

1 **Title:**

2 Pitfalls of tree planting show why we need people-centered natural climate solutions

3 **Authors:**

4 Forrest Fleischman, University of Minnesota, Dept. of Forest Resources. ffleisch@umn.edu

5 Shishir Basant, Department of Ecology and Conservation Biology, Texas A&M University.
6 shishir.basant@tamu.edu.

7 Ashwini Chhatre, Bharti Institute of Public Policy, Indian School of Business, Hyderabad, India
8 ashwini_chhatre@isb.edu

9 Eric A. Coleman, Florida State University, Department of Political Science, ecoleman@fsu.edu

10 Harry W. Fischer, Department of Urban and Rural Development, Swedish University of
11 Agricultural Sciences, Uppsala. harry.fischer@slu.se.

12 Divya Gupta, Bharti School of Public Policy, Indian School of Business, Hyderabad, India.
13 divya_gupta@isb.edu.

14 Burak Güneralp, Department of Geography, Texas A&M University, College Station, USA.
15 bguneralp@tamu.edu

16 Prakash Kashwan, Department of Political Science, University of Connecticut, Storrs,
17 prakash.kashwan@uconn.edu.

18 Dil Khatri, Southasia Institute of Advanced Studies, Kathmandu, Nepal. khatridb@gmail.com,
19 Robert Muscarella, Department of Ecology & Genetics, Uppsala University.
20 robert.muscarella@ebc.uu.se

21 Jennifer S. Powers, University of Minnesota, Depts. of Ecology, Evolution and Behavior and
22 Plant and Microbial Biology, Saint Paul, MN USA. powers@umn.edu

23 Vijay Ramprasad, Center for Ecology, Development and Research, Dehradun, India.
24 vijay.ramprasad@cedarhimalaya.org.

25 Pushpendra Rana, Indian Forest Service, Talland, Shimla, Himachal Pradesh, India,
26 pranaifs27@gmail.com

27 Claudia Rodriguez Solorzano, University of Minnesota, Dept. of Forest Resources.
28 rodr0423@umn.edu

29 Joseph W. Veldman, Department of Ecology and Conservation Biology, Texas A&M University,
30 College Station, TX, USA; Instituto Boliviano de Investigación Forestal, Santa Cruz, Bolivia.
31 veldman@tamu.edu

32

33 **Authorship statement**

34 FF & JV conceived of and drafted the manuscript. All authors provided substantive and
35 significant feedback during the writing process.

36 **Main Text:**

37 Scientists, corporations, mystics, and movie stars have convinced policymakers around the world
38 that a massive campaign to plant trees should be an essential element of global climate policy.

39 Public dialogue has emphasized potential benefits of tree planting while downplaying pitfalls and
40 limitations that are well established by social and ecological research. We argue that if natural
41 climate solutions are to succeed while economies decarbonize (Griscom et al. 2017),
42 policymakers must recognize and avoid the expense, risk, and damage that poorly designed and
43 hastily implemented tree plantings impose upon ecosystems and people.

44 We propose that people-centered climate policies should be developed that support the social,
45 economic, and political conditions that are compatible with the conservation of Earth's diversity
46 of terrestrial ecosystems. Such a shift in focus, away from tree planting and toward people and
47 ecosystems, must be rooted in the understanding that natural climate solutions can only be
48 effective if they respond to the needs of the rural and indigenous people who manage ecosystems
49 for their livelihoods.

50 To motivate this shift in focus, we highlight ten pitfalls and misperceptions that arise when
51 large-scale tree planting campaigns fail to acknowledge the social and ecological complexities of
52 the landscapes they aim to transform. We then describe more ecologically effective and socially
53 just strategies to improve climate mitigation efforts.

54 **1. Ecosystems, not tree planting campaigns, capture and store carbon**

55 In terrestrial ecosystems, plants capture carbon from the atmosphere, which is stored in biomass
56 and soils. Through processes including microbial decomposition, herbivory, and fire, carbon is
57 released back to the atmosphere. Because most ecosystems have the potential to capture more
58 carbon than they lose, a host of natural climate solutions have been proposed to enhance carbon

59 sequestration (Griscom et al. 2017). Despite the importance of belowground biomass and soil
60 organic matter to carbon storage, the most visible and easily measured carbon resides
61 aboveground in trees. The high visibility and cultural resonance of trees has led advocates to
62 elevate tree planting as paramount among natural climate solutions (Veldman et al. 2019).
63 Unfortunately, large-scale tree planting programs have high failure rates, resulting in wasted
64 resources and little carbon sequestration (Duguma et al. 2020). Worse yet, planting in
65 ecosystems with naturally sparse tree cover, like savannas and peatlands, is destructive for
66 biodiversity and counterproductive for addressing climate change (Temperton et al. 2019). By
67 focusing on forests and trees, scientists and policymakers miss the opportunity to conserve and
68 restore the wide diversity of Earth's ecosystems that contribute to climate change mitigation and
69 adaptation.

70 **2. Preventing ecosystem destruction is the most cost-effective natural climate solution**

71 Because ecosystems are crucial to carbon sequestration, avoided deforestation, improved forest
72 management, and protection of grasslands, peatlands, and shrublands from land-use conversion
73 should be the priority (Temperton et al. 2019). Tree planting campaigns divert funding from
74 conservation toward riskier, more costly, and less effective interventions. Planting trees without
75 addressing the social drivers that caused deforestation in the first place will not mitigate climate
76 change because those same drivers will destroy planted forests or shift ecosystem destruction
77 elsewhere. Globally, the most prominent land-based source of carbon emissions is the expansion
78 of commodity agriculture (IPBES et al. 2018). To protect ecosystems from commodity
79 agriculture, it is essential to secure the rights of rural and indigenous people to make land
80 management decisions. Land rights must be coupled with economic policies that support
81 ecosystem-friendly land-use practices, provide just compensation for the carbon that ecosystems

82 store, and offer incentives for governments, corporations, and land managers to conserve
83 ecosystems (IPBES et al. 2018).

84 **3. Forests can regrow on deforested land without tree planting**

85 In most places where reforestation is desirable, forests can regenerate naturally from seeds or
86 resprouts, even in landscapes that appear to be highly degraded. Because natural regeneration
87 requires little human intervention, it is usually much less expensive than tree planting. Whereas
88 natural regeneration often leads to faster forest recovery, greater carbon storage, and more co-
89 benefits for biodiversity and people, misapplied tree planting can hinder forest regrowth
90 (Duguma et al. 2020). Where natural regeneration is insufficient, assisted natural regeneration
91 may involve planting a small number of trees targeted to specific goals—such as establishing
92 seed sources or species that are valued by local people—rather than maximizing the number of
93 trees planted.

94 **4. Tree plantations sequester less carbon, less securely, than naturally regenerated forests**

95 Global forest restoration initiatives promote fast-growing plantations of commercial pulp and
96 timber species as a natural climate solution despite clear evidence that these plantations lead to
97 little long-term carbon storage (Lewis et al. 2019; figure 1). Worse yet, widely planted species in
98 the genera *Pinus* and *Eucalyptus* are extremely flammable and can exacerbate wildfire risk and
99 ecosystem carbon loss (Veldman et al. 2019). To be clear, fast growing trees can serve an
100 economic purpose, but should not be confused for forest restoration or a natural climate solution.

101 [suggested placement of figure 1]

102 **5. Tree plantations in grasslands, shrublands, and peatlands destroy biodiversity**

103 Many ecosystems that do not naturally support dense tree cover are targeted for large-scale tree
104 planting (Veldman et al. 2019; figure 2). Establishing tree plantations where forests did not

105 historically occur destroys the habitats of plants and animals adapted to open ecosystems and
106 threatens the livelihoods of people dependent on those ecosystems to produce wild game and
107 domestic livestock. The iconic savannas of Africa are a prime example of the ecosystems that are
108 threatened by large-scale afforestation campaigns (Bond et al. 2019). In addition to the
109 biodiversity cost, because fire and tree-killing megafauna, like elephants, are natural forces in
110 these ecosystems, afforestation provides less long-term carbon storage than maintaining
111 savannas in their open state, where most carbon is protected from fire and herbivory
112 underground.

113 **6. Trees can reduce water availability**

114 Advocates of tree planting often assume that trees improve ground and surface water recharge,
115 but the reality is more complicated: in the wrong places planted forests deplete ground water and
116 can cause streams to dry up (Jackson et al. 2005). Although trees can facilitate water infiltration
117 into soils, they also increase evaporation of intercepted rainfall and transpiration from leaf
118 surfaces. The impact of trees on the balance between recharge and evapotranspiration is
119 complicated and depends on many factors (Jackson et al. 2005). If a co-benefit of a proposed tree
120 planting scheme is to enhance water resources, a careful site-specific evaluation is imperative to
121 determine if potential gains in recharge will be offset by increased evapotranspiration.

122 **7. Trees can warm the atmosphere**

123 Trees interact with the climate system in ways that can cause warming to exceed the cooling
124 benefit of carbon sequestration (Li et al. 2015). Trees, particularly evergreen conifers, are darker
125 and taller than most other land covers, and thus absorb more visible and ultraviolet sunlight
126 (shortwave radiation) compared to highly reflective bare ground, snow, or grasses. When trees
127 replace highly reflective surfaces, the albedo of the ecosystem decreases and more shortwave

128 radiation is absorbed, which is emitted as heat (longwave radiation). The warming effect of trees
129 is particularly pronounced in cold, snowy regions, like alpine and boreal forests, as well as arid
130 and seasonally dry regions, where cloud cover is sparse. In general, natural forest restoration in
131 high rainfall regions, like the humid tropics, cools the climate, but there are many locations on
132 Earth where tree planting cannot be considered a natural climate solution because of unintended
133 warming (Griscom et al. 2017).

134 **8. Perverse financial incentives lead to rushed planting and high tree mortality.**

135 When ambitious targets for the number of hectares or number of saplings planted are rewarded
136 with large monetary commitments, governments and other organizations tend to focus on the act
137 of planting rather than long-term maintenance to ensure tree survival and growth (Duguma et al.
138 2020). As a result, many tree planting initiatives have very high tree mortality rates. In the rush
139 to achieve targets, forest restoration fails because trees are planted incorrectly, in the wrong
140 places, and without the support of local people. Successful reforestation programs must plan for
141 long-term maintenance by people who live and work nearby. Glamorizing and rewarding the act
142 of tree planting undermines local institutions and social networks that are required for long-term
143 carbon sequestration.

144 [suggested placement of figure 2]

145 **9. Tree planting threatens rural livelihoods**

146 Tree planting programs often target ecosystems or farmland that rural people depend on for
147 subsistence livelihoods (Malkamäki et al. 2018). Frequently these people have insecure land
148 tenure, and the land may be viewed by governments or other actors as “available” for tree
149 planting. Replacing croplands with trees can result in unemployment for agricultural workers and
150 elevate food prices (Lewis et al. 2019). Tree planting can bring positive livelihood benefits, but

151 only if land rights enable people to select the trees they need, maintain their local food
152 production systems, and secure the future benefits of ecosystem conservation (Duguma et al.
153 2020, Malkamäki et al. 2018).

154 **10. Tree planting targets the global south to capture emissions from the global north**

155 While the majority of carbon emissions come from the industrialized countries of the global
156 north, large-scale planting schemes focus on the opportunity to plant trees in the global south
157 (Bond et al. 2019, Lewis et al. 2019). Proponents of large-scale tree planting, such as Plant-For-
158 the-Planet and the Trillion Tree Campaign, equate tree planting with climate justice and
159 prosperity for the global south. Unfortunately, these proponents ignore the opportunity costs of
160 using land for trees instead of for other economically beneficial activities. Further they feed the
161 public perception that tree planting at its best is good and at its worse is benign. To the contrary,
162 because tree planting poses significant risks to ecosystems and people, critical questions of social
163 justice must be answered by proponents of tree planting for climate change mitigation. Is it just
164 for the states of the global north to ask the world's poorest people and most threatened
165 ecosystems to bear the costs of fossil fuel emissions?

166 **Effective climate solutions require social systems that support people to conserve
167 ecosystems.**

168 Climate change is a complex problem for which tree planting is a simplistic solution that often
169 results in a mismatch between the technical capacity of foresters and the ecosystems and social
170 contexts they target. For natural climate solutions to be effective, they must focus on the people
171 whose decisions determine the long-term viability of ecosystem conservation and carbon storage.
172 Because long-term investments require local support, natural climate solutions are more likely to
173 be successful if they provide benefits for rural and indigenous people who rely on ecosystems for

174 their livelihoods. For small-scale farmers, pastoralists, and forest-dwelling people to prosper
175 while conserving and restoring ecosystems, they must be empowered with decision-making
176 rights over land and must benefit economically from sustainable land management (IPBES et al.
177 2018).

178 For example, expansion of commodity agriculture, which is often driven by distant investors, can
179 be checked by securing land rights and enhancing the political power of indigenous and rural
180 people. This involves redirecting investment and using modern technology to monitor and
181 enforce certifications and bans on commodity agricultural expansion (IPBES et al. 2018). Land
182 managers will invest in restoring carbon storage when their land rights are secure and they are
183 confident that investments in ecosystems will benefit their livelihoods (Duguma et al. 2020).

184 Increasing the carbon stored in ecosystems is an important element of any climate mitigation
185 strategy. Unfortunately, the current focus on large-scale tree planting initiatives is at best a
186 distraction from this goal. We suggest instead that efforts to implement natural climate solutions
187 should focus on policies that support the restoration efforts of small farmers, hunters, and
188 pastoralists, and hinder the displacement of ecosystems with export-oriented commodity
189 agriculture. Once developed, people-centered climate solutions will be the most effective natural
190 climate solutions because they will align conservation goals and the interests of the rural people
191 responsible for managing ecosystems. Natural climate solutions that count saplings rather than
192 address both the ecological and social drivers of ecosystem destruction are unlikely to succeed.

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225 **Author Biographical**

226 Forrest Fleischman (ffleisch@umn.edu) is an assistant professor in the Department of Forest
227 Resources at the University of Minnesota, in St. Paul, MN. Shishir Basant is a doctoral candidate
228 in the Department of Ecology and Conservation Biology at Texas A&M University, in College
229 Station, TX. Ashwini Chhatre is an associate professor of public policy, and academic director of
230 the Bharti Institute of Public Policy, at the Indian School of Business, in Hyderabad, India. Eric
231 A. Coleman is an associate professor of Political Science at Florida State University, in
232 Tallahassee, FL. Harry W. Fischer is assistant professor (Biträdande Universitetslektor) in the
233 Department of Urban and Rural Development at the Swedish University of Agricultural
234 Sciences, in Uppsala. Divya Gupta is a research associate at the Bharti School of Public Policy,
235 and Indian School of Business, in Hyderabad, India. Burak Güneralp is an assistant professor in
236 the Department of Geography at Texas A&M University, in College Station, TX. Prakash
237 Kashwan is an associate professor in the Department of Political Science at the University of
238 Connecticut, in Storrs, CT. Dil Khatri is the executive director of the Southasia Institute of
239 Advanced Studies, in Kathmandu, Nepal. Robert Muscarella is senior lecturer and associate
240 professor in the Department of Ecology & Genetics, at Uppsala University. Jennifer S. Powers is
241 an associate professor in the Department of Ecology, Evolution and Behavior and the

242 Department of Plant and Microbial Biology, at the University of Minnesota, in St. Paul, MN.
243 Vijay Ramprasad is a research associate at the Center for Ecology, Development and Research,
244 in Dehradun, India. Pushpendra Rana is Chief Conservator of Forests at the Himachal Pradesh
245 Forest Department, in Shimla, India. Claudia Rodriguez Solorzano is an adjunct assistant
246 professor in the Department of Forest Resources, at the University of Minnesota, in St. Paul,
247 MN. Joseph W. Veldman is an assistant professor in the Department of Ecology and
248 Conservation Biology at Texas A&M University, in College Station, TX, and a research
249 associate of the Instituto Boliviano de Investigación Forestal, in Santa Cruz, Bolivia.



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251 *Figure 1. Government officials inspect a two-year-old plantation of Eucalyptus clones on*
252 *government-controlled land in Telangana, India. Low biodiversity, soil disturbance,*
253 *exacerbated fire risk, altered hydrology, and restricted access to local people mean that this*
254 *afforested land, although a potentially valuable source of wood fiber for paper, disrupts rural*
255 *livelihoods and should not be considered a natural climate solution.*

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258 *Figure 2. As part of an effort to “improve” forest cover in Telangana, India, foresters bulldoze*
259 *savanna-woodlands to establish a plantation of Eucalyptus clones. Similar plantation*
260 *activities around the world frequently replace intact ecosystems with commercial tree species*
261 *that offer few carbon, biodiversity, or livelihood benefits.*