Rivers in the Sky: How Deforestation Is Affecting Global Water Cycles

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Moisture produced by the world's forests generates rainfall thousands of miles away. Richard Whitcombe / Shutterstock

Every tree in the forest is a fountain, sucking water out of the ground through its roots and releasing water vapor into the atmosphere through pores in its foliage. In their billions, they create giant rivers of water in the air – rivers that form clouds and create rainfall hundreds or even thousands of miles away.

But as we shave the planet of trees, we risk drying up these aerial rivers and the lands that depend on them for rain. A growing body of research suggests that this hitherto neglected impact of deforestation could in many continental interiors dwarf the impacts of global climate change. It could dry up the Nile, hobble the Asian monsoon, and desiccate fields from Argentina to the Midwestern United States.

Until recently, the nuggets of data delivering such warnings were fragmented and often relegated to minor scientific journals. But the growing concerns came to the fore in reports presented at two forest forums held by the United Nations and the Norwegian government in recent weeks.

In Norway, Michael Wolosin of the U.S. think tank Forest Climate Analytics and Nancy Harris of the World Resources Institute published a study that concluded that "tropical forest loss is having a larger impact on the climate than has been commonly understood." They warned that large-scale deforestation in any of the three major tropical forest zones of the world – Africa's Congo basin, southeast Asia, and especially the Amazon – could disrupt the water cycle sufficiently to "pose a substantial risk to agriculture in key breadbaskets halfway round the world in parts of the U.S., India, and China."

> The water that a single tree transpires daily has a cooling effect equivalent to two domestic air conditioners for a day.

And in a background paper for the UN event, David Ellison of the Swedish University of Agricultural Sciences in Uppsala, reported on "increasingly sophisticated literature" assessing "the potential impact of forest cover on water availability across the broad expanse of continental, terrestrial surface."

It is well known that carbon dioxide emissions from deforestation add 10 percent or so to global warming by reducing the quantity of CO_2 that the world's forests pull from the atmosphere. But the authors of both papers say this understanding about global impacts of deforestation has tended to eclipse findings about other "non-carbon" climatic impacts that may play out intensively at local and regional scales.

The impact of deforestation on rainfall is one of the most important non-carbon effects. But there are others. For instance, healthy forests release a range of volatile organic compounds that "have an overall cooling effect on our climate," mostly by blocking incoming solar energy, says Dominick Spracklen of Leeds University in England. Removing forests eliminates this cooling effect and adds to warming, he and an international team concluded in a study published earlier this year.

Meanwhile, lost forests are usually replaced by agriculture, which produces its own emissions. Add in these impacts and the real contribution of deforestation to global climate warming since 1850 is as much as 40 percent, conclude Wolosin and Harris. At that rate, tropical deforestation could add 1.5 degrees Celsius (2.7°Fahrenheit) to global temperatures by 2100 – even if we shut down fossil fuel emissions tomorrow, calculates Natalie Mahowald of Cornell University.

On Indonesia's island of Sumatra, which has one of the worst deforestation rates in the world, temperatures in logged areas have increased an average 1.05 degrees Celsius since 2000. Aulia Erlangga / CIFOR

But there are local effects, too. Forests moderate local climate by keeping their local environments cool. They do this partly by shading the land, but also by releasing moisture from their leaves. This process, called transpiration, requires energy, which is extracted from the surrounding air, thus cooling it. A single tree can transpire hundreds of liters of water in a day. Each hundred liters has a cooling effect equivalent to two domestic air conditioners for a day, calculates Ellison.

Monitoring of rapidly deforesting regions of the tropics has recently shown the effect of losing this arboreal air conditioning. Take the Indonesian island of Sumatra, which has been losing forests to palm oil cultivation faster than almost anywhere else on the planet. A study last year found that since 2000, surface temperatures there have on average increased by 1.05 degrees Celsius (1.8°F), compared with 0.45 degrees in forested parts. Clifton Sabajo at the University of Gottingen, Germany, found temperature differences between forest and clear-cut land of up to 10 degrees Celsius (18°F) in parts of Sumatra.

Meanwhile in the Amazon, Michael Coe of the Woods Hole Research Center recently reported a difference of 3 degrees Celsius (5.4°F) between the cool of the forested Xingu indigenous park and surrounding croplands and pastures.

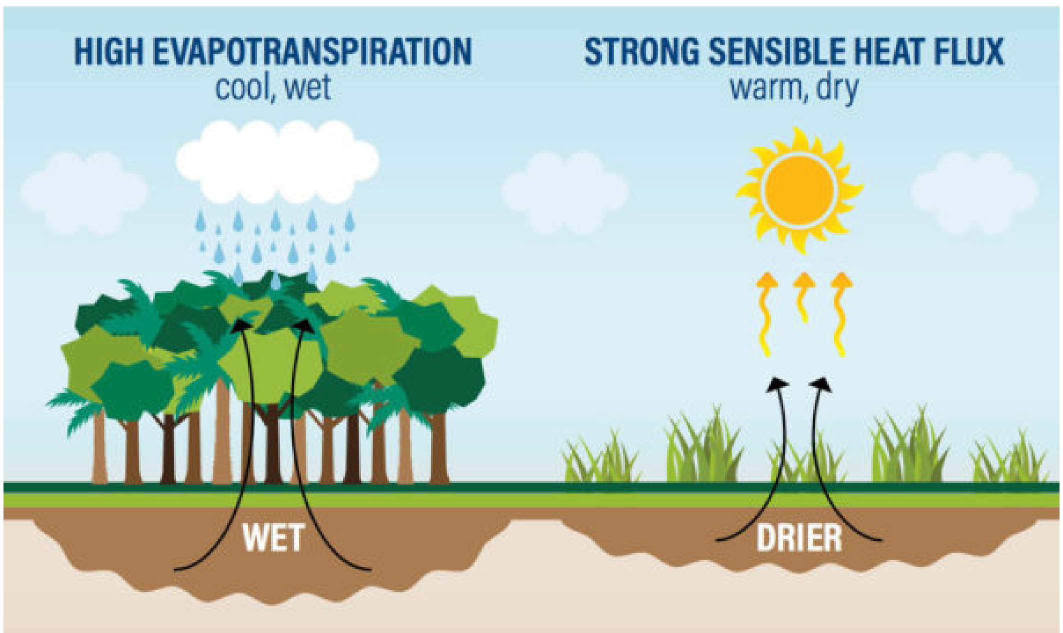
> “The forests cause the rainfall, and if they weren’t there the interior of these continental areas would be deserts,” says one expert.

But heat is only the start. There is drought, too — not just in and around former forest lands, but far away. And a host of new studies are forcing a reassessment of exactly why it rains where it does.

We are used to thinking of rainfall as the end result of water evaporating from the oceans. In coastal regions that is overwhelmingly the case. But it turns out that the interiors of continents often get most of their precipitation from water that has been rained out and recycled back into the air several times in a precipitation cascade following the winds. The further inland, the more dominant this recycling becomes.

Some of the recycling is straightforward evaporation from lakes, rivers, or wet soil. But much of it is fast-tracked by plants, and especially trees. Tree roots tap moisture from deep in the soil. This circulation system is driven by releases of moisture into the air through their leaves via transpiration.

By one estimate, the planet's land vegetation recycles 48 cubic miles of water each day. A tenth of that is released by the Amazon rainforest alone – rather more than the daily discharge of the Amazon River.



Trees pull water from the ground and release water vapor through their leaves, generating atmospheric rivers of moisture. World Resources Institute

Transpiration is essential to generating new rainfall downwind. And the heart of this process is in the surviving tropical rainforests, where transpiration is most intense.

"Traditionally, people have said areas like the Congo and the Amazon have high rainfall because they are located in parts of the world that experience high precipitation," says Doug Sheil of the Norwegian University of Life Sciences, near Oslo. "But the forests cause the rainfall, and if they weren't there the interior of these continental areas would be deserts."

In a study of tropical areas downwind of deforestation, Spracklen found that "air that has passed over extensive vegetation in the preceding few days produces at least twice as much rain as air that has passed over little vegetation." He predicts that forest loss is set to reduce dry-season rainfall across the Amazon basin by 21 percent by 2050.

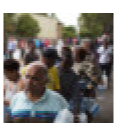
Arie Staal of Wageningen University in the Netherlands reported earlier this year that one-third of the rain falling in the Amazon basin comes from moisture generated within the basin, mostly by transpiring trees. The dependence was greatest downwind in the west of the basin, farther from the Atlantic Ocean. With a fifth of the Amazon forests gone, the risks of drought grow for such regions. Coe reported less rainfall and a longer dry season in Rondônia, an Amazon province on Brazil's western border with Bolivia.

> The Amazon provides moisture as far as the Midwestern U.S., which gets 50 percent of its rainfall from water evaporating from land.

Daniel Ruiz of Columbia University says rainfall in the Colombian Andes is becoming more seasonal, with reduced humidity and fewer clouds. Some researchers believe the desiccation could stretch south to Argentina and north across the Caribbean to North America. The Amazon is thought to provide moisture as far as the Midwest, which gets 50 percent of its rainfall from water evaporating from the land.

Attributing changes in rainfall to altered land use is difficult. But a growing body of research asserts that the fingerprints of deforestation are increasingly visible. In Borneo, an analysis of nine watersheds found that those with the greatest forest loss have seen a reduction in rainfall of around 15 percent. In India, Supantha Paul of the Indian Institute of Technology in Mumbai found that patterns of declining rainfall during the Indian monsoon matched changing forest cover.

Patrick Keys of the Stockholm Resilience Center in Sweden says the downwind effect of deforestation is not limited to the tropics. "China receives a very large fraction of its rainfall from water that is recycled from evaporation on land," he told *Yale Environment 360*. It "has very high potential for changes to its precipitation driven by upwind land-use change" as far away as Eastern Europe and the jungles of Southeast Asia.



This matters for farmers, but also for city dwellers. In a study of 29 megacities around the world, Keys found that 19 relied on evaporation and transpiration from land He singled out as the most vulnerable Karachi in Pakistan and China's Shanghai, Wuhan, and Chongqing. Other cities such as Delhi and Kolkata in India, Istanbul, and Moscow were not far behind.

Forest mist in Pico da Neblina National Park, in the northern Brazilian state of Amazonas. Peter van der Sleen / University of Leeds

In the Americas, he warned that the Brazilian megacities of Rio de Janeiro and Sao Paulo and Argentina's Buenos Aires could also be vulnerable because much of their rainfall originates in the Mato Grosso region, where forests and grassland are rapidly being replaced by corn and soy fields. And what of Africa, the region of the world whose people are most dependent on rain-fed agriculture? In Africa, drought can mean death. But Keys estimates that up to 40 percent of sub-Saharan rainfall is created by moisture that has been recycled by vegetation. In the arid Sahel region, the figure may rise to 90 percent, says Louis Verchot of the Center for International Forestry Research (CIFOR).

Recent research has highlighted the threat posed by deforestation to the Nile River, the world's longest river, and the 300 million people who depend on it. Most of the Nile's flow begins in the Ethiopian highlands, a small rain-drenched part of the river's catchment. But recent research suggests that much of the rainfall in the Ethiopian highlands comes courtesy of moisture recycled by the forests of West Africa and, especially, the jungles of the Congo basin in the continent's heart. These rainforests "may provide as much as 30 to 40 percent of the total annual rainfall in the Ethiopian highlands," says Ellison.

Two questions arise. Has deforestation in West Africa been responsible for the reduced Nile flows out of Ethiopia seen in the final quarter of the 20th century, as suggested by Ellison's colleague, Solomon Gebrehiwot, a researcher at Justus-Liebig University, Giessen in Germany. And could future loss of the Congo jungle empty the river further? Sheil says Gebrehiwot's data suggest a further 25 percent decline in Nile flow is a realistic estimate.

Both Keys and Ellison see an urgent need for climate scientists and diplomats alike to begin addressing these issues, so that pressure points can be identified and policies adopted to protect rainfall in critical places. We have treaties governing river flows in most rivers that cross international borders, they point out. But the rivers of moisture in the atmosphere are rarely measured and never governed.

Egypt and Ethiopia have spent years working toward an agreement on managing water flows in the Nile. But a deal on sharing the water will be pointless if rains falter in the Ethiopian highlands because of deforestation in the distant Congo basin.

In the current human-dominated era of the Anthropocene, says Keys, "processes such as moisture recycling… can, and ought, to be governed."