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Floristic Assessment of Natural Regeneration in an Enhanced Post-Remediated Hydrocarbon Impacted Land: A Window for Selection of Remediation Potential Native Macrophyte

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study was aimed at revealing the composition and demographic status of forest regeneration in a post remediatied hydrocarbon impacted site by enhanced natural attenuation.
Study Design: A stratified systematic transect method was used to assess the regeneration status.
Place and Duration of Study: Field sampling: in parts of Edovna vegetation landscape in Emohua Local Council area of Rivers State, Niger Delta, Nigeria and site remediation activity carried out for 10 weeks.

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Methodology: Site remediation treatment technique, Vegetation assessment, Regeneration Assessment and data analysis were carried out.

Results: The hydrocarbon activities around the SPDC marginal oil field manifold in Emuoha study area negatively impacted the Edovna forest vegetation landscape at Umuobizu resulting to a retrogressively mosaic trend condition. However, following the p-RENA process a progressively secondary succession has resulted to such classified flora: as lowland secondary vegetation mosaic nature, with heterogeneous continuum in spatial and closed horizontal assemblage of structural arrangement. Several species of diverse life forms were found existing through diverse mode of regeneration. New species were found regenerating and were absent as adult. Greater mode of single level of regeneration than multiplier level of regeneration was exhibited among the recruits through coppicing, stolon, seedling, sapling, rhizome and tuber. The HG exhibited greater multiplier mode while HH had greater single mode of regeneration. The herbaceous recruits among the life forms revealed a secondary physiognomic unit, heterogeneous in nature as a result of the regeneration process with few regenerating shrubby recruits. A total of 115,549 seedlings and 7,825 saplings ha^{-1} of 96 recruits of 70 genera under 23 families were found in 800 m^2 sampled site. The dominant family was Poaceae richest in species diversity (24 species). The phytosociological composition of recruits has recorded highest frequency (1675), abundance (621), density ha-1 (49,600), IVI (104.81), diversity richness (11.75) and evenness (5.96) with Herbaceous herb (HH) in highest number of regenerating recruits in the order (*HH>HG>Sh>HCl>HS>ShCl>T*) of habit forms. The Chamaephytes and Hemi-cryptophytes across diverse herbaceous life forms, Mesophanerophytes, Microphaneropytes, Nanophanerophytes and Hemi-cryptophytes across shrubby life forms and a megaphanerophyte tree life form were recorded among recruits. The percentage mode of regeneration had 40 recruits of herbaceous form that exhibited 12 multiplier and 4 single mode of regeneration respectively. Four shrubby recruits exhibited 2 multiplier and 13 recruits exhibited 2 single mode of regeneration.

Conclusion: The demographic status of regeneration revealed a greater seedling density than sapling density thus implying a successful and new regeneration which through protection of natural regeneration can return back to it complete forest cover again. It can be deduced in this present study that the success of natural regeneration depends on both the demographic status and rate of establishment of natural recruits which was maximal at the p-RENA landscape of the study site across the herbaceous, tree and shrubby recruits in the present study.

Keywords: Demography; life form; phytosociology; recruits; regeneration; vegetation.

1. INTRODUCTION

Oil pollution whether acute or chronic has simultaneous and / or instantaneous deleterious effect on environmental landscape. The impact of hydrocarbon pollution on environmental media involving soil, air, and water and associated ecosystem of communities have been documented in several studies [1-9]. Therefore the incidence of oil spill constituting diverse environmental damage may not be overemphasized hence, different parts of the Niger Delta region have in the past experienced and are still facing serious ecosystem depletion from the activities of hydrocarbon industries. such scenario has similarly affected the environment in the operational areas, right of ways (ROW) and third party areas in parts of Emuoha study area. The Emuoha study area is one of the agrarian communities among the upland localities in Rivers State. The area is known for its diverse unique, natural and socio-economically important biodiversity characterized by rich vegetation systems of distinct patches of low land primary and secondary tropical rainforest, adjoining fresh water forest locally known as “Ugologo, Mininknu, Miniowhna, (i.e. Wetland forests); fallowed low land vegetation known as Ejohia (evil forest); low land agronomic vegetation land scape of various farm lands with such local names as: Okologba, Alinkpu, Uzookohia, Oriogbo, ovuzor, Owhela, Uzoomuobizu, and adjoining ROW low land vegetation land scape locally known as Nzuruptata and Edovna forest (p-RENA project site) at Umuobizu.

The threat posed by the impact of hydrocarbon on the Edovna forest and its adjoining vegetation cover can be adequately addressed via concerted effort. This requires understanding the diversity and natural dynamics of plant species, (causes, mechanisms and factors) that drive the process of plant species regeneration, population change and replacement over time to maintain remaining patches of forest vegetation [10,11]. Understanding and managing the disturbances of landscape under past natural and semi-natural regeneration condition is one of the bases for conservation of biodiversity in vegetation landscapes [12]. Furthermore, the crucial role of natural regeneration in the sustainable management of forest and woodland resources has been demonstrated [13].

The occurrence of oil spill and subsequent the physical clean-up (such as containment, recovery and surface scarification) by operating companies, usually render the lands bare, without adequate reforestation to restore the environment back to its natural or near-natural status. This was a similar trend at Umuobizu impacted site in Ibaa study location after the 2005 oil spill, without any form of replanting and recuperation until 2013 after 8 years of p-RENA when the site has started recuperating by natural regeneration of recruits in diverse life forms. Recruitment, growth, and survival are influenced by a range of microclimatic and edaphic factors, which vary among different tropical forest vegetation formations [14]. Regeneration of any species holds a vantage point for the perpetuation of forests vegetation, which can be exemplified in diverse recruits of seedlings, sapling, and coppices. Parameters of seedling stands are crucial components of population dynamics [15]. As floristic and structural composition changes from one community to another there are also changes in the competitive abilities of seedlings that depend on shifting opportunities for regeneration [16]. Earlier studies of tropical tree regeneration have focused mainly on seedlings, which are usually more abundant than other demographic status [17,18]. Research has shown that plant species in their diverse capabilities in a post-remediated hydrocarbon polluted site can re-establish through various mode of regeneration status such as coppicing, seedling, rhizome and sapling with few resilient species exhibiting multiplier mode of regeneration [15,19].

Although there have been reports of investigations on natural regeneration of polluted and post-remediated site, but no investigation of such at Emuoha study area in Rivers State. This informed the evaluation of demographic ability of native plant species and natural regeneration status at Umuobizu marginal oil field for remediation potential in polluted site as observed in Emuoha study area in Rivers State. It is one of the best and easy ways to find a plant species suitable for phytoremediation. Several plant species by natural regeneration have demonstrated resilience and remediation potentials in contaminated or polluted sites [20-23]. Yet there is paucity on plant species natural regeneration in parts of Niger Delta hydrocarbon impacted sites particularly in remediated sites. This study was therefore aimed at evaluating the remediation potential of some species as either: hydrocarbon tolerant macrophytes, (HTM); demonstrated phytoremediation macrophyte (DPM) or suspected phytoremediation macrophytes (SPM). with the objective of understanding their fate of natural recruits based on the mode of regeneration across their demographic status in crude oil hydrocarbon post-remediated soil habitat in parts of Emuoha study area in Rivers State, Nigeria.

2. MATERIALS AND METHODS

2.1Study Area, Location and Site

The study area was Emohua Local Council, situated between Lat. 04^{o}25'4"N to 05^{o}25'20"N and Long.06^{o}30'27"E to 07^{o} 31'36"E (Fig. 1) in Rivers State, South-South Nigeria. It is one of the oil exploration areas in the Niger Delta region of Nigeria. The area is generally a lowland with diverse forest vegetation land scape characterized by oil exploration activities. It is predominantly an agrarian community of farmers, hunters and fishermen fully exploiting the rich biodiversity of the area. The edaphic condition of the area is a sandy-loam soil texture rich in nutrients composition of organic and inorganic components. The successive vegetation of the area is characterized by prevalent species of diverse life forms. The study area is characterized by two seasons, (Rainy and Dry seasons) with an annual rainfall between 2400 - 4000mm and maximum temperature range of 28°C for its hottest month and 26°C as lowest temperature in its coldest month [24]; diurnal variation seldom exceeded 15^{o}C. The study area is comprised of over 31 communities among major towns and villages including: Ogbakiri, Emuoha, Odoegu, Elele-Alimini, Rumuekpe, Akpabu, Egbeda, Obele-Ibaa, Omudioga, Ubimini, Egamini and the study location -Ibaa.

The study location – Ibaa with its' situate between Lat. 4^{o}50'0"N – 5^{o}0'0"N and Long. 6^{o}40'0"E – 5^{o}0'0"E (Fig. 2) is a secondary vegetation low land habitat lying in the rainforest belt of Rivers State within the equatorial climate region characterized by maximum rainfall, relative humidity and maximum temperature associated with the study area. The study site – Umuobizo and its environ geo-referenced to Lat.4^{o}55'0"N to 4^{o}58'0"N and Long. 6^{o}48'0"E to 6^{o}50'0"E (Fig. 3) is an agrarian community with its adjoining ROW low land vegetation landscape locally known as Edovna forest rich in forestry resources for their traditional ethnobotanical and agrarian utilization.

The Edovna forest vegetation system is associated with network of crude oil pipeline [Right of Ways (ROWs)] linking the SPDC marginal oilfield manifold. The Edovna forest ecosystem was often designated as one the landscape for agronomic activities before the discovery of oil in the area, thus was given up as one of the SPDC marginal oil field manifold. The edaphic and topographic status revealed a table land characterized by sandy loam soil.

Based on Key Informant Interview (KII) [25] it was originally known to be a climax vegetation of various strata observed to be under retrogressive ecological succession. This was due to anthropogenic influence of hydrocarbon exploration, farming activities far and near residential areas as well as encroachment to ROWs by the local inhabitants coupled with the 2005 post-oil spill impact thereby leaving the study location with some form of irregular heterogeneous vegetation features characterized by prevalent species of shrubs, and herbaceous climbers, liana and under the prevailing local condition dominated by suspected hydrocarbon tolerant families (Poaceae, Euphorbiaceae, Rubiaceae, Tiliaceae, Cyperaceae, Commelinaceae, Asteraceae, Convolvulaceae, Malvaceae, Onagraceae, Fabaceae, Sterculiaceae, and Acanthaceae) of plant species . However, the vegetation landscape of the area can still be described as rainforest vegetation corroborating the views of Edwin-Wosu and Edu, [19].

2.2 Study Site Remediation Treatment Technique

An integrated approach of Focused Group Discussion (FGD) and Key Informant Interview (KII) at the period of reconnaissance survey and enumeration was carried out. With the site still void of vegetation recruits, 8 years after the oil spill incident in 2005, RENA technique was adapted. This was deployed on the impacted soil in 2013 following containment and recovery of oil in the polluted site around the SPDC manifold at Umuobizu marginal oil field, Ibaa. At the end of recovery initial tilling using shovels was deployed after four weeks. The second tilling after 14 days was to break and homogenize lumps of soil in the crude oil impacted site and allowed to stand for another 14 days. This was followed with soil ridges of about 1x1foot windrow been constructed and allowed to stand for another 14 days. At the 14 day elapse of the windrow ridges, shovels and rakes were used to break down ridges for effective exposure to local environmental condition. The breaking and gathering of windrow ridges was to enhance porosity, soil aeration and moisture content that would promote biodegradation activities of resident microorganisms, enhance natural regeneration and recruitment of plant species. The exposed site was under monitoring and evaluation for 8 years after RENA, upon which second enumeration in 2021 was carried out to ascertain the degree and demographic status of natural recruit regeneration.

2.3 Vegetation Assessment

This study adopted an integrated approach involving: Stratified randomized designed, sub-sampled units (10 x 20m) of sampled plot (40 x 20 meters) in a systematic transect design outlay [26]; Geospatial tools (Geographical Positioning System (GPS); Remote Sensing (RS); Geographic Information System (GIS) (BHnav 300 model ESRI'S ARCMAP version 10.4); and floristic Identification / Authentication [27-40].

2.4 Regeneration Assessment

The regeneration assessment [41] was based on trend condition of the following demographic indices:

"**Good**" when seedling density > sapling/coppicing density > adult tree density.
"**Fair**" when seedling density > sapling/coppicing density = adult density.
"**Poor**", when the species survived in only the sapling/coppicing stage but not in the seedling stage.
"None", for species with no sapling/coppicing or seedling stages but present as adult trees.
"**New**" when adults of a species were absent but sapling / coppicing and/or seedling stage(s) were present.

2.5 Data Analyses

Data was analysed for percentage Frequency [42]; Abundance [43]; Density Chikkahuchaiah *et* *al*. [44]; Relative frequency, Relative abundance, Relative density [45]; Coefficient of frequency Pryor scale semi-quantitative (+ ---- >) representation, [46]; Importance Value Index [47]; Species diversity richness: (H') = - $\sum \rho i \ I\eta \ \rho i$ [48]; Species evenness or Equitability Index: $E = H'/ Log.S$ [49]; Life form spectrum ***I*** classification [50]; Distribution patterns: Ratio of Abundance: Frequency (A/F): Regular (< 0.03), Random (0.03 - 0.05) and Contiguous (> 0.05) [51].

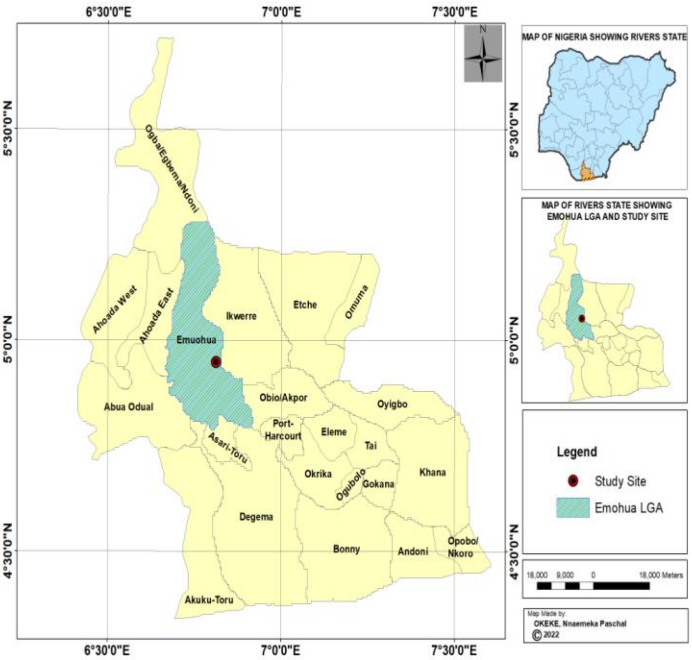

Fig. 1. Rivers State showing study area-Emohua

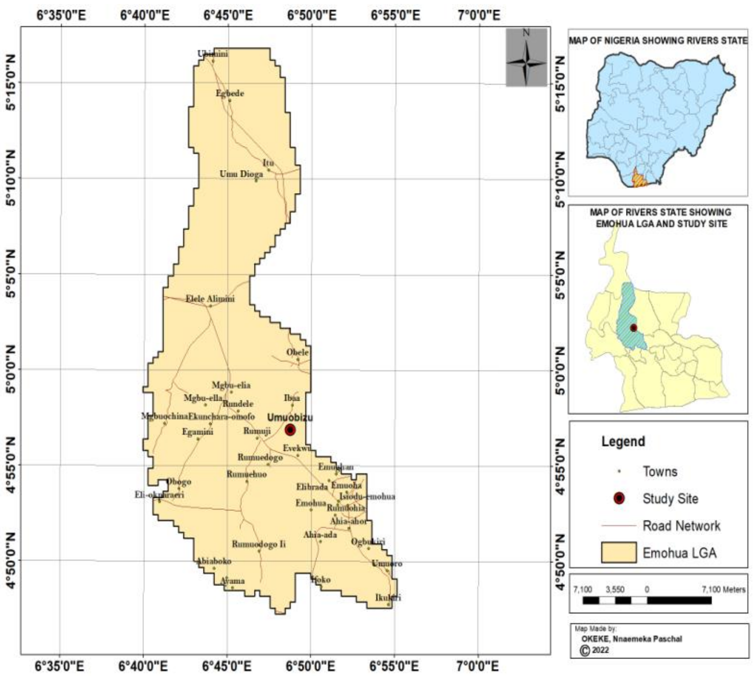

Fig. 2. Emohua study area showing study location - Ibaa

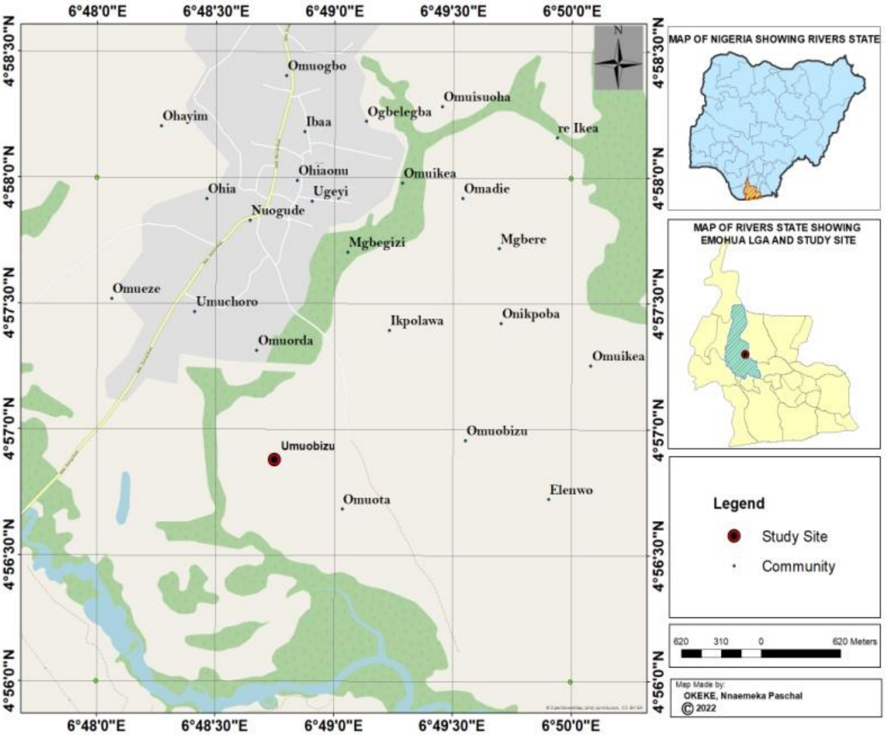

Fig. 3. Ibaa town showing study site- Umuobizu

3. RESULTS

i. Floristic classification, structure and composition

Under the scenario of hydrocarbon activities around the SPDC marginal oil field manifold in Emuoha study area the Edovna forest had its vegetation landscape at Umuobizu negatively impacted retrogressively to a mosaic trend condition however, following the p-RENA process the impact influence of progressive secondary succession resulted to such classified flora: as lowland secondary vegetation with mosaic nature, heterogeneous continuum in spatial and closed horizontal assemblage of structural arrangement. The floristic composition revealed changes and variation among various habit and life forms of 96 representative species of 70 genera under 23 families of angiosperm (Table 1). Diverse dominance of families (Poaceae, Cyperaceae, Fabaceae Commelinaceae, Malvaceae, Tiliaceae, Asteraceae, Rubiaceae, Euphorbiaceae, Sterculiaceae, Passifloraceae and Amaranthaceae) was recorded among regenerating recruits. Eight families were very abundant with the highest diversity species richness. Poaceae (30.38%) had 24 species, Cyperaceae (11.39%) 9 species, Fabaceae (16.46%) 13 species, Asteraceae (6.33%) 5 species, Rubiaceae and Euphorbiaceae (7.60%) 6 species respectively, and Sterculiaceae and Amaranthaceae (5.06%) 4 species respectively. Four families (Commelinaceae, Malvaceae, Tiliaceae and Passifloraceae) with respective percentage and three species each were in abundance (Table 1).

The family phytosociological composition indicated Poaceae with the highest composition of frequency (1675 = 27.96%), abundance (621 = 36.67%), density (49,600 = 40.18%) ha^{-1}, IVI (104.81 = 34.95%), species diversity richness (11.75) and evenness (5.96) values recorded across phytosociological indices (Table 1). Verbanaceae, Euphorbiaceae, and Vitaceae respectively recorded least frequency (25 = 0.42%). Least composition across abundance (5 = 0.30%), density (125 = 0.10%) ha^{-1} and IVI (0.82 = 0.27%) was recorded by Vitaceae. Arecaceae recorded least density (125 = 0.10%) while Aizoaceae had the least species diversity richness (0.05) and evenness (0.03).

Table 1. Qualitative and quantitative phytosociological representative of hydrocarbon tolerant regenerating recruits; 8 years after post-remediation by enhanced natural attenuation (p - RENA) of hydrocarbon impacted soil in parts of rivers state, Niger Delta, Nigeria

S/N	SPECIES	Family	Common name	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
1	*Paspalum conjugatum* Berg.	Poaceae	Sour grass	75	16.67	1250	1.25	0.99	1.01	3.25	1.08	0.04	0.02	0.22	+++
2	*Ischaemum rogusum* Salisb	Poaceae	Saramilla grass	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
3	*Chloris pilosa* Schumach.	Poaceae	Finger grass	50	8.00	400	0.83	0.47	0.32	1.62	0.54	0.14	0.07	0.16	++
4	*Digitaria horizontalis* Willd.	Poaceae	Digit grass	25	35.00	875	0.42	2.07	0.71	3.20	1.07	0.03	0.02	1.40	+
5	*Digitaria gayana* (Kunth) Stapf.	Poaceae	NA	25	30.00	750	0.42	1.77	0.61	2.80	0.93	0.03	0.02	1.20	+
6	*Brachiaria deflexa* (Schumach) CE. Hubbard ex. Robyns	Poaceae	Annual brachiaria	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
7	*Brachiaria lata* (Schumach) CE. Hubbard	Poaceae	Grass	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
8	*Panicum maximum* Jacq.	Poaceae	Guinea grass	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
9	*Axonopus flexuosus* (Peter) Troupin	Poaceae	Grass	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
10	*Andropogon repens* Steud	Poaceae	Grass	100	20.00	2000	1.67	1.18	1.62	4.47	1.49	0.26	0.13	0.20	++++
11	*Cenchrus biflorus* Roxb	Poaceae	Bur grass	50	50.00	2500	0.83	2.95	2.03	5.81	1.94	0.56	0.28	1.00	++
12	*Eragrostis ciliaris* (Linn) R.Br.	Poaceae	Love grass	100	62.50	6250	1.67	3.69	5.07	10.43	3.48	1.88	0.95	0.63	++++
13	*Eragrostis tenella* (Linn) P. Beauv ex. Roem	Poaceae	Feathery love grass	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
14	*Andropogon tectorum* Schum & Thonn	Poaceae	Giant blue stem	75	20.00	1500	1.25	1.18	1.22	3.65	1.22	0.11	0.06	0.27	+++
15	*Cyanodon dactylon* (Linn) Pers	Poaceae	Bahama grass	100	62.50	6250	1.67	3.69	5.07	10.43	3.48	1.88	0.95	0.63	++++
16	*Schizachyrum brevifolium* (SW) Nees	Poaceae	NA	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
17	*Cynodon nlemfuensis* Vandergst	Poaceae	Giant star grass	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
18	*Sorghum arundinaceum* (Desv) Stapf	Poaceae	Wild sorghum	75	18.33	1375	1.25	1.08	1.11	3.44	1.15	0.07	0.04	0.24	+++
19	*Setaria megaphylla* (Steud) Dur & Schinz	Poaceae	Big-Leaf bristle grass	100	8.75	875	1.67	0.52	0.71	2.90	0.97	0.01	0.01	0.09	++++
20	*Setaria barbata* (Lam) Kunth	Poaceae	Bristly fox tail grass	100	3.75	375	1.67	0.22	0.30	2.19	0.73	0.10	0.05	0.04	++++
21	*Perotis indica* (Linn) O.Ktze	Poaceae	Grass	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
22	*Setaria pumila* (Poir) Roem & Schult	Poaceae	NA	75	15.00	1125	1.25	0.89	0.91	3.05	1.02	0.01	0.01	0.20	+++
23	*Brachiaria falciflera* (Trin) Stapf	Poaceae	NA	75	5.00	375	1.25	0.30	0.30	1.85	0.62	0.13	0.07	0.07	+++
24	*Acroceras zizanioides* (Kunth) Dandy	Poaceae	Oat grass	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
	SUBTOTAL			**1675**	**621**	**49,600**	**27.96**	**36.67**	**40.18**	**104.81**	**34.95**	**11.75**	**5.96**	**10.07**	
25	*Mariscus flabelisformis* Kunth	Cyperaceae	Sedge	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
26	*Cyperus esculentus* Linn.	Cyperaceae	Yellow nut sedge	100	22.50	2250	1.67	1.33	1.82	4.82	1.61	0.33	0.17	0.23	++++
27	*Fimbrystalis littorali* Guadich	Cyperaceae	Fimbry sedge	75	32.67	2450	1.25	1.93	1.99	5.17	1.72	0.41	0.21	0.44	+++
28	*Cyperus haspan* Linn.	Cyperaceae	Haspan flat sedge	100	17.50	1750	1.67	1.03	1.41	4.11	1.37	0.19	0.10	0.18	++++
29	*Cyperus rotundus*Linn.	Cyperaceae	Purple nut sedge	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
30	*Mariscus longibrecteatus* Cherm.	Cyperaceae	Sedge	25	18.00	450	0.42	1.06	0.36	1.84	0.61	0.13	0.07	0.72	+
31	*Kyllinga erecta* Schumach	Cyperaceae	Sedge	25	30.00	750	0.42	1.77	0.61	2.80	0.93	0.03	0.02	1.20	+
32	*Mariscus alternifolius* Vahl	Cyperaceae	Sedge	25	15.00	375	0.42	0.89	0.30	1.61	0.54	0.14	0.07	0.60	+

S/N	SPECIES	Family	Common name	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
33	*Cyperus iria* Linn	Cyperaceae	Sedge	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
	SUBTOTAL			**550**	**220.67**	**14775**	**9.18**	**13.02**	**11.96**	**34.16**	**11.39**	**2.68**	**1.37**	**4.57**	
34	*Mimosa invisa* Mart.	Fabaceae	Sensitive plant	50	5.50	275	0.83	0.33	0.22	1.38	0.46	0.16	0.08	0.11	++
35	*Pueraria phaseloides* (Roxb) Benth	Fabaceae	Tropical kudzu	75	22.67	1700	1.25	1.34	1.38	3.97	1.32	0.16	0.08	0.30	+++
36	*Centrosema pubescence* Benth	Fabaceae	Centrosema	25	7.00	175	0.42	0.41	0.14	0.97	0.32	0.16	0.08	0.28	+
37	*Milletia arboensis* (Hook F.) Bak.	Fabaceae	Fermentation plant	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
38	*Chamaecrista mimosoides* (Linn) Greene	Fabaceae	Japanese tea	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
39	*Aeschynomene indica* Linn	Fabaceae	Curly indigo	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
40	*Desmodium tortusum* (SW) DC	Fabaceae	Florida beggar weed	75	13.33	1000	1.25	0.79	0.81	2.85	0.95	0.02	0.01	0.18	+++
41	*Calopogomium mucunoides* Desv	Fabaceae	Calopo weed	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
42	*Zonia latifolia* SM	Fabaceae	NA	100	23.75	2375	1.67	1.40	1.93	5.00	1.67	0.37	0.19	0.24	++++
43	*Shrankia leptocarpa* DC	Fabaceae	NA	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
44	*Crotolaria retusa* Linn	Fabaceae	Rattle box	50	15.00	750	0.83	0.89	0.61	2.33	0.78	0.08	0.04	0.30	++
45	*Albizia zygia* (DC) JF Macbride	Fabaceae	West African Albizia	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
46	*Desmodium triflorum* (Linn) DC	Fabaceae	NA	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
	SUBTOTAL			**800**	**225.25**	**16850**	**13.33**	**13.31**	**13.67**	**40.31**	**13.44**	**3.17**	**1.61**	**3.48**	
47	*Cynotis lanata* Benth.	Commelinaceae	Cynotis	50	22.50	1125	0.83	1.33	0.91	3.07	1.02	0.01	0.01	0.45	++
48	*Aneilema benninense* (P.Beauv) kunth.	Commelinaceae	NA	25	7.00	175	0.42	0.41	0.14	0.97	0.32	0.16	0.08	0.28	+
49	*Commelina benghalensis* Linn	Commelinaceae	Wandering Jew	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
	SUBTOTAL			**100**	**37.50**	**1500**	**1.67**	**2.21**	**1.21**	**5.09**	**1.69**	**0.33**	**0.17**	**1.05**	
50	*Ipomea involucrata* P.Beauv.	Convolvulaceae	Morning glory	75	7.33	550	1.25	0.43	0.45	2.13	0.71	0.11	0.06	0.10	+++
51	*Ipomoea asarifolia* (Desv) Roem & Schult	Convolvulaceae	Ginger leaf morning glory	75	6.67	500	1.25	0.39	0.41	2.05	0.03	0.05	0.03	0.09	+++
	SUBTOTAL			**150**	**14**	**1050**	**2.50**	**0.82**	**0.86**	**4.18**	**0.74**	**0.16**	**0.09**	**0.19**	
52	*Sida cordifolia* Linn.	Malvaceae	Flannel weed	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
53	*Hibiscus suratensis* Linn	Malvaceae	Wild sour	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
54	*Urena lobata* Linn	Malvaceae	Hibiscus bur	25	16.00	400	0.42	0.95	0.32	1.69	0.56	0.14	0.07	0.64	+
	SUBTOTAL			**75**	**24**	**600**	**1.26**	**1.43**	**0.48**	**3.17**	**1.05**	**0.43**	**0.22**	**0.96**	
55	*Triumfetta eriophlebia* Hook. F.	Tiliaceae	NA	50	5.00	250	0.83	0.30	0.20	1.33	0.44	0.16	0.08	0.10	++
56	*Triumfetta cordifolia* A. Rich	Tiliaceae	Cord-Leaf bur back	75	13.33	1000	1.25	0.79	0.81	2.85	0.95	0.02	0.01	0.18	+++
57	*Triumfetta rhomboidea* Jacq	Tiliaceae	Chinese bur	100	11.25	1125	1.67	0.66	0.91	3.24	1.08	0.04	0.02	0.11	++++
	SUBTOTAL			**225**	**29.58**	**2375**	**3.75**	**1.75**	**1.92**	**7.42**	**2.47**	**0.22**	**0.11**	**0.39**	
58	*Chromolaena odorata* (Linn)RM. King & Robinson	Asteraceae	Siam weed	100	6.00	600	1.67	0.35	0.49	2.51	0.84	0.06	0.03	0.06	++++
59	*Vernonia cineria* (Linn) Less	Asteraceae	Little iron weed	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
60	*Eclipta alba* (Linn.) Hassk	Asteraceae	False daisy	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
61	*Tridax procumbense* Linn	Asteraceae	Coat button	100	40.00	4000	1.67	2.36	3.24	7.27	2.42	0.93	0.47	0.40	++++
62	*Acanthospermum hispidum* DC	Asteraceae	Bristly starbur	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
	SUBTOTAL			**325**	**66.33**	**5500**	**5.43**	**3.85**	**4.46**	**13.74**	**4.58**	**1.38**	**0.70**	**1.01**	
63	*Pentodon pentandrus* (Schum & Thonn) Vatke	Rubiaceae	NA	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
64	*Spermacocci ocymoides* Burm F.	Rubiaceae	NA	25	15.00	375	0.42	0.89	0.30	1.61	0.54	0.14	0.07	0.60	+

S/N	SPECIES	Family	Common name	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
65	*Oldenlendia affinis* Roem & Schult	Rubiaceae	NA	25	17.00	425	0.42	1.00	0.34	1.76	0.59	0.14	0.07	0.68	+
66	*Oldenlendia corymbosa* Linn.	Rubiaceae	Flat top mille graines	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
67	*Spermacoce verticillata* Linn.	Rubiaceae	White head broom	75	26.67	2000	1.25	1.58	1.62	4.45	1.48	0.25	0.13	0.36	+++
68	*Diodia sermentosa* Sw.	Rubiaceae	Tropical button weed	100	18.75	1875	1.67	1.11	1.52	4.30	1.43	0.22	0.11	0.19	++++
	SUBTOTAL			**300**	**97.92**	**5500**	**5.01**	**5.79**	**4.45**	**15.25**	**5.08**	**1.02**	**0.52**	**2.40**	
69	*Elaeis guineensis* Jacq.	Arecaceae	Oil palm	50	2.50	125	0.83	0.15	0.10	1.08	0.36	0.16	0.08	0.05	++
	SUBTOTAL			**50**	**2.50**	**125**	**0.83**	**0.15**	**0.10**	**1.08**	**0.36**	**0.16**	**0.08**	**0.05**	
70	*Clarodendron splendense*	Verbanaceae	NA	25	6.00	150	0.42	0.35	0.12	0.89	0.30	0.16	0.08	0.24	+
	SUBTOTAL			**25**	**6.00**	**150**	**0.42**	**0.35**	**0.12**	**0.89**	**0.30**	**0.16**	**0.08**	**0.24**	
71	*Ludwigia hysopifolia* (G.Don)Excell	Onagraceae	Water prime rose	75	6.00	450	1.25	0.35	0.36	1.96	0.65	0.12	0.06	0.08	+++
	SUBTOTAL			**75**	**6.00**	**450**	**1.25**	**0.35**	**0.36**	**1.96**	**0.65**	**0.12**	**0.06**	**0.08**	
72	*Scolporia dulcis* Linn.	Schrophulariaceae	Sweet broom weed	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
	SUBTOTAL			**25**	**10.00**	**250**	**0.42**	**0.59**	**0.20**	**1.21**	**0.40**	**0.16**	**0.08**	**0.40**	
73	*Phyllanthus muellerianus* (O.Ktze) Excell	Euphorbiaceae	NA	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
74	*Euphorbia prostrata* (Linn) L.	Euphorbiaceae	NA	100	17.50	1750	1.67	1.03	1.42	4.12	1.38	0.19	0.10	0.18	++++
75	*Euphorbia hysopifolia* Linn	Euphorbiaceae	Hyssop leaf sandmat	100	16.25	1625	1.67	0.96	1.32	3.95	1.32	0.16	0.08	0.16	++++
76	*Mallotus subulatus* Mull-Arg	Euphorbiaceae	Kamala plant	50	5.00	250	0.83	0.30	2.00	3.13	1.04	0.02	0.01	0.10	++
77	*Euphorbia heterophylla* Linn	Euphorbiaceae	Spurge weed	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
78	*Mallotus oppositifolius* (Geisel) Mull-Arg	Euphorbiaceae	Kamala plant	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
	SUBTOTAL			**425**	**63.75**	**5250**	**7.09**	**3.77**	**6.06**	**16.92**	**5.64**	**0.66**	**0.35**	**0.91**	
79	*Melochia melissifolia* Benth	Sterculiaceae	NA	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
80	*Waltheria indica* Linn	Sterculiaceae	Sleepy morning	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
81	*Melochia corchorifolia* Linn	Sterculiaceae	Chocolate weed	75	26.67	2000	1.25	1.58	1.62	4.45	1.48	0.25	0.13	0.36	+++
82	*Melochia pyramidata* Linn	Sterculiaceae	Beson plant	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
	SUBTOTAL			**250**	**67.17**	**5075**	**4.17**	**3.97**	**4.11**	**12.25**	**4.08**	**0.97**	**0.50**	**1.08**	
83	*Cissus aralioides* (Welw) Planch	Vitaceae	NA	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
	SUBTOTAL			**25**	**5.00**	**125**	**0.42**	**0.30**	**0.10**	**0.82**	**0.27**	**0.15**	**0.08**	**0.20**	
84	*Nelsonia canescens* (Lam) Spreng	Acanthaceae	Blue pussy leaf	100	15.00	1500	1.67	0.89	1.22	3.78	1.26	0.13	0.07	0.15	++++
	SUBTOTAL			**100**	**15.00**	**1500**	**1.67**	**0.89**	**1.22**	**3.78**	**1.26**	**0.13**	**0.07**	**0.15**	
85	*Hyptis lanceolata* Poir	Lamiaceae	NA	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
86	*Hyptis spicigeria* Lam	Lamiaceae	Black sesame	75	28.33	2125	1.25	1.67	1.72	4.64	1.55	0.30	0.15	0.38	+++
	SUBTOTAL			**150**	**40**	**3000**	**2.50**	**2.38**	**2.43**	**7.29**	**2.43**	**0.35**	**0.18**	**0.54**	
87	*Passiflora foetida* Linn	Passifloraceae	Stinging weed	50	39.00	1950	0.83	2.30	1.58	4.71	1.57	0.31	0.16	0.78	++
88	*Adenia cissampeloides* (Planch) Harms	Passifloraceae	NA	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
89	*Adenia lobata* (Jacq) Engl	Passifloraceae	NA	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
	SUBTOTAL			**175**	**54.83**	**2950**	**2.91**	**3.23**	**2.39**	**8.53**	**2.84**	**0.55**	**0.29**	**1.04**	
90	*Laportea ovalifolium* (Schum) Chew.	Urticaceae	Tropical stinging nettle	75	6.67	500	1.25	0.39	0.41	2.05	0.68	0.11	0.06	0.09	+++

S/N	SPECIES	Family	Common name	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
	SUBTOTAL			**75**	**6.67**	**500**	**1.25**	**0.39**	**0.41**	**2.05**	**0.68**	**0.11**	**0.06**	**0.09**	
91	*Cleom rotundosperma* DC	Cleomaceae	NA	75	10.00	750	1.25	0.59	0.61	2.45	0.82	0.07	0.04	0.13	+++
	SUBTOTAL			**75**	**10.00**	**750**	**1.25**	**0.59**	**0.61**	**2.45**	**0.82**	**0.07**	**0.04**	**0.13**	
92	*Achyranthes aspera* Linn	Amaranthaceae	Devil horse whip	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
93	*Celosia leptostachya* Benth	Amaranthaceae	NA	50	5.00	250	0.83	0.30	0.20	1.33	0.44	0.16	0.08	0.10	++
94	*Cyathula prostrata* (L.) Blume	Amaranthaceae	Cyathule	75	18.33	1375	1.25	1.08	1.11	3.44	1.15	0.07	0.04	0.24	+++
95	*Pupalia lappacea* (Linn) Juss	Amaranthaceae	NA	50	10.00	500	0.83	0.59	0.41	1.83	0.61	0.13	0.07	0.20	++
	SUBTOTAL			**275**	**58.33**	**4625**	**4.58**	**3.45**	**3.75**	**11.78**	**3.93**	**0.77**	**0.40**	**0.79**	
96	*Trianthema portulacastrum* L.	Aizoaceae	Purslane plant	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
	SUBTOTAL			**75**	**11.67**	**875**	**1.25**	**0.69**	**0.71**	**2.65**	**0.88**	**0.05**	**0.03**	**0.16**	
	TOTAL			**6000**	**1692.17**	**123375**	**100.1**	**99.93**	**101.76**	**301.79**	**99.93**	**25.55**	**13.05**	**29.98**	

Note: %F= Percentage frequency. D = Density (number of individual ha^{-1}). A = Abundance. %RF = Relative frequency. %RD = Relative density. %RA = Relative abundance. IVI = Importance Value Index. SdH'= Species diversity richness. SdE = Species diversity evenness. A/F = Ratio A: F distribution pattern *with the "thumb of rule" designated as follows: Regular (<0.03), random (0.03 – 0.05), and contiguous (>0.05) distribution.* ***+ (1-25) Very scarce, ++ (26-59) Scarce, +++ (60-79) Abundant, ++++> (100-α) Very abundant, NA- Not available***

Table 2. Phytosociological representative of habit based life form of hydrocarbon tolerant regenerating recruits; 8 years after post-remediation by enhanced natural attenuation (p - RENA) of hydrocarbon impacted soil in parts of rivers state, Niger Delta, Nigeria

S/N	SPECIES	Family	Life Form	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
1	*Paspalum conjugatum* Berg.	Poaceae	HG	75	16.67	1250	1.25	0.99	1.01	3.25	1.08	0.04	0.02	0.22	+++
2	*Ischaemum rogusum* Salisb	Poaceae	HG	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
3	*Chloris pilosa* Schumach.	Poaceae	HG	50	8.00	400	0.83	0.47	0.32	1.62	0.54	0.14	0.07	0.16	++
4	*Digitaria horizontalis* Willd.	Poaceae	HG	25	35.00	875	0.42	2.07	0.71	3.20	1.07	0.03	0.02	1.40	+
5	*Digitaria gayana* (Kunth) Stapf.	Poaceae	HG	25	30.00	750	0.42	1.77	0.61	2.80	0.93	0.03	0.02	1.20	+
6	*Brachiaria deflexa* (Schumach) CE. Hubbard *ex.* Robyns	Poaceae	HG	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
7	*Brachiaria lata* (Schumach) CE. Hubbard	Poaceae	HG	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
8	*Panicum maximum* Jacq.	Poaceae	HG	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
9	*Axonopus flexuosus* (Peter) Troupin	Poaceae	HG	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
10	*Andropogon repens* Steud	Poaceae	HG	100	20.00	2000	1.67	1.18	1.62	4.47	1.49	0.26	0.13	0.20	++++
11	*Cenchrus biflorus* Roxb	Poaceae	HG	50	50.00	2500	0.83	2.95	2.03	5.81	1.94	0.56	0.28	1.00	++
12	*Eragrostis ciliaris* (Linn) R.Br.	Poaceae	HG	100	62.50	6250	1.67	3.69	5.07	10.43	3.48	1.88	0.95	0.63	++++
13	*Eragrostis tenella* (Linn) P. Beauv ex. Roem	Poaceae	HG	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
14	*Andropogon tectorum* Schum & Thonn	Poaceae	HG	75	20.00	1500	1.25	1.18	1.22	3.65	1.22	0.11	0.06	0.27	+++
15	*Cyanodon dactylon* (Linn) Pers	Poaceae	HG	100	62.50	6250	1.67	3.69	5.07	10.43	3.48	1.88	0.95	0.63	++++
16	*Schizachyrum brevifolium* (SW) Nees	Poaceae	HG	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
17	*Cynodon nlemfuensis* Vandergst	Poaceae	HG	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
18	*Sorghum arundinaceum* (Desv) Stapf	Poaceae	HG	75	18.33	1375	1.25	1.08	1.11	3.44	1.15	0.07	0.04	0.24	+++
19	*Setaria megaphylla* (Steud) Dur & Schinz	Poaceae	HG	100	8.75	875	1.67	0.52	0.71	2.90	0.97	0.01	0.01	0.09	++++
20	*Setaria barbata* (Lam) Kunth	Poaceae	HG	100	3.75	375	1.67	0.22	0.30	2.19	0.73	0.10	0.05	0.04	++++
21	*Perotis indica* (Linn) O.Ktze	Poaceae	HG	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
22	*Setaria pumila* (Poir) Roem & Schult	Poaceae	HG	75	15.00	1125	1.25	0.89	0.91	3.05	1.02	0.01	0.01	0.20	+++
23	*Brachiaria falciflera* (Trin) Stapf	Poaceae	HG	75	5.00	375	1.25	0.30	0.30	1.85	0.62	0.13	0.07	0.07	+++
24	*Acroceras zizanioides* (Kunth) Dandy	Poaceae	HG	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
	SUBTOTAL			**1675**	**621**	**49,600**	**27.96**	**36.67**	**40.18**	**104.81**	**34.95**	**11.75**	**5.96**	**10.07**	

S/N	SPECIES	Family	Life Form	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
25	*Mariscus flabelisformis* Kunth	Cyperaceae	HS	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
26	*Cyperus esculentus* Linn.	Cyperaceae	HS	100	22.50	2250	1.67	1.33	1.82	4.82	1.61	0.33	0.17	0.23	++++
27	*Fimbrystalis littorali* Guadich	Cyperaceae	HS	75	32.67	2450	1.25	1.93	1.99	5.17	1.72	0.41	0.21	0.44	+++
28	*Cyperus haspan* Linn.	Cyperaceae	HS	100	17.50	1750	1.67	1.03	1.41	4.11	1.37	0.19	0.10	0.18	++++
29	*Cyperus rotundus*Linn.	Cyperaceae	HS	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
30	*Mariscus longibrecteatus* Cherm.	Cyperaceae	HS	25	18.00	450	0.42	1.06	0.36	1.84	0.61	0.13	0.07	0.72	+
31	*Kyllinga erecta* Schumach	Cyperaceae	HS	25	30.00	750	0.42	1.77	0.61	2.80	0.93	0.03	0.02	1.20	+
32	*Mariscus alternifolius* Vahl	Cyperaceae	HS	25	15.00	375	0.42	0.89	0.30	1.61	0.54	0.14	0.07	0.60	+
33	*Cyperus iria* Linn	Cyperaceae	HS	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
	SUBTOTAL			**500**	**220.67**	**14.775**	**9.18**	**13.02**	**11.96**	**34.16**	**11.39**	**2.68**	**1.37**	**4.57**	
34	*Mimosa invisa* Mart.	Fabaceae	HH	50	5.50	275	0.83	0.33	0.22	1.38	0.46	0.16	0.08	0.11	++
35	*Zonia latifolia* SM	Fabaceae	HH	100	23.75	2375	1.67	1.40	1.93	5.00	1.67	0.37	0.19	0.24	++++
36	*Shrankia leptocarpa* DC	Fabaceae	HH	100	50.00	5000	1.67	2.95	4.05	8.67	2.89	1.33	0.67	0.50	++++
37	*Desmodium triflorum* (Linn) DC	Fabaceae	HH	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
38	*Cynotis lanata* Benth.	Commelinaceae	HH	50	22.50	1125	0.83	1.33	0.91	3.07	1.02	0.01	0.01	0.45	++
39	*Aneilema benninense* (P.Beauv) kunth.	Commelinaceae	HH	25	7.00	175	0.42	0.41	0.14	0.97	0.32	0.16	0.08	0.28	+
40	*Commelina benghalensis* Linn	Commelinaceae	HH	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
41	*Chromolaena odorata* (Linn)RM. King & Robinson	Asteraceae	HH	100	6.00	600	1.67	0.35	0.49	2.51	0.84	0.06	0.03	0.06	++++
42	*Vernonia cineria* (Linn) Less	Asteraceae	HH	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
43	*Eclipta alba* (Linn.) Hassk	Asteraceae	HH	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
44	*Tridax procumbense* Linn	Asteraceae	HH	100	40.00	4000	1.67	2.36	3.24	7.27	2.42	0.93	0.47	0.40	++++
45	*Acanthospermum hispidum* DC	Asteraceae	HH	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
46	*Spermacocci ocymoides* Burm F.	Rubiaceae	HH	25	15.00	375	0.42	0.89	0.30	1.61	0.54	0.14	0.07	0.60	+
47	*Oldenlendia affinis* Roem & Schult	Rubiaceae	HH	25	17.00	425	0.42	1.00	0.34	1.76	0.59	0.14	0.07	0.68	+
48	*Oldenlendia corymbosa* Linn.	Rubiaceae	HH	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
49	*Spermacoce verticillata* Linn.	Rubiaceae	HH	75	26.67	2000	1.25	1.58	1.62	4.45	1.48	0.25	0.13	0.36	+++
50	*Ludwigia hysopifolia* (G.Don)Excell	Onagraceae	HH	75	6.00	450	1.25	0.35	0.36	1.96	0.65	0.12	0.06	0.08	+++
51	*Euphorbia prostrata* (Linn) Linn	Euphorbiaceae	HH	100	17.50	1750	1.67	1.03	1.42	4.12	1.38	0.19	0.10	0.18	++++
52	*Euphorbia hysopifolia* Linn	Euphorbiaceae	HH	100	16.25	1625	1.67	0.96	1.32	3.95	1.32	0.16	0.08	0.16	++++
53	*Euphorbia heterophylla* Linn	Euphorbiaceae	HH	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
54	*Melochia melissifolia* Benth	Sterculiaceae	HH	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
55	*Melochia corchorifolia* Linn	Sterculiaceae	HH	75	26.67	2000	1.25	1.58	1.62	4.45	1.48	0.25	0.13	0.36	+++
56	*Melochia pyramidata* Linn	Sterculiaceae	HH	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
57	*Nelsonia canescens* (Lam) Spreng	Acanthaceae	HH	100	15.00	1500	1.67	0.89	1.22	3.78	1.26	0.13	0.07	0.15	++++
58	*Hyptis lanceolata* Poir	Lamiaceae	HH	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
59	*Hyptis spicigeria* Lam	Lamiaceae	HH	75	28.33	2125	1.25	1.67	1.72	4.64	1.55	0.30	0.15	0.38	+++
60	*Laportea ovalifolium* (Schum) Chew.	Urticaceae	HH	75	6.67	500	1.25	0.39	0.41	2.05	0.68	0.11	0.06	0.09	+++
61	*Cleom rotundosperma* DC	Cleomaceae	HH	75	10.00	750	1.25	0.59	0.61	2.45	0.82	0.07	0.04	0.13	+++
62	*Achyranthes aspera* Linn	Amaranthaceae	HH	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++
63	*Celosia leptostachya* Benth	Amaranthaceae	HH	50	5.00	250	0.83	0.30	0.20	1.33	0.44	0.16	0.08	0.10	++
64	*Cyathula prostrata* (Linn) Blume	Amaranthaceae	HH	75	18.33	1375	1.25	1.08	1.11	3.44	1.15	0.07	0.04	0.24	+++
65	*Pupalia lappacea* (Linn) Juss	Amaranthaceae	HH	50	10.00	500	0.83	0.59	0.41	1.83	0.61	0.13	0.07	0.20	++
66	*Trianthema portulacastrum* Linn	Aizoaceae	HH	75	11.67	875	1.25	0.69	0.71	2.65	0.88	0.05	0.03	0.16	+++
	SUBTOTAL			**2200**	**523.51**	**39,600**	**36.70**	**30.91**	**32.10**	**99.71**	**33.24**	**7.09**	**3.64**	**8.52**	
67	*Pueraria phaseloides* (Roxb) Benth	Fabaceae	HCl	75	22.67	1700	1.25	1.34	1.38	3.97	1.32	0.16	0.08	0.30	+++
68	*Centrosema pubescence* Benth	Fabaceae	HCl	25	7.00	175	0.42	0.41	0.14	0.97	0.32	0.16	0.08	0.28	+
69	*Calopogomium mucunoides* Desv	Fabaceae	HCl	100	25.00	2500	1.67	1.48	2.03	5.18	1.73	0.41	0.21	0.25	++++

S/N	SPECIES	Family	Life Form	%F	A	D	%RF	%RA	%RD	IVI	RIVI	SdH'	SdE	A/F	Remark
70	*Ipomea involucrata* P.Beauv.	Convolvulaceae	HCl	75	7.33	550	1.25	0.43	0.45	2.13	0.71	0.11	0.06	0.10	+++
71	*Ipomoea asarifolia* (Desv) Roem & Schult	Convolvulaceae	HCl	75	6.67	500	1.25	0.39	0.41	2.05	0.03	0.05	0.03	0.09	+++
72	*Hibiscus suratensis* Linn	Malvaceae	HCl	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
73	*Pentodon pentandrus* (Schum & Thonn) Vatke	Rubiaceae	HCl	25	8.00	200	0.42	0.47	0.16	1.05	0.35	0.16	0.08	0.32	+
74	*Diodia sermentosa* Sw.	Rubiaceae	HCl	100	18.75	1875	1.67	1.11	1.52	4.30	1.43	0.22	0.11	0.19	++++
75	*Cissus aralioides* (Welw) Planch	Vitaceae	HCl	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
76	*Passiflora foetida* Linn	Passifloraceae	HCl	50	39.00	1950	0.83	2.30	1.58	4.71	1.57	0.31	0.16	0.78	++
77	*Adenia cissampeloides* (Planch) Harms	Passifloraceae	HCl	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
78	*Adenia lobata* (Jacq) Engl	Passifloraceae	HCl	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
	SUBTOTAL			**700**	**158.25**	**10,650**	**11.68**	**9.34**	**8.64**	**29.66**	**9.22**	**2.11**	**1.09**	**2.89**	
79	*Milletia arboensis* (Hook F.) Bak.	Fabaceae	Sh	25	3.00	75	0.42	0.18	0.06	0.66	0.22	0.14	0.07	0.12	+
80	*Chamaecrista mimosoides* (Linn) Greene	Fabaceae	Sh	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
81	*Aeschynomene indica* Linn	Fabaceae	Sh	50	17.50	875	0.83	1.03	0.71	2.57	0.86	0.06	0.03	0.35	++
82	*Desmodium tortusum* (SW) DC	Fabaceae	Sh	75	13.33	1000	1.25	0.79	0.81	2.85	0.95	0.02	0.01	0.18	+++
83	*Crotolaria retusa* Linn	Fabaceae	Sh	50	15.00	750	0.83	0.89	0.61	2.33	0.78	0.08	0.04	0.30	++
84	*Albizia zygia* (DC) JF Macbride	Fabaceae	Sh	50	12.50	625	0.83	0.74	0.51	2.08	0.69	0.11	0.06	0.25	++
85	*Sida cordifolia* Linn.	Malvaceae	Sh	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
86	*Urena lobata* Linn	Malvaceae	Sh	25	16.00	400	0.42	0.95	0.32	1.69	0.56	0.14	0.07	0.64	+
87	*Triumfetta eriophlebia* Hook. F.	Tiliaceae	Sh	50	5.00	250	0.83	0.30	0.20	1.33	0.44	0.16	0.08	0.10	++
88	*Triumfetta cordifolia* A. Rich	Tiliaceae	Sh	75	13.33	1000	1.25	0.79	0.81	2.85	0.95	0.02	0.01	0.18	+++
89	*Triumfetta rhomboidea* Jacq	Tiliaceae	Sh	100	11.25	1125	1.67	0.66	0.91	3.24	1.08	0.04	0.02	0.11	++++
90	*Scolporia dulcis* Linn.	Schrophulariaceae	Sh	25	10.00	250	0.42	0.59	0.20	1.21	0.40	0.16	0.08	0.40	+
91	*Mallotus subulatus* Mull-Arg	Euphorbiaceae	Sh	50	5.00	250	0.83	0.30	2.00	3.13	1.04	0.02	0.01	0.10	++
92	*Mallotus oppositifolius* (Geisel) Mull-Arg	Euphorbiaceae	Sh	75	8.33	625	1.25	0.49	0.51	2.25	0.75	0.09	0.05	0.11	+++
93	*Waltheria indica* Linn	Sterculiaceae	Sh	50	7.50	375	0.83	0.44	0.30	1.57	0.52	0.15	0.08	0.15	++
	SUBTOTAL			**775**	**155.24**	**8350**	**12.91**	**9.19**	**8.56**	**30.66**	**10.20**	**1.45**	**0.75**	**3.44**	
94	*Elaeis guineensis* Jacq.	Arecaceae	T	50	2.50	125	0.83	0.15	0.10	1.08	0.36	0.16	0.08	0.05	++
	SUBTOTAL			**50**	**2.50**	**125**	**0.83**	**0.15**	**0.10**	**1.08**	**0.36**	**0.16**	**0.08**	**0.05**	
95	*Clarodendron splendense*	Verbanaceae	ShCl	25	6.00	150	0.42	0.35	0.12	0.89	0.30	0.16	0.08	0.24	+
96	*Phyllanthus muellerianus* (O.Ktze) Excell	Euphorbiaceae	ShCl	25	5.00	125	0.42	0.30	0.10	0.82	0.27	0.15	0.08	0.20	+
	SUBTOTAL			**50**	**11.00**	**275**	**0.84**	**0.65**	**0.22**	**1.71**	**0.57**	**0.31**	**0.16**	**0.44**	
	TOTAL			**6000**	**1692.17**	**123375**	**100.1**	**99.93**	**101.76**	**301.79**	**99.93**	**25.55**	**13.05**	**29.98**	

Note: %F= Percentage frequency. D = Density (number of individual ha^{-1}). A = Abundance. %RF = Relative frequency. %RD = Relative density. %RA = Relative abundance. IVI = Importance Value Index. SdH'= Species diversity richness. SdE = Species diversity evenness. A/F = Ratio A: F distribution pattern with the "*thumb of rule*" designated as follows: *Regular (<0.03), random (0.03 – 0.05),* and *contiguous (>0.05)* distribution. **+ (1-25) Very scarce, ++ (26-59) Scarce, +++ (60-79) Abundant, ++++> (100-α) Very abundant, NA- Not available**

Life Form Note: HG = Herbaceous grass. HS = Herbaceous sedge. HH = Herbaceous herb. HCl = Herbaceous climber. SH = Shrubby herb. T = Tree. ShCl = Shrubby climber.

Table 3. Qualitative representative of recruit life form (based on environmental adaptation), mode of regeneration and demographic regeneration status of hydrocarbon tolerant species; 8 years after post-remediation by enhanced natural attenuation (p - RENA) of hydrocarbon impacted soil in parts of rivers state, Niger Delta, Nigeria

S/N	SPECIES	Family	Life Form	Mode of Regeneration	Density ha^{-1}	Regeneration status
1	*Paspalum conjugatum* Berg.	Poaceae	HG– Hemi-cryptophytes	S / C / R	1250	Seedling
2	*Ischaemum rogusum* Salisb	Poaceae	HG - Chamaephytes	C / S / R	250	Seedling
3	*Chloris pilosa* Schumach.	Poaceae	HG– Hemi-cryptophytes	S / ST	400	Seedling
4	*Digitaria horizontalis* Willd.	Poaceae	HG– Hemi-cryptophytes	S / C	875	Seedling
5	*Digitaria gayana* (Kunth) Stapf.	Poaceae	HG– Hemi-cryptophytes	S / C	750	Seedling
6	*Brachiaria deflexa* (Schumach) CE. Hubbard *ex.* Robyns	Poaceae	HG- Chamaephytes	S	250	Seedling
7	*Brachiaria lata* (Schumach) CE. Hubbard	Poaceae	HG- Chamaephytes	S	75	Seedling
8	*Panicum maximum* Jacq.	Poaceae	HG- Chamaephytes	S / R / C	250	Seedling
9	*Axonopus flexuosus* (Peter) Troupin	Poaceae	HG– Hemi-cryptophytes	S / ST / C	5000	Seedling
10	*Andropogon repens* Steud	Poaceae	HG – Hemi-cryptophytes	S / R / C	2000	Seedling
11	*Cenchrus biflorus* Roxb	Poaceae	HG- Chamaephytes	S	2500	Seedling
12	*Eragrostis ciliaris* (Linn) R.Br.	Poaceae	HG- Chamaephytes	S	6250	Seedling
13	*Eragrostis tenella* (Linn) P. Beauv ex. Roem	Poaceae	HG- Chamaephytes	S	2500	Seedling
14	*Andropogon tectorum* Schum & Thonn	Poaceae	HG- Chamaephytes	S / R / C	1500	Seedling
15	*Cyanodon dactylon* (Linn) Pers	Poaceae	HG– Hemi-cryptophytes	S / R / ST	6250	Seedling
16	*Schizachyrum brevifolium* (SW) Nees	Poaceae	HG– Hemi-cryptophytes	S / R / ST	5000	Seedling
17	*Cynodon nlemfuensis* Vandergst	Poaceae	HG– Hemi-cryptophytes	S / R / ST	5000	Seedling
18	*Sorghum arundinaceum* (Desv) Stapf	Poaceae	HG- Chamaephytes	S	1375	Sapling
19	*Setaria megaphylla* (Steud) Dur & Schinz	Poaceae	HG- Chamaephytes	S / C	875	Seedling
20	*Setaria barbata* (Lam) Kunth	Poaceae	HG- Chamaephytes	S / C	375	Seedling
21	*Perotis indica* (Linn) O.Ktze	Poaceae	HG- Chamaephytes	S / C	5000	Seedling
22	*Setaria pumila* (Poir) Roem & Schult	Poaceae	HG- Chamaephytes	S / C	1125	Seedling
23	*Brachiaria falciflera* (Trin) Stapf	Poaceae	HG- Chamaephytes	S	375	Seedling
24	*Acroceras zizanioides* (Kunth) Dandy	Poaceae	HG- Chamaephytes	S / C	375	Seedling
	SUBTOTAL				**49,600.00**	
25	*Mariscus flabelisformis* Kunth	Cyperaceae	HS- Chamaephytes	R / S	875	Seedling
26	*Cyperus esculentus* Linn.	Cyperaceae	HS- Chamaephytes	C / S	2250	Seedling
27	*Fimbrystalis littoralis* Guadich	Cyperaceae	HS– Hemi-cryptophytes	S	2450	Seedling
28	*Cyperus haspan* Linn.	Cyperaceae	HS- Chamaephytes	R / S	1750	Seedling
29	*Cyperus rotundus*Linn.	Cyperaceae	HS- Chamaephytes	S / R / T	875	Seedling
30	*Mariscus longibrecteatus* Cherm.	Cyperaceae	HS- Chamaephytes	S	450	Seedling
31	*Kyllinga erecta* Schumach	Cyperaceae	HS- Chamaephytes	R / S	750	Seedling
32	*Mariscus alternifolius* Vahl	Cyperaceae	HS- Chamaephytes	R / S	375	Seedling
33	*Cyperus iria* Linn	Cyperaceae	HS- Chamaephytes	S	5000	Seedling
	SUBTOTAL				**14,775.00**	
34	*Mimosa invisa* Mart.	Fabaceae	HH– Hemi-cryptophytes	S	275	Seedling
35	*Zonia latifolia* SM	Fabaceae	HH- Chamaephytes	S	2375	Seedling
36	*Schrankia leptocarpa* DC	Fabaceae	HH- Chamaephytes	S	5000	Seedling
37	*Desmodium triflorum* (Linn) DC	Fabaceae	HH– Hemi-cryptophytes	S	875	Seedling
38	*Cynotis lanata* Benth.	Commelinaceae	HH– Hemi-cryptophytes	C / S / ST	1125	Seedling
39	*Aneilema beniniense* (P.Beauv) kunth.	Commelinaceae	HH– Hemi-cryptophytes	S / C /ST	175	Seedling
40	*Commelina benghalensis* Linn	Commelinaceae	HH– Hemi-cryptophytes	C / S / ST	200	Seedling

S/N	SPECIES	Family	Life Form	Mode of Regeneration	Density ha^{-1}	Regeneration status
41	*Chromolaena odorata* (Linn)RM. King & Robinson	Asteraceae	HH- Chamaephytes	S / C / R	600	Seedling
42	*Vernonia cineria* (Linn) Less	Asteraceae	HH- Chamaephytes	S	200	Seedling
43	*Eclipta alba* (Linn.) Hassk	Asteraceae	HH- Chamaephytes	S	75	Seedling
44	*Tridax procumbense* Linn	Asteraceae	HH– Hemi-cryptophytes	S	4000	Seedling
45	*Acanthospermum hispidum* DC	Asteraceae	HH- Chamaephytes	S	625	Seedling
46	*Spermacoce ocymoides* Burm F.	Rubiaceae	HH– Hemi-cryptophytes	S / C	375	Seedling
47	*Oldenlendia affinis* Roem & Schult	Rubiaceae	HH– Hemi-cryptophytes	S	425	Seedling
48	*Oldenlendia corymbosa* Linn.	Rubiaceae	HH– Hemi-cryptophytes	S	625	Seedling
49	*Spermacoce verticillata* Linn.	Rubiaceae	HH- Chamaephytes	S	2000	Seedling
50	*Ludwigia hysopifolia* (G.Don)Excell	Onagraceae	HH- Chamaephytes	S	450	Sapling
51	*Euphorbia prostrata* (Linn) Linn	Euphorbiaceae	HH– Hemi-cryptophytes	S	1750	Seedling
52	*Euphorbia hysopifolia* Linn	Euphorbiaceae	HH- Chamaephytes	S	1625	Seedling
53	*Euphorbia heterophylla* Linn	Euphorbiaceae	HH- Chamaephytes	S	875	Seedling
54	*Melochia melissifolia* Benth	Sterculiaceae	HH– Hemi-cryptophytes	S / C	200	Seedling
55	*Melochia corchorifolia* Linn	Sterculiaceae	HH- Chamaephytes	S / C	2000	Seedling
56	*Melochia pyramidata* Linn	Sterculiaceae	HH- Chamaephytes	S / C	2500	Seedling
57	*Nelsonia canescens* (Lam) Spreng	Acanthaceae	HH– Hemi-cryptophytes	C / S	1500	Seedling
58	*Hyptis lanceolata* Poir	Lamiaceae	HH- Chamaephytes	S	875	Seedling
59	*Hyptis spicigeria* Lam	Lamiaceae	HH- Chamaephytes	S	2125	Seedling
60	*Laportea ovalifolium* (Schum) Chew.	Urticaceae	HH– Hemi-cryptophytes	S / C	500	Seedling
61	*Cleom rotundosperma* DC	Cleomaceae	HH– Hemi-cryptophytes	S	750	Seedling
62	*Achyranthes aspera* Linn	Amaranthaceae	HH- Chamaephytes	S	2500	Seedling
63	*Celosia leptostachya* Benth	Amaranthaceae	HH- Chamaephytes	S	250	Seedling
64	*Cyathula prostrata* (Linn) Blume	Amaranthaceae	HH- Chamaephytes	S	1375	Seedling
65	*Pupalia lappacea* (Linn) Juss	Amaranthaceae	HH- Chamaephytes	S	500	Seedling
66	*Trianthema portulacastrum* Linn	Aizoaceae	HH– Hemi-cryptophytes	S / C	875	Seedling
	SUBTOTAL				**39,600.00**	
67	*Pueraria phaseloides* (Roxb) Benth	Fabaceae	HCl– Hemi-cryptophytes	S	1700	Seedling
68	*Centrosema pubescence* Benth	Fabaceae	HCl– Hemi-cryptophytes	S	175	Seedling
69	*Calopogomium mucunoides* Desv	Fabaceae	HCl– Hemi-cryptophytes	S	2500	Seedling
70	*Ipomea involucrata* P.Beauv.	Convolvulaceae	HCl– Hemi-cryptophytes	S / C	550	Seedling
71	*Ipomoea asarifolia* (Desv) Roem & Schult	Convolvulaceae	HCl– Hemi-cryptophytes	S / C	500	Seedling
72	*Hibiscus suratensis* Linn	Malvaceae	HCl– Hemi-cryptophytes	S / C	75	Seedling
73	*Pentodon pentandrus* (Schum & Thonn) Vatke	Rubiaceae	HCl- Chamaephytes	S	200	Seedling
74	*Diodia sermentosa* Sw.	Rubiaceae	HCl– Hemi-cryptophytes	S	1875	Seedling
75	*Cissus aralioides* (Welw) Planch	Vitaceae	HCl– Hemi-cryptophytes	S / C	125	Seedling
76	*Passiflora foetida* Linn	Passifloraceae	HCl– Hemi-cryptophytes	S	1950	Seedling
77	*Adenia cissampeloides* (Planch) Harms	Passifloraceae	HCl– Hemi-cryptophytes	S / C	375	Seedling
78	*Adenia lobata* (Jacq) Engl	Passifloraceae	HCl– Hemi-cryptophytes	S / C	625	Seedling
	SUBTOTAL				**10,650.00**	
79	*Milletia arboensis* (Hook F.) Bak.	Fabaceae	Sh- Mesophanerophytes	C / S	75	Sapling
80	*Chamaecrista mimosoides* (Linn) Greene	Fabaceae	Sh- Microphanerophytes	S	625	Sapling
81	*Aeschynomene indica* Linn	Fabaceae	Sh- Nanophanerophytes	S	875	Seedling
82	*Desmodium tortusum* (SW) DC	Fabaceae	Sh- Nanophanerophytes	S	1000	Seedling
83	*Crotolaria retusa* Linn	Fabaceae	Sh- Nanophanerophytes	S	750	Sapling
84	*Albizia zygia* (DC) JF Macbride	Fabaceae	Sh- Mesophanerophytes	S	625	Seedling
85	*Sida cordifolia* Linn.	Malvaceae	Sh- Nanophanerophytes	S	125	Seedling

S/N	SPECIES	Family	Life Form	Mode of Regeneration	Density ha^{-1}	Regeneration status
86	*Urena lobata* Linn	Malvaceae	Sh- Microphanerophytes	S	400	Sapling
87	*Triumfetta eriophlebia* Hook. F.	Tiliaceae	Sh- Microphanerophytes	S	250	Sapling
88	*Triumfetta cordifolia* A. Rich	Tiliaceae	Sh- Microphanerophytes	S	1000	Sapling
89	*Triumfetta rhomboidea* Jacq	Tiliaceae	Sh- Microphanerophytes	S	1125	Sapling
90	*Scolporia dulcis* Linn.	Schrophulariaceae	Sh- Nanophanerophytes	S	250	Sapling
91	*Mallotus subulatus* Mull-Arg	Euphorbiaceae	Sh- Microphanerophytes	S / C	250	Sapling
92	*Mallotus oppositifolius* (Geisel) Mull-Arg	Euphorbiaceae	Sh- Microphanerophytes	S / C	625	Sapling
93	*Waltheria indica* Linn	Sterculiaceae	Sh- Microphanerophytes	S	375	Sapling
	SUBTOTAL				**8350.00**	
94	*Elaeis guineensis* Jacq.	Arecaceae	T- Megaphanerophytes	S	125	Sapling
	SUBTOTAL				**125.00**	
95	*Clarodendron splendense*	Verbanaceae	ShCl– Hemi-cryptophytes	S / C	150	Sapling
96	*Phyllanthus muellerianus* (O.Ktze) Excell	Euphorbiaceae	ShCl– Hemi-cryptophytes	S	125	Seedling
	SUBTOTAL				**275.00**	
	TOTAL				**123375**	

Note: %F= Percentage frequency. D = Density (number of individual ha^{-1}). A = Abundance. %RF = Relative frequency. %RD = Relative density. %RA = Relative abundance. IVI = Importance Value Index. SdH'= Species diversity richness. SdE = Species diversity evenness. A/F = Ratio A: F distribution pattern with the "*thumb of rule*" designated as follows: *Regular (<0.03), random (0.03 – 0.05),* and *contiguous (>0.05)* distribution. **+ (1-25) Very scarce, ++ (26-59) Scarce, +++ (60-79) Abundant, ++++> (100-α) Very abundant, NA- Not available**

Life Form Note: HG = Herbaceous grass. HS = Herbaceous sedge. HH = Herbaceous herb. HCl = Herbaceous climber. SH = Shrubby herb. T = Tree. ShCl = Shrubby climber.

Regeneration Note: S = Seedling. SA = Sapling. R = Rhizome. C = Coppicing. T = Tuber. ST = Stolon.

Table 4. Degree and percentage mode of regeneration of recruits

No of individual of life form recruits	Degree of mode of regeneration	% Composition	Remark
Herbaceous Grass (HG)			
5	Seed / Coppice / Rhizome	20.83	Multiplier
1	Seed / Stolon	4.17	Multiplier
7	Seed / Coppice	29.17	Multiplier
7	Seed	29.17	Single
1	Seed / Stolon / Coppice	4.17	Multiplier
3	Seed / Rhizome / Stolon	12.50	Multiplier
Herbaceous Sedge (HS)			
4	Rhizome / Seed	44.44	Multiplier
1	Coppice / Seed	11.11	Multiplier
3	Seed	33.33	Single
1	Seed / Rhizome / Tuber	11.11	Multiplier
Herbaceous Herb (HH)			
22	Seed	66.67	Single
3	Coppice / Seed / Stolon	9.09	Multiplier
7	Seed / Coppice	21.21	Multiplier
1	Seed / Coppice / Rhizome	3.03	Multiplier
Herbaceous Climber (HCl)			
6	Seed	50.00	Single
6	Seed / Coppice	50.00	Multiplier
Shrub (Sh)			
3	Coppice / Seed	20.00	Multiplier
12	Seed	80.00	Single
	Shrubby Climber (ShCl)		
1	Seed / Coppice	50.00	Multiplier
	Seed	50.00	Single

ii. Phytosociology of habit based recruits.

The habit based regenerating recruit recorded variation in the phytosociological indices in their relative percentages of the representative species as: the herbaceous (78), shrubby (15), tree (1) and shrub climber (2) among the regenerating recruits (Table 2). The herbaceous grass (HG) recruits had 10 species with the highest frequency (100%) of occurrence and six individual recruits with least frequency (25%) class. The herbaceous sedge (HS) recorded three species (*C. esculentus, C. haspan,* and *C. iria*) of highest (100%) frequency class and three species (*M. longibrecteatus, K. erecta* and *M. alternifolius*) of least (25%) frequency.. The herbaceous herb (HH) recorded 9 species with highest frequency (100%) of occurrence and seven species of least (25%) frequency while the herbaceous climbers (HCl) of highest frequency (100%) for two recruits (C. *mucunoides* and *D. sermentosa*) and four recruits of least (25%) frequency occurrence were recorded. Generally in all bounding coordinates the frequency of herbaceous recruits has recorded a varying trend of occurrence in the order of *HH > HG > HCl > HS* by percentage ratio of 43.35: 30.01: 13.79: 9.85 respectively. The shrubby habit (Sh) had one species (*T. rhomboidea*) with highest frequency (100%) and four recruits with least frequency (25%) of occurrence while the shrubby climbers (ShCl) had two recruits (*C. splendense* and *P. muellerianus*) with least frequency (25%) of occurrence respectively and a varying order of *Sh > ShCl* by ratio of 93.94: 6.06. A tree habit (*E. guineensis*) of 50% frequency of occurrence was recorded. On the whole the herbaceous recruits recorded a greater frequency (5,075), than shrubby recruit (775), and shrubby climber and tree recruit (50) respectively.

Two recruits (*E. ciliaris* and *C. dactylon*) recorded highest abundance (62.50 = 3.69%) and *B. lata* least abundance (3.00 = 0.18%) among the HG habit. *Cyperus iria* with highest abundance (50 = 2.95%) and *M. alternifolius* least abundance (15 = 0.89%) among HS recruits was recorded. The HH recruits recorded highest abundance (50 = 2.95%) with *S. leptocarpa* and least abundance (3 = 0.18%) with *Eclipta alba*. The HCl recruit showed highest abundance (39 = 2.30%) with *P. foetida* and least abundance (3.00 = 0.18%) with *Hibiscus suratensis*. Generally, the herbaceous recruits have recorded variation in abundance in the order *HG>HH>HS>HCl* by ratio of 40.76: 34.36: 14.49: 10.39. A shrubby recruit (*A. indica*) with highest abundance (17.50 = 1.03 %), *M. arboensis* least abundance (3.00 = 0.18 %) with shrubby climber (*C. splendense*) of highest abundance (6 = 0.35%) and *P. muellerianus* with least abundance (5 = 0.30%) were respectively noted with a varying order of *Sh > ShCl* by ratio of 93.38: 6.62. A tree habit (*E. guineensis*) of 2.50 abundance was recorded. An overall abundance (1523.43) of herbaceous, shrubby (155.24), tree (2.50) and shrubby climber (11) recruits were recorded.

The highest density (6,250ha^{-1} = 5.07%) of two regenerating recruits (*E. ciliaris* and *C. dactylon*) and *B. lata* of least density (75ha^{-1} = 0.06%) among herbaceous grass (HG) was recorded. *Cyperus iria* with high density (5000ha^{-1} = 4.05%) and *M. alternifolius* with least density (375ha^{-1} = 0.30%) among HS habit, while *S. leptocarpa* with high density (5000ha^{-1} = 4.05%) and *Eclipta alba* with least density (75ha^{-1} = 0.06%) were noted among HH recruits. Herbaceous climber (HCl) of highest density (2500ha^{-1} = 2.03%) and least density (75ha^{-1} = 0.06%) was recorded by *Calopogonium mucunoides* and *Hibiscus suratensis* recruits respectively. Generally, the herbaceous recruits showed variation in the density ha^{-1} of individuals in the orders of *HG> HH>HS>HCl* by percentage density ratio of 43.27: 34.55: 12.89: 9.29. *Triumfetta rhomboidea* was noted for highest density (1125ha^{-1} = 0.91%) with *M. arboensis* recording least density (75ha^{-1} = 0.06%) among the shrubby recruits, while shrubby climber (*C. splendense*) of highest density (150ha^{-1} = 0.12%) and *P. muellerianus* of least abundance (125ha^{-1} = 0.10%) were recorded with a varying order of *Sh > ShCl* by ratio of 96.81: 3.19. A tree habit (*E. guineensis*) of 125 density ha^{-1} was recorded. On the whole an herbaceous recruit density of 114,625ha^{-1} and shrubby recruit (8,625ha^{-1}) was recorded.

The importance value index (IVI) recorded the following across the species habit. *E. ciliaris* and *C. dactylon* highest IVI (10.43%) and least IVI (1.21%) in three recruits (*I. rogosum*, *B. deflexa* and *P. maximum*) members of HG; HS highest IVI (5.17%) in *F. littoralis* and least IVI (1.61%) in *M. alternifolius* respectively; the HH recruits highest IVI (8.67%) in *S. leptocarpa* and least (1.05%) in *C. benghalensis, V. cineria and M. melissifolia*; HCl highest (5.18%) IVI in *C. mucuniodes* and least (0.66%) in *Hibiscus suratensis*. Generally an herbaceous IVI order of *HG> HH>HS> HCl* by relative percentage ratio of 39.06: 37.16: 12.73: 11.05 was recorded. The shrubby recruits recorded a highest IVI (2.85%) in *D. tortusum, T. cordifolia* and least (0.66%) in

M. arboensis, while shrubby climber (*C. splendense*) in highest IVI (0.89%) and *P. muellerianus* with least abundance (0.82%) were recorded with a varying order of *Sh* > *ShCl* by ratio of 94.72:5.28. A tree habit (*E. guineensis*) with 1.08% IVI was recorded. On the whole an herbaceous recruit IVI of 268.34 and shrubby recruit IVI (32.37%) was recorded.

The Shannon-Weinner species diversity richness and evenness noted *E. ciliaris* and *C. dactylon* for highest richness (1.88); evenness (0.95) and least richness (0.01); evenness (0.01) for *S. megaphylla* and *S. pumila* respectively among HG recruits. *Cyperus iria* with highest richness (1.33); evenness (0.67) and least richness (0.03); evenness (0.02) for *K. erecta* were recorded among HS. The HH recruits with highest richness (1.33); evenness (0.67) for *S. leptocarpa* and least richness (0.01); evenness (0.01) for *C. lanata* were recorded. The HCl recruit with highest richness (0.41); evenness (0.21) was in *C. mucunoides* and least richness (0.05); evenness (0.03) with *I. asarifolia*. The general trend of herbaceous richness and evenness was in the order *HG> HH>HS> HCl* by percentage ratio (49.73:30.00:11.34:8.93) and evenness ratio of 49.42:30.18:11.36:9.04 respectively. The shrubby recruit recorded highest richness (0.16) and evenness (0.08) in *T. eriophlebia* and *S.dulcis*; least richness (0.02) and evenness (0.01) in *T. cordifolia*, *M. subulalus* while shrubby climber (*C. splendense*) in highest richness (0.16); evenness (0.08) and *P. muellerianus* in least richness (0.15); evenness (0.08) were recorded with a varying order of *Sh* > *ShCl* by the richness ratio of 82.39:17.61 and evenness ratio of 82.41:17.58. A tree habit (*E. guineensis*) with 0.16 richness and 0.08 evenness was recorded. On the whole an herbaceous recruit with richness (23.63); evenness (12.06) and shrubby recruit richness (1.76); evenness (0.91) was recorded.

The pattern of distribution among the regeneration recruits based on abundance: frequency ratio recorded a highest contiguous pattern with *D. horizontalis* and least distribution (0.07) with B*. falcifera,* random (0.04) with *S. barbata* among HG. The HS highest (1.20) contiguous distribution was in *K. erecta* and least (0.18) in *C. haspan*, The HH had a highest (0.68) contiguous pattern with *O. affinis* and least (0.06) with *C. odorata*, while HCl highest contiguous (0.78) in *P. foetida* and least (0.09) in *I. involucrata* was recorded. The general trend of herbaceous distribution pattern was in the order *HG> HH>HS> HCl* by the relative ratio of 38.66: 32.71: 17.54: 11.10 respectively. The shrubby recruits had a highest (0.64) contiguous pattern with *Urena lobata* and least (0.10) in regular pattern with *T. eriophlebia* and *M. subulalus*, while shrubby climber (*C. splendense*) in highest distribution (0.24); and *P. muellerianus* with least distribution (0.20) were recorded with a varying order of *Sh* > *ShCl* by the distribution ratio of 88.39:11.34. Generally, the herbaceous recruits had higher distribution (26.05) pattern than shrubby recruits with 3.88.

iii. Life form regeneration based on environmental adaptation

A total of 78 recruits of herbaceous life form under ecological resilience revealed diverse environmental adaptation with 37 (47.44%) Hemi-cryptophytes and 41 (52.56%) Chamaephytes recorded in the p-RENA landscape condition (Table 3). Across the diverse environmental adapted life forms are various composition [10 (12.82%) HG; 1 (1.28%) HS; 15 (19.23%) HH; and11 (14.10%)] HCl of herbaceous Hemi-cryptophytes recorded. Similarly, HG had 14 (17.99%); HS 8 (10.26%); HH 18 (23.08%) and HCl 1 (1.28%) Chamaephytes respectively. Seventeen shrubby life form had 2(11.77%) Mesophanerophytes, 8(47.06%) Microphanerophytes and 5 (29.41%) Nano-phanerophytes, while ShCl had 2 (11.77%) Hemi-cryptophytes with one megaphanerophyte (Tree life form) recorded.

iv. Degree mode of regeneration

Diverse mode of regeneration involving single and multiplier level of regeneration was recorded across the life forms of recruits (Table 3). The HG recorded six levels of regeneration among 24 recruits; 17 recruits recorded multiplier mode and 7 recruits with single level of regeneration recorded with their relative percentage composition across individual HG life form (Table 4). The HS had four levels of regeneration among 9 recruits; six recruits exhibiting multiplier mode and three recruits had single mode of regeneration with their relative percentage composition across individual HS life form. The HH showed four levels of regeneration among 33 recruits; in which 11 recruits had multiplier mode, with 22 recruits having single mode of regeneration with their relative percentage composition across individual HH life form. HCl recorded two levels of regeneration among 12 recruits; six had multiplier and single mode of regeneration respectively with their equal relative percentage composition across individual HCl life form. The shrubby life form recorded has two levels of regeneration among 15 recruits; 3 recruits had multiplier mode and 12 recruits with single mode of regeneration with their relative percentage composition across individual Sh life form. The tree life form had single mode of regeneration. ShCl had two levels of regeneration with each recruits recording a multiplier and a single mode of regeneration respectively.

v. Demographic regeneration status

The demographic status of regeneration with a total of 96 recruits composed of 80 (83.33%) seedling and 16 (16.67%) sapling was maximal at the p-RENA land scape of the study site across the herbaceous, tree and shrubby recruits (Table 3). Of the total density (49,600ha^{-1}) across the 23 HG seedlings (Table 3) two seedlings (*E. tenella* and *C. dactylon*) with highest density (6250ha^{-1}) respectively were recorded. One seedling (*C. iria*) of the 9 HS recruits had highest density (5000ha^{-1}) of the total density (14775ha^{-1}). The HH with 31 recruits had one seedling (*Shrankia leptocarpa*) with highest density (5000ha^{-1}) of the total density (39,600ha^{-1}) of recruits. The HCl recruits recorded one seedling (*C. mucunoides*) with highest density (2500 ha^{-1}) of the total density (10650ha^{-1}). The shrubby (Sh) recruits had one seedling (*D. tortusum*) with highest density (1000 ha^{-1}) of the total density (8625ha^{-1}). Across the seedling status, the HG had the highest seedling density (49,600 ha^{-1}) and HCl least density (10,650ha^{-1}) in the order of *HG> HH>HS>HCl*. Across the Herbaceous life forms one sapling recruit (*Sorghum arundinaceum*) with highest density (1375ha^{-1}) of the total density (114,625ha^{-1}) was recorded. The Shrubby sapling recruit had *Triumfetta rhomboidea* with highest density (1125ha^{-1}) of the total density (8625ha^{-1}). Generally the regenerating recruits of the herbaceous life forms had greater seedling density (112, 600ha^{-1}) than sapling density (2,025ha^{-1}) while the shrubby life forms had greater sapling density (6500ha^{-1}) than seedling density (2125ha^{-1}).

4. DISCUSSION

The Edovna forest of Umuobizu is one of the ROW low land vegetation landscape adjoining the low land primary and secondary tropical rainforest at Emuoha study area. The floristic classification, structure and composition have revealed successional changes following the anthropogenic impact of crude oil spill and impact of p-RENA treatment. A floristic trend of low land secondary scrub vegetation, mosaic in nature with heterogeneous continuum in spatial and closed horizontal assemblage of structure arrangement was revealed. Successional changes due to ecological alteration by anthropogenic influences across human dominated physiognomic units have been documented [19, 25, 52].

There was variation in the composition of family members of representative species and with the Poaceae having the highest both in abundance and diversity species richness. This corroborates a study recording increased composition among members of the Poaceae in a naturally regenerating disturbed site [53]. The Poaceae in the study site was higher in species richness as compared to other recruitments of the remediated landscape. The reason for such higher species diversity could be variation in abiotic and biotic features and association, which were not considered in this present study. However, research has shown that different intensities of anthropogenic disturbances and local variation in land scape condition can lead to higher number of grass land association [54].

The phytosociological analysis of the habit based form has revealed variation in terms of species frequency, abundance density; IVI, diversity richness, evenness, and distribution pattern among the various (herbaceous, shrubby, tree and shrubby climber) habit forms. The overall phytosociological evaluation in various percentage ratio was higher in herbaceous grass (HG) in the order *HG>HH>HS>HCl* across the indices. However, the HH habit form exhibited the highest species richness with 33 of the recruits belonging to different families followed by HG exhibiting species richness with 24 of the recruits belonging to the Poaceae family. Similar level of abundance was revealed in a naturally regenerating disturbed habitat [55]. Attempts have been made to analyse the pattern of species diversity in human dominated landscape [56].

Species diversity plays a vital role in restoration ecology in similar assertion by Magurran [57] in conservation biology. It is one of the important phytosociological index of plant community, a major index connected to conservation dynamics and environmental quality [19, 58]. A change in species diversity is often used as an indicator of anthropogenic or natural disturbances in an ecosystem [58]. Therefore characterization of recruits' diversity through phytosociological inventories can be useful in regeneration study that aims to evaluate and select resilience and tolerant species with demonstrated potential for remediation. In addition, the highest frequency, abundance, density, and hence IVI values were exhibited by different species in the HG habit forms. Of the herbaceous forms of recruits the overall horizontal distribution across habit forms represented by the frequency of occurrence of the regenerating recruits was relatively low with 10 species (*Axonopus compressus, Andropogon rapens, Eragrostis ciliaries, Eragrostis tenella, Cynodon dactylon, Schizachyrum brevifolium, Cynodon nlemfuensis, Setaria megaphylla, Setaria barbata,* and *Perotis indica*) of 24 HG recruits, three species (*Cyperus esculentus, Cyperus haspan* and *Cyperus iria*) of 9 HS recruits, nine species (*Zonia latifolia, Shrankia leptocarpa, Chromolaena odorata, Tridax procumbense*, *Euphorbia prostrata, Euphorbia hysopifolia, Melochia pyramidata, Nelsonia canescens*, and *Achyranthes aspera*) of 33 HH recruits and two species (*Calopogonium mucuniodes* and *Diodia sermentosa*) of 12 HCl recruits having 100% frequency value at the p-RENA landscape. One species (*Triumfetta rhomboidea*) of the 15 shrubby recruits and one species (*Elaeis guineensis*) of the tree recruit were respectively 100% and 50% frequency of occurrence. This could imply that the other recruits among the regenerating habit form have scarce horizontal distribution across the habit forms. This might require further investigation that can assist in the future design of appropriate remediation intervention for the selection of species with demonstrated phytoremediation potentials.

Importance Value Index (IVI) is an important parameter that reveals the ecological significance of species in a given ecosystem [19, 25, 59, 60]. *Eragrostis ciliaries,* and *Cynodon dactylon* of the HG, *Cyperus iria* (HS), *Shrankia leptocarpa* (HH), *Calopogonium mucuniodes* (HCl) and *Triumfetta rhomboidea* of shrubby habit form can be considered the most ecologically important regenerating recruits with IVI value range of 3.24 to 10.43 contributed by their high values of frequency, density and abundance. It is pertinent to note that *E. ciliaris* and *C.dactylon* have recorded greater IVI among the most ecologically important regenerating recruits of the p-RENA Edovna landscape, which corroborates an earlier assertion that IVI indicates the dominance of species in a heterogeneous plant community [61].

The class distribution pattern has revealed a more contiguous pattern across regenerating recruits of herbaceous and shrubby habit form. Though the general trend of herbaceous distribution pattern was in the order *HG>HH>HS>HCl* in their relative percentage ratios, *Kyllinga erecta* among regenerating recruit of herbaceous sedge had the highest contiguous distribution pattern among the herbaceous habit form which generally had higher distribution pattern than shrubby recruit. However, a least random distribution in HG and least regular pattern in shrubby recruits were also reported. As observed the patterns of distribution among various regenerating recruits across habit forms are indicative of their ability to reproduce and establish efficiently in such a remediated site. In a similar assertion the prevalent nature of contiguous distribution unlike random and regular distribution found in very uniform environments has been documented (Edwin-Wosu and Edu, 2013) [62]. Also documented was that class distribution of species is a potential and reliable tool to reveal status of population structures, regeneration of species and also predict responses of species to disturbances and resultant changes in population structure [63 - 67]. There fore as observed from the present study it was evident that the p-RENA Edovna landscape was turning into diverse heterogeneous natural forest again.

The recruited life form based on environmental adaptation at the p-RENA habitat condition has revealed variation across the various life forms with a higher (52.56%) adaptation of Chamaephyte than Hemi-cryptophytes (47.44%). Across the individual herbaceous life forms, the Chamaephytes was in the order of *HH>HG>HS>HCl* (23.08:17.91:10.26:1.28) while Hemi-cryptophytes was in the order *HH>HCl>HG>HS* (19.23:14.10:12.82:1.28). Similarly across the habit-based shrubby life form was a highest composition (47.06%) of Microphanerophytes followed by Nanophanerophytes (29.41%) then Mesophanerophytes (11.77%) and Hemi-cryptophytes (11.77%) while a Megaphanerophytes was revealed by a habit – based tree life form environmental adaptation. The presence of these demographic variation is an indication that the p-RENA landscape was at one time under anthropogenic disturbance such as the oil spill and remediation intervention which can be supported in a similar assertion by Edwin-Wosu and Edu, [19]]; Kalacska et al., [68].

Under variant local environmental conditions the existence of species greatly depends on its regeneration [61]. Upon such premise could also suffice in the present findings that the species existence, tolerance, resilience and survival under such hydrocarbon remediated soil depend largely on the mode of regenerating recruits. Regeneration is a critical phenomenon in forest management because it maintains the desired species composition and stocking after disturbances [69]. Study has revealed that through regeneration a degraded land scape can be recruited back to complete forest cover [61]. In the present study several species of diverse life forms were found existing through diverse mode of regeneration. New species were found regenerating and were absent as adult. Greater mode of single level of regeneration than multiplier level of regeneration was exhibited among the life forms through coppicing, stolon, seedling, sapling, rhizome and tuber. The HG exhibited greater multiplier mode while HH had greater single mode of regeneration. The herbaceous lower vascular recruits among the life forms revealed a secondary physiognomic unit, heterogeneous in nature as a result of the regeneration process with few regenerating shrubby recruits. Research has revealed that in tropical pastures new trees may emerge from residual seed bank or from seed dispersal and / or from sprouts arising from roots and stems [70]. Also the occurrence of true forest in a secondary scrub or old-field vegetation due to ability of certain shrubs to coppice and persist through root suckers after forest clearing has been documented [43].

Understanding the demography of recruits is a fundamental challenge that will help achieve restoration goals [71]. Though the demographic status of regeneration was maximal at the p-RENA land scape of the study site across the herbaceous, tree and shrubby recruits in the present study, research has also revealed that forest recovery is a function of demographic status across life form recruits in which seeds arrival on a disturbed site could establish into seedling which grows into adult trees [55]. While many studies have identified seed limitation as a bottle neck for seedling recruitment during forest restoration [72], this goes to affirm the assertion [41, 73, 74, 75] that greater seedling than other demographic status implies new regeneration as observed in the present research. There was variation among the seedling of herbaceous recruits with the HG having greater seedling density across life forms.

However, between the two demographic statuses, the seedling status was greater in density than the sapling status. Variation in demographic status as noted across the above life forms can explain divergent successional trajectories as opined in a similar assertion by Rozendaal et al. [76]. Though the demographic status and rate of natural recruits had apparent variation depending on species identity, density size, and life forms in light of the local environmental (p-RENA) land scape condition, it can be deduced in this present study that the success of natural regeneration depends on both the demographic status and rate of establishment of natural recruits.

5. CONCLUSION

The result revealed various life forms of 96 different species of genera under 23 families. Twelve families were dominant, with eight very abundant and four in abundance with diverse species richness. Poaceae had the highest phytosociological composition. The habit based life form had diverse representative species among 78 herbaceous, 15 shrubby, 1 tree and 2 shrub climber of regenerating recruits. Other than greater frequency trend recorded by the herbaceous herbs, the herbaceous grass across all phytosociological indices had greater composition of regenerating recruits among the life forms. The life form environmental adaptation revealed greater Chamaephytes with herbaceous herb life form than Hemi-cryptophytes with herbaceous sedge life form. The shrubby life form revealed a higher Microphanerophytes, followed by Nanophanerophytes and Mesophanerophytes, while shrubby climber was represented by Hemi-cryptophytes and tree life form with Megaphanerophyte. The mode of regeneration involved single and multiplier levels with HG recording the highest levels of regeneration. The demographic and density of regenerating recruits has shown the herbaceous life form with greater seedling density ha^{-1} than sapling density. Though such demography had apparent variation it can be concluded in this present study that the success of natural regeneration depends on both the demographic status and rate of establishment of natural recruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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