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Policy Forums

Afforestation of savannas: an impending ecological disaster

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The restoration of terrestrial ecosystems damaged by human activities is an urgent priority worldwide (Higgs et al., 2014). Reforestation is one of the most direct and efficient methods for reversing ecosystem degradation (Lamb et al., 2005) and contributing to biodiversity conservation. Reforestation

is also seen as a fundamental tool for mitigating greenhouse gas emissions, and has inspired programs such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) and CDM (Clean Development Mechanism) (Canadell and Raupach, 2008). While reforestation implies planting trees on deforested land, afforestation is the planting of trees where they do not occur naturally (Putz and Redford, 2009). The term afforestation remains widely used in reference to this

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phenomenon, although the products, such as monoclonal or monocultures, cannot be considered forests in the ecological sense of the word (Putz and Redford, 2010). In their natural condition, many ecosystems are not dominated by trees (i.e., open ecosystems), including savannas and grasslands, for which reforestation is inappropriate (Veldman et al., 2015b,c). Savannas, in particular, cover approximately 33 million km² at mostly tropical latitudes, and are one of the planet's largest non-forest biomes (see Beerling and Osborne, 2006, and references therein).

The so-called reforestation agenda that targets these naturally non-forested ecosystems is actually not reforestation at all, but a different process – afforestation. Afforestation has been applied massively in Asia, Africa, and South America, with the main focus being short-term economic benefit from rapidly obtaining timber, charcoal, pulp, oil or fruits (Jaiyeoba, 2001; Epron et al., 2009; Xu, 2011; Jagoret et al., 2012; Koh and Wilcove, 2008; Romero-Ruiz et al., 2012; Tang et al., 2013; Vargas et al., 2015). Afforestation of open ecosystems is an incongruous disturbance and, indeed, an impending ecological disaster. The practice of afforestation is in need of urgent evaluation of its causes and its consequences, and the need for policies to address it. Here we review what is known about the ecology and biodiversity of savannas and document current trends of afforestation and discuss its future, with particular emphasis on South America.

Afforestation in savannas

We define a savanna as a phytogeographic domain comprised of a complex of physiognomies (Bourlière and Hadley, 1983; Coutinho, 1978, 2006). Savanna ecosystems are increasingly becoming recognized for their essential ecosystem services, including provisioning of water, production of livestock forage and carbon storage, that latter being comparable to that of forests when above and belowground biomass is considered (Overbeck et al., 2015). However, savannas around the world have been impacted by anthropogenic activities and are currently threatened by many factors, including afforestation (Veldman et al., 2015b,c; Bond, 2016). The practice of afforestation of savanna areas is rapidly growing, such as the planting of exotic eucalypt and pine monocultures, especially in Brazil, Colombia, Nigeria, Congo, and China. In other countries, savannas are being afforested for the production of other commodities, such as palm oil in Latin America, and fruit in China (Jaiyeoba, 2001; Xu, 2011; Jagoret et al., 2012; Tang et al., 2013). In Colombia, for instance, the area occupied by oil palm plantations more than doubled over the last ten years (Vargas et al., 2015) largely through the afforestation of savannas (Romero-Ruiz et al., 2012).

Since savannas are largely located in developing countries, where the economy is fundamentally based on primary activities (e.g., agriculture, livestock, mining and silviculture), they have suffered considerable historical conversion (Myers et al., 2000; Silva and Bates, 2002; Klink and Machado, 2005; Fernandes et al., 2016a,b). Such conversion is translated into a major impact on biodiversity and ecosystem services, which we summarize here based on an analysis of afforestation of the Brazilian savanna known as cerrado, with the hope of

raising awareness of the impending disaster that this practice represents for all the world's savannas.

The Brazilian savanna: concepts and threats

As is the case with many savannas, the cerrado is a rich ecological mosaic with more than a dozen different formations or physiognomies ranging from open natural grasslands where trees are absent (e.g., open grasslands, rupestrian grasslands) to savannic vegetation (cerrado *stricto sensu*), to partly forested vegetation under some particular local ecological conditions (e.g., cerradão, gallery forests) (Sano et al., 2007; Fernandes et al., 2016a). While the non-forest formations (grasslands and savannas) are fire-tolerant, the forested formations are not (Dantas et al., 2013a,b).

Cerrado has a significant number of endemic species, and it is one of the five South American biodiversity hotspots (Myers et al., 2000; Joppa et al., 2011), with 4.8% of the world's plant species (Fig. 1) (Ratter et al., 1997). Almost 40% of its 13,140 angiosperm species are endemic. Eighty-five percent of the plant species are shrubs and herbs, with trees representing only 15% (LEFB, 2015). In addition, cerrado landscapes hold the headwater springs of major Brazilian rivers that are responsible for the maintenance of critical hydrological dynamics of vast areas (Fernandes et al., 2016a). Yet, despite its critical biodiversity and the importance of its ecosystem services, the cerrado vegetation is being destroyed, with its natural plant cover being removed faster than that of any of the world's savannas. More than half of its 2 million km² (an area about the size of western Europe, or slightly larger than Mexico) has been converted to agricultural land and pasture since the 1960s, and it is now ranked second among the Brazilian vegetation types in the number of threatened species (Klink and Machado, 2005). The expansion of agribusiness into the cerrado, which largely serves Chinese and European markets, was hailed as an economic miracle and shows no sign of attenuation (Liu and Diamond, 2005; Coelho et al., 2013; Gibbs et al., 2015). In light of this situation, this savanna was recently targeted as a potential "region for reforestation" to meet the Bonn Challenge target to globally "revegetate" 150 million ha by 2020 (Laestadius et al., 2011). An *Atlas of Forest Landscape Restoration Opportunities* (hereafter the *Atlas*) was published by the World Resources Institute and targeted 23 million km² of forested lands to be restored (WRI, 2014). Surprisingly, the cerrado was listed for "reforestation" therein, under the premise that "all lands biophysically capable of supporting a tree canopy cover of at least 10% were included" (Rojas-Briales, 2015). The initiative of the *Atlas* to identify and map opportunities for landscape restoration is undoubtedly well intended. Nevertheless, the implementation of a reforestation program in savannic formations – that is, afforestation – of this large region would be an act of extraordinary folly. It is an ecologically incorrect and, indeed, hard to achieve initiative (Veldman et al., 2015b,c), for the cerrado is not, and never was, a forested ecosystem. Even scientists have been ignored this incongruence in some specific analysis (Beuchle et al., 2015). With the exception of riparian or otherwise very localized woodlands, most of the cerrado is grassland and scrub (Simon et al., 2009).

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