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Soil seed bank characteristics in two central African forest types and implications for forest restoration

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ABSTRACT

This study evaluates the characteristics of soil seed bank in two types of central African rainforests: *Celtis* forest on clay soils and *Manilkara* forest on sandy soils. In each study site, 30 samples were collected per soil layers (litter, 0–5 cm, 5–10 cm and 10–20 cm depth). The species diversity and abundance of the soil seed bank were estimated after soil samples were brought to germination. We globally observed 297 seedlings of 53 species for the *Celtis* forest and 222 seedlings of 39 species for the *Manilkara* forest. The total densities of germinated seeds were 330 seedlings m^{-2} and 247 seedlings m^{-2}, respectively. Herbaceous species dominated with percentages of 41.0 and 45.3%, respectively in the *Manilkara* forest and the *Celtis* forest. Both forest types displayed a regeneration potential through the soil seed bank. However, this potential seems higher in the *Celtis* forest. Pioneer taxa were more abundant in the soil seed bank of the *Celtis* forest (13 woody pioneer species) than the *Manilkara* forest (9 woody pioneer species). The values of Sorensen similarity index between the standing tree vegetation and the soil seed bank in each site were relatively low: 11.0% for the *Celtis* forest and 8.8% for the *Manilkara* forest. But these similarity values were higher when only the pioneer species were considered: 46.8% in the *Celtis* forest and 38.9% in the *Manilkara* forest. The highest species richness were obtained in the first two soil layers (0–10 cm depth) while 21.8% and 21.4% of the species were exclusively found in the deepest layer (10–20 cm) in the *Celtis* forest and the *Manilkara* forest, respectively. Among the timber species found in the forest, only three were observed in the soil seed bank of the two sites: *Nauclea diderrichii*, *Erythrophleum suaveolens* and *Staudtia kamerunensis*. *N. diderrichii* was particularly abundant in the soil seed stock of the two sites (14.4–34.4 seeds m^{-2}). Results suggested that to improve regeneration of timber species, planting in open forest habitats with seedlings coming from tree nursery should be more efficient.

1. Introduction

The soil seed bank which designates the stock of viable seeds in the soil (Garwood, 1989; Roberts, 1981; Savadogo et al., 2016) plays an important role in the maintenance of the ecological diversity of natural ecosystems (Brown and Venable, 1986; Houle and Phillips, 1988; Saatkamp et al., 2014; Thompson and Grime, 1979). Recruitment from transient or persistent soil seed banks has long been considered an important pathway for regeneration of tropical pioneer species (Dalling et al., 1998; Hall and Swaine, 1980). Seeds buried in the soil may be brought back to the surface either by the movements of roots or organisms living in the soil, or by anthropogenic disturbances (Saulei and Swaine, 1988; Vasquez-Yanes and Orozco-Segovia, 1993). They can then germinate and compose a seedling bank of crucial role for the forest regeneration. In particular, long-term persistent categories of seed bank can contribute to restore plant populations which were extinct from the standing vegetation (Csontos and Tamas, 2003). Therefore for a long time now, the soil seed bank is frequently employed in

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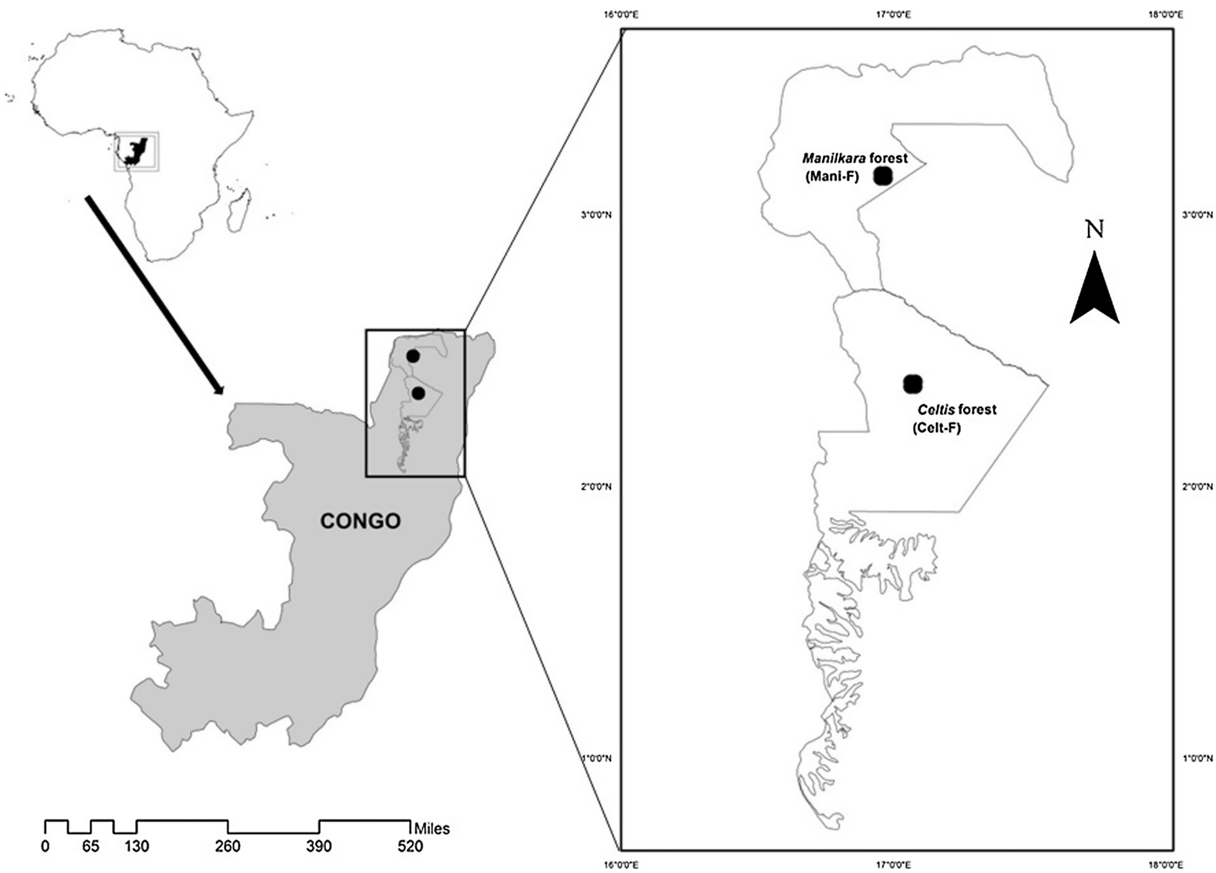

Fig. 1. Location of the two study sites in the forest management units of Mokabi-Dzanga, Rougier Company (*Manilkara* forest = Mani-F) and Loundoungou, CIB/OLAM Company (*Celtis* forest = Celt-F).

restoration ecology (the use of seed bank to restore degraded sites was largely exemplified in Lamb, 2010). The majority of viable seeds in the soil is supplied by weedy species and the investigations of the soil seed bank are mostly conducted in non woody vegetation or open canopy forest types: grasslands, pastures, savannas (Clark et al., 1999; Garwood, 1989; Tessema et al., 2017; Witkowski and Garner, 2000). Even studies dealing with soil seed bank patterns in forest habitats confirmed the dominance of herbaceous taxa belonging to the pioneer group in the soil (≥70% of the observed species; Daïnou et al., 2011; Hall and Swaine, 1980; Martins and Engel, 2007). Recently, Shen et al. (2014) questioned the influence of sampling effort in terms of surface area for detecting a high percentage of woody species in forest soils. They suggested that a minimum sample area of 4 m^2 was needed for a temperate forest, when the depth of soil collection is restricted to 10 cm. Shen et al. (2014) did not emphasize the impact of soil depth on the species richness. But more importantly and as Forcella (1984) also recommended, these authors proposed the use of a species-area curve to estimate species richness and verify the representativeness of the samples.

In central Africa, studies dealing with the soil seed bank are extremely rare (Douh et al., 2014). A few years ago, Daïnou et al. (2011) first characterized the soil seed bank of a central African forest but the work was restricted to a single Cameroonian site and only the first 5 cm of the top soil was collected.

Our study goes beyond these limitations by investigating the soil seed bank of two types of central African forests that differ in terms of substrates and soil conditions (clay vs. sandy soils), and stand structure. The substrate and the forest types may play a crucial role in the soil seed bank characteristics. They may not only influence the abundance of specific seeds in the soil, independently of plant community density (Warr et al., 1993), but also promote or not the emergence of the buried seeds. In addition, for long-persistent taxa in the soil seed bank, the viability of seeds may increase with depth providing a higher abundance or exclusive presence of such taxa in deep soil layers. Large-seeded taxa which are pioneers and belong to the first stages of the forest succession can persist through their seeds in various soil layers over many decades (Dalling et al., 1998; Dalling and Brown, 2009) even when they are no more present in the standing vegetation (Csontos and Tamas, 2003; Grandin and Rydin, 1998; Warr et al., 1993).

We quantitatively and qualitatively evaluated the characteristics of the soil seed bank as a function of soil and forest types. We performed a soil sampling deeper than commonly realised before (20 cm vs. 5–10 cm) in order to check specificities of deep strata of forest soils. In addition, because seeds in the soil should come from the standing vegetation, we also compared the soil seed stock floristic composition to that of the standing forest. Although previous studies consistently reported a very low similarity between the two floristic compartments (more or less 10%; Daïnou et al., 2011; Hall and Swaine, 1980; Uasuf et al., 2009), we assumed that these estimates were biased as they compared incompatible data: the forest stand in mature vegetation is not dominated by pioneer taxa in contrast to the flora of the soil seed stock. Comparison of pioneer taxa of both compartments for instance would be more relevant. Our hypotheses were: (1) soil seed bank characteristics in terms of seed abundance and species richness are associated to forest and soil types; (2) as only long-living seeds may be represented in deep soil layers, seed abundance and species richness would decrease with soil depth; (3) the majority of the tree taxa observed in the soil seed bank may originate from the forest stands resulting in a significant similarity value, if one considers only the dominant species category in the soil bank.