United Nations University
Institute for Water, Environment and Health

POLICYBRIEF

Beyond Planting Trees: Taking Advantage of Satellite Observations to Improve Forest Carbon Management and Wildfire Prevention

Executive Summary

1. In many parts of the world, forests and peatlands, previously considered to be the largest terrestrial carbon storehouses, are transitioning into super carbon emitters under warming conditions, due to large and frequent wildfires.
2. Carbon mitigation actions and policies— including carbon pricing, credit verification, and Voluntary Carbon Market (VCM) projects under the forestry and land-use category, as well as the Paris Agreement— fail to properly account for wildfire-related carbon emissions.
3. Natural carbon sequestration in dry soils through forestation policies might be ineffective in warming environments with more frequent wildfires.
4. Under certain conditions and mostly in arid and warming environments where the efficiency of photosynthesis is reduced, controlled harvesting and grazing could be actively considered as a strategy for maintaining soil and vegetation moisture and preventing increased carbon emissions.
5. A global platform of near-real-time satellite observations of forest conditions is needed to ensure transparency and accountability of VCMs in accordance with the changing conditions of forests under global warming.

Context

Forests have historically been seen as one of the most effective terrestrial carbon sinks. However, over the past 10 years, forests and peatlands have increasingly transitioned into massive carbon emitters in many parts of the world due to increasing wildfires. Carbon mitigation actions and climate policies including Voluntary Carbon Market (VCMs), REDD+ (Reducing Emissions from Deforestation and forest Degradation), ARR (Afforestation, Reforestation, and Revegetation), IFM (Improved Forest Management), and the Paris Agreement fail to account for these substantial emissions[1]. These actions and policies have primarily been focused on encouraging the growth of VCM markets, which have had limited progress in actual carbon reduction. This is because in practice, these policies do not reflect our changing environments and increasing wildfires. Forests, especially in boreal forests, where the world's largest wildfires occur, are currently being assessed by the Verified Carbon Standard (VCS) program for carbon offset projects that do not consider the recent explosive fire-driven carbon emissions. In the absence of systematic monitoring of forest conditions – whether they are developed as fire fuels or heat storage or carbon sequester, forestation policies or VCMs may unintentionally exacerbate wildfire hazards,

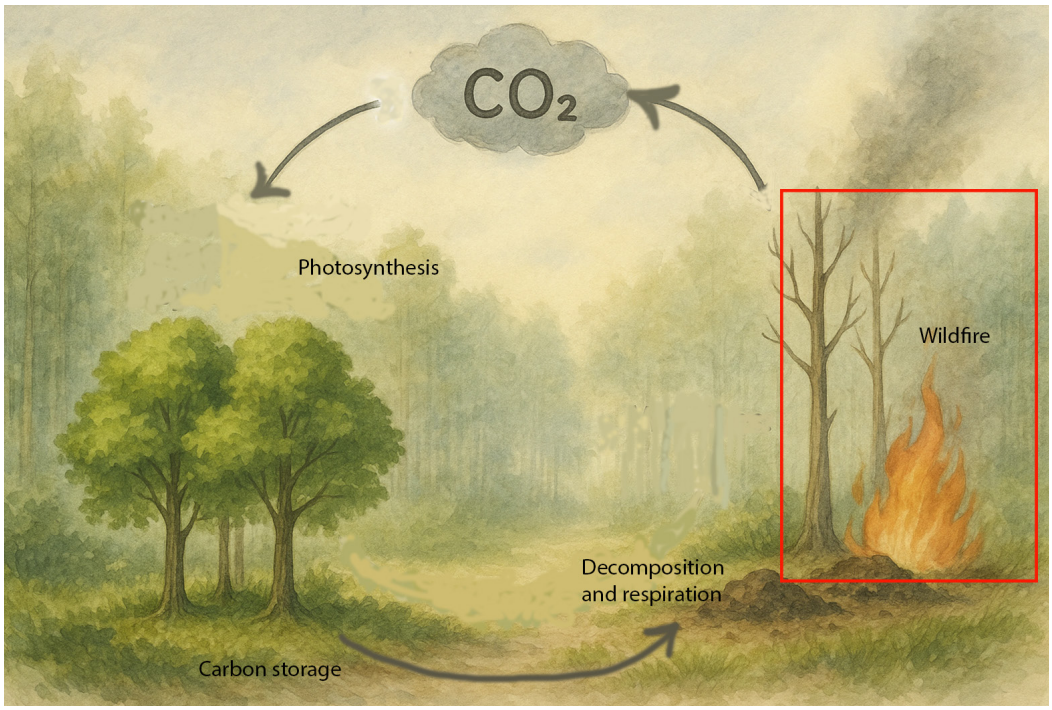


Figure 1. In the conventional carbon accounting schemes, carbon emissions from wildfires are largely neglected shown in red (image generated with assistance from ChatGPT)

further fueled by overheated carbon markets. Given the growing complexity of forest ecosystems under warming environments, there is an urgent need for a more responsive and adaptive policy.

Problem Statement

In traditional carbon policies, vegetation is considered as a carbon sink, and deforestation must be completely prevented. When affected by wildfires or droughts, forests fail to perform the functions that carbon markets expect from them and instead release massive amounts of carbon. This issue is often ignored in the VCMs-based carbon verification and trading frameworks.

In a warming environment, forests not only act as huge carbon emitters but also can turn into heat reservoirs with the power to trigger and exacerbate wildfires. The boreal forests, once considered one of the largest terrestrial carbon sinks, are now evolving to super carbon emitters. For instance, in 2023, Canadian wildfires covering 18.5 million hectares emitted approximately 23% of the global carbon from wildfires, nearly six times Canada's 20 years-average[2]. This approximately 2 gigatonnes of fire-driven carbon dioxide emissions far exceeded Canada's average annual carbon emissions of 670 megatonnes from all its major economic sectors[3,4]. In 2024, hottest year on record so far, emissions from the Siberian taiga ranked 3rd in two decades, after 2019 and 20202. In 2022, Amazon wildfires recorded the highest level of carbon emissions in 20 years while 84 million hectares in northern Australia burned in 2023 – the largest bushfire in more than a decade[3,5]. However, such massive carbon emissions are often ignored or underestimated by VCMs, and carbon offset schemes[6]. Accordingly, they fail to adequately account for the dual functionality of forests, mechanically assuming forests as carbon sinks. This issue has led to an overestimation of the role of forestation as a solution to climate change.

Policy Recommendations

1. Reform carbon offset schemes to address natural carbon emissions from forests

Warming environments naturally expand forests and vegetation in most areas, often without human intervention (referred to as global greening). That is because more CO_2 in the atmosphere enhances vegetation growth, and warm temperatures can extend the growing season and increase evapotranspiration (i.e. water use for growth and

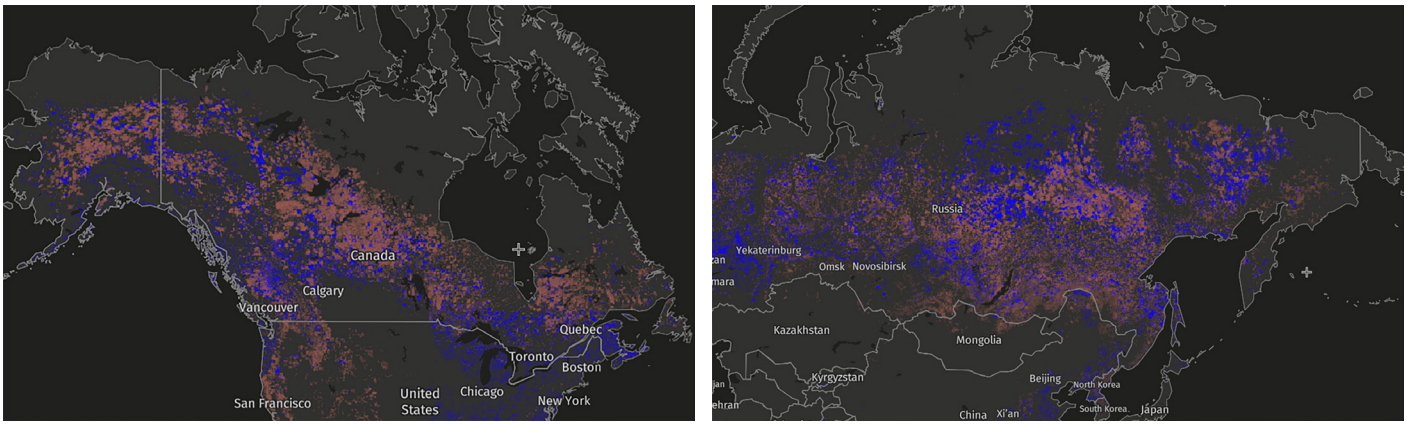


Figure 2. Annual tree cover loss because of fires during 2001-2023 (pink) in places where forests grew during 2000-2020 (blue): (a) Canada (b) Russia (data source: Global Forest Watch)..

cooling purposes), depending on region and vegetation type. If forests expand in warming environments, their heat adsorption also increases the risk of fires[7]. In addition, when root zone soil moisture is depleted during droughts, forests do not effectively uptake carbon[8,9]. Planting more and more trees in such an environment with the purpose of carbon mitigation will likely increase carbon emissions due to future wildfires. Pest spreads can also reduce the carbon sequestration capacity of forests, especially during droughts. Carbon offset schemes such as VCMs and VCS should be reformed to better account for these conditions and prevent unintended consequences. Instead of solely focusing on conservation of forests or expanding forested areas, carbon policies must consider the hydrological and thermal conditions of forests and manage them holistically. Annual precipitation, soil health, and expected future droughts and heatwaves should be considered before implementing forestation as a caron emission reduction solution. During extreme droughts and heatwaves, removing dead trees as the main source of fuel for fires should be implemented. However, in many regions, environmental regulations do not allow forest fuel management, leading to high levels of emissions during fires. This does not suggest that reforestation will always have negative environmental consequences as the benefits of reforestation may well be justified depending on the location and purpose.

2. Implement adaptive-anticipatory governance for forest fire management

To address the shortcomings of the existing carbon mitigation schemes, an adaptive-anticipatory governance for forest and fire management should be developed and implemented. An adaptive governance[10,11] acknowledges the limitations and facilitates adaptation to the dynamic and constantly changing environments[12,13]. Such an adaptive governance should be locally co-developed based on inputs from stakeholders and communities. Based on this management strategy, instead of "pre-determining" whether forests are sources or sinks of carbon, the governance approach "responds to" the state of the forests.

3. Leverage satellite observations to advance Voluntary Carbon Markets

Warming temperatures alter global forests and influence how much carbon they can sequester. Near-real-time satellite observations of forests can be effective for evaluating the changing forest environments. Thus, earth observation of these forest environments should be leveraged to advance carbon policies and management strategies. Currently, carbon management is largely driven by market incentives driven by climate actions that are not holistic. According to the United Nations Development Programme (UNDP), the forestry and land use management category has the most popular and highest trading values among VCM projects[14]. According to the World Bank[15], the revenues from global carbon pricing mechanisms such as carbon taxes and emissions trading schemes (ETS) reached an all-time high in 2023, but this did not lead to clear real carbon reductions. This is not surprising, given the market-orientated carbon management schemes that were designed based on a set of

mechanical assumptions that do not reflect the dynamics and changing conditions of living ecosystems and increasing wildfires.

Satellite observations can identify areas where forests are growing, and fuels are accumulating. Such forest environments should be excluded from carbon offset markets and forestation plans, due to potential high emissions in case of future fires. For example, wildfire often occurs in areas where trees flourish, particularly in vulnerable boreal forests, which turn into fire fuels during drought and heatwaves. Carbon offset projects, such as the boreal wildlands forest project in Canada, are being currently considered by the VCS, relying on historical patterns, without proper assessments of historical and future fires. However, these circumpolar and unpopulated boreal forests (approximately 30% of the total planetary forest cover) are growing and will potentially contribute to more emissions due to future fires.

Currently, there is no initiative or platform to generate information on dynamics of forest environments for real-time carbon management. So, fuel built-up and future fires are not properly incorporated into VCM projects, REDD+, ARR, IFM, and other similar schemes. Earth observations such as data from the Moderate Resolution Imaging Spectroradiometer (MODIS), Soil Moisture and Ocean Salinity (SMOS), and Soil Moisture Active Passive (SMAP) can be used to generate dynamic forest conditions and fuel information for developing dynamic forest management plans[7,16].

Several studies have attempted to monitor thermal and hydrological changes in large forests[7,17,18]. However, these efforts have not yet been systematically integrated into VCM schemes. Initiatives such as the Global Wildland Fire Network launched by UNISDR or Global Fire Management Hub launched by the Food and Agriculture Organization (FAO) and United Nations Environment Programme (UNEP) in 2023 might be proper platforms for integrating satellite observations to inform VCM plans.

Final Remarks

Warming temperatures and increasing wildfires are significantly affecting forest environments and the amount of carbon they can sequester. However, this is not reflected by the traditional carbon management schemes that predefines vegetation as a carbon sink. Instead of a blanket assumption that forestation will always increase carbon capture, we need to develop an adaptive-anticipatory governance that considers forest conditions, extreme events (e.g., drought and heatwave) and expected future fires. Such a system of governance can greatly benefit from Earth observations and near-real-time monitoring of changing forest conditions. Without such a process, the estimated carbon capture from reforestation efforts may not be reliable and can misinform forest management decisions.

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