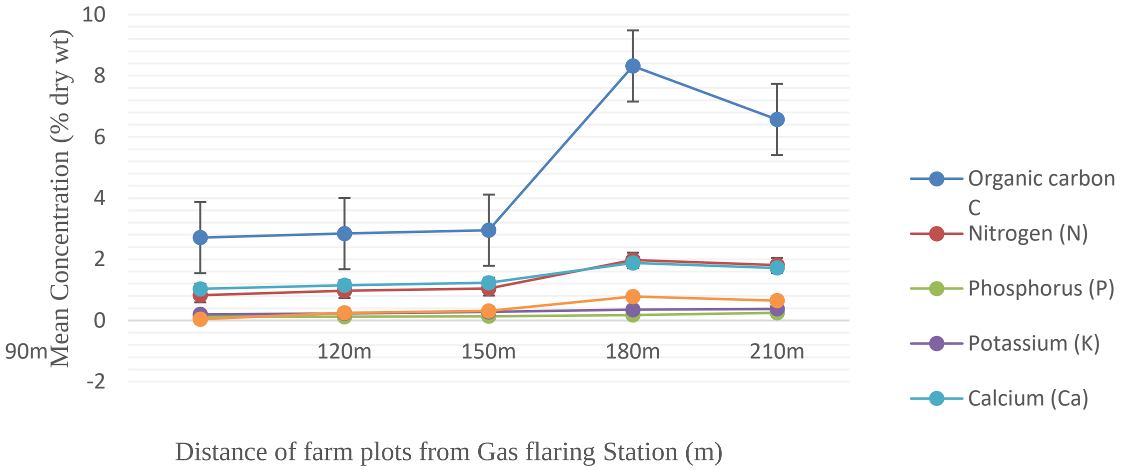

Fig. 1: Nutrient composition in Cassava leaves along gas flare gradient

Discussions

The poor yield at 90-120m location farmlands may not be unrelated with the stress leaf condition due to the temperature from the flare site. This is because at the thermal condition of these farmlands, most of the leaves are stressed and even while still attached to the stem, a good number may have lost significant phloem essential for nutrient exchanges. This may have accounted for the high quantity of discolored cassava leaves that often littered the farmlands around gas flaring site (Odu, 2016). The loss of leaves significantly influenced the yield since photosynthetic processes that manufacture food and translocate to the stem and roots for storage as tuber may have suffered serious reduction (Njoku-Tony*et al*, 2017).

The *Heveabrasillensis*stand shielded the cassava on agroforestry practice farmland that was significant different from others except the control which was not in the region of gas flare. This revealed that Hevea vegetation acted as a multiple greenbelt shield of over 100m wide to ameliorate the associated high temperature with increase in relative humidity for the growth of cassava. The result may not be unconnected with height and relatively glossy leaves of the para-rubber which was established before the cultivation of cassava and probably have the capacity to relatively withhold large quantity of the soot from reaching most of the cassava leaves, stem and underlying soil

(Seyyednejad*et al*., 2011). The pockets of air trapped within the stand may have potentially and significantly neutralized the binding characteristics often associated with hot soot from gas flare. Therefore, the absence of vegetation in other farmlands could have accounted for the poor cassava yield in the vicinity of the flare station in agreement withAtuma andOje(2013) thatcassava yields and soil nutrient decreased with nearness of farmland to gas flare station.

However, the distance of Hevea agroforestry farmland which was closer to the flare station than the 210m farmland showed that agroforestry adaptation could be a panacea to the poor cassava yield reported in gas flare communities. Even at lower levels within the Hevea–agroforestry plot, the leftover/residual gas and black flakes may have lost significant concentration as a result of dispersion to minimize the impact on cassava stand and underlying soil nutrient. The probable decomposition of neutralized soot materials in the forest floor by different components could equally have contributed to increased organic carbon matter for enhanced porosity and water-holding capacity of underlying soil.

Low P and K nutrients exhibited the same trend at 90 and 120m while Ca and Mg with the same trend at 90, 120 and 150m farmlands. The farmlands at 180 and 210m accommodated higher and more nutrientthat includes C, N, Ca and Mg which has potential to enhance meristematic cell elongation and division as well as constituent chlorophyll for better growth and yield. The high organic C cassava in the Hevea-agroforestry corroborates the finding of Ekwudayo and Orhue (2011) that cassava cropped on riparian forest land had stored more organic C than conventional farmlands under the same fertilization probably due to the higher decomposition potential of the cassava and Hevea leaves on the floors (Clough *et al*., 2010).

Furthermore, the low P and K at farmlands closer to the flare station may not be unconnected with volatilization of nutrients as a result of thermal differentialsalong the study farmland (Anomohanran, 2012)to have influenced the yields unequivocally since K is essential for metabolism, protein synthesis and development of chlorophyll (Remison, 2005).This ease of volatilization could be substantiated with the results of findings, especially with N as most critical due to the ease of association with readily available radical elements from the flare. This may have affected the relatively “unprotected NPK nutrients” in plant and soil of farmlands without scattered trees for better yield of cassava tuber (Chen *et al*, 2019). N-volatilization may have therefore been highest at the closest farmlands to the flare station and thus less available to have encouraged synthesis of methanotropic bacteria for enhanced methane uptake and accounted for the low yield as a result of probable low chlorophyll formation.

However, the tap rooting system of the agroforestry farmland may also have functioned as additional source of moisturefor cooling soil temperature, reduce and moderate concentration of oxides of sulphur and nitrate that may have enhanced pH shift towards alkalinity unlike the strongly acidic conditions at the 90, 120 and 150m farmland (Lin *et al*,2008; Efe, 2010). This correspondingly resulted in better tuber formation from the various nodes of cassava stem under cultivation probably as a result of the consistent supply of nutrient as reflected in the moderate ECEC of agroforestry plot (Namwata*et al*., 2012).

Conclusion

This study provides context for further application of agroforestry system in combating the growingmenace of gas flaringin potential arable agricultural-crude oil conurbations.Poor yield in NPK-unprotected farmlands close to the flare stationmay be reversed by adaptation to the scattered tree agroforestry model with a view to reducing thermal gradients, nutrient volatilization and black flakes while at the same time increase moisture content. Similar studies with multiple tree species at different canopy story as well as temperature-combatant morphological structures is suggested for possible better black flake intersections and increased groundwater suction pressure to facilitate synergy for prompt microclimatic responses within an agroforestry system in gas flare vicinities.

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