Weather and Climate Science for Service Partnership Programme

Drought and the Amazon rainforest carbon sink

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Summary

The ability of the Amazon rainforest to act as a land carbon sink and store is a key part of the global carbon cycle and its conservation is important for achieving climate targets. Increasing drought activity threatens this system and the ecological and human communities that rely on it. This briefing summarises the latest research in the Brazilian portion of the Amazon, highlighting the work of the Climate Science for Service Partnership (CSSP) Brazil.

- Drought activity is increasing around the world and is projected to continue to increase in the future with continued climate change. Droughts can reduce plant productivity and their ability to absorb and store carbon.
- The Amazon rainforest stores an enormous amount of carbon, but has become a net source of carbon during recent climate extremes, such as droughts. Further climate change could continue this trend or push the Amazon towards major ecosystem change, reducing its carbon absorption strength and the size of its carbon store.
- Future increases in drought activity could present increasingly severe impacts on ecological and human communities in the Amazon, affecting transportation, agriculture and livelihoods.
- Recent progress on reducing deforestation could help provide resilience to the Amazon and its carbon sink by reducing drought activity, supporting climate adaptation and mitigation efforts.

Land carbon sinks and stores, such as soils and forests, absorb and retain a large amount of carbon, forming a key part of the carbon cycle and the wider climate system. They are also important for achieving climate targets, as some countries include natural carbon absorption within their borders in their climate accounting. The Amazon rainforest has such a large carbon sink it plays a major role in the global climate, storing vast amounts of carbon and regulating regional temperature and humidity. However, this sink is vulnerable to extreme climatic events, including severe droughts, which can lead to carbon release from stores or reduced carbon uptake, and are increasing due to human-induced climate change. This briefing details how climate change is altering droughts and their effects on the Amazon rainforest carbon sink, and the significance of this for local communities and climate policy.

Climate change impacts on the Amazon rainforest carbon sink

The Amazon rainforest is the largest contiguous forest in the world, absorbing and storing a huge amount of carbon in plant tissues and soils. This store is on the order of hundreds of billions of metric tons of carbon[1], meaning the Amazon alone is a significant component of the global carbon cycle. This also means the health of the rainforest and its functioning as a net carbon sink are crucial to slowing the growth of carbon dioxide concentrations in the atmosphere.

Recent research[2] has demonstrated that the Amazon's ability to absorb and retain carbon is being affected by climate change. The Amazon was observed to become a net source of carbon during the recent drought events of 2010 and 2015/16, likely due to the mortality of large trees that are particularly vulnerable to droughts and contribute disproportionately to the forest carbon store. Increasing human-induced disturbances, such as deforestation and forest degradation by wildfires, can further amplify forest dieback during drought years, shifting the Amazon system from a carbon sink to a source.

Dynamic global vegetation model projections of future climate scenarios accounting for an increasing co-occurrence of droughts and heatwaves indicate a reduction of global tree coverage and carbon stored in vegetation[3]. A high-emissions future scenario could see the eastern Amazon experiencing longer dry spells, while the western Amazon develops a more distinct dry season and the general intensity of rainfall and drought extremes increases[4].

Droughts as drivers of major Amazon ecosystem change

Droughts are among the drivers of large-scale dieback that could move the Amazon towards an irreversible tipping point, transforming the tropical forest system into a drier, degraded state, with lower biomass and biodiversity, and more open structures or canopies. This could occur locally or regionally, and over decades to a century in affected regions, perhaps reinforced by a positive feedback between droughts and wildfires[5]. Significant rainforest loss would have major effects on the Amazon carbon sink, reducing absorption strength and the size of the carbon store.

The risk of crossing such a tipping point is difficult to quantify; thresholds relating to temperature rise, deforestation and rainfall reduction have all been proposed as triggers of Amazon dieback[5]. One study suggests that by 2050, on current trends of warming, drying, extreme droughts and deforestation, 10% to 47% of the Amazon rainforest will be exposed to compounding disturbances that could trigger forest collapse and exacerbate regional climate change[6]. On the other hand, studies have demonstrated that the forest was able to reorganize after two decades of experimental drought, avoiding a catastrophic collapse[7], and that simulated ecosystem transitions may have only moderate impacts on the regional water cycle[8]. Such studies highlight the complex feedback between the Amazon rainforest and climate. Overall, the latest IPCC Assessment Report concluded there was low confidence of a major forest transition beginning across the entire Amazon before 2100, but that continuing changes in the Amazon, such as deforestation, could raise this possibility over time[9]. Modelling of Amazon dieback in a moderate emissions future climate scenario found that it led to an additional 0.3°C of global warming as a result of rainforest loss[10].

Implications for local populations and climate policy

The future of the Amazon rainforest and its carbon sink have major implications, not just for local populations, but also for national and international efforts to address climate change.

Droughts directly impact the biosphere, as well as ecosystem services. At local scales, low river levels are harming riverine and indigenous communities that rely on rivers for food and transportation. At regional scales, falling rainfall totals are hindering regional agriculture and hydropower, and increased wildfire activity is decreasing air quality even in metropolitan areas far from the Amazon, such as in the São Paulo region, home to over 20 million people. More major impacts, such as Amazon dieback and degradation, would have a profound effect on the current biodiversity of the region, as well as the livelihoods of local populations[10].

Drought and land carbon sink changes also have the potential to impact progress towards climate mitigation targets, such as countries' Nationally Determined Contributions, especially where these include removal of carbon dioxide from the atmosphere by land carbon sinks. As droughts shift the Amazon from a carbon sink to a source, it becomes more important to prevent further emissions from the forest, such as through actions to reduce deforestation. This could include well-designed international deforestation – free trade agreements[11], effective law enforcement[12], and Indigenous stewardship[12,13]. At the same time, efforts to strengthen reforestation and regenerative agriculture in already deforested areas can be scaled up, with additional support from carbon markets also possible[14,15].

Given the link between drought activity and deforestation, which can reduce rainfall by around 0.25 mm for each percentage point of forest lost[16], reducing deforestation and forest degradation could help slow down future trends in drought activity and protect the Amazon rainforest carbon sink. Agricultural policy can play important role in this through encouraging more sustainable farming practices and the re-use of degraded pastures, reducing the need for further deforestation. Recent efforts to reduce deforestation in Brazil and enhance rainforest restoration can strengthen the resilience of Amazonia and its communities, supporting both climate adaptation and mitigation.

Our understanding of these issues is being improved by the joint Brazil-UK Climate Science for Service Partnership (CSSP) Brazil, a collaborative climate science initiative between UK and Brazilian institutions. Work undertaken by this project, which underpins much of this briefing, is helping to improve our understanding of drought impacts on the crucial land carbon sink held in the Amazon rainforest and inform policies to protect it.

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