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Fruit spectrum of Niangoloko Natural Reserve in Southwest Burkina Faso

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Abstract

Plant communities can be characterized by their fruit spectrum, which indicates the frequency of different types of fruit. The fruits of 354 species, representing the total floristic richness of the Niangoloko natural reserve, southwest Burkina Faso, were described and classified by type of fruit, which helped to establish the fruit spectrum of this reserve. The different fruits harvested were described and classified according to three main criteria: the consistency of fruit at maturity, number of carpels, and dehiscence (or not) of fruits. The fruit spectrum comprised seven main types of fruit: capsules (24.86%), achenes (18.36%),pods (16.38%), berries (16.10%), caryopses (9.61%), drupes (10.17%), and follicles (4.52%). Dry fruits were the dominant fruit group with 73.73% of total fruit, and 26.27% of plants had fleshy fruits. Dry dehiscent and indehiscent fruits represented 45.76% and 27.97% of the total fruit, respectively. The fruit spectrum of the natural reserve is characteristic of a tropical biseasonal climate; dry fruits need the drying atmosphere of the dry season for maturation or dehiscence and the majority of fleshy fruits mature in the rainy season when the air humidity is very high. For diaspore dispersal, anemochory was the most important mode of dissemination in the dry fruits group, while zoochory was the predominant means of dispersal for fleshy fruits. Finally, we show that different classes of diasporas are not subject to environmental degradation to the same degree in the natural reserve and, thus, some species require special attention due to the difficulties they will face spreading their diasporas if degradation of the natural reserve continues.

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Introduction

The plant communities of West Africa have been studied by many researchers. Some studies have described the flora and vegetation of the West Africa region (Dalziel, 1937; Aubreville, 1950 ; Hutchinson and Dalziel, 1954; Schnell, 1976 ; White, 1983; Ake Assi, 1984 ; Guinko, 1984; Arbonnier, 2002), while other studies of small vegetation communities have provided detailed data for some tropical areas (Saadou, 1990 ; Fournier, 1991 ; Sinsin, 1993 ; Sawadogo, 1984 ; Hahn-Hadjali, 1997; Neumann and Müller-Haude, 1999; Ouoba, 1999 ; Lykke, 2000; Houinato, 2001; Thiombiano, 2005; Ouoba, 2006). Studies of these plant communities have focused on characteristics such as floristic richness, floristic diversity, vegetation physiognomy, and biological spectrum. The characterization of West African plant communities based on the classification of fruit types has not been well studied.

Many authors working on the phenology of plant communities in tropical areas of Asia and Latin America have shown the importance of climate to all the phenophases of plant reproduction (Shukla and Ramakrishnan, 1982; Batalha and Martins, 2004; Ramirez, 2009).

The plant species in an area can reproduce, maintain their populations, and colonize neighboring territories only if local ecological and climatic factors facilitate the production and dissemination of diaspores. Atmospheric humidity, for example, affects the dehiscence of pods, capsules, and follicles of many species. Thus, the classification of all the species in a community, based on the types of fruit produced, enables us to highlight the largest groups of diaspores and can also reveal the existence of any convergence between these types of diaspores and ecological factors. The fruit spectrum of a plant community can therefore reflect the climatic and ecological conditions of the region.

Natural reserves, where conservation activities have attempted to maintain all of the plant species since the creation of the reserve, are useful examples for these types of study. According to Ramade (2003), natural reserves should receive special research attention for studies of fundamental ecology and applied ecology for biodiversity conservation. Good knowledge of the ecosystem structure of natural reserves can facilitate measurement of the extent of change in degraded ecosystems.

The present study explored the vegetation communities of the Niangoloko natural reserve, Burkina Faso, which has relatively good protection against human pressures, and aimed to characterize the plant community based on the proportion of different fruit types produced in this area. For this natural reserve, the classification of fruits into categories enabled us to establish the fruit spectrum, which represents the proportion of each type of fruit.

Materials and methods

Study area

The study was carried out in the Niangoloko natural reserve (UTM: X=290000; Y =1129000), Burkina Faso, which borders on Niangoloko town.

The reserve was created in 1936 and is located in the southwest of Burkina Faso (Fig. 1.).

The natural reserve covers 7300 ha and the vegetation is a mosaic of savannas and gallery forests; savannas (Fig. 2.) occupy 99.41% of the area of the reserve, compared with 0.59% for forest galleries (Ouoba, 2006).

Climate

The study area belongs to the phytogeographical district of the Comoé, in the south Sudanese sector of Burkina Faso (Guinko, 1984).

The area has a Sudanese climate with two seasons: a rainy season from April to October and a dry season from November to March. The average annual rainfall between 1975 and 2017 was 1115 mm and the wettest month was August (Fig. 3.).

The average temperature from 1975 to 2017 was 27.35 °C, with a minimum of 18.3 °C in December and a maximum of 36.6 °C in March (Fig. 4); the thermal amplitude was 18.3 °C.

March and April were the hottest months while December and January were the coldest (Fig. 4). Air humidity, which is conditioned by the monsoon and harmattan flows, varies with the seasons; it is very high during the rainy season and very low during the dry season. In the dry season, the winds are dominated by the harmattan and during the rainy season, the winds are dominated by the monsoon, which generates the rains.

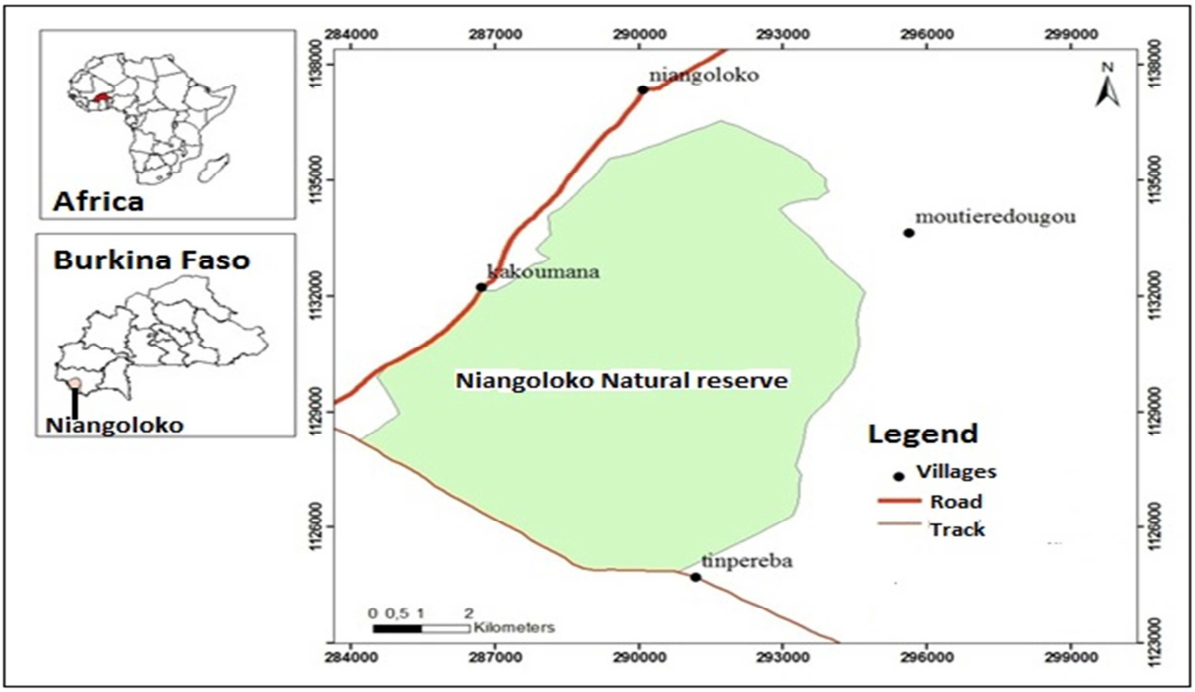

Fig. 1. Location of the study area.

The lowest values of atmospheric humidity were observed in December, January, and February and gradually increased from March to reach a maximum in August. During the month of August, the relative humidity of the atmosphere was close to 100%.

Fruit data collection

The fruit spectrum is defined in this study as the proportion of each type of fruit in the natural reserve. To identify fruiting individuals, a georeferenced map of the plant communities of the Niangoloko Nature Reserve was used. An inventory made in the nature reserve (Ouoba, 2006) made it possible to map the plants communities and to count a total of 354 plant species. We collected and classified mature fruits of all plant species recorded. The fruits were harvested over one year to take into account the fruiting period of each species. Two fruit harvestings per month were conducted in the first and last weeks of each month. In this study, the different species were grouped into genera and families.

Classification of fruits

The harvested fruits were described and classified according to three main criteria: the consistency of fruit at maturity, the number of carpels, and the dehiscence (or not) of fruits (Table 1).

Data analysis

Microsoft Excel 2010 version was used as data analysis software.

Results and discussions

Flora

The Niangoloko natural reserve flora inventory identifies 354 species, distributed between 78 families and 238 genera (Table 2). Nine families were most represented with at least ten species (Table 3).

Thirty-five families were represented by one species. This natural reserve has significant floristic richness with 354 recorded species which are adapted to local ecological factors and the climate regime of the region.

Fruit spectrum

The different fruits of Niangoloko Natural Reserve were classified into seven main types: achenes, caryopses, follicles, pods, capsules, drupes, and berries (Fig. 5., Fig. 6., Fig. 7., Fig. 8. & Fig. 9.). In spite of this strong species diversity (354 species recorded), there is a convergence of reproductive and dissemination organs.

Table 1. Fruit classification key.

Fleshy fruits: fruit mesocarp hypertrophied to give the pulp
Berry : fruit endocarp non-lignified
Drupe: fruit endocarp lignified , protecting the seed
Dry fruits: fruit pericarp dehydrated and lignified, becoming hard
Dry fruit indehiscent
Achene : fruit with a seed not welded to the pericarp
Caryopsis : fruit with a seed welded to the pericarp
Dry fruit dehiscent
Follicle: fruit with one carpel and having one dehiscence slit
Pod: fruit withone carpel and two dehiscence slits
Capsule: fruit with several carpels and many dehiscence slits or pores

This convergence implies that certain vital processes such as fruit ripening, dehiscence, and dispersal of diaspores are adapted to local ecological factors and the climate regime of the region. The fruit spectrum of Niangoloko natural reserve, had thus several notable characteristics:

Fruits ripening seasons

There was a high proportion of dry fruit species (73.73% vs. 26.27% fleshy fruit species) and dry fruits were the most common fruits in the natural reserve (Fig.5.). In addition, dry dehiscent fruits (follicles, pods, and capsules) also represented a very important sector of the fruit spectrum with 45.76% of the total fruits in the reserve (Fig. 5.).

Thus, a substantial proportion of the species of the natural reserve need, for the maturation or dehiscence of their fruits, a desiccating environment.

Table 2. Distribution of flora in higher taxa.

	Dicotyledons Number	Monocotyledons Number	Total
Species	274	80	354
Genera	189	49	238
Families	63	15	78

Most of the species in this dry fruits group mature in the dry season between November and April. During this period, there is a decrease or absence of precipitation and very low atmospheric humidity.

These climatic conditions make it possible for the fruits of these species to reach maturity by drying.

The atmospheric humidity, which is very low at this time of the year, is also important for the process of dehiscence in a large proportion of this group of dry fruits. Indeed, 45.76% of dry fruits are dehiscent (follicles, pods, and capsules), which requires a dry atmosphere for the opening of the dehiscence slits.

For the fleshy fruit group (26.27% of the species produced drupes or berries), the main fruit ripening period was from April to September, which corresponds to the rainy season when the humidity of the air is very high. Ramirez (2009) made similar observations at the Llanos biological station in Venezuela; dry fruits ripened during the dry season and fleshy fruits during the rainy season. He concluded that since fleshy fruits contain a lot of water, their maturation period must coincide with a season of high availability of water in the environment. Similar observations have also been made in northeastern India in a subtropical humid forest (Shukla and Ramakrishnan, 1982) and in southern India (Murali and Sukumar, 1994). Thus, we can say that the fruit spectrum of the Niangoloko Natural Reserve also shows a certain duality, connected to the seasonality of the climate and this spectrum is characteristic of a tropical seasonal climate where the ripening period of each fruit group coincides with a specific season.

Table3. Distribution of species by fruit type and by family.

Number of species	Fruit type	Dry Fruits (FS)					Fleshy Fruits	
		Indehiscent			Dehiscent			
		achenes	caryopses	follicles	pods	capsules	drupes	berries
	Family							
9	Acanthaceae					9		
1	Aloaceae					1		
3	Amaranthaceae					3		
1	Amaryllidaceae					1		
7	Anacardiaceae	1					6	
4	Annonaceae							4
1	Anthericaceae					1		
9	Apocynaceae			5				4
3	Araceae							3
1	Araliaceae							1
3	Arecaceae = Palmae						3	
9	Asclepiadaceae			7		2		
1	Asparagaceae							1
16	Asteraceae	16						
2	Bignoniaceae					1		1
3	Bombacaceae					3		
12	Caesalpiniaceae				11		1	
2	Capparidaceae							2
1	Caryophyllaceae					1		
1	Celastraceae					1		
2	Chrysobalanaceae						2	
1	Cochlospermaceae					1		
1	Colchicaceae					1		
14	Combretaceae	14						
4	Commelinaceae					4		
1	Connaraceae					1		
2	Convolvulaceae					2		
14	Cyperaceae	14						
6	Dioscoreaceae					6		
1	Dipterocarpaceae	1						
1	Ebenaceae							1
11	Euphorbiaceae					6	2	3
38	Fabaceae	1			36		1	
1	Flacourtiaceae							1
1	Hippocrateaceae					1		
1	Hymenocardiaceae	1						
1	Hypericaceae							1
1	Hypoxidaceae					1		
1	Iridaceae					1		

8	Lamiaceae	6				1		1
1	Lauraceae							1
4	Loganiaceae					1		3
3	Loranthaceae						3	
1	Malpighiaceae					1		
6	Malvaceae					6		
1	Marantaceae					1		
3	Melastomataceae					3		
5	Meliaceae					4		1
10	Mimosaceae				10			
9	Moraceae	8					1	
1	Myrsinaceae							1
1	Myrtaceae						1	
2	Ochnaceae	1					1	
2	Olacaceae						2	
1	Onagraceae					1		
1	Ophioglossaceae					1		
1	Opiliaceae						1	
4	Orchidaceae					4		
1	Oxalidaceae					1		
1	Pedaliaceae					1		
34	Poaceae		34					
4	Polygalaceae	1				2	1	
1	Ranunculaceae	1						
17	Rubiaceae					4		13
1	Rutaceae					1		
1	Sapindaceae					1		
2	Sapindaceae						2	
3	Sapotaceae							3
1	Scrophulariaceae					1		
1	Smilacaceae							1
1	Solanaceae							1
6	Sterculiaceae			4		2		
3	Tiliaceae					3		
3	Tiliaceae						3	
1	Cannabaceae						1	
6	Verbenaceae						5	1
9	Vitaceae							9
3	Zingiberaceae					3		
Total: 354	Number of species per fruit type	65	34	16	58	86	36	57
	Number of families per fruit type	13	1	3	4	40	17	22

Dispersal of diaspores

In the achene group, we noted that 53.03% of the fruits were winged (samaras) (Fig. 6.) or egrets. The wings of the samaras and egrets facilitate the dispersal of the diaspores by anemochory. In the pods and capsules group (Fig. 7. & Fig. 8.), most fruits were flat or light or had light seeds, which facilitates their dissemination by wind. Finally, in the fleshy fruits group (berries and drupes) (Fig. 9.), most of the fruits were succulent and edible, which predisposes this category of fruits to dispersal by zoochory.

Thus, for each fruit type, we observed a set of characteristics adapted to one or more dispersal modes. Several authors have shown that the means of dissemination of the diaspores of a specie depends on the morphological characteristics of the fruits (Ozenda, 1982; Dos Reis and Guillaumet, 1983; Gautier-Hion*etal*., 1985) and this was observed in the present study. For achenes, the dominant mode of dispersal in the natural reserve is anemochory and the diasporas have different systems facilitating their dispersal by the wind; 53.03% of achenes had wings

(samaras) or egrets (fruits of Asteraceae, for example). Similarly, in the pods and capsules group, which represented 55.94% of dry fruits in the natural reserve, the fruits and seeds were mostly flat and light.

Fig. 2. Woody savanna during the dry season.

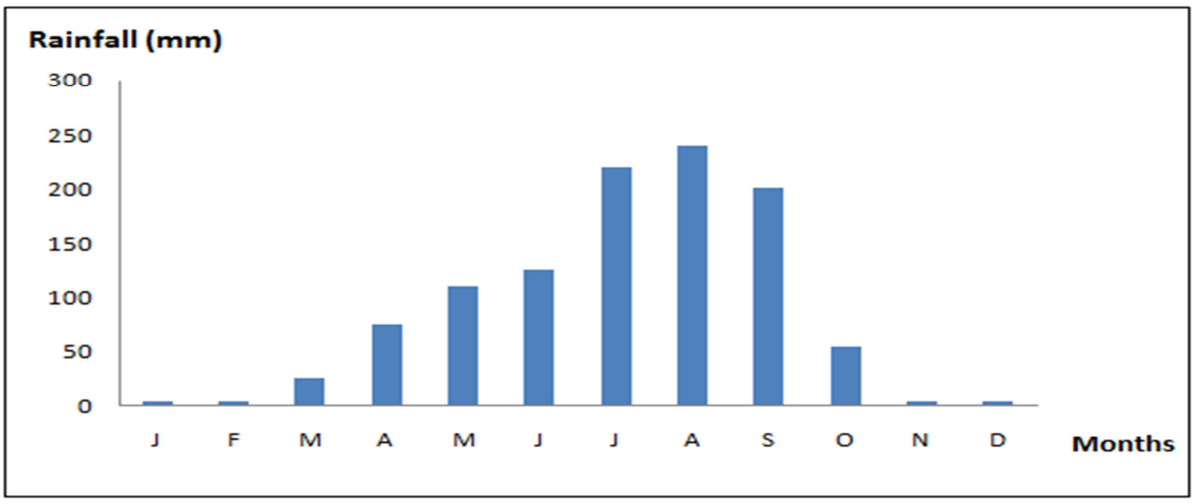

Fig. 3. Average rainfall in Niangoloko town per month (from 1975 to 2017).

These forms of fruits and seeds are also adapted to anemochory. Some researchers have also found that in dry fruits, the majority of species show adaptations for wind dispersal of their diaspores during the dry period (Ramirez, 2002; Batalha and Martins, 2004). Within the dry fruit group, we also noted other disseminating agents. Many species had hanging fruits, facilitating their dissemination by animals. For example, the flower heads of Asteraceae had twisted bracts and the fruits of Acanthaceae had spines that allow dispersal of the diaspores by zoochory. Thus, in this group of achenes, the dissemination agents are varied, so that many species may have several options for diaspores dispersal.

In the group of berries and drupes, which are often fleshy and succulent fruits, zoochory is the dominant mode of diaspores dispersal. In fact, in the Niangoloko Natural Reserve, most of the fruits in this group are eaten either by mammals or birds.

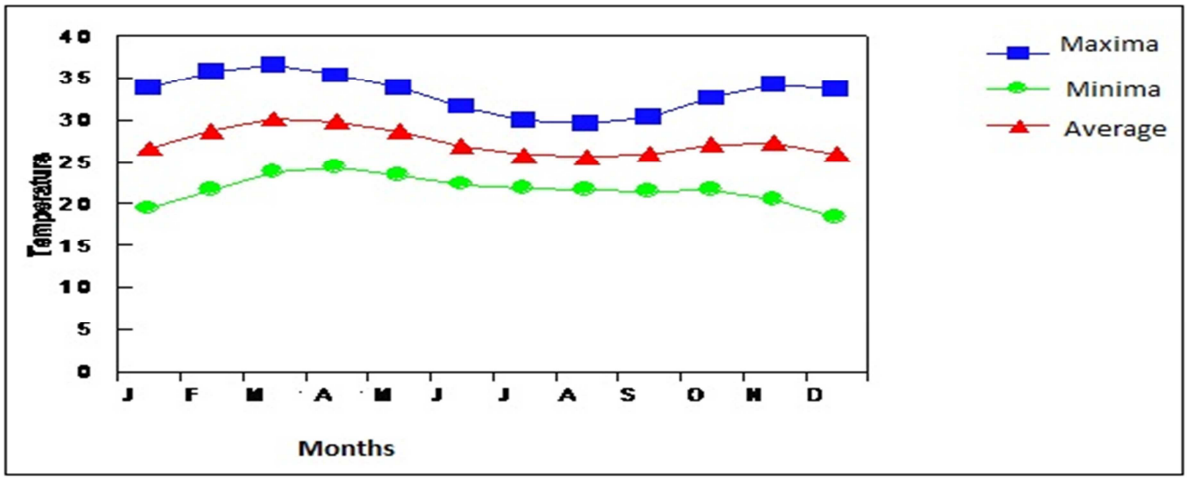

Fig. 4. Average temperatures (in degrees Celsius) in Niangoloko town.

A significant portion of the species in the reserve (26.27%), produce berries or drupes, and the species of this group must have a symbiosis with the wildlife of the reserve for the dissemination of their diaspores. Ramirez (2009) made the same observation at the Biological Station of Llanos in Venezuela. He concluded that zoochory was the main means of dissemination of fleshy fruits because of their succulence. The ecological role of zoochory is important for many plant species. For Reis and Guillaumet (1983), the high consumption of fruits, and sometimes beneficial influence of intestinal transit and the intense movement of animals, undoubtedly facilitate the colonization of abandoned lands and the distribution of pioneer plants. Similarly, germination tests on the seeds of *Faidherbia albida* (Delile) A. Chev. have shown that seeds that had an intestinal transit had a variable germination duration, which could then increase the chance of survival of the seedlings because of the gradual germination of the seed stock (Peltier, 1996).

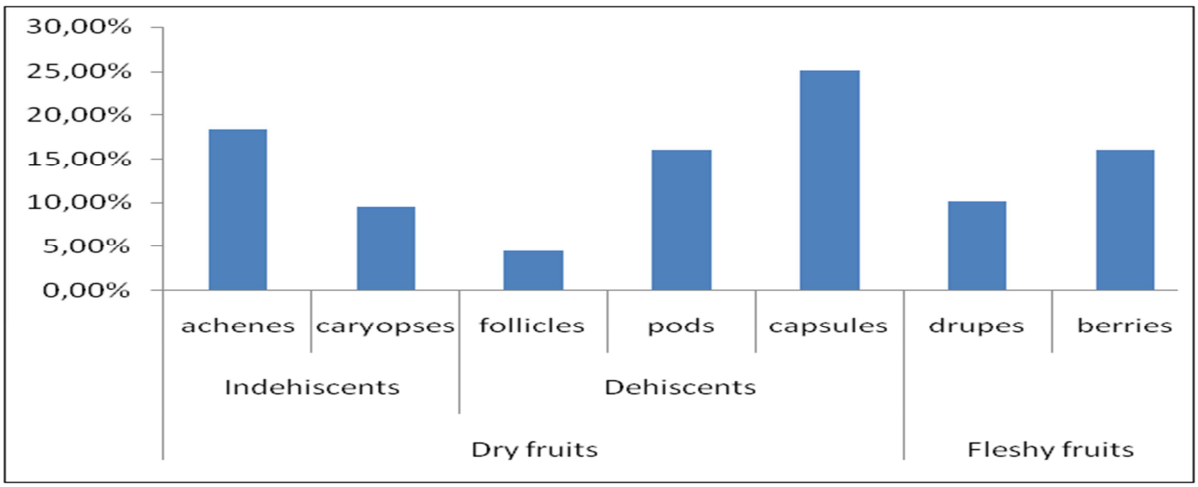

Fig. 5. Fruit spectrum of Niangoloko natural reserve.

The fleshy fruit species may face difficulties in the dissemination of their diaspores because of the progressive degradation of ecosystems in the natural reserve. Indeed, multiple anthropic pressures have led to a gradual disappearance of wildlife from the natural reserve.

This natural reserve, once rich in wildlife, has seen many animal species decimated by poaching (Ouoba, 2006). Big mammals such as the elephant (*Loxodonta africana* Cuvier), buffalo (*Syncerus caffer* Sparrman), and roan antelope (*Hippotragus equines* É. Geoffroy Saint-Hilaire) have disappeared from the natural reserve (Ouoba, 2006).

These big mammals play important roles and their impact on vegetation is still noticeable in some natural formations and natural parks in Burkina Faso where the density of fauna is still high.

In the W National Park in Burkina Faso, seeds of several plant species such as *Adansonia digitata* L. and *Acacia sieberiana* DC are frequently observed in elephant feces (Nacoulama and Ouedraogo, 2010).

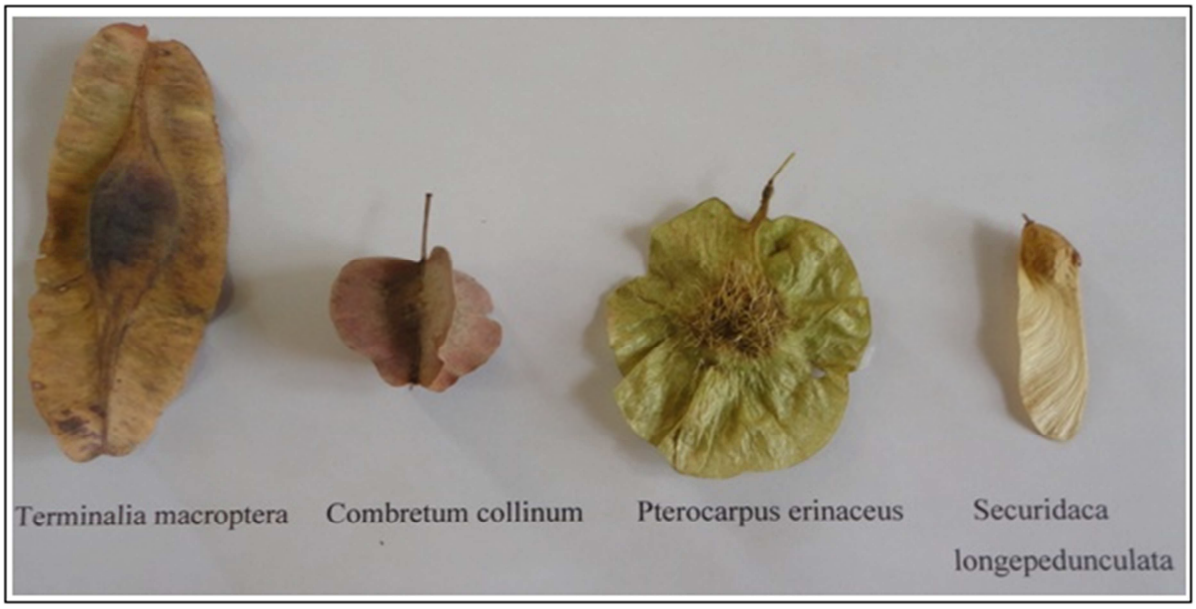

Fig. 6. Dry indehiscent fruits (achenes). Samaras were found in four different species: *Terminalia macroptera* Guill. & Perr., *Combretum collinum* Fres., *Pterocarpus erinaceus* Poir. and *Securidaca longepedunculata* Fres.; Samaras, winged achenes, were the most common type of achene in the natural reserve.

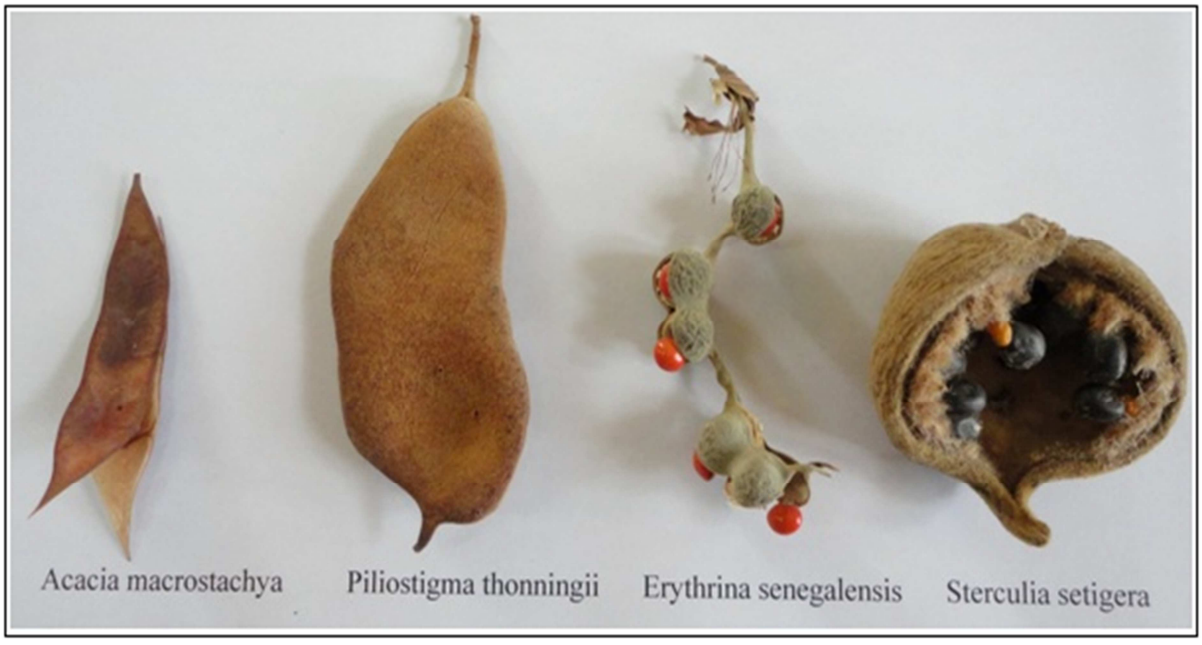

Fig. 7. Pods and follicles of different species: pods of *Acacia macrostachya* Reichend. ex De., *Piliostigma thonningii* (Schumach.) Milne-Redh., and *Erythrina senegalensis* DC, and follicle of *Sterculia setigera* Delile.The pods are the characteristic fruit type of the three main families in the nature reserve (*Fabaceae, Caesalpiniaceae*, and *Mimosaceae*).

The authors of this study also observed that monkeys, bats, and birds mainly disseminate the seeds of sweet fruit species such as *Annona senegalensis* Pers., *Sclerocarya birrea* Hochst., *Adansonia digitata* L., *Detarium microcarpum* Guill. & Perr., *Vitellaria paradoxa* Gaertn. F., *Lannea microcarpa* Engl. &K. Krause, and *Parinari curatellifolia* Planch. ex Benth. All these plant species are also present in the Niangoloko Natural Reserve.

Fig. 8. Capsules of *Khaya senegalensis* (Desr.) A.Juss. and *Cochlospermum planchonii* Hook. f., two very common species in the reserve. The capsules are the types of fruits produced by more than 24% of the total species and represented more than 54% of dry dehiscent fruits. This type of fruit was thus the most common in the nature reserve.

The disappearance of the fauna of the natural reserve decreases the opportunities for propagation by zoochory of the diaspores of species producing berries and drupes. The expansion of the area of a species is essentially a function of its modes of dissemination (Ozenda, 1982).Thus, the decline or extinction of a plant species may be due to the inefficacy of its means of dissemination. In addition, the species producing berries and drupes, need the entirety of the frugivorous fauna to maintain the dissemination potential of their diaspores. In a study of the interactions between frugivorous vertebrates and the fruits they consume, Gautier-Hion *et al.* (1985) showed that the choices of frugivores were influenced by the characteristics of the fruit. They showed that plants producing berries or drupes did not necessarily have the same frugivorous and disseminating species. An absence of one or more frugivorous species may, therefore, limit the dispersal effectiveness of one or more plant species.

Species threatened

The fruit spectrum was dominated by nine families of plants, which represented 46.89% of the fruit species. These were, in order of importance, Fabaceae, Poaceae, Rubiaceae, Asteraceae, Combretaceae, Cyperaceae, Caesalpiniaceae, Euphorbiaceae, and Mimosaceae (Table 3). Each family of plants contributed to the fruit spectrum with the same type of fruit (Table 3): the Fabaceae produced pods, except for *Andira inermis* (Wright) DC. and *Pterocarpus erinaceus* Poir., which produced drupes and achenes (Fig. 6.) respectively; Caesalpiniaceae and Mimosaceae produced pods, except for *Detarium microcarpum* Guill. & Perr. (Caesalpiniaceae), which produced drupes (Fig. 9.). Combretaceae, Cyperaceae, and Asteraceae produced achenes, however, Combretaceae species produced samaras, which are winged achenes. The species of the Asteraceae family had fruits with egrets. Most Rubiaceae produced berries and only four species in this family

[*Crossopteryx febrifuga* Benth., *Mitragyna inermis* (Willd.) Kuntze, *Spermacoce filifolia* (Schum. & Thonn.) J.-P. Lebrun &Stork, and *Spermacoce stachydea* DC.] produced capsules. Similarly, most Euphorbiaceae produced capsules and only two species produced drupes (*Antidesma venosum* E.Mey ex Tul., *Bridelia ferruginea* Benth.) and three species produced berries [*Flueggea virosa* (Roxb. ex Willd.) Voigt, *Phyllanthus muellerianus* (Kuntze) Exell., and *Uapaca togoensis* Aubrév. & Leandri].

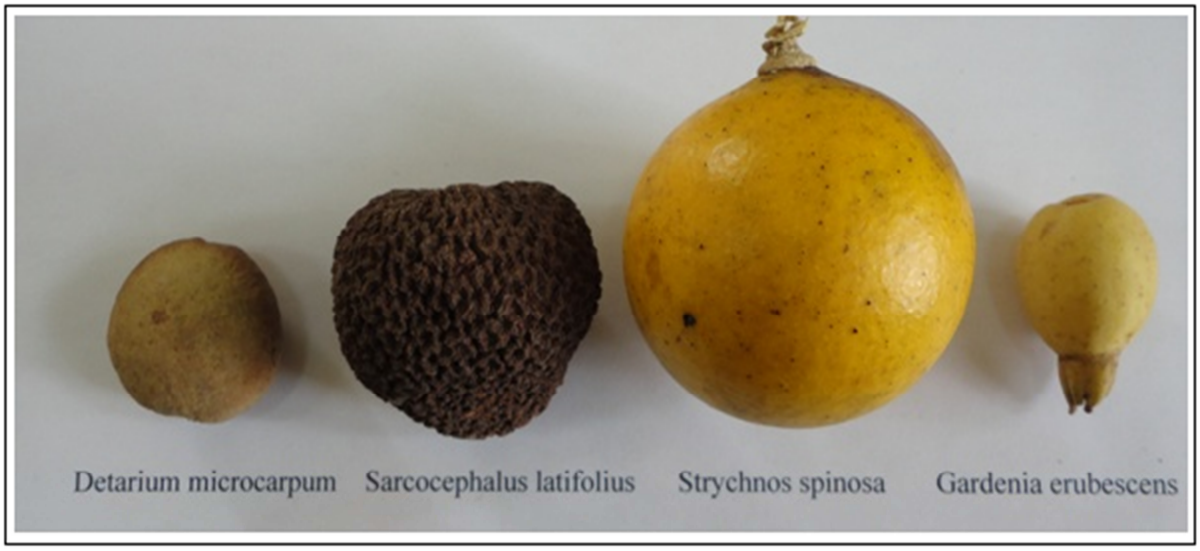

Fig. 9. The most frequent fleshy fruits (drupes and berries). *Detarium microcarpum* Guill. & Perr. drupe; *Sarcocephalus latifolius* (Sm.) Bruce, *Strychnos spinosa* Lam., and *Gardenia erubescens* Stapf & Hutch. berries. More than 26% of the species in the natural reserve produced drupes or berries.

The Poaceae family was the only one to produce caryopses. Finally, the species of these nine important families produced mostly dried fruits and influenced significantly the fruit spectrum of the natural reserve. Considering the number of families contributing to each fruit type, the capsule group was the most diverse with 40 families (Table 3), followed by berries (22 families), and drupes (17 families). The least diverse type of fruit was caryopses, with only one contributing family (Poaceae). Finally, 35 families contributed, with one species each, to the total fruit of the natural reserve (Table 3). Certain families of species in the natural reserve need special attention with the aim of conserving the overall biodiversity of the natural reserve. Nine families dominate the fruit spectrum of the natural reserve. These families are sufficiently represented in the natural reserve such that the disappearance of one specie will not necessarily mean the extinction of the family in the reserve. In contrast, 35 families are represented by only one specie. Of these, 12 monospecific families produce berries or drupes. They are Myrtaceae (*Syzygium guineense* DC.), Opiliaceae (*Opilia amentacea* Roxb.), Cannabaceae (*Trema orientalis* (L.) Blume), Araliaceae (*Cussonia arborea* Hochst, ex A. Rich.), Asparagaceae (*Asparagus africanus* Lam.), Ebenaceae (*Diospyros mespiliformis* Hochst, ex A.DC.), Flacourtiaceae (*Flacourtia flavescens* Willd.), Hypericaceae (*Psorospermum corymbiferum* Hochr.), Lauraceae (*Cassytha filiformis*), Myrsinaceae (*Embelia guineensis* Baker), Smilacaceae (*Smilax anceps* Willd.), and Solanaceae (*Solanum incanum* L.). Among these 12 families, some are in a critical situation because of the extreme rarity of their species in the reserve (Ouoba, 2006). They are Myrtaceae (*Syzygium guineense*), Cannabaceae (*Trema orientalis*), Hypericaceae (*Psorospermum corymbiferum*), Ebenaceae (*Diospyros mespiliformis*), Araliaceae (*Cussonia arborea*), and Myrsinaceae (*Embelia guineensis*). For the fruit species in these families, the disappearance of a specific dispersal agent could be followed, in the long term, by extinction of the family in the nature reserve.

Conclusion

Establishing the fruit spectrum of a natural reserve enables us to understand the diversity of fruit types in the reserve and, above all, the relative importance of each category of fruits. Fruit spectra can be used as tools for investigating the ecological conditions of plant species. This study of the Niangoloko natural reserve fruit spectrum revealed seven main types of fruit: achenes (18.36%), caryopses (9.61%), follicles (4.52%), pods (16.38%), capsules (24.86%), drupes (10.17%), and berries (16.10%). Dry fruits represented the dominant fruit group with 73.73% of all the fruit, compared to 26.27% for fleshy fruits.

In addition, dehiscent and indehiscent dry fruits represented 45.76% and 27.97%, respectively. This spectrum is adapted to a tropical climate with two seasons, namely, a dry season and a rainy season. These adaptations are based on a convergence of the characters carried by the different groups of diaspores (fruits) and local ecological factors. Thus, by showing the link between diaspore characters and ecological factors, our study has shown, the types of diaspores and the proportion of species that may be threatened by the continual deterioration of ecological factors in the natural reserve.

Conflicts of Interest

The authors have not declared any conflicts of interest.

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