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Print hed: Restore natural forests to sequester carbon

Online hed: Restoring natural forests is the best way to sequester carbon

Plans to triple the area of plantations under the guise of 'forest restoration' will not meet 1.5 degree climate goals, argue Simon L. Lewis, Charlotte E. Wheeler and colleagues – new natural forests can.

Keeping global warming below 1.5°C to avoid dangerous climate change[1] requires extreme cuts to emissions *and* removing vast amounts of carbon dioxide out of the atmosphere. The IPCC suggest that around 730 billion tonnes of CO_2 (200 Pg C) must be extracted by the end of this century[2] --- equivalent to all the CO_2 emitted by the USA, UK, Germany and China since the industrial revolution.

No-one knows how to capture that much CO_2. But forests must play a role. Locking up carbon in ecosystems is proven, safe and often affordable[3]. Increasing tree cover also offers many more benefits, from protecting biodiversity to managing water and generating jobs.

The IPCC suggests that increasing the total area of the world's forests, woodlands and woody savannas by 9% by 2030 could sequester one quarter of the necessary atmospheric carbon on land to comply with 1.5°C pathways[2]. In practice this means adding new forest totalling about 350 million hectares (Mha) --- that's an area roughly the size of India[2].

Despite the enormous areas involved policymakers are sowing the seeds. For example, in 2011 the Bonn Challenge, which aims to restore the required area of forest by 2030, was launched by the German government and the International Union for Conservation of Nature[4]. Under this initiative and others, 43 countries, including Brazil, Indian and China, have already committed to restore nearly 300 Mha of degraded land into forest (see Table S1). That's encouraging.

But will this policy intervention work? Here we show that it will not, under current plans. Compiling country-level data shows that almost half of the pledged area is set to become plantations of commercial trees (Table S1). While they can support local economies, plantations are poor at storing carbon in comparison to natural forests. The regular tree harvests and clearing the land to replant it means that the carbon stored on the land is periodically released back to atmosphere. By contrast, naturally regenerating lands sequester carbon for decades as they revert back to their carbon-rich intact state. To succeed in stemming global warming means restoration programs must allow all these degraded lands to return back into natural forests – and protect them.

To maximise the contribution of forests to limiting warming to 1.5°C deforestation needs to stop. In addition, while recognising the competing pressures to deliver food, fuel, fodder and fibre, land carbon stocks must also increase. We call on the restoration community, forestry experts, and policymakers, to prioritize the regeneration of natural forests for sequestering carbon, over all other types. This shift of focus will entail tightening the definition of 'forest restoration', reporting project plans and their outcomes transparently, and clearly stating the trade-offs between the different ecosystem services and income streams that alternative land uses provide.

Misdirected efforts

To combat climate change, the most effective place to plant trees is in the tropics and sub-tropics, and this is where the majority of the restoration commitments are found. Trees grow (and thus take up carbon) quickly there and land is relatively cheap and more readily available[5] (Figure 1). Indeed, by merely protecting tropical land from fire and other direct human disturbances, trees return and new forests flourish. Carbon stocks can rapidly accumulate under these conditions of natural forest regeneration, reaching levels seen in mature forest in just 70 years[6]. Establishing new tropical forests also has little effect on the albedo (reflectivity) of the land surface, unlike at high latitudes where trees obscure snow that reflects solar energy and helps to cool the planet. In income-poor regions well-managed forests can also help to alleviate poverty as well as conserve biodiversity, supporting the United Nations Sustainable Development Goals.

So far, just over half (24) of the countries in the Bonn Challenge and other schemes have published detailed restoration plans, which cover two thirds of the pledged area (Table S1). Nations are following three main approaches: leaving degraded and abandoned agricultural land to regenerate to natural forest, largely allowing plant succession to proceed on its own, although some areas are planted with native species to accelerate recovery rates; converting marginal agricultural lands into plantations of valuable trees like *Eucalyptus* (for paper) or *Hevea braziliensis* (for rubber); and fostering agroforestry, the growing of agricultural crops and useful trees together.

Natural regeneration is the cheapest and technically the easiest option. One third (34%) of the land allocated is to be managed in this way. With legislation and incentives, such as those pioneered in Costa Rica, managing land for trees to re-establish can allow forest cover to rapidly increase. Plantations are the most popular restoration plan, covering 45% of commitments. Thus vast areas are to be planted as monocultures of trees as profitable enterprises. Brazil, for example, has pledged 19 Mha of wood, fibre, and other plantations under a variety of recent announcements.

Agroforestry accounts for the rest of the plans (21%). This is the practice of growing useful trees and crops together that is widely used by subsistence agriculturalists, but is rarely seen at the large-scale. The focal crops benefit from trees, such as coffee grown under the shade of larger trees, or a maize crop interspersed with lines of leguminous trees that provide nitrogen inputs. The trees themselves are also useful, supplying fuel, timber, fruit, or nuts.

Hence, looking at the detail of global forest restoration plans reveals that two-thirds of the area is slated to grow crops of some form. The preponderance of plantations raises serious concerns.

First, plantations are poorer than natural forests at storing carbon in the long run. Initially, the land is cleared, releasing carbon to the atmosphere. Then, fast growing trees such as *Eucalyptus* and *Acacia* take up carbon rapidly (at up to 5 Mg C ha^{-1} yr^{-1}). But after they are harvested and the land cleared again for re-planting, typically every 10-20 years, the carbon is released again to the atmosphere as the plantation waste and wood products (mostly paper and wood-chip boards) decompose. Thus, on average, plantations hold little more carbon than the degraded land that was cleared to plant them. By contrast, restoration natural forest means carbon accumulates for decades[6]. It might be possible to increase the amount of carbon stored on plantation lands, by harvesting less often, using different species, or converting timber into very long-lived products[3], but this will likely reduce profitability. Little research has been done on increasing carbon storage in plantations; more is needed.

Second, dramatically increasing the area of plantations may undercut their profitability – and thus the reason nations are prioritising them in the first place. Large countries like Brazil, China, Indonesia, Nigeria and the Democratic Republic of Congo are where most of the new plantations are planned (Table S1). If all countries followed suit with the average 45% of restoration areas given to plantations, restoration plans add 157 Mha of new monocultures, meaning the world's tropical and sub-tropical plantation estate would triple to 327 Mha --- a major shift in global land use[7]. Prices of woodchip and paper products would likely fall**.** But without a recognition that such a change is envisaged there's been no research on the potential economic impacts of this major shift in forestry policy[7].

Third, policy makers are interpreting forest restoration in ways that are contrary to what most people think of as 'restoring a forest'. Few think planting a monoculture of *Eucalyptus* trees for regular harvest by the paper industry is forest restoration. By exploiting broad definitions and confused terminology policy-makers and their advisors are misleading the public. Given that plantations typically meet the UN Food and Agriculture Organisation definition of a forest (greater than 0.5 ha in area, trees at least 5m in height and more than 10% canopy cover[7]), then planting monocultures is technically 'forest restoration'. Yet, the expected climate change mitigation and biodiversity protection is missing. Plantations are an important land use, but they should not be classified as 'forest restoration'. The definition of forest restoration urgently needs an overhaul to exclude monoculture plantations.

Finally, reports on restoration to new natural forest often mix up the process (regeneration to natural forest) with the resulting land-type (natural forest)[8]. Land may be labelled as natural forest when it is far from mature as regeneration processes are still occurring. Meanwhile climate benefit calculations usually assume that this land becomes forest and remains as this new land-type forever. But there is no guarantee that these forests will be protected far into the future, particularly as demand for land grows. Schemes should protect these new forests to ensure that the advertised climate benefits can be realized. Overall, increased clarity on the short- and long-term benefits that different restoration schemes provide is essential.

A better strategy

Natural forest restoration is clearly the most effective approach for storing carbon. But how much better is it than the alternatives? We use the 43 countries' pledges to calculate carbon uptake under a series of restoration scenarios to illustrate how clashing priorities are sabotaging carbon storage potential (see TEXT BOX/GRAPHIC and Supp Info).

In short, we find that if the entire 350 Mha is given over to natural forests they would sequester 42 Pg C by 2100 (Figure 1). This is some 38 times as much carbon as the 1.1 Pg C sequestered by giving the same area exclusively to plantations, and 6 times more than a switch to only agroforestry (6.8 Pg C). Natural forests under current schemes can get us most of the way to the 57 Pg C median estimate for forest uptake used in IPCC 1.5°C compliant pathways (our figure is lower due to more optimistic assessments of tree growth in some model runs[2]). Any other approach will fall far short of this.

Maintaining the current reported mix of natural forest restoration, plantations and agroforestry sequesters a third of the carbon (16 Pg C) of the natural forest only scenario, largely because plantations are ineffective at storing carbon (Figure 1). And even this may be optimistic, as it assumes all new forests are protected. And climate policy itself may threaten them.

Central to the 1.5°C pathways is another technology to remove carbon from the atmosphere: Bioenergy with Carbon Capture and Storage, known as BECCS, which is expected to remove 130 Pg C by 2100. Assuming the technology is rolled out, by mid-century it requires a further 300-800 Mha of land to grow crops for biofuel. *Eucalyptus*, maize (*Zea mays*) and switchgrass (*Panicum virgatum*) would be burnt in power stations and the carbon emissions captured and stored underground[2]. This huge new demand for land could displace restored forests. Converting them to bioenergy crops after 2050 reduces sequestration to a paltry 3 Pg C by 2100, as high-storage forest that is still increasing in carbon stocks is replaced by annual crops or plantations (and would delay by decades the point in time when BECCS becomes carbon negative[9]).

There are, of course, uncertainties at every stage of our calculations, from where exactly the restoration will take place, to the species planted and their carbon sequestration rates. We rely on median literature estimates and the latest carbon stock maps, with our results being relatively conservative compared to median IPCC figures. However, while we include future CO_2 fertilization and climate impacts on future forests these are inherently uncertain and could be better assessed using Earth System Model runs.

Critics will counter that it is unrealistic to expect all areas slated for restoration to become natural forests that are protected in perpetuity. Certainly, tree-based agriculture and plantations are essential parts of many landscapes. What is required is an extension of the restoration agenda, not a retreat. Reaching 350 Mha of new natural forest is possible as part of a much larger total area that would include plantations and agroforestry.

Clearly, pressures on land will influence the areas available for re-establishing forests. Landscapes need to provide food, fuel, fodder and fibre as well as a multitude of ecosystem services that human societies depend upon. Research effort is needed to establish optimum responses to these pressures[10]. However, these pressures are not only in one direction: there is potential for rising agricultural productivity to spare land, as well as shifts in consumer habits, such as towards healthier low meat and dairy diets. And synergies exist: using habitat restoration to connect existing forests would allow species to move as the climate changes, lessening future waves of extinction.

What next

Even in the absence of new land, today's forest restoration schemes should increase their carbon sequestration potential in four ways. First and foremost countries should increase the proportion of land that is being regenerated to natural forest: each additional 8.6 Mha, an area the size of the island of Ireland, sequesters another 1 Pg C by 2100.

Second, prioritize natural regeneration in the humid tropics, such as Amazonia, Borneo or the Congo Basin, which all support very high biomass forest compared to drier regions of the tropics. International payments to recreate and maintain new forests from either carbon sequestration, climate adaptation, or conservation funds could mobilize further restoration action in these regions.

Third, restoration efforts must build on existing carbon stocks. Target degraded forests and partly wooded areas for natural regeneration; focus the plantations and agroforestry systems on treeless regions, and where possible select agroforestry over plantations as they store more carbon.

Fourth, once natural forest is restored, protect it. This could be via the expansion of protected areas; giving title to indigenous peoples who tend to protect forested land; changing the legal definition of the newly forested land so it cannot be converted to agriculture, or encouraging commodities companies with zero-deforestation commitments to extend these to not cutting restored natural forests.

The ambitious global restoration agenda is good news. And this month's declaration that the 2020s will be the UN Decade on Ecosystem Restoration affirms its importance. But, these efforts will only remove sufficient carbon from the atmosphere to contribute to avoiding dangerous climate change if forest restoration really means forest restoration and schemes permanently re-establish largely natural, largely intact forest.

Simon. L. Lewis *is professor of global change science in the Department of Geography, University College London and the School of Geography, University of Leeds.* ***Charlotte. E. Wheeler****, is a forest researcher at the School of GeoSciences University of Edinburgh.* ***Edward T.A. Mitchard*** *is Senior Lecturer in Forest Change Mappingat the School of GeoSciences, University of Edinburgh.* ***Alexander Koch*** *is a recently completed a PhD in the Department of Geography, University College London on forests and the global carbon cycle. Lewis and Wheeler contributed equally to this work. Email: c.wheeler@ed.ac.uk.*

TEXT BOX <this could go with a graphic showing the relevant data/nos]

CARBON CHALLENGE

Best way to restore forests

We looked at 4 ways the Bonn Challenge could be met (see Supp Info). First, today's commitments extend to 2100. Second, these extend to 2050, after which natural forest is converted to plantations for biofuels. Third, the whole area (350 Mha) regenerates to natural forest. And fourth, everything becomes plantations.

For 43 countries we took the area identified as having restoration potential under the Bonn Challenge[5] (Figure 1). We estimated the pre-existing carbon on that land from published maps. We then used published estimates of the carbon sequestration in plantations, restored natural forests and agroforestry systems based on species appropriate to each country, then subtracted the initial carbon stocks, to estimate the change between 2015 and 2100 for each hectare, and summed these for each country (Table S1).

We find, on average, that natural forests are better than agroforestry and plantations at storing carbon, sequestering 0.120, 0.019 and 0.003 Pg C per Mha by 2100, respectively.

Figure 1. Areas of potential restoration[5] (**top**); Eighteen year-old naturally regenerating forest in Kibale, Uganda (**bottom left**, photo: S. Lewis); Live biomass carbon stock increase (above- and below-ground) over the Bonn Challenge Area of 350 million hectares following four restoration pathways: Natural Forest Only (use natural regeneration only to restore forests over entire area); Mixed Restoration, With Protection (using natural regeneration, plantations and agroforestry areas using nationally published plans, plus long-term protection for naturally regenerated forest); Mixed Restoration, No Protection (nationally published plans, but naturally regenerated forest is converted to bioenergy after 2050); and Plantation Only (regeneration area is converted to plantations), showing median and 95% confidence intervals (**bottom right**).

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