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# Community and ecosystem ramifications of increasing lianas in neotropical forests

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## Abstract

Lianas (woody vines) are increasing in neotropical forests, representing one of the first large-scale structural changes documented for these important ecosystems. The potential ramifications of increasing lianas are huge, as lianas alter both tropical forest diversity and ecosystem functioning. At the community level, lianas affect tree species co-existence and diversity by competing more intensely with some tree species than others, and thus will likely alter tree species composition. At the ecosystem level, lianas affect forest carbon and nutrient storage and fluxes. A decrease in forest carbon storage and sequestration may be the most important ramification of liana increases. Lianas reduce tree growth and increase tree mortality – thus reducing forest-level carbon storage. The increase in lianas, which have much less wood than trees, compensates only partially for the

amount of carbon lost in the displaced trees. Because tropical forests contribute approximately one-third of global terrestrial carbon stocks and net primary productivity, the effect of increasing lianas for tropical forest carbon cycles may have serious repercussions at the global scale.

This article refers to:

Tropical forests contain most of the earth's plant species and contribute more to carbon storage in the form of above ground biomass than any other terrestrial ecosystem. Temperate and boreal forests are changing rapidly in response to global anthropogenic drivers. Similar large-scale changes are now being detected in tropical forests. One of the largest contemporary changes in tropical forests is an increase in lianas (woody vines),<sup>1</sup> which could have serious consequences for tree species diversity and composition, as well as the reducing capacity of tropical forests to store carbon.<sup>1-3</sup>

## Evidence for Neotropical Liana Increases

We conducted a comprehensive survey of all published literature with data on longterm changes in liana abundance, biomass and productivity.<sup>1</sup> Fourteen studies had long-term data on lianas: eight from the American tropics and subtropics (neotropics), two from Africa and four from North American and European temperate forests. All eight neotropical studies reported striking increases in liana abundance, biomass or productivity. For example, in a comprehensive survey of 58 forests from South and Central America, liana biomass nearly doubled relative to tree biomass over a 20-year period.<sup>3</sup> On Barro Colorado Island, Panama, liana productivity increased 40% relative to tree productivity over a 17-year period,<sup>4</sup> the proportion of trees infested by lianas doubled over the past 40 years,<sup>5</sup> and the number of trees that were severely infested by lianas increased by 65% over a recent 11-year period.<sup>5</sup> In central Amazonia, liana seedling recruitment increased by as much as 500% over a six-year period in the 1990s.<sup>6</sup> Combined, these eight studies provide strong support for the pattern of rapid increases in the importance of lianas in neotropical forests.<sup>1</sup>

In contrast, the two African studies reported decreasing lianas and the temperate forests reported mixed results, with some forests increasing in lianas and other forests remaining the same. We did not find any long-term data from Asia or Australia. Consequently, more data from other regions of the world are necessary to allow us to evaluate global patterns of liana change.

## Putative Mechanisms for Neotropical Liana Increases

A quantitative and mechanistic understanding of liana responses to changing environmental conditions will be essential to predict future changes in neotropical forests. Lianas may be increasing in the neotropics due to elevated forest disturbance, seasonal drought or atmospheric CO<sub>2</sub> concentrations, with these factors operating simultaneously and synergistically.<sup>1</sup> Increased nitrogen deposition is an additional anthropogenic driver that might contribute to increasing liana importance, but was not addressed in the original paper.<sup>1</sup> Nitrogen deposition is increasing rapidly in the tropics<sup>7</sup> and might favor lianas for the same reasons that elevated atmospheric CO<sub>2</sub> concentrations might favor lianas. The leaves of lianas tend to be smaller and thinner and have higher levels of nitrogen, phosphorus and potassium per unit area than do the leaves of their host trees.<sup>8</sup> These leaf traits characterize phenotypically plastic species that are able to respond strongly to fertilization, be it through nutrient deposition or rising CO<sub>2</sub> concentrations, to achieve rapid growth rates.

## Ramifications of Neotropical Liana Increases

Lianas are structural parasites of trees, using the tree architecture to climb to the forest canopy and deploy their leaves over those of their host tree. Lianas compete intensely with trees for both above- and below-ground resources and trees infested by lianas suffer substantial decreases in growth, fecundity and survival.<sup>5,9-13</sup> An

increase in the abundance and biomass of lianas will result in a greater proportion of trees infested, and higher mean per-tree infestation. Indeed, this exact pattern recently has been reported for Barro Colorado Island, Panama.<sup>5</sup>

As liana infestation of trees increases, forest level above ground biomass (AGB) in tropical forests will decrease. Trees compose over 90% of the AGB in tropical forests, with lianas constituting a relatively small fraction (5–10%). However, lianas have a disproportionately large effect on trees and relatively small lianas have the capacity to reduce the growth and survival of large trees that store large amounts of carbon. Integrated across the entire forest, lower rates of tree growth and survival will reduce forest-wide carbon storage. A recent correlative study showed that lianas reduced tree carbon gain by approximately 10% per year, but the liana biomass compensated for only 30% of the displaced tree biomass.<sup>13</sup> Other studies have shown that forest AGB is far lower in areas of high liana abundance.<sup>14</sup> If lianas have a greater negative effect on trees with more dense wood, which has been reported previously in references <sup>1,9</sup> and <sup>13</sup>, then lianas could have an even larger effect on forest carbon storage and sequestration.

Lianas may also redistribute and homogenize soil nutrients throughout the forest. A single liana can extend through the canopies of many host trees, and lianas might homogenize soils and nutrient availability by taking up nutrients and depositing them as leaf litter a long distance from their roots.<sup>15</sup> Homogenization of soil conditions would reduce the potential for edaphic niche diversification and thus neutralize the edaphic specialization of tree species.

Increasing lianas may also alter tree community composition and relative species abundances, as well as reduce species diversity. By competing intensely with some tree species,<sup>9</sup> lianas reduce the ability of those species to compete with trees of other species. Thus, lianas can influence which species can persist in the community and the relative abundance of those species. Lianas also contribute to recruitment limitation of many tree species by reducing seed production of their host trees<sup>12</sup> and by intense competition, which reduces the number of trees that recruit into the community.<sup>9,10</sup>

## Determining the Mechanisms and Consequences of Liana Increases

The large increases observed in lianas will alter forest-level carbon and nutrient storage and fluxes, as well as tree species' relative abundance, but the extent to which forests will change is currently unknown. To address this issue, a mechanistic understanding of the drivers of increasing lianas is critical to develop models to predict future changes in liana abundance (reviewed in ref. <sup>4</sup>). To determine the consequences of liana infestation in tropical forests, well-replicated experimental approaches across a range of liana infestation levels are necessary. Liana cutting experiments will allow us to quantify the effect of varying liana abundance and biomass on tree growth, fecundity and survival. By experimentally cutting lianas across a gradient of low to high liana biomass, one can determine the shape of the response of such parameters as forest carbon, soil nutrients and tree community composition to liana infestation. Areas with particularly high liana abundance are important because they may resemble forests of the future, and liana cutting in these areas will allow us to quantify how high liana abundance affects forest standlevel parameters. Liana augmentation studies will also provide valuable information on how stand-level parameters will change when lianas increase in abundance. Consequently, while the amount of change that increasing lianas will impose on forests is still uncertain, the striking pattern of increasing liana abundance, biomass and productivity in neotropical forests is now clear.

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