Soy production indirectly drives Brazilian deforestation

A case for considering spatial dependence

Nikolas Kuschnig & Stefan Giljum

Institute for Ecological Economics, Vienna University of Economics and Business, Austria

FINEPRINT Brief No. 8, September 2019

Deforestation plays a crucial role in climate change and is related to a wide range of environmental and social impacts. In this Brief, we analyse the drivers of deforestation in Mato Grosso, Brazil, applying a spatial econometric model on the municipal level. We find significant spatial dependence in deforestation processes, with croplands, cattle density and dry climate being the most important drivers. Deforestation pressure from croplands, which are predominantly used for soy production, propagate via indirect spillovers across municipality borders. These considerable spillover effects would be neglected in traditional models that disregard spatial dependence.

The Amazon rainforest is the world's largest forest and provides a wide range of ecosystem services. It is an unparalleled biodiversity hotspot, essential to the livelihoods of rural and indigenous peoples and plays an important role in stabilising the regional and global climate. Deforestation is a threat to the continued provision of these services and thus a primary focus of environmental policy in countries sharing the Amazon. Yet, the rate of forest loss in Brazil has remained high (Figure 1). Whilst Brazil has long set the pace for curbing deforestation, latest developments have led to a paradigm shift. Vast forest fires in the Amazon have recently drawn international attention. The executive arm of the Ministry of the Environment and environmental policy in general have come under heavy criticism by the government [1] and protection laws were revoked. This hands-off approach of the national government further stresses the need to reveal incentives and drivers behind deforestation. With forests taking a key role in tackling a variety of future challenges, an understanding of deforestation dynamics is crucial for actors from the local to the global levels.

A large number of studies on deforestation employ econometric methods and/or take a spatially

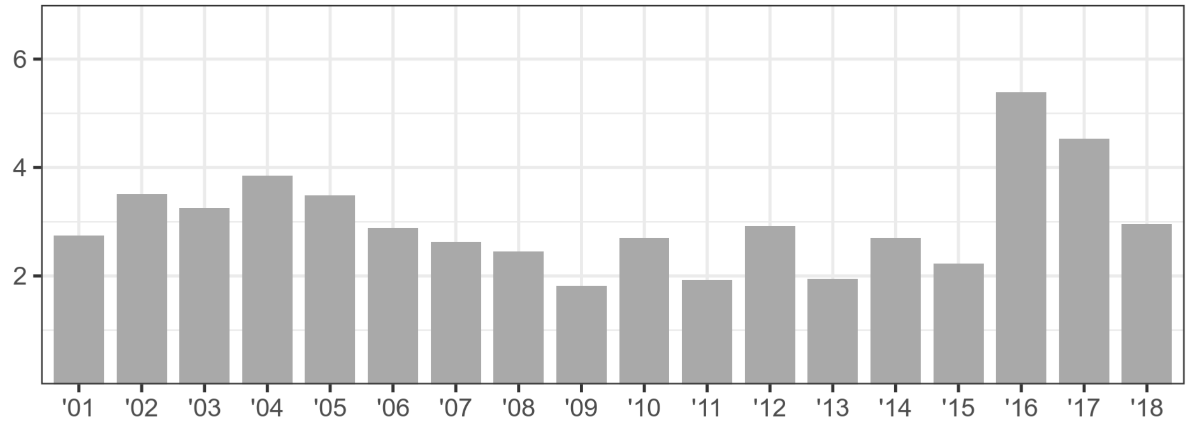

Figure 1: Forest cover loss in Brazil, 2001-2018, in million ha.

explicit approach. However, very few consider the underlying spatial dependence. Deforestation and land use dynamics in general have been found to contain significant spatial interactions that need to be accounted for in an econometric model. Disregarding spatial autocorrelation yields biased and inconsistent estimators, severely limiting the validity of results. Furthermore, the spatial dimension carries additional information, that may provide novel insights into deforestation dynamics and the transmission of effects.

In our work we examine the role of agriculture as a driver of deforestation in the state of Mato Grosso, Brazil. We apply a spatial econometric model, which considers the possibilities of spatial autocorrelation and heterogeneity, to panel data on the municipal level, ranging from 2006 until 2016. The use of high-resolution, remotely sensed land cover data by Camara et al. [2] (see Figure 2) means that our approach may be replicated and expanded – from general large-scale analyses to fine-scale investigations of local drivers. Investigations could even be carried out in unsurveyed regions with poor availability of conventional data.

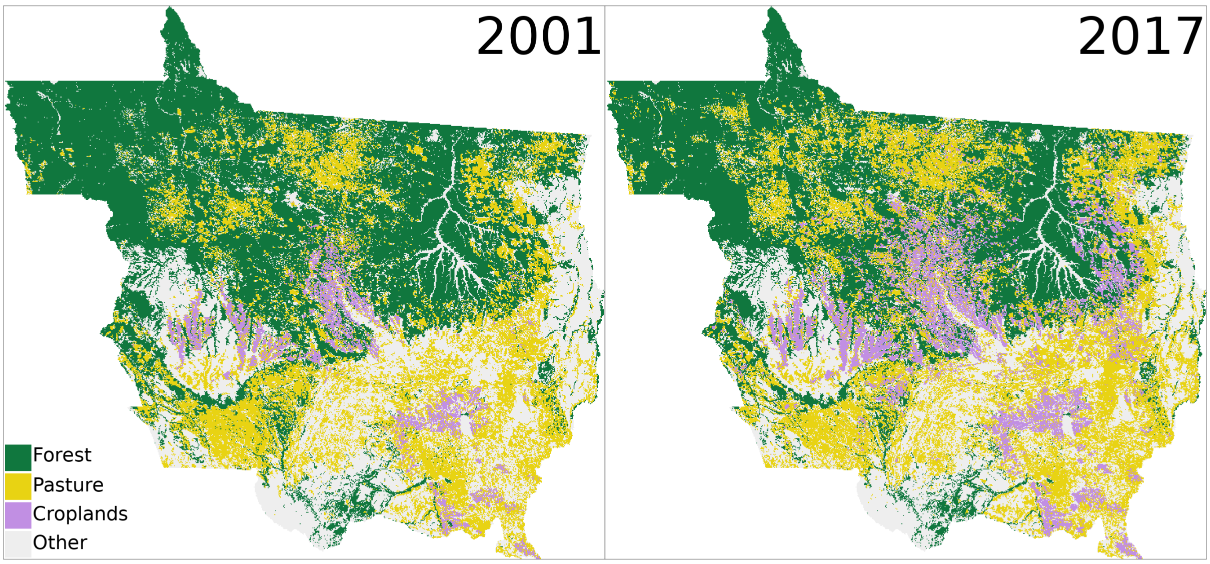

Figure 2: Land use cover in Mato Grosso, 2001 and 2017. Adapted from Camara et al., 2019.

Table 1: Estimation results of the SDM compared to reference models.

Variable	SDM-direct	SDM-indirect	SAR	SAR-indirect	CLM
Forest	-14,433 ***	-10,371 *	-12,339 ***	-23,07 ***	-17,007 ***
Pasture	-0,752 *	0,005	-1,064 ***	-1,99 ***	0,703
Croplands	-0,134	-10,907 ***	-1,708 ***	-3,195 ***	-2.367 ***
Population density	-0,002	0,012	0	0	-0,003
GDP per capita	0,001	0,005	0,001	0,002	0,001
Cattle density	-0,003 ***	-0,007 *	-0,003 ***	-0,006 ***	-0,004 ***
Soy yields	0,138 ***	0,05	0,131 ***	0,244 ***	0,148 ***
Wet	0,125 **	0,293	0,15 ***	0,28 ***	0,259 ***
Dry	-0,054 **	-0,02	-0,056 ***	-0,104 ***	-0,056 ***
Rho	0,774 ***		0,696 ***		
R^2	0,816		0,8		0,659

We specify a spatial Durbin model (SDM) with deforestation as the dependent variable. Results from our model are compared with those obtained from classical linear models (CLM) as well as spatial autoregressive (SAR) and spatial error models (SEM). Our specification allows for identifying global and local spillover effects across the borders of municipalities. These we analyse with the metrics of average direct and average indirect effect. Thereby, we are able to gain additional insights into the spatial structure of processes and the direct versus indirect impacts of various deforestation drivers.

For the data we rely on three sources: (1) Land cover change maps by Camara et al. [2] (Figure 2), providing variables such as deforestation, forest cover, croplands and pasture areas; (2) municipal statistics by the Brazilian Statistical Office IBGE, including population data, gross domestic product and agricultural data; (3) the Standardised Precipitation-Evapotranspiration Index (SPEI) [3], a multi-scalar drought index that is factored in to control for variations of climatic conditions.

A first visual interpretation of the dynamics of deforestation in Mato Grosso can already be taken from Figure 2. The expansion of agricultural crop production was mainly located in areas with high density of pastures, rather then forests. This general finding is supported by our estimation results, illustrated in Table 1. First off, we find that deforestation displays strong spatial autocorrelation, meaning that regions that are close to each other tend to have similar deforestation rates. To control for this, our model additionally includes deforestation and possible drivers from neighbouring regions. The deforestation drivers identified by our approach are generally consistent with the literature [4], but reveal additional detail about the spatial relations. Croplands and thus soy production drive deforestation indirectly, i.e. expansion of croplands in one municipality has a significant effect on deforestation in neighbouring municipalities. Increasing soy production does not rely directly on deforested areas, but stems from pastures instead. With constant or growing herd sizes these are then displaced to other regions, causing deforestation. In contrast to the indirect effect of crop production, cattle density, dry climate and initial forest cover have direct impacts.

Table 1 also compares the results of our spatial Durbin model (SDM) with those from other, conventional models. The spatial lag model does not seem to fully capture the spillover effects from croplands, while the classical linear model fully ignores them. Notably, neither population density and GDP per capita show any relationship to deforestation whatsoever. Instead, Mato Grosso is shaped by international market forces [5], with land use for soy and beef being determined via economic incentives. This is hard to reconcile with the notion of a deforestation Kuznet's curve. Our results suggest that vast land requirements for producing export commodities and related deforestation may simply be shifted to more remote regions.

These findings carry important implications for future studies and policy evaluations. Any econometric investigation of deforestation needs to examine spatial dependence and potentially control for it, on account of problematic estimators. This can be done in a rather straightforward fashion, improves the model fit significantly and may yield additional insights that remain hidden in classical models. In the case of deforestation it is paramount to consider both direct and indirect drivers. The efficacy of REDD+ implementations or supply-chain interventions, such as the soy moratorium, can only be assessed properly with both aspects in mind.

All code used for this work is openly available under the GNU General Public License (GPL-v3) license at https://github.com/fineprint-global/defor_sp. All data used is available publicly.

Update March 2020: Estimation is now performed using Bayesian methods for all models. Some previous results suffered from a bug in the construction of fixed effects. This led inter alia to insignificant coefficients for croplands.

Citation

Kuschnig, N., Giljum, S., 2019. Soy production indirectly drives Brazilian deforestation. A case for considering spatial dependence. FINEPRINT Brief No. 8. Vienna University of Economics and Business (WU). Austria.

References

[1] Escobar H. Brazilian institute head fired after clashing with nation's president over deforestation data. Science Magazine 2019. doi:10.1126/science.aay9857.

[2] Camara G, Picoli M, Maciel A, Simoes R, Santos L, Andrade PR, et al. Land cover change maps for Mato Grosso state in Brazil: 2001–2017 (version 3) 2019. doi:10.1594/PANGAEA.899706.

[3] Vicente-Serrano SM, Beguería S, López-Moreno JI. A multiscalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index. Journal of Climate 2010;23:1696–718. doi:10.1175/2009jcli2909.1.

[4] Busch J, Ferretti-Gallon K. What drives deforestation and what stops it? A meta-analysis. Review of Environmental Economics and Policy 2017;11:3–23.

[5] Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, et al. The causes of land-use and land-cover change: Moving beyond the myths. Global Environmental Change 2001;11:261–9. doi:10.1016/s0959-3780(01)00007-3.