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Spatial distribution of *bowal* and differences in physicochemical characteristics between *bowal* and woodland soils in Benin, West Africa

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ABSTRACT

Bowal, is degraded land surface characterized by ferricrete exposure due to soil surface erosion. This study aims at assessing the spatial distribution of *bowé* in Benin and the physicochemical differences between *bowé* and soil of adjacent woodlands. *Bowé* surfaces were identified during field investigations and mapped. Soil samples were taken on the *bowé* surfaces and nearby woodland. Mann–Whitney test was applied to analyze the different physicochemical characteristics of *bowé* and woodland. The results show that *bowé* were directly related to ferruginous soils and rainfall regime. *Bowé* soils are characterized by significantly lower values of electrical conductivity, organic matter, extractable phosphorus, silt and total nitrogen than woodland soils, while potassium exchangeability of *bowé* soils is higher. *Bowé* can be expected wherever ferruginous soils and/or ferricretes are observed under unimodal rainfall regimes condition. The disaggregation of *bowé* ferricretes may improve the soil physicochemical characteristics and sustain the regrowth of forest under more humid conditions.

1. Introduction

In the intertropical region, the drier conditions that occurred during paleoclimatic changes (Tardy and Roquin, 1998) led to ferricrete exposures due to degradation of the land surfaces and erosion of the upper leached horizon (Büdel, 1982; Butt, 1987; Millot, 1983). The exposition of ferricrete resulted in *bowal* expansion (plural *bowé*) (Aubréville, 1947; Goldman et al., 2011). *Bowalization* might be human induced (Aubréville, 1947; Goldman et al., 2011; Padonou et al., 2014) or a natural process (André et al., 2003; Thomas et al., 2003). The soil characteristics of *bowé* impede plant root growth because of absorption of water and burns in dry season. Trees on *bowé* are dwarfed, gnarled, and widely scattered (Thompson, 1911). *Bowal* occupies the top of plateaus and does not change appreciably over decades by either growing or disintegrating (Lacroix, 1913; Shantz and Marbut, 1923). However, under humid climatic conditions, the exposed ferricretes are disaggregating and degrading geochemically to form soil (Beauvais, 1999, 2009; Beauvais and Tardy, 1993). Thus one could expect change in the spatial distribution of *bowé* since the climate has becoming more humid particularly in West Africa (Diallo et al., 2012; Diawara et al., 2014). In West Africa, *bowé* are found in the semiarid and the sub humid climate zone (Padonou et al., 2012, 2014; Sieglstetter et al., 2012; Zwarg et al., 2012). Hardened ferruginous soils (i.e., ferricretes) could be the only soil types on which *bowé* occur.

Disaggregation of *bowé* ferricrete can sustain forest regrowth and lead to a soil formation (Beauvais, 2009). Since it is common to observe *bowé* adjacent to woodland in the protected area in West Africa (Fig. 1), we can assume that the woodland is formed after the biophysical disaggregation of the *bowé*. Thus, assessing the physical chemical differences between ferricretes exposed on *bowé* and soil of contiguous woodlands documents the change of the physical chemical characteristics linked to the disaggregation of *bowé*.

The aim of this study is to assess the spatial distribution of *bowé* in Benin and to analyze the physicochemical characteristics of topsoil on *bowé* surfaces compared to the topsoil of adjacent woodland. If the spatial distribution of *bowé* is related to the occurring climate and soil types, it may be possible to determine what climate and soil types are more vulnerable for *bowalization*. In addition, if the physicochemical characteristics of topsoil on *bowé* are different to those of adjacent woodland, it may be possible to predict the physical chemical characteristics of soil, as the soils are derived from the disaggregation of *bowé* ferricretes.

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Fig. 1. Typical *bowal* surface in dry season (February, 2011).

2. Materials and methods

2.1. Study area

The Republic of Benin is located in West Africa between the latitudes of 6°10′N and 12°25′N and longitudes of 0°45′E and 3°55′E. The size of the national territory is of 114,673 km^2. Three rainfall regimes (Fig. 2b) are found: (1) bimodal rainfall between the coast and 7°30′N, with the first rainy season being more intense, (2) a broad peak with a tendency to unimodal rainfall in central Benin, and (3) unimodal rainfall characterized by a slow increase and a sudden decrease. The geomorphology of Benin is closely linked to its geologic structure. The main geologic units of Benin are the sedimentary rocks and the metamorphic and crystalline rocks of the Dahomeyan basement (Faure and Volkoff, 1998). Three major geomorphologic units are observed on the sedimentary rocks and seven on the crystalline rocks besides the Atacora, the main relief and the quartzitic crest in the Kandi-Bimbéréké (Faure and Volkoff, 1998). The geomorphologic units of the sedimentary rocks are the sedimentary basins located in north (Kandi basin and Volta basin) and in south Benin (Coastal basin) (Fig. 2a). Plateaus landscapes are important in the sedimentary basins compared to slopes and lowlands. The Coastal and Kandi Basins are characterized by landscapes with low plateaus. Erosion and flood plains of the Pendjari are other characteristics of the Volta Basin. The crystalline rocks are characterized by peneplain dominated by hills and small relict plateaus. The main geomorphological units are the peneplain of Kouandé-Péhonco westward, the plain of the Alibori in the north, the plateau of Djougou and the peneplain of Pira in the south, the plateau of Parakou and the peneplain of Nikki in the east and the erosion-plain of the lower Ouémé in the south (Fig. 2a). Four major soil types with characteristic vegetation are distinguished in the territory of Benin (Volkoff and Willaine, 1976): (1) ferralitic soils covered by semi-deciduous forest, (2) ferruginous soils covered by dry forest, woodland, and savanna, (3) vertisol in the depression of Lama covered by a dry semi-deciduous forest, and (4) hydromorphic soils covered by swamp and riparian forests. The country is subdivided in ten phytogeographical districts (Adomou et al., 2006) (Table 1; Fig. 3).

2.2. Data collection and analysis

2.2.1. Spatial distribution of bowé

The spatial distribution of *bowal* in Benin is assessed based on field work and phytogeographical districts maps (Adomou et al., 2006). Two main transects oriented according to rainfall gradients and soil types are investigated (Fig. 3). The first transect of 540 km long run

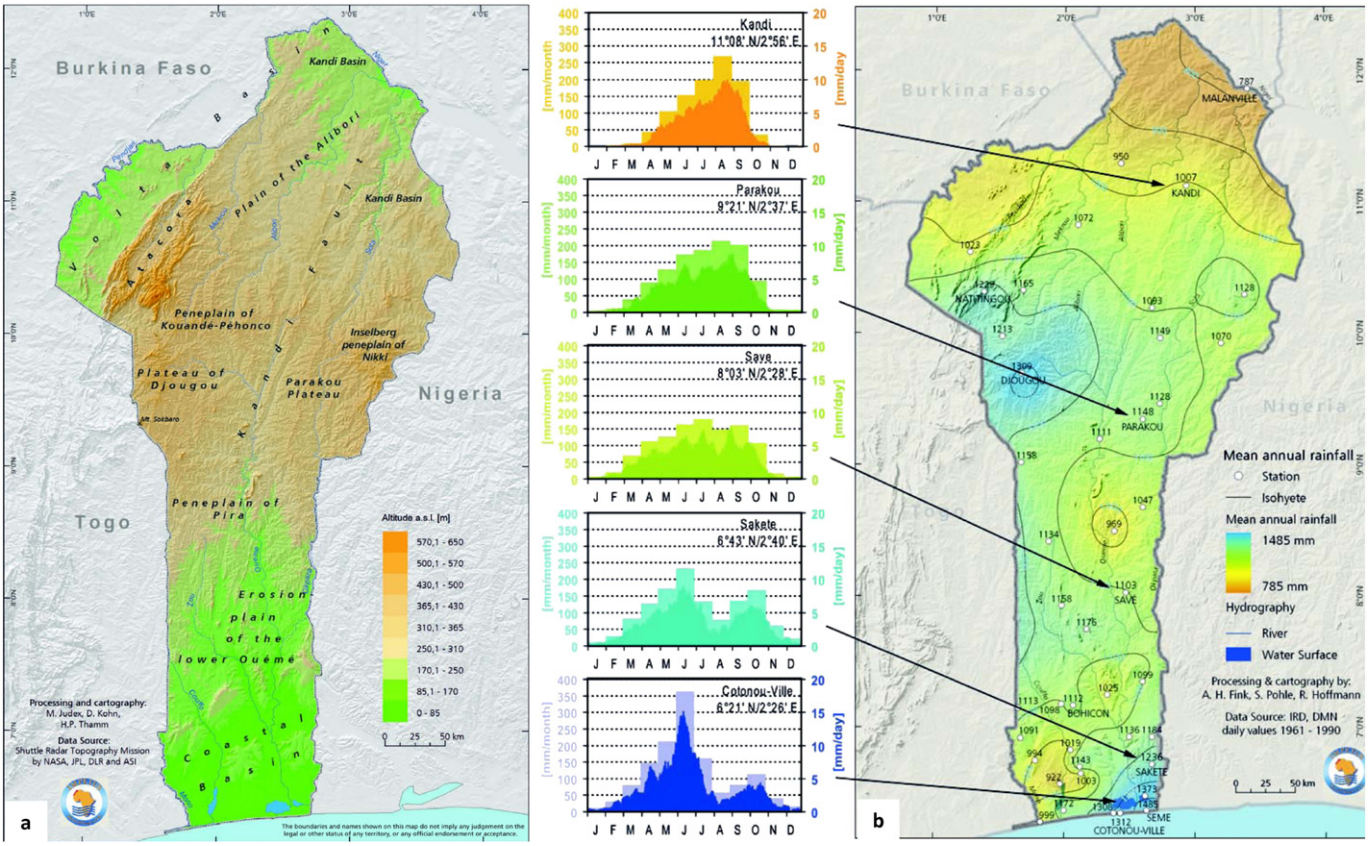

Fig. 2. (a) Landscape units in Benin (Giertz and Schönbrodt, 2008) and (b) mean annual rainfall in mm (Fink et al., 2008) for the period from 1961 to 1990 in Benin.