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Acacia communities and species responses to soil and climate gradients in the Sudano-Sahelian zone of West Africa

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ABSTRACT

Abiotic environmental factors have a major impact on the distribution and performance of plant species. In order to assess two major species–environmental relations in Sudano-Sahelian *Acacia* woodlands, we tested the relationship of soil and climate variables on plant diversity as well as on species responses.

The indicator species values clustered in five vegetation units characterized by three to ten diagnostic species with woody species richness means varying from three to seven species per 0.09 ha. The NMS ordination explained 65% of the variation in species composition and revealed that soil properties, annual precipitations and temperature range structured the diversity of *Acacia* communities. Along the annual precipitations gradient, the response of *Acacia polyacantha* and *Acacia hockii* showed maxima in the wettest zone of our study area (more than 850 mm/year) whilst *Acacia laeta* showed a maximum response in the driest zone (below 500 mm/year). The unimodal response of *A. hockii, Acacia gourmaensis* and *Acacia seyal* to the soil available water gradient spanned their central borders, respectively from 13 to 18% (optimum 16%), 11–20% (optimum 15%) and 4–12% (optimum 7.5%).

The response of *Acacia* communities and species to soil and climate gradients, makes them performant afforestation species in specific habitats of the Sudano-Sahelian zone.

1. Introduction

Acacia woodlands represent one of the most widespread vegetation types of drylands in Africa. The *Acacia* species predominate the vegetation of the Sahelian region and are widely distributed in the Sudanian savannas (Wittig et al., 2004) where they are associated to specific soil groups (Bertrand, 1998). These woodlands have an enormous ecological and economic importance in agro-ecosystems of arid and semi-arid lands (Vassal, 1998; Wiegand and Jeltsch, 2000). *Acacia* species provide resources (fodder, gum, timber), improve soil fertility by nitrogen fixation and rehabilitate degraded lands (Vassal, 1998). Their seed pods, leaves and flowers are of high nutritive value and an important food source to wild and domestic browsers, especially when grass is short in supply.

In the context of land degradation and desertification, *Acacia* species hold a preferential place in agroforestry and land afforestation systems due their high resiliency to drought and grazing. Species such as *Acacia senegal* (L.) Willd., *Acacia seyal* Delile., *Acacia laeta* R. Br. and *Acacia nilotica* (L.) Delile are known as valuable afforestation and agroforestry species for soil conservation and regeneration of degraded lands (Ahmed, 1986; Hien, 1995). Furthermore, afforestation of degraded lands has a large potential of soil carbon sequestration, and realization of this potential is a challenge in the mitigation of climate change (Lal, 2004). However, lack of knowledge on the biology and ecology of indigenous species and their adaptation to environmental stress limited their use in the afforestation programs (Gebrekirstos et al., 2006).

Abiotic environmental factors are a principal part of the environmental niche and therefore have a major impact on the distribution and performance of plant species. To improve the use of *Acacia* species in afforestation and agroforestry systems we need to study the environmental factors determining the ecological optimum and species growth performance. There are many analytical approaches for species niche modelling to answer the

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fundamental question "what are the environmental factors controlling species performance and distribution". Knowledge of *Acacia* woodland typology in relation to environmental variables, and modelling of *Acacia* species occurrence are essential for using these species in the afforestation of arid and semi-arid lands.

This paper aims to determine the environmental parameters influencing *Acacia* woodland's typology (change in species composition) with specific reference to climate and soil parameters as well as to establish the response of the main diagnostic species to relevant environmental variables.

The following questions arise and are discussed: (i) Do soil and climate gradients determine the change in species composition of *Acacia* woodlands in the Sudano-Sahelian zone? (ii) What are the responses and ecological requirements of the dominant diagnostic species to specific environmental variables?

2. Study area and species

Acacia species are widely distributed in the Sahelian and Sudanian zones of West Africa (Nongonierma, 1978). According to Vassal (1998) and Wittig et al. (2004), the distribution of *A. laeta* and *A. senegal* is restricted to the Sahelian zone, while *Acacia gourmaensis, Acacia hockii, Acacia dudgeonii* Craib ex Holland, *Acacia polyacantha* Willd. and *Acacia sieberiana* DC. are concentrated in the Sudanian zone. *A. seyal* and *A. nilotica* occur in the Sahelian as well as in the Sudanian zones. The Sahelian *Acacia* species experience a higher wood-cutting and grazing pressure than those of the Sudanian woodlands.

We studied *Acacia* woodlands in the Sudano-Sahelian zone with an annual precipitation of 450–1000 mm (Fig. 1). The study extends over three phytogeographical sectors (sub-Sahelian, North Sudanian, South Sudanian) according to the classification of Fontès and Guinko (1995). The climatic conditions range from the sub-Sahelian with an annual precipitation below 600 mm and 8–9 consecutive dry months via North Sudanian with an annual precipitation of 700–900 mm to South Sudanian with more than 900 mm and 5–6 consecutive dry months.

The overall vegetation of this Sudano-Sahelian zone is dominated by species from Combretaceae and Leguminosae families. The major soil types are leptosols, regosols, lixisols, luvisols, gleysols, cambisols and vertisols.

3. Methods

3.1. Vegetation and soil sampling

The sampling was based on a three-factor nested design considering the climatic zone (sub-Sahelian, North Sudanian, South Sudanian), the dominance of different *Acacia* species (floristic stratum) and the different soil types classified at the second level of the World Reference Base classification (WRB, 2006). Following this design, forty research sites including fallow lands with spontaneous regeneration of woody plants for more than fifty years and natural forest reserves (protected forests) were randomly selected. As Sudano-Sahelian ecosystems in general, these sites were affected by irregular grazing and bush-fires. In addition, soil unit's discontinuity, topography and/or land use gradients structured the fragmentation of vegetation at site scale.

Three sample-plots were randomly replicated within each site to cover floristic composition and species dominance that are potentially patchy by these ecological factors (soil unit's discontinuity, topography or/and land use). In total, the woody layer of *Acacia* communities was investigated in 120 sample-plots (Fig. 1) with a size of 900 m^2 (30 m × 30 m). This plot size is widely used for woody vegetation sampling in West African savannas and generally

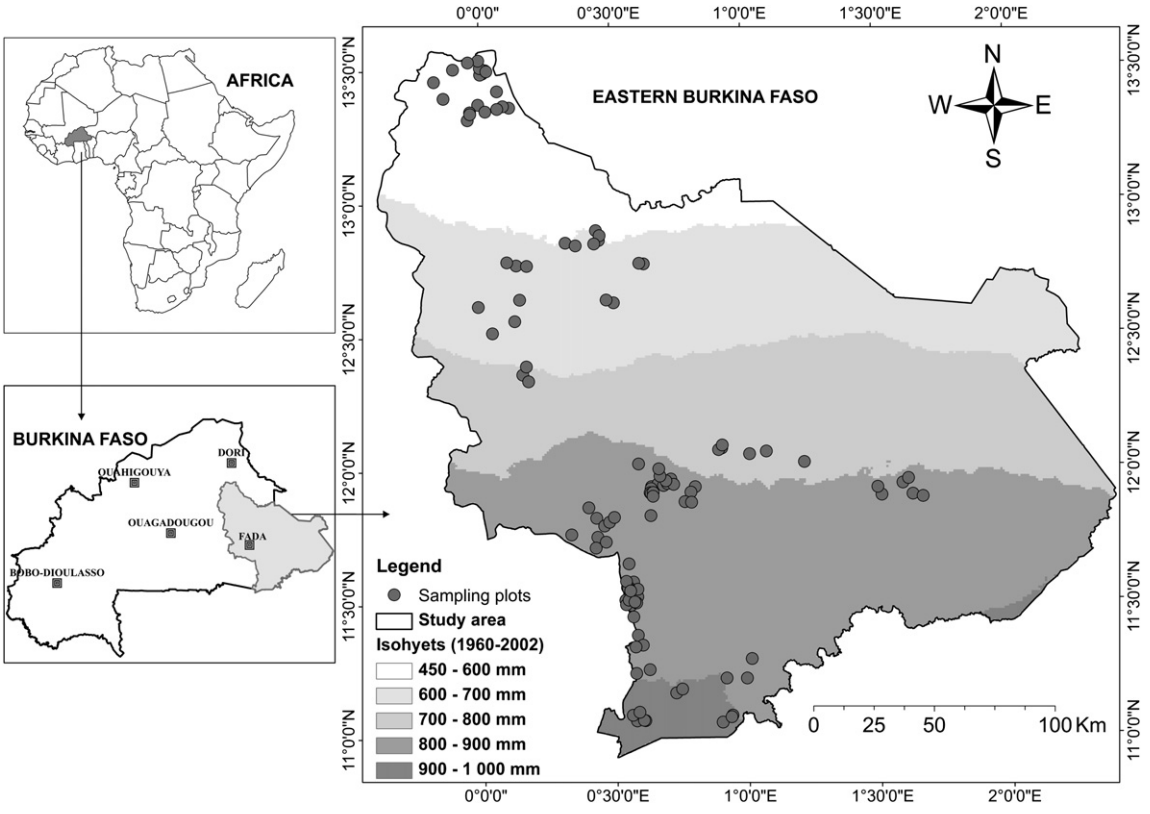

Fig. 1. Localization of sample-plots in the study area (eastern Burkina Faso).