PLOS CLIMATE

OPINION

Funding research using climate change mitigation: The case of the Carbone boréal research infrastructure

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OPEN ACCESS

Citation: Faubert P, Ribeiro Paula R, Bouchard S, Marty C, Fradette O, Villeneuve C (2023) Funding research using climate change mitigation: The case of the Carbone boréal research infrastructure. PLOS Clim 2(6): e0000232. https://doi.org/10.1371/journal.pclm.0000232

Editor: Jamie Males, PLOS Climate, UNITED KINGDOM

Published: June 22, 2023

Funding: This opinion paper was funded by Carbone boréal, a research infrastructure from the Université du Québec à Chicoutimi. As all authors are members of Carbone boréal, they had a role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

Since 1988, the Intergovernmental Panel on Climate Change (IPCC) has gathered research and produced reports to inform decision makers on climate change. Among crosscutting topics, ecosystem management and nature-based solutions (NBS) have received growing attention as they are readily available and relatively inexpensive. NBS are part of the Agriculture, Forestry and Other Land Uses economical sector [1]. While carbon prices can reach up to USD100 t^{-1} CO_2-eq, greenhouse gas (GHG) land-based mitigation can be achieved for less in agriculture (*e.g.* soil carbon management, agroforestry, soil biochar addition), forestry (*e.g.* afforestation, reforestation, decreased deforestation) and using other ecosystems (*e.g.* peatland and wetland restoration) [1]. NBS have the potential to reduce GHG emissions by 8–14 Gt CO_2-eq yr^{-1} between 2020–2050 [1], which represents 32–82% of the emission gap by 2030 to limit global warming between 1.5–2˚C by 2100 compared with the preindustrial era [2]. In addition to CO_2 removal from the atmosphere, NBS also render valuable ecosystem services such as biodiversity conservation, water and nutrient cycling regulation and soil preservation [3–6]. Several positive impacts on human well-being and sustainable development goals can also be achieved through NBS [1].

One of the widely applied NBS is afforestation. Hence, numerous commitments have been pledged to plant billions of trees [7,8] but general concerns remain on the net efficiency relative to costs. Such afforestation efforts demand long-term research that must be financed accordingly but that does not match with conventional funding usual timeframes. One of the enticing prospects is in using offset markets to fund ecosystem conservation and rehabilitation projects, as recognized in the 2001 Clean Development Mechanism of the United Nations Framework Convention on Climate Change. However, claims of additional capture and permanence are subject to many inaccuracies and risks. While it is relatively simple to estimate the amount of carbon stored in trees, the dynamics of its accumulation and its conservation in ecosystems over time is more uncertain and must be assessed by combining modelling methods and field measurements. This is especially important and time sensitive in slow-growing forests such as the boreal forest where decades are necessary to confirm or invalidate the projections. This poses two main challenges: first, establishing study plots that can be monitored to answer specific questions over several decades; second, ensuring that research is funded for the duration, which is unusual at best for conventional research grant programs.

Operationalizing a carbon market-funded research infrastructure

For a NBS afforestation project to provide the expected climate mitigation benefits, one must ensure additionality (additional amount of carbon absorbed relative to a reference scenario) and permanence (duration of the carbon stock) of the project. This can only be achieved through rigorous planification, monitoring and independent verification on the one hand, and the cooperation of several institutions guaranteeing the protection and the sustainability of the carbon stocks. Once these two aspects are guaranteed, the carbon sequestration function of the land can generate incomes from the voluntary carbon markets. Revenues can be used to fund research bettering our knowledge on carbon dynamics in forest ecosystems and in turn, improving management practices. This type of carbon offset-funded research model has been successfully implemented and carried out by Carbone boréal for over 15 years in Québec, Canada.

Carbone boréal is both a research infrastructure of the Université du Quebec à Chicoutimi (UQAC; Québec, Canada) and a GHG offset program through afforestation, designed to associate research and sustainable actions for climate change mitigation (Fig 1). Carbone boréal was founded in 2008 based on three hypotheses: 1) it is possible to plant trees in boreal areas considered as unproductive for forestry and to grow forests comparable to spruce-feather moss stands, 2) the amount of carbon stored in these new stands will be greater than in the absence of intervention, and 3) this additional carbon absorption can be quantified (according to the ISO 14064–2 standard) and offered to the public as a trustworthy GHG offset solution. Based on its success and shown sustainability, Carbone boréal was recognized in 2018 as a

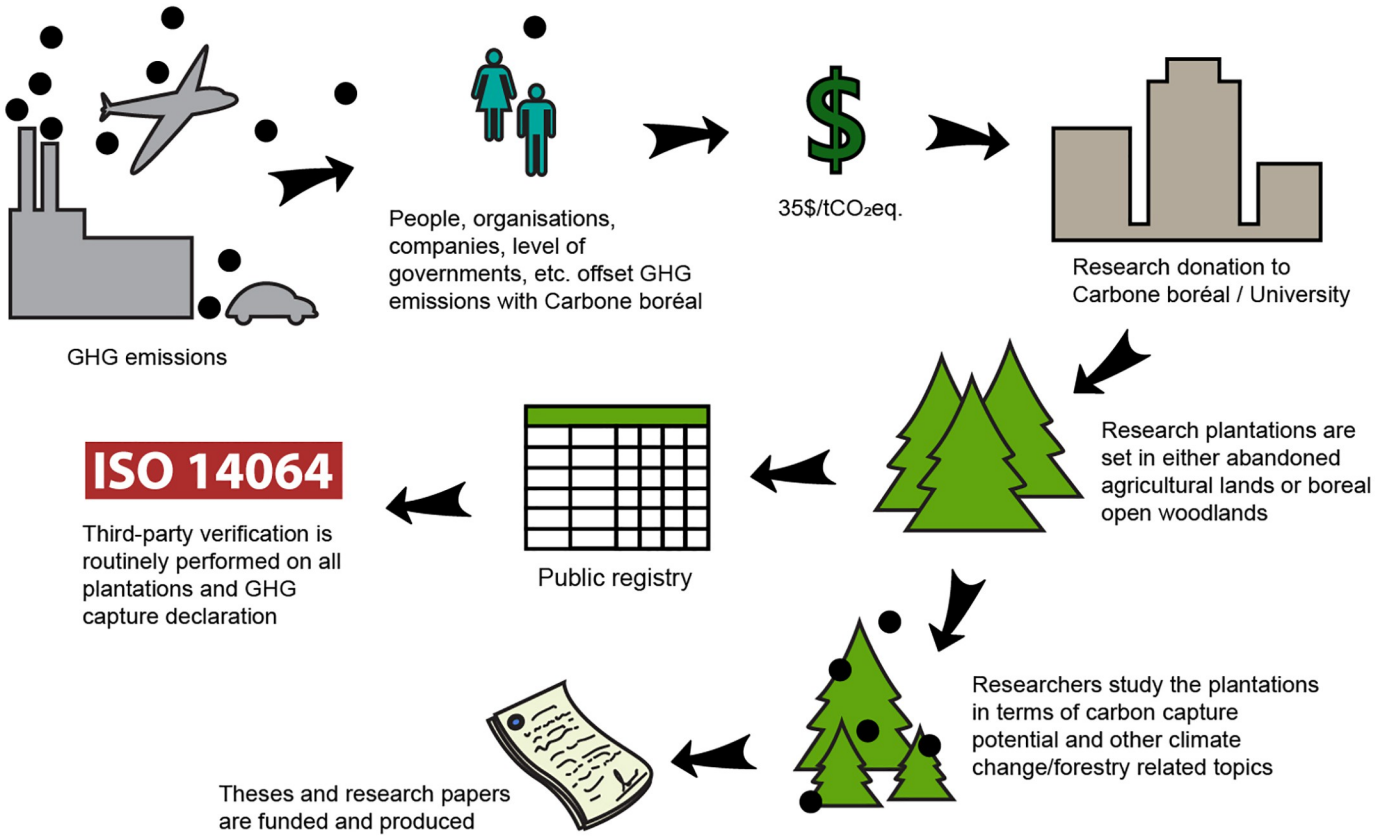

Fig 1. Overview of the mechanics of the Carbone boréal research infrastructure at the Université du Québec à Chicoutimi (Québec, Canada).

https://doi.org/10.1371/journal.pclm.0000232.g001

UQAC research infrastructure, with a management and multidisciplinary scientific committees under the UQAC board of directors.

As Carbone boréal requires large parcels of land to establish research plantations it partnered up with the Ministère des Ressources naturelles et des Forêts of Québec (MRNF; Ministry of natural resources and forests), the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation of Québec (MAPAQ; Ministry of agriculture, fisheries, and food) and the Pekuakamiulnuatsh Takuhikan (First Nation political organization). These entities are essential and help to identify suitable landscapes for afforestation in boreal open woodlands (BOWs) and abandoned agricultural lands (AALs). The partnership allowed for the first plantations to be performed. To date, Carbone boréal has planted more than 1.6 million trees (and growing at *ca*. 100–200 000 trees yr^{-1}) in both BOWs and AALs that are protected via long-term agreements and special status of experimental forest on Crown land, which guarantee the permanence of the sequestered carbon stocks. The plantations yield GHG offsets for organizations and individuals (each recorded in the public registry with assigned number of trees necessary to mitigate emissions) which become research donations to Carbone boréal. The funds collected (of which 20% are capitalized and yield interests) contribute to the financial stability of the infrastructure and allow for non-conventional long-term funding of research projects and student fellowships at the UQAC.

Research is at the core of Carbone boréal's mission and first and foremost, the net carbon sequestration of the BOW plantations was estimated by life cycle analysis at 77 t C ha^{-1} over a 70-yr period (0.14 t CO_2-eq per planted tree; 1.1 t C ha^{-1} yr^{-1}) [9]. This conservative and third-party verified estimate was used to establish the offsets but the aging and growing experimental stands allow for actual carbon sequestration to be measured. Several studies already have been conducted to validate the modelling approaches, assess various management methods and forest regeneration dynamics [10–14] (see https://carboneboreal.uqac.ca/publications-scientifiques/ for more details). Afforestation of AALs commenced in 2013 as a pilot project and counts more than 400 000 planted trees. Plantations were first designed to measure and estimate the additional carbon sequestration potential compared with a reference scenario, like the one in BOWs, with other hypotheses to be tested (*e.g*. the performance of different tree species) [15]. Additional carbon capture of the research plantations is periodically verified by an independent third party under ISO 14064–3 and offered to the public as GHG offsets, closing the loop between science and its funding.

Carbone boréal is an original grassroot, horizontal, collaborative, voluntary and transparent way of funding climate and environmental science research. It is a living laboratory for present and future scholars of the boreal zone that creatively and concomitantly finances relevant science projects while mitigating climate change through NBS.

As Carbone boréal, other research infrastructures worldwide could acquire resilience by funding their projects via the carbon markets. Other NBS can and must be applied globally to answer the challenges of net GHG reductions and should be used in research to measure their efficiency. For instance, other NBS such as soil carbon sequestration in agriculture (*e.g*. biochar addition and change of practices), peatland and wetland restoration are as promising as afforestation but research gaps are still wide to ensure sustainable net GHG reductions [1]. Using carbon markets for financing such research on the long term is one of the solutions to assist in NBS management and to increase their efficient implementation to mitigate climate change.

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Conceptualization: Patrick Faubert, Ranieri Ribeiro Paula, Sylvie Bouchard, Charles Marty, Olivier Fradette, Claude Villeneuve.

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