Trees and Negative Carbon

Louise Pryor and Izaak Jephson

Louise Pryor *has had a varied career as an actuary, academic, and software developer. She has practised as an independent consultant in the areas of software risk and sustainability and has worked on financial modelling for social security and pensions reform in a number of emerging economies. She currently focuses on sustainability and co-chairs the Actuaries Carbon Collaboration. Louise is President of the Institute and Faculty of Actuaries, Chair of the London Climate Change Partnership and a non-executive director of the Ecology Building Society.*

Izaak Jephson *is a part-qualified actuary working in pensions and data analytics. He works primarily as a consultant, advising on benefits, funding, governance and sustainability for pension scheme trustees. Izaak also works on the development of interactive dashboards for analysing and reporting carbon emissions. He hopes that by transforming the way we think about and interact with our environment we can create a sustainable and ethical future.*

This discussion paper was issued in November 2021. It was reviewed by Roelof Coertze of the Actuaries' Carbon Collaboration.

Introduction

Trees, like all plants, use photosynthesis to capture carbon dioxide (CO_2) from the air and turn it into plant matter such as wood and leaves. The soil in which they grow also captures CO_2. Forest ecosystems play a major role in both absorbing and emitting carbon. It has been estimated that they absorb around 30% of emissions from fossil fuel use and industry and account for around 12% of global carbon emissions (through the effects of land use change)[1]. Together, forest ecosystems have a total carbon content that is more than the amount of carbon in the entire atmosphere[2]. Trees are thus highly significant factors in global carbon emissions and the achievement of net zero.

[1] Brack, D. Forests and climate change: Background analytic study prepared for the fourteenth session of the United Nations Forum on Forests. https://www.un.org/esa/forests/wp-content/uploads/2019/03/UNFF14-BkgdStudy-SDG13-March2019.pdf

[2] United Nations. Land Use, Land-Use Change and Forestry (LULUCF). http://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf/land-use--land-use-change-and-forestry

In this paper we outline the potential for reforestation and its impact on atmospheric carbon, as well as some of the additional benefits it can provide. We then discuss issues around the timing, permanence and uncertainty of the carbon removal provided by reforestation.

Reforestation

There are currently around three trillion trees in the world, which is estimated to be about half the number there were before the start of human civilisation[3]. Forests cover around four billion hectares, which is nearly a third of the global land area. Between 2015 and 2020 around 10 million hectares of forest were lost each year, mainly driven by the expansion of large-scale agriculture. However, the establishment of new forest, either by natural processes or through human agency, means that the net loss was 4.7 million hectares per year during 2010-2020[4]. Researchers estimate that the earth could support a further 0.9 billion hectares of forest, representing a storage capacity of 25% of the current atmospheric carbon pool[5].

Due to their role as an effective carbon sink, reforestation projects underlie many carbon offsets, the idea being that the carbon captured by newly planted trees (i.e. that would not otherwise exist) can offset carbon emitted elsewhere. Such offsets have been leveraged in mandatory emissions trading schemes and are also popular in voluntary offset markets, in which organisations and individuals elect to purchase offsets in the absence of explicit regulation to aid them in reaching net-zero targets.

Forests also provide numerous other benefits beside CO_2 sequestration. Along with the carbon cycle, trees help regulate the water and energy cycles – indeed, the three cycles are intricately linked. Furthermore, it is estimated that 80% of animal and plant life on land is associated with forest ecosystems[6]. Biodiversity and control of energy and water resources are key areas which should not be overlooked when planning for a sustainable future[7].

Timing

Despite its many benefits, reforestation is not a panacea. Many estimates of the potential benefits of carbon sequestration in trees focus on the total amount of CO_2 removed from the atmosphere during the trees' lifetimes. However, the rate of removal is also significant. In order to meet the goals of the Paris agreement and keep the rise in mean global temperature to well below 2°C above pre-industrial levels, we must reduce emissions rapidly from today.

---

[3] Crowther, T., Glick, H., Covey, K. et al. Mapping tree density at a global scale. Nature 525, 201–205 (2015). https://doi.org/10.1038/nature14967

[4] FAO and UNEP. 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. https://doi.org/10.4060/ca8642en

[5] Bastin, J.-F., Finegold, Y., Garcia, C. The global tree restoration potential. Science 365, **6448**, 76-79 (2019). https://doi.org/10.1126/science.aax0848

[6] See https://www.worldwildlife.org/habitats/forest-habitat

[7] Ellison, D., Morris, C. E., Locatelli, B., et al. Trees, forests and water: Cool insights for a hot world, Global Environmental Change, Volume 43, 2017, Pages 51-61. https://doi.org/10.1016/j.gloenvcha.2017.01.002

Net zero is a vital goal, but the gradient of the path taken to reach it is also critical: continuing to emit CO_2 at current rates until 2049 and then precipitously dropping to net-zero at the last possible moment will not achieve the Paris goal.

Newly planted trees require decades to reach maturity, and over 70% of total carbon accumulation occurs in the second half of a tree's life[8]. While the total amount of carbon sequestered by a reforestation project over, say, 100 years may be significant, if the bulk of the removal occurs in 50 or more years' time it will be too late to slow global heating in the short and medium term.

Furthermore, trees are only one part of forest ecosystems. Both soil and detritus also act as carbon pools, and are slow to accumulate. This reinforces the back-loading of carbon storage in forests[9].

Permanence

Because forests must grow and survive over many decades to achieve substantial carbon sequestration, there will always be an element of uncertainty about the longevity of carbon offsets associated with trees. To be permanent reservoirs of carbon, forests must exist in a state of dynamic equilibrium around an average carbon store. If a reforested area is perhaps subsequently disturbed, the sequestered carbon may be released into the atmosphere leaving potentially no net gain. They must therefore be managed to maintain the overall mix of trees over a long time period.

Threats forests may face include challenges associated with climate change such as droughts, floods or heat waves as well as disruptions such as invasive pests, diseases or timber poaching. Forest fires – often exacerbated by climate change – have a catastrophic effect, releasing large quantities of carbon at once. Close coordination with local land users is also vital to ensure that those who live nearby the forest have a stake in ensuring its continued protection.

Even if the timber acquired from clearing a forest is used for construction of buildings, there will be some inevitable waste. Moreover, as with living trees, the carbon removal from buildings depends on how the timber is decommissioned at the end of the buildings' life.

Location

Not all locations where forests could be planted would result in net carbon removal from the atmosphere – the carbon sequestered in soil and detritus must also be considered. Planting forests in areas which already have a high concentration of soil organic carbon (SOC) has been shown to release this SOC into the atmosphere, reducing or completely cancelling out the effect of the carbon sequestered within the trees themselves[10]. Planting forests in certain areas could even result in a net increase in atmospheric CO_2. Therefore, care must be taken when selecting sites for afforestation to ensure that the projects actually achieve the promised CO_2 removal.

---

[8] Köhl, M., Neupane, P., Lotfiomran, N. 2017. The impact of tree age on biomass growth and carbon accumulation capacity: A retrospective analysis using tree ring data of three tropical tree species grown in natural forests of Suriname. PLoS ONE. 12. **8** https://doi.org/10.1371/journal.pone.0181187

[9] Harmon, M.E. Carbon Sequestration in Forests – Addressing the Scale Question. Journal of Forestry. 2001. https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub2772.pdf

[10] Friggens, N. L., Hester, A. J., Mitchell, R. J., et al. Tree planting in organic soils does not result in net carbon sequestration on decadal timescales . Glob Change Biol. 2020; 26: 5178–5188. https://doi.org/10.1111/gcb.15229

Moreover, even if reforestation would result in net carbon sequestration, there may be undesirable impacts on biodiversity. For example, increased tree cover on wetlands or grasslands and savannah ecosystems might result in significant habitat loss.

Practical challenges

There are also potential practical problems. Many countries and corporations cite forestry as an essential part of their plans to reach net-zero[11]. But would it be possible to implement reforestation on the massive scale that is implied by some of the offsetting commitments that have been made by large organisations? A review of the net-zero pledges of four oil and gas producers concluded that "their plans alone could require an area of land twice the size of the U.K."[12] In addition, it has been estimated that it would require at least 1.6bn hectares, an area equivalent to the total land currently being farmed, to reach net zero by 2050 through tree planting alone. If forestry is over-used as a carbon offsetting mechanism, it has been suggested that food prices could rise by 80%[13].

Conclusions

There is uncertainty around the viability and effectiveness of proposed afforestation and reforestation efforts as a mechanism for achieving net zero by 2050. There is also uncertainty around the estimates of the amount and timing of carbon sequestration, its permanence and practical challenges.

Overall, reforestation is a valuable tool for limiting climate change, but is by no means a panacea. Limiting emissions being released continues to be a key pursuit.

[11] The Economist. 2021. *Up a tree – If the world loves forests, it should put a price on their carbon*. https://www.economist.com/international/the-world-should-prove-its-love-for-forests-by-putting-carbon-prices-on-them/21806086

[12] The Conversation. 2021. *Forests can't handle all the net-zero emissions plans – companies and countries expect nature to offset too much carbon*. https://theconversation.com/forests-cant-handle-all-the-net-zero-emissions-plans-companies-and-countries-expect-nature-to-offset-too-much-carbon-170336

[13] Oxfam. Tightening the net: Net zero climate targets – implications for land and food equity. https://oxfamilibrary.openrepository.com/handle/10546/621205