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Changing climate in Brazil's "breadbasket"

Marks *et al*. (2020) critiqued the paper by Costa *et al*. (2019), which warned that Amazonian deforestation would lead to a lengthening dry season in the northern part of the Brazilian state of Mato Grosso. Marks *et al*. found no relationship between forest clearing within 50 km of weather stations in Mato Grosso and the number of dry days recorded. They also criticized Costa *et al*.'s conclusions regarding how to confront changes in rainfall that threaten the area's ability to produce two crops of soybeans every year. I disagree with Marks *et al*.'s interpretations for the following reasons.

Marks *et al*. (2020) implied that deforestation is not the cause of the changes documented by Costa *et al*. (2019). One complication is that Marks *et al*.'s analysis was based on data from weather stations positioned throughout Mato Grosso, whereas Costa *et al*. (2019) focused on climatological data from only the northern portion of the state, which is where the state's tropical forest is located. Marks *et al*. also considered vegetation clearing only in the vicinity of the weather stations; however, changes in precipitation are predominantly attributable to distant deforestation and changes in global circulation patterns influenced by global warming. Using models of deforestation across all of Amazonia, including but not limited to Mato Grosso, Costa *et al*. (2019) compared one scenario (with deforestation halted at the extent it had reached in 2005) with another scenario (that simulated continued deforestation through 2029). Costa *et al*. (2019) made clear that the impacts stem from deforestation throughout Amazonia and pointed to the importance of region-wide land-use change on rainfall in northern Mato Grosso demonstrated by their previous model (Costa and Pires 2010).

The regional landscape plays an important role in determining weather patterns. In most of Amazonia, prevailing winds blow from east to west due to the Earth's rotation; these winds retain water vapor not only from the Atlantic Ocean but also from the forest via evapotranspiration (eg Marengo *et al*. 2002; Arraut *et al*. 2012; Zemp *et al*. 2014). Unable to pass over the Andes Mountains, especially in the austral summer, the winds are deflected across Mato Grosso, thereby supplying critical rainfall to population centers such as São Paulo (see review in Fearnside [2015]).

Marks *et al*. also criticized Costa *et al*. for implying that farmers in Mato Grosso would limit their deforestation out of self-interest. Costa *et al*. are open to criticism on this point, but it is a minor part of their paper, mentioned in a single sentence: "If people are not provided with sufficient reasons to protect the ecosystems in which they reside, then habitat destruction and degradation are expected to continue". Almost everyone would agree with this general principle, but the mention of "people" diverts attention from other actors that are more relevant here. Throughout the rest of the text Costa *et al*. repeatedly referred to governments, agribusiness associations, and companies (large international purchasers, not individual soy growers) as those who must act in response to the authors' warnings. Maintaining high agricultural productivity in Mato Grosso is of paramount interest to Brazil's federal government due to its contribution to national gross domestic product (GDP) and export earnings. Taking action to stop deforestation in the rest of Amazonia outside of Mato Grosso should be high on the government's agenda (Fearnside 2017).

Marks *et al*. were correct in their claim that, out of self-interest to avoid a lengthening dry season, individual farmers are unlikely to refrain from clearing. In addition to the "tragedy of the commons" problem they highlighted, there is also the value of time. Destroying any potentially sustainable resource for short-term profits can be a rational financial choice, assuming that the actors are free to move elsewhere and/or switch to other economic activities (Clark 1973, 1990). Self-interest is also

unlikely to limit farmers' deforestation because clearing a hectare of forest on any given property would affect rainfall at other locations downwind of the property.

Marks *et al*. suggested that the impact of the projected alterations in rainfall could be countered by intensifying agriculture through the promotion of pivot irrigation. This option was recommended on the grounds that "growth in crop production through such intensification could also conceivably reduce the pressure on clearing remaining forests". They called for government agencies and financial institutions to support this, implying that a subsidy from "green" money was justified on the basis of avoiding deforestation. However, the degree of land-sparing required to achieve this outcome will likely not materialize, and would not represent a wise use of limited funding as compared to directly confronting deforestation. Theoretically, land-sparing would apply if the farmers were satisfied with their increased production. This logic holds for isolated subsistence groups that would stop expanding agriculture when their stomachs are full, but it does not apply to modern economies. Instead, when an activity such as intensified agriculture shows itself to be profitable, the response is to expand that activity (eg Fearnside 1987), which implies still more deforestation.

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