**Floristic diversity of herbaceous vegetation in the edges of cultivated fresh water wetlands in Yaounde and its perphery**

**ABSTRACT**

The present study conducted in Yaounde and its periphery aims to analyse the floristic diversity of herbaceous vegetation in the edges of fresh water wetlands. Phytosociological survey was done using the Braun-Blanquet approach. In total, 98 herbaceous species distributed among 32 families and 74 genera were recorded. *Asteraceae* constitute the most represented botanical family. Four herbaceous plant groups were discriminated. The floristic diversity index varies from 2.30 to 3.13 bits indicating that the herbaceous plant groups are moderately diversified. Biologically, therophytes are the most dominant to the detriment of other biological forms identified. Similarly, the biogeographic classification of the flora highlights several Phytochorological groups, among which species with a wide distribution are the most representative; which reflects the openness and instability of the environment. These results should therefore alert researchers, decision-makers and technicians to the need to continue thinking, training and raising awareness among farmers about the advantages and benefits offered by the edges of fresh water wetlands in Yaounde and its surrounding areas.

**Keywords:** environmental safety, floristic diversity, Yaounde, marshy area.

**I. INTRODUCTION**

In the tropics, wetlands fulfil numerous protective functions at the local and global levels. They thus play a vital role in regulating greenhouse gases, in major climatic balances, in meeting various needs of local populations (Sambaré *et al*., 2020; Djangbedja, 2020) and in the creation of large reservoirs of biodiversity. The conversion of these wetlands to the detriment of housing development, agriculture, public infrastructure and the development of tourist facilities, leads to a risk of disappearance of fauna and flora. The wetlands of the city of Yaoundé and its surroundings in Cameroon have important edges in and around which agriculture and livestock farming are practiced. In these edges, food crops are grown which provide not only food for the populations but also substantial income to easily meet most of their socioeconomic needs (Menyengue *et al*., 2021). Due to human activity, these edges are mainly covered with herbaceous vegetation. They are used all year round for agricultural purposes (market gardening), traditional pharmacopoeia, and grazing (Mbarga Bindzi *et al*., 2014). The needs of populations determine the floristic composition in most plant formations exploited by humans (Dona, 2023). The edges of wetlands are sources of food production and local populations are dependent on them, more specifically in the city of Yaoundé and its surroundings. Indeed, the agricultural exploitation of these wetland edges, once secondary, has nowadays become the pillar of food security for households, but also one of the sources of income for farmers in a context of climate change. Land pressure and the degree of urbanization, in terms of the size of the urban population, forces the population to invest more in the intensive development of the wetland edges, where cassava, sweet potato, lettuce, cabbage, plantain, sugar cane, corn, vegetables, etc. are grown. Despite their importance, these edges are subject to a large number of threats, including market gardening, overexploitation, pollution, etc., with the main consequence being abiotic and biological modification (Dajoz , 2006). Much work has been devoted to wetland vegetation in Cameroon in general (Kono *et al*., 2020; Mbarga *et al*., 2017; Fobane *et al.*, 2023). However, these studies have not addressed the floristic diversity of herbaceous vegetation in the edges of market garden wetlands. Such a study sees the preservation of biodiversity in urban and peri-urban environments as a breach in the emergence of ecologically viable cities in third world countries. The present work aims to characterize the plant groups of the edges of market garden wetlands in the city of Yaoundé and its surroundings. Specifically, it involved: (1) assessing the floristic diversity of herbaceous vegetation in the edges of market garden wetlands; (2) determining and characterizing the different herbaceous plant groups.

**II. METHODOLOGY**

**II.1. Presentation of the study area**

The study environment is located southwest of Yaounde and its surroundings, between latitudes 3°42' and 4°05'N, and longitudes 11°17' and 11°35' E (Figure 1). This densely populated environment is subject to the influence of a subequatorial climate with four seasons, two rainy and two dry, with average rainfall of 1564.7 mm / year and an average annual temperature of 23.5°C (thermal amplitude of 2.4°C), observed over a period from 1895 to 2005 (Abossolo et al., 2015). The pedological substrate consists of ferralitic and hydromorphic organic or mineral soils with definite agricultural potential. The natural vegetation of the study environment is a dense humid semi-deciduous forest dominated by *Ulmaceae* and *Sterculiaceae* (Letouzey, 1985). This forest is currently severely degraded due to strong anthropic pressure which is causing floristic and structural changes (Mbarga et al., 2017). Two direct factors, namely agriculture and habitat, are the causes of overexploitation of land and rapid degradation of the vegetation cover.



Figure 1. Location of floristic data collection sites and plots.

**II.2. Data collection**

**II.2.1. Floristic sampling plan**

For the floristic inventories, nine plots of 500 m² (50 mx 10 m) subdivided into ten strips of 50 m² (10 mx 5 m) each rectangular in shape were surveyed, distributed over five sites each comprising one or more market garden edges (Table I). At the level of each type of market garden edge, a single plot was installed in a floristically homogeneous and representative area. In each strip of 50 m², a phytosociological survey of all herbaceous species was carried out using the sigmatist method defined by Guinochet (1973). For each herbaceous species present in the strip, it is assigned an abundance-dominance coefficient according to the Braun-Blanquet scale (1932). This coefficient is the expression of the relative coverage of all the individuals of each species. It is:

+: individuals of the species are not very abundant, with low coverage (0 to 1%);

1: abundant individuals, but the degree of coverage is low (1 to 5%);

2: abundant individuals, covering between 5 and 25% of the surface area considered;

3: abundant individuals covering 25 to 50% of the surface area considered;

4: abundant individuals covering 50 to 75% of the surface area considered;

5: abundant individuals covering 75 to 100% of the area considered.

The nomenclature of species, followed in this study, is that of APG IV (2016).

Table 1. Typology of edges and distribution of plots in the sites.

|  |  |  |
| --- | --- | --- |
| Sites | Types of selvedgesScientific name / French name | Plot code (P) |
| Mvan | *Amaranthus* edge *esculentus / Amaranth* | P1 |
| *Capsicum* edge *frutescens / Chili pepper* | P2 |
| edge of *Zea mays / Corn* | P3 |
| Nkolbisson | *Lactuca sativa / Lettuce* edge | P4 |
| Municipal Lake | edge of *Zea mays / Corn* | P5 |
| Bastos | edge of *Musa sapiente / Plantain banana* | P6 |
| edge of *Manihot esculenta / Cassava* | P7 |
| University of Yaounde I | edge of *Zea mays / Corn* | P8 |
| edge of *Saccharum officinalis / Sugarcane* | P9 |

**II.2.2. Analysis and digital processing of data**

**II.2.2.1. Individualization of herbaceous plant groups**

The determination of herbaceous plant groups was carried out on the basis of the species matrix with their presence/absence. Thus, an ascending hierarchical classification was made in order to highlight the different types of herbaceous plant groups. In addition, the collected data were subjected to a Correspondence Factor Analysis (CFA) using R software version 4.0.5 (CORETEAM, 2021) in order to describe the relationships between herbaceous plant groups and ecological variability.

**II.2.2 .2. Specific diversity**

The comparison of the specific diversity of the herbaceous plant groups was carried out on the basis of the specific richness (RS), the Shannon index (ISH), the Simpson index (D') and the Piélou equitability (E). Before importing the data into the R software, the abundance-dominance coefficients were replaced by their average overlaps ( Rmi ) which made it possible to obtain the semi-quantitative values of the species present in each herbaceous group.

In this formula, Ri = Semi-quantitative value of species i; Rmi = “Average recovery” of species i in a survey (obtained from the conversion of the Braun-Blanquet code); n = number of surveys where species i is present; N = Number of all surveys.

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In this formula, Ri is the semi-quantitative value that expresses the dominance of species “i” while “s” is the total of species inventoried. The Shannon index is sensitive to variations in the importance of rare species; it is zero when there is only one species and its maximum value is obtained when all species have the same dominance (Dajoz, 2006). Piélou 's equitability (E) measures the degree of diversity reached by a population compared to its maximum value and allows the comparison of two groups which do not have the same number of species.

 Or

Simpson's diversity index (D) measures the probability that two individuals drawn at random from a given stand are of the same species ( Dajoz , 2006). This index is sensitive to variations in the importance of more abundant species ( Peet , 1974); it reaches its maximum value in monospecific groups and its minimum value when all species have the same dominance. The formula used is as follows:

In which ni is the abundance of each species and N is the total number of individuals in the grouping.

**II.2.2. 3. Comparison of herbaceous plant groups**

Sørensen 's similarity coefficient. It varies from 0% (for groups that have no species in common) to 100% (for groups that have all species in common). The Sørensen coefficient is calculated from the following formula:

With, C = number of species common to herbaceous plant groups G1 and G2; A = number of species in G1 and B = number of species in G2.

**II.2.2.4. Functional organization of plant groups**

Biological types refer to all the morphological characteristics that play a role in resistance to unfavorable conditions, and therefore in the location of plant species ( Raunkier , 1934). The biological types (Table 2) used are adapted by various authors (White, 1986; Bassène et al., 2020). The geographical distribution of the species was carried out according to the work of Bassène et al. (2012).

Table 2. Biological traits and modalities retained.

|  |  |  |
| --- | --- | --- |
| Trait categories | Types of traits | Stroke modalities |
| Life trait | Ecology | ChamephyteGeophyteHemicryptophytePhanerophyteTherophyte |
| Flora stability trait | Geographic distribution | Widely distributed species (Afro-American; Afro-Malagasy; Afro-tropical; Cosmopolitan; Paleotropical; Pantropical);Guinean-CongoleseSudanese-Zambéziennes |

**III. RESULTS**

**III.1. Floristic composition and distribution**

On the sampled plots, the number of species recorded per plot is heterogeneous and varies from 20 species (P1) to 44 species (P8) with an average number of species equal to 30 (Figure 2).

From a taxonomic point of view, the herbaceous flora reveals the presence of 98 species distributed among 31 families and 74 genera. This flora is dominated by *Asteraceae* (18.36%) and *Fabaceae* (10.20%). *Cyperaceae* (9.18%), *Poaceae* (8.16%), *Euphorbiaceae* (6.12%) and *Amaranthaceae* (5.10%) come in second place. The other families are represented by less than 5% (Figure 3). Structurally, dicotyledons are dominant with 72 species (73.47%). Monocotyledons represent 24.49% (24 species). while Pteridophytes are weakly represented with only 2 species (2.04%).

Figure 2. Spectrum of abundance of families of recorded ruderal species.

Figure 3. Floristic richness of the sampled plots.

The classification of species recorded by biological type (Figure 4) shows a dominance of the types best adapted to the different constraints of the environment, namely therophytes (38 species, or 39.17%) and chamaephytes (30 species, or 30.93%). Geophytes capitalize 18 species, or 18.56%; phanerophytes (6 species, or 6.19%); hemicrytophytes (4 species, or 4.12%) and hydrophytes (1 species, or 1.03%). This distribution follows the following pattern: TH > CH > GEO > PH > HE > HYD (Figure 3).

Figure 5 shows the biogeographic distribution of the recorded species. Pantropical species (50.52%) account for more than half of the biogeographic distribution of the recorded species. The other seven biogeographic affinities accounted for 49.48% of the species.

Figure 4. Contribution of the number of species according to biological types.

Figure 5. Contribution of the number of species according to biogeographic types.

**III.2. Plant groups**

**III.2.1. Determination of herbaceous plant groups**

The ascending hierarchical classification (Figure 6) allows us to identify four herbaceous plant groups; namely: group I (GI), group II (GII), group III (GIII) and group IV (GIV).

Group I includes 2 plots (22.22%) carried out at the level of the marsh of the reservoir pond located below the Faculty of Sciences of the University of Yaoundé I; in an area with less anthropized periodic flooding. It is made up of plots P8 (edge at *Zea mays*) *and P9* (*Saccharum* edge *officinalis*). Floristically, this group is dominated by Acanthospermum hispidum, Carpologonium mucunoides, Commelina benghalensis, Drymaria cordata, Echinochloa pyramidalis, Emilia coccinea, Mimosa pudica and Panicum maximum.

Group II includes 4 plots (44.44%) all created in the area crossed and flooded by the Nkié River; which limits its access and the extent of disturbances. These are plots P1 (*Amaranthus edge esculentus*), P2 (*Capsicum edge frutescens*), P3 (edge at Zea mays) and P4 (edge of *Lactuca sativa)*. The most representative species concern Alternanthera sessilis, Amaranthus hybridus, Bidens pilosa, Commelina benghalensis, Cyperus difformis, Cyperus rotundus, Drymaria cordata, Eleusine indica, Euphorbia hirta, Galinsoga ciliata, Portulaca oleracea and Rhynchospora corymbosa.

Group III includes a single plot (11.11%), P6 (*Musa sapiente edge) carried out far from the area crossed by the* Mindja river. This station shows signs of anthropogenic impacts. The species characterizing this group are Achyranthes aspera, Aneilema Benin, Brachiaria lata, Costus afer and Yua thomsonnii.

Finally, group IV includes 2 plots (22.22%), P5 (edge at *Zea mays*) carried out around the municipal lake and P7 (edge at *Manihot esculenta) carried out far from the area crossed by the* Mindja water course in Bastos, a very weakly anthropized station. Floristically this grouping is characterized by Acanthospermum hispidum, Ageratum conyzoides, Diodia scandens, Euphorbia hyssopifolia and Sida rhombifolia.



Figure 6: Arrangement on a dendrogram of the four individual herbaceous plant groups in the edges of the wetland market gardens. P1-P9: surveys; GI-GIV: the four individual plant groups.

**III.2.2.** **Ecological determinism of individual plant groups**

The spatial distribution of the individualized groupings is shown in Figure 7. The first two factorial axes alone present a cumulative variance of 37.44%. The ecological significance of the two axes is explained by field observations and the ecology of the characteristic species. Thus, on the negative side of axis 1 (on the abscissa), are positioned the two plots (surveys) forming group 1 (less anthropized zone) and plot P5 of group 4 (disturbed zone). On the positive side of this same axis, are plot P6 forming group 3 corresponding to the zone more disturbed by anthropic activities (off-season agriculture, removal of fodder resources, etc.). Clearly, axis 1 therefore expresses an increasing gradient of disturbances of anthropic origin.

Similarly, on the negative side of axis 2 (on the ordinate), the plots constituting group 2 corresponding to the flood zone are positioned. On the other hand, on the positive side of this axis, we find the plots forming group 1 and group 4, in particular plot P7. The latter is located far from the crossing of the Mindja River . Axis 2 therefore reflects a gradient of decreasing humidity of the hydromorphic soil going from group 2 on more humid soil to groups 1 and 4 developing on less humid ground.



Figure 7. Phytosociological surveys on the first two axes of the AFC based on floristic data.

**III.2.3.** **Floristic diversity of herbaceous plant groups**

From a floristic point of view, heterogeneity is observed between the plant groups (Table 3). Species richness is highest in the GII group with 61 species. The Shannon diversity index (H') oscillates between 2.30 bits (GIV) and 3.13 bits (GII). These values reflect a more or less abundant diversity of species within these herbaceous plant groups. The highest value of this index is obtained in the GII plant group (3.13 bits). Thus, it is more diverse with a better distribution of individuals within the group. On the other hand, the low value of the Shannon diversity index (2.30 bits) was recorded in the GIV group. The dominance of species like *Acanthospermum hispidum* (*Asteraceae* ), *Ageratum conyzoides* (*Asteraceae* ), *Diodia scandens* (*Asteraceae* ), in the plots constituting this grouping explains the observations from the field well. The Piélou equitability index made it possible to measure the distribution of species within the plant grouping. It is generally less than 0.6; proof that the groups are anthropized.

Table 3. Biological diversity indices of herbaceous plant groups.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Floristic groups | RS | ISH | EQ | 1-D | D |
| GI | 58 | 3.05 | 0.52 | 0.08 | 0.92 |
| GII | 61 | 3.13 | 0.53 | 0.06 | 0.94 |
| GIII | 24 | 2.40 | 0.52 | 0.12 | 0.88 |
| GIV | 46 | 2.30 | 0.42 | 0.19 | 0.81 |

**III.2 .4.** **Similarities between species groups**

Sørensen 's similarity coefficients (Table 4) are very high between the GI and GII groups (57.14%) with a common background of 34 species, GI and GIV (59.61%) with a common background of 31 species and GII and GIV (56.07%) with a common background of 30 species. This indicates that a large number of species are found in these plant groups, so the difference in biodiversity between the habitats is low. On the other hand, the similarity coefficients between the GIII group and the other plant groups (GI, GII and GIV) are low (less than 50%); indicating that this group constitutes a relatively distinct unit from the others. These similarity coefficients prove similar environmental conditions between plant groups GI, GII and GIV and decisive differences in environmental conditions between plant group GIII and the other groups (GI, GII and GIV).

Table 4. Similarity coefficients of S Ø rensen between the different plant groups.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | GI | GII | GIII | GIV |
| Group I (GI) | 100 |  |  |  |
| Group II (GII) | 57.14 | 100 |  |  |
| Group III (GIII) | 31.71 | 30.59 | 100 |  |
| Group IV (GIV) | 59.61 | 56.07 | 31.43 | 100 |

**III.2.5.** **Biological and phytogeographic types of groups**

The biological and phytogeographic types of the identified herbaceous plant groups are illustrated in Figures 8 to 10. The analysis of these groupings shows that the biological types of the identified herbaceous plant groups are composed of chamephytes , geophytes, hemicryptophytes , hydrophytes, therophytes and phanerophytes . The predominance of biological types varies depending on the herbaceous plant groups. Thus, the rate of therophytes is high in the herbaceous plant groups GI (46.60%), GII (49.20%), GIII (29.20%) and GIV (34.80%) to the detriment of other biological forms including chamephytes , geophytes, hemicrytophytes and hydrophytes. The proportion of hydrophytes (1.70%) is very low; they are only represented in the GI group.

Regarding the phytogeographic types, the herbaceous plant groups GI, GII, GIII and GIV are dominated at 87.93%, 96.72%, 87.50% and 93.48% by the species with a wide distribution (Afro-American, Afro-Malagasy, Afro-tropical, cosmopolitan, paleotropical and pantropical) respectively (Figure 9). These are followed by the Guineo-Congolian and Sudano- Zambezi species . Figure 10 shows the results of the detailed examination of the phytogeographic distribution. It highlights the preponderance in the plant groups of the pantropical species GI (51.72%), GII (55.74%), GIII (54.17%) and GIV (63.04%).

Figure 8. Proportions of biological types of species by herbaceous plant grouping.

Figure 9. Proportions of biogeographic types of species by herbaceous plant grouping.

Figure 10. Detailed phytogeographic spectrum of herbaceous plant groups.

**III. Discussion**

**III.1. Floristic composition**

The floristic inventories made it possible to identify 98 plant species over an area of 0.45 ha. This high specific richness can be explained by environmental heterogeneity and habitat diversity (Mabafei et al., 2021); combined with anthropozoogenic actions (Bouhissi et al., 2021). However, it is not exhaustive for the study area, because many annual herbaceous species have not been inventoried due to the difficulty of access in certain wetland market gardens. The flora is dominated by *Asteraceae* (18.36%), *Fabaceae* (10.20%), *Cyperaceae* (9.18%), *Poaceae* (8.16%), *Euphorbiaceae* (6.12%) and *Amaranthaceae* (5.10%). *Asteraceae* and *Fabaceae* which occupy a prominent place in the edges of the marshy wetlands of the city of Yaoundé and its surroundings are also reported by Kono et al. (2024) as being the most numerous in Central Africa. Studies carried out in several regions of Cameroon also highlight the preponderance of these families which fall into the category of cosmopolitan families with great ecological plasticity (Mbarga Bindzi *et al*., 2017; Momo Solefack *et al*., 2018).Their preeminence is therefore a characteristic of open environments (Mbarga Bindzi *et al*., 2014). Variations in biological spectra are mainly linked to local variations in bioclimatic and edaphic parameters as well as to anthropogenic pressures (Adiko *et al*., 2020). This work highlighted a high rate of therophytes in the identified herbaceous plant groups. Their high proportion compared to other biological forms is linked to the opening of vegetation. The low proportion of hydrophytes could be explained by the drying out of hydromorphic soils through agricultural activities ( Menyengue *et al*., 2021). These agricultural activities would be at the origin of the disappearance of hydrophytes and the extension of therophytes which dominate in anthropized formations (Gbodjinou *et al*., 2022). Analysis of the chorological spectrum shows that the floristic procession is dominated by pantropical species. This predominance is an indicator of disturbance attesting that the flora has lost its specificity ( Abrou *et al*., 2019). This disturbance is due to grazing pressure and agricultural activities which strongly modify the original flora.

**III.2. Herbaceous plant groups**

**III.2.1. Biological diversity**

Floristic diversity indices are objective criteria for extracting the maximum ecological information from a plant community (Dajoz , 2006). Examination of Shannon's diversity index (H') and Pielou 's equitability shows that the GII group has a higher diversity index (3.13 bits). The factor discriminating this group is the humidity of the hydromorphic soil. Generally, the trend of the equitability indices reflects the anthropization of herbaceous plant groups. Indeed, equitability varies from 0 to 1. It tends towards zero when one species largely dominates the others and is equal to 1 when all species have the same abundance (Barbault , 1997). An equitability index lower than 60% (< 0.6) characterizes a disturbed environment ( Dajoz , 2006). Ultimately, the edges of market garden wetlands are subject to various disturbances requiring mitigation measures.

**III.2.2. Floristic affinities between plant groups**

The study of plant groups constitutes a fundamental source of basic data important for the conservation, development and sustainable management of natural ecosystems even if, in certain cases, the ecological interpretation of the identified groups may seem difficult (Hakizimana et al., 2012). The individualized plant groups in the herbaceous vegetation explain the spatial heterogeneity of the edges of market garden wetlands. The analysis of this spatial heterogeneity shows that the edges of wetlands are subdivided into four floristically distinct herbaceous plant groups. Indeed, the herbaceous plant group GIII and the herbaceous plant groups GI, GII and GIV are floristically heterogeneous. The plant group GIII is distinguished from the others by a low species richness and by the presence of a small group of species specific to this group. This group consists of ombrophytes (*Achyranthes aspera* , *Aneilema Benin* , *Brachiaria lata* , *Costus afer* and *Yua thomsonnii* ) growing under the cover of the plantain plantation. Such a grouping can be translated by a strong presence of trees and the nature of the substrate (Faye et al., 2020). On the other hand, the floristic procession of the herbaceous plant groups GI, GII and GIV appears to be dominated by species of the *Asteraceae* , *Cyperaceae* and *Poaceae families* , the presence of which indicates an advanced degradation of the soil structure (Ousseina et al., 2013).

**III.2.3. Ecological spectra**

The spectrum of biological forms provides valuable information on the structure, physiognomy and adaptive strategies of plant groups (Bangirinama et al., 2010). The analysis of biological forms highlights the importance of therophytes in terms of abundance in the GI (46.60%), GII (49.20%) and GIV (34.80%) plant groups. According to Yota et al. (2013), the high coverage of therophytes is an indicator of degradation within herbaceous plant groups. This degradation is explained by the preponderance of agricultural activities (market gardening) in the edges of wetlands. Phytogeographic types are good indicators of the dynamism or stability of plant groups (Sanou et al., 2023). On the chorological level, the distribution of species in phytogeographic types at the level of market gardening wetlands shows an abundance of species with a wide distribution. These results corroborate those obtained in the Koupa forest gallery Matapit , West Cameroon (Momo Solefack et al., 2018). Indeed, these same authors have shown that the presence of species of this phytogeographic type in the vegetation is an indicator of the degradation and instability of ecosystems.

**Conclusion**

This work allowed floristic diversity of herbaceous vegetation in the edges of the market gardening wetlands of the city of Yaoundé and its surroundings. This flora is dominated by *Asteraceae* (18.36%) and *Fabaceae* (10.20%). In addition, four herbaceous plant groups were identified. The diversity index shows that the herbaceous plant groups are moderately diversified. The analysis of biological forms shows a significant proportion of therophytes and the phytogeographic types are essentially dominated by species with a wide distribution which reflect anthropization. It is therefore appropriate to place particular emphasis on the preservation of the edges of the wetlands of the city of Yaoundé and its surroundings from agricultural activities and in particular market gardening; and to explore their contribution to carbon storage.

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