Research article

Floristic diversity of receiving environments polluted by effluent from agri-food industries

N.A. Noukeu a,b,*, R.J. Priso a,1, S.D. Dibonga a,b, D. Ndongo a,1, L. Kono b,1, D. Essono b,1

a Faculty of Science, University of Douala, P.O. Box 24157, Douala, Cameroon
b Faculty of Science, University of Yaounde I, P.O. Box 812, Yaounde, Cameroon

A R T I C L E   I N F O

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A B S T R A C T

Till date, there are few studies on the flora found in receiving environments polluted by effluent from agri-food industries. Floristic inventories of ten receiving environments in Cameroon were carried out using the line transect method from upstream to downstream discharge areas in the Littoral and Center regions during the dry and rainy season. The abundance/dominance (AD) values of each floristic survey was assessed using Braun-Blanquet scale. Species richness of the different receiving environments is marked by higher and lower Shannon Weaver (H') diversity index values, respectively in the rainy season and dry season from upstream to downstream. Regularity values (R) show that the maximum number of species is involved in the covering of the surface. In terms of floristic composition, the Simpson's diversity index (D) shows similarities between the different receiving environments. The Sorensen index (Q) shows similar number of species from upstream and downstream zones of the same site. Nitrophilous species are abundant. Some could be organic pollution indicators, namely: Pennisetum purpureum, Cynodon dactylon, Commelina benghalensis, Lemna minor, Acroceras zizanoides, Echinochloa pyramidalis and Panicum maximum. The Poaceae family dominates the ten receiving environments.

1. Introduction

In the world, the role played by agro-industries is crucial for the food security of populations that are growing exponentially. However, the damage caused by their solid or liquid discharges is a problem for the preservation of the environment. In Cameroon there are more than 500 agro-industries spread over all ten regions. The agri-food industries are the most represented with sectors such as breweries, dairies, oil mills, confectioneries, sugar factories, distilleries, slaughterhouses and livestock farms, and chocolate factories (Noukeu et al., 2016). These industries use natural ecosystems as landfills due to the lack of an appropriate treatment system. Indeed, the effluents they produce are sometimes discharged into the environment in an uncontrolled manner. The environment here represents the receiving environments that are natural environments. The receiving environments of the coastal and central regions receive wastewater from the agro-food industries that have been established in Cameroon for more than 40 years today. These receiving environments have a purifying potential and it is the living organisms present in these ecosystems, such as plants, that will consume and degrade the polluting molecules resulting from effluents.

These fairly diversified effluents, mainly characterized by high levels of more or less biodegradable organic matter (Vymazal, 2014), have a significant impact on receiving environments (Magdalena et al., 2019). As a result, the eutrophication of the receiving waters due to high levels of nitrogen and phosphorus in the effluents is very marked (Peu et al., 2004; Vaverková et al., 2012). In addition, the obvious consequence of such discharges in receiving environments is the strong colonization of these environments by vegetation resulting from the change of some environmental, physical and/or chemical parameters. Thus, plants in an ecosystem are affected by the phenomena that it undergoes, and may appear as environmental change markers (Natalia et al., 2017; Xiaoyun et al., 2018).

Today, biological data are increasingly used for environmental monitoring as they reflect the disturbances on ecosystems (Priso et al., 2014; Suchkovaa et al., 2014; Nguemt et al., 2017; Sehinde et al., 2016). Biomonitoring of pollution is a valuable tool for the implementation of environmental policy. Plants provide a singular opportunity to explore biological effects of contamination and give reliable information about the quality and characteristics of the environment. On the other hand, plant species are affected by anthropogenic activities, this process of
disturbance, or in other words an event at which some plant species are suppressed, opening the space for colonization by allochthonous plant species. On the basis of this reasoning, it has been hypothesized that effluent discharges from the agri-food industries could modify the floral diversity of receiving environments.

Vegetation is a key aspect given its habitat and trophic role, and also because it helps observe species. Given the biodiversity of receiving environments, many plant species can be identified and classified in a pollution context according to their dominance in the environment (Fonkou et al., 2005; Qureshi et al., 2011; Marianne, 2012). Floristic diversity is a reflection of environmental condition, physiognomy and biotic influences. Floristic Inventory by plant taxonomists is a general practice throughout the world to have collected more information about plants. A flora is a complete checklist of plant species growing in any geographic area (Zeb et al., 2017). Through this practice, important data is recorded like the concept of indicator assemblages based on the observation that specific groups of species are found in certain habitats and not in others. Those species most tolerant to a particular type of pollution have been referred to as pollution indicators and a particular association or constellation of species which consistently occurs under specific pollution conditions is referred to as a pollution indicator assemblage. The aim is to monitor the impact of disturbances on vegetation in these environments. It is worth noting that studies have been carried out by several authors in Cameroon on the use of macrophytes as river water quality indicators (Priso et al., 2012); on the impact of pollution on the ecology, behavior and distribution of vegetation in aquatic ecosystems (Dibong and Ndjourondo, 2014). Similarly, studies carried out by Fonkou et al. (2005), showed the diversity of macrophytes in some polluted and unpolluted swamps. However, in this study, several receiving environments are disturbed by a common source of pollution, namely effluents from agri-food industries. Moreover, vegetation in the receiving environments of agri-food effluent is rather poorly known and still nascent in Cameroon. Floral inventories are therefore necessary. In order to understand the extent of degradation and the floral diversity of receiving environments, the main objective of this study is to show the floristic diversity of receiving environments polluted by effluent from agri-food industries in Cameroon in terms of species richness, composition and diversity. More specifically, it will involve inventorying the plant flora of ten receiving environments upstream and downstream of the pollution source during the rainy and dry seasons. We compared the species number of ten receiving environments upstream and downstream sites and evaluated the absolute cover of the most abundant species, species richness and diversity at each site.

2. Materials and methods

2.1. Study site

The floristic inventory was conducted from January-2014 to March-2015. The tools during research work were map of the areas, note book, pencil, plant presser, old newspaper, bags, knife and digital camera. Ten receiving environments of agri-food industries were studied (Table 1). The inventory of plant species was carried out during two periods, 2014 and 2015. The tools during research work were map of the areas, note book, pencil, plant presser, old newspaper, bags, knife and digital camera. Transects were established upstream to 1 km apart. For vegetation inventories, 1m² quadrats were delimited on each side of each transect. Plant species found in the different receiving environments were collected and identified by botanist-systematicians with the help of flora of Cameroon. Unknown species have been identified at the Cameroon National Herbarium in Yaounde.

2.2. Data collection

The linear transect method was used during the floristic inventory. It consists of identifying the vegetation along a random line in the study area with the objective to follow the variation of the vegetation at both the upstream and downstream levels (Duvigneaud, 1981; Skinner et al., 1994; Dibong and Ndjourondo, 2014). The number and length of transects depended on the area, the accessibility of the sites, but also on the homogeneity of the vegetation. Transects were established upstream to downstream of the discharge area of effluent from agri-food industries; the upstream and the downstream levels are 1 km apart. For vegetation surveys, 1m² quadrats were delimited on each side of each transect. Plant species found in the different receiving environments were collected and identified by botanist-systematicians with the help of flora of Cameroon. Unknown species have been identified at the Cameroon National Herbarium in Yaounde.

2.3. Data analysis

The biodiversity changes caused by the impact of effluent discharges from the agri-food industries into receiving environments were assessed based on the species diversity measured by the Shannon-Weaver Index (1963). This species diversity index (H') is based on both the number of species identified in the surveys and the cover of the different species. In this study, the Braun-Blanquet abundance-dominance coefficient was used according with Priso et al. (2010, 2012); Fonkou et al. (2005); Jafari et al. (2006). Ecological Indices were calculated as per the formulae given by Ludwig and Reynolds (1988).

The calculation of the species diversity index of receiving environments was therefore determined by the following equation:

\[
H' = \sum P_i \log_2 P_i 
\]

where \(P_i\) is the occurrence probability or presence index which is calculated on the basis of the ratio between average cover of the species i (RMI) and the total average cover; RMI/RMI.

The regularity index (R) or Pielou fairness index that often comes with the Shannon-Weaver index has been used to measure the distribution of individuals within the species. It is calculated using the following formula:

\[
R = H'/H'_{\text{max}} 
\]

\(H'_{\text{max}}\) is the maximum diversity and corresponds to \((\log_2 S)\) where S is the total number of species (Priso et al., 2014).

The Simpson Index by Simpson (1949); \(D\), which represents the probability for two individuals randomly selected from a sample to belong to the same species, is calculated using the following formula:

\[
D = \sum P_i^2 
\]

### Table 1

Receiving environments inventoried according to agri-food sectors.

| Study sites        | Type of industry sector       | Geographical coordinates | Transect labels and quadrant number in each site |
|--------------------|--------------------------------|--------------------------|------------------------------------------------|
| SOSUCAM            | Sugar refinery               | N04.44383°C14            | T1 (36), T2 (40), T3 (26), T4 (20) |
| Mbandjock          |                               | E011.90853°C14           | T1 (36), T2 (40), T3 (26), T4 (20) |
| SOSUCAM Nkoteng    | Sugar refinery               | N04.28331°C14           | T1 (22), T2 (30), T3 (26) |
|                   |                               | E012.06019°C14           | T1 (22), T2 (30), T3 (26) |
| ADIC Mbandjock     | Distillery                   | N04.44641°C14           | T1 (20), T2 (30), T3 (26) |
|                   |                               | E011.90167°C14           | T1 (20), T2 (30), T3 (26) |
| FERMENCAM Douala   | Distillery                   | N04.06541°C14           | T1 (20), T2 (30), T3 (26) |
|                   |                               | E009.37180°C14           | T1 (20), T2 (30), T3 (26) |
| Douala             | Slaughterhouse               | N04.11097°C14           | T1 (20), T2 (34), T3 (26) |
|                   |                               | E009.64572°C14           | T1 (20), T2 (34), T3 (26) |
| Yaounde            | Sugar refinery               | N03.92236°C14           | T1 (20), T2 (34), T3 (26) |
|                   |                               | E011.53264°C14           | T1 (20), T2 (34), T3 (26) |
| SLOKHUVING Yaounde | Slaughterhouse               | N04.44383°C14           | T1 (20), T2 (34), T3 (26) |
|                   |                               | E011.90853°C14           | T1 (20), T2 (34), T3 (26) |
| SCR. MAYA Douala   | Oil Mill/Soap                | N04.09846°C14           | T1 (24), T2 (30), T3 (26) |
|                   |                               | E009.963154°C14         | T1 (24), T2 (30), T3 (26) |
| GUINNESS Douala    | Brewery                      | N04.05057°C14           | T1 (24), T2 (30), T3 (26) |
|                   |                               | E009.74431°C14           | T1 (24), T2 (30), T3 (26) |
| FERME H & F        | Livestock                    | N03.84495°C14           | T1 (20), T2 (30), T3 (26) |
| Yaounde            |                               | E011.45466°C14           | T1 (20), T2 (30), T3 (26) |
The Sorensen’s similarity coefficient enabled to compare the similarities between the communities (Priso et al., 2012). This coefficient emphasizes the joint presence of two species in the same place, and is determined by the relation:

\[ Q = \frac{2a}{(2a + b + c)}. \] (4)

With \( a \) = number of species common to both environments; \( b \) = number of species present in the environment A and absent in the environment B; \( c \) = number of species present in the environment B and absent in the environment A.

The use of Microsoft Excel and XLSTAT 15.2 version 2015 allowed for both tabular and graphical presentation of the hierarchical classification of vegetation data (Chessel et al., 2004). The correspondence factor analysis (CFA) for upstream and downstream vegetation data according to seasons (Greenacre and Pardo, 2006).

3. Results

3.1. Floristic composition of the upstream and downstream zones in rainy and dry season

Table 2 shows the number of species identified upstream and downstream in receiving environments during the rainy and dry seasons. Table 3 shows the dominant species in each environment according to upstream, downstream, and different seasons. In the rainy season, sixty-four species were identified upstream and downstream of the Fermencam site. Analysis carried along the upstream transects shows that a total of 18 plant species, divided into 16 genera and 10 families. The species identified are emergent hydrophytes and herbaceous, with some shrubby species. Two families appear to be the most represented; the Poaceae and the Commelinaceae. The landscape of the receiving environment is largely dominated by a high number of Cydonon dactylon individuals. This number is higher in downstream with a total of 46 species divided into 43 genera and 28 families. The dominant species are: Cydonon dactylon, Commelina benghalensis and Acroceras zizanoides. In the dry season, upstream of the Fermencam site has 17 plant species divided into 16 genera and 13 families with the dominance of Commelina benghalensis and Cydonon dactylon individuals. Downstream 35 species divided into 35 genera and 23 families were identified. Lemna minor and Pistia stratiotes individuals dominate the downstream waterbodies of Fermencam discharges. Upstream and downstream are dominated by Poaceae family.

In the rainy season at the Douala slaughterhouse, there are 47 species divided into 40 genera and 23 families. The dominant families are Poaceae and Cyperaceae. The environment is dominated by a high number of Setaria barbata and Cydonon dactylon individuals. Analysis carried along the upstream transects shows a total of 18 plant species, divided into 16 genera and 10 families. The species identified are emergent hydrophytes and herbaceous, with some shrubby species. Two families appear to be the most represented; the Poaceae and the Commelinaceae. The landscape of the receiving environment is largely dominated by a high number of Cydonon dactylon individuals. This number is higher in downstream with a total of 46 species divided into 43 genera and 28 families. The dominant species are: Cydonon dactylon, Commelina benghalensis and Acroceras zizanoides. In the dry season, upstream of the Fermencam site has 17 plant species divided into 16 genera and 13 families with the dominance of Commelina benghalensis and Cydonon dactylon individuals. In downstream 35 species divided into 35 genera and 23 families were identified. Lemna minor and Pistia stratiotes individuals dominate the downstream waterbodies of Fermencam discharges. Upstream and downstream are dominated by Poaceae family.

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The Yaounde slaughterhouse in the rainy season is dominated upstream by Echinoclooa pyramidalis and downstream by Cyanodon dactylon. A total of 36 upstream and downstream species divided into 34 genera and 23 families were identified. The Poaceae and Asteraceae are the most dominant families. Thirty one species, divided into 28 genera and 20 families dominated by Poaceae and Asteraceae, have been identified at the upstream discharges of the Yaounde slaughterhouse in the dry season. The dominant species are Luffa aegyptiaca, Tithonia diversifolia and Hallea stipulosa. Downstream has 22 species divided into 22 genera and 11 families, dominated by Poaceae and Amaranthaceae. The dominant species are Tithonia diversifolia, Echinoclooa pyramidalis and Pennisetum purpureum.

The receiving environment of the company SCR Maya is dominated upstream and downstream by Ipomea carica and Echinoclooa pyramidalis in the rainy season. 27 species divided into 26 genera and 11 families were identified. Poaceae and Cyperaceae are the dominant families. In the dry season, 41 species divided into 39 genera and 20 families with the dominance of Cyperaceae and Poaceae were identified upstream. The dominant species are Eclipta prostrata, Commelina benghalensis, Echinoclooa pyramidalis and Kyllinga erecta. Downstream has 21 species divided into 18 genera and 13 families, dominated by Cyperaceae. The dominant species are Hallea stipulosa and Acroceras zizanoides.

In the rainy season, upstream of the company Guinness is dominated by Panicum maximum and Bambusa vulgaris. Downstream is dominated by Commelina benghalensis. Twelve species in upstream and downstream divided into 10 genera and 11 families were identified. In the dry season, upstream discharge area of the company Guinness is dominated by Passiflora sp. and Commelina benghalensis. Downstream is dominated by Panicum maximum. 10 species divided into 9 genera and 9 families were identified. Upstream and downstream are dominated by Poaceae family.

In the rainy season, upstream of the company Ferme Henri et Frères (Ferme H & F) is dominated by Commelina benghalensis and Acroceras zizanoides. Downstream is dominated by Echinoclooa pyramidalis and Chromolaena odorata. Eighty-seven plant species were inventoried. Upstream has 23 families and downstream 21 families both dominated by the Poaceae, Cyperaceae and Asteraceae families. In the dry season, the

| Table 2 |
| Number of species identified in receiving environments according to upstream, downstream and the seasons. |

| Season | Transect | Abattoir Douala | Abattoir Yaounde | ADIC | FERMENCAM | GUINNESS | FERME H & F | SCR MAYA | SOSUCAM Mbandjock | SOSUCAM Nkoteng | SOFAVINC |
|--------|---------|----------------|-----------------|------|-----------|----------|------------|----------|-----------------|----------------|----------|
| Rainy season | Upstream | 47 | 16 | 9 | 18 | 5 | 52 | 17 | 43 | 42 | 17 |
| Dry season | Downstream | 28 | 20 | 20 | 46 | 7 | 35 | 10 | 29 | 31 | 19 |
|        | Upstream | 37 | 31 | 14 | 17 | 4 | 10 | 41 | 28 | 20 | 11 |
|        | Downstream | 57 | 22 | 26 | 35 | 5 | 12 | 21 | 36 | 26 | 33 |
upstream discharge area of the Ferme H & F is dominated by *Echinochloa pyramidalis* and *Ageratum conosoides*, while downstream discharge area is dominated by *Commelina benghalensis* and *Polygonum lanigerum*. Twenty-two plant species divided in 20 genera and 12 families, with Poaceae as the most represented, were inventoried.

The receiving environment of the company Sofavinc is dominated upstream by *Pennisetum purpureum* and *Panicum maximum* individuals in rainy season. Downstream is dominated by *Echinochloa pyramidalis* and *Polygonum limbatum*. Forty plant species divided in 41 genera and 17 families, with Poaceae as the most represented family, were inventoried.

The site of the company Sosucam Bmandjock is dominated upstream by *Pennisetum purpureum* and *Panicum maximum* individuals. Downstream is dominated by *Acrorcas zizanoides* and *Halopegia sp.* In both areas, 72 plant species divided into 64 genera and 29 families were inventoried.

### Table 3
Dominate species identified upstream and downstream of receiving environments according to the seasons.

| Season | Upstream | Downstream |
|--------|----------|------------|
|        | Rainy    | Dry        | Rainy    | Dry        |
|        |          |            |          |            |
| Fermente |          |            |          |            |
| Guiness |          |            |          |            |
| SCR Maya |          |            |          |            |
| Sofavinc |          |            |          |            |
| Sosucam Nkoteng |      |            |          |            |
| Sosucam Mbandjock |      |            |          |            |
| Adic  |          |            |          |            |

represented families. In the dry season, the upstream receiving environment of Sofavinc is dominated by *Pennisetum purpureum*, *Panicum maximum*, *Commelina benghalensis* and *Luffa aegyptiaca*. Downstream is dominated by *Echinochloa pyramidalis*, *Amaranthus esculentus* and *Polygonum limbatum*. 44 plant species divided in 41 genera and 17 families, with Poaceae as the most represented family, were inventoried.

The site of the company Sosucam Bmandjock is dominated upstream by *Pennisetum purpureum* and *Panicum maximum* individuals. Downstream is dominated by *Acrorcas zizanoides* and *Halopegia sp.* In both areas, 72 plant species divided into 65 genera and 29 families were inventoried.

### Table 4
Indices calculated with floristic data in rainy and dry season.

| Season | Sites | Transect | Rainy | Dry |
|--------|-------|----------|-------|-----|
|        |       |          | H^2 | H_{max} | R | D | Q | H^2 | H_{max} | R | D | Q |
| FERMECAM | Upstream | 2.56 | 4.17 | 0.61 | 0.73 | 0.52 | 1.41 | 4.09 | 0.35 | 0.58 | 0.39 |
|        | Downstream | 3.97 | 5.61 | 0.71 | 0.82 | 0.24 | 3.38 | 5.21 | 0.64 | 0.25 | 0.37 |
| Abattoir Douala | Upstream | 3.45 | 5.55 | 0.44 | 0.91 | 0.67 | 3.83 | 5.21 | 0.64 | 0.25 | 0.37 |
| Abattoir Yaounde | Downstream | 1.46 | 4.8 | 0.3 | 0.75 | 0.67 | 5.12 | 5.83 | 0.87 | 0.35 | 0.25 |
| ADIC | Upstream | 3.71 | 5.16 | 0.72 | 0.96 | 0.77 | 4.58 | 4.95 | 0.92 | 0.25 | 0.41 |
|        | Downstream | 3.39 | 5.32 | 0.63 | 0.89 | 0.77 | 3.26 | 4.46 | 0.73 | 0.17 | 0.25 |
| SCR Maya | Upstream | 3.46 | 4.86 | 0.71 | 0.77 | 0.37 | 3.17 | 3.81 | 0.36 | 0.22 | 0.25 |
|        | Downstream | 1.83 | 2.6 | 0.65 | 0.71 | 3.6 | 4.7 | 0.77 | 0.14 | 0.25 |
| Sosucam Nkoteng | Upstream | 4.54 | 5.39 | 0.87 | 0.86 | 0.6 | 4.74 | 5.24 | 0.90 | 0.55 | 0.63 |
|        | Downstream | 3.84 | 4.95 | 0.77 | 0.90 | 0.67 | 3.76 | 5.13 | 0.73 | 0.14 | 0.41 |
| Sosucam Mbandjock | Upstream | 4.65 | 6.27 | 0.74 | 0.88 | 0.93 | 4.78 | 6.13 | 0.78 | 0.66 | 0.8 |
|        | Downstream | 4.83 | 6.04 | 0.81 | 0.81 | 0.75 | 4.11 | 5.78 | 0.71 | 0.35 | 0.25 |
| Sofavinc | Upstream | 3.25 | 4.08 | 0.78 | 0.67 | 0.75 | 4.4 | 5.36 | 0.82 | 0.77 | 0.68 |
|        | Downstream | 2.93 | 4.32 | 0.68 | 0.64 | 3.81 | 4.39 | 0.87 | 0.49 | 0.25 |
| SCR Maya | Upstream | 3.17 | 4.64 | 0.68 | 0.79 | 0.88 | 3.31 | 4.46 | 0.74 | 0.14 | 0.27 |
|        | Downstream | 3.56 | 5.12 | 0.69 | 0.721 | 0.43 | 4.16 | 4.86 | 0.86 | 0.78 | 0.86 |
| Ferme H & F | Upstream | 5 | 6.04 | 0.82 | 0.95 | 0.43 | 3.16 | 3.89 | 0.90 | 0.89 | 0.86 |
|        | Downstream | 4.96 | 5.55 | 0.89 | 0.87 | 0.25 | 2.84 | 3.58 | 0.80 | 0.95 | 0.25 |
| Guinness | Upstream | 2.26 | 3.58 | 0.63 | 0.75 | 0.72 | 2.4 | 3.16 | 0.75 | 0.26 | 0.54 |
|        | Downstream | 1.71 | 3.45 | 0.49 | 0.71 | 0.71 | 1.66 | 3.32 | 0.5 | 0.42 | 0.25 |
Poaceae and Cyperaceae are the most represented families. In the dry season, the upstream discharge area of Sosucam Mbandjock is dominated by *Acroceras zizanoides*, *Pennisetum purpureum*, *Panicum maximum* and *Halopegia azurea*, while its downstream discharge area is dominated by *Echinochloa pyramidalis*. Sixty seven plant species divided into 64 genera and 25 families were inventoried. Poaceae and Cyperaceae are the most represented families.

3.2. Indices calculated with floristic data in upstream and downstream

Table 4 shows the index values calculated with the plant data of the upstream and downstream receiving environments according to the seasons.

3.2.1. In the rainy season

Values obtained upstream for the Shannon-Weaver index (H') ranged from 2.26 in the Guinness site to 4.65 in the Sosucam Mbandjock site. Values obtained downstream range from 1.46 at the Douala slaughterhouse to 4.83 at the Sosucam Mbandjock site.

High maximum diversity values (H'\text{max}) are observed at Sosucam Mbandjock (6.27); at the Douala slaughterhouse (5.55) and at Sosucam Nkoteng (5.39). Values obtained downstream are 5.61 at Fermecam; 5.12 at Sofavinic and 6.04 at the Sosucam Mbandjock site.

PieuIo's equitability or regularity (R) ranges from 0.61 to 0.82 respectively in the upstream discharge area of Fermecam and Ferme Henri et Frères. Downstream, it ranges from 0.3 to 0.81 respectively at the Douala slaughterhouse and at Sosucam Mbandjock.

In all sites, the Sorensen index (Q) calculated between upstream and downstream of each site ranges from 0.52 in the Fermecam site to 0.93 in the Sosucam Mbandjock site. The Simpson index (D) is comprised between 0.64 and 0.95.

3.2.2. In the dry season

Values obtained upstream for the Shannon-Weaver index (H') ranged from 1.37 in the Adic site to 4.78 in the Sosucam Mbandjock site. Values obtained downstream range from 3 at Fermecam to 5.12 at the Douala slaughterhouse site.

High maximum diversity values (H'\text{max}) are observed upstream at Sosucam Mbandjock (6.63) site; at the Scr Maya (5.36) and Sosucam Nkoteng (5.24) site. Values obtained downstream are 5.17 at Fermecam, 5.83 at the Douala slaughterhouse and 5.78 at the Sosucam Mbandjock site.

PieuIo's equitability or regularity (R) ranges from 0.35 to 0.92 respectively in the upstream discharge area of Fermecam and Ferme Henri et Frères. It ranges from 0.59 to 0.87 in the downstream discharge area of Fermecam and Douala slaughterhouse respectively.

In all sites, the Sorensen index (Q) calculated between upstream and downstream of each site ranges from 0.27 in the Sofavinic site to 0.8 in the Sosucam Mbandjock site. Similarly, the Simpson index varies across sites.

3.3. Correspondence factor analysis in the rainy and dry season

The Correspondence factor analysis (CFA) carried out for the rainy season in Fig. 1a shows that *Ipomoea caica* and *Acroceras zizanoides* species are found in the Scr Maya site (upstream-downstream) and downstream of the Douala slaughterhouse. *Rynchospora corymbosa*, *Triumfetta cordifolia*, *Kyllinga erecta*, *Alternanthera sessilis* and *Costus afer* species are found in the Fermecam site (upstream and downstream) and downstream of the Sosucam Mbandjock site. *Opilimens hirtellus*, *Cynodon dactylon*, *Fleuria ovalifolia*, *Setaria barbata*, *Convoluus involucrat*, *Asystasia gangetica* and *Zehnaria scabra* species are found both upstream and downstream of the site of the Yaounde slaughterhouse, and upstream of Adic and Douala slaughterhouse discharge areas. Other species, such as *Panicum maximum*, *Ageratum conyzoides*, *Commelina benghalensis*, *Echinochloa pyramidalis*, *Senna occidentalis*, *Bambusa vulgaris*, *Elesline indica*, *Amaranthus viridis*, *Ricinus communis*, *Euphorbia heterophylla*, *Tithonia diversifolia*, *Chromolaena odorata*, *Pennisetum purpureum*, *Mimosa pudica*, *Halopegia azurea*, *Amaranthus esculentus*, *Passiflora foetida* and *Musanga cecropoides* are found in the upstream and downstream discharge area of Ferme H & F, Guinness and Sofavinic, upstream discharge area of Sosucam Mbandjock, Sosucam Nkoteng and Adic.

Correspondence factor analysis (CFA) carried out for the dry season in Fig. 1b shows that species such as: *Acroceras zizanoides*, *Pennisetum purpureum*, *Alternanthera sessilis*, *Echinochloa pyramidalis*, *Halopegia azurea*, *Alchornea cordifolia*, *Saccarum officinarum*, *Kyllinga erecta*, *Centrosema pubescens*, *Ludwigia decurrens*, *Senna javanica*, *Ipomoea cairica*, *Nymphaea lotus*, *Chromolaena odorata*, *Cleonie ciliata*, *Panicum maximum*, *Paspalum vaginatum*, *Polygonum limbatum*, *Amaranthus esculentus*, *Hallea stipulosa*, *Tithonia diversifolia* and *Musanga sp*. are found in the upstream and downstream discharge area of Sofavinic, Scr Maya, Yaounde slaughterhouse, Adic, Ferme H & F, and in the downstream discharge area of the Douala slaughterhouse. *Cynodon dactylon*, *Commelina benghalensis*, *Ipomoea involucrat* and *Senna occidentalis* are found in the upstream discharge areas of Fermecam and of Douala slaughterhouse, and both upstream and downstream discharge area of Guinness. However, *Lemna minor*, *Pistia stratiotes*, *Eclipta prostrata*, *Asystasia gangetica*, *Physalis angulata*, *Brachiaria decumbens* are found in the downstream discharge area of Fermecam.

3.4. Ascending hierarchical classification carried out in the rainy and dry season

The Ascending Hierarchical Classification of the floristic data in the rainy season of Fig. 2a made it possible to group species inventoried in all the receiving environments into three classes: the first includes *Acroceras zizanoides* and *Triumfetta cordifolia*; the second includes *Echinochloa pyramidalis* and *Polygonum limbatum*, and the third one includes *Tyttonia diversifolia* and *Musanga cecropoides*.

The Ascending Hierarchical Classification of the floristic data in the dry season in Fig. 2b made it possible to group the species inventoried in all the receiving environments into five classes: the first one includes *Elesine indica* and *Setaria barbata*; the second includes *Tyttonia diversifolia*, the third one includes *Cleonie ciliata* at *Panicum maximum*; the fourth class includes *Commelina benghalensis* and *Pistia stratiotes*; the fifth includes *Kyllinga erecta* and *Halopegia sp.*.

3.5. Some dominant plant species in all the receiving areas inventoried

Species observed in Fig. 3 (Supplementary content) showed, in the various receiving environments, a strong colonization with their number of individuals. Table 5 lists the species inventoried in all study sites.

4. Discussion

4.1. Influence of season, upstream and downstream, on the floristic diversity of receiving environments

The floristic inventory over two seasons made it possible to see the dynamics of the vegetation. The species richness of the upstream in the rainy season is higher than the downstream, whereas in the dry season the species richness of the downstream is higher than the upstream. However, in all receiving environments, the rainy season is more diverse than the dry season. This is marked by very high values of maximum diversity (H'\text{max}), Shannon index (H') and Pieulou equitability (R). The diversity indices obtained are in accordance with Dajoz (2006), who points out that a high diversity index represents favorable environmental conditions.

The diversity indices H' and H'\text{max} vary between upstream and downstream of each site, and this can be explained by the richness of the soils upstream in organic matter necessary for the development of the vegetation. However, the influence of seasons on soil characteristics may play a role in the species richness between upstream and downstream.
Fig. 1. The CFA of floristic data of the upstream and downstream receiving environments during the 1.a) rainy season; 1.b) dry season; A: upstream, V:downstream, 1:Fermencam, 2:Douala slaughterhouse, 3: Adic, 4: Yaounde slaughterhouse, 5: Scr Maya, 6: Guininess, 7: Ferme H&F, 8: Sofavinc, 9: Sosucam Mbandjock, 10: Sosucam Nkoteng. Aziz: Acroceras zizanoides, Agco: Ageratum conyzoides, Halo: Halopegia sp, Alse: Alternanthera sessilis, Ame: Amaranthus esculentus, Amvi: Amaranthus viridis, Asyg: Asystasia gangetica, Bavu: Bambusa vulgaris, senoc: Sena occidentalis, Chdo: Chromolaena odorata, Com: Commelina benghalensis, Coinv: Convovulus involucrata, Cafe: Costus afer, Cyty: Cynodon dactylon, Echi: Echinochloa pyramidalis, Soli: Solanum nigrum, Tyto: Tytoria divertifolia, Zeh: Zehnaria scabra, Euli: Eleusine indica, Ephh: Euphorbia heterophylla, Plou: Pleria ovalifolia, Ipot: Ipomoea invisa, Mipu: Mimosa pudica, Musp: Musanga cecropoides, Opl: Oplismenus hirtellus, Pan: Panicum maximum, Pas: Passiflora foetida, Pen: Pennisetum purpureum, Poli: Polygonum limbatum, Kill: Kyllinga erecta, Rhy: Rhynchospora sp, Rymi: Ricinus communis, Seba: Setaria barbata, Aziz: Acroceras zizanoides, Alex: Alchornea cordifolia, Ames: Amaranthus esculentus, Brasp: Bracharia sp, Cydy: Cydonia dactylon, Cyp: Cynodon dactylon, Ecl: Eclipta prostrata, Emil: Emilia praetermissa, Hast: Halea stipulosa, Halpa: Halopegia sp, Ipot: Ipomoea cairica, Ipot: Ipomoea involucrata, Kille: Killinga erecta, Lemn: Lemna minor, Ludes: Ludwigia decurrens, Musp: Musa sp, Nym: Nymphaea lotus, Pan: Panicum maximum, Pasp: Paspalum sp, Phys: Physalis, Son: Solanum nigrum, Tito: Tityonia divertifolia.
Fig. 2. Dendrogram of floristic data obtained during the 2.a) rainy season and 2.b) dry season; Aczi: Acroceras zizanoides, Alco: Alchornea cordifolia, Alse: Alternanthera sessilis, Ames: Amaranthus esculenthus, Asyg: Asystasia gangetica, Brasp: Bracharia sp, Cenc: Centrosema pubescens, Chro: Chromolaena odorata, Cleom: Cleome ciliata, Comb: Commelina benghalensis, Cydc: Cydonon dactylon, Echipp: Echinochloa pyramidalis, Eclip: Eclipta prostrata, Emip: Emilia praeremissa, Euli: Eleusine indica, Hast: Hallea stipulosa, Hallo: Halopegia sp, Ipod: Ipomoea involucrata, Ipom: Ipomoea caurica, Ipotr: Ipomoea invisa, Kiler: Killinga erecta, Lemmi: Lemma minor, Ludes: Ludwigia decurrens, Musp: Musa sp, Nym: Nymphaea lotus, Pani: Panicum maximum, Pasp: Paspalum sp, Penp: Pennisetum purpureum, Phys: Physalis, Seba: Setaria barbata, Soni: Solanum nigrum, Tito: Tithonia diversifolia; Aziz: Acroceras zizanoides, Agco: Agaratum conyzoides, Hallo: Halopegia sp, Alse: Alternanthera sessilis, Amvi: Amaranthus viridis, Asyg: Asystasia gangetica, Bavu: Bambusa vulgaris, senoc: Sena occidentalis, Chlo: Chromolaena odorata, Coinv: Commelina benghalensis, Cypit: Cynodon dactylon, Echi: Echinochloa pyramidalis, Epli: Eclipta prostrata, Flov: Fleuria ovalifolia, Ipom: Ipomoea mauritiana, Mipu: Mimosa pudica, Mucr: Musanga cecropoides, Opli: Oplismenus hirtellus, Pass: Passiflora foetida, Penp: Pennisetum purpureum, Poli: Polygonum limbatum, kill: Killinga erecta, Rhyn: Rhynechospora sp, Rym: Ricinum comminnes, Seba: Setaria barbata.
Table 5: Floral composition of the upstream and downstream of the effluent receiving environments of the agri-food industries.

| Names of species Family |_names of species Family |
|-------------------------|-------------------------|
| Abutilon indicum (Link) Sweet Malvaceae | Ipomoea batatas (L.) Lam. Convolvulaceae |
| Acacia sp. Mimosaceae | Ipomoea caerica Sweet. Convolvulaceae |
| Acroclya citriata Forr. Euphorbiaceae | Ipomoea indica (Burm. f. Merr.) Merrill. Convolvulaceae |
| Acroclya hispida Burm. f. Euphorbiaceae | Ipomoea involucrata P. Beauv. Convolvulaceae |
| Acanthospermum hispidum DC Asteraceae | Ipomoea mauritiana Jacq. Convolvulaceae |
| Acrocarpus zizanoides (Kunth) Dandy Fabaceae | Kyllinga bulbosa P. Beauv. Cyperaceae |
| Aesculyna indica L. Asteraceae | Kyllinga erecta Schum. Cyperaceae |
| Ageratum conyzoides L. Euphorbiaceae | Lactuca araxeofolia (Wild.) Asteraceae |
| Alchornea cordifolia (Pers.) C.D. Diels & Schott Acanthaceae | Lema guineensis G.Don. Lamiaceae |
| Alstonia boonei De Wild. Amaranthaceae | Leonotis nepetifolia (L.) Ait. Lamiaceae |
| Alternanthera sessilis (L.) R. Br. ex DC Amaranthaceae | Leuca herbaespansa (L.) Alt. Lamiaceae |
| Amaranthus esculentus (L.) Amaranthaceae | Lippia multiflora Molderene Verbenaceae |
| Amaranthus spinosus (L.) Amaranthaceae | Ludwigia decurrens L. Onagraceae |
| Amaranthus viridis (L.) Amaranthaceae | Ludwigia decurrens L. Onagraceae |
| Arachis hypogaea L. Fabaceae | Ludwigia hyssopifolia (G.Don) Exell. Onagraceae |
| Aspilia africana (Pers.) C.D. Asteraceae | Manihot esculenta Crantz. Euphorbiaceae |
| Bidens pilosa L. Asteraceae | Mariatia sp. Marattiaceae |
| Borretia diffusa DC Rubiaceae | Mariscus altissimus Vahl Cyperaceae |
| Brachiaria decumbens Stapf Poaceae | Molochia cochinorlicia L. Malvaceae |
| Canna indica L. Cannaceae | Millettia macrophylla Benth. Fabaceae |
| Carica papaya L. Caricaceae | Mimosa invisa Mart. Mimosaceae |
| Cepocria pelata L. Cepocriciaceae | Mimosa pudica L. Mimosaceae |
| Celastris laxa Schum & Thonn. Celastraceae | Mimosa nigra Huber Mimosaceae |
| Centrocarpus pubescens Benth. Fabaceae | Mitracarpus villosus (Swartz) Malvaceae |
| Chromolaena odorata (L.) Capparidaceae | Morodera chloranti L. Cucurbitaceae |
| Cleome ciliata Schumach. & Thonn. Commelinaeae | Mucuna pruriens (L.) DC. var. pruriens Fabaceae |
| Colocasia esculenta (L.) Schott Araceae | Musa sapientum L. Musaceae |
| Combretum afrieri Engl. & Diels Combretaceae | Musa paradisiaca L. Musaceae |
| Combretum benghalensis L. Combretaceae | Musanga ceccropioides R. Br. ex Teijs. Capparidaceae |
| Combretum indicum (Link) Sweet Combretaceae | Myrianthus arboreus Rubiaceae |
| Commelina differa Burm. subsp. differa Poaceae | Nauclea diderrichii (De Wild. & T.Durand) Merrill. Rubiaceae |
| Commelina differa Burm. Poaceae | Neprolepis bissurata (Sw.) Schott Nephrolepidaceae |
| Commelina differa Burm. subsp. differa Poaceae | Neprolepis tremula (Lamarck) Schott Nephrolepidae |
| Convulvulus invovatus L. Convulvulaceae | Phrynchopara corymbosa (L.) Briton Fabaceae |
| Convulvulus sp. Convulvulaceae | Phyllanthus amarus (L.) Wild. Euphorbiaceae |

Table 5 (continued)

| Names of species Family | Names of species Family |
|-------------------------|-------------------------|
| Corchorus capsularis L. Tiliaceae | Nymphoides alba L. Nymphaeaceae |
| Corchorus olitorius L. Tiliaceae | Oldenlandia corymbosa L. Rubiaceae |
| Corchorus olitorius L. Tiliaceae | Opisthomena barmannii (Retz.) P. Beauv. Poaceae |
| Cucumeropsis manhii Naudin. Cucurbitaceae | Opisthomena hirtellus (L.) P.Bau. Poaceae |
| Cucumeropsis manhii Naudin. Cucurbitaceae | Oxalis barteri (Herb Smith) Oxalidaceae |
| Cucumis melo L. Cucurbitaceae | Oxalis corniculata L. Oxalidaceae |
| Cyathus marniana Hook. Cynodontidaceae | Panicum maximum Jacq. Poaceae |
| Cyatula prostrata (L.) Blume Amphicarpaeae | Papapalum conjugatum Berg. Poaceae |
| Cyperus distans L. Cyperaceae | Papapalum vaginatum Sw. Poaceae |
| Cyperus difformis L. Cyperaceae | Passiflora foetida L. Passifloraceae |
| Cyperus esculentus L. Cyperaceae | Penniisetum purpureum Schumach. Poaceae |
| Cyperus haspan L. Cyperaceae | Phyllanthus amarus Schum. & Thonn. Poaceae |
| Cyperus iria L. Cyperaceae | Phyllanthus discoideus (Bail.) Muhl. Poaceae |
| Cytosperma senegalense Schott Engl. Araceae | Phyllanthus sp. Phyllanthaceae |
| Dacryodes buettneri (Engl.) H. J. Lam Burseraceae | Physalis angulata L. Solanaceae |
| Digitaria horizontalis W. D. Wild. Poaceae | Pista stratiotes L. Araceae |
| Dioscorea bulbifera L. Dioscoreaceae | Polygonum lanigerum R. Br. Poaceae |
| Dioscorea senegalense Schott & Schinz Poaceae | Portulaca oleracea L. Portulacaceae |
| Drymaria cordata (L.) Wild. Cariophyllaceae | Pseudospondias microcarpa (A.Rich.) Engl. Anacardiaceae |
| Echinochloa pyramidalis (L.) Poaceae | Pyreus lanceolatus (Poir.) C.B.Clarke Poaceae |
| Echinochloa pyramidalis (L.) Poaceae | Rhynchosporum corymbosa (L.) Britton Fabaceae |
| Eclipsia prostrata L. Asteraceae | Rhus occidentalis Gray. Fabaceae |
| Elaeis guineensis Jacq. Areaceae | Saccharum officinarum Linn. Poaceae |
| Eleusine indica (L.) Gaertn. Poaceae | Sesamum occidentalis Gaertn. Caesalpiniaiflora Poaceae |
| Emilia praemorsa Muthe-Rehding Asteraceae | Setaria barbata (Lam.) Kunth Poaceae |
| Eragrostis ciliaris Poaceae | Setaria megaphylla (Steud) Dur. & Schinz Poaceae |
| Eragrostis ciliaris Poaceae | Sida alba L. Malvaceae |
| Eragrostis ciliaris Poaceae | Sida rhombifolia L. Malvaceae |
| Eragrostis ciliaris Poaceae | Solanum nigrum L. Solanaceae |
Table 5 (continued)

| Names of species | Family | Names of species | Family |
|------------------|--------|------------------|--------|
| Eucalyptus globulus | Myrtaceae | Solanum torvum | Solanaceae |
| Lahill. | Euphorbiaceae | Solanum monosperum | Solanaceae |
| Euphorbia heterophylla Desf. | Euphorbiaceae | Spathodea campanulata P. Beauv. | Bignoniaceae |
| Euphorbia hirta L. | Euphorbiaceae | Spathanthes acmella (L.) Murray | Asteraceae |
| Euphorbia hispida L. | Euphorbiaceae | Spathanthes filiculoides (Schumach. & Thonn.) | Asteraceae |
| Ficus exasperata Vahl. | Moraceae | Spondias mombin L. | Anacardiaceae |
| Ficus macrocarpa Welw. Ex Cufidlo | Moraceae | Sporophyllum pyramidalis P. Beauv. | Poaceae |
| Fimbristylis ferruginea (L.) Gailloud | Cyperaceae | Stachy认pha canaryensis (Rich.) vahl. | Verbenaceae |
| Flesara ovalifolia (Schum. & Thonn.) | Urticaceae | Sterculia rhinopetala K. Schum | Malvaceae |
| Flesara austrosteum (L.) Gaudich | Urticaceae | Syndrella nodiflora (Jacq.) Willd | Asteraceae |
| F. P. Blake | Urticaceae | Talinum triangulare (Schum.) | Tiliaceae |
| Halalea stipulosa (DC.) Leroy | Urticaceae | Tepliosa vogelli Hook.f. | Fabaceae |
| Halopogon sp. | Poaceae | Terminalis superba Engl. & Diels | Compositae |
| Haunninga danckelmaniana (J. & K.) | Maranthaceae | Tithonia diversifolia A. Gray | Asteraceae |
| Hewittia sublobata (L.f) Kuntze | Convolvolaceae | Vernonia amygdalina Delile | Asteraceae |
| Hydrolocarpus sp. | Hydrophyllaceae | Vitex doniana Sweet | Lamiaceae |
| Impatiens irvingii Hook. f. ex Oliv. | Balsaminaceae | Xanthosoma | Araceae |
| Imperata cylindrica (L.) Ritter | Poaceae | Zehneria scabra (Linn. (L.) Sonnd. | Cucurbitaceae |

(Chen et al., 2015). Frontier and Pichod-viaile (1995), pointed out that the species richness is optimal for an intermediate level of perturbation. Moreover, given the swampy nature of sites inventoried, the species richness upstream can also be explained by instability of the vegetation associated with a strong presence of xenocenous species but also by a pioneer character of permanent degradation, destructuring or rejuvenation. Marshy-type study sites experience fluctuations in water levels during the changing seasons, and these can influence the variation in soil concentrations and plant composition (Alenka et al., 2018). Indeed, when infiltrating, rain dilutes the concentrations of pollutants in the soil and thus allows plants to grow better during this season because of the process of self-purification (Noukeu and Priso, 2014; Sehar et al., 2015). Macrophytes inventoried at the various sites are subjected to periodic or permanent floods, and the degree of anoxic stress in the environment will depend on the frequency or degree of flood and will dictate the type of vegetation (Alenka et al., 2018).

In the 10 sites inventoried, the greater the Sorensen similarity index, the more upstream and downstream are similar to the number of common species (Priso et al., 2014). This is explained by the fact that the characteristics of the soil samples taken upstream and downstream are identical for certain measured physicochemical parameters. For the Simpson index (D), the closer its value is to 100%, the closer the environment is to the floristic composition.

Lower values of regularity (R) were found in rainy season upstream compared to downstream. The dry season, on the contrary, shows a regularity that decreases from upstream to downstream in four sites (Fernencam, Doula slaughterhouse, Adic and Sofavinc). The rest of the sites have regularity values where the upstream is higher than the downstream. Indeed, the regularity makes it possible to apprehend the relative disorder of the population. For Priso et al. (2012), a regularity greater than 0.5 shows that a maximum of species participates in the covering of the surface. A weak regularity indicates a great importance for some dominant species (Dujoz, 2006).

The receiving environments are colonized by a diversified flora, and the hypothesis that the changing seasons, upstream and downstream of the effluent discharge zones, can increase the species richness of the receiving environments has been proved. The use of plants to monitor the effects of pollution from agri-food industries shows their interest in disturbance and alarm conditions (Remon et al., 2005; Ramade, 2009). This is why plants appear as markers of environmental change (Diego et al., 2019).

4.2. Influence of the characteristics of the different sites on the floristic diversity of the receiving environments

The distribution of plant species in the various sites shows a variation. This variability depends on environmental conditions and the ability of plants to tolerate changes in the environment (Wafaa et al., 2010; Fahky et al., 2018). This variability depends on environmental conditions and the ability of plants to tolerate changes in the environment (Wafaa et al., 2010; Fahky et al., 2018). The increasing pollution associated with the discharge of agri-food effluents has led to an increase in the total nitrogen, total phosphorus, organic carbon and a high C/N ratio in the soils of receiving environments analyzed. Thus, the influence of upstream and downstream of rejection areas on the floristic diversity of receiving environments is clearly visible in the same site and across sites. In the upstream zone, the potential vegetation has been destroyed or replaced by groupings of species that are more resistant to organic pollution and to physical changes in the environment (Koutika et al., 2007; Liao et al., 2009).

In the downstream zone, the presence of certain groupings is more consistent with the potential vegetation and indicates better environmental conditions.

The presence of organic matter in the effluents from agri-food industries and their accumulation in the soil of the receiving environments has led to the growth of nitrophilous species which prefer substrates rich in easily absorbed organic matter and nitrogenous and phosphorus substances (Sharma et al., 2017). The nitrophilous plants that dominate all the sites are: Cynodon dactylon, Panicum maximum, Pennisetum purpureum, Pylanthus amarus, Physalis angulata, Kyllinga erecta, Cyathula prostrata, Althenarhenna sessilis, Cleome ciliata, Cyperus distans, Commelina benghalensis, Eleusine indica, Amaranthus spinosus, Amaranthus viridis, Acanthospermum hispidum, Mimosa invisa, Euphorbia hirta, Ludwigia hyssopifolia.

However, it is likely that all species inventoried in receiving environments will not be polluted and that increased nutrient levels will lead to the disappearance of susceptible species in favor of tolerant species (Muhammad et al., 2018). This is the case for Echinoclora pyramidalis, which is a fast-growing emerging hydrophytic plants species whose competitiveness would lead to the disappearance of submerged and floating species, as well as slow-growing emerging species in some sites. This makes it possible to understand why only a few species are more represented upstream than downstream. Priso et al. (2010) found that during the wet season in swamps subjected to organic pollution, the species Pistia stratiotes is more abundant and more robust than in the dry season. In this respect, after working in a polluted swamp next to Ferencam, Noukeu and Priso (2014) showed that the sensitivity of a species in the presence of polluting substances is marked by a modification or a regression of the potentialities of the plant or by its disappearance. These observations are consistent with the assertion of Collins and Glenn (1997); on biological diversity affected by the level of disturbance (Suchkova et al., 2014). The observation of the analysis of the vegetation data depending on soil parameters with the Multiple Factor Analysis can confirm this (Natalia and Patricia, 2015).

The receiving environments showed the dominance of the Poaceae
family and their herbaceous biological form. However, analysis of the results shows that the floristic diversity of this family varies in each site according to the upstream and downstream. This finding showing that polluted sites are dominated by the Poaceae family whatever the season is also observed by Priso et al. (2012); Dibong and Ndjourou (2014); Priso et al. (2014); Carmine et al. (2019). Except Poaceae, other most represented families in all analyzed soils are the Asteraceae, Cyperaceae, Fabaceae and Convolvulaceae. These results are similar to those found by Bazzaz (1996), Baize (2008), and Abusaief and Dakhil (2013) according to which Asteraceae and Poaceae are the most abundant families on polluted land. According to Fonkou et al. (2005), species that thrive in polluted marshes could be potential candidates for phytoremediation tests in artificial wetland. Noukeu et al. (2016), showed that Panicum maximum and Eichhornia crassipes could reduce the pollution load of distillery residues from Fermencam. Indeed, the presence of a species in polluted soil reveals its bioindicator character (Priso et al., 2000; Suchkovaa et al., 2014; Carmine et al., 2019). In this study, the dominance of some species individuals was observed and these species could be organic pollution indicators namely: Pennisetum purpureum, Cydonon dactylon, Commelina benghalensis, Lemma minor, Acrocras sizzanoides, Ricasus communis, Echinochloa pyramidalis and Panicum maximum.

Comments on the impact of effluent discharges from agri-food industries on floristic diversity of receiving environments are identical to the studies carried out by Shalouti et al. (2015); who assessed the impact of sewage pollution on plant diversity and structure of community in the north of Libya. His study shows the role of the characteristics of contaminated soil in the formation of vegetation groups. He found that therophytes were the dominant biological species. In this study, the dominant species in the receiving environments belong to different biological species namely: therophytes (Commelina benghalensis, Alternanthera sessilis, Cleome ciliata, Ludwiga hyssopofilia, Cyperus esculentus); hemicycrophytes (Echinochloa pyramidalis, Pennisetum purpureum, Panicum maximum and Acrocras sizzanoides) and geophytes (Eleusine indica, Cydonon dactylon).

5. Conclusion

The impact of agri-food industry effluent discharges in this study was observed by the physiognomy of the vegetation in the receiving environments. During the floristic inventories, the specific richness varied at each site according to the season and the pollution gradient. In all receiving environments, the rainy season is more diversified than the dry season. This is characterized by very high values of maximum diversity, Shannon index and Pielou equitability that depend on environmental conditions and the ability of plants to tolerate changes in the environment. The Sorensen index showed that the upstream and downstream of the sites are similar in relation to the number of common species. The high regularity values show that a maximum number of species participate in the recovery of the surface of the receiving environments. The presence of organic matter in effluents and consequently their accumulation in the soil has led to an increase in nitrophilic species that prefer substrates rich in nitrogen and phosphorus substances that are easily assimilated. The most represented family in all the sites is the Poaceae family. The approach of using biological components to express the impact of effluent discharge pollution has revealed the dominance of certain species that could be indicators of organic pollution in several disturbed ecosystems.

Declarations

Author contribution statement

NOUKEU NKOUAKAM armelle: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

R. J. Priso, S. D. Dibong, Daniel Ndongo Din: Analyzed and interpreted the data.

LEON Kono, Damien Essono: Performed the experiments.

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The authors declare no conflict of interest.

Additional information

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