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Evolution of pteridologic flora of Southeast of Côte d'Ivoire with respect to the variation in forest cover

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Three ecological environments (cultivated plots - palm groves, fallow plots and forests) were selected in order to study the distribution of Pteridophytes (fern plants), and also to study the evolution of these species over the age of crops (palm groves) in Southeast Côte d'Ivoire. The study site which contains these ecological environments has an area of 29710 km^2. A distinction was made between plots grown in village-based cultivated plots and industry-based cultivated plots. The results showed that only the forests are ecological communities that have the largest number of Pteridophytes and more the aged that the palm groves are, the greater number of Pteridophytes they contain. Forests are the development of supportive environments Pteridophytes, so it is important to protect these ecological environments (forests) to maintain these taxa.

Key words: Evolution, pteridophytes (fern plants), Southeast of Côte d'Ivoire

INTRODUCTION

Pteridophytes or vascular cryptogams are flowerless plants. These plants constitute one of the components of Ivorian vegetation. They participate in enriching the biodiversity and are encountered in various environments (natural or manmade). Several works mainly with a focus on the floristic inventory of Pteridophytes have already been undertaken in Ivory Coast (see for example: Des Abbayes and Tardieu-Blot, 1951; Adjanohoun et al., 1966; Assi Aké, 1984; Tra Bi, 1993; Adou, 2000; Adou et al., 2005; Adou, 2007). It follows from these observations that the number of species of this group of plants varies according to the environments that are sampled. However, studies on the analysis of the impact of degradation or recovery of plant cover with respect to Pteridophyta flora are almost nonexistent.

Furthermore, the distribution of these plants in ecological environments in Ivory Coast is still very poorly understood.

This study is a contribution to the knowledge of Pteridophytes in Ivory Coast. It aims to assess the evolution of Pteridologic flora with respect to the evolution of forest cover. The discussion will be aimed at several types of environmental media (cultivated plots, fallow plots, and primary forests).

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MATERIAL AND METHODS

Study Area

The present work was conducted in the administrative regions of Lagunes, Agnéby and Sud-Comoé (Figure 1). This area is bound to the East by Ghana, to the west by the Bandama River, to the North by the 6th degree of North latitude, and to the south by the Atlantic Ocean. The climate of the area is characterized by four seasons: two dry seasons and two rainy seasons. The soil is predominantly ferralitic and extremely desaturated in high rainfall conditions. The hydrographic network includes two main river basins: Bandama basin and Comoe basin. The relief of the area consists of hills, plateaux and plains (Adou, 2007). The study area is located in the Guinean domain, and has two types of vegetation that are semi-deciduous forest and dense evergreen rain forest for which there are only a few fragments because of their excessive exploitations.

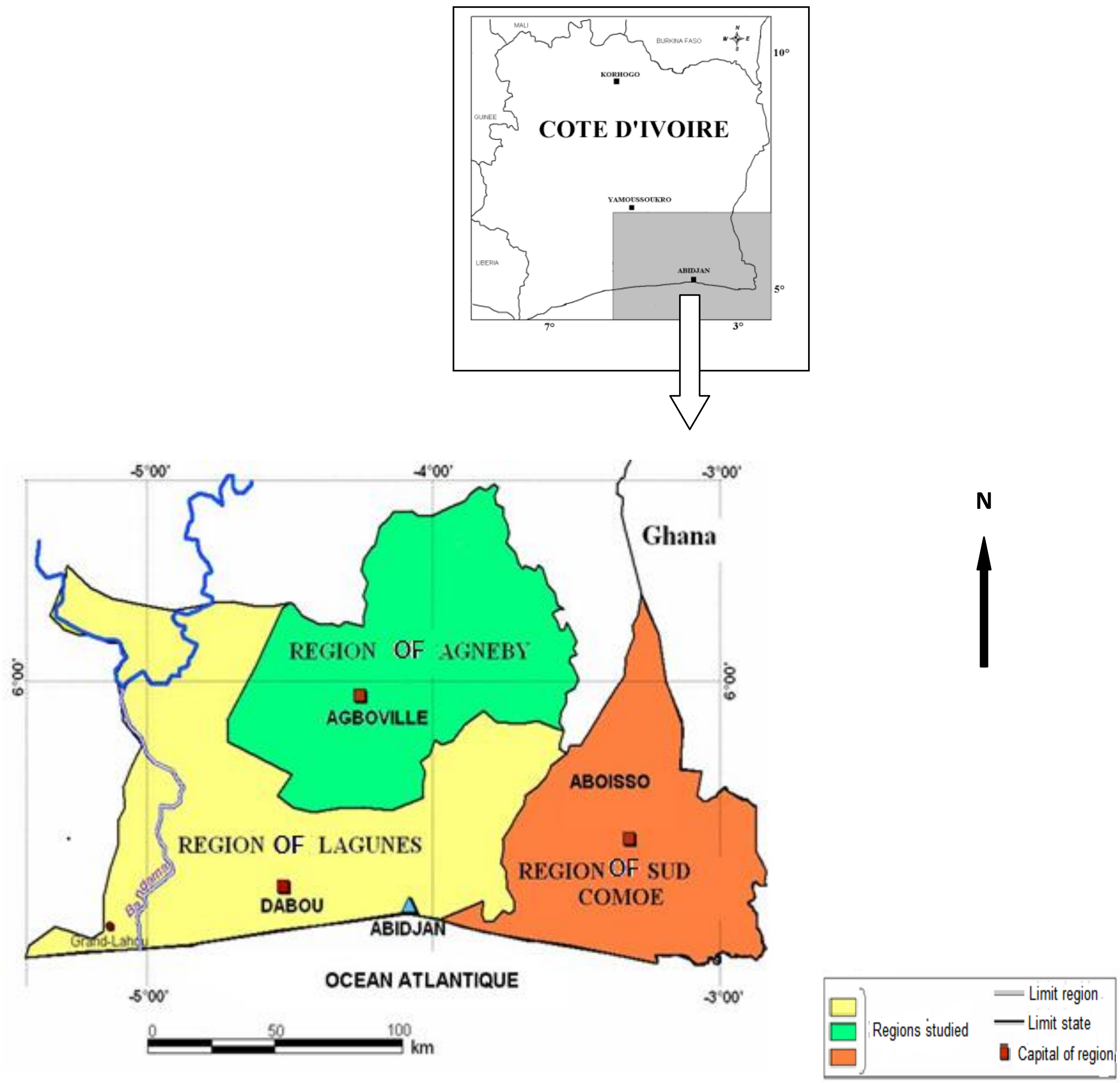

Figure 1: Location of the study area (Source: National Remote Sensing and Information Centre Geographic (C.N.T.I.G), 2001)

Materials

The biological materials consist of the pteridophytes species we discovered during our investigation. The technical materials include among other things, newsprint papers for the constitution of a herbarium, a photographic camera for pteridophytes shooting, a binocular microscope for their description, the Microsoft Word and Microsoft Excel software which served respectively for the word processing and the different analyses.

Methods

Pteridophytes inventory and mesological records

Two types of observations were made. The first study consisted of undertaking surveys in different types of vegetation, for which stratification of different ecological environments has been performed. The first layer constituted primary forests; the second layer is constituted by forest fallow and secondary forests, and the third level is constituted by palm groves that represent cultivated environments. In the first phase of the study, the inventory itself concerned Pteridophytes that were encountered in different settings. In the first phase of the study, the information needed to characterize the environment was collected. The inventory was constructed from a roving information gather, and for each parcel, the ecological characteristics were noted (vegetation type, soil texture etc.).

The second type of observation was performed in the palm groves and it was aimed at assessing the development of the Pteridophyta flora depending on the age of the palm groves. The information collected here had a focus on the age of the culture and the type of land.

Exploitation of the data

The floristic list of Pteridophytes has been established for each of the inventoried areas and a summary or general flora list was designed. Each identified species is affected by the biological type (BT) to which it belongs. The classification model of biological type which was adopted is after Aké-Assi (1984, 2001, 2002), who adapted the plant life-form model of Raunkiaer (1905): A multivariate analysis, Factorial Correspondence Analysis (FCA), permitted correlation of each species with its ecological environment. The matrix used is composed as follows: the FCA used two data matrices Y (n, p) and X (n, q) where: n is the number of records; p is the number of species; q is the number of environmental variables. Following this principle two types of analyses were conducted. The first analysis was aimed at assessing the amount of Pteridophytes that were likely to be encountered in the three surveyed areas. The Y matrix contains species presence/absence and the matrix X contains the environment variables, with n = 185 surveys; p = 47 species; q = 4 variables.

The second analysis was aimed at assessing the qualitative evolution of flora depending on the rehabilitation of forest cover. Here we are only concerned with Pteridophyta species that were harvested in cultivated settings such as palm groves. Matrix Y (n, p) comprises 150 records (n) and 15 species (p). There are four variables: the plantations of 1 to 5 years of age, plantations of 6 to 10 years of age, plantations of 11 to 15 years of age and the plantations of 16 years of age and over.

RESULTS

Pteridophyte flora of Southeast Ivory Coast

The number of Pteridophyta species that were identified was 47 (Table 1), and they are distributed among 29 genera and 17 families with a greater number of species represented by Aspidiaceae with 8 species, and Adiantaceae with 6 species. The majority of recorded species are specific to Africa and belong to the Guinea-Congo region. The dominant life forms are Hemicryptophytes and Epiphytes.

Distribution of species with respect to ecological environment

Choice of main factorial axes

In Figure 2 is a summary of the Factorial Correspondence Analysis (FCA), according to which the first two factorial axes F1 and F2 each have 0.477 and 0.137 of information, and are the largest eigenvalues. F1 and F2 represent 91.39% cumulative variance which is sufficient to explain the species distribution. This high value shows the dispersion of the majority of information on these two axes. Thus, the factorial planes F1 and F2 were selected for all representations. Forests and village parcels have the highest projected inertia for F1 and F2, respectively. The projection of environmental variables in the factorial plane F1 X F2 (Figure 3) allows us to observe that factorial axis 1 puts village plots in opposition to forests, and factorial axis 2 opposes the variables of village plots and fallow land. Forests make a greater contribution on factorial axis 1 with respect to the other factors in an amount of 68.2% with respect to the inertia of this axis. However, it is the village plots that bring the largest contribution (68.74%) on factorial axis 2 (Table 2).

Table 1: General list of identified Pteridophytes

N°	Species name	Family	BT	CAW	CAA
1	*Adiantum vogelii* Mett. ex Keys	Adiantaceae	H	A	GC
2	*Arthropteris palisoti* (Desv.) Alston	Davalliaceae	Lmp (Se Ep)	A	GC
3	*Asplenium africanum* Desv	Aspleniaceae	Ep	A	GC
4	*Asplenium variabile* Hook. var. *Variabile*	Aspleniaceae	H	A	GC
5	*Bolbitis acrostichoides* (Afz. ex Sw.) Ching	Lomariopsidaceae	H	AM	GC
6	*Bolbitis auriculata* (Lam.) Alston	Lomariopsidaceae	H	A	GC
7	*Ctenitis jenseniae* (C. Chr.) Tard.	Aspidiaceae	H	A	GC
8	*Ctenitis lanigera* (Kühn) Tard.	Aspidiaceae	H	A	GC
9	*Ctenitis pilosissima* (J. Sm.) Alston	Aspidiaceae	H	A	GC
10	*Ctenitis protensa* (Afz. ex. Sw) Ching	Aspidiaceae	H	A	GC
11	*Ctenitis securidiformis* (Hook.) Copel var *securidiformis*	Aspidiaceae	H	A	GC
12	*Cyathea camerooniana* Hook.	Cyatheaceae	np	A	GC
13	*Cyclosorus afer* (Christ) Ching	Thelypteridaceae	H	A	GC
14	*Cyclosorus dentatus* (Forsk.) Ching	Thelypteridaceae	H	PT	GC
15	*Cyclosorus striatus* (Schum) Ching	Thelypteridaceae	Gr	A	GC
16	*Diplazium proliferum* (Lam.) Kaulf.	Athyriaceae	H	Mc	GC
17	*Diplazium welwitschii* (Hook.) Diels	Athyriaceae	H	A	GC
18	*Gleichenia linearis* (Burm.) C.B. Clarke	Gleicheniaceae	Lmp	PT	GC
19	*Lastreopsis efulensis* (Bak.) Tard.	Aspidiaceae	H	A	GC
20	*Lastreopsis vogelii* (Hook.) Tindale	Aspidiaceae	H	A	GC
21	*Lomariopsis guineensis* (Underw.) Alston	Lomariopsidaceae	Lnp(Se Ep)	A	GC
22	*Lomariopsis palustris* (Hook.) Mett. ex Kuhn	Lomariopsidaceae	Rhé	A	GC
23	*Lonchitis currori* (Hook.) Mett. ex Kuhn	Dennstaedtiaceae	H	A	GC
24	*Lonchitis reducta* C. Chr.	Dennstaedtiaceae	H	A	GC

Table I continued

N°	Species name	Family	BT	CAW	CAA
25	*Lycopodium cernuum* (L.) Pic.Ser.	Lycopodiaceae	np	PT	GC-SZ
26	*Lygodium microphyllum* (Cav.) R. Br.	Schizaeaceae	Lmp	PT	GC-SZ
27	*Lygodium smithianum* Presl. ex Kuhn	Schizaeaceae	Lmp	A	GC
28	*Marattia fraxinea* Sm.	Marattiaceae	np	Mc	GC
29	*Microgramma owariensis* (Desv.) Alston	Polypodiaceae	Ep	A	GC
30	*Microsorium punctatum* (L.) Copel.	Polypodiaceae	Ep	PT	GC
31	*Nephrolepis biserrata* (Sw.) Schott	Davalliaceae	H + Ep	Pt	GC
32	*Oleandra distenta* Kunze	Davalliaceae	Ep	Mc	GC
33	*Pellaea doniana* Hook.	Polypodiaceae	H	A	GC
34	*Phymatodes scolopendria* (Burm.) Ching	Polypodiaceae	H + Ep	PT	GC
35	*Pityrogramma calomelanos* (L.) Link	Adiantaceae	H	PT	GC
36	*Platycerium stemaria* (P.Beauv.) Desv.	Polypodiaceae	Ep	A	GC
37	*Pteridium aquilinum* (L.) Kühn	Dennstaedtiaceae	Gr	Cos	GC
38	*Pteris acanthoneura* Alston	Adiantaceae	H	A	GC
39	*Pteris atrovirens* Willd.	Adiantaceae	H	A	GC
40	*Pteris burtoni* Bak.	Adiantaceae	H	A	GC
41	*Pteris mildbraedii* Hieron.	Adiantaceae	H	A	GC
42	*Selaginella myosorus* (Sw.) Alston	Selaginellaceae	Lnp	A	GC
43	*Selaginella vogelii* Spring	Selaginellaceae	Ch	A	GC
44	*Tectaria fernandensis* (Bak.) C. Chr.	Aspidiaceae	H	A	GC
45	*Trichomanes erosum* Willd.	Hymenophyllaceae	Ep	A	GC
46	*Trichomanes guineensis* Afz. Wx. Sw. Schrad.	Hymenophyllaceae	H	A	GC
47	*Vittaria guineensis* Desv.	Vittariaceae	Ep	A	GC

Abbreviations:

Ch= Chamaephytes;
E=Epiphytes;
Gr= rhizomateuse Geophytes;
H= Hemicryptophytes ;
Lmp= Lianas microphanrrophytes ;
Lnp= lianas nanophanerophytes ;
np= nanophanerophytes.

Species were also classified according to their chorological affinities in Africa and in the world:
A= African taxa;
CAA= Chorological Affinities in Africa;
CAW= Chorological Affinities in the world;
AM= taxa in common with those of Africa and Madagascar (Afro-Malgasy);
Cosm= Cosmopolitan taxa;
GC= taxa of the Guinea-Congo Region;
Mc=taxa in common with Africa and the Mascarene Islands;
PT= paleotropical taxa;
taxa in common with the Old World Tropics (Africa, Australasia, Pacific Isles);
Pt = paleotropical taxa in common with all countries of the world;
SZ=taxa of the Sudano-Zambezi Region.

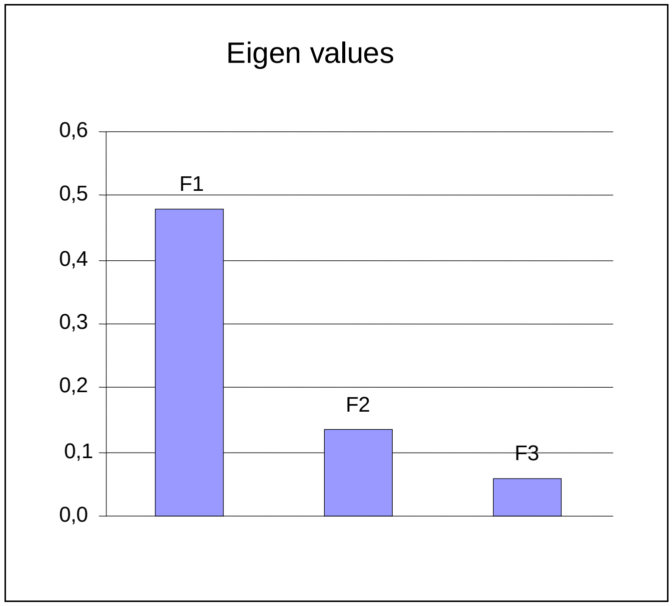

Figure 2: Eigen values factors
F1, F2, F3 = Factorial axes

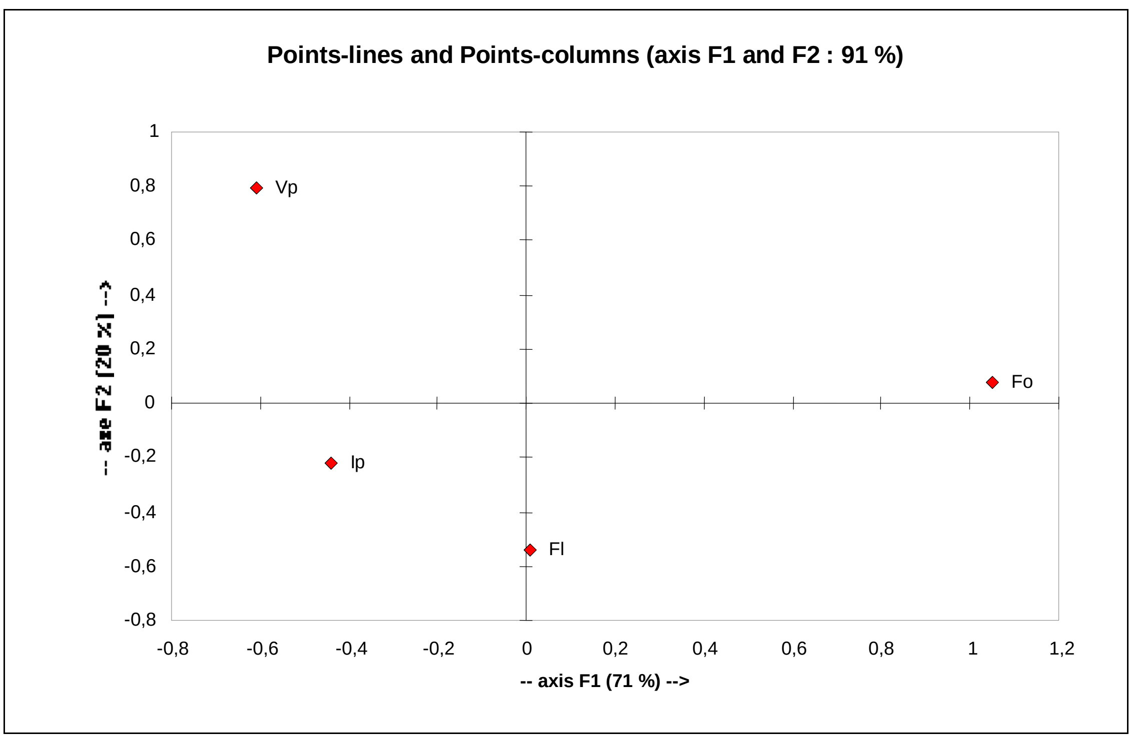

Figure 3: Representation of variables in factorial plane F1 X F2

Fo = Forest
Vp = Village Parcel
Ip = Industrial Parcel
Fl = Fallowland

Table 2: Contribution of points - columns (%)

	F1	F2
Vp	11,614	68,736
Ip	20,164	17,955
Fl	0,001	12,036
Fo	68,222	1,272

Legend of table II:
Fo = Forest
Vp = Village Parcel
Ip = Industrial Parcel
Fl = Fallowland

Plant association of the three ecological environments

It can be assumed that *Nephrolepis biserrata* and *Phymatodes scolopendria* contribute strongly to the inertia of factorial axis F1. To the right of this axis, there is a group of species that oppose *Nephrolepis biserrata* et *Phymatodes scolopendria* (Figure 5). *Selaginella myosorus* contributes strongly to the inertia of factorial axis F2, which is also opposed to another group of species located in the lower part of the graph. In Figure 4, we distinguish three blocks of species. The species located around the variable forests, those at the side of fallowland and the third block comprising the species of cultivated land (village plots and industrial plots). Species is therefore divided into three main groups; the first group consists of 47 species related to forests which include *Bolbitis auriculata*, *Lomariopsis guineensis*, *Marratia fraxinea*, *Ctenitis protensa*, etc. The second group is made up of 15 species (*Nephrolepis biserrata*, *Phymatodes scolopendria, Pteris atrovirens* and *Vittaria guineensis, Selaginella myosorus*, etc.) related to cultivated plots. Finally, the third group consists of 11 species (*Pteridium aquilinum*, *Cyclosorus dentatus*, *Cyclosorus striatus*, etc.) related to fallowland. *Nephrolepis biserrata* et *Phymatodes scolopendria* are strongly related to cultivated plots. We therefore find that there are a greater number of species in the forests (Table 3).

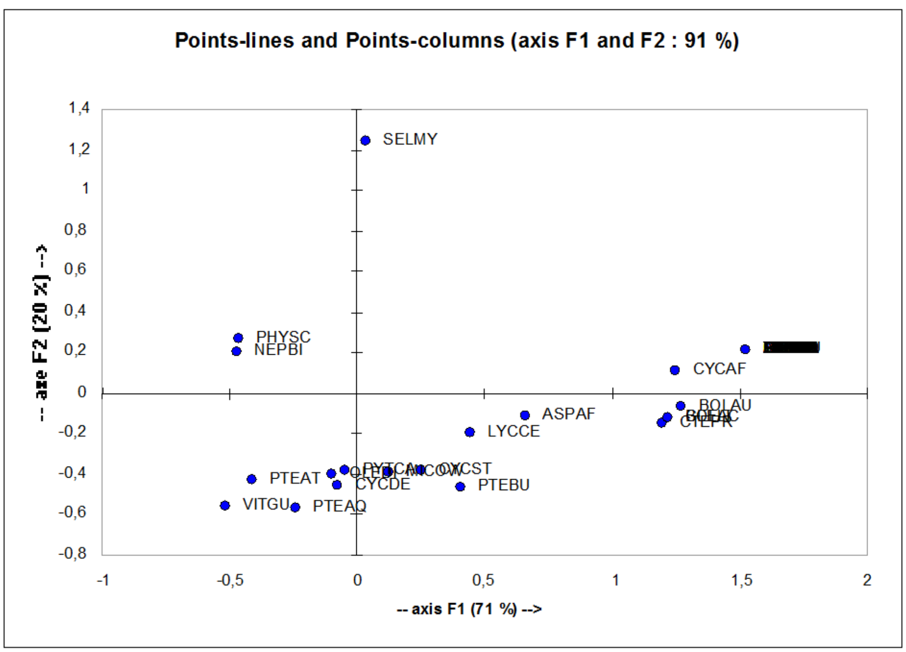

Figure 4: Representation of species in the factorial plane F1 X F2

Fo = Forest
Vp = Village Parcel
Ip = Industrial Parcel
Fl = Fallowland

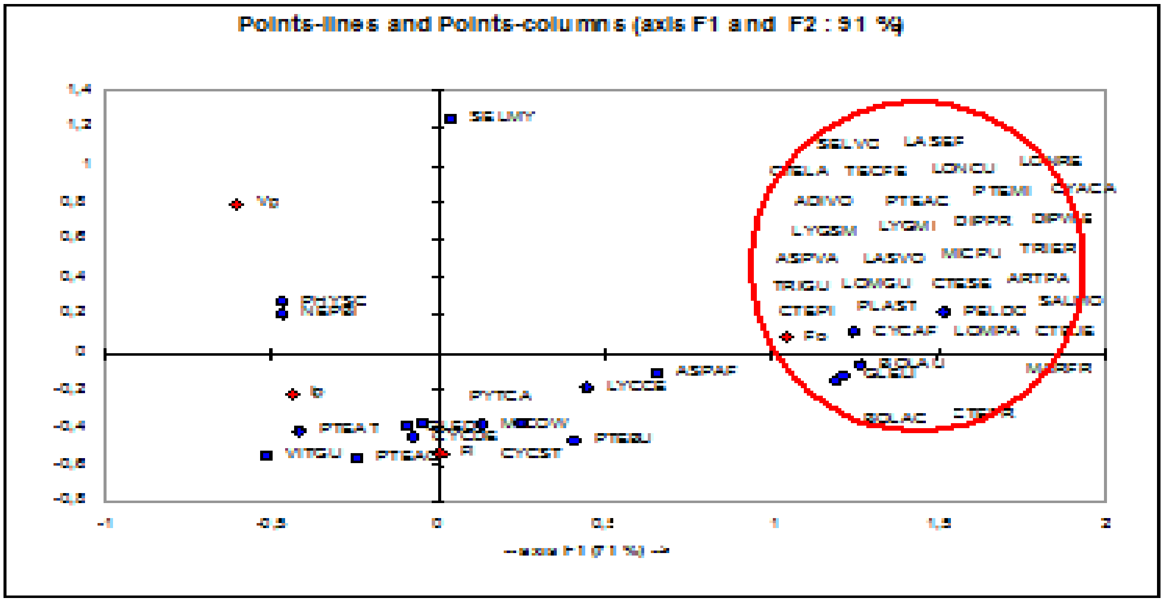

Figure 5: Representation of species and variables in factorial plane 1 X 2

Forest species

Table 3: Distribution of species with respect to les ecological environment

Forest species	Cultivated plot species (industrial plots and village plots)	Fallowland species
Arthropteris palisoti, *Bolbitis acrostichoides*, *Bolbitis auriculata*, *Marattia fraxinea*, *Lomariopsis guineensis*, *Ctenitis jenseniae*, *Ctenitis securidiformis*, *Trichomanes erosum, Lomariopsis palustris*, *Microsorium punctatum*, *Lastreopsis vogelii*, *Asplenium variabile*, *Platycerium stemaria*, *Diplazium welwitschii*, *Diplazium proliferum*, *Lygodium microphylum, Lygodium smithianum*, *Trichomanes guineensis*, *Ctenitis pilosissima*, *Pteris acanthoneura*, *Pteris mildbraedii*, *Tectaria fernandensis*, *Lonchitis currori*, *Lonchitis reducta*, *Cyathea camerooniana*, *Ctenitis lanigera*, *Selaginella vogelii*, *Lastreopsis efulensis*, *Pellaea doniana*, *Ctenitis protensa*, *Cyclosorus afer*, *Asplenium africanum*, *Lycopodium cernuum*, *Gleichenia linearis,* etc.	*Asplenium africanum,* *Nephrolepis biserrata*, *Phymatodes scolopendria*, *Pteridium aquilinum, Pteris atrovirens*, *Cyclosorus afer* *Cyclosorus dentatus*, *Cyclosorus striatus*, *Microgramma owariensis*, *Oleandra distenta* *Pteris atrovirens* *Pteris burtoni*, *Pityrogramma owariensis* *Selaginella myosorus* *Vittaria guineensis,*	*Nephrolepis biserrata*, *Phymatodes scolopendria* *Pteridium aquilinum*, *Cyclosorus dentatus*, *Cyclosorus striatus*, *Pteris atrovirens* *Pteris burtoni*, *Microgramma owariensis*, *Ctenitis protensa* *Bolbitis acrostichoides*, *Bolbitis auriculata*,

Influence of age of culture on Pteridophyta flora

Choice of main factorial axes

Figure 6 provides a summary of the AFC. From this figure, the first two factorial axes F1 and F2 have the largest eigen values 0.133 and 0.055, respectively, with F1 and F2 representing 86.96% of cumulative variance, which is sufficient to explain the species distribution. This high value shows the dispersion of the majority of information on these two axes, hence factorials F1 and F2 were selected for all representations.

Plantations with greater than 16 years of age, and cultures of 1 to 5 years of age have the highest projected inertia in F1 and F2, respectively. From the projection of environmental variables in the factorial plane F1 X F2 (Figure 7), we can observe that factorial axis 1 opposes the variables of plantations of 16 years of age and over and those whose age is between 6 and 10 years. Meanwhile, factorial axis 2 opposes cultivations of 1 to 5 years of age and of 11 to 15 years of age. The plantations 16 years of age and over bring a stronger contribution than other factors at a rate of 61.43% to the inertia of factorial axis 1. Along factorial axis 2, it is the plantations of 1 to 5 of age that bring the largest contribution (51.80%) as shown in Table 4.

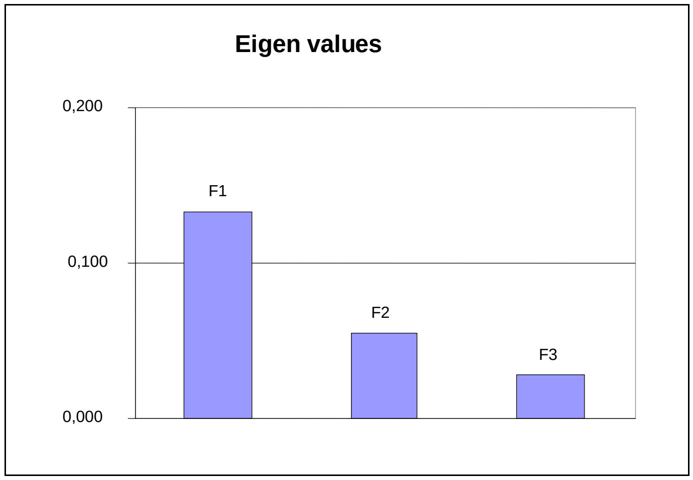

Figure 6: Eigen values

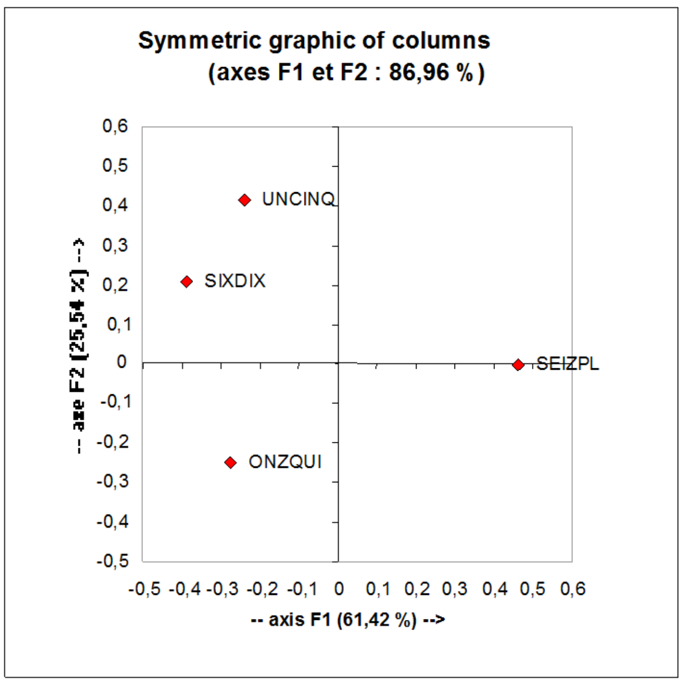

Figure 7: Representation of variables in le factorial plane F1 X F2
F1, F2= Factorial axes

Species distribution according to age of cultivations

There were 15 species identified on cultivated plots and are divided into three groups (Table V) and Figure 8. The first group consists of three (3) species (*Pityrogramma calomelanos*, *Pteridium aquilinum*, *Pteris atrovirens*) that are related to plots of 1 to 10 years of age. The second group is composed of six (6) species (*Vittaria guineensis, Cyclosorus afer, Cyclosorus striatus, Pteris burtoni*, *Asplenium africanum* et *Lycopodium cernuum*) which are related to plots of 11 to 15 years of age. The last group consists of six (6) species (*Oleandra distenta, Selaginella myosorus, Microgramma owariensis, Nephrolepis biserrata, Phymatodes scolopendria* et *Cyclosorus dentatus*) which are related to plots of over 16 years of age. The plots of 1 to 10 years of age contain fewer species than those plots of 11 years of age and older. These observations allow us to conclude that the number pteridophyte species increases with respect to the age of the plots and the more species they contain.

Table 4: Contribution of points - columns (%)

Code	F1	F2	F3
UNCINQ	7.19	51.80	24.42
SIXDIX	11.11	7.69	71.29
ONZQUI	20.28	40.51	3.65
SEIZPL	61.43	0.00	0.64

F1, F2, F3 = Factorial axes
UNCINQ=Species of 1-5 years of age
SIXDIX= Species of 6-10 years of age
ONZQUI = Species of 11-15 years of age
SEZPL= Species of 16 years of age

Table 5: Distribution of species with respect to the age of plantations

Species of 1-5 and 6-10 years of age	Species of 11-15 years of age	Species of 16 years of age
Pityrogramma calomelanos	*Vittaria guineensis*	*Oleandra distenta*
Pteridium aquilinum	*Cyclosorus striatus*	*Selaginella myosorus*
Pteris atrovirens.	*Pteris burtoni*	*Microgramma owariensis*
	Asplenium africanum	*Nephrolepis biserrata*
	Lycopodium cernuum	*Phymatodes scolopendria*
	Cyclosorus afer	*Cyclosorus dentatus*

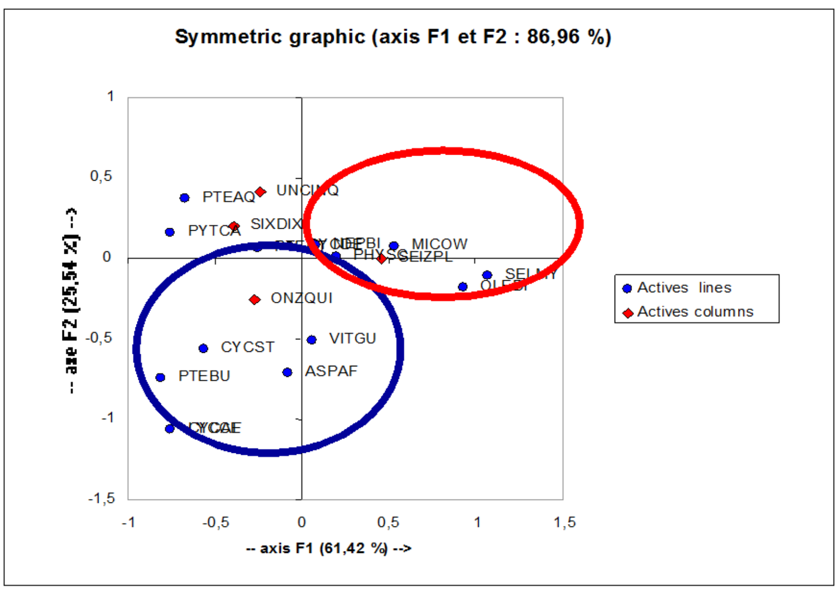

Figure 8: Representation of species and variables in the factorial plane 1 X 2

SEZPL = ≥ 16 years species
ONZQUI = [11 ; 15] years

DISCUSSION

Species distribution following three ecological environments

The Factorial Correspondence Analysis (FCA) initially allowed us to correlate each of the 47 species into three environmental groups (forests, cultivated land and fallow land). In forest areas, we note the presence of all inventoried species. This flora is characterised by the predominance of Aspidiaceae (8 species). and Adiantaceae (6 species). Some species found in forests can be harvested in two ecological settings. But, in contrast, others such as *Cyathea camerooniana*, *Marattia fraxinea*, *Tectaria fernandensis* only meet in the forests. We note that these latter species are characteristic forest species. Eleven species are present in fallow land that are usually characteristic plants of open habitats, and these species are *Nephrolepis biserrata*, *Phymatodes scolopendria*, *Pteridium aquilinum*, *Cyclosorus dentatus*, *Cyclosorus striatus*, *Pteris atrovirens*, *Pteris burtoni*, *Microgramma owariensis, Ctenitis protensa, Bolbitis acroisticoides* and *Bolbitis auriculata*. The three latter species (*Ctenitis protensa, Bolbitis acroisticoides* and *Bolbitis auriculata*) which are of forest species were found in fallow land, and this could be explained by the fact that they have been inventoried in fallow land of older age. Indeed, fallow land gets replenished with age, hence their composition will resemble that of forests. The flora of the plots are composed of fifteen (15) species (*Vittaria guineensis*, *Nephrolepis biserrata*, *Phymatodes scolopendria* and *Selaginella myosorus,* etc.). Two of those species, *Nephrolepis biserrata* and *Phymatodes scolopendria*, are dominant in cultivated plots and are both epiphytic and terrestrial species. These two species, *Asplenium africanum*, *Oleandra distenta* et *Vittaria guineensis*, that are characteristic species of cultivated plots such as palm groves, are strictly epiphytes, and the other ten species are terrestrial species.

Our results have shown that forests are ecological environments containing mostly Pteridophytes. Certainly, these taxa have the necessary conditions (humidity, shade, etc.) for their optimal development in these areas. This observation has been confirmed by other botanists who work on their floristic inventories in Ivory Coast and who have recorded Pteridophytes; such as Adjanohoun and Ake Assi (1967) who worked in the woodlands and identified 11 species; Adjanohoun (1965) who worked in coastal savannas in Ivory Coast and found 9 species; and Traoré (1985) who recorded 8 species in hydrophytic environments. Indeed as the forest is degraded, so Pteridophytes disappear.

Grouping species with respect to the age of the crop

The linking of each of the 15 recorded species (in cultivated settings such as palm groves) to the age of cultures has shown that the older the age of the plantation, the more likely they are to contain a large number of species. The plots of 1 to 10 years are comprised of three species of Pteridophytes. When the plantations reach 15 years of age, six other species are added, and beyond 16 years of age, six other species are added. We, therefore, find that the number of Pteridophytes increase with the increasing age of cultivated plots. This could be explained by the fact that in older cultivated plots, palm leaves fall by themselves, before their scheduled cutting time, and once fallen, they will dry, decompose and form humus in the soil, thus supporting the development of a large number of Pteridophytes species. In young plantations, it is during the maintenance that the palm leaves are cut, and especially in industrial plantations. In the village plantations, maintenance is quite rare.

CONCLUSION

The current study assisted in the realisation that, with the massive destruction of forests, the number of pteridophyte species decreases considerably. Indeed, this study shows that of the three ecological environments that were considered (forests, cultivated plots and fallow land), forests are environments that have the largest number of Pteridophytes and that with respect to the ages of cultivated plots, the number of Pteridophytes increases considerably, to the detriment of younger plots. As a part of the conservation of biological diversity, these plants deserve protection, which means the conservation of forests, which provide a favorable environment for the development of these taxa.

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