Heliyon 5 (2019) e02747

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.heliyon.com

Research article

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

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ARTICLE INFO

Keywords:
Agriculture
Environmental science
Receiving environments
Species richness
Nitrophilous species
Agri-food industries
Organic pollution

ABSTRACT

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) 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 common species between 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; Nguemté 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

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https://doi.org/10.1016/j.heliyon.2019.e02747
Received 5 July 2019; Received in revised form 6 September 2019; Accepted 25 October 2019

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 Ndjouondo, 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 seasons of the year: the dry season, in March 2014, and the rainy season, in November 2014, in the towns of Mbandjock, Nkoteng and Yaounde. In the city of Douala, these inventories took place in the dry season in February 2014 and in the rainy season in August 2014.

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, 1980; Skinner et al., 1994; Dibong and Ndjouondo, 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, 1m^2 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.

Table 1
Receiving environments inventoried according to agri-food sectors.

Study sites	Type of industry sector	Geographical coordinates	Transect labels and quadrat number in each site
SOSUCAM Mbandjock	Sugar refinery	N:04.44383° E:011.90853°	T_1 (36), T_2 (40), T_3 (30), T_4 (50)
SOSUCAM Nkoteng	Sugar refinery	N:04.28331° E:012.06019°	T_1 (46), T_2 (30), T_3 (26), T_4 (28)
ADIC Mbandjock	Distillery	N:04.44641° E:011.89167°	T_1 (25), T_2 (30), T_3 (50), T_4 (28)
FERMENCAM Douala	Distillery	N:04.06451° E:009.37180°	T_1 (28), T_2 (30), T_3 (22), T_4 (28)
Douala slaughterhouse (SODEPA)	Slaughterhouse	N:04.11097° E:009.64572°	T_1 (40), T_2 (34), T_3 (26), T_4 (25)
Yaounde slaughterhouse (SODEPA)	Slaughterhouse	N:03.92336° E:011.53264°	T_1 (30), T_2 (24), T_3 (22), T_4 (20)
SOFAVINC Yaounde	Winery	N:03.81464° E:011.51001°	T_1 (26), T_2 (40), T_3 (24), T_4 (20)
SCR. MAYA Douala	Oil Mill/Soap Factory	N:04.09846° E:00963154°	T_1 (46), T_2 (40), T_3 (24), T_4 (20)
GUINNESS Douala	Brewery	N:04.05057° E:009.74431°	T_1 (30), T_2 (40), T_3 (27), T_4 (20)
FERME H& F Yaounde	Livestock	N:03.84495° E:011.45468°	T_1 (36), T_2 (30), T_3 (26), T_4 (20)

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 Reynold (1988).

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

$$(H') = -\sum P_i \log_2 P_i, \quad (1)$$

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/RM_T .

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 is calculated using the following formula:

$$R = H'/H'_{max}; \quad (2)$$

H'_{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:

$$D = \sum Pi^2. \quad (3)$$

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:

$$Q = [2a / (2a + b + c)]. \quad (4)$$

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 *Cynodon 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: *Cynodon 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 *Cynodon 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.

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 *Cynodon dactylon* individuals. Downstream, there are 28 species dominated by *Acroceras zizanoides* and *Ipomoea mauritiana*. There are 19 families, dominated by Poaceae and Asteraceae. In the dry season the receiving environment of the Douala slaughterhouse is dominated upstream by *Cynodon dactylon* with a large number of individuals; followed by *Alternanthera sessilis*. A total of 37 species divided into 35 genera and 25 families were identified. In downstream, 57 species divided into 55 genera and 32 families were identified. Downstream is dominated by *Ipomea cairica* and *Acroceras zizanoides.* The dominant families are Poaceae, Fabaceae and Amaranthaceae.

In the receiving environment of the company Adic in rainy season, upstream is dominated by *Panicum maximum, Setaria barbata* and *Halopegia* sp. There are 29 species in total divided into 28 genera and 18 families. The downstream has a high number of *Echinochloa pyramidalis* followed by *Halopegia* sp. and *Pennisetum purpureum.* Some shrubby species such as *Dacryodes buettneri, Vitex doniana* and *Alchornea cordifolia* have been found. In general, the Poaceae family is the most dominant in upstream and downstream. In the dry season upstream of Adic Mbandjock site has 14 species, of which *Cyperus tuberosus*, *Alternanthera sessilis* and *Commelina benghalensis* are the most dominant. The downstream has 26 species, the most dominant being *Echinochloa pyramidalis*, *Halopegia azurea* and *Pennisetum purpureum.* Poaceae is the dominant family, followed by Asteraceae. Twenty five families were identified upstream and downstream.

In the rainy season, upstream of Sosucam Nkoteng is dominated by *Panicum maximum* and *Pennisetum purpureum.* A total of 42 species was identified upstream and 31 species downstream. Poaceae is the dominant family. In the dry season upstream of Sosucam Nkoteng is dominated by *Ipomea* sp. and *Pennisetum purpureum.* Downstream is dominated by *Setaria barbata* and *Panicum maximum.* A total of 46 plant species divided in 44 genera and 18 families, with Poaceae as the most represented family, were inventoried.

The Yaounde slaughterhouse in the rainy season is dominated upstream by *Echinochloa pyramidalis* and downstream by *Cynodon 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 divertifolia* and *Hallea stipulosa*. Downstream has 22 species divided into 22 genera and 11 families, dominated by Poaceae and Amaranthaceae. The dominant species are *Tithonia divertifolia, Echinochloa pyramidalis* and *Pennisetum purpureum.*

The receiving environment of the company SCR Maya is dominated upstream and downstream by *Ipomea cairica* and *Echinochloa 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, Echinochloa 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 *Echinochloa 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
	Downstream	28	20	20	46	7	35	10	29	31	19
Dry season	Upstream	37	31	14	17	4	10	41	28	20	11
	Downstream	57	22	26	35	5	12	21	36	26	33

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

Season	Upstream		Downstream	
	Rainy	Dry	Rainy	Dry
Fermencam	- *Cynodon dactylon* - *Commelina benghalensis* - *Acroceras zizanoides*	- *Commelina benghalensis* - *Cynodon dactylon*	- *Cynodon dactylon* - *Commelina benghalensis* - *Acroceras zizanoides*	- *Lemna minor* - *Pistia stratiotes*
Abattoir Douala	- *Setaria barbata* - *Cynodon dactylon*	- *Cynodon dactylon* - *Alternanthera sessilis*	- *Acroceras zizanoides* - *Ipomoea mauritiana*	- *Ipomea cairica* - *Acroceras zizanoides*
Abattoir Yaounde	- *Echinochloa pyramidalis*	- *Luffa aegyptiaca* - *Tithonia divertifolia* - *Hallea stipulosa*	- *Cynodon dactylon*	- *Tithonia divertifolia* - *Echinochloa pyramidalis* - *Pennisetum purpureum*
Adic	- *Panicum maximum* - *Setaria barbata* - *Halopegia* sp	- *Cyperus tuberosus* - *Alternanthera sessilis* - *Commelina benghalensis*	- *Echinochloa pyramidalis* - *Halopegia sp.* - *Pennisetum purpureum* - *Dacryodes buettneri* - *Vitex doniana* - *Alchornea cordifolia*	- *Echinochloa pyramidalis* - *Halopegia azurea* - *Pennisetum purpureum*
Sosucam Nkoteng	- *Panicum maximum* - *Pennisetum purpureum*	- *Ipomea* sp. - *Pennisetum purpureum*	- *Pennisetum purpureum*	- *Setaria barbata* - *Panicum maximum*
Sosucam Mbandjock	- *Panicum maximum* - *Pennisetum purpureum*	- *Acroceras zizanoides* - *Pennisetum purpureum* - *Panicum maximum* - *Halopegia azurea*	- *Acroceras zizanoides* - *Halopegia sp.*	- *Echinochloa pyramidalis*
SCR Maya	- *Ipomea cairica* - *Echinochloa pyramidalis*	- *Eclipta prostrata* - *Commelina benghalensis* - *Echinochloa pyramidalis* - *Kyllinga erecta.*	- *Echinochloa pyramidalis*	- *Hallea stipulosa* - *Acroceras zizanoides*
Sofavinc	- *Pennisetum purpureum* - *Panicum maximum*	- *Pennisetum purpureum* - *Panicum maximum* - *Commelina benghalensis* - *Luffa aegyptiaca*	- *Polygonum limbatum* - *Echinochloa pyramidalis*	- *Echinochloa pyramidalis* - *Amaranthus esculentus* - *Polygonum limbatum*
Ferme H & F	- *Commelina benghalensis* - *Acroceras zizanoides*	- *Echinochloa pyramidalis* - *Ageratum conozoides*	- *Echinochloa pyramidalis* - *Chromolaena odorata*	- *Commelina benghalensis* - *Polygonum lanigerum*
Guinness	- *Panicum maximum* - *Bambusa vulgaris*	- *Passiflora* sp. - *Commelina benghalensis*	- *Commelina benghalensis*	- *Panicum maximum*

upstream discharge area of the Ferme H & F is dominated by *Echinochloa pyramidalis* and *Ageratum conozoides*, 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 maximun* individuals in rainy season. Downstream is dominated by *Echinochloa pyramidalis* and *Polygonum limbatum*. Thirty-six plant species divided into 34 genera and 14 families were inventoried. The Poaceae and Asteraceae are the most 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 Mbandjock is dominated upstream by *Pennisetum purpureum* and *Panicum maximun* individuals. Downstream is dominated by *Acroceras 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		Rainy					Dry				
Sites	Transect	H′	H'_{max}	R	D	Q	H′	H'_{max}	R	D	Q
FERMENCAM	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		3	5.17	0.59	0.24	
Abattoir Douala	Upstream	3.45	5.55	0.44	0.91	0.67	3.38	5.21	0.64	0.25	0.37
	Downstream	1.46	4.8	0.3	0.75		5.12	5.83	0.87	0.35	
Abattoir Yaounde	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		3.26	4.46	0.73	0.17	
ADIC	Upstream	3.46	4.86	0.71	0.77	0.37	1.37	3.81	0.36	0.22	0.25
	Downstream	1.83	2.8	0.65	0.71		3.6	4.7	0.77	0.14	
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		3.76	5.13	0.73	0.14	
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		4.11	5.78	0.71	0.35	
SCR MAYA	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	
SOFAVINC	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		4.16	4.86	0.86	0.78	
FERME H&F	Upstream	5	6.04	0.82	0.95	0.43	3.19	3.16	0.90	0.891	0.86
	Downstream	4.96	5.55	0.89	0.87		2.84	3.58	0.80	0.95	
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		1.66	3.32	0.5	0.42	

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'_{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 Fermencam; 5.12 at Sofavinc and 6.04 at the Sosucam Mbandjock site.

Pielou's equitability or regularity (R) ranges from 0.61 to 0.82 respectively in the upstream discharge area of Fermencam 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 Fermencam 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 Fermencam to 5.12 at the Douala slaughterhouse site.

High maximum diversity values (H'_{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 Fermencam, 5.83 at the Douala slaughterhouse and 5.78 at the Sosucam Mbandjock site.

Pielou's equitability or regularity (R) ranges from 0.35 to 0.92 respectively in the upstream discharge area of Fermencam and Ferme Henri et Frères. It ranges from 0.59 to 0.87 in the downstream discharge area of Fermencam 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 Sofavinc 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 cairica* and *Acroceras zizanoides* species are found in the Scr Maya site (upstream-downstream) and downstream of the Douala slaughterhouse. *Rhynchospora corymbosa, Triumfetta cordifolia, Kyllinga erecta, Alternanthera sessilis* and *Costus afer* species are found in the Fermencam site (upstream and downstream) and downstream of the Sosucam Mbandjock site. *Oplismenus hirtellus, Cynodon dactylon, Fleuria ovalifolia, Setaria barbata, Convovulus involucata, 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*, *Eleusine indica*, *Amaranthus viridis*, *Ricinus communis*, *Euphorbia heterophylla*, *Tithonia divertifolia*, *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 Sofavinc, 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, Saccharum officinarum, Kyllinga erecta, Centrosema pubescens, Ludwigia decurrens, Senna javanica, Ipomoea cairica, Nymphaea lotus, Chromolaena odorata, Cleome ciliata, Panicum maximum, Paspalum vaginatum, Polygonum limbatum, Amaranthus esculenthus, Hallea stipulosa, Tithonia divertifolia and Musa* sp. are found in the upstream and downstream discharge area of Sofavinc, Scr Maya, Yaounde slaughterhouse, Adic, Ferme H & F, and in the downstream discharge area of the Douala slaughterhouse. *Cynodon dactylon, Commelina benghalensis, Ipomoea involucata* and *Senna occidentalis* are found in the upstream discharge areas of Fermencam 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 fermencam.

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 *Tytonia divertifolia* 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 *Eleusine indica* and *Setaria barbata*; the second includes *Tithonia divertifolia*, the third one includes *Cleome 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'_{max}), Shannon index (H′) and Pielou 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'_{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

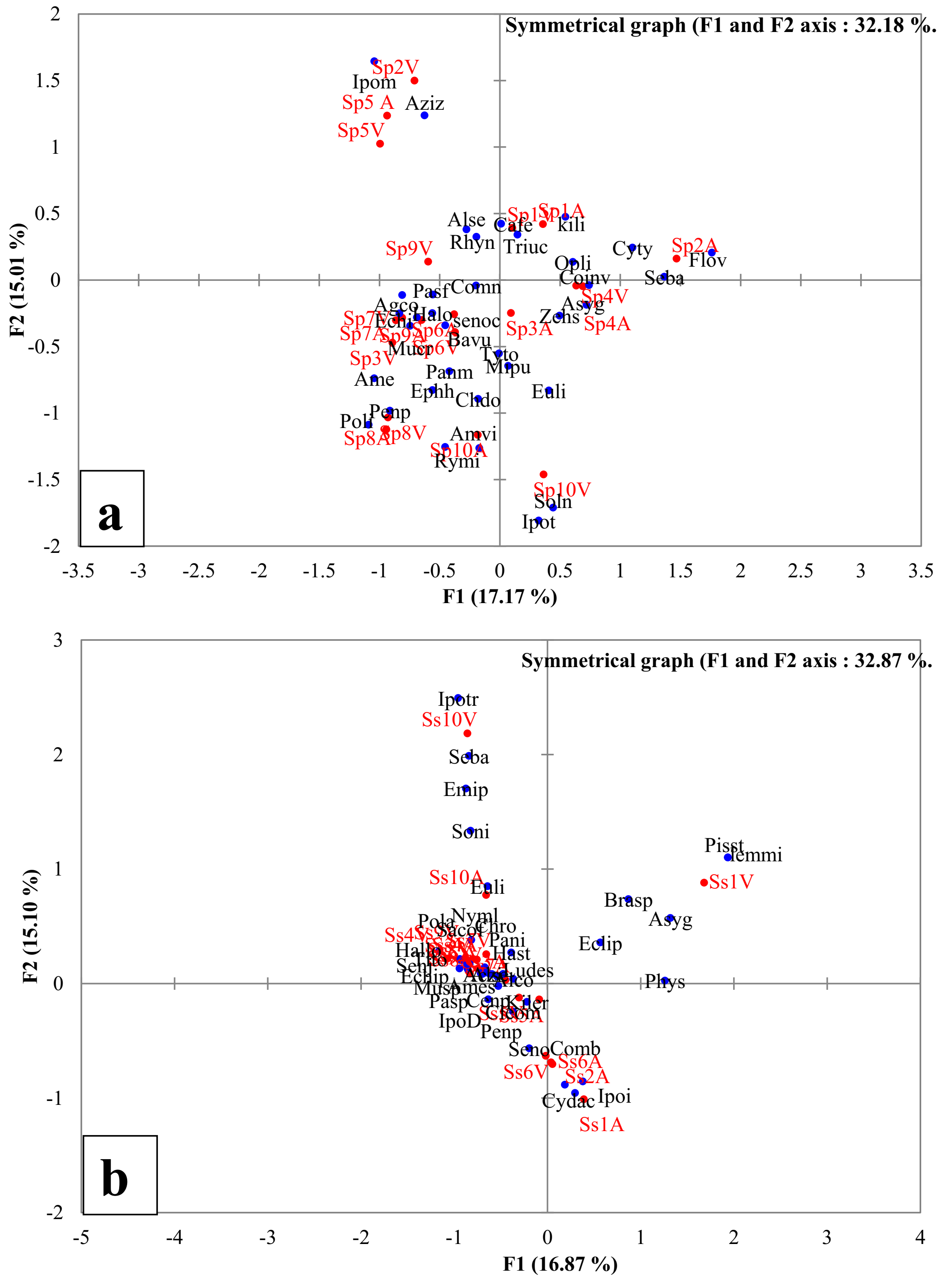

Fig. 1. The CFA of floristic data of the upstream and downstream receiving environments during the **1.a) rainy season**; **1.b) dry season**; A: upstream, V:downstream, 1:Fermencam, 2:Douala slaughterhouse, 3: Adic, 4: Yaounde slaughterhouse, 5: Scr Maya, 6: Guinness, 7: Ferme H& F, 8: Sofavinc, 9: Sosucam Mbandjock, 10: Sosucam Nkoteng. Aziz: *Acroceras zizanoides*, Agco:*Ageratum conyzoïdes,* Halo:*Halopegia* sp, Alse:*Alternanthera sessilis,* Ame:*Amaranthus esculentus,* Amvi: *Amaranthus viridis*, Asyg:*Asystasia gangetica*, Bavu:*Bambusa vulgaris*, senoc:*Sena occidentalis*, Chdo:*Chromolaena odorata,* Comn:*Commelina benghalensis,* Coinv: *Convovulus involucata,* Cafe:*Costus afer*, Cyty:*Cynodon dactylon*, Echi:*Echinochloa pyramidalis*, Soln:*Solanum nigrum*, Triuc:*Triumffeta cordifolia*, Tyto:*Tytonia divertifolia*, Zeh:*Zehnaria scabra*, Euli:*Eleusine indica*, Ephh:*Euphorbia heterofila*, Flov:*Fleuria ovalifolia*, Ipom: *Ipomoea mauritiana*, Ipoi:*Ipomoea invisa*, Mipu:*Mimosa pudica*, Mucr:*Musanga cecropoides*, Opli:*Oplismenus hirtelus*, Panm:*Panicum maximum*, Pasf:*Passiflora foetida*, Penp:*Pennisetum purpureum,* Poli:*Polygonum limbatum*, kili:*Kyllinga erecta*, Rhyn:*Rhynchospora* sp, Rymi:*Ricinus comminus*, Seba:*Setaria barbata*. Aczi: *Acroceras zizanoides,* Alco: *Alchornea cordifolia,* Ames: *Amaranthus esculenthus,* Brasp: *Bracharia* sp,Cenp:*Centrose pubescens,* Chro: *Chromeleana odorata,* Cleom: *Cleome ciliata,* Comb: *Commelina bengalensis,* Cydac:*Cynodon dactylon,* Echip:*Echinochloa pyramidalis*, Eclip:*Eclipta prostata,* Emip: *Emilia praertermissa,* Hast:*Halea stipulosa*, Hallo:*Hallopegea* sp, Ipod: *Ipomoea cairica,* Ipotr:*Ipomoea involucata,* Kiler:*Killinga erecta,* lemmi:*Lemna minor,* Ludes:*Ludvigia decurens,* Musp:*Musa* sp, Nyml:*Nymphea lotus,* Pani:*Panicum maximum,* Pasp:*Paspalum* sp, Phys:*Physalis*, Soni:*Solanum nigrum,* Tito:*Titonia divertifolia.*

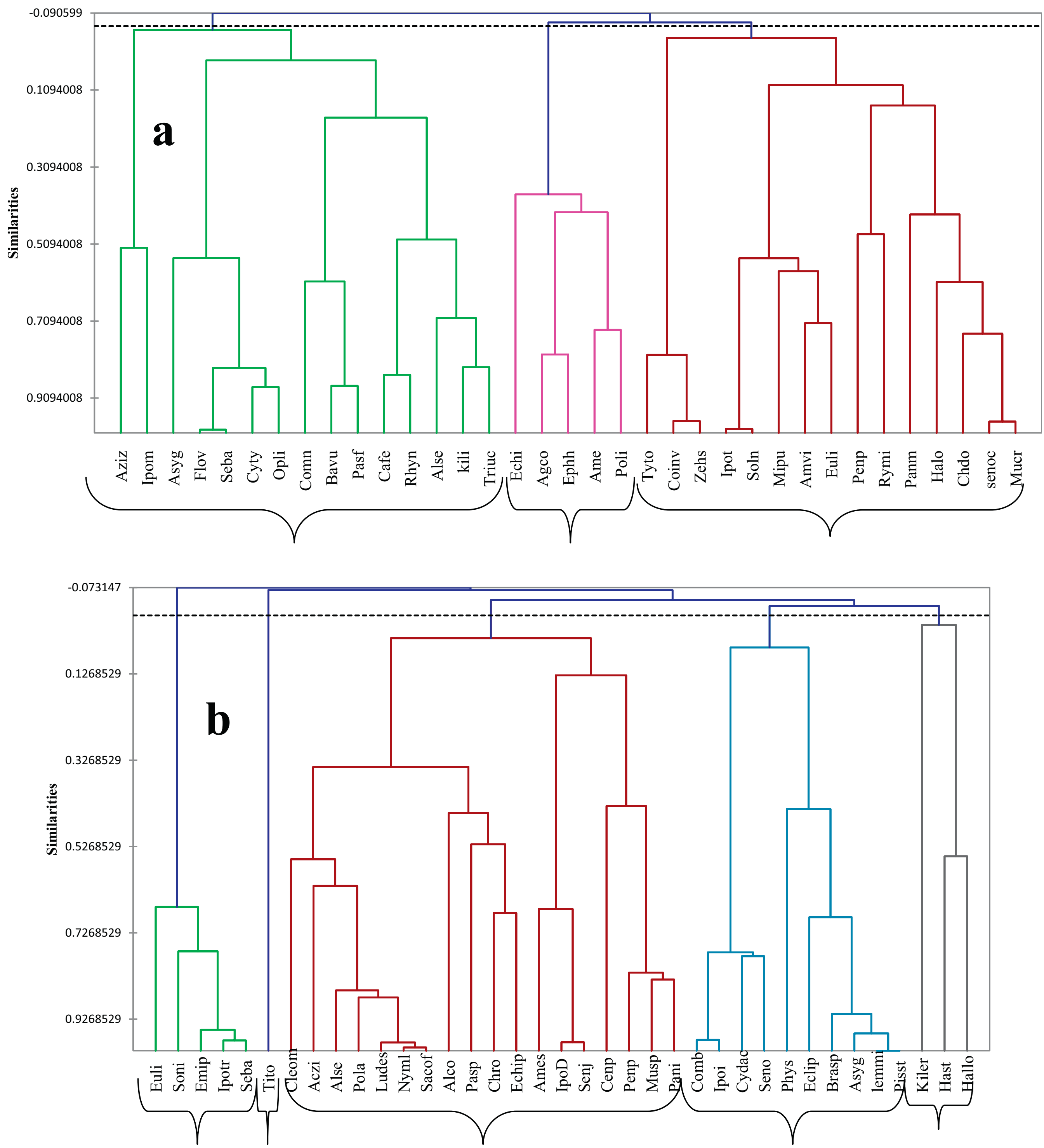

Fig. 2. Dendrogram of floristic data obtained during the 2.a) rainy season and 2.b) dry season; Aczi: *Acroceras zizanoides,* Alco:*Alchornea cordifolia,* Alse: *Alternantera sessilis,* Ames:*Amaranthus esculenthus,* Asyg:*Asystasia gangetica,* Brasp:*Bracharia sp,* Cenp:*Centrosema pubescens,* Chro: *Chromeleana odorata,* Cleom:*Cleome ciliata,* Comb: *Commelina benghalensis,* Cydac:*Cynodon dactylon,* Echip:*Echinochloa pyramidalis*, Eclip:*Eclipta prostata,* Emip:*Emilia praertermissa,* Euli:*Eleusine indica,* Hast:*Halea stipulosa*, Hallo:*Hallopegea* sp, Ipoi:*Ipomoea involucata*, Ipod:*Ipomoea cairica,* Ipotr: *Ipomoea invisa,* Kiler: *Killinga erecta,* lemmi:*Lemna minor,* Ludes:*Ludwigia decurens,* Musp:*Musa sp,* Nyml: *Nymphaea lotus,* Pani:*Panicum maximum,* Pasp: *Paspalum sp,* Penp: *Pennesetum purpureum,* Phys:*Physalis*, Seba: *Setaria barbata*, Soni: *Solanum nigrum,* Tito: *Tithonia divertifolia;* Aziz:*Acroceras zizanoides*, Agco: *Agératum conyzoïdes,* Halo: *Halopegia* sp, Alse: *Alternanthera sessilis,* Amvi: *Amaranthus viridis*, Asyg: *Asystasia gangetica*, Bavu: *Bambusa vulgaris*, senoc: *Sena occidentalis*, Chdo: *Chromolaena odorata,* Comn: *Commelina benghalensis,* Coinv: *Convovulus involucata,* Cafe: *Costus afer*, Cyty: *Cynodon dactylon*, Echi: *Echinochloa pyramidalis*, Soln: *Solanum nigrum*, Triuc: *Triumffeta cordifolia*, Zeh: *Zehnaria scabra*, Ephh: *Euphorbia heterofila*, Flov: *Fleuria ovalifolia*, Ipom: *Ipomoea mauritiana*, Mipu: *Mimosa pudica*, Mucr: *Musanga cecropoides*, Opli:*Oplismenus hirtelus*, Panm: *Panicum maximum*, Pasf: *Passiflora foetida*, Penp: *Pennisetum purpureum,* Poli: *Polygonum limbatum*, kili: *Kyllinga erecta*, Rhyn: *Rhynchospora* sp, Rymi: *Ricinus comminus*, 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 cairica Sweet.*	Convolvulaceae
Acalypha ciliata Forssk.	Euphorbiaceae	*Ipomoea indica (Burm.) Merr.*	Convolvulaceae
Acalypha hispida Burm. f.	Euphorbiaceae	*Ipomoea involucrata P. Beauv.*	Convolvulaceae
Acanthospermum hispidum DC	Asteraceae	*Ipomoea mauritiana Jacq.*	Convolvulaceae
Acroceras zizanoides (Kunth) Dandy	Poaceae	*Ipomoea sp.*	Convolvulaceae
Aeschynomene indica L.	Fabaceae	*Kyllinga bulbosa P. Beauv.*	Cyperaceae
Ageratum conyzoides L.	Asteraceae	*Kyllinga erecta Schumach*	Cyperaceae
Alchornea cordifolia Müll.Arg.	Euphorbiaceae	*Lactuca taraxacifolia (Willd.)*	Asteraceae
Alstonia boonei De Wild.	apocynaceae	*Leea guineensis G.Don*	Leaceae
Alternanthera sessilis (L.) R. Br. ex DC	Amaranthaceae	*Leonotis nepetifolia (L.) Ait.*	Lamiaceae
Amaranthus esculentus (L.)	Amaranthaceae	*Lippia multiflora Moldenke*	Verbenaceae
Amaranthus spinosus (L.)	Amaranthaceae	*Ludwigia decurrens Walt.*	Onagraceae
Amaranthus viridis (L.)	Amaranthaceae	*Ludwigia decurrens Walt.*	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	*Marattia sp.*	Marattiaceae
Borreria diffusa DC	Rubiaceae	*Mariscus alternifolius Vahl*	Cyperaceae
Brachiaria decumbens Stapf	Poaceae	*Melochia corchorifolia L.*	Malvaceae
Canna indica L.	Cannaceae	*Millettia macrophylla Benth.*	Fabaceae
Carica papaya L.	Caricaceae	*Mimosa invisa Mart.*	Mimosaceae
Cecropia peltata L.	Cecropiaceae	*Mimosa pudica L.*	Mimosaceae
Celosia laxa Schum & Thonn.	Amaranthaceae	*Mimosa nigra Huber*	Mimosaceae
Centrosema pubescens Benth	Fabaceae	*Mitracarpus villosus (Swartz)*	Rubiaceae
Chromolaena odorata (L.)	Asteraceae	*Momordica charantia L.*	Cucurbitaceae
Cleome ciliata Schumach. & Thonn.	Capparidaceae	*Mucuna pruriens (L.) DC. var. pruriens*	Fabaceae
Colocasia esculenta (L.) Schott	Araceae	*Musa sapientum L.*	Musaceae
Combretum zenkeri Engl. & Diels	Combretaceae	*Musa paradisiaca L.*	Musaceae
Commelina benghalensis L.	Commelinaceae	*Musanga cecropioides R. Br. Ex Tedlie*	Cecropiaceae
		Myrianthus arboreus	Cecropiaceae
Commelina diffusa Burm. subsp.diffusa	Commelinaceae	*Nauclea diderrichii (De Wild. & T.Durand) Merrill*	Rubiaceae
Convolvulus involucrata L.	Convolvulaceae	*Nephrolepis bisserata (Sw.) Schott*	Nephrolepidaceae
Convolvulus sp.	Convolvulaceae		Nephrolepidaceae

Table 5 (*continued*)

Names of species	Family	Names of species	Family
		Nephrolepis undulata (Afzel. Ex Sw.) J. Sm	
Corchorus capsularis L.	Tiliaceae	*Nymphaea alba L.*	Nymphaeaceae
Corchorus olitorius L.	Tiliaceae	*Oldenlandia corymbosa L.*	Rubiaceae
Corchorus olitorius L.	Tiliaceae	*Oplismenus burmannii (Retz.) P. Beauv.*	Poaceae
Cucumeropsis mannii Naudin.	Cucurbitaceae	*Oplismenus hirtellus (L.) P.Beauv.*	Poaceae
Cucumeropsis mannii Naudin.	Cucurbitaceae	*Oxalis barrelieri (Herb Smith)*	Oxalidaceae
Cucumis melo L.	Cucurbitaceae	*Oxalis corniculata L.*	Oxalidaceae
Cyathea manniana Hook.	Cyatheaceae	*Panicum maximum Jacq.*	Poaceae
Cyatula prostrata (L.)Blume	Amaranthaceae	*Paspalum conjugatum Berg.*	Poaceae
Cynodon dactylon L.	Poaceae	*Paspalum vaginatum Sw.*	Poaceae
Cyperus difformis L.	Cyperaceae	*Passiflora foetida L.*	Passifloraceae
Cyperus distans L.f.	Cyperaceae	*Pennisetum pedicellatum Trin.*	Poaceae
Cyperus esculentus L.	Cyperaceae	*Pennisetum purpureum Schumach.*	Poaceae
Cyperus haspan L.	Cyperaceae	*Phyllanthus amarus Schumach. & Thonn.*	Phyllantaceae
Cyperus iria L.	Cyperaceae	*Phyllanthus discoideus (Baill.) Müll.Arg.*	Phyllantaceae
Cyrtosperma senegalense Schott Engl.	Araceae	*Phyllanthus sp.*	Phyllantaceae
Dacryodes buettneri (Engl.) H. J. Lam	Burseraceae	*Physalis angulata L.*	Solanaceae
Digitaria horizontalis Willdenow	Poaceae	*Pistia stratiotes L.*	Araceae
Dioscorea bulbifera L.	Dioscoreaceae	*Polygonum lanigerum R. Br.*	Polygonaceae
Dissotis rotundifolia (Sm.) Triana	Melastomataceae	*Portulaca oleracea L.*	Portulacaceae
Dissotis sp.	Melastomataceae	*Pseudospondias microcarpa (A.Rich.) Engl.*	Anacardiaceae
Drymaria cordata (L.) Wild.	Cariophyllaceae	*Pueraria phaseoloides (Roxb.) Benth.*	Fabaceae
Echinochloa pyramidalis (Lam.)	Poaceae	Pycreus lanceolatus (Poir.) C.B.Clarke	Cyperaceae
Echinochloa sp.	Poaceae	*Rhynchospora corymbosa (L.) Britton*	Cyperaceae
Eclipta prostrata L.	Asteraceae	*Ricinus communis L.*	Euphorbiaceae
Elaeis guineensis Jacq.	Arecaceae	*Saccharum officinarum Linn.*	Poaceae
Eleusine indica (L.) Gaertn.	Poaceae	*Scleria verrucosa Wild.*	Cyperaceae
Emilia praetermissa Milne-Redh.	Asteraceae	*Senna occidentalis (L.) Link*	Caesalpiniaceae
Eragrostis ciliaris (L.) R.Br.	Poaceae	*Setaria barbata (Lam.) Kunth*	Poaceae
Eragrostis tenella (L.)	Poaceae	*Setaria megaphylla (Steud) Dur. & Schinz*	Poaceae
Eragrostis tremula (Lamarck)	Poaceae	*Sida alba L.*	Malvaceae
Erigeron floribundus (Kunth) Sch. Bip.	Asteraceae	*Sida rhombifolia L.*	Malvaceae
Erigeron sp.	Asteraceae	*Solanum nigrum L.*	Solanaceae

(*continued on next page*)

Table 5 (*continued*)

Names of species	Family	Names of species	Family
Eucalyptus globulus Labill.	Myrtaceae	*Solanum torvum Sw.*	Solanaceae
Euphorbia heterophylla Desf.	Euphorbiaceae	*Solenostemon monostachyus (P Beauv.) Briq.*	Lamiaceae
Euphorbia hirta L.	Euphorbiaceae	*Spathodea campanulata P. Beauv.*	Bignogniaceae
Euphorbia hissopifolia L.	Euphorbiaceae	*Spilanthes acmella (L.) Murray*	Asteraceae
Ficus exasperata Vahl.	Moraceae	*Spilanthes filicaulis (Schumach. & Thonn.)*	Asteraceae
Ficus mucuso Welw. Ex Ficalho	Moraceae	*Spondias mombin L.*	Anacardiaceae
Ficus sp.	Moraceae	*Sporobolus pyramidalis P. Beauv.*	Poaceae
Fimbristylis ferruginea (L.) Vahl	Cyperaceae	*Stachytarpheta cayennensis (Rich.) vahl.*	Verbenaceae
Fleurya ovalifolia (Schum. & Thonn.)	Urticaceae	*Sterculia rhinopetala K. Schum*	Malvaceae
Fleurya aestuans (L.) Gaudich	Urticaceae	*Synedrella nodiflora (L.) Gaertn*	Asteraceae
Fuirena umbellata Rottb.	Cyperaceae	*Talinum triangulare (Jacq.) Willd*	Talinaceae
Galinsoga ciliata S. F. Blake	Asteraceae	*Tephrosia vogelii Hook.f.*	Fabaceae
Hallea stipulosa (DC.) Leroy	Rubiaceae	*Terminalia superba Engl. & Diels*	Combretaceae
Halopegia sp.	Maranthaceae	*Tithonia divertifolia A. Gray*	Asteraceae
Haumania danckelmaniana (J. & K..)	Maranthaceae	*Vernonia amygdalina Delile*	Asteraceae
Hewittia sublobata (L.f.) Kuntze	Convolvulaceae	*Vigna radiata (L.) R. Wilczek*	Fabaceae
Hydrolea sp.	Hydrophyllaceae	*Vitex doniana Sweet*	Lamiaceae
Impatiens irvingii Hook. f. ex Oliv.	Balsaminaceae	*Xanthosoma mafaffa Schott.*	Araceae
Imperata cylindrica (L.) Raeuschel	Poaceae	*Zehneria scabra (Linn. f.) Sond.*	Cucurbitaceae

(Chen et al., 2015). Frontier and Pichod-viale (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 (Fermencam, Douala 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 (Dajoz, 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; Fakhry 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*, *Phyllanthus amarus*, *Physalis angulata*, *Kyllinga erecta*, *Cyathula prostrata*, *Althernanthera sessilis*, *Cleome ciliata*, *Cyperus distans*, *Commelina benghalensis*, *Eleusine indica*, *Amaranthus spinosus*, *Amaranthus viridis*, *Acanthospermum hispidium*, *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 *Echinochloa 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 Fermencam, Noukeu and Priso (2014) show 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 (Suchkovaa 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 Ndjouondo (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 phyto-purification 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*, *Cynodon dactylon, Commelina benghalensis*, *Lemna minor*, *Acroceras zizanoides, Ricinus 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 Shaltout 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, Amaranthus viridis, Alternanthera sessilis, Cleome ciliata, Ludwigia hyssopifolia, Cyperus esculentus*)); hemicryptophytes (*Echinochloa pyramidalis, Pennisetum purpureum, Panicum maximum and Acroceras zizanoides*) and geophytes (*Eleusine indica, Cynodon 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.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

Supplementary content (Fig. 3) related to this article has been published online at https://doi.org/10.1016/j.heliyon.2019.e02747.

Acknowledgements

We thank the entire laboratory of the Department of Plant Biology at the University of Douala.

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