Global Ecology and Conservation 13 (2018) e00373

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Long term impacts of crop cultivation and tree shading on *Piliostigma thonningii* (Schumach) Milne-Redhead population, growth and biomass production after charcoal production in central Zambia

Emmanuel Ngulube Chidumayo

Makeni Savanna Research Project, P.O. Box 50323, Lusaka, Zambia

ARTICLE INFO

Article history:
Received 3 October 2017
Received in revised form 10 January 2018
Accepted 10 January 2018

Keywords:
Agroforestry
Mortality
Natural regeneration
Seed germination

ABSTRACT

Charcoal production in Sub-Saharan Africa is often perceived to have serious ecological and environmental effects even although it does not necessarily result in forest conversion to other land uses. Forest recovery through natural or assisted regeneration is particularly appealing for managing tropical dry forests following degradation by charcoal production because of the coppicing ability of the majority of tree species. However, the impacts of crop cultivation and tree enrichment planting on the regeneration of indigenous trees following charcoal production have rarely been investigated. The present study was conducted on adjacent cultivated and control subplots for over 20 years after charcoal production at a site in central Zambia, southern Africa, to assess the effects of short term crop cultivation, tree enrichment planting and tree shading on *Piliostigma thonningii*, a potential agroforestry species in sub-Saharan Africa. Seedling emergence, sapling survival and annual tree growth were monitored from 2000 to 2017 and aboveground wood biomass estimated using an allometric equation developed from trees cut at the site and the surrounding area. Seedling emergence from untreated seeds occurred over a 6-year period and tree shading significantly reduced seedling germination and survival. Saplings grew very slowly and none transitioned into a tree after 12 years of observations. Although crop cultivation had no significant effect on the population dynamics of *P. thonningii*, it reduced tree growth rates, biomass production and peak biomass accumulation. Peak aboveground wood biomass on post-cultivation blocks of 13.7 t ha^{-1} represented only 61% of the 22.5 t ha^{-1} on control blocks. Some of the major challenges in cultivating *P. thonningii* as an agroforestry species are seed dormancy and slow sapling growth and these need to be resolved if the species is to be widely cultivated.

1. Introduction

Charcoal production in Sub-Saharan Africa is often perceived to have serious ecological and environmental effects, such as deforestation. However, since the Intergovernmental Panel on Climate Change (IPCC) defines deforestation as the conversion

E-mail addresses: echidumayo@gmail.com, chidumayoe@yahoo.com.

https://doi.org/10.1016/j.gecco.2018.e00373

of forest to non-forest land use, charcoal production in Sub-Saharan Africa does not necessarily result in forest conversion to other land uses and therefore should be regarded as a form of forest degradation (Fig. 1) as defined by Oyugi et al. (2007), Acharya et al. (2011) and Kutsch et al. (2011). Lambin et al. (2003) estimated that the annual rate of forest degradation in Africa is almost half of the annual rate of deforestation, thereby making it an important process to monitor and quantify in the context of global carbon cycling. At the end of the 20th century, degraded and second growth forests accounted for roughly 60% of tropical forested areas (International Tropical Timber Organization (ITTO), 2002) and emissions of greenhouse gases from charcoal production in tropical ecosystems in 2009 were estimated at 71.2 million t of carbon dioxide and 1.3 million t of methane (Chidumayo and Gumbo, 2013) which need to be mitigated to reduce their impact on climate change. Reducing emissions from deforestation and forest degradation, and enhancing forest carbon stocks in developing countries (REDD+) is a mechanism for climate change mitigation and this can be done through reforestation, agroforestry and natural forest regeneration. These restoration activities can also be undertaken on abandoned cropland (fallow). Schultz (1974) estimated that 20.8% of the land in Zambia was cropland and fallow and Mayaux et al. (2004) estimated that 8.63% of the land in the country is cropland, implying that nearly 12.2% or 8.3 million ha in Zambia might be fallow land that can be managed for carbon sequestration. Natural regeneration is particularly appealing for managing tropical dry forests following degradation by charcoal production in east and southern Africa because of the coppicing ability of the majority of tree species after cutting and the existence of a sapling bank in the herbaceous layer (Banda, 1988; Boaler and Sciwale, 1966; Chidumayo, 1989; Handavu et al., 2011; Louga et al., 2004; Lowore, 1999; Strang, 1974).

The majority of studies on forest recovery following abandonment of cultivation or after charcoal production are based on chronosequencies or space-for-time substitution (Boaler and Sciwale, 1966; Goncalves et al., 2017; McNicol et al., 2015; Oyama, 1996; Strang, 1974; Stromgaard, 1985; Williams et al., 2008). The results from these studies indicate a linear progression in aboveground wood biomass with increasing time after woodland clearing or abandonment of cultivation. However, studies conducted elsewhere in tropical forests suggest that the rates of aboveground biomass accumulation are typically fastest in the first two decades of forest succession and decline thereafter (Feldpausch et al., 2004; Silver et al., 2000) indicating a non-linear progression. In most cases the previous land-use practices and their intensity exert a strong effect on the long term biomass production, such that long periods of intensive use and/or disturbance can significantly retard biomass accumulation in second growth tropical dry forests (Chidumayo and Gumbo, 2013).

Piliostigma thonningii (Schumach.) Milne-Redhead is a leguminous tree belonging to the family Caesalpiniaceae that grows to a height of 15 m in Zambia (Storrs, 1979). It is one of the first tree species to colonize abandoned cropland in the Sudano-Sahelian zone of West Africa and because it also improves soil fertility, the species is increasingly used in agroforestry systems in the region (Yélémou et al., 2013). In Nigeria and Malawi the conservation of *P. thonningii* is a national priority (Ayisire et al., 2009; Mwase and Mvula, 2011). *Piliostigma thonningii* is also widely used in Africa for poles, firewood, charcoal and its pods are eaten by wild ungulates and livestock. The indehiscent pods can be up to 20×7 cm (White, 1962) and on average ($\pm$1se) contain 29.5 ± 2.5 seeds. The distribution range of *P. thonningii* extends from West Africa to the Sudan and south wards to South Africa. The present study aimed at investigating seed dormancy and how short term crop cultivation, tree enrichment planting and tree shading during canopy development affect *P. thonningii* population dynamics, aboveground wood biomass production and accumulation following charcoal production. Unlike space-for-time substitution studies, this study is based on observations made on adjacent permanent subplots over a period of 20 years from 1997 to 2017 following charcoal production (Fig. 1) at a tropical dry forest site in central Zambia. The study findings have implications for the practical management and conservation of *P. thonningii* in agroforestry, forest restoration through natural regeneration and carbon sequestration projects in tropical dry areas of Africa where this species occurs.

Fig. 1. Forest degradation by charcoal production in central Zambia.