Safeguarding of Benin wild pigs habitats to increase the resilience of spontaneous and marginal populations

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Abstract

The Red river hogs and the Common warthog are privileged game, quite prolific and their habitats are undergoing quite a bit of modification due to human activities. The phyto-ecological characterization of their habitats in South Benin has been carried out in their current range distribution. The Braun-Blanquet sigmatist method was used to carry out inventories in 70 phytosociological surveys taking into account the floristic community strata and anthropo-environmental data were collected following occurrence indices. A total of 184 plant species were enumerated and reduced to a Detrended Correspondence Analysis while a Hierarchical Ascending Classification was carried out to form ecological groups. After the diversity indices, the ecological spectra were produced and a linear model with a proportion test was performed. Low values of Shannon diversity indices (0-0.4 bits), Pielou Equitability (0-0.1) and Simpson index (0-0.01) and an ecological dissimilarity of habitats were observed in their communities. They are more fond of the herbaceous-arbustive groups but the ecological preference of red river hog, contrary to the common warthog, is marshy to semi-aquatic. It is fundamental to propose a master plan for reconversion, restoration of degraded habitats, review land use policies and evaluate these suids Average Daily Gain (ADG).

Keywords: Benin, domestication, habitats, Suids, threats

INTRODUCTION

The satisfaction of man's vital needs leads to numerous pressures on natural resources causing innumerable threats to animal and plant species (Bardin, 2013). Biodiversity being for Sinsin and Kampmann, (2010) a fullness of life in all its forms, profound and rapid changes in the environment are observed as a result of the economic growth of the 20th century. Global biodiversity has been in extreme decline for decades, a decline confirmed by an evolving trend in the number of species threatened with extinction (Barnosky *et al.*, 2011). With the aim of mitigating these losses, discussions were beginning to emerge with a view to creating geographically defined areas for the sustainable conservation of biodiversity with the involvement of the local population. These are protected areas whose management continues to suffer from numerous dysfunctions despite all the efforts made. Several forest habitats are still under major anthropic pressure causing fragmentation of the areas (Ouattara *et al.*, 2019). Habitat destruction, pollution of ecosystems, biological invasions, changes in interspecific competition (Amandine, 2011; Violette, 2008), the overexploitation of resources, global warming (Alves *et al.*, 2018; Brncic *et al.*, 2015) and poaching are also cited as factors contributing to significant biodiversity loss. The African continent is not spared by this loss even though it is known to be home to some remarkable and diverse genetic resources, including some of the most intact mammalian groups on the Earth's surface. Among these, wild suids represent a very important group, distributed throughout several African countries with different species and subspecies. Several countries, especially in Benin, attention is focused on facing situations leading to habitat alteration which had been addressed by the work of Baldus (2008). We underline that in Benin, there are three suid species: *Phacochoerus africanus*, *Potamocheorus porcus* and *Sus scrofa domesticus* (Codjia *et al.*, 2020) playing a key role in many ecosystems because they are reasonably sized and mainly omnivorous mammals (Souron *et al.*, 2015). Therefore they contribute to the ecosystems regeneration. In some habitats, the role of seed dispersal is attributed to them (Kerley *et al.*, 1996) and thus their level of intervention in the structuring of the floristic community could be considerable (Beaune *et al.*, 2012) as well as in the dynamics of tropical forests (Stoner *et al.*, 2007). Despite this, they are heavily poached and serve as food resources and a source of income for the local populations living in protected areas (Adjin *et al.*, 2011).

Wild suids *Phacochoerus africanus* (Gmelin 1788) and *Potamochoerus porcus* (Linnaeus 1758) are among the most sought-after game animals by hunters and are of obvious economic importance (Agassounon, 2005). Unfortunately, pig populations are declining in African forests (Breuer *et al.*, 2009; Vliet *et al.*, 2007). New adaptation strategies must be developed in the face of the considerable reduction wild species metapopulations for sustainable conservation (Ouattara *et al.*, 2019). Not only is the habitat of these two suids at stake, but also the plant resources they live on (Kidjo *et al.*, 2011). It is then important to make an inventory of the floristic community found in the *Phacochoerus africanus* and *Potamocheorus porcus* protected areas. Since the distribution of a species is a function of several factors, it is fundamental to measure parameters related to determinants of the presence of these suids in habitats where several ecosystem functions are fulfilled, as well as identification of plant communities around the occurrence areas. For these reasons, this work aim was to carry a phyto-ecological characterization of the *Phacochoerus africanus* and *Potamocheorus porcus* habitats. There are anthropogenic activities that modify the habitat and ecology of the *Phacochoerus africanus* and *Potamocheorus porcus*. There is no variation in the specific diversity of plant species found in the *Phacochoerus africanus* and *Potamocheorus porcus* habitats. The distribution of *Phacochoerus africanus* and *Potamocheorus porcus* is subject to variations in environmental/anthropogenic factors specific to different chorological zones. We will try to answer these four hypotheses through this study.

MATERIALS AND METHODS

Study area

The study sites extend between latitudes 8°00' and 7°12' N and longitudes 1°36' and 2°48' E (Figure 1) with an area of 2.250.000 ha characterized by two climatic zones, the Sudano-Guinean transition zone and the Guinean zone. The first is composed of shrubby/wooded savannah, forest galleries and fallow fields. Semi-deciduous dense forests, swampy formations, and thickets are often found in the Guinean zone, in addition to agricultural fields. The choice of these sites was based on the various results of our previous surveys and work where the presence of these suids was confirmed in Benin (Agassounon, 2005; Codjia *et al.*, 2007; Adjin *et al.*, 2011; Houehounha, 2011). The work of Codjia *et al.*, (2020) showed that in addition to the low representativeness of the Guinean zone, the transition zone of Benin, on the other hand, is a determining factor in the explanation of these two sympatric species. Also from the works of INSAE, (2016), a severe degradation of the vegetation cover is noted in the Benin southern part due to a high concentration of more than half of the population.

The Lokoli swamp forest is located in the district of Koussoukpa, (commune of Zogbodomey) between 7°03' N and 2°15' E on an area of about 3000 ha. The average annual temperature is between 26 and 28°C. In the Guinean zone, the gazetted Lama forest extends between latitudes 6°55' to 7°00' N and longitudes 2°04' to 2°12' E halfway between Allada and Bohicon. The southern part of this forest is accessible by the Ouègbo-Toffo trail while to the north, an Agrimey-Koto trail leads to the edge of the forest. The climate in southern Benin is sub-equatorial with four seasons unevenly distributed. The Gbidji swamp meadow is located in the commune of Dévé within the Mono Biosphere Reserve which is between latitudes 6° 11 '14.2" and 6° 59 '58.7" N and between longitudes 1° 35 '47.1" E and 1° 59' 28.1" E. It is an integral part of the RAMSAR 1017 site. The main habitat types found in the study area are: Dense semi-deciduous forests, swampy formations, open forests, wooded savannas, wooded savannas, mosaics of fields and fallows, swampy meadows and plantations. The Gnanhouizoun Community Area is found in the village Gnanhouizounmè located in Damè-Wogon district (Bonou commune). The commune of Bonou is located in the Department of Ouémé between 6°72' and 6°95' north latitude and between 2°15' and 2°40' east longitude. The Agbé and Mongnigbé Complex is located in the Zou department while the Djaloukou Ranch in the hills. The Sédjè Denou and Houegoudo Complex is located in the Atlantic Department, more precisely in the Zé commune. We finally have the Gazetted Dogo-Kétou Forest and the Sacred Forest of Kouvizoun which are located in the Plateau department. The main soils encountered in this study area are hydromorphic, ferruginous, ferralitic, sandy loam, colluvial, alluvial and vertisol.

Data collection

Before our field inventory on vegetation, the presence of *Phacochoerus africanus* or *Potamocheorus porcus* was verified by direct observation and by using indirect evidence such as bauges, footprints, lodgings, droppings, swill digging and food remains (Codjia *et al.*, 2009). This floristic and phyto-sociological evaluations was carried out in 20 m x 20 m (400 m^2) plots according to the sigmatist method of Braun-Blanquet (1932) and the methodological approach of Sokpon (1995); Houinato (2001) and Oumorou (2003).

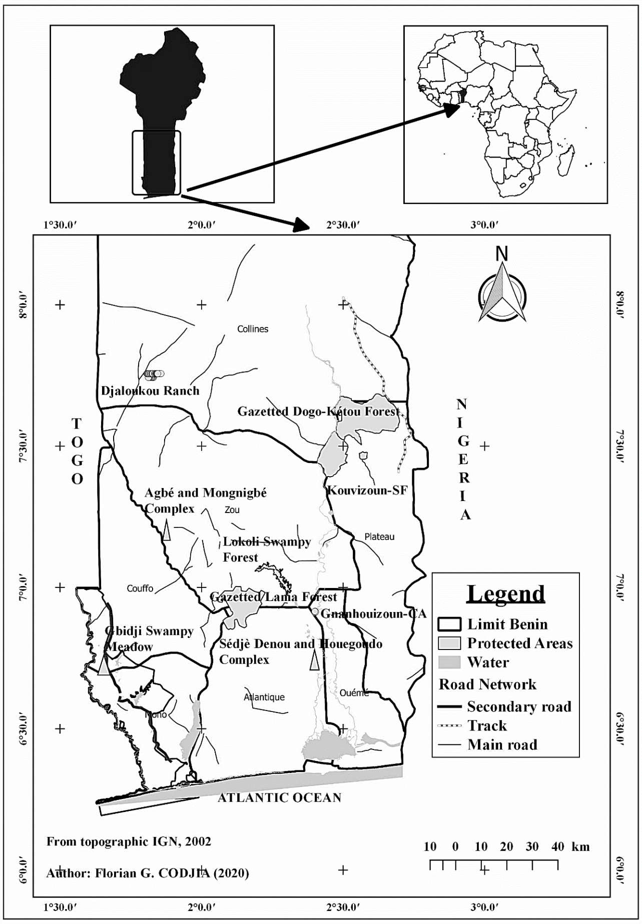

Figure 1: Study area

In addition to the direct/indirect species presence indices, the number of plots was also obtained by taking into account the floristic community strata in presence (Kidjo *et al.*, 2011) per site. Abundance-dominance coefficients (ranging from + to 5) were assigned to the species with +: Species covering less than 1% of the survey area and with a mean overlap of 0.5%; 1: species covering 1-5% of the survey area and with a mean overlap of 3%, 2: species covering 5 to 25% of the survey area and with a mean recovery of 15%, 3: species covering 25 to 50% of the survey area and with a mean recovery of 37.5%, 4: species covering 50 to 75% of the survey area and with a mean recovery of 62.5%, 5: species covering 75 to 100% of the survey area and with a mean recovery of 87.5%. These floristic data were collected from 15 December 2019 to 29 March 2020 at 9 sites (Figure 1). A total of 70 plots were installed and the species recorded were noted. For species that were not identified or that raised doubts, parts and organs of the latter were collected and then conveyed to the National Herbarium of Benin for confirmation of their identities. Some botanical books such as: La Flore du Bénin (De-Souza, 2006, 2008) et Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest (Arbonier, 2019) were also used.

The ecological analysis was based on parameters likely to influence the distribution and abundance of the considered suids species. The variables that were selected and that could explain the presence or absence of these species in these ecosystems are: vegetation overlay, the number of trees and shrubs in the ecosystem (De-Jong and Butynski, 2014), vegetation density, type of habitat (Swanepoel *et al.*, 2016), distance to the nearest water point, distance to the water point, distance between each site (De-Jong, Cumming, *et al.*, 2016). In addition to these variables, there was also the distance between each site and fields, distance between each shins and fields, type of soil, size of riparian population and fires management (De-Jong, Butynski, *et al.*, 2016). Vegetation, topography, anthropization, lodgings, etc., were selected on the basis of factors that could influence habitat selection (Codjia *et al.*, 2007), soil texture and water sources (Rodgers, 1984), are the main elements likely to govern the habitat choice for both species. About the distances measured, both species presence points were recorded by GPS in the field. These different points were integrated into the Qgis 2.18.9 software and the *nnjoin* extension (Euclidean distance method) provided the shortest distance.

Data analysis

To carry out a phyto-ecological habitats characterization of the two suids species found below 8 degrees of longitude in Benin, the presence/absence plant species data in 70 phyto-ecological surveys were subjected to a DCA (Detrended Correspondence Analysis) with the package *vegan* (Oksanen *et al.*, 2019) then to a Hierarchical Ascending Classification (HAC) to build ecological groups. For each ecological grouping, the Shannon-Weaver Diversity Index (Shannon and Weaver, 1949), Pielou Equitability (Pielou, 1966), Simpson index (Simpson, 1949) as well as the ecological spectra (raw and weighted spectra) were calculated.

- ***Shannon-Weaver diversity index***

$$H' = -\sum_{i=1}^{n} Pi \log_2 Pi$$

where Pi is the proportion of the species i in the grouping.

- ***Pielou Equitability Index***

$$Ed = H'/\log_2 S$$

With Ed ∈ [0,1] and S denoting total diversity, it is also the number of species categories. If $0 < Ed < 0.5$ the diversity is low, If $0.5 < Ed < 0.7$ the diversity is medium, If $Ed > 0.7$ the diversity is high.

- ***Simpson index***

$$D = 1 - \sum_{i=1}^{n} Pi^2$$

The ecological spectra (raw and weighted spectra) of the different plant groups were presented on graphs made with the *ggplot2* package (Hadley *et al.*, 2020).

- ***Raw Spectrum (Sb)***

It expresses the ratio between the number of life forms/chorological species type and the total number of species in the plant grouping.

$$Sb = \frac{ni}{N} * 100$$

ni= total number of a given type

N= total number of species in a group

(Sb)= raw spectrum in %.

- ***Weighted Spectrum (Sp)***

It expresses the ratio between the cumulative mean overlay of life forms/chorological species type and the total species mean overlay making up the plant grouping.

$$Sp = \frac{ri}{R} * 100$$

ri= total overlay

R= mean overlay

(Sp)= Weighted Spectrum in %.

To analyze the distribution of stratum types (shrub, herbaceous, lower tree and upper tree) according to plant groupings, a comparison of proportions was carried out. In addition, a primary and secondary habitats overview of the groupings was made. Finally, a linear model was fitted to the Abundance Kilometric Index (IKA) relating to indirect indices explained by environmental and anthropogenic characteristics. An analysis in principal components (Husson *et al.*, 2018) mixed (mixed PCA) with the package *PCAmixdata* (Chavent *et al.*, 2017) on significant environmental and anthropogenic variables. All analyses were performed using R (R Core-Team, 2019) and the level of significance of the statistical tests was set at 5%.

RESULTS

Plant groupings individualization

The DCA performed on the presence/absence matrix of 184 plant species data in 70 phytoecological surveys allowed to build 3 plant groupings (Figure 2).

• **G1** (Grouping at *Dioscorea praehensilis* (Benth.) A.Chev. and *Detarium microcarpum* Harms).

Group 1 consists of 31 surveys installed at Djaloukou Ranch, Gnanhouizoun-CA, Kouvizoun-SF, Gazetted Dogo-Kétou Forest and Agbé and Mongnigbé Complex. It is characterized by the presence of species such as *Andropogon gayanus* (Kunth), *Antiaris toxicaria* (*Lesch*), *Senegalia caffra* (Thunb), *Chromolaena odorata* L. and *Schizachyrium pulchellum* (D.Don ex Hook.) Stapf.

• **G2** (Grouping to *Stachyanthus occidentalis* (Keay & Miège) Boutique and *Cynometra megalophylla* L.)

It is the group of plots installed in the Gazetted Lama Forest. There were 27 of them and the group is distinguished from the others by the preponderant presence of forest species, notably *Culcasia scandens* (P. Beauv), *Lecaniodiscus cupanioides* (Planch.), *Jaundea pinnata* (P. Beauv), *Stachyanthus occidentalis* (Keay & Miège) Boutique, etc.

• **G3** (Grouping with *Cyclosorus striatus* (Schum) Ching and *Anthocleista vogelii* Planch.)

Group 3 consists of all 12 surveys installed mostly in Gbidji Swampy Meadow, Lokoli Swampy Forest, Sédjè Denou and Houegoudo Complex. Here there is the presence of *Symphonia globulifera* L., *Cyclosorus striatus* (Schum) Ching, *Anthocleista vogelii* Planch. and *Xylopia aethiopica* (Dunal) A. Rich.

Table 1: Values of the 70 surveys and 184 species explained by the four main factor axes

Axes	1	2	3	4
Eigen values	0.81	0.78	0.68	0.67

Partitioning ecological surveys into elemental assemblies

The results of the hierarchical classification carried out on the presence/absence plant species data in the phytoecological surveys are presented in figure 3. The results show that the surveys are arranged into 3 main groups (with the conservation of 68.4% of the information) and confirm the DCA.

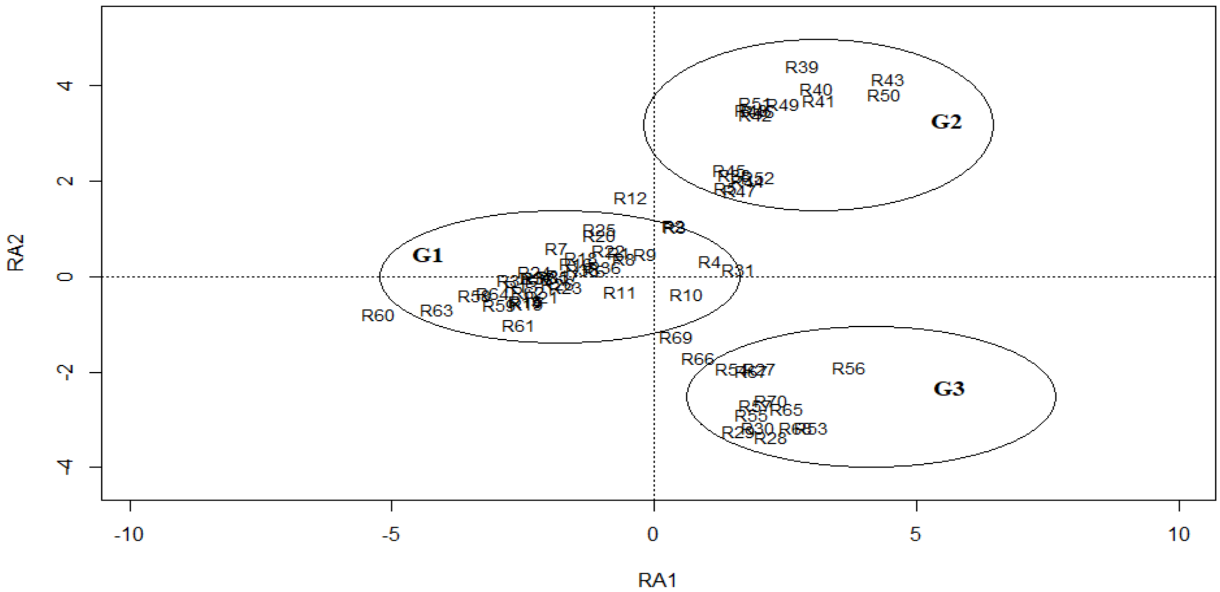

Figure 2: Projection on axes 1 and 2 of the DCA carried out on the presence/absence data of 184 plant species in 70 phyto-ecological surveys

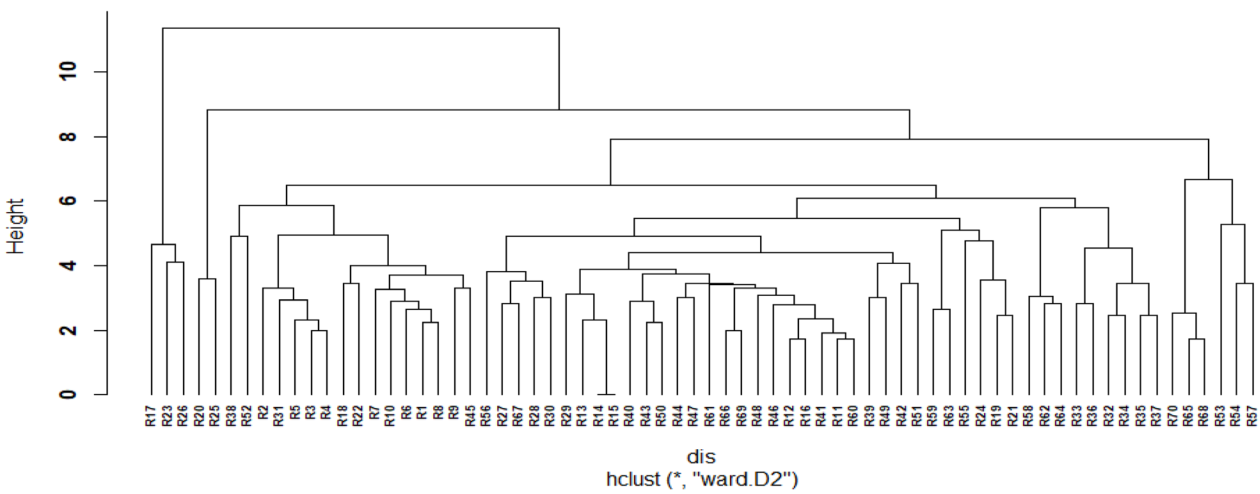

Figure 3: Hierarchical tree of the 70 surveys

Specific diversity of elementary assemblies

A total of 184 species belonging to 62 families were counted. Euphorbiaceae (16 species either 26%), Rubiaceae (15 species either 24%), Leguminosae-Papilionoideae and Poaceae (10 species either 16% of each) are the families most represented in the inventories carried out. Table 2 presents the ecological parameters of the different formation groups. The highest species richness (102 species) is obtained for group 1, while the lowest (36 species) is obtained for group 3; group 2 has a species richness of 46 species. The Shannon diversity index (H) varies between 0.13 bits (group 2) and 2.97 bits (group 1). Group 1 had the highest value of this index. Pielou's Equitability index was low for group 2. The same trend was observed based on the Simpson's index (D) where the probability that two randomly selected individuals belonged to the same species was higher (0.1) for group 1.

Fundamentals of the life form and chorological spectra of elementary assemblages

The raw and weighted spectra of the life form and chorological types of the plant grouping G1, G2 and G3 are shown in figures 4 and 5, respectively.

The figure 4a shows that meso-phanerophytes (Sb = 56.9%, Sp = 61.3 %) were the dominant biological types, whereas chamephytes were very poorly represented. The figure 5a spectra show that Guinean-Congolese species were the most abundant with raw and weighted spectra of 38.2% and 39.1% respectively.

The life form and chorological types encountered within the G2 group are illustrated in figures 4b and 5b.

It can be seen from figure 4b that mesophanerophytes (Sb = 54.3 % and Sp = 60.5 %) were more abundant and dominant. Geophytes and epiphytes were absent. Chorological spectra (Figure 5b) showed that Guinea-Congolese species were more abundant. Cosmopolitan species were absent.

The life form and chorological types encountered within the G3 group were represented in figures 4c and 5c. Mesophanerophytes (Sb = 66.7 %) were abundant and dominant with a weighted spectrum of 70.8%. Epiphytes and geophytes were absent. About chorological types, pantropical (Pt) species were the most dominant and abundant (Sb = 25.0 % and Sp = 24.0 %). Cosmopolitan species are absent.

Comparative analysis of strata by elemental assemblage and identification of typical habitats

The different strata observed in the groupings are presented in Table 3. Group 1 consists mostly of herbaceous and less species of the upper tree stratum with a non-significant difference ($p > 0.05$) while groups 2 and 3 are characterized by shrubs. A significant difference ($p < 0.05$) is noted between the species of the lower shrub and tree strata and those of the upper tree strata within group 3.

Table 2: Ecological parameters of plant formation groups

Groups	Parameters			
	S (Species)	H (bits)	Eq	D
Group 1	102	2,97	0,45	0,1
Group 2	46	0,13	0,023	0,0003
Group 3	36	0,39	0,076	0.007

S= species richness, the Shannon diversity index (H), the Simpson's index (D).

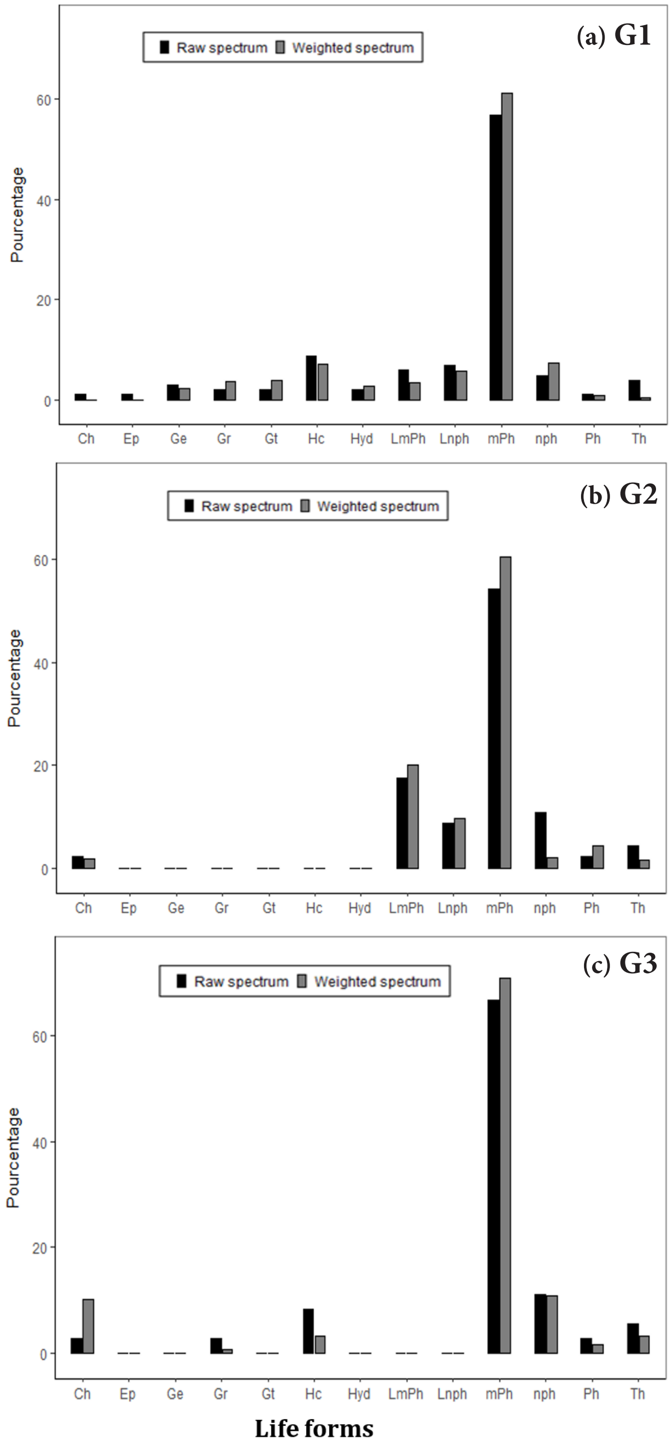

Figure 4: Life forms spectrum

Life forms: ***MPh:*** *megaphanerophyte (> 30 m tall),* ***mPh:*** *mesophanerophyte (8-30 m),* ***mph:*** *microphanerophyte (2-8 m),* ***nph:*** *nanophanerophyte (0.5-2 m),* ***Ch:*** *chamephyte, Ge: Geophyte,* ***HC:*** *Hemicryptophyte,* ***Th:*** *Therophyte,* ***L:*** *Liana,* ***Ep:*** *Epiphyte,* ***LmPh:*** *mesophanerophyte lianas,* ***Lnph:*** *nanophanerophyte lianas,* ***Hyd:*** *Hydrophyte,* ***Gr:*** *rhizome Geophyte.*

Table 3: Different stratum of plant formation groups

Groupe-ments	Stratum	Num-ber	Frequen-cy (%)	Prop. test (p value)
Group 1	Herbaceous	31	30.39 a	0.12
	Lower Tree	26	25.49 a	
	Shrub	28	27.45 a	
	Upper Tree	17	16.67 a	
Group 2	Herbaceous	11	23.91 a	0.06
	Lower Tree	8	17.39 a	
	Shrub	18	39.13 a	
	Upper Tree	9	19.56 a	
Group 3	Herbaceous	6	16.67 a	0.01
	Lower Tree	12	33.33 a	
	Shrub	14	38.89 a	
	Upper Tree	4	11.11 b	

The species of the G1 plant grouping were most commonly found in dense, semi-deciduous, swampy forest and secondarily in wooded savannah (Table 4). In contrast to Group 2 species found in semi-deciduous forest and wooded savannah and sometimes in plantations. Group 3 species were found in swamp forest and wooded savannah and sometimes in open forest and plantations.

Table 4: Primary and secondary habitats of plant formation groups

Groupe-ments	Main Habitats	Secondary Habitats
Group 1	Dense forest	Tree Savannah
	Semi-deciduous forest	Swampy Meadow
	Swampy forest	
	Lower Swamp Degraded Forest	
Group 2	Semi-deciduous forest	Planting
	Woodland Savannah	Tree Savannah
Groupe 3	Swampy forest	Open Forest
	Woodland Savannah	Planting
	Tree Savannah	

Analysis of factors contributing to the two suids presence in habitats

The results of the linear model (Table 5) show that the altitude, vegetal overlay, distance to the water point, rainfall, distance of Mono/Zou/Oueme river, distance to the nearest site, type of formation, the habitat, fire use and the soil type significantly influenced relative IKA. When the altitude increased by one meter the relative IKA decreased by 0.0023. Thus when rainfall increased by 1mm the relative IKA decreased by 0.00311.

The Mixed Principal Component Analysis showed that 37.93% of the variability in the factors explaining the relative IKA was summarized on the two main axes. The correlation between the factors and the first factor axes and the modalities projection of the qualitative and quantitative variables are presented in table 6, figures 6 and 7, respectively.

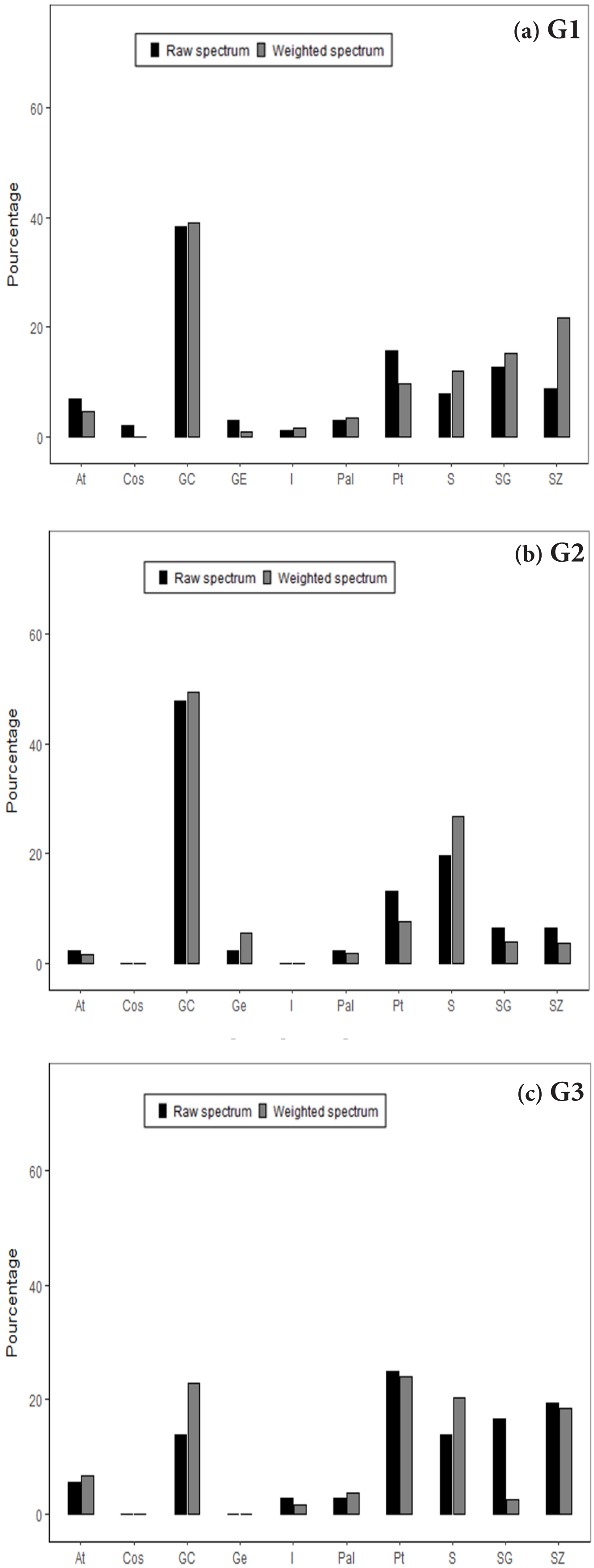

Figure 5: Chorological types spectrum

Chorological types: ***At:*** *Tropical African,* **GC:** *Guineo-Congolian,* **GE:** *Lower Guinean,* **GO:** *Upper Guinean,* **Pt:** *Pantropical,* **PAL:** *Paleotropical* **SG:** *Sudano/Guinean transition,* **S:** *Sudanian,* **SZ:** *Sudano-Zambezian,* **Cos:** *Cosmopolitan,* **I:** *Introduced.*

Red river hog were encountered in the sites of Gnanhouizoun-CA, Kouvizoun-SF, Sédjè Denou and Houegoudo Complex, Gazetted Lama Forest, Lokoli Swampy Forest, Gbidji Swampy Meadow. Warthogs in the Djaloukou Ranch, Agbé and Mongnigbé Complex, Gazetted Dogo-Kétou Forest sites. Common warthogs were found in high elevation environments (104.2 ± 20.2 m) with 48.3 % vegetation overlay and a rainfall of 1026.0 mm with high habitat cover. They were found in open formations, in mosaics of fields and fallow land, in shrubby and wooded savannah and open forest with hydromorphic soils.

Red river hog were found on sites where water points are close, with a vegetative overlay (62.1%) and altitude (71.3 ± 13.8 m) but low rainfall (1193.4 ± 49.7 mm). In these environments, the formation was not very open, but above all closed, sometimes dense, and the soil was hydromorphic, vertisol or clay-silt type (meadows and forests/marsh formations, dense and semi-deciduous forests, wooded savannas).

Table 6: PCAmix results: Correlations between quantitative factors and main axes

Parameters	dim 1	dim 2
Altitude	0.4670351	0.61271631
Overlay	0.1749086	0.78895318
Rainfall	0.9423518	-0.12214579
The distance to the nearest stream	-0.1205161	0.82116999
Distance of Mono Zou Oueme river	-0.4539760	0.35308357
Distance to the nearest site	0.7592328	-0.08233344
Distance from the presence point to the water point	0.2114551	0.61138298

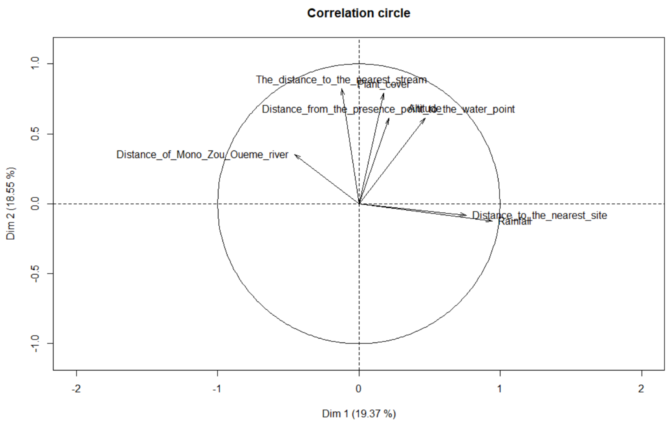

Figure 6: Projection of quantitative variables

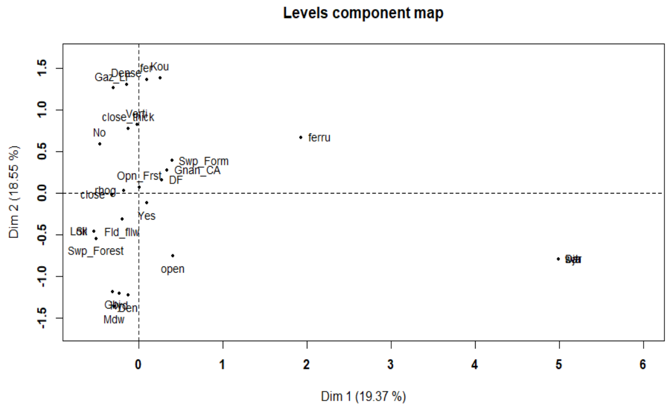

Figure 7: Modalities projection of the qualitative variables

*Gnanhouizoun Community Area= **Gnan_CA**, Sacred Forest of Kouvizoun= **Kou**, Sédjè Denou and Houegoudo Complex= **Den**, gazetted Lama forest= **Gaz_LF**, Lokoli swamp forest= **Lok_SF**, Gbidji swamp meadow= **Gbi**, Djaloukou Ranch= **Dja**, Red_river_hog= **rhog**, common Warthog= **war**, swampy formations= **Swp_Form**, Dense_forest= **DF**, Open forest= **Opn_Frst**, Fields and fallow= **Fld_fllw**, Semi-deciduous dense forests= **Dense**, thickets= **thick**, Meadow= **Mdw**, tree_savannah= **svh**, Swamp_forest= **Swp_Forest**, ferralitic= **fer**, ferruginous= **ferru**, Hydromorphic= **Hyd**, Silty= **Sil**, Vertisol= **Verti**.*

Table 5: Linear model results

Parameters	**Coefficients**	**Standard Error**	**t-value**	**p**
(Intercept)	2.27e-01	1.04e-15	2.18 e+14	<0,001
Species warthog	1.05e+01	1.97e-14	5.34 e+14	<0,001
Altitude	-2.30e-03	1.40e-18	-1.63e+15	<0,001
Overlay	7.41e-03	1.56e-17	4.73e+14	<0,001
Distance to the nearest site	-1.48e-04	1.15e-19	-1.28e+15	<0,001
Distance from the presence point to the water point	1.84e-04	9.15e-20	2.01e+15	<0,001
Type of formation closed	-7.43e-01	5.07e-16	-1.46e+15	<0,001
Type of habitat Swamp forest	1.52e-03	2.14e-16	7.13e+12	<0,001
Type of habitat Field and fallow	-1.96e-01	5.84e-16	-3.36e+14	<0,001
Type of habitat Open forest	9.07e-01	7.68e-16	1.18e+15	<0,001
Type of habitat Dense semi-deciduous forest	-2.63e-02	5.74e-16	-4.58e+13	<0,001
Type of habitat Swamp formations	2.30	9.17e-16	2.51e+15	<0,001
Type of habitat Dense forest	2.55e+00	1.61e-15	1.58e+15	<0,001
Rainfall	-3.11e-04	1.70e-18	-1.83e+14	<0,001
The distance to the nearest stream	4.67e-04	1.44e-19	3.23e+15	<0,001
Forest management fire No	3.753e-01	2.06e-16	1.81e+15	<0,001
Soil type Hydromorphic	2.04	1.13e-15	1.80e+15	<0,001
Soil type Vertisol	-2.44	8.56e-16	-2.85e+15	<0,001
Soil type Silty clayey	2.46	1.76e-15	1.39e+15	<0,001
Distance of Mono/Zou/Oueme river	3.34e-05	4.43e-20	7.55e+14	<0,001

DISCUSSION

Habitats used by Red river hogs and Common warthogs

In this study, the Red river hog presence was mainly felt in grasslands, swamp forests/marshlands, dense and semi-deciduous forests, wooded savannahs, field mosaics and fallow land in southern Benin. The Red river hogs are thus intimately linked to their ecology though that today wildlife species specifically and biodiversity in general are facing an anthropogenic series threats and climate change. Their presence in these different habitats was also reflected in the work of Houehounha, (2011); Leus & Vercammen, (2013). Like the Sitatunga, the Red river hog loves swampy areas (Kidjo *et al.*, 2011) already that it ensures its thermoregulation by the mud baths (Kimmel, 1998) and is quite dependent on water. Shrubby savannah, wooded savannah, open forest, field mosaics and fallow are more representative of the open formations identified in the Common warthog in this study. Not only the work of Seydack, (1990); Le-Glaunec, (2006); Codjia *et al.*, (2007) are evidence of the great affinity of warthogs for drier, less closed environments where water points are not as frequent. The two suids covered by this study react in the same way as the common hippopotamus (Dunham *et al.*, 2010) and the Europe Boar (Blouch, 1988) which apply strong depredation on crops in the field. It is therefore right that 65% of the plant species consumed by Common warthog and Red river hog in this study area came from the fields or were species introduced by man (Codjia *et al.*, in press b). Although agriculture requiring the humans presence disturbs the peace and encroaches on the Common warthog and Red river hog ecology. Even if the hypothesis is accepted, it is essential to limit the agricultural land expansion in these areas where these suids are long-term subject to their preferred habitats loss. Vegetation fires and cattle grazing by transhumant herders, on the other hand, should be banned as they disturb the suids peace and quiet and cause migration from one habitat to another. In contrast to wildfires, uncontrolled grazing of oxen was most observed in sites where Common warthog was present, which explains the great savannahs advance into their preferred habitats. It would also be important to assess the suids vulnerability to variations in climatic conditions; already no wildlife work had yet mentioned these suids existence in some places including Gnanhouizoun-CA, Sédjè Denou and Houegoudo Complex, Lokoli Swampy Forest, Gbidji Swampy Meadow, Djaloukou Ranch, Agbé and Mongnigbé Complex in Benin. A significant difference (pvalue <0,05) was noted between species in the lower and upper shrub/tree strata within group 3, which is related to the habitat nature in this grouping, which is swampy, where these species occurence probability in the upper tree stratum is low, as was the case in groups 1 and 2. Following this statistical difference, we hypothesize that Red river hogs found in swampy habitats do not often venture into vegetation facies where species from the upper tree stratum predominate.

Specific elementary assemblies diversity

The Pielou Equitability Coefficient and the Shannon Index (H) were calculated following the associative groupings determination in order to appreciate specific diversity more better. A greater diversity was observed in group 1, which was made up of *Andropogon gayanus*, *Antiaris toxicaria*, *Senegalia caffra*, *Chromolaena odorata* et *Schizachyrium pulchellum*. Strong equality of individual contributions (Akpo *et al.*, 1999) could thus be highlighted at the Djaloukou Ranch, Gnanhouizoun-CA, Kouvizoun-SF, Gazetted Dogo-Kétou, Agbé and Mongnigbé Complex Forest level. Futhermore, non-regularity in the individuals distribution resulted in groups 2 and 3. This situation is not necessarily related to competition effects (Djego, 2006) between native species and the climatic phytocenosis emergence. It could be justified here by factors such as habitat type/formation, direct/indirect frequency inventory indices in the survey, overharvesting and overcutting, individuals density, discreteness, abundance and Red river hogs diet type practiced in Groupings 2 and 3. The low values of the Shannon Index (0-2 bits) in groups 2 and 3 show that environmental conditions are not too favourable for many species establishment because of a stability lack. This explains the dominance of species such as:

- *Echinochloa pyramidalis* in association with *Ipomoea aquatica* and *Typha domingensis* (Gbidji Swampy Meadow) or in association with *Dissotis rotundifolia* and at *Sterculia tragacantha* and *Symphonia globulifera* (Sédjè Denou and Houegoudo Complex).
- *Anthocleista vogelii* in association with *Xylopia rubescens* and *Culcasia scandens*; or at *Syzygium owariense* in the association *Lasiomorpha senegalensis* and *Hallea stipulosa* (Lokoli Swampy Forest).

Other species such as *Elaeis guineensis*, *Pterocarpus santalinoides*, are mostly encountered at the edge of these swampy areas as was the case in the work of Natta, (2003) in Lokoli Swampy Forest, as well *Gossypium Hirsutum* to Gbidji Swampy Meadow.

- *Dioscorea sagittifolia* in association with *Memecylon afzelii* and *Strychnos splendens* ; or at *Commelina erecta* in the association *Holarrhena floribunda* and *Reissantia indica* (Gazetted Lama Forest). Groupings 2 and 3 have Shannon Index and Pielou Equitability values similar to those obtained in the work of Lejoly, (1995); N'zala *et al.*, (1997) while those in group 1 tend towards those obtained by Chidumayo, (1986) in the natural Zambésian forest and by Djego, (2006). The most dominant ecological families (Euphorbiaceae, Rubiaceae, Leguminosae) in this study are also dominant in the work of Adomou *et al.*, (2005) and Natta (2003). This is thus explained cause they had worked in some phytodistricts (2-Pobé, 3-Plateau, 4-Ouémé-vallée et 5-Zou) of great interest where ecological and even climatic conditions were fairly similar even if the study objectives were not identical. This is also the reason why Dioscoraceae, Arecaceae, Euphorbiaceae, Poaceae and Leguminosae.-Papilionoideae were the most represented in the most consumed species family of these two suids (Codjia *et al.*, in press b). Several other families including Balanophoraceae, Curcubitaceae, Sapotaceae, Vitaceae, Zingiberaceae were cited in the work of Adjin *et al.*, (2011) as an integral part of the plant species consumed by the Common warthog in the Gazetted Dogo-Kétou Forest and Azili. This could be explained by the in these forests degradation today, reducing species richness. Although among all the studies carried out so far, this study reveals enough information at the same time on both suids about their basic and food ecologies. The Poaceae predominance reflects an opening of the canopy, a degradation under the edge effects influence (Natta, 2003) that is more concentrate at the Gazetted Dogo-Kétou Forest (11.3 %), in Agbé and Mongnigbé Complex (4.83 %) and Djaloukou Ranch (3.22%). The initial hypothesis is accepted because whatever the species of suids, there is a variation in the family, in the plant species found in the preferred habitats. Trough the work by Dan *et al.*, (2016), the primary pioneer species presence such as *Hallea stipulosa*, *Alstonia congensis*, *Spondianthus preussii, Ficus trichopoda, Cyclosorus striatus*; and others introduced (Dan *et al.*, 2012) which *Elaeis guineensis*, *Raphia hookeri*, *Oryza sativa*, *Mangifera indica*, *Newbouldia laevis* s were noticed in most of the wetland areas in Group 3. Inappropriate holes make way for the continuous mat, making the long term less homogenous (Fahr *et al.*, 2006), less preserved (Dossou *et al.*, 2012) the preferred habitats of these species.

Life form and chorological type in the three elementary assemblages

The results showed that whatever the grouping, mesophanerophytes were the abundant and dominant biological types. The strong overlap observed in the phanerophytes (Djego, 2000) in particular mesophanerophytes, underlies a woodland attributes capitalisation of the different habitats in the sites investigated in tropical environments, as was the case in the works of Marra *et al.*, (2012). In addition, in these formations, the low Chamephytes representativeness (group 1) shows the not very dry character of the habitats of group 1 favourable to the Common warthogs. We know these Chamephytes live only a few years contrary to the Phanerophytes. Indeed, like the Phanerophytes, the Chamephytes develop accessory assimilation organs to fight against desiccation. This high proportion of Phanerophytes also reflects their capacity to limit (competition) the invasive plants development through their root systems. The low coverage of perennial grasses within groups 1 and 3 explains the lower dominance of Hemicryptophytes in the surveys. Mesophanerophytes, Geophytes, and Therophytes were respectively the life forms most involved in the two suids feeding (Codjia *et al.*, in press b). Geophytes are known to get through the bad season by burrowing into the soil through certain organs (buds, bulb, rhizome/tubercule) thus making them invisible. This situation relatively explains the lowest level of Geophytes in clusters 2 and 3 during the dry season (period of data collection). The Red river hog is known to also consume roots and tubers by digging into the soil (Cerling and Viehl, 2004; Clauss *et al.*, 2008), This situation could limit this species Average Daily Gain (ADG) in game ranching conditions. Although it would be important to make a comparative study in natural environment and in semi-intensive breeding of this species Average Daily Gain (ADG) in terms of Geophytes consumed in dry season on the one hand and in rainy season on the other hand. Thus, this study could be extended to Common warthog under the same conditions. As a result, the Guinean-Congolese base element species were the most preponderant in groups 1 and 2, while Pantropical species were the most preponderant in group 3. These results further support the conclusions drawn from the work of Oumorou, (2003) where semi-aquatic and synanthropic groupings would better promote the good representativeness of species with a wide distribution. It's the same thing for grassy and forested groupings, where incursions of savannah species due to the Dahomey Gap (Adjin *et al.*, 2011) pursue to stand out in forested landscapes. The predominance in groupings 1 and 2 of the Guinean-Congolese base element species reflects a balance of ecological flora with mesophilic factors: soil, climate as highlighted in the work of Djego and Sinsin, (2007). This is also helped by the conservation efforts contribution in Gazetted Lama Forest, Djaloukou Ranch, Gnanhouizoun-CA and Kouvizoun-SF which is still sacred to it. It would be helpful to strengthen conservation actions in these habitats serving as refuge for the suids sub-populations leftover in Benin. If the phyto-ecological habitats characterization was not based on the Red river hog and the Common warthog presence we would not have these results, but the environment would not be very stable and would be highly degraded, especially in groups 1 and 3.

Factors Predicting the Red river hog and common Warthog distribution

The results showed that Common warthog was found in open formations with 48.33% vegetal overlay where the altitude was high. Also they are found on hydromorphic soils with high men's dwelling, mosaics of fields and fallow land, in shrubby and wooded savannah and open forest were their preferred habitats under a rainfall of 1026.04mm. These results are in the same vein with the work of Codjia *et al.*, (2020); Codjia *et al.*, (2007) and Le-Glaunec, (2006) where the Common warthog was generally savannah hogs, preferred open forests and fallow land, generally avoided dense and thick forests, and was found at altitudes between 0 and 2500 m. The strong men's dwelling in the Common warthog environments is evidence of the lack of land use policy, especially in the Gazetted Dogo-Kétou Forest and at the Agbé and Mongnigbé Complex as observed in the Codjia, (in press a). Like the Gazetted Mont Kouffé Forest, it is very important to assess the possibilities of local population separating from the Gazetted Dogo-Kétou Forest, which is in a advanced degradation state. It is the same in Agbé and Mongnigbé Complex where simultaneously it is still noted the presence of the two suids under study as it was the case previously in the Djaloukou Ranch in Savalou. Moreover, the Red river hog presence in this complex in the Abomey township representing the Zou phytodistrict confirms the hypothesis put forward in the work of Codjia *et al.*, (2020). Plant overlay and soil type are also specific in the Common warthogs distribution (De-Jong and Butynski, 2014). The Red river hogs were found in this study at lower elevations, in formations that were not very open but mostly closed and sometimes dense, with an average rainfall of 1193.4 mm. They were found in grasslands, swamp forests/marshlands, dense and semi-deciduous forests, wooded savannahs on hydromorphic, vertisol or silty-clay soil where water points are close with vegetation overlay (62.1 %). These results find their meaning in the work of Houehounha, (2011); Leslie and Huffman, (2013); Leus and Vercammen, (2013); Seydack, (1990) and Vercammen *et al.*, (1993) where hogs were rarely reported in open wooded, savannah or other more arid habitats. Similarly they are tropical and gallery forest species but can be found in wooded savannah and cultivated areas (case of Agbé and Mongnigbé Complex). Also, food availability, swampy areas, vegetation cover and light soils, and the water presence determine their presence. Contrary to the Common warthog, the Red river hogs are highly dependent on water as pointed out by Kimmel (1998) and Le-Glaunec (2006). This situation is not favourable to the individuals remains of Red river hog in Agbé and Mongnigbé Complex during the dry season, thus explaining the almost inexistence of direct observation outside the droppings of the latter on this site. *Phacochoerus africanus* and *Potamocheorus porcus* distribution is therefore subject to variations in environmental/anthropogenic factors specific to different phytogeographical zones, confirming the initial hypothesis.

CONCLUSION

Phyto-ecological characterization of the Red river hog and Common warthog habitat using phytosociological/ecological methods has made it possible to highlight groupings on the basis of plant species and factors predicting their distributions. In the light of the results, it was found that both suids species are very exacting in terms of the ecological conditions offered by the different preferred habitats, which unfortunately are under the influence of strong anthropic pressures. Even if the Common warthog habitats seem more wooded and diversified, they are subject to advanced degradation phenomena especially at the Gazetted Dogo-Kétou Forest and Agbé and Mongnigbé Complex. The swampy areas of Sédjè Denou and Houegoudo Complex, Lokoli Swampy Forest, Gbidji Swampy Meadow are not spared by the abusive resources exploitation and face the introduction of exotic species. We suggest:

• To review the land use policy and, above all, to raise public awareness of the cohabiting importance with animal species;

• To test a master plan proposal for the conversion and restoration of degraded habitats, also for agriculture;

• To evaluate the Average Daily Gain (ADG) of the Red River Hog and Common Warthog in natural environments and in semi-intensive livestock farming in terms of Geophytes consumed in the dry and rainy seasons;

• To carry out an analysis of the physico-chemical characteristics of the water of these suids drinking water contributing to the installation of artificial pond in the gazetted Lama forest and the Djaloukou Ranch in Savalou putting the bases for a forthcoming reintroduction of the Red river hog in this ranch;

• To study the similarities in the Red river hog and the Common warthog diet with metabarcoding approaches;

• To estimate the parasites prevalence in the Red river hog and Common warthog in South Benin;

• To assess the Red river hog and Common warthog vulnerability to climatic variations;

• To genetically study the suids species found in Benin.

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