Influence of anthropic and eco-hydrological factors on the floristic diversity of the herbaceous vegetation around the temporary ponds in Ferlo, Northern Senegal

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Abstract

Aims

Temporary ponds play substantial roles in preserving biodiversity in the Sahel. This study investigated the influence of anthropic and eco-hydrological factors on the plant diversity around two grazed ponds and one ungrazed pond in Ferlo, northern Senegal.

Methods

Two phytoecological transects were established per pond. On each transect, homogeneous herbaceous vegetation units were identified and characterized (herbaceous cover, exposure, soil texture, soil moisture and pH, average height, and slope).

Important findings

The herbaceous flora comprised 55 species, 41 genera, and 22 families across the three ponds. Species of the *Poaceae*, particularly *Eragrostis tremula* and *Enteropogon prieurii*, mostly colonized the grazed ponds, while the ungrazed pond favored other families' species such as *Achyranthes* sp, *Commelina forsskaolii*, *Corchorus* sp. The Shannon's diversity index (H') of Wendu Marodi (ungrazed pond) was slightly higher (4.9 bits) than that of Belel Lougal and Belel Sow (grazed ponds) with 4.8 and 4.5 bits, respectively. The equitability indices were relatively high in the three ponds (0.85, 0.83, 0.78). Eco-ecological factors distinguished four species' groupings: a *Tribulus terrestris* grouping colonizing the constraining and over-grazed zones, a *Digitaria horizontalis* grouping, and *Chloris barbata* grouping found in the transition zones, and an *Achyranthes aspera* grouping in the wetlands, where woody plants were strongly present and the anthropic action low. This study highlighted the importance of maintaining a landscape mosaic of ungrazed or semi-protected ponds and grazed ponds to preserve the herbaceous floristic diversity in the center of Ferlo (Senegal) and the Sahel in general.

***Key words**:* Ponds, Ferlo, grazing, herbaceous vegetation, transect

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INTRODUCTION

In the Sahelian and Sudano-Sahelian zone in Africa, the landscapes depend essentially on geomorphological factors (Penning de Vries and Djitèye 1982). These factors significantly influence the redistribution of water that accumulates around depressions where a great diversity of flora and fauna coexist (White 1970). Temporary ponds are found in the singular and remarkable wetlands (Quezel 1982, Allem *et al.* 2018), harboring an exceptional species richness and a diversity of habitat and reproduction niches (Sajaloli and Dutilleul 2001, Jourdas 2013).

In Senegal, in the northern part commonly known as the Ferlo, the topography, although dominated by flat areas, reveals longitudinal clayey depressions, occasionally limestone where temporary ponds are formed during rainy seasons (Michel 1969). The area is characterized by many small endorheic ponds of great economic, ecological, and social value. These are particularly important micro-habitats in the management of Ferlo's pastoral systems because of their positive influence on grassland productivity and water availability for domestic needs and livestock watering (Sy 2009). Because of their socio-economic importance for local populations, ponds remain frequented, and heavily exploited micro-habitats suffer from anthropic impacts that can prevent their proper functioning.

Within the framework of the fight against climatic change and the conservation of biodiversity, the preservation of ponds is becoming indispensable in the future socio-environmental resilience of the Ferlo ecosystems. In this context, this study was carried out to understand the influence of anthropic and eco-hydrological factors on the floristic diversity of the herbaceous vegetation around the ponds. Specifically, the aim was to determine the

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floristic composition of the herbaceous vegetation and to assess the impact of grazing and ecological factors on the diversity of the herbaceous vegetation.

MATERIALS AND METHODS

Study site

The study was carried out in Ferlo in northern Senegal in the Widou Tiengoly station (15°58'30''N et 15°17'90''O) from August 2018 to September 2019. The presence of many very diverse temporary ponds, the development of postoral activities, the passage of the Great Green Wall (GGW) route, and the influence of the various agriculture- and environment-related development projects installed in the area justified why we chose this zone. The climate of Widou Thiengoly is of arid Sahelian type. It is characterized, according to Niang *et al.* (2014), by the alternation of a long dry season of nine months (from October to June) and a short rainy season of three months (from July to September). The Widou station has received a yearly average rainfall of 371.67 mm over the last fifty years (Ndiaye e*t al.* 2015) with an average annual temperature of around 27.73°C (Ndiaye *et al.* 2013).

The study area's topography is flat with tropical and reddish-brown sub-arid soils made of sandy materials with low clay content (Ndiaye *et al.* 2013). The absence of rugged landscapes limits the development of a hydrographic network with an organized flow. The number of ponds in the Ferlo is estimated to be at least 363, including many small endorheic temporary ponds with a very short lifespan (Lebel and Redelsperger 2007, Sarr 2009). Vegetation is a shrub to tree steppe consisting of generally thorny trees and shrubs and a discontinuous herbaceous mat of annual species dominated by *Alysicarpus ovalifolius* (Schumach. & Thonn.) J. Léonard, *Aristida mutabilis* (Trin. & Rupr.), *Cenchrus biflorus* (Roxb), *Digitaria horizontalis* Willd, *Eragrostis tremula* ((Lam.) Hochst. ex Steud.), *Schoenefeldia gracilis* Kunth, *Zornia glochidiata (*Rchb. ex DC.) and *Tribulus terrestris*

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(auct.) (Akpo 1992, Niang 2009). The tree stratum is marked by the strong presence of thorny trees such as *Balanites aegyptiaca* (L.) Del, *Acacia tortilis raddiana* (Forst.) and *Acacia senegal* (L.), while the shrub stratum is mainly composed of *Calotropis procera* (Ait.) and *Boscia senegalensis* (Niang 2009, Ndiaye *et al.* 2015). Although fruit gathering is increasingly practiced thanks to wild fruit trees such as *Balanites aegyptiaca* (L.) Del, *Sclérocarya birrea* (A. Rich), and *Zizyphus mauritiana* Lam, livestock farming remains the dominant socio-economic activity (Niang 2009).

Choice of ponds

Most of the temporary ponds in the Ferlo are filled by runoff from slopes. They often can benefit from management to ensure a sufficient filling for use in various activities. Thus, based on the type of activities developed and the management type, three ponds were chosen as shown in Fig. 1: Wendou Marodi or the Lion's pond, Belel Sow, and Belel Lougal or the hole pond (artisanal surface wells). The Wendou Marodi pond has a shallow anthropic pressure. It has been fenced for decades to host the Ferlo Pastoral Self-Promotion Project PAPF) funded by the German government from 1975 to 2008 (Ka 2016). In 2008, the fence was reinforced by the Great Geen Wall project. The Great Green Wall appears to be a pan-African-driven reforestation project from Senegal in the West of Africa to Djibouti in the East of African to combat climate change and provide socio-economic means to habitants of the areas it crosses (Ka 2016). Belel Sow is a private pond owned by a family head from the village Belel Sow. It is very protected, but the human-made action is very regular. The local population dug Belel Lougal to exploit the water of a small superficial alluvial aquifer. It is undoubtedly a grazed pond, but its accessibility is limited by many holes representing a threat to animals.

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Survey method of herbaceous plants

The herbaceous vegetation was studied during the rainy season when most herbaceous plants are recognizable (August-September-November), following a phytoecological approach (Diallo *et al.* 2009, Mangara *et al.* 2010, Mboup 2014, Faye *et al.* 2020a). The sampling was carried out along a flooding or drought gradient at each pond. One transect was perpendicular to the axis of runoff flow in the pond, and the other was arranged longitudinally from the upstream end of the pond to its center (Fig. 2a). In total, six transects (two per pond) of 40 m to 82 m long, depending on the size of the pond (Fig. 1), were established. After placing the transects, we first visually identify the different homogenous vegetation groupings (Fig. 2b) and the soil texture's uniformity. We then ensure that each grouping has a homogenous and repeatable floristic composition with no discontinuity. Following that, the list of herbaceous plants, their average height, the exposure to the sun, the cover of the herbaceous stratum (established according to the Braun-Blanquet's scale 1932) were determined in each delimited grouping. A critical step in the survey consisted of describing certain abiotic factors such as the slope, the soil moisture content, and soil texture that could influence the structure and the distribution of herbaceous plants around ponds. Soil samples were collected from the different units to measure the soil pH at a 2:5 soil-to-distilled water slurry using a pH meter.

Data analysis

All data collected from the three sampling periods (August, September, November) were entered and processed using the Excel spreadsheet and the free software R studio (Xie *et al.* 2018) for Discriminating Factorial Analysis (DFA), Principal Component Analysis (PCA), and floristic composition. The PCA was carried out on the eight measured parameters (ground cover, average height of species, number of species, slope, texture, humidity,

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exposure to the sunlight, pH) on transects to identify the ecological factors that best characterize each pond. The species names were updated, referring to several online sources such as the African Plants Database, West African Plants, The Plant List, African Plants, and the Burkina Faso vascular plants catalog (Thiombiano *et al.* 2012). Several parameters such as species richness, specific contribution, the diversity index (Shannon and Weaver 1963), and the regularity index (Pielou 1966) were evaluated and defined. The specific contribution of species i (C_{Si}) is calculated as (Barmo et *al*., 2020) :

$$Csi = (\mathrm{Fsi}/\sum_{\mathrm{Fs}=1}^{55} \mathrm{Fsi}) * 100$$

where Fsi specific frequency the «i» species. 55 represents the total number of species

The diversity index used to assess the heterogeneity and diversity of a biotope is expressed in bits and generally varies from 0 to 5. It was calculated following the equation:

$$\mathrm{H}' = -\sum_{\mathrm{n}=1}^{55} \mathrm{Csi} \text{ x } \log 2\mathrm{Csi}.$$

Finally, the regularity or equitability index (varying between 0 and 1), which expresses the distribution of species in a unit, was calculated using the formula:

$R = \frac{H'}{Hmax}$ with $Hmax = Log2S$ representing the maximum Shannon specific diversity, and S was the total number of species. The phytoecological study was carried out using data collected in September since, during this period, all biotic and abiotic conditions were met. The soil was humid because the ponds were filled with water and the plant species were well-differentiated.

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RESULTS

1. Composition and floristic diversity of herbaceaous plants in ponds

The three ponds contained 55 herbaceous plant species belonging to 41 genera and 22 families. Species were unevenly distributed in the ponds (Table 1). There were 42 species, distributed into 33 genera and 15 families, around the Belel Lougal pond. We found 31 species ascribed to 28 genera and 18 families around the Belel Sow, while the Wendou Marodi pond comprised 47 species, members of 36 genera and 20 families. Among the 20 plant families of Wendou Marodi (ungrazed pond), five (*Acanthaceae*, *Araceae*, *Capparaceae*, *Commelinaceae*, and *Pedaliaceae*) were present only in this pond. Each of these five families was represented by a single species: *Peristrophe bicalyculata* (Retz.) Nees, *Stylochaeton hypogaeus* Lepr., *Cleome viscosa* L., *Commelina forsskaolii* Vahl., and *Sesamum sp*, respectively. The three families *Amaranthaceae*, *Convolvulaceae*, and *Malvaceae* were common to Wendou Marodi and Belel Sow, while the two families *Amaryllidaceae* and *Limeaceae* were strickly found in Belel Lougal and Belel Sow. The rest of the plant families were distributed across the three ponds. The herbaceous biodiversity indices did not show significant differences among the three ponds (Table 2). The Shannon index (H') varied from 4.5 bits (Belel Sow) to 4.9 bits (Wendou Marodi). These values, close to 5, prove the homogeneity of the specific composition of each pond. The regularity or equitability oscillated between 0.78 to 0.85, with the lowest value recorded at the Belel Sow pond. Since these equitability values were close to 1, the species composing the ponds were evenly distributed.

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2. Specific contribution and recovery

Two herbaceous species *Eragrostis ciliaris* (L.) R.Br. and *Cyperus esculentus* L. showed fairly significant specific contributions of over 5% at each of the three ponds. Depending on the pond, other species had specific contributions above this average of 5%. Precisely, these contributions were 6.9% for *Senna obtusifolia (L.)* H.S.Irwin & Barneby at the Wendou Marodi pond, *Zornia glochidiata* (9%), *Indigofera hirsuta* (7.3%), *Enteropogon prieurii* (6.8%), *Tribulus terrestris* (6%) and *Dactyloctenium aegyptium* (5.6%) at the Belel Lougal pond, and *Indigofera hirsuta* (9.7%), *Tribulus terrestris* (8.1%), *Portulaca oleracea* (6%) at the Belel Sow pond. The ground cover by the herbaceous vegetation was significantly ($p < 0.05$) greater at the Wendou Marodi pond (82.6%) than at the Belel Lougal (55.3%) and Belel Sow (46.5) ponds (Table 3). The species with a rather significant contribution (> 5%) in the coverage of ponds were *Eragrostis ciliaris* (21.42%), *Peristrophe bicalyculata* (7.21 %), and *Cyperus esculentus* (6 %) at the Wendou Marodi pond, *Eragrostis ciliaris* (8.39 %) and *Zornia glochidiata* (7.15 %) at the Belel Lougal pond, and *Tribulus terrestris* (10.25 %), *Eragrostis ciliaris* (6.41 %), and *Cyperus esculentus* (5.78 %) at the Belel Sow pond.

3. Ecological characteristics of ponds

The principal component axis referred to as dimensions, varied from 53.6% (Dim1) to 16.7% (Dim2). The first two dimensions that explain 70.3% of the information were retained for the analysis and the interpretations of results (Fig. 3). Except the exposure which contributed to 34.7% on these two first axes, the other variables all showed high contributions from 60% to 80% (Grass_cover (74.4%), Average_height (86.7%), Number_species (67.5%), pH (65.6%), Slope (61.3%), Humidity (83.5%) and Texture (78.7%)). Most of the homogenous units (groupings) of Wendou Marodi (ungrazed pond) located at the positive side of Dim1. These units were species-rich, with tall species intensely covering the ground.

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They developed on soils with a clayey to silty texture. At this pond, the slopes were gentle, and the exposure to the sun was low. Fig. S1 summarizes the phytosociological transect of the ungrazed Wendi Marodi pond. As for the grazed Belel Sow pond, the homogenous vegetation units were found on the negative side of Dim1, characterized by a neutral soil pH and high exposure to the sun. The distribution of groupings at the grazed Belel Lougal pond was relatively homogenous on the two first axes' plan. This result indicated that none of the measured parameters was predominant in this pond. These homogenous groupings formed four distinct characteristic classes (1, 2, 3, and 4) of determining environmental factors.

The synthetic analysis of figures 3 and 4 identified four distinct classes of environmental factors. The first class comprised eight and six groupings from the grazed Belel Lougal and Belel Sow ponds, respectively. Soils in these groupings are sandy, with a pH close to neutrality, and very exposed to the sun. The ground cover was weak, and the herbaceous layer was shallow, but the herbaceous biodiversity was quite important. The second class consisted of five and two groupings from the grazed Belel Lougal and Belel Sow ponds, respectively. Like the first class, the soils were also sandy, and the ground cover and the herbaceous stratum were low. However, the pH was acidic, and the exposure to the sun was weak. The third class was composed of three groupings of the grazed Belel Lougal pond and six groupings of the ungrazed Wendou Marodi pond. In this class, the soils had a silty-clay texture, with a medium exposure to the sun and a medium ground cover. The height of the herbaceous layer was high, and the biodiversity was important. Three groupings from the grazed Belel Lougal pond and nine groupings from the Wendou Marodi pond formed the fourth class. The soils had a silty-clay texture in this class, with medium exposure to the sun and a medium ground cover. The ground cover was more a less important, and the herbaceous layer reasonably high, with a shallow diversity. These homogenous vegetation groupings had the particularity to evolve on a very humid ground, with a very weak slope.

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4. Influence of ecological factors on the distribution of the herbaceous flora of ponds

The Discriminating Factorial Analysis (DFA) highlighted the existing links between the herbaceous flora of ponds and the ecological factors (texture, pH, slope, exposure, herbaceous cover, humidity, and average height). The DFA varied from 76.2% (Dim1) to 15.5% (Dim2), indicating that these two first dimensions contained most of the information (91.7%) of the DFA (Fig. 5). There were four groups of species with discriminated ecological preferences. The first group located on the positive side of axis 1 (Dim1) and contained plant species such as *Tribulus terrestris*, *Zornia glochidiata*, *Tripogon minimus*, *Alysicarpus ovalifolius*, *Amaranthus hybridus*, *Aristida mutabilis*, *Dactyloctenium aegyptium*, *Fimbristylis hispidula*, *Indigofera hirsuta*, *Gisekia pharnaceoides*, *Portulaca oleracea*, *Mollugo nudicaulis*, *Limeum viscosum*, *Phyllanthus niruri*, and *Ipomoea coptica*. These species have a clear preference for the ecological conditions characteristic of the class 1 groupings. The second group positioned on the positive side of axis 2 (Dim2) comprised *Digitaria horizontalis*, *Phyllanthus pentandrus*, *Kilinga brevifolia*, *Boerhavia diffusa*, *Oldenlandia corymbosa* and *Boerhavia erecta*. The third group was found on the negative side of axis 2 (Dim2). It consisted of *Chloris barbata*, *Cleome viscosa*, *Stylochaeton hypogaeus*, *Corchorus tridens*, *Cucumis melo var. agrestis*, *Corchorus aestuans*, *Commelina forsskaolii*, *Brachiaria lata*, and *Brachiaria ramosa*. Group 4 comprised *Achyranthes aspera*, *Cyperus esculentus*, *Senna obtusifolia*, *Spermacoce ruelliae*, *Corchorus olitoris*, *Echinocholoa colona*, *Eragrostis tremula*, and *Trianthema pentandra*, which prefers humid, sandy-silty textured areas with a gentle slope and a pH close to 6.

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DISCUSSION

In this study, the herbaceous flora around the temporary ponds comprised 55 species belonging to 41 genera and 22 families. The most represented family was the *Poaceae*, followed by the *Rubiaceae* and the *Fabaceae*. The significant presence of *Fabaceae* in the study area could be related to their high ability for regrowth. Similarly, Ndiaye *et al.* (2013) and Diallo *et al.* (2015) also reported a high frequency of *Poaceae* in the Ferlo. The ponds showed specific differences among them in their floral composition. For instance, the ungrazed Wendou Marodi flora, with an intense species richness and a small group of specific species, was distinct from grazed Belel Sow and Belel Lougal ponds. The pond-specific species of the ungrazed Wendou Marodi pond developed densely and consisted of embrophytes such as *achyranthes aspera*, *Brachiaria Lata*, *Commelina forsskaolii*, *Peristrophe bicalyculata*, and *Senna obtusifolia*. As stated by Diallo *et al.* (2011), Ibrahima *et al.* (2017), and Agbodan *et al.* (2019), this community can host tall trees with large crowns. The better soil fertility around the ungrazed Wendou Marodi pond (Faye *et al.* 2020b) and the more prolonged water stagnation period may justify its species singularity compared to the two other ponds. Moreover, it is known that ponds are original ecosystems whose functioning is tightly linked to the surrounding environment (Jourdas 2013). The ungrazed Wendou Marodi pond is protected by a fence for decades, with a new fence added in 2018 in connection with the activities of the Great Green Wall in Senegal. For these reasons, the pond evolves naturally with no disturbance from grazing and with low anthropic action, thus explaining the development of species characteristic of the non-grazed areas (Ouédraogo *et al.* 2011).

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Moreover, the influence of grazing was noticeable at the Belel Sow pond, where grew short plants species and where the soil could be visible (Pantis and Mardiris 1992, Jamaa *et al.* 2014). While livestock grazing is a regular activity at the Belel Sow pond, animals could hardly get in the Belel Lougal pond during the rainy season. Based on these observations, grazing appears to be one of the factors controlling the composition of the herbaceous vegetation of ponds.

Floristic diversity indices are objective criteria for assessing the diversity of a plant community (Ramade 1994, Yoka *et al.* 2013). The Shannon's diversity index (H') revealed a slightly higher species diversity in the ungrazed Wendou Marodi pond (4.9 bits) than in the grazed ponds of Belel Louga (4.8 bits) and Belel Sow (4.5 bits). The three ponds showed a reasonably high regularity or equitability index of 0.85, 0.83, and 0.78, respectively. Eco-hydrological factors such as soil pH, soil texture, soil humidity, and exposure to the sunlight are also putative determinants. The ground cover, average species height, soil humidity, and soil texture positively correlate together. These factors are negatively correlated with the slope, sun exposure, soil pH, and the number of species.

In this study, the principal component analysis grouped the eco-hydrological parameters (pH, soil texture, soil humidity, exposure to the sunlight) into four classes that showed differences in their floristic composition. The first class had dry and sandy soil, steep slopes, sun exposure, and grazed. This biotope was more a less clearly discriminated against the fourth class, which evolved on a clayey soil texture, covered, humid ground with low slopes, and ungrazed. However, the second and third classes harbored common species. These results matched that of Akpo *et al.* (1999), Akpo and Grouzis (1996, 2009), Diallo *et al.* (2011), and Faye *et al.* (2020a). These authors showed that the distribution of the herbaceous vegetation in the Sahelian rangelands' is linked to two orthogonal gradients corresponding to the light factor and the topographic gradient. Both factors are likely related

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to the hydrological signature of the area. Moreover, they identified the soil texture and the anthropic action as other factors influencing species distribution.

The statistical analysis of the phytoecological surveys revealed that the four described classes were correlated with four plant groupings. The *Tribulus terrestris* grouping comprised species growing in constraining areas with a sandy soil texture, a complete exposition to the sun, and a meager soil moisture. These species are short and less abundant (Thiombiano *et al.* 2012). The *Digitaria horizontalis* grouping also had short species with a low ground cover. They colonize degraded and sandy lands (Agbodan *et al.* 2019) around villages and camps. The *Chloris barbata* grouping contained large and very diverse species found in very humid areas, with often a clay-silty soil texture. The species in these last two groupings can colonize humid or dry areas and covered or uncovered zones. They can be sciaphilic and hygrophilous under trees, xerophilic outside shade, which justify their high diversity (Akpo and Grouzis 2009) in the Sahelian ecosystems. The species forming the *Achyranthes aspera* grouping were found in low or flat areas with a shallow exposure to the sunlight and a soil pH of around 6. They were very abundant and large but not very species-rich. It is worth noting that the presence of trees is beneficial for the development of other species as demonstrated by Ovalle and Avendano (1987) with the *Acacia caven* (Mol.) au Chili species association, Weltzin et Coughenour (1990) in the East African savannahs, Akpo and Grouzis (2009) in the Sahelian ecosystems. However, trees can also favor the interspecific competition for light.

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CONCLUSIONS

This study evaluated the floristic diversity of the herbaceous vegetation around the temporary ponds in Ferlo (Senegal). Although it focused on three ponds, the phytoecological analysis showed heterogeneity of the floristic structure related to environmental factors. The herbaceous flora recorded in the ungrazed temporary pond was more diverse and dense than in the grazed ponds. These results demonstrated the significant influence of grazing, which favors establishing species with a high regrowth capacity. In contrast, the Wendou Marodi pond, protected by fences for decades, had a more species-rich community and contained more species specialized to the pond's habitat conditions. The species composition of the ungrazed Wendou Marodi pond was closer to that of the semi-protected Belel Lougal pond. The vegetation's structure and composition are also potentially influenced by abiotic factors such as soil moisture, texture, slope, and sun exposure. This study demonstrates the necessity of maintaining a landscape mosaic comprising ungrazed ponds and grazed ponds reserved exclusively for livestock watering to conserve the floristic diversity. Since there are many temporary ponds in Widou Thiengoly, the only wetlands in the center of Ferlo, it would be essential to implementing such management to preserve the floristic diversity.

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AUTHORS' CONTRIBUTIONS

NF, MBS, AD and AG designed the study; NF, MBS and AD did the field survey; NF, MBS, AD, AG and PJL analyzed the data; PSS revised the English version and polished the format of the manuscript; NF prepared the first draft; all authors revised the manuscript.

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Table 1: Composition of the hearbaceous flora in each pond

Taxons			Codes	Ponds		
Families	***Genera***	***Species***		**1**	**2**	**3**
Acanthaceae	*Peristrophe*	*Peristrophe bicalyculata (Retz.) Nees*	*Pep*	+	-	-
Aizoaceae	*Zaleya*	*Trianthema pentandra L.*	*Trp*	+	+	+
Amaranthaceae	*Achyranthes*	*Achyranthes aspera var. indica L*	*Aca*	+	-	-
		Achyranthes sp	*Acs*	+	-	-
	Amaranthus	*Amaranthus hybridus L.*	*Amh*	-	-	+
Amaryllidaceae	*Pancratium*	*Pancratium trianthum auct.*	*Pat*	-	+	+
Araceae	*Stylochaeton*	*Stylochaeton hypogaeus Lepr.*	*Sth*	+	-	-
Capparaceae	*Cleome*	*Cleome viscosa L.*	*Clv*	+	-	-
Commelinaceae	*Commelina*	*Commelina forsskaolii Vahl*	*Cof*	+	-	-
Convolvulaceae	*Ipomoea*	*Ipomoea coptica (L.) Roth ex Roem. & Schult*	*Ipc*	+	-	+
Cucurbitaceae	*Cucumis*	*Cucumis melo var. agrestis Naudin*	*Cum*	+	+	+
	Momordica	*Momordica charantia L.*	*Moc*	+	+	-
Cyperaceae	*Cyperus*	*Cyperus esculentus L.*	*Cye*	+	+	+
	Kilinga	*Kyllinga brevifolia Rottb*	*Kyb*	-	+	-
	Fimbristylis	*Fimbristylis hispidula (Vahl) Kunth*	*Fim*	-	+	-
Fabaceae	*Alysicarpus*	*Alysicarpus ovalifolius (Schumach. & Thonn.) J.Léonard*	*Alo*	+	+	+
	Indigofera	*Indigofera hirsuta L.*	*Inh*	+	+	+
	Senna	*Senna obtusifolia (L.) H.S.Irwin & Barneby*	*Seo*	+	+	-
	Zornia	*Zornia glochidiata Rchb. ex DC.*	*Zog*	+	+	+
Gisekiaceae	*Gisekia*	*Gisekia pharnaceoides L.*	*Gip*	+	+	+
Limeaceae	*Limeum*	*Limeum viscosum (J. Gay) Fenzl*	*Liv*	-	+	+
		Limeum indicum Stocks ex T.Anderson	*Lii*	-	+	-
Malvaceae	*Corchorus*	*Corchorus aestuans L.*	*Coa*	+	-	-
		Corchorus olitorius L.	*Coo*	+	-	+
		Corchorus sp	*Cos*	+	-	-
		Corchorus tridens L.	*Cot*	+	+	+
Molluginaceae	*Mollugo*	*Mollugo nudicaulis Lam*	*Mon*	+	+	+
Nyctaginaceae	*Boerhavia*	*Boerhavia diffusa L.*	*Bod*	+	+	+
		Boerhavia erecta L.	*Boe*	+	+	+
		Boerhavia sp	*Bos*	+	+	-
Pedaliaceae	*Sesamum*	*Sesamum sp*	*Ses*	+	-	-

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Phyllanthaceae	*Phyllanthus*	*Phyllanthus niruri auct.*	*Phn*	+	+	+
		Phyllanthus pentandrus Schumach. & Thonn.	*Php*	-	+	+
Poaceae	*Aristida*	*Aristida mutabilis Trin. & Rupr.*	*Arm*	+	+	+
	Brachiaria	*Brachiaria lata (Schumach.) C.E.Hubb.*	*Brl*	+	-	-
		Brachiaria orthostachys (Mez) Clayton	*Bro*	+	+	-
		Brachiaria ramosa (L.) Stapf	*Brr*	+	+	+
	Cenchrus	*Cenchrus biflorus Roxb*	*Ceb*	+	+	+
	Chloris	*Chloris barbata Sw.*	*Chb*	+	+	-
	Dactyloctenium	*Dactyloctenium aegyptium (L.) Willd.*	*Daa*	+	+	+
	Digitaria	*Digitaria horizontalis Willd.*	*Dih*	+	+	+
	Echinocholoa	*Echinochloa colona (L.) Link*	*Ecc*	+	+	-
	Enteropogon	*Enteropogon prieurii (Kunth) Clayton*	*Enp*	+	+	+
	Eragrostis	*Eragrostis ciliaris (L.) R.Br.*	*Erc*	+	+	+
		Eragrostis tremula (Lam.) Hochst. ex Steud.	*Ert*	+	+	+
	Poaces	*Poacés sp*	*Pos*	+	+	+
	Schoenefeldia	*Schoenefeldia gracilis Kunth*	*Scg*	+	+	-
	Tripogon	*Tripogon minimus (A.Rich.) Hochst. ex Steud*	*Trm*	+	+	+
Portulacaceae	*Portulaca*	*Portulaca oleracea L.*	*Poo*	+	+	+
Rubiaceae	*Oldenlandia*	*Oldenlandia corymbosa L.*	*Olc*	+	+	+
		Oldenlandia linearis DC.	*Oll*	-	+	-
		Oldenlandia sp	*Ols*	+	+	+
	Spermacoce	*Spermacoce ruelliae DC.*	*Spr*	+	+	-
		Spermacoce sp	*Sps*	+	+	-
Zygophyllaceae	*Tribulus*	*Tribulus terrestris auct.*	*Trt*	+	+	+
22	**41**	**55**		**47**	**42**	**31**

1: Wendou Marodi**;** **2**: Belel Lougal**;** **3**: Belel Sow ; **-:** Absent**;** **+:** Present

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Table 2: Diversity Indices

Diversity Index	Wendou Marodi	Belel Lougal	Belel Sow
Specific richness (S)	47.00	42.00	31.00
Shannon Index (H') (bits)	04.90	04.80	04.50
Equitability of Pielou (E)	00.85	00.83	00.78

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Table 3: Comparative analysis of the contribution and recovery of deferent vegetation ponds

Statistical parameters		Average	Standard deviation	Coefficient of Variation (%)	*p*-value		
					WM	BL	BS
Recovery	WM	3.8	5.0	4.1	-		
	BL	2.5	3.9	3.9	1.9 E-11	-	
	BS	2.1	3.1	3.0	4.6 E-07	4.5 E-10	-
Contribution	WM	4.5	5.0	2.9	-		
	BL	4.5	5.5	3.4	9.8 E-12	-	
	BS	4.5	4.8	3.1	9.2 E-11	9.8 E-16	-

WM = Wendou Marodi; BL = Belel Lougal ; BS = Belel Sow

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Figure legends

Figure 1: Localization map of ponds

Figure 2: Arrangement of phytosociological transects (a), and delimitation method of plant groupings around transects (b)

Figure 3: Representation on the plan formed by the two first axis with groupings from each pond (L = Belel Lougal, M = Wendou Marodi, S = Belel Sow; A and B = transect numbers; 1, 2, ...10 = numbers of groupings)

Figure 4: Dendrogram representing the different classes of the obtained groupings

Figure 5: Representation on the plan of the different species groupings

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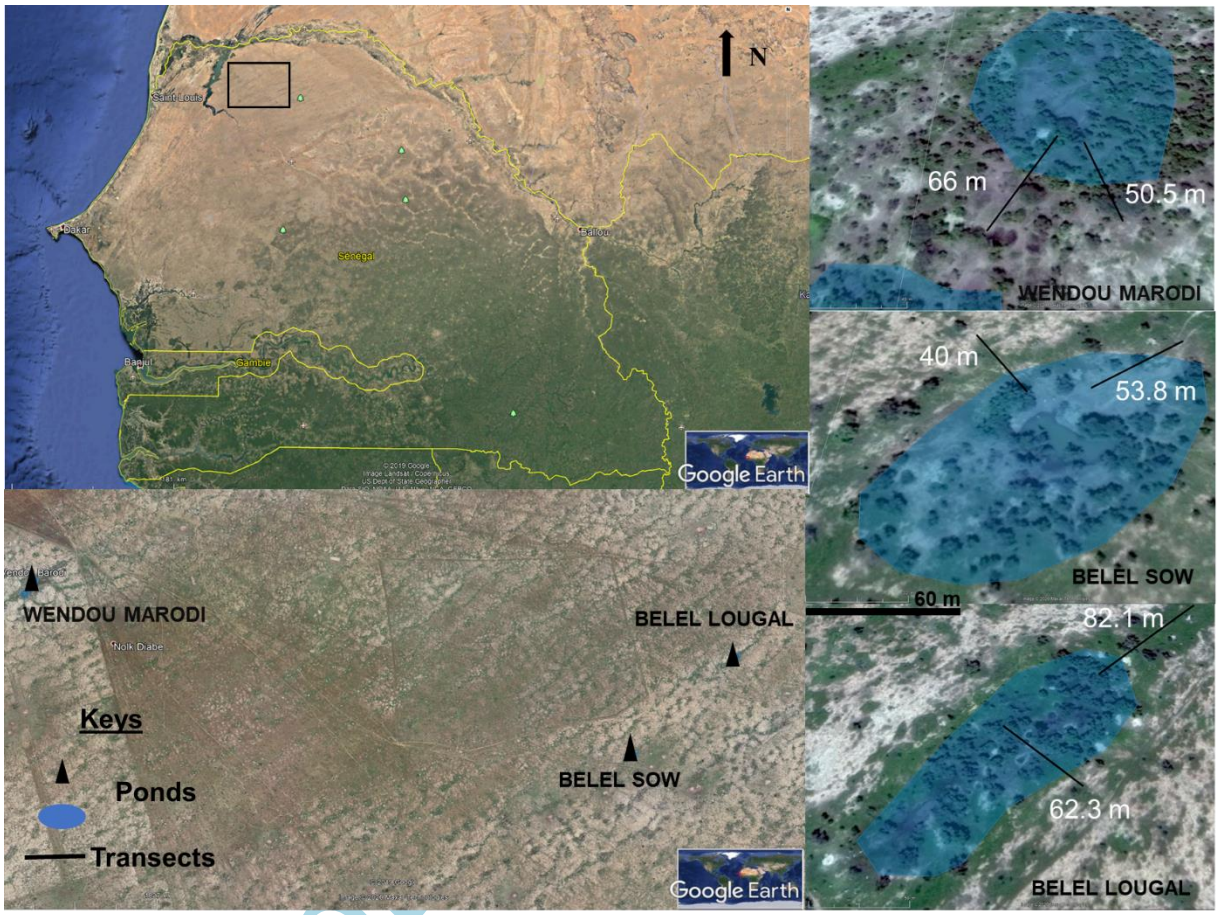

Figure 1: Localization map of ponds

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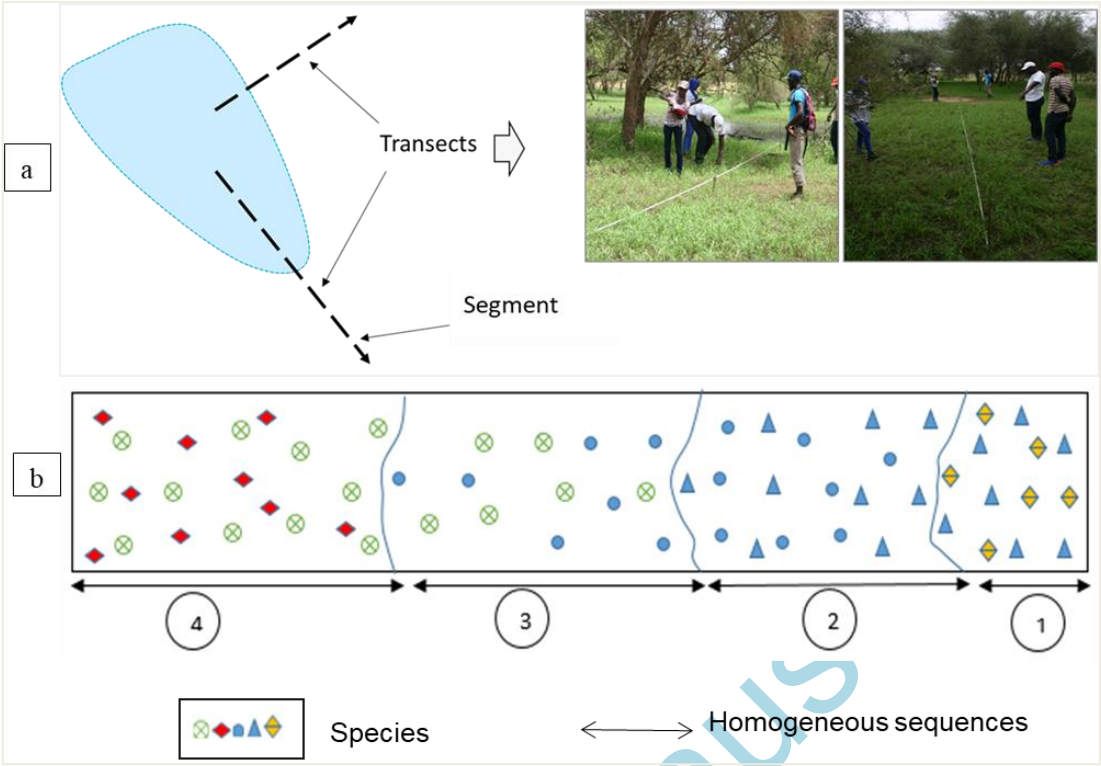

Figure 2: Arrangement of phytosociological transects (a), and delimitation method of plant

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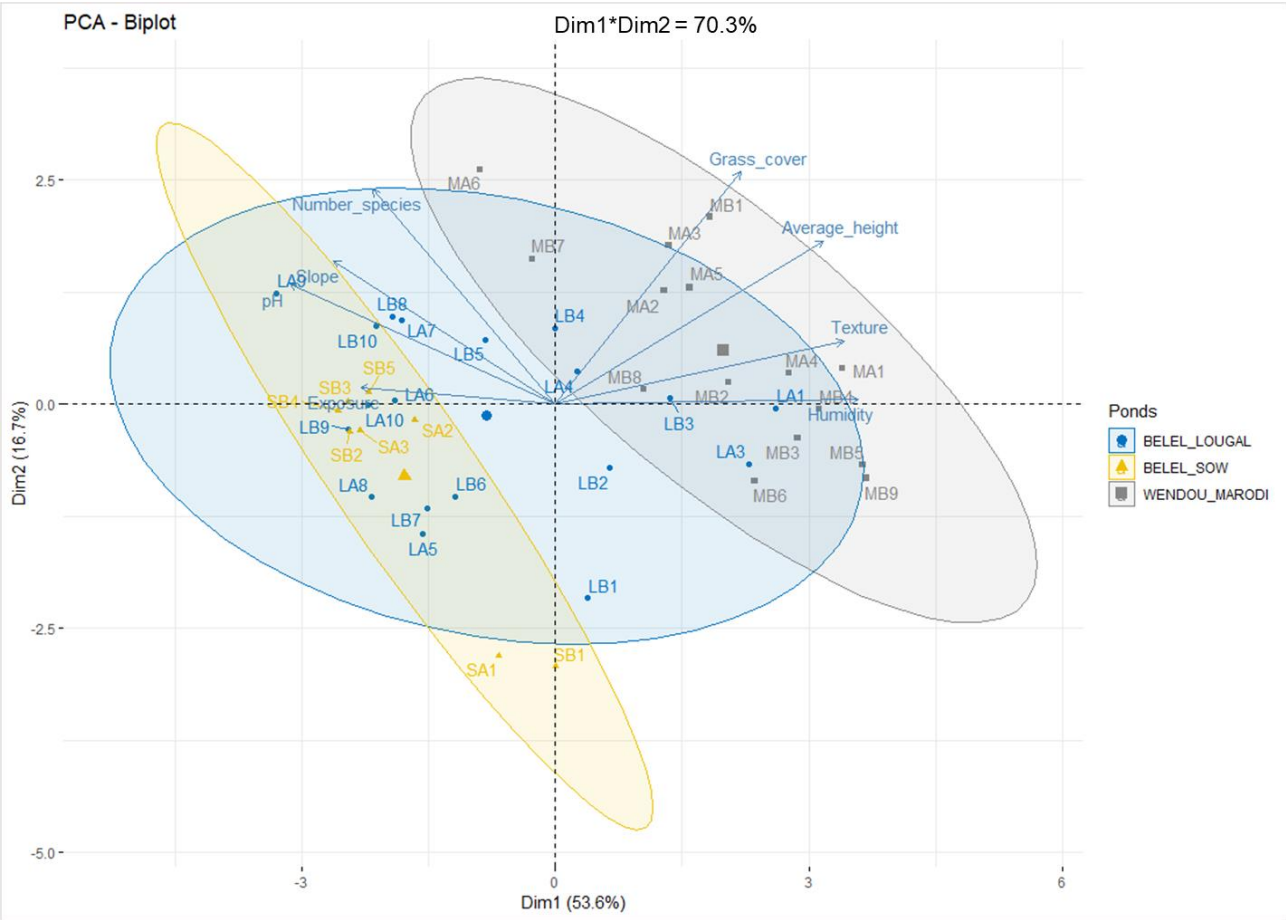

Figure 3: Representation on the plan formed by the two first axis with groupings from each pond (L = Belel Lougal, M = Wendou Marodi, S = Belel Sow; A and B = transect numbers; 1, 2, ...10 = numbers of groupings)

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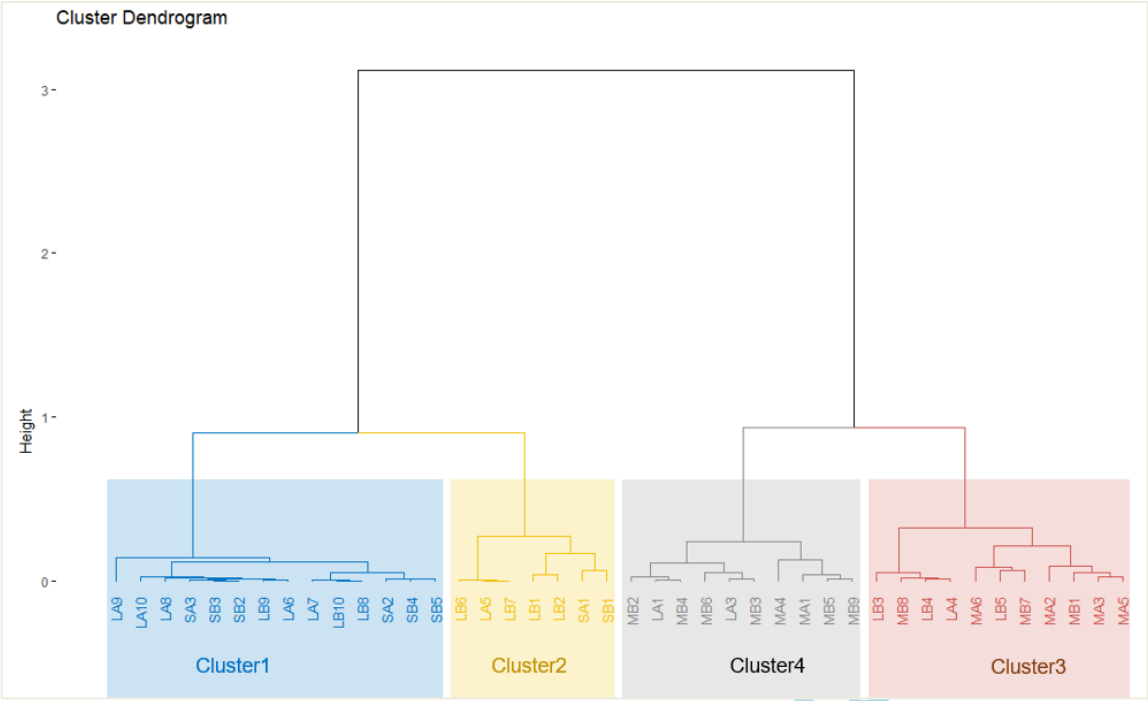

Figure 4: Dendrogram representing the different classes of the obtained groupings

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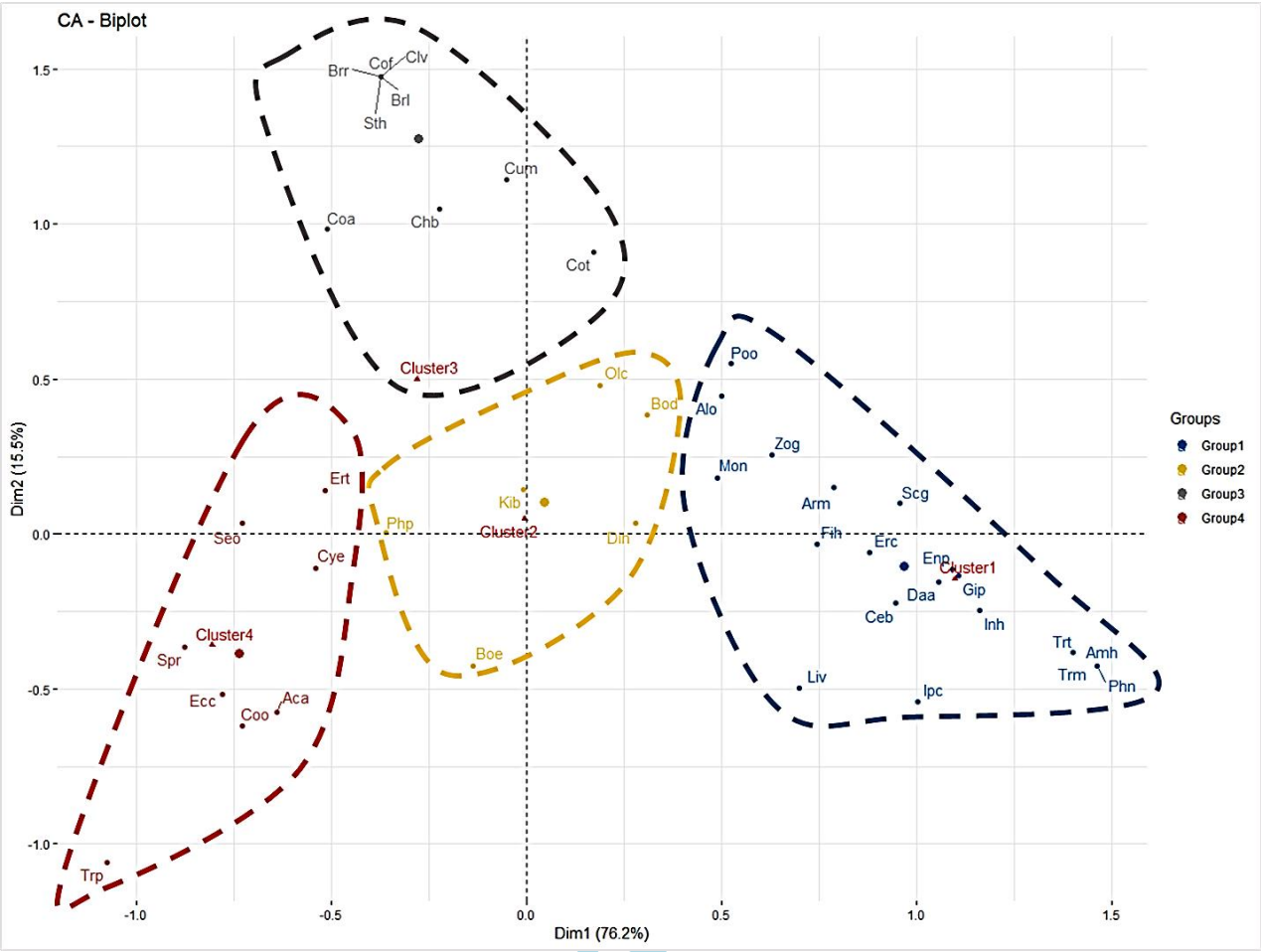

Figure 5: Representation on the plan of the different species groupings

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