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ECOLOGY OF *PILIOSTIGMA THONNINGII* IN EARLY SUCCESSIONAL PLOTS IN NORTHWESTERN NIGERIA

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ABSTRACT

In the Kainji Basin, Mokwa and Yelwa areas of northwestern Nigeria early successional plots are usually dominated in terms of number of stems by the Caesalpinioid shrub *Piliostigma thonningii.* An ecological study of 17 sample plots from the areas was carried out in order to define the niche of *Piliostigma* because of its potential in providing soil cover and rehabilitation of degraded lands.

In the plots studied it was found that *Piliostigma* abundance was associated with a high soil sand: clay ratio, open vegetation canopy and low species diversity. These characteristics identify *Piliostigma* as an early successful species.

INTRODUCTION

Most studies of vegetation often involve mature systems or those that have not been disturbed for a long time. Such studies are important in that a knowledge of such natural systems serve as ideals for environmental managers towards which they always aim. Management of vegetation and ecosystems, however often results in drastic changes that may make restoration of vegetation to its natural state difficult if not impossible such that disturbed and transformed systems become a permanent feature of ecosystems.

The rate of environmental degradation in Nigeria is now such that disturbed vegetation ecosystems have become a feature of the environment. The effective management of such ecosystems requires the understanding of their functioning not only for their improvement but also to arrest their further degradation. One aspect of this understanding of the functioning of these systems is the knowledge of their species composition and the interaction of these species with their environment.

Ecosystems disturbed by cultivation for subsistence farming in the Guinea Savanna zone of Nigeria are dominated (in terms of numbers of stems) in early succession, by *Piliostigma thonningii** a woody shrub of the family Fabaceae and sub-family Caesalpinioideae. Menaut and Cesar (1979) have observed that although the plant is a microphanerophyte, many individuals of the plant behave as true hemicryptophytes during the first few years of their life. This life form is achieved when perennial plagiotropic underground shoots whose buds are at ground level produce a large number of annual suckers. This transitory behaviour may

* Plant names are according to Hutchinson, Dalziel, Keay and Hepper (1954–1972).

account for its success in early savanna formations. Since it thrives well in early stages of succession it could be useful in land rehabilitation and provision of soil cover. Arnborg (1988) has named it as one of the dozen recommended agro–forestry trees for Sokoto State. Vegetation cover is important in soil conservation so the study of early succession communities is of prime ecological importance. Cossalter (1986) has observed that woody species are crucial for environmental protection and provision of fuelwood in semi-arid regions, in nutrient cycling and conservation. Sanford and Isichei (1986) state that "the main factors which allow a community of plants to persist are a multilayered canopy cover to lessen the impact of rain, a close network of roots to absorb nutrients as soon as they go into solution to prevent their loss by leaching or runoff, and adequate litterfall and decomposition to return nutrients to the soil for reuse".

It is against the above background of the importance of woody shrubs and trees in conservation that the study of early successional vegetation in the Guinea Savanna zone of northwestern Nigeria was embarked upon, with emphasis on the dominant shrub, *Piliostigma thonningii*. *P. thonningii* is widely distributed in the humid and subhumid savanna zones of West and Central Africa.

Apart from its value for soil cover *P. thonningii* also has medicinal (Irvine 1961) and fodder value. Skerman (1977) observes that the plant yields a heavy crop of pods which are eaten by livestock, game, monkeys and man. Pods collected in Zambia in August, had a crude protein content of 5.1% (Skerman, 1977). The leaves are also browsed by cattle in the dry season and young shoots and leaves collected in November also in Zambia contained 9.88% crude protein, 0.70% calcium and 2.45% potassium.

In this study, the vegetation of early sucession systems in northwestern Nigeria will be analysed for their *species* composition and abundance. The abundance of *P. thonningii* in these systems will also be studied in relation to soil and biotic factors with the aim of defining the niche of *P. thonningii.*

MATERIALS AND METHODS

1. *The Study Area:*

Three areas in the Southern Guinea and Northern Guinea Savanna zone (*Sensu* Keay, 1959) of Nigeria centred around Mokwa (9° 18'N, 5° 04' E), Kainji (9° 14'N, 4° 35'E) and Yelwa (10° 55'N, 4° 45'E) were chosen for the study.

The areas studied are underlain by Basement Complex rocks of Pre–Cambrian age. The soils are mainly ferruginous tropical soils on crystalline acid rocks in the Kainji and Yelwa areas and undifferentiated ferrisols in the Mokwa area (Klinkenberg and Higgins, 1968; Valette, 1973). Soil organic carbon in the area ranges from 0.13 to 1.98% (Kadeba, 1982). Soil nutrient levels are generally low with low cation exchange capacity (Nnadi and Balasubramanian, 1982).

Total annual rainfall in the area varies between 1200mm in the Southern parts to 1000mm in the northern parts (Afolayan, 1982). The wet season lasts from May to October while the dry season occurs between October and April. The highest annual mean temperature recorded is 38°C while the lowest is 14°C.

The Mokwa area is in the Southern Guinea Savanna zone of Keay (1959) and in the "Guinea – Congolian secondary grassland and wooded grassland", consisting of a mosaic of lowland rainforest, *Isoberlinia* woodland and secondary grassland" (White, 1983). Kainji and Yelwa areas are in the Northern Guinea zone of Keay (1959) while White (1983) group them into 'Sudanian woodland with abundant *Isoberlinia*'. Detailed vegetation studies of the Kainji area have been reported by Milligan (1979) and Isichei (1983); Chachu (1982) also describes the vegetation of the Kainji and Yelwa areas. Ohiagu (1976) describes the vegetation of the Mokwa area.

2. *Sampling Methods:*

(a) *Sample Plots:*

Seventeen sample plots each measuring 50m by 70 m were used for the study. Ten plots (numbers 1 to 10) were chosen from the Kainji area, four (11–14) from the Yelwa area and three (15–17) in the Mokwa area. The plots were subjectively chosen based on reliable land use history and therefore estimated age, and uniformity in appearance. All the plots have been cultivated in the recent past and their estimated ages after disturbance ranged from two to twenty years. Easier access determined the very high number of plots chosen in the Kainji area.

(b) *Vegetation Sampling:*

The 50m baseline of each plot, was divided into ten 5m–wide belt transects out of which 4 belt transects were randomly chosen for sampling.

Each belt transect was sampled systematically at 1m intervals so that seventy 1m x 5m quadrats were sampled along each transect. Thus 280, 5m^2 quadrats were sampled in each plot.

The following data were collected from each quadrat:

(i) numbers and names of all woody plants over 1m high and the density of each species.

(ii) the girths at 15cm from soil surface of all woody species $\geq$ 1m high (since most of the plants branch well below breast height.).

(iii) height classes of all woody plants, namely $<$1m, 1–2m and $>$2m.

(iv) canopy cover, that is, whether open or closed. When canopy is present the species providing the canopy was noted. The height class of the canopy was also noted based on whether the canopy was greater or less than 5m high. Density of woody stems was calculated using the method of Cochran (1963) for semi-systematic sampling. Species diversity was calculated using the Shannon – Weiner index.

(c) *Soil sampling for chemical and physical attributes.*

Twelve surface soil samples (0–15cm depth) were randomly taken in each plot, bulked for the plot and sub-sampled for the plot for analyses for the following:

(i) p*H*.

(ii) textural composition by the Bouyoucos (1936) method, organic matter by the wet – oxidation method of Walkley–Black. Total nitrogen, total phosphorus and extractable potassium were determined at the International Institute of Tropical Agriculture, Ibadan (Tel and Rao, 1982).

(d) Ordinations:

Ordinations by principal components analysis of the vegetation and soil data from the plots were carried out as follows:

(i) Ordination of the study plots based on the following twelve attributes: (1) total number of plant species, (2) total number of individual woody plants, (3) species diversity index, (4) percentage open space, (5) relative contribution of the five most abundant species, (6) mean girth of woody species, (7) relative contribution of the most abundant species, (8) soil total nitrogen, (9) soil organic matter, (10 sand/clay ratio, (11) density of *Piliostigma* per hectare, and (12) soil pH.

(ii) Ordination of these twelve attributes based on their scores in the 17 study plots.

In all ordinations standardization of data was carried out using Z–score transformation. Ordinations were carried out at the Obafemi Awolowo University Computer Centre.

RESULTS

1. *Species Composition and Density in the Sample Plots*

Some vegetation attributes as well as soil attributes and estimated ages (years since last cultivation) of the sample plots are presented in Table 1. The twenty-nine most abundant species are presented in Table 2. Overall, sixty-six species were encountered in the study.

The three areas studied, Mokwa, Kainji and Yelwa, have many species in common but the Mokwa and Kainji areas are similar in species composition. Thus, Sorensen's coefficient of similarity (of species composition) for the Mokwa/Kainji plots was 0.56, for the Mokwa/Yelwa plots it was 0.47 and 0.49 for the Kainji/Yelwa plots. The major difference between the Mokwa and Kainji areas is the greater number of individuals per species in the Mokwa plots, leading to a higher density of woody stems. The Yelwa plots has fewer species and number of individuals per species except for *Piliostigma thonningii* which formed almost homogenous stands (up to 80% of all individuals) in the sample plots in that locality.

There are variations in species composition and density from one sample area to another. *Acacia spp.* are absent from Mokwa whilst only one individual of *Detarium microcarpum* was observed in the Yelwa area. *Anona senegalensis* was the only species that occurred in all the 17 plots sampled.

P. thonningii is present in all the plots sampled and is most abundant in the Yelwa area followed by the Kainji plots which have more than the Mokwa plots. The ratio of *P thonningii* density to total plot woody plant density is statistically higher ($P < 0.05$, Analysis of variance using angularly transformed ratios) in the Yelwa area than in the Kainji area which in turn is statistically higher than in the Mokwa area.

TABLE 1

Vegetation and soil attributes of early successional plots used for the study of the ecology of Piliostigma thonningii *in northwestern Nigeria.*

		VEGETATION ATTRIBUTES							SOIL ATTRIBUTES								
Plot	*Locality*	*Approx. age of plot (yrs)*	*Shannon Wiener species diversity index*	*% Open space*	*Relative % contribution of most aun-dant species*	*Total Basal Area (m^2ha^{-1}) of all stems 1m high*	*Density of Piliostigma m^{-2}*	*Density of all species m^{-2}*	*pH*	*% organic matter*	*% Total nitrogen.*	*C:N ratio**	*% sand*	*% clay*	*% silt*	*Textural class*
1.	Kainji	2	1.67	99.9	63.3	3.11	0.35 ± 0.5	0.55±0.3	6.46	1.73	0.11	9.1	74.76	14.24	11.0	Sandy Loam
2.	,,	2	1.72	100.0	47.5	0.39	0.36 ± 0.5	0.75±0.22	6.11	3.32	0.18	10.7	67.76	20.24	12.0	
3.	,,	11	2.16	61.0	35.6	16.25	0.08 ± 0.1	1.39±0.4	5.12	2.03	0.13	9.6	58.76	14.24	27.0	
4.	,,	20	3.22	49.5	20.5	27.14	0.04 ± 0.1	0.39±0.1	5.46	2.88	0.15	11.1	66.76	17.24	16.0	
5.	,,	10	2.70	92.8	24.5	5.35	0.12 ± 0.1	0.51±0.10	6.17	2.85	0.14	11.8	72.76	12.24	15.0	
6.	,,	7	2.18	96.5	30.9	3.53	0.15 ± 0.2	0.51±0.2	6.11	3.19	0.16	11.0	80.76	18.24	1.0	
7.	,,	10	1.95	91.8	46.0	2.87	0.03 ± 0.1	0.16±0.1	6.05	1.66	0.11	8.7	69.76	14.24	16.0	
8.	,,	5	2.65	100.0	24.2	5.11	0.07 ± 0.1	1.16±0.2	5.17	1.68	0.11	8.8	63.76	12.24	24.0	
9.	,,	6	2.46	98.8	22.5	3.90	0.12 ± 0.2	0.52±0.2	5.90	1.71	0.09	11.0	74.76	18.24	7.0	
10.	,,	2	1.32	100.0	63.0	0.27	0.12 ± 0.2	0.18±0.16	5.69	3.09	0.13	13.7	57.76	23.24	20.0	
11.	Yelwa	10	0.89	100.0	80.3	3.04	0.41 ± 0.4	0.51±0.3	5.68	2.45	0.12	11.8	77.76	13.24	9.0	Loamy Sand
12.	,,	3	0.96	100.0	73.3	0.14	0.03 ± 0.1	0.04±0.10	5.37	1.79	0.11	9.5	82.76	10.24	7.0	
13.	,,	3	1.76	100.0	56.5	1.30	0.25 ± 0.4	0.44±0.3	5.25	2.30	0.13	10.2	81.76	10.24	8.0	
14.	,,	2	0.98	100.0	78.0	0.16	0.80 ± 0.6	1.03±0.4	5.72	1.17	0.08	8.5	82.76	9.24	8.0	
15.	Mokwa	8	1.99	89.5	45.7	9.29	0.24 ± 0.4	2.56±0.6	5.26	1.23	0.08	8.9	63.76	12.24	24.0	Sandy Loam
16.	,,	7	1.85	93.4	50.9	7.31	0.06 ± 0.2	2.14±0.6	6.60	1.33	0.09	8.6	82.76	10.24	7.0	Loamy Sand
17.	,,	2	2.71	100.0	21.6	1.75	0.05 ± 0.2	2.77±0.7	6.01	1.45	0.06	14.0	82.76	10.24	7.0	

* Organic carbon estimated as 58% of organic matter.

Estimated plot age is positively correlated with Shannon Wiener species diversity index ($P < 0.05$). The density of *P. thonningii* is negatively correlated with the species diversity index, an indication that *P. thonningii* occurs more in the younger, more open plots. Plot woody plant basal area is also correlated with plot age ($P < 0.05$) with the basal area of *P. thonningii* contributing up to 90% of the total basal area in some of the younger plots. Most of the species encountered have their girths in the 1–10 and 11 – 20cm girth – size classes and the <1m height class.

2. *Ordinations:*

(i) *Ordination of Site Attributes*

The twelve site attributes listed in the Materials and Methods section were used to ordinate the 17 sample plots. These attributes were first ordinated using principal components analysis to find out how they relate to each other, based on their scores in the 17 sites.

The ordination of the attributes (Figure 1) shows there are two groups of attributes on the first axis which in itself accounted for 40% of the variance in the data. In the first group of attributes are total number of woody plants, percentage open space, relative contribution of the most abundant species, soil sand: clay ratio, density of *P. thonningii* and soil p^H. In the other group are total number of species, species diversity index, mean girth of woody species, percent total soil nitrogen and soil organic matter. Broadly, apart from the soil–related factors, these attributes could be divided into two direct vegetation attributes and attributes derived from them. As would be expected

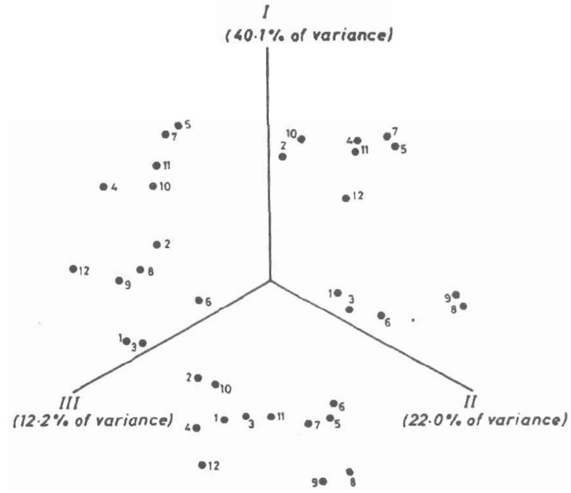

Figure 1: **Ordination by principal components analysis of the 12 vegetation and soil attributes (listed in the text) used to characterize 17 early successional plots used in the study of the ecology of *P. thonningii* in northwestern Nigeria (I, II, III = first, second and third principal components respectively).**

TABLE 2

The 29 most abundant woody species in seventeen early successional plots used for the study of the ecology of Piliostigma thonningii *in the Mokwa, Kainji and Yelwa areas of northwestern Nigeria.*

S./No.	*Species*	*Constancy**	*Distribution in the varipus area (% of sample plots)*		
			Mokwa	*Kainji*	*Yelwa*
1.	*Acacia hockii*	61	0	90	50
2.	*Afromosia laxiflora*	28	75	20	0
3.	*Annona senegalensis*	100	100	100	100
4.	*Bridelia ferruginea*	72	100	80	25
5.	*Burkea africana*	44	100	40	0
6.	*Combretum sp.*	72	100	70	50
7.	*C. glutinosum*	78	25	100	75
8.	*C. hypopilinum*	89	100	90	75
9.	*C. lamprocarpum*	39	0	70	0
10.	*C. molle*	50	100	50	0
11.	*Crossopteryx febrifuga*	33	25	50	0
12.	*Daniellia oliveri*	44	100	10	75
13.	*Detarium microcarpum*	67	100	70	25
14.	*Dichrostachys cinerea*	33	0	30	50
15.	*Entada africana*	83	100	90	50
16.	*Gardenia erubescens*	89	100	90	75
17.	*Grewia mollis*	67	100	80	0
18.	*Lannea acida*	78	100	90	25
19.	*Maerua crassifolia*	39	0	40	75
20.	*Maranthes curatellifolia*	33	100	20	0
21.	*Maytenus senegalensis*	89	100	90	75
22.	*Piliostigma thonningii*	94	75	100	100
23.	*Pseudocedrela kotschyii*	50	100	50	0
24.	*Pterocarpus erinaceus*	67	100	80	0
25.	*Strychnos spinosa*	28	50	30	0
26.	*Terminalia avicennioides*	78	100	70	75
27.	*T. macroptera*	39	0	60	25
28.	*Vitellaria paradoxa*	89	100	80	75
29.	*Ximenia americana*	33	0	40	50

* Constancy – the percentage of all the plots sampled in which a species occurs.

percent open space and density of *P. thonningii* are closely associated, so are relateive density contribution of 5 most abundant species and relative contribution of the most abundant species. Since *Piliostigma* density which contributes to overall density in the plots, is associated with open canopy which is in turn associated with a high sand: clay ratio, the association between total woody plant density and sand: clay ratio is not surprising.

On the second axis, which accounts for 22% of the variance in the attributes data, sand: clay ratio and total number of individuals are both negatively associated with percent soil total nitrogen and percent soil organic matter. Relative contribution of the most abundant species and soil organic matter are closely associated on this axis.

On the third axis (12% of variance) mean girth of woody plants is negatively associated with percentage open space and soil pH. Earlier, on the first axis, association had been shown between girth of woody plants and soil organic matter/total nitrogen. Mean girth is increased when there are larger trees left in plots. Such trees contribute to soil organic matter. Overall the attributes most closely associated with *P. thonningii* are percentage open space (axes I & II) and sand/clay ratio (Axis III).

(ii) Ordination of Plots

The ordination of the plots based on their scores on the 12 attributes is shown in Figure 2.

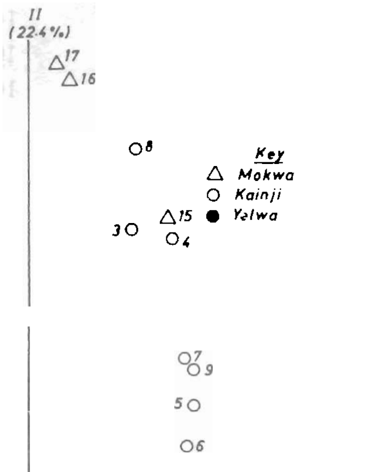

Figure 2: Ordination by principal components analysis of the 17 early successional plots used for the study of the ecology of *P. thonningii* in northwestern Nigeria. (I & II = first and second principal components respectively).

There is very little separation of the plots of the first axis which accounted for over 75% of the variation but the extreme positions in this axis seem to be related to sand: clay ratios. Thus plots 17, 16, and 12 have relatively high sand: clay ratios compared to plots 5, 6 and 9. On the second axis, the plots are arranged in a north-south gradient with Mokwa plots at the top of the diagram, Kainji plots in the middle and the Yelwa plots at the bottom end. There are however, some notable exceptions such as Kainji plots 1, 2 and 10 which are closely associated with the Yelwa plots and Mokwa plot 15 grouped with the Kainji plots. The positioning of the plots on this axis is consistent with observed ratio of total number of woody stems to total number of *P. thonningii* in plots. Those with high ratios are clustered at the top of the ordination diagram while those with low ratios are at the bottom of the diagram.

DISCUSSION

Of the 12 attributes measured in this study the ones that are most closely associated with density of *P. thonningii* are open canopy and sand/clay ratio. Attributes negatively associated with *Pilliostigma* include species diversity index (which was correlated with plot age), percent soil organic matter and soil total nitrogen. Aweto (1981a, b) observed increases in these attributes with age of forest fallow in his study of soil fertility restoration in relation to succession in southwestern Nigeria. Thus the abundance of *Piliostigma* is related to the age of the plots. *Piliostigma* is more abundant in those plots with smaller basal areas, small girths of the woody species and lower tree heights (see also Aweto, 1981a). Sanford *et al.* (1982) found girth – size class distribution useful for assessing savanna maturity.

Age as used here indicates the last time the plot in question was cultivated. So it could be concluded that *P. thonningii* is found mainly in early successional stages in the Guinea savanna zone of northwestern Nigeria.

Open areas are more prone to run–off and rain–splash and hence are more likely to have higher sand/clay ratio.

The trend whereby *Piliostigma* contributed the highest proportion of total density in the Yelwa area followed by the Kainji area and then the Mokwa area could be due to climatic factors or levels of disturbance. *Piliostigma* is widely distributed in the more humid transition and Southern Guinea Savanna zones but its greatest concentration is in the Northern Guinea zone. First, *Piliostigma* may be a poor competitor that pre-empts disturbed environments and is later replaced during succession. The results obtained from this study bear this assertion out. *Piliostigma* was most abundant in the younger plots and was most associated with open space. This may also account for its relatively low density in the more humid savanna zones where there are more competing species.

The Yelwa area is subject to very intense cattle activity being the southern limit of the tse–tse free zone and is consequently highly disturbed. In fact the dominance of *Piliostigma thonningii* continues further north until it is supplanted by its close relative, *P. reticulatum* in the Sudan zone (Arnborg, 1988).

Edaphic factors as influenced by disturbance may also account for the presence of *P. thonningii.* Trampling and cultivaton lead to an increased sand: clay ratio and decreased organic matter in soils. Topsoil (1–10cm depth) nutrient and organic matter status were found to account for most of the variation in forest fallow vegetation in Southwestern Nigeria (Aweto, 1981c). According to Walker (1980) human disturbance is a third major factor after rainfall and soil type which could give rise to different vegetation types under otherwise similar environmental conditions. Lawson *et al* (1968) had also observed that the abundance of *P. thonningii* in the riverain woodland near Lovi Camp in Ghana may be related to the amount of disturbance in that area. Nnadi and Balasubramanian (1982) reported that the soil of the Mokwa area is characterized by reddish–brown ferrisols which are poor in nutrients. The Yelwa and Kainji soils, on the other hand, are ferruginous tropical soils on crystalline acid rocks. This difference in soil will affect soil–water relations in the area and will affect species composition and density.

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