Researchers from Brown University tracked the expansion of agriculture in the Brazilian state of Mato Grosso over the last decade. Their work suggests that ideal land for agriculture in the state may be starting to dwindle. That scarcity of land may have contributed to a slowing in deforestation over the last decade.

"I'm sure that policy is helping, but we suggest it might not be all policy," said Stephanie Spera, a graduate student at Brown and the study's lead author. "It might also be a decrease in the amount of highly suitable agricultural land. The effect of policy may have been overestimated."

The findings are published in the journal *Environmental Research Letters*.

**Mapping changes in land use**

Over the last few years, Spera and her colleagues have been using data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) satellite to track changes in land use in Mato Grosso. Using a measure called the Enhanced Vegetation Index—essentially a measure of greenness in land cover—the researchers are able to distinguish between forestland and land used for agriculture. Forestland remains green all year. Land used for agriculture displays spikes in greenness that correspond with growing seasons.

By looking for changes on those patterns of greenness, Spera and her colleagues have mapped land use patterns in Mato Grosso from 2001 to 2011—a time during which agriculture exploded in the state.

"The rigorous mapping of land cover change and cropping is unprecedented in the temporal scope and spatial accuracy," said Jack Mustard, professor of geological sciences at Brown and another of the study's authors. "It shows huge transformations happening in this agricultural frontier that were unexpected but are hugely important."

Among those transformations was a dramatic expansion of agriculture on newly cleared forestland. In 2001, 3.3 million hectares of mechanized agriculture were cultivated in Mato Grosso. By 2011, agriculture had expanded to cover about 5.8 million hectares. Most of that...
expansion, however, was concentrated in the early part of the decade.

Later in the decade—after about 2006—clearing of forestland slowed and the intensification of farming on existing farmland increased. That intensification came mostly in the form of double cropping—planting two crops in the same field in a single growing season. In the satellite data, double-cropped land shows up as having two peaks in the greenness index per growing season, one just before the first crop is harvested, and a second peak for the second crop. In 2001, 0.5 million hectares were double cropped. By 2011, that had increased to 2.9 million hectares.

"Such increases in food production from double cropping—without expanding to new lands—are the key to meeting global food needs as populations and incomes go up around the world in the next 50 years," said Leah VanWey, a study co-author, professor of sociology and deputy director of Brown's Institute for the Study of Environment and Society. "Mato Grosso shows that this is possible on the most suitable lands in a new agricultural region."

The next step in the work was to learn more about the factors that influence agricultural growth patterns.

"What I was curious about next was whether or not there are certain characteristics of that land—like soil or slope or [proximity to] roads—that promoted either clearing new land or intensifying on existing agricultural land," Spera said. "That was the question we looked at for this paper."

**Land characteristics**

To get an idea of what might make for ideal agricultural land in Mato Grosso, Spera and her colleagues turned to a classic economic theory. In the 1800s, the economist David Ricardo developed a theory positing "the most fertile and most favorably situated land will be first cultivated."

Following the theory, Spera looked to see what characteristics may have been common to the land developed at the beginning of the agriculture expansion. Those characteristics included soil quality, the degree of slope of the land, average temperature in the area, the proximity to roads that could deliver goods to market, and other factors. In all, the researchers looked at seven factors that could contribute to the usability of the land. They found that the land initially converted to agriculture tended to be flat, low elevation, and close to roads. Weather around agricultural lands tended to be relatively cool and wet.

Armed with data about what makes good agricultural land, the researchers combined those factors with their land-use maps. They found that the forestland cleared for agriculture over the decade tended to be similar in those characteristics to the land developed at the beginning of the study period. Moreover, land on which agriculture was started but then abandoned during the study period tended to be significantly different from the initial land developed for agriculture, suggesting that land that deviates too much from those characteristics is less than ideal for agriculture.

Spera then set out to see how much land with those ideal characteristics remains in Mato Grosso. They found available land with those characteristics declined by as much as 40 percentage points over the decade.

Taken together, the results suggest that "a scarcity of high-quality land available for agricultural expansion may be influencing patterns of agricultural development in the region," the researchers write.

An understanding of the characteristics that make land suitable for agriculture could inform future policymaking, Spera said. "Maybe policies shouldn't be broad brush, but should take into account land suitability," she said. "Maybe the land that we know isn't well-suited for agriculture anyway should be prioritized for protection from deforestation."

Spera and her colleagues plan to continue monitoring land use changes across Mato Grosso. Understanding these patterns of change, the researchers say, could help manage Brazil's agricultural expansion in a way that helps to feed a growing world population while maintaining the
precious forests of the Amazon.

**More information:** Paper:
http://iopscience.iop.org/1748-9216/9/6/064010/article

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