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ELABORATION OF MANAGEMENT PLAN OF AN INVASIVE AQUATIC PLANT SPECIES: THE CASE OF THE NYONG RIVER BASIN MBALMAYO CAMEROON

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ABSTRACT: Wetlands and their biodiversity species have been undergoing an alarming degradation in the past recent years. The overall objective has been to determinate the various invasive plant species found in the study area. Floristic inventories based on the development of transects and quadrats helped to make surveys by using coefficients of abundance-dominance and sociability. Physico-chemical parameters of the Nyong river were measured. Species richness of study sites amounts to 20 species distributed in 17 families. Results shown that the distribution of macrophytes varies with Shannon diversity index, from 3.193695 (Ekombitie/Mbega) to 1.263136 (CDE/CAMWATER). *Echinochloa pyramidalis* (51 %) is the most abundant specie in the study sites. The result shown the causes and factors limiting the potential of the biotope of the Nyong River. It has been clearly shown that invasive plants contribute in a significant way to euthrophication of the river: *Echinocloa pyramidalis,* 51%; *Ipomea aquatic,* 18.31%; *Nymphaea lotus,*12.83%; *Leersia hexandra,* 9.15%; *Commelina benghalensis,* 9.15%. The ecosystem approach for the better management of this site is proposed. From this study we therefore open another parenthesis for research which is based on managing wastes within the Mbalmayo council area and monitoring the quantity and quality of the waste stream leaving Yaounde and other environs into the Nyong River. This will help to reduce the pollution of this river, monitor point source and non-point source pollution sources and hence to reduce the proliferation of macrophytes since one of the best options of ecosystem restoration is preventing nutrient loading.

KEYWORDS: Wetlands, diversity, aquatic plants, Nyong, Mbalmayo.

1 INTRODUCTION

Wetlands are vital resources rich in biodiversity from which goods and services such as food, flood control and potable water can be obtained which is of great importance to millions of people throughout the world [1]. Many Wetlands in Cameroon constitute an aquaculture biodiversity hence the source of sustenance and revenue for the riverside dwellers. However, in spite of these undeniable profits, these ecosystems and their biodiversity have been undergoing an alarming degradation in the past recent years [2]. The Nyong river basin is not left out being that for some years now, it has been witnessing continuous degradation due to combined anthropogenic and climatic factors which has as consequence loss of halieutic biodiversity, uncontrolled development of certain invasive plant species, rarefaction of water resources, food insecurity, decrease in revenue and rural exodus [3] which have proven to be unhealthy to the state of this vital ecosystem.

This river basin is not only important for its designation as a RAMSAR site [4] and the conservation of bird species, but also for the fact that it represents the cultural heritage of the indigenous population [5]. Another very pertinent aspect is the fact that this river serves as the sole potable water supply to the entire town of Mbalmayo and the capital city of Yaounde. This flooded plain assumed great socio-economic importance for the indigenous population resulting from activities of fishing, forest exploitation, agriculture, poaching [6] and on the basis of forests conservation in the Congo basin making it to feature amongst the 200 ecological zones deserving particular attention for sustainable and participative management initiatives in the world [2]. According to [7] amongst the numerous problems that affect lotic freshwater ecosystems are agricultural and industrial pollution, development of infrastructure, intensive local fishing, global warming related to climate change, forest exploitation along drainage basins and the proliferation of invasive aquatic plant species (IAPS). These plants according to their phyto sociological grouping and their specific nutritional requirements are true indicators of the state and health of the environment [8]. Based on the impacts caused by these IAPS which include sedimentation of the water body, obstruction of navigable water courses and proliferation disease causing agents [9], [10], [11], the Cameroon government initiated a project through the ministry of Environment Nature Protection and Sustainable Development ((MINEPDED) «Plan of battle against water yacinthe and others types of aquatic invasive plants in Mbalmayo District**»** executed by the Watershed Task Group (WTG) alongside which this research was carried out. This was done in accordance to article 27 of Law N^{o} 96/12 of 5th August 1996 relative to the protection of flood plains (wetlands) in the national territory.

Study has as overall objective to determinate the various invasive plant species found in the study area. Specific objectives are to : (1) make a floristic inventory and cartography; (2) evaluate the ecological and socio-economic impacts of the invasion and the elaboration of a draft IAPS management plan.

2 Materials And Methods

2.1 Description Of Study Area

This research was based principally in the Nyong River basin of the Mbalmayo council area which is situated on the southern Cameroon plateau and has the most important relief features of the national territory [12]. This area is delimited in the North by Mbega (N 03.5485; E011.59974) (N 03.55^{0}, E 11.59^{0}) and in the south by the So'o River in the Nkol-yama locality (N 03.37583^{0}; E 011.41209^{0}) (N 03.38^{0}, 11.412^{0}) [1]. It is made up of eleven (11) villages namely; Mbega, Nkolngock I, Nkolngock II, Akomnyada I, Akomnyada II, Ngallan, Oyack I, Oyack II, Nsenlong I, Nsenlong II and Ebogo. Below is a map showing the location of the various villages in the project area.

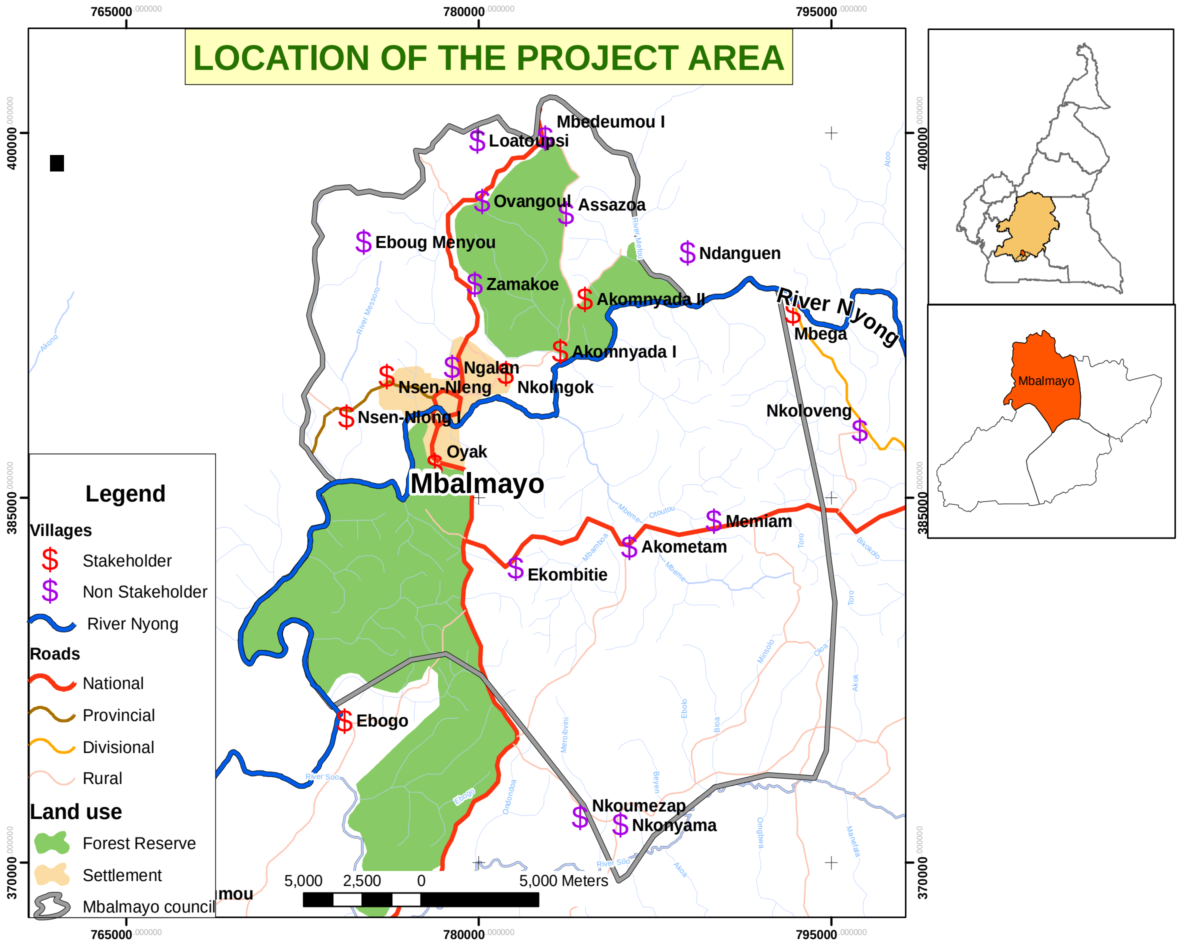

Figure 1 : Location of the Project Area (Source : [12]).

2.2 Physical characteristics

This zone is characterised by an equatorial climate of the Congo-Guinea type with four seasons: Two rainy seasons which alternates with two dry seasons [13]. It has a mean annual rainfall of 1700 mm with a mean annual temperature of 24 °C (Figure 2; Table 1). Effects due to climate change is observed by the frequent early or late arrival, or early disappearance of rains which culminates dry periods and which seriously distorts the agricultural calendar of the region and causes low agricultural yields [14].

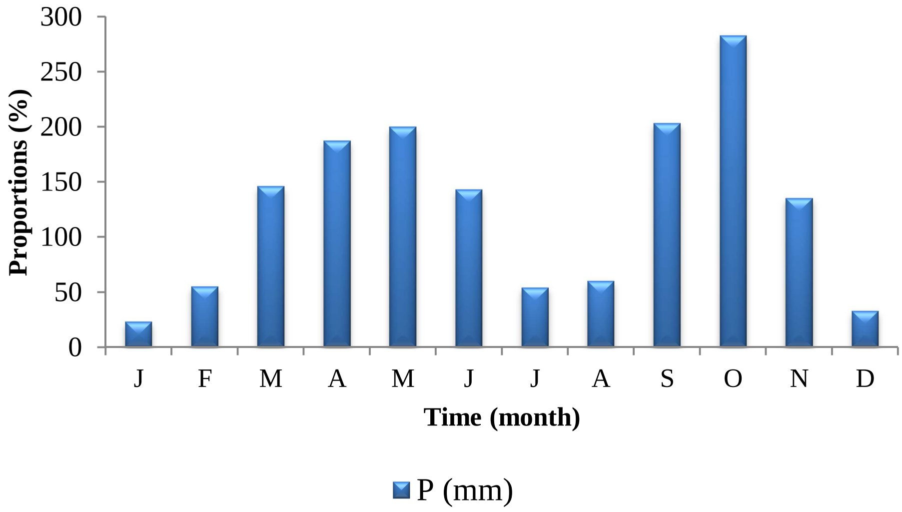

Figure 2 : Variation of Rainfall According to Months in Mbalmayo

Table 1: Mean Temperature of Mbalmayo (°C) from 1968-1996

Month		J	F	M	A	M	J	J	A	S	O	N	D
Temperatures	Mean maximum	31.5	32.5	32.6	32.0	30.9	29.9	28.6	26.6	29.2	29.8	29.8	30.1
	Mean minimum	16.5	17.1	17.7	17.9	17.6	17.2	17.1	17.9	17.5	17.3	17.5	16.5
	Average	24.4	25.2	25.2	24.7	24.2	23.3	22.5	22.6	23.2	23.4	23.7	23.8

The area is characterised by many mountains of average altitude which varies between 600 m and 1000 m. The rest of the area constitutes vast plains and plateaux. This accidental relief renders certain localities of the community inaccessible especially during the rainy season and explains the great enclosure of villages in this community. The area is covered by red ferrous unsaturated soils. They equally have hydrophilic soils especially around the river banks which are poorly drained and difficult to valorise and lastly raw infertile mineral soils [15].

They have a dense hydrology network made up of many water courses with the most important being the Nyong River, So'o, Kama, Mfala and Nsoumou. The division derives its name from the Nyong and So'o Rivers which belongs to the Atlantic basin. It's on this river banks in the village of Akomnyada I that the CDE water treatment plant and pumping station has been constructed which supplies the Mbalmayo town and the Capital city Yaoundé with potable water. These waters follow an equatorial system of flow that is it flows throughout the year but its flow rate varies according to the seasons having a greater volume during the rainy season and a lesser one in the dry season. The rich aquatic fauna found therein, constitutes an important resource for the population. In addition to these water courses are numerous natural and artificial lakes in the lower end of the community [2], [15].

2.3 Methodology inherent to inventory

From the literature on the various methodologies employed in plant biodiversity assessment, we chose the transect and quadrant method of plant evaluation. Questionnaires were used to obtain additional information from the various stakeholders and the surrounding villages constituting the study area. This was demonstrated based on qualitative techniques, such as noted observations, focus groups discussions and historical information reviews as stated by [16]. This method is commonly referred to as the triangulation. The general approach of the research methodology was based on the following phases:

Choice and description of experimental site were done based on accessibility and invasiveness but the whole water path was covered and emphasis was laid on areas with significant human activity to monitor point and non-point source pollution. The subject area was divided into four zones based on the number of villages to be covered thus (Table 2).

Table 2: Partition of the Study Area to ease Data Collection and Analysis

Zone	Sample points	Sites
I	Section of the ferry, fishing points and logging areas.	Mbega, Nkolngock II, Nkolngock I.
II	River Mefou, Camwater catchment site, fishing point.	Akomnyada II, Akomnyada I, Nsengnlong II.
III	The Oyack bridge, fishing point, nearby farmlands.	Nsenglong I, Ngallan, Oyack II.
IV	Slaughterhouse, Japan market, touristic site.	Oyack I, hold bridge, Ebogo.

2.4 TREATMENT AND ANALYSIS OF COLLECTED DATA

These was achieved with the use of appropriate analytical softwares such as word, excel and consisted in representing information on tabular and graphical form.

2.5 SPECIFIC METHODOLOGY

2.5.1 WATER SAMPLING AND ANALYSIS

The length of assessment was 50 km constituting 10 points in descending order from upstream to downstream thus; Mbega, Ekudmbad, Akomnyada II, CDE/CAMWATER, hold SNEC/SOCAFOAM, Japan market, Slaughterhouse Nsenglon I and Nsenglon II. The following parameters were under investigation: pH, MES, NTK, BOD, COD, TEMP, EC, ORP, DO. Orthophosphates, Chloride, Nitrates.

2.5.2 COLLECTION OF SAMPLES

At each sampling point, in situ parameters such as T °C, pH and EC were measured by EC/pH meter, DO by DO and ORP by ORP meter. This was followed by collection of the samples in labelled plastic bottles (1.5 l) which had been well washed and rinsed to prevent contamination of the samples. The containers were completely submerged in the river which was then corked tight immediately after collection to avoid contamination and ease transportation of the samples. One sample was collected at each sample point making a total of 10 samples. During the collection of these samples observations were made at each point alongside biodiversity assessment while taking down the various coordinates and altitudes to ease location of the points using a GPS. The samples were then transported to the laboratory at the Ministry of Mines and Energy within a period of 24 hrs for analysis. Laboratories can provide additional testing methods for samples. This allows several types of parameters to be analyzed in a sample. The following parameters were under investigation: MES, NTK, BOD_5, COD, NO^-_3, CL^- and PO^-_3. Which are all parameters that determine the level of pollution of a water body. The results were then obtained and statistical variables such as the sum, average, maximum and minimum values and the standard deviation were used to interpret results.

2.6 BIODIVERSITY ASSESSMENT

The quadrant method of biodiversity assessment was employed to identify the various aquatic plants present. The river itself was considered as a transect (path through which the assessment was carried out) therefore enabling quadrants to be formed on both sides of the river with the aid of a GPS to track the length. Gaps of 5 m each were obtained on both sides to ensure uniformity of the transect. The various plant species present where noted down and their point of location recorded using a GPS. The surface area was then calculated using the formula for area thus.

Area (m^2) = length (m) x width (m).

Each quadrant was measured at 5m x 5m (being 3 m in water and 2 m inland) giving the area for each quadrant at 25 m^2.The various areas obtained were then summed up and the total surface area cover was then divided by 10000 to get the total surface area in hectares (ha).

The transect was also used to capture the greatest diversity of land-use and ecosystems along the river banks such as interactions between the physical environment and human activities, geographical conditions, settlement, water supply service and sanitation.

The method of diversity indices was then employed to analyse the data collected. The following indices were calculated based on their significance.

2.6.1 THE SHANNON WEAVER INDEX

The Shannon diversity index (H) is an index that is commonly used to characterize species diversity in a community. It accounts for both abundance and evenness of the species present. The proportion of species (*i*) relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by -1 [12].

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

2.6.2 THE SIMPSONS INDEX

It is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species [35].

$$D = \frac{\Sigma\, n(n-1)}{N(N-1)}$$

Where n = the total number of organisms of a particular species, N = the total number of organisms of all species**.** The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give:

2.6.3 SIMPSON'S INDEX OF DIVERSITY (1 – D)

The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

2.6.4 THE PIELOU EQUITABILITY INDEX

It determines the degree of diversity attained as compared to the theoretical maximum [14]. It is calculated thus;

$$E_H = H / H_{max} = H / \ln S$$

Where H= Shannon's index, Hmax = total number of species seen in the area, lnS = Logarithm of total number of species seen in the area

2.7 ECOLOGICAL EVALUATION (TRANSECT WALK)

The transect walk is a walk cross-cutting the community to capture the greatest diversity of land use and ecosystem. This helped to bring the community members together in an assessment of problems and available resources in the community. The various villages were targeted through their respective village heads who selected some members in the community for the walk. Areas targeted were those with the largest variety in terms of landmarks, types of land use, water resources and where water use could be seen. This was accompanied by observations, formal and open ended interviews with people living in the area. Emphases were laid on critical issues such as water availability, waste disposal, sanitation and usefulness of some aquatic plant species in the community including their local names.

3 RESULTS

3.1 SPECIES RICHNESS OF STUDY SITES

Species richness of study sites amounts to 20 species distributed in 17 families (Table 3). *Araceae* family contains 1 species: *Pistia stratiotes*. *Asteraceae* family contains 1 species: *Vernonia* sp.. *Boraginaceae* family contains 1 species: *Heliotropium indicum*. *Commelinaceae* family contains 1 species: *Commelina benghalensis*. *Convolvulaceae* family contains 1 species: *Ipomea aquatica*. *Cyperaceae* family contains 1 species: *Cyperus iria*. *Euphorbiaceae* family contains 1 species:

Alchornea cordifolia. *Hydrolea* family contains 1 species: *Hydrolea* sp. *Lemnaceae* family contains one species, *Lemna minor*. *Loganaceae* family consists of 1 species: *Anthocleista djalonensis*. *Malastomataceae* family consists of 1 species: *Dissotis rotundifolia*. *Moraceae* family consists of 1 species: *Ficus exasperata*. *Nymphaceae* family consists of 1 species: *Nymphaea lotus*. *Poaceae* family consists of 4 species: *Echinochloa pyramidalis*, *Leersia hexandra*, *Acroceras zizanoides* and *Bracharia* sp.. *Polygonaceae* family consists of 1 species: *Polygonum lanigerum*. *Phyllanthaceae* family consists of 1 species: *Uacapa guineensis*. *Rubiaceae* family consists of 1 species: *Nauclea diderichii*.

Table 3: Summary of Plant Biodiversity Inventory of the Study Area.

Famille	Espèce
Araceae	*Pistia stratiotes*
Asteraceae	*Vernonia* sp.
Boraginaceae	*Heliotropium indicum*
Commelinaceae	*Commelina benghalensis*
Convolvulaceae	*Ipomoea aquatica*
Cyperaceae	*Cyperus iria*
Euphorbiaceae	*Alchornea cordifoloia*
Hydroleaceae	*Hydrolea* sp.
Lemnaceae	*Lemna minor*
Loganaceae	*Anthocleista djalonensis*
Melastomataceae	*Dissotis rotundifolia*
Moraceae	*Ficus exasperata*
Nympheaceae	*Nymphaea lotus*
Poaceae	*Echinochloa pyramidalis*
Poaceae	*Leersia hexandra*
Poaceae	*Acroceras zizanoides*
Poaceae	*Bracharia* sp.
Polyganaceae	*Polygonium lanigerum*
Pyllanthaceae	*Uapaca guineensis*
Rubiaceae	*Nauclea diderichii*

3.2 SURFACE AREA OCCUPIED BY INVASIVE AQUATIC PLANT SPECIES

According to the various zones as mentioned in the methodology and their respective villages, the table below gives the distribution of plant species. See map of distribution of invasive aquatic plants (Table 4). This shows that the total length occupied by these plants is 92 km with a surface area cover of 140.6083 ha showing that the invasion is important and requires serious attention. Zone IV showed a greater invasion meaning invasive species are more abundant upstream. The identity and percentages of the various plants are shown in the results of aquatic plant inventory below.

Table 4: Distribution of invasive aquatic plants according to zones in the study areas

S/N	Name	Length (Km)	Surface area (ha)	Intensity (ha/km)
1	Zone I	14	23.7167	1.694
2	Zone II	27	25.0973	0.9295
3	Zone III	18	23.9444	1.33
4	Zone IV	33	69.1079	2.0941
Total		92	140.6083	6.0476

3.3 INVENTORY OF NATURAL VEGETATION IN THE PROJECT AREA

Five of these plant species were found to be invasive to the river as shown in the table below in regressive order of abundance including their respective percentages (Table 5).

Table 5: Invasive Aquatic Plants of the Nyong River

Species	Abundance	Percentage
Echinochloa pyramidalis	2760	51 %
Ipomoea aquatica	1000	18,31 %
Nymphaea lotus	700	12,83 %
Leersia hexandra	500	9,15 %
Commelina benghalensis	500	9,15 %

These plants and water samples were collected at various locations as shown below (Table 6).

Table 6: Geographical Location of the Various Sample Areas.

Sample Point	Name	Coordinates/Altitude
I	Mbega/Ekombitie	N 03°33’492’’, E 11°36’764’’, 636 m
II	Ekudmbad	N 03°33’496’’, E 11°37’671’’, 638 m
III	Mefou tributary	N 03°33’140’’, E 11°35’975’’, 635 m
IV	Akomnyada II	N 03°31’919’’, E 11°33’674’’, 637 m
V	CDE/CAMWATER	N 03°31’567’’, E 11°32’962’’, 640 m
VI	SNEC/SOCAFOAM	N 03°30’780’’, E 11°31’102’’, 638 m
VII	Marché Japon	N 03°30’797’’, E 11°30’169’’, 635 m
VIII	Abatoir	N 03°30’656’’, E 11°29’827’’, 637 m
IX	Nsenglon I	N 03°30’149’’, E 11°29’539’’639 m
X	Nsenglon II	N 03°29’638’’, E 11°29’602’’, 639 m

Shannon’s index is variable to 3.193695 (Ekombitie/Mbega) at 1.263136 (CDE/CAMWATER). Simpson’s index varies to 0.414488 (Akomnyada II) at 0.162929 (Ekombitie/Mbega). Pielou equitability varies to 0.354855 (Ekombitie/Mbega) at 0.210029 (Ekudmbad) (Table 7).

Table 7: Computing Diversity Indices for the Various Quadrants

Quadrants	Site	Simpson’s Index	Shannon’s Index	Pielou Equitability
I	Ekombitie/Mbega	0.162929	3.193695	0.354855
II	Ekudmbad	0.482779	1.680235	0.210029
III	Akomnyada II	0.414488	1.735645	0.289274
IV	CDE/CAMWATER	0.567951	1.263136	0.252627
V	Ancien SNEC	0.582538	1.155317	0.288829
VI	Nouveau Pond	0.321721	1.852901	0.231612
VII	Marché Japon	0.362571	1.645711	0.434313
VIII	Abattoir	0.2496484	2.171566	0.434313
IX	Nsenglon I	0.249648	2.132964	0.426592
X	Nsenglon II	0.346891	1.609863	0.402465

Table 8a: Results of samples collected and analysis using statistical variables (pH : hydrogen potential; T: temperature; OD:

Dissolved oxygen; ORP: oxygen reduction potential; EC: electrical conductivity; MES: suspended solids; BOD_5: Biological oxygen demand; COD: chemical oxygen demand; NTK: Total nitrogen).

Point/Parameter	pH	T (°C)	DO	ORP	EC (µs/cm)	MES (mg/l)
Mbega	4.75	26.20	0.32	120.00	295.00	0.03
Ekunmbad	4.50	25.70	1.36	200.00	250.00	0.15
Mefou	5.75	23.20	3.28	177.00	873.00	0.14
Akomnyada II	5.40	25.70	2.51	175.00	415.00	1.60
CDE	4.15	25.10	0.10	244.00	813.00	0.06
SOCAFOAM	4.77	24.70	0.88	160.00	331.00	0.04
Marché Japon	5.06	25.50	2.25	188.00	427.00	0.11
Abattoir	5.35	25.50	2.25	193.00	413.00	0.09
Nsenglon I	4.48	25.50	2.42	158.00	418.00	0.06
Nsenglon II	5.35	25.50	2.26	181.00	415.00	0.08
SUM	4.95	252.60	17.63	1796.00	4650.00	2.36
AVERAGE	4.95	25.26	1.763	179.60	465.00	0.236
MAX	5.75	26.20	3.28	244.00	873.00	1.60
MIN	4.15	23.20	0.10	120.00	250.00	0.03
STD DEV	0.51	0.82	1.04	32.05	208.70	0.48

Table 8b: Results of samples collected and analysis using statistical variables (pH : hydrogen potential; T: temperature; OD:

Dissolved oxygen; ORP: oxygen reduction potential; EC: electrical conductivity; MES: suspended solids; BOD_5: Biological oxygen demand; COD: chemical oxygen demand; NTK: Total nitrogen).

Point/Parameter	BOD5 (mg/l)	COD (mg/l)	NTK (mg/l)	Nitrates (mg/l)	Chloride (mg/l)	Ortho-phosphate (mg/l)
Mbega	99.70	146.60	6.30	3.09	22.70	0.02
Ekunmbad	139.56	223.30	6.43	1.34	25.56	0.05
Mefou	91.66	183.33	6.02	1.12	28.40	0.06
Akomnyada II	64.30	120.00	7.10	3.78	36.92	0.78
CDE	226.66	340.00	6.44	0.99	36.92	0.80
SOCAFOAM	0.00	0.00	4.67	0.78	34.02	0.07
Marché Japon	0.00	0.00	5.43	0.76	22.72	0.08
Abattoir	80.00	120.00	5.78	1.32	34.02	0.08
Nsenglon I	0.00	0.00	6.89	2.89	28.40	0.76
Nsenglon II	123.78	173.33	6.89	2.89	25.56	0.08
SUM	825.66	1306.56	61.95	18.96	295.22	2.77
AVERAGE	82.57	130.66	6.20	1.90	29.52	0.28
MAX	226.66	340.00	7.10	3.78	36.92	0.80
MIN	0.00	0.00	4.67	0.76	22.70	0.02
STD DEV	72.17	109.90	0.75	1.13	5.54	0.34

3.4 CIRCLE OF VISUALISATION FOR CORRELATIONS BETWEEN THE DIFFERENT PARAMETERS

The circle enables the study and visualisation of correlations between variables, with the aim of eventually limiting the number of variables to be measured subsequently (Figure 3). These variables are projected on an area or space in three dimensions and are linked with the Pearson index of similarity. The visualisation inscribed shows for example a perfect correlation between the parameters COD and BOD_5 whose correlation coefficient between the two parameters is very probably equal to 1. Furthermore on making projections of variables on the axes, taking into consideration similarity distances and angles, we also obtain a perfect correlation between ORP and NTK parameters.

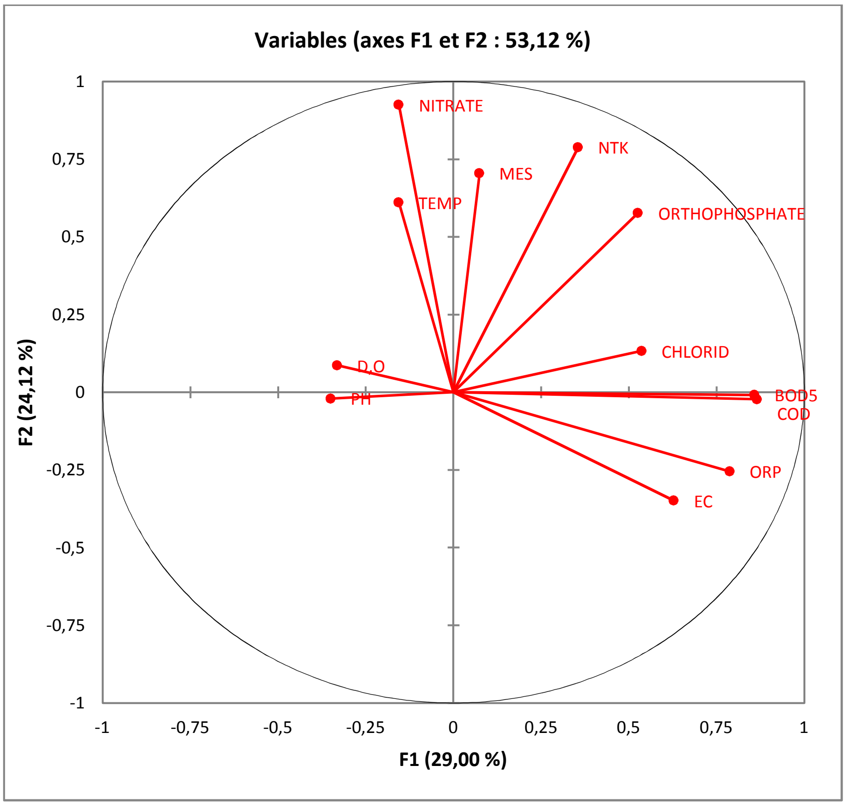

Figure 3: Variation of physicochemical parameters of study area

3.5 ACP ILLUSTRATING VISUALISATION OF CORRELATIONS BETWEEN PARAMETERS AS A FUNCTION OF DIFFERENT LOCATIONS

This link is also made by the Pearson index of similitude and permits the understanding that by taking into consideration all the variables, the sites which appeared to have different abiotic parameters can be closer between each other like Japan market and SOCAFOAM which are close to variables or parameters somewhere else (Figure 4). It is the case of the site of NSENGLON I which has a very high concentration of Nitrates. Somewhere else, site projections on the axes taking into consideration distances and similitude angles also shows the proximity of two sites which appears visually far from each other like the sites of MBEGA and EKUNMBAD. It is also in this point of view of improving this visualisation subject to projections of objects on the axes that a classification dendrogramme was obtained.

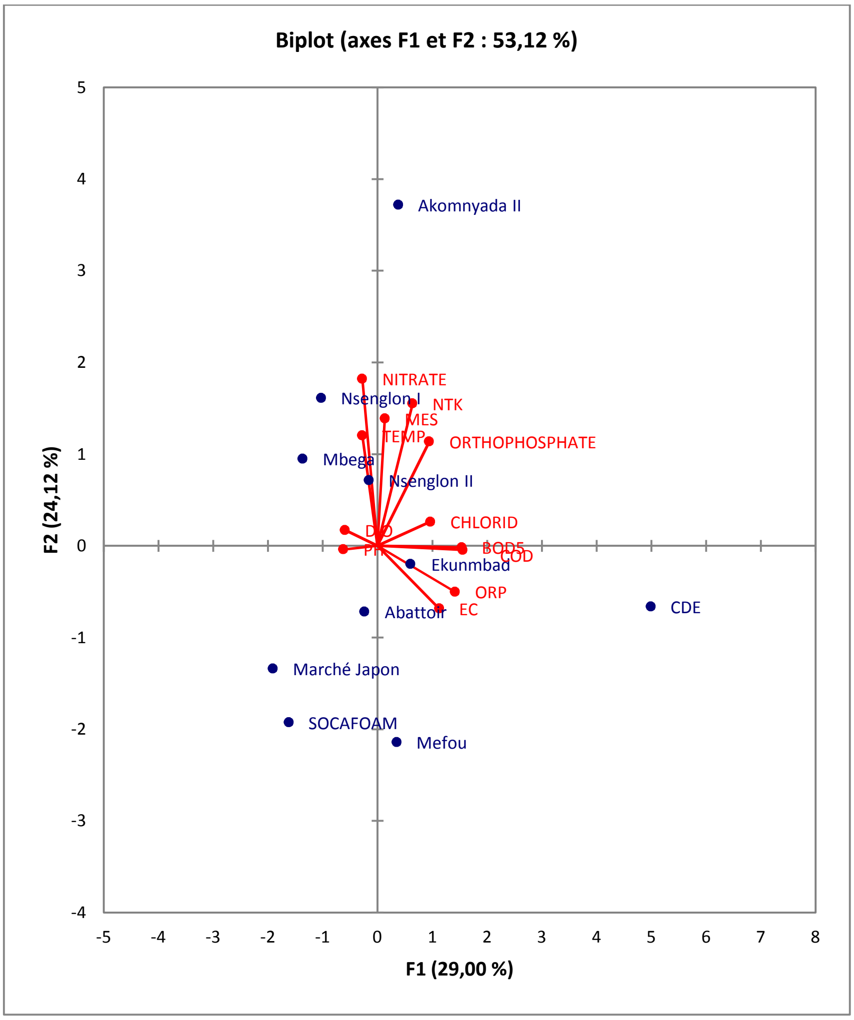

Figure 4: ACP illustrates the link between the sites as a function of the variables

3.6 DENDROGRAM SHOWING SIMILITUDE BETWEEN DIFFERENT LOCATIONS AS A FUNCTION OF DIFFERENT PARAMETERS

The dendrogram brings clarity on the proximity of locations as a function of different parameters and shows a net class separation of the different sites (Figure 5). The short interrupted line on the perpendicular axis of dissimilarity cuts the dendrogam into four points bringing to light four classes which are basically differentiated by a set of colours. Each class contains a well delimited number of sites and distances and on the other hand by a calculated dissimilarity from the Pearson similitude index. For example the first class contains two sites (EKUDMBAD and MBEGA).

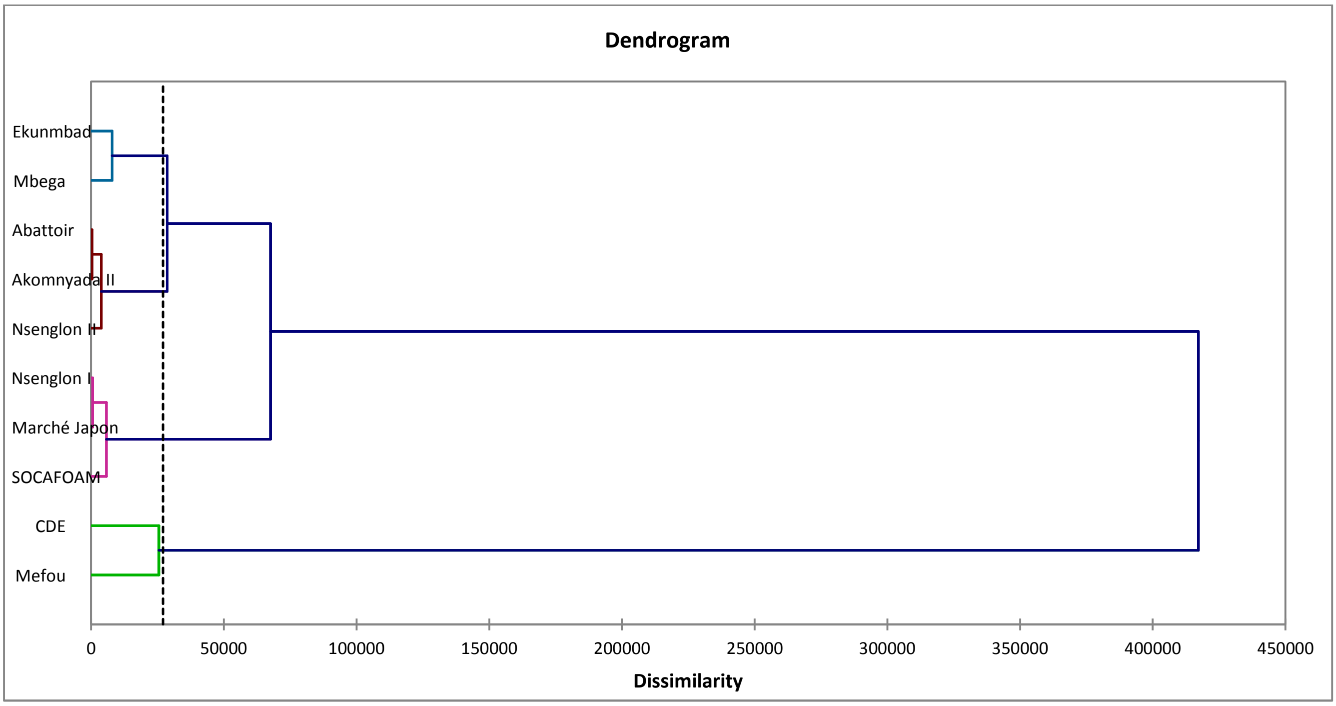

Figure 5: Dendrogram classing study stations in function of physicochemical parameters

3.7 PROFILE OF CLASSES SHOWING ZONES OF DISSIMILARITIES BETWEEN DIFFERENT CLASSES OF THE DENDROGRAM AS A FUNCTION OF THE DIFFERENT PARAMETERS

The class profile shows four classes as a function of the different parameters investigated (Figure 6). The four classes are always represented by a set of colors and each point on the abscissa represents a parameter. The profile therefore shows from which parameter a strong similitude or dissimilitude exists between the classes. For example the pH where all other classes are otherwise overcome cannot make a distinction between the classes. On the contrary, the EC point shows a good distinction between all the classes. This parameter can serve as a criterion for differentiation between the classes.

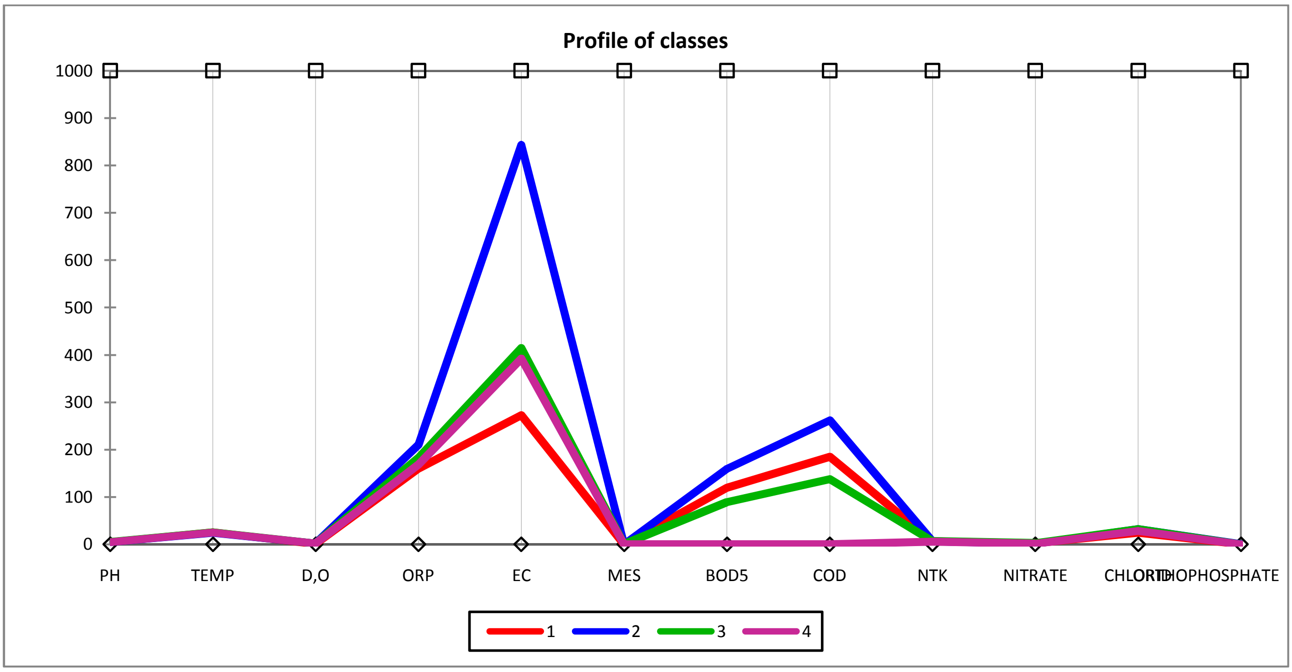

Figure 6: Profiles of classes showing parameters which reproached study sites

3.8 AFC ILLUSTRATING THE VISUALISATION OF CORRELATIONS BETWEEN STATIONS AS A FUNCTION OF DIFFERENT SPECIES

AFC shows the proximity of stations between each other as a function of qualitative variables which are species (Figure 7). But for all ACP as such, it is necessary to produce a dendrogram of classification to bring about good precisions of different classes constituted by the stations.

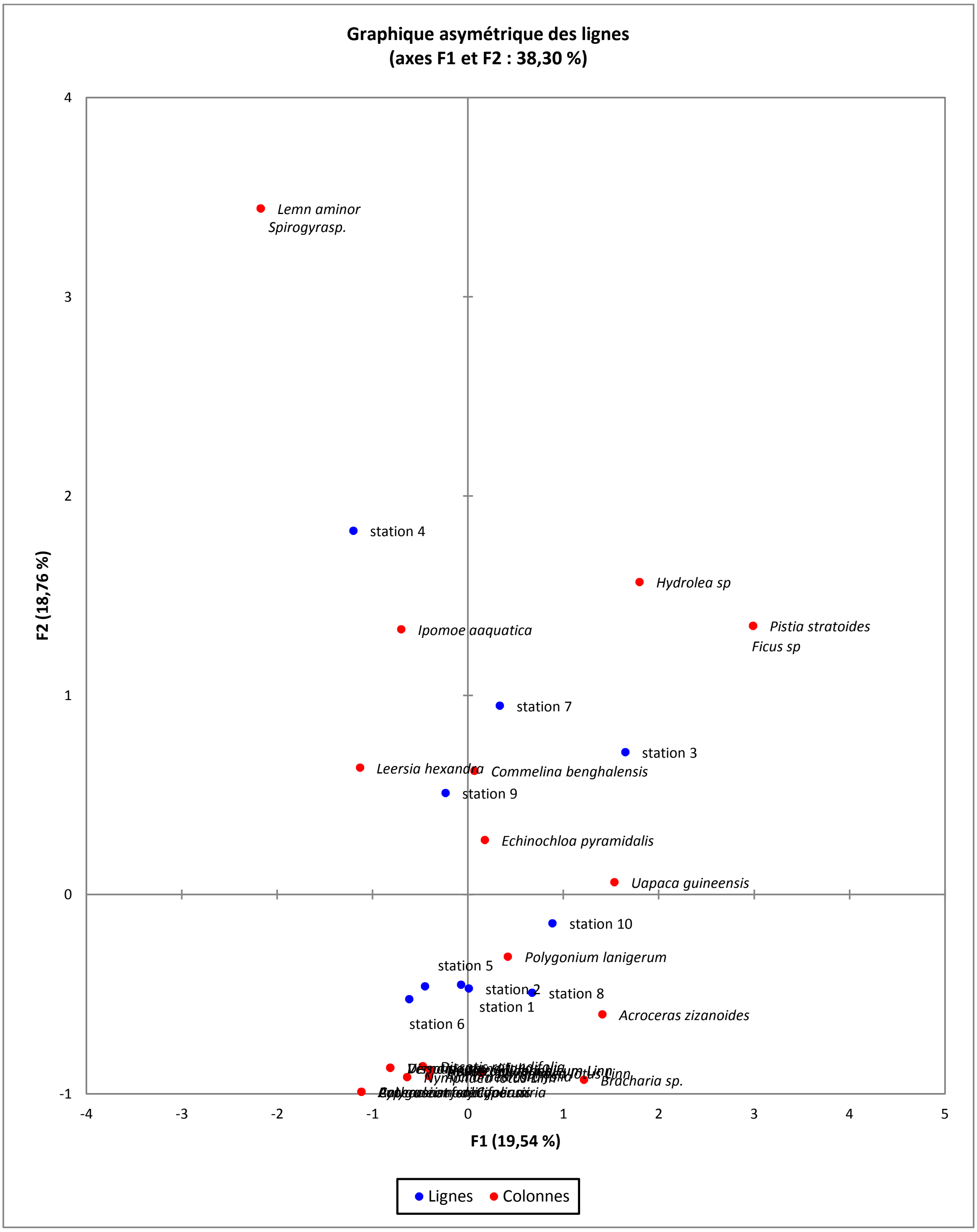

Figure 7: AFC showing study sites in function of species

3.9 DENDROGRAM SHOWING SIMILITUDE BETWEEN DIFFERENT STATIONS AS A FUNCTION OF DIFFERENT SPECIES

The short perpendicular line on the dissimilarity axis cuts through the dendrogram at four points showing four classes which are basically differentiated by a set of colors (Figure 8). Each class contains a number of well delimited stations and is distant from others by a calculated dissimilarity from the Pearson index of similitude. For example the first class which contains four stations (Station 10, station 8, Station 5, and Station 3).

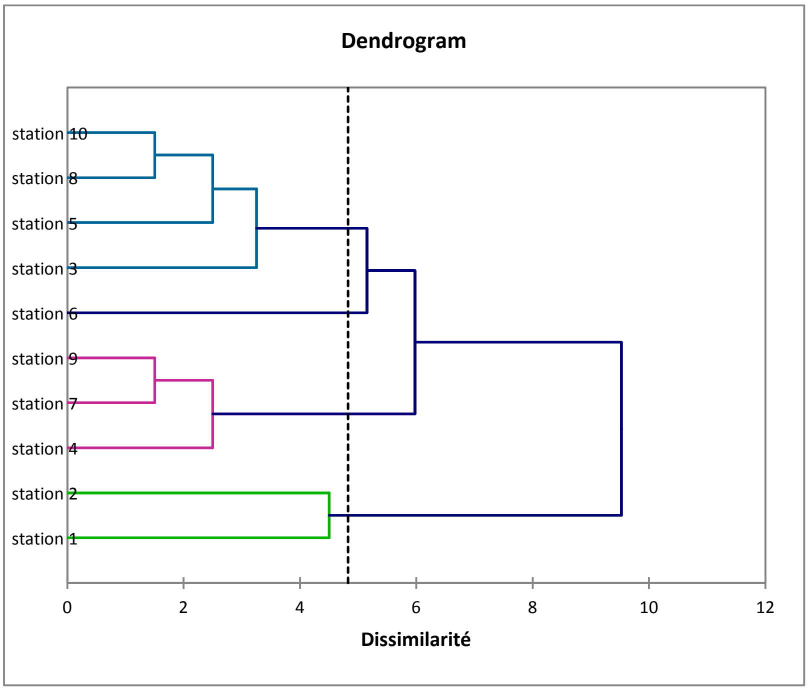

Figure 8: Dendrogram classing study stations in function of species

4 DISCUSSION

Results show that *Echinicloa Pyramidalis* is the dominant invasive aquatic plant species followed by *Ipomea aquatica*, *Nymphea lotus*, *Leersia hexandra* and *Commelina benghalensis* which are mostly found in areas where the speed of the water is slow, at tributaries and areas where there is significant anthropogenic activity [7]. This can be seen in areas like the Mefou tributary, Japan market/hold bridge, Nsenglon I and II which results from wastes discharges. These areas enable the supply of organic matter which favours the proliferation of these plants coupled with their physiological anatomy which enables them to easily adapt and displace native species [8]. Other observations where drawn from the fact that IAPS mostly spread in areas where they could anchor such as edges of the river banks. This gave an important focus to the plant *Nymphea lotus* which according to some fishermen and observations is very active in the proliferation of these IAPS because it serves as an anchor for such plants since its roots penetrate to a length of about a meter in the water body. Another invasive plant which is also gaining way and on the verge of increasing drastically in population is *Pistia stratoides* although its abundance as of date is very low and it is a good indicator of water population from anthropogenic input. At Akomnyada II there is a high proliferation of algae which is an indication of euthrophisation [18], [19] coming from the Mefou River and which is also influenced by agriculture at the banks of the river. At the CDE/CAMWATER plant, the presence of these species were almost absent except for highly tolerant plants such as *Dissotis rotundifolia* due to the discharge of residual chlorine to which most macrophytes are not tolerant. Another important aspect is the proliferation of plants such as *Polygonium laginerum, Polygonium salicifolium, Heliotropium* which are indicators of pollution (Bio- indicators).

Computing diversity indices in the study area, Shannon's index does not have a theoretical limit but can be used alongside the Pielou index to give information on abundance and evenness and to study pollution of an area [14]. From the results we can see that the Pielou equitability index is nearer 0 than 1 meaning there is variety of species in the quadrants but for five points (SNEC/SOCAFOAM, hold bridge/Japan market, slaughterhouse and Nsenglon I and II) were the indices are shown to increase. These increases are noted more as we move upstream and this particular stretch of the study area is noted for many anthropogenic activities hence significant pollution [13]. This means that species are less abundant and even, as we move from upstream to downstream.

The Simpson's index on the other hand is generally low, values range between 0.0242 and 0.567 but show a slightly greater value at Akomnyada II indicating low species diversity and values fluctuate as one leaves downstream to upstream. The physic-chemical analysis of 12 elements in the area under study summarised in table 19 is thus; it shows that the pH varies between 4.15 at CDE to 5.75 at the Mefou with an average value of 4.956. This p^H is relatively acidic and according to [4] it is a result of the development of aquatic macrophytes such as, *Echinocloa pyramidalis*, *Ipomea aquatica*, *Nymphea lotus*, *Leersia hexandra* and *Pistia stratoides* since they cause a reduction in pH.

The temperature varies very little with a mean value of 25.56, maximum value of 26.20 and a minimum value of 23.20, obtained at Mbega and Mefou respectively.

The dissolved oxygen content of the water body is comprised between 0.10 mg/l (CDE) -3.28 mg/l (Mefou) with the mean level in the water body being 1.76 mg/l which is far below the norm (>50) indicating an oxygen deficient water body. Implying that there is poor respiration by aquatic organisms and low oxidation and degradation of organic matter, which is a serious cause of asphyxia and hence death of aquatic life [19].

The increased concentration of NTK between 4.67 and 7.10mg/l with the highest concentration recorded at Akomnyada II which is an area with high agricultural produce indicates anthropogenic contamination, fertilization, poor agricultural practices which cause displacement of minerals from upstream to downstream. The level of phosphates is relatively low in the water body between 0.02 mg/l with the values registered between 0.02-0.08. Maximum levels (0.08) were recorded in significant zones such as the CDE, Japon Market, Abbatoir and Nsenghenlon which are endowed with serious human activities especially that of huge production of untreated waste and washing of household items. This is a very important aspect of euthrophisation of the water body since phosphates starts posing problems at a concentration of 0.2 mg/l [20].

According to [21], BOD and COD are both valuable means by which natural phenomenons of destroying organic matter (BOD) and estimation of the oxidisable matter content (COD) present in a water body. They are both indicators of organic water pollution. The high levels of BOD 82.57 mg/l and COD 130.66 mg/l is mainly due to an increase in the waste stream of organic materials with oxygen deficiency of the water body.

The concentration of chloride ions in the water body meets the norms but looking at the point of CDE it is relatively high and this can also be responsible for the very low pH recorded at this point reason why even plant species diversity recorded in this area is very low, only highly tolerant plants could be seen. This chlorine according to some fishermen is responsible for the deformation of some fish species ("machoiron"). The water content of suspended solids is within the limits of the norms, also the electrical conductivity and oxygen reduction potentials.

We note therefore in the discussion that all parameters with the correlation coefficient 1 can undergo selections. Subsequently, we can choose one out of the two parameters to carry out a similar study. The representation of sites to study the similarity between them and between the parameters enables us to achieve an ACP.

5 CONCLUSION

Haven met the objectives and hypothesis of this research as shown in the results, of the causes and factors limiting the potential of the biotope of the Nyong River, it has been clearly shown that invasive plants contribute in a significant way to euthrophication of the river: *Echinocloa pyramidalis,* 51%; *Ipomea aquatic,* 18.31%; *Nymphea lotus,* 12.83%; *Leersia hexandra,* 9.15%; *Commelina bengalensis,* 9.15%. Inspite of its undeniable benefits, this ecosystem and its species have witnessed an alarming degradation which merits its immediate restoration for the present and future generation. The project initiated by the government alongside which this research is carried out was based on controlling the invasive plant *Eichornia crassipes* (water hyacinthe), the results obtained shows that this plant is not found in this area. We rather found some patches of *Pistia stratoides* hence this research in addition has enlightened the government's knowledge about the invasion for better management options. We therefore propose the ecosystem approach for the better management of this site. From this study we therefore open another parenthesis for research which is based on managing wastes within the Mbalmayo council area and monitoring the quantity and quality of the waste stream leaving Yaoundé and other environs into the Nyong River. This will help reduce the pollution of this river, monitor point source and non-point source pollution sources and hence reduce the proliferation of macrophytes since one of the best options of ecosystem restoration is preventing nutrient loading.

REFERENCES

[1] O.V. Singh, S. Labana, G. Pandey, R. Budhiraja, R.K. Jain, 2003. "Phytoremediation : an overview of metallic ion decontamination from soil". Appl. Microbiol. Biotechnol., vol. 61, pp. 405-412, 2003.

[2] Anonymous, "Exposé sur la Thématique des Zones Humides et des Eaux Internationales au Cameroun", p. 13, 2014.

[3] Nguelo, "Gestion Intégrée de la Jacinthe d'eau (Eichornia crassipes Mart. Solms lamb) dans l'estuaire du Wouri", Mémoire, Université de Dschang, p. 96, 2007.

[4] Nguelo, "Gestion Intégrée de la Jacinthe d'eau (Eichornia crassipes Mart. Solms lamb) dans l'estuaire du Wouri", Mémoire présenté pour le Diplôme d'ingénieur de génie rural l'université de Dschang, P. 96, 2007.

[5] S.D. Dibong, G.P. Ndjouondo, "Inventaire floristique et écologie des macrophytes aquatiques de la rivière Kambo à Douala (Cameroun)", J. Appl. Biosci., vol. 80, pp. 7147-7160, 2014.

[6] N.Z. Fogwé, M. Tchotsoua, "Evaluation géographique de deux décennies de lutte contre les inondations dans la ville de Douala (Cameroun)", Rapport, Université de Douala
http://www.infotheque.info/fichiers/JSIR-AUF- Hanoi07/articles/AJSIR_2-p3_Fogwe.pdf, 2007.

[7] J.E. Byers, "Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes", Oikos, 97:449-458, 2002.

[8] Whites and Edwards, "Invasive species challenge in estuarine and coastal environments: marrying management and science", Estuaries and coasts, vol. 31, pp. 3-20, 2001.

[9] S.D. Dibong, G.P. Ndjouondo, "Inventaire floristique et écologie des algues des rivières Kambo et Longmayagui de la zone humide de Douala (Cameroun) ", Int. J. Biol. Chem. Sci., vol. 8, no. 6, pp. 2560-2577, 2014.

[10] R.P. Tatso, "Étude exploratoire des techniques de réalisation des cartes d'aléa d'inondation : Cas de la ville de Douala Cameroun". Projet personnel, Université Douala/ENSG UMLV, p. 16, 2011.

[11] Berne, "Méthodes d'analyse et d'appréciation des cours d'eau : donnée Niveau R (région)". OFEV, p. 122, 2007.

[12] A.D. Meva'a, M. Fouda, C.Z. Bonglam, M. Kamwo, "Analyse spatiale du risque d'inondation dans le bassin versant du Mbanya à Douala, capitale économique du Cameroun", NOVATECH, p. 10, 2010.

[13] G.P. Ndjouondo, M.L. Ba'ana Etoundi, R.D. Nwamo, H. Fankem, S.D. Dibong, "Impact des activités anthropiques sur les zones humides des rivières Kambo et Longmayagui", International Journal of Innovation and Scientific Research, vol. 26, n° 2, pp. 410-420.

[14] G.R. Tadonki, "Douala : les exclus des marécages, Environnement et habitat marginal des bas-fonds : quartiers Maképé, Bépanda, TSF, Siccacao, Ndogbati", (eds), S.D.S. Mandara, pp. 113-115, 1999.

[15] J. Bengtsson, "Which species? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function", Applied Soil Ecology, vol. 10, n° 3, pp. 191-199, 1998.

[16] A. Thiam, "Contribution á l'étude phytoécologique de la zone de décrus du lac de Guiers (Sénégal)", Thèse de troisième cycle, Institut des Sciences de l'Environnement, Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, p. 105, 1984.

[17] N.F. Diop, "Intégration de la biodiversité d'eau douce dans le processus de développement en afrique : Mobilisation de l'information et sites de démonstration", Projet de démonstration du bassin du fleuve Gambie, p. 48, 2010.

[18] J. Roman, "Aquatic invasive species". Retrieved from http://www.eoearth.org/view/article/150156, 2010.

[19] K. Prabha, L.Y. Padmavathiamma, Li, "Phytoremediation Technology : Hyper-accumulation Metals in Plants". Water Air Soil Pollut., vol. 184, pp. 105–126, 2007.

[20] N. Sauberer, K.P. Zulka, M. Abensperg-Traun, H.M. Berg, G. Bieringer, N. Milasowsky, D. Moser, C. Plutzar, M. Pollheimer, C. Storch, R. Trostl, H. Zechmeister, G. Grabherr, "Surrogate taxa for biodiversity in agricultural landscapes of Eastern Austria". Biological Conservation, vol. 117, pp. 181-190, 2004.

[21] A. Ouattara, "Premières données systématiques et écologiques du phytoplancton du lac d'Ayamé (Côte d'Ivoire)". Thèse de l'Université Catholique Leuven, Belgique, p. 200, 2000.