

## Vegetation characteristics of *bowé* in Benin (West Africa)

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**Abstract:** *Bowé* are particular form of degraded land where ferricrete, a hard erosion-resistant layer, is exposed. This study investigated vegetation characteristics of *bowé* (species composition, life form, chorological type, and plant family) in the semiarid and sub-humid climate zones in Benin. In both climate zones, *bowé* sites were characterized by grassland and savanna. The species composition on *bowé* varied according to the climate zone. Woody species were frequent on *bowé* in sub-humid (51% of the total species recorded) than in semiarid (44%). Geophytes, hemicytrophites and phanerophytes were frequent on *bowé* in the sub-humid than in the semiarid climate zone. The difference between the two climate zones on the occurrence of the therophytes on *bowé* was not significant. The frequency of chamaephytes was higher on *bowé* sites in the semiarid zone. Afro-tropical, Afro-Malgache, Pluri regional African and Pantropical chorological types were frequent on *bowé* than in woodlands in each climate zone while the opposite was found for Guineo-Congolian and Sudano-Zambesian chorotypes. Plant families such as Amaranthaceae, Zingiberaceae, Chrysobalanaceae, Connaraceae, Loganiaceae, Moraceae and Ochnaceae were only found on *bowé* in the sub-humid climate zone, while Convolvulaceae, Loganiaceae, Rhamnaceae, Araceae, Colchicaceae, Cucurbitaceae, Olacaceae, Pedaliaceae, Amaranthaceae, and Cyperaceae were only found on *bowé* in the semiarid zone.

**Keywords:** *Bowal*, Ferricrete, Climate Zone, Species Composition, Life Form, Chorological Type, Plant Families

## 1. Introduction

In West Africa, distinctive landscapes exist where ferricrete, a hard erosion-resistant layer, is exposed. An area with exposed ferricrete (Fig. 1) is called *bowal* (plural *bowé*) [4, 6, 10]. *Bowalization* can be a natural process [4, 28] or human induced [6, 10, 20]. *Bowé* retain nearly no moisture [4, 10] so the vegetation on *bowé* desiccates quickly and burns by early fires in the dry season. The soils rapidly absorb and reradiate solar energy, thus during the dry season *bowé* are extremely hot and barren [10]. *Bowé* impede root growth and resist water absorption [8, 11, 23, 29] so that trees become dwarfed, gnarled and widely scattered.

The vegetation observed on *bowé* is poor in species and dominated by therophytes life form [19, 31]. Thus one could expect particular vegetation characteristics on *bowé* since soil conditions influence species composition [14, 27], chorological type and life form [16, 19].

In Benin, *bowé* are found in both semiarid and sub-humid climate zones [21]. Since *bowé* are a particular form of degraded land, one could expect the same vegetation characteristics in the two climate zones. Thus, this study aims at assessing the vegetation characteristics of *bowé*; species composition, life form, chorological type and plant family composition in semiarid and sub-humid climate zones in Benin.



Fig. 1. Typical bowal surface in dry season

## 2. Material and Methods

### 2.1. Study Area

The study was conducted in two climate zones in Benin where *bowé* are distributed [21]: the semiarid zone (between the latitudes 9°45' N - 12°25' N and longitudes 0°45' E - 3°55' E) and the sub-humid zone (between the latitudes 7°30' N - 9°45' N and longitudes 0°45' E - 3°55' E). Data were collected in the phytogeographical districts of Mekrou-Pendjari in the semiarid zone and Zou in the sub-humid zone (Fig. 2). In the semiarid zone, the rainfall regime is unimodal with one rainy season from April to October. Mean annual rainfall varies from 785 to 1000 mm and relative humidity from 18 to 99% (being highest in August and lowest in February). Mean annual temperature ranges from 24 to 31 °C. Hydromorphic, well drained, ferruginous soils and lithosols are the major soil types here. The rainfall distribution in the sub-humid zone is unimodal. The rainy season starts in April and ends in October. The mean annual rainfall range is 900-1110 mm. The relative humidity from 31 to 98% and the mean annual temperature ranges from 25 to 29 °C. Soils in this zone are ferruginous with variable fertility. The natural vegetation of the two zones is characterized by a mosaic of woodlands, dry dense forests, tree and shrub savannas and gallery forests.

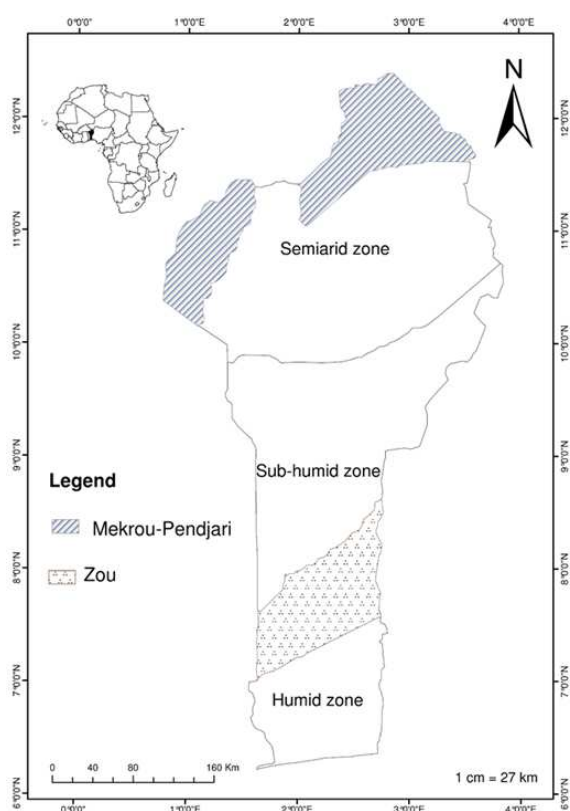


Fig. 2. Study area

### 2.2. Data Collection

In total 72 sampling plots (30 m × 30 m) were established, half of them in the semiarid and the other half in the sub-humid climate zone. In each climate zone, 18 of the 36

sampling plots were set up on *bowé* sites and 18 in woodlands for reference (control plot). The presence of all woody species was identified in the 30 m × 30 m plots. In every plot, five sub-plots (10 m × 10 m) were placed in the four corners and in the center where the presence of all herbaceous species was noted. On each plot, vegetation type and the dominant species were recorded. Life form, chorological type and plant family were noted. The data were collected at the end of the rainy season (October) when the *bowé* sites were 90% covered with vegetation. Species were determined by botanists of the National Herbarium of Benin. Species nomenclature [5], life form [2, 13, 25] and chorological types [30] were considered.

### 2.3. Data Analysis

The difference in species composition between *bowé* and woodlands in the two climate zones was computed using the Jaccard's similarity coefficient [15], which is given by the formula:

$$P_j = c/(a+b-c) \quad (1)$$

Where  $P_j$  is Jaccard's community coefficient,  $a$  is the number of species present in the community A,  $b$  is the number of species in the community B, and  $c$  is the number of species shared by A and B. The computation was automatically performed with the software CAP [22]. Plant communities were dissimilar if  $P_j \leq 0.5$ .

Two-way ANOVA was used to test if the climate zones have an effect on the vegetation characteristics (life forms and chorological types), if the vegetation types (vegetation on *bowé* vs. woodlands) have an effect on the vegetation characteristics and finally if the interaction between climate zones and vegetation types have an effect on the vegetation characteristics using R software [26] as data were normally distributed. Post-hoc t-test was used to test if the vegetation characteristics (life forms and chorological types) on *bowé* were different between the climate zones.

## 3. Results

### 3.1. Species and Plant Family Composition on *Bowé*

In both climate zones, *bowé* sites are characterized by grassland and savanna; the tree cover being no more than 15% (Fig. 3). The woody species are frequent on *bowé* in the sub-humid zone (51% of the total species recorded) than in semiarid zone (44% of the total species recorded). The species composition on *bowé* varies according to the climate zone. The similarity  $P_j$  in species composition between semiarid and sub-humid zone is 0.12. In the semiarid climate zone, the dominant woody species on *bowé* are *Acacia macrostachya* Rehb. ex DC., *Combretum glutinosum* Perr. ex DC., *Combretum nigricans* Lepr. ex Guill. & Perr. var. *elliottii* (Engl. & Diels) Aubrév., *Combretum collinum* Fresen., *Strychnos spinosa* Lam., *Cassia sieberiana* DC., *Ziziphus mucronata* Willd. subsp. *mucronata*, *Lannea microcarpa* Engl. & Krause, *Anogeissus leiocarpa* (DC.) Guill. & Perr. The herb layer is dominated by *Aristida kerstingii* Pilger, *Loudetiopsis*

*kerstingii* (Pilg.) Conert, *Aristida stipoides* Lam., *Lepidagathis alopecuroides* (Vahl) R.Br. ex Griseb., and *Lepidagathis collina* (Endl.) Milne-Redh.

In the sub-humid climate zone the dominant woody species on *bowé* are *Combretum nigricans* Lepr. ex Guill. & Perr. var. *elliottii* (Engl. & Diels) Aubrév., *Combretum collinum* Fresen., *Detarium microcarpum* Guill. & Perr., *Daniellia oliveri* (Rolfé) Hutch. & Dalziel, while the dominant herb species are *Hyparrhenia welwitschii* (Rendle) Stapf, *Indigofera bracteolata* DC., *Oldenlandia corymbosa* L., *Chlorophytum macrorhizum* (A.Rich.) Aschers.

The plant families observed on *bowé* in both zones are Poaceae, Rubiaceae, Combretaceae, Fabaceae, Acanthaceae, Vitaceae, Malvaceae, Lamiaceae, Euphorbiaceae, Annonaceae, Verbenaceae, Liliaceae, Commelinaceae, Cochlospermaceae, Asteraceae and Anacardiaceae. Families only found on *bowé* in the sub-humid zone are Amaranthaceae, Zingiberaceae, Chrysobalanaceae, Connaraceae, Loganiaceae, Moraceae and Ochnaceae; while Convolvulaceae, Loganiaceae, Rhamnaceae, Araceae, Colchicaceae, Cucurbitaceae, Olacaceae, Pedaliaceae, Amaranthaceae, and Cyperaceae are exclusively found on *bowé* in semiarid zone.

In the sub-humid climate zone, Malvaceae, Olacaceae, Convolvulaceae, Sapotaceae, Sapindaceae, Rhamnaceae, Pontederiaceae, Salicaceae, Ebenaceae, Dioscoreaceae, Clusiaceae, Boraginaceae, Bignoniaceae, Araliaceae, Apocynaceae, Rubiaceae, Ochnaceae and Lamiaceae are only observed in woodlands.

In the semiarid zone, Rubiaceae, Bignoniaceae, Chrysobalanaceae, Connaraceae, Convolvulaceae, Dioscoreaceae, Ebenaceae, Moraceae, Opiliaceae, Sapindaceae, Zingiberaceae are exclusively found in woodlands.



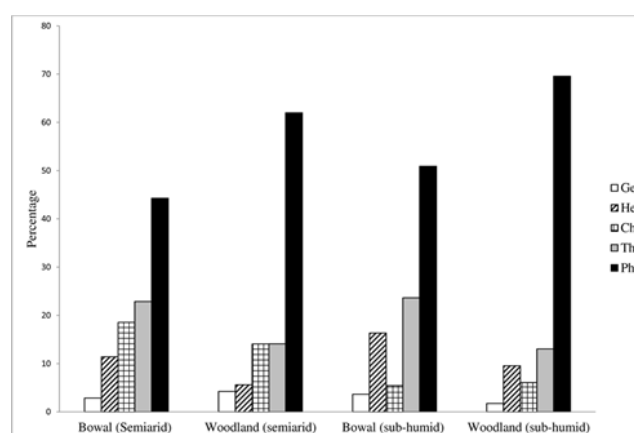
**Fig. 3.** Sample of vegetation on *bowé* in the semiarid zone dominated by *Aristida kerstingii*

### 3.2. Effect of Bowalization on Species, Life Form and Chorological Type

Plant species composition on *bowé* is not similar to that of woodlands ( $P_j = 0.42$  in the sub-humid climate zone and  $P_j = 0.38 < 0.5$  in the semiarid climate zone). The woody species are frequent in woodlands (70% of the total species recorded in the sub-humid zone and 62% in the semiarid zone) than on *bowé* (51% of the total species recorded in the sub-humid zone and 44% in the semiarid zone).

The output of the two-way ANOVA reveals significant

difference between semiarid zone vs. sub-humid zone and *bowé* vs. woodlands on the occurrence of hemicryptophytes, chamaephytes, and phanerophytes (Table 1). Phanerophytes and hemicryptophytes are frequent in sub-humid than in semiarid while the opposite is found for chamaephytes and geophytes (Fig. 4). The interaction between the climate zones and the vegetation types is significant for the occurrence of geophytes, chamaephytes and therophytes. However, we could not conclude that there is an interaction between the climate zones and the vegetation types on the occurrence of hemicryptophytes and phanerophytes (Table 1). In each climate zone, therophytes are frequent on *bowé* than in woodlands (Fig. 4). Geophytes are frequent in woodlands than on *bowé* in the semiarid zone while the opposite is found in the sub-humid zone. Chamaephytes are frequent on *bowé* in the semiarid zone than in the sub-humid zone (Fig. 4).



**Fig. 4.** Plant life forms on *bowé* and woodland in the two climate zones

Ge: Geophytes; He: hemicryptophytes; Ch: chamaephytes; Th: therophytes; Ph: phanerophytes.

There is significant difference between the semiarid zone vs. sub-humid zone and *bowé* vs. woodlands on the occurrence of Afro-Tropical, Afro-American, Guineo-Congolian, Pluri regional African, Pan Tropical, Sudano-Guinean and Sudano-Zambesian (Table 2). The difference between *bowé* vs. woodlands on the occurrence of Afro-Malgache and Sudanian chorological types is not significant. The interaction between the climate zones and the vegetation types is significant for these chorological types except for Sudanian, Sudano-Guinean and Afro-American. In each climate zone (Fig. 5), Afro-Tropical, Pluri regional African, and Pan Tropical chorological types are frequent on *bowé* than in woodlands while the opposite is found for Guineo-Congolian and Sudano-Zambesian. However Sudanian and Sudano-Zambesian are frequent in the semiarid zone than the sub-humid zone while the opposite is found for the Sudano-Guinean and Guineo-Congolian chorological types (Fig. 5). We could not conclude that there is an interaction between the climate zones and the vegetation types on the occurrence of Sudanian, Sudano-Guinean and Afro-American chorological types (Table 2).

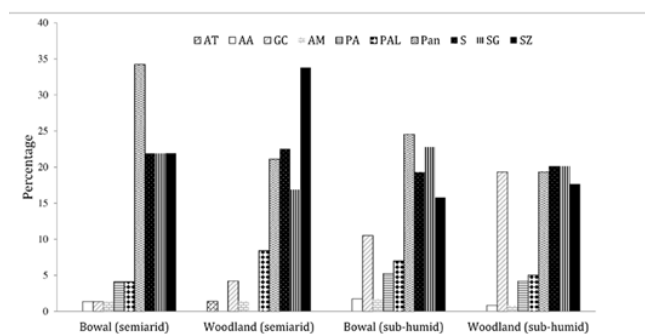


Fig. 5. Plant chorological type on bowé and woodland in the two climate zones

AT: Afro-Tropical; AA: Afro-American; GC: Guineo-Congolian; AM: Afro-Malgache; PA: Pluri regional African; PAL: Paleo Tropical; Pan: Pan Tropical; S: Sudanian; SG: Sudano-Guinean; SZ: Sudano-Zambesian.

### 3.3. Life Form and Chorological Type on Bowé

Regarding life form, geophytes ( $t$  value = 3.85;  $p < 0.001$ ), hemicryptophytes ( $t$  value = 10.71;  $p < 0.001$ ) and phanerophytes ( $t$  value = 8.14;  $p < 0.001$ ) are significantly less frequent on bowé in the semi-arid than in the sub-humid climate zone (Fig. 4) while chamaephytes are more frequent on bowé in the semi-arid zone ( $t$  value = -38.37;  $p < 0.001$ ; Fig. 4). The difference between the two climate zones on the occurrence of therophytes on bowé is not significant ( $t$  value = 0.48;  $p > 0.05$ ).

Regarding the chorological types, the Sudano-Zambesian ( $t$  value = -10.78;  $p < 0.001$ ), Sudanian ( $t$  value = -8.60;  $p < 0.001$ ) and Pan-Tropical plant chorological types ( $t$  value = -16.62;  $p < 0.001$ ) are more frequent on bowé in the semi-arid climate zone than in the sub-humid zone (Fig. 5). The Guineo-Congolian ( $t$  value = 52.26;  $p < 0.001$ ), Sudano-Guinean ( $t$  value = 3.99;  $p < 0.001$ ), Paleo-Tropical ( $t$  value = 3.99;  $p < 0.001$ ), Pluri regional African ( $t$  value = 10.17;  $p < 0.001$ ), Afro-American ( $t$  value = 7.162;  $p < 0.001$ ) and Afro-Malgache ( $t$  value = 7.16;  $p < 0.001$ ) plant chorological types are less frequent on bowé in the semi-arid climate zone than the sub-humid zone (Fig. 5). The difference between bowé in the two climate zones on the occurrence of Afro-Tropical is not significant ( $t$  value = 0.53;  $p > 0.05$ ).

## 4. Discussion

The vegetation characteristics on bowé in the two climate zones of Benin are identified as grassland and savanna. Comparable findings were made in Burkina Faso [31], Côte d'Ivoire [24] and Mali [17]. The woody species are more frequent on bowé in the sub-humid zone than the semi-arid zone. This may be due by the more humid condition observed in the sub-humid climate zone or by less frequent of fires in this zone. Higher humidity leads to higher woody abundance [1] and more the climate is dry more the woody species die [3]. In addition the fire regime also affects the species composition [9]. Thus the differences observed between the plant species compositions on bowé of the two contrasting climate zones

indicate that climate and fire regime play an important role for species distribution and in the colonization of bowé by plant species.

Both in general and within the climate zones, the composition of species on bowé is not similar to the one in woodlands. The reason for this may be found in the great frequency of species with large distribution range on bowé (Afro-Tropical, Afro-Malgache, Pluri regional African and Pan Tropical). These species are mostly therophytes well adapted to degraded and poor land [7, 18]. This life form is frequent on bowé in both climate zones.

In woodlands, the Sudano-Zambesian and Sudanian species are more frequent in the semi-arid zone and the Sudano-Guinean and Guineo-Congolian species in the sub-humid climate zone. Sudanian and Sudano-Zambesian species characterize and dominate the vegetation of the Sudanian zone where semi-arid climate prevail [1, 12], while the Sudano-Guinean and Guineo-Congolian species characterize and dominate the Sudano-Guinean zone [1], where the sub-humid prevails.

## 5. Conclusion

Bowé are characterized in general by grassland and savanna with more frequency of Afro-Tropical, Afro-Malgache, Pluri regional African and Pan Tropical chorological types and therophytes life forms. However there are some differences between the climate zones on the vegetation characteristics on bowé.

In the semi-arid climate zone, the dominant woody species on bowé are *Acacia macrostachya*, *Combretum glutinosum*, *Combretum nigricans*, *Combretum collinum*, *Strychnos spinosa*, *Cassia sieberiana*, *Ziziphus mucronata*, *Lannea microcarpa*, *Anogeissus leiocarpa*. The herb layer is dominated by *Aristida kerstingii*, *Loudetiopsis kerstingii*, *Aristida stipoides*, *Lepidagathis alopecuroides* and *Lepidagathis collina*.

In the sub-humid climate zone the dominant woody species on bowé are *Combretum nigricans*, *Combretum collinum*, *Detarium microcarpum*, *Daniellia oliveri*. The dominant herb species are *Hyparrhenia welwitschii*, *Indigofera bracteolata*, *Oldenlandia corymbosa* and *Chlorophytum macrophyllum*.

Geophytes, hemicryptophyte and phanerophyte life forms are more frequent on bowé in the sub-humid than in the semi-arid climate zone while the opposite is found for chamaephytes.

Sudano-Zambesian, Sudanian and Pan-Tropical plant chorological types are more frequent on bowé in the semi-arid climate zone than in the sub-humid zone. The Guineo-Congolian, Sudano-Guinean, Paleo-Tropical, Pluri regional African, Afro-American and Afro-Malgache plant chorological types are less frequent on bowé in the semi-arid climate zone than the sub-humid zone.

Amaranthaceae, Zingiberaceae, Chrysobalanaceae, Connaraceae, Loganiaceae, Moraceae and Ochnaceae plant families are exclusively found on bowé in the sub-humid climate zone, while Convolvulaceae, Loganiaceae,

Rhamnaceae, Araceae, Colchicaceae, Cucurbitaceae, exclusively found on *bowé* in semiarid zone. Olacaceae, Pedaliaceae, Amaranthaceae, and Cyperaceae are

**Table 1.** Two way ANOVA results for life forms on *bowé* and woodland in semiarid and sub-humid climate zones in Benin

Source	Ge	He	Ch	Th	Ph
Semiarid-Sub-humid	12.13***	289.63***	2562.10***	1.84ns	181.87***
<i>Bowé</i> -Woodland	1.09ns	631.50***	158.40***	1605.33***	1031.35***
Interaction	84.44***	0.63ns	143.50***	4.59*	0.52ns

The value is F value; Ge: Geophytes; He: hemicryptophytes; Ch: chamaephytes; Th: therophytes; Ph: phanerophytes  
ns: non significant at 0.05; \*: significant at 0.05; \*\*: significant at 0.01; \*\*\*: significant at 0.001

**Table 2.** Two way ANOVA results for chorological types on *bowé* and woodland in semiarid and sub-humid climate zones in Benin

Source	AT	AA	GC	AM	PA	PAL	Pan	S	SG	SZ
Semiarid-Sub-humid	11.32**	85.41***	4218.40***	8.84**	538.36***	0.22ns	220.00***	155.78***	53.00***	1034.90***
<i>Bowé</i> -Woodland	11.32**	67.99***	902.70***	0.48ns	278.10***	47.48***	810.30***	2.783ns	101.68***	720.70***
Interaction	5.59*	1.27ns	262.50***	47.86***	62.22***	152.50***	176.50***	0.81ns	0.23ns	252.30***

The value is F value; AT: Afro-Tropical; AA: Afro-American; GC: Guineo-Congolian; AM: Afro-Malgache; PA: Pluri regional African; PAL: Paleo Tropical; Pan: Pan Tropical; S: Sudanian; SG: Sudano-Guinean; SZ: Sudano-Zambesian.  
ns: non significant at 0.05; \*: significant at 0.05; \*\*: significant at 0.01; \*\*\*: significant at 0.001.

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