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**Citation for published version:**
Bond, WJ, Stevens, N, Midgley, GF & Lehmann, C 2019, 'The trouble with trees; afforestation plans for Africa', *Trends in Ecology & Evolution*, vol. 34, no. 11, pp. 963-965.
https://doi.org/10.1016/j.tree.2019.08.003

**Digital Object Identifier (DOI):**
10.1016/j.tree.2019.08.003

**Link:**
Link to publication record in Edinburgh Research Explorer

**Document Version:**
Peer reviewed version

**Published In:**
Trends in Ecology & Evolution

# The trouble with trees; afforestation plans for Africa

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Keywords: carbon sequestration, savannas, afforestation

**Abstract**

Extensive tree planting is widely promoted for reducing atmospheric $CO_2$. In Africa, 1 million km$^2$, mostly of grassy biomes, has been targeted for 'restoration' by 2030. The target is based on the erroneous assumption that these biomes are deforested and degraded. We discuss the pros and cons of exporting fossil fuel emission problems to Africa.

**Main text**

Africa is the grassiest continent. The grasses support Africa's great natural asset, the remaining herds of the Pleistocene megafauna (Figure1). Africa's grassy biomes are rich in forest-averse birds, reptiles, plants, and insects. They were the cradle of our hominid ancestors and today are home to over 300 million people. But these open grassy landscapes could be transformed if trees-for-carbon projects inappropriately target them, for example, by 'restoring forest landscapes' over 1 million km$^2$ by 2020 and 3.5 million km$^2$ by 2030 (http://www.bonnchallenge.org). These are vast areas: the 2030 target is equivalent to the combined area of the 10 largest European countries (France, Spain, Sweden, Norway, Germany, Finland, Poland, Italy, the UK and Romania), or 45% of Australia, or 36% of the USA. But much of this new plantation area is planned for Africa rather than the global North.

Targeted areas are based on global maps of 'deforestation' and 'degradation' [1]( http://www.wri.org/applications/maps/flr-atlas/#). The maps erroneously assume that low tree cover, in climates that can support forests, are deforested and 'degraded'. The bizarre result is that ancient savanna landscapes, including the Serengeti and Kruger National Park, are mapped as deforested and degraded (because tree cover is reduced by elephants, antelope and several million years of grass-fuelled fires). This profound misreading of Africa's grassy biomes has now led to an off-shoot of the Bonn challenge, the AFR100, targeting 100 million hectares of mostly savanna for 'reforestation' by 2030 (Figure 1)(https://afr100.org). Funding has been secured from Germany, the World Bank and other donors with more than one billion dollars pledged over the next 10 years. Twenty eight African countries have signed up to AFR100 with each country pledging to afforest an explicit target area. For example, Mozambique has committed to 'restoration' of one million hectares, South Africa to 3.6 Mha, Kenya to 5.1 Mha, and Cameroon to 12 Mha. Cameroon's pledge requires converting a quarter of the country to plantations, Nigeria's 32% and Burundi's 72% [2].

Committing such vast areas to plantations for the next century should raise many questions. An obvious one for industrial countries that are funding these projects is whether afforestation (planting new trees, rather than restoring areas known, historically, to have been closed forests) will work to cool the climate. There is growing scientific scepticism. Smith et al. [3] discussed all 'negative emissions technologies' (NET), including afforestation, enhanced mineral weathering, and chemical capture, and concluded that none will be effective in reducing carbon at the scale needed. The NET are merely a distraction, they argue, from the serious business of reducing emissions by reducing fossil fuel use. Baldocchi and Penuelas [4] evaluated the potential of the Earth's ecosystems to sequester carbon and concluded that planting trees will not significantly reduce atmospheric $CO_2$. Lewis et al [2] argued that restoration of forests is effective, but that plantation forestry is not. They calculated that if 350 Mha were restored natural forests, 42 Gt of C would be sequestered by 2100 compared to 1 Gt C for the same area afforested with pines and eucalypts. Their analysis implies that converting African savannas to plantations is pointless as a mitigation measure. At the optimistic extreme, Bastin et al [5] estimated 205 Gt C could be stored by planting up the world's potential forest land, including 'sparse vegetation and grasslands'. Their estimates have been challenged, not least because they assumed zero soil C stocks in targeted sites [J. Veldman, Pers. Comm. 2019]. An underappreciated problem is that biophysical consequences of afforestation can negate climate effects of reducing $CO_2$ [6]. Forests absorb more incoming radiation than grasslands so that plantations may cause a net warming, rather than the intended cooling. The net radiative effects of planting trees, warming or cooling, vary with latitude and local conditions. Evaluating their magnitude requires a different set of scientific skills from carbon accounting so that biophysical effects are seldom considered in trees-for-carbon projects [6].

The limited benefits of afforestation for reducing atmospheric $CO_2$ have not been widely appreciated. Exploring aspects of the Bonn challenge helps give perspective. Carbon dioxide in the atmosphere is currently increasing at about 4.7 Gt C per year (1 Gt= 1000 000 000 tons) [7]. To nullify this growth rate in atmospheric $CO_2$ ($G_{ATM}$) by a NET programme, such as planting trees, would cost $47 billion at $10 per Mg C sequestered ($172 billion at $10/Mg $CO_2$). The billion dollars promised for the Bonn programme, over a 10-year programme, is <0.5% of the minimum needed to balance $G_{ATM}$. Other NET technologies are supposedly workable at $100 per Mg C sequestered making them even less affordable [3]. Either the funders are short-changing African participants, or they do not see afforestation as a serious contributor to $CO_2$ reduction.

Tree planting is land hungry. To appreciate how hungry, consider the area needed to sequester current $G_{ATM}$ of 4.7 $GtCy^{-1}$. This will depend on total C sequestered in plantations which varies with climate, tree species, soil type, forest management, and rotation time. Carbon sequestered increases after planting and then diminishes as trees mature. Trees would need harvesting, their carbon preserved, and plantations re-established to maintain their sequestration potential [8]. Optimistic estimates are of 10-year cycles for tropical plantations [11]. Mean carbon sequestered ranges from 1 to 3.4 Mg C $ha^{-1}y^{-1}$ in the tropics [3,9] (the Bonn challenge used 1.32 $MgCha^{-1}y^{-1}$). Using these values, you would need to plant up 14 to 47 million $km^2$ of plantations to sequester current $G_{ATM}$. For optimistic estimates, you would need to afforest an area 53% larger than the USA or 85% of Russia. For less productive plantations you would need upwards of a third of the world's land area. If Africa reached the 100 million ha target, $G_{ATM}$ would be mitigated by a mere 2.7 % per year. If this seems very small reward for afforesting a continent, consider that the coal that drove 200 years of the industrial revolution took 400 million years to accumulate. How can we possibly expect to grow enough trees to stuff all the carbon back again in just a few decades?

Ironically, several researchers have argued that the grassy biomes targeted for afforestation are better than forests at conserving carbon [10]. This is partly because forests, especially plantations of eucalypts and pines, are vulnerable to high severity fires and will become more so as the world warms. Most of the carbon stored in grasslands is below-ground, where it persists through fire [10]. In Africa, which accounts for 70% of the world's annually burnt area, suppressing grass-fuelled fires is manageable but suppressing high intensity plantation fires is not. Furthermore, grasslands themselves can have high rates of carbon sequestration below-ground. It has even been hypothesised that the Pliocene spread of grasslands locked up so much carbon in soils that it triggered the Ice Ages [11].

What will massive afforestation of Africa's grassy biomes mean for the countries committing themselves to AFR100? The initial cash injection into 'restoration' is attractive for governments funding job creation and infrastructure. However, one billion dollars spread over 100 million hectares is just $10 per hectare. In the rush to launch AFR100, there has been little time to explore costs, social, economic, ecological, of converting Africa's grasslands and savannas to plantations [12]. The global scale of tree planting promoted by AFR100 and similar programmes ignores local concerns over land tenure, competition with agriculture and conservation and imposes this single dominant land use for generations to come.

In trading water for carbon, it has been repeatedly shown using multi-decadal catchment experiments and hydrological models that replacing native grasslands with plantations reduces streamflow [13]. Reduction in streamflow from savanna afforestation will have critical impacts on dry season water supply for local communities. In South Africa, new afforestation is restricted by legislation so as to conserve water resources for land users backed by a major government programme to remove invasive trees spreading from plantations.

What of the alternatives to NET of drastically reducing emissions by reducing dependence on fossil fuels? In one year (2016-2017), the UK reduced overall emissions by 12 million tons of $CO_2$ equivalent (=3.7 M tons C), through reduced use of coal for electricity generation (https://www.gov.uk/government/statistics). That equates to 3.3 M ha of open ecosystems turned into plantations (at 1 Mg C $ha^{-1}y$). Given the land use change envisaged for tree planting, over enormous areas, sustained for decades, with such poor gains in carbon reduction, we find it difficult to understand why afforestation is so widely supported. As demonstrated by the UK, emissions reductions by reducing fossil fuel dependency are feasible without reducing economic growth and are far more effective in reducing rates of $CO_2$ increase than afforestation. Indeed, trees-for-carbon projects can be seen as a distraction from the urgent business of reducing fossil fuel emissions. Planting 100 million hectares of trees, far away in Africa, might reduce the urgency of emissions reductions in industrial countries that are the major sources of greenhouse gases [3].

We suggest that serious and urgent consideration needs to be given to the wisdom of continuing continental scale afforestation in Africa and elsewhere. We strongly endorse tree planting to restore closed forests destroyed in historical times (reforestation), the retention of intact forests that remain, and the planting of trees in urban areas for shade and enjoyment. But the afforestation envisaged by global tree-planting programmes is based on wrong assumptions. Far from being deforested and degraded, Africa's savannas and grasslands existed, alongside forests, for millions of years before humans began felling forests. A better way of supporting Africa's transition to a future warmer world might be to promote energy efficient cities in this rapidly urbanizing continent so that Africa follows a less carbon-intensive trajectory of development than other emerging economies.

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**Figure Legend**

Figure 1. Large scale tree-planting in Africa will severely impact African grassy biomes. a)Areas identified as suitable for reforestation [14] (http://www.wri.org/applications/maps/flr-atlas/#) have significant overlap with the distribution of African grassy ecosystems (adapted from [15]) which are important centres of b) ungulate and c) carnivore diversity [16] (number species/10kmx10km grid cell)that also provide valuable ecosystem services to much of Africa's population as indicated by the d) distribution of cattle across Africa [17]. Figures created by Nicola Stevens.