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1 **The trouble with trees; afforestation plans for Africa**

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14 Keywords: carbon sequestration, savannas, afforestation

15

16 **Abstract**

17 Extensive tree planting is widely promoted for reducing atmospheric CO<sub>2</sub>. In Africa, 1  
18 million km<sup>2</sup>, mostly of grassy biomes, has been targeted for 'restoration' by 2030. The target  
19 is based on the erroneous assumption that these biomes are deforested and degraded. We  
20 discuss the pros and cons of exporting fossil fuel emission problems to Africa.

21 **Main text**

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

32

33 Targeted areas are based on global maps of 'deforestation' and 'degradation' [1](  
34 <http://www.wri.org/applications/maps/flr-atlas/#>). The maps erroneously assume that low  
35 tree cover, in climates that can support forests, are deforested and 'degraded'. The bizarre  
36 result is that ancient savanna landscapes, including the Serengeti and Kruger National Park,  
37 are mapped as deforested and degraded (because tree cover is reduced by elephants,

38 antelope and several million years of grass-fuelled fires). This profound misreading of  
39 Africa's grassy biomes has now led to an off-shoot of the Bonn challenge, the AFR100,  
40 targeting 100 million hectares of mostly savanna for 'reforestation' by 2030 (Figure  
41 1)(<https://afr100.org>). Funding has been secured from Germany, the World Bank and other  
42 donors with more than one billion dollars pledged over the next 10 years. Twenty eight  
43 African countries have signed up to AFR100 with each country pledging to afforest an  
44 explicit target area. For example, Mozambique has committed to 'restoration' of one million  
45 hectares, South Africa to 3.6 Mha, Kenya to 5.1 Mha, and Cameroon to 12 Mha. Cameroon's  
46 pledge requires converting a quarter of the country to plantations, Nigeria's 32% and  
47 Burundi's 72% [2].

48

49 Committing such vast areas to plantations for the next century should raise many questions.  
50 An obvious one for industrial countries that are funding these projects is whether  
51 afforestation (planting new trees, rather than restoring areas known, historically, to have  
52 been closed forests) will work to cool the climate. There is growing scientific scepticism.  
53 Smith et al. [3] discussed all 'negative emissions technologies' (NET), including afforestation,  
54 enhanced mineral weathering, and chemical capture, and concluded that none will be  
55 effective in reducing carbon at the scale needed. The NET are merely a distraction, they  
56 argue, from the serious business of reducing emissions by reducing fossil fuel use. Baldocchi  
57 and Penuelas [4] evaluated the potential of the Earth's ecosystems to sequester carbon and  
58 concluded that planting trees will not significantly reduce atmospheric CO<sub>2</sub>. Lewis et al [2]  
59 argued that restoration of forests is effective, but that plantation forestry is not. They  
60 calculated that if 350 Mha were restored natural forests, 42 Gt of C would be sequestered

61 by 2100 compared to 1 Gt C for the same area afforested with pines and eucalypts. Their  
62 analysis implies that converting African savannas to plantations is pointless as a mitigation  
63 measure. At the optimistic extreme, Bastin et al [5] estimated 205 Gt C could be stored by  
64 planting up the world's potential forest land, including 'sparse vegetation and grasslands'.  
65 Their estimates have been challenged, not least because they assumed zero soil C stocks in  
66 targeted sites [J. Veldman, Pers. Comm. 2019]. An underappreciated problem is that  
67 biophysical consequences of afforestation can negate climate effects of reducing CO<sub>2</sub> [6].  
68 Forests absorb more incoming radiation than grasslands so that plantations may cause a net  
69 warming, rather than the intended cooling. The net radiative effects of planting trees,  
70 warming or cooling, vary with latitude and local conditions. Evaluating their magnitude  
71 requires a different set of scientific skills from carbon accounting so that biophysical effects  
72 are seldom considered in trees-for-carbon projects [6].

73

74 The limited benefits of afforestation for reducing atmospheric CO<sub>2</sub> have not been widely  
75 appreciated. Exploring aspects of the Bonn challenge helps give perspective. Carbon dioxide  
76 in the atmosphere is currently increasing at about 4.7 Gt C per year (1 Gt= 1000 000 000  
77 tons) [7]. To nullify this growth rate in atmospheric CO<sub>2</sub> ( $G_{ATM}$ ) by a NET programme, such  
78 as planting trees, would cost \$47 billion at \$10 per Mg C sequestered (\$172 billion at  
79 \$10/Mg CO<sub>2</sub>). The billion dollars promised for the Bonn programme, over a 10-year  
80 programme, is <0.5% of the minimum needed to balance  $G_{ATM}$ . Other NET technologies are  
81 supposedly workable at \$100 per Mg C sequestered making them even less affordable [3].  
82 Either the funders are short-changing African participants, or they do not see afforestation  
83 as a serious contributor to CO<sub>2</sub> reduction.

84 Tree planting is land hungry. To appreciate how hungry, consider the area needed to  
85 sequester current  $G_{\text{ATM}}$  of  $4.7 \text{ GtCy}^{-1}$ . This will depend on total C sequestered in plantations  
86 which varies with climate, tree species, soil type, forest management, and rotation time.  
87 Carbon sequestered increases after planting and then diminishes as trees mature. Trees  
88 would need harvesting, their carbon preserved, and plantations re-established to maintain  
89 their sequestration potential [8]. Optimistic estimates are of 10-year cycles for tropical  
90 plantations [11]. Mean carbon sequestered ranges from 1 to  $3.4 \text{ Mg C ha}^{-1}\text{y}^{-1}$  in the tropics  
91 [3,9] (the Bonn challenge used  $1.32 \text{ MgCha}^{-1}\text{y}^{-1}$ ). Using these values, you would need to  
92 plant up 14 to 47 million  $\text{km}^2$  of plantations to sequester current  $G_{\text{ATM}}$ . For optimistic  
93 estimates, you would need to afforest an area 53% larger than the USA or 85% of Russia. For  
94 less productive plantations you would need upwards of a third of the world's land area. If  
95 Africa reached the 100 million ha target,  $G_{\text{ATM}}$  would be mitigated by a mere 2.7 % per year.  
96 If this seems very small reward for afforesting a continent, consider that the coal that drove  
97 200 years of the industrial revolution took 400 million years to accumulate. How can we  
98 possibly expect to grow enough trees to stuff all the carbon back again in just a few  
99 decades?

100

101 Ironically, several researchers have argued that the grassy biomes targeted for afforestation  
102 are better than forests at conserving carbon [10]. This is partly because forests, especially  
103 plantations of eucalypts and pines, are vulnerable to high severity fires and will become  
104 more so as the world warms. Most of the carbon stored in grasslands is below-ground,  
105 where it persists through fire [10]. In Africa, which accounts for 70% of the world's annually  
106 burnt area, suppressing grass-fuelled fires is manageable but suppressing high intensity

107 plantation fires is not. Furthermore, grasslands themselves can have high rates of carbon  
108 sequestration below-ground. It has even been hypothesised that the Pliocene spread of  
109 grasslands locked up so much carbon in soils that it triggered the Ice Ages [11].

110

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

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

127

128 What of the alternatives to NET of drastically reducing emissions by reducing dependence  
129 on fossil fuels? In one year (2016-2017), the UK reduced overall emissions by 12 million tons  
130 of CO<sub>2</sub> equivalent (=3.7 M tons C), through reduced use of coal for electricity generation  
131 (<https://www.gov.uk/government/statistics>). That equates to 3.3 M ha of open ecosystems  
132 turned into plantations (at 1 Mg C ha<sup>-1</sup>y). Given the land use change envisaged for tree  
133 planting, over enormous areas, sustained for decades, with such poor gains in carbon  
134 reduction, we find it difficult to understand why afforestation is so widely supported. As  
135 demonstrated by the UK, emissions reductions by reducing fossil fuel dependency are  
136 feasible without reducing economic growth and are far more effective in reducing rates of  
137 CO<sub>2</sub> increase than afforestation. Indeed, trees-for-carbon projects can be seen as a  
138 distraction from the urgent business of reducing fossil fuel emissions. Planting 100 million  
139 hectares of trees, far away in Africa, might reduce the urgency of emissions reductions in  
140 industrial countries that are the major sources of greenhouse gases [3].

141

142 We suggest that serious and urgent consideration needs to be given to the wisdom of  
143 continuing continental scale afforestation in Africa and elsewhere. We strongly endorse tree  
144 planting to restore closed forests destroyed in historical times (reforestation), the retention  
145 of intact forests that remain, and the planting of trees in urban areas for shade and  
146 enjoyment. But the afforestation envisaged by global tree-planting programmes is based on  
147 wrong assumptions. Far from being deforested and degraded, Africa's savannas and  
148 grasslands existed, alongside forests, for millions of years before humans began felling  
149 forests. A better way of supporting Africa's transition to a future warmer world might be to



150 promote energy efficient cities in this rapidly urbanizing continent so that Africa follows a  
151 less carbon-intensive trajectory of development than other emerging economies.

152

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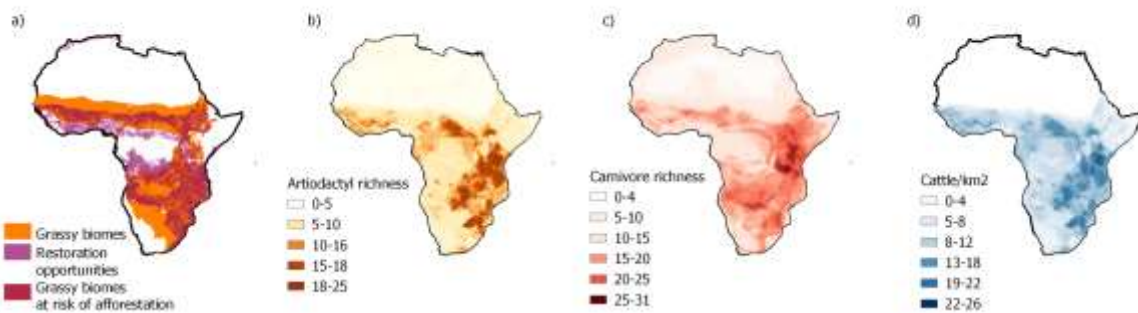
187 **Figure Legend**

188 Figure 1. Large scale tree-planting in Africa will severely impact African grassy biomes.

189 a) Areas identified as suitable for reforestation [14]

190 (<http://www.wri.org/applications/maps/flr-atlas/#>) have significant overlap with the  
191 distribution of African grassy ecosystems (adapted from [15]) which are important centres  
192 of b) ungulate and c) carnivore diversity [16] (number species/10kmx10km grid cell) that also  
193 provide valuable ecosystem services to much of Africa's population as indicated by the d)  
194 distribution of cattle across Africa [17]. Figures created by Nicola Stevens.

195



196