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Patterns and processes of pasture to crop conversion in Brazil: Evidence from Mato Grosso State

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ABSTRACT

The rate and location of cropland expansion onto cattle pastures in Brazil could affect global food security, climate change, and economic growth. We combined mapping, statistical modeling, and qualitative methods to investigate patterns and processes of pasture to crop conversion (P2C) in Mato Grosso State (MT), Brazil, a globally important center of agricultural production. P2C land constituted 49% of cropland expansion from 2000 to 2013. For a random sample of ~250 m pixels in MT, we estimated a regression model skilled at predicting P2C land in the rest of the state as a function of cattle ranching suitability, cropping suitability, and P2C conversion costs. Surprisingly, just 1/7 of pasture agronomically suitable for cultivation had undergone P2C. Hedonic regressions revealed that agronomic characteristics of land were associated with less than 20% of the variation in cropland suitability. Instead, the majority of the variation stemmed from a combination of proximity to agricultural infrastructure, characteristics of neighboring lands, and time fixed effects. The weak relationship between agronomic characteristics of land and P2C location suggests a less certain future for P2C than projections made with agronomic models. Consequentially, complications may arise for greenhouse gas mitigation policies in Brazil predicated on widespread expansion of cropland on pasture vs. natural areas. Our follow-up qualitative research shows that because P2C has often involved land rentals or sales, poorly functioning land institutions may have constrained P2C. Locally poor land quality, omitted from agronomic P2C predictions, can either catalyze or constrain P2C by limiting returns to ranching, farming, or both. Interventions to control rates and locations of P2C should take these insights into account.

1. Introduction

Expansion of agricultural areas and more recently agricultural intensification have transformed Mato Grosso, Brazil (MT) into a globally important center of agricultural production (Brando et al., 2013). Advances in tropical crop breeding, abundant land, lax land governance, several periods of high international soybean prices, and a weak national currency, all helped prompt the value of agriculture production in MT to increase roughly fivefold from 1990 to 2013 (Brazilian Institute of Geography and Statistics, 2013; Chaddad and Jank, 2006; Nepstad et al., 2014; Richards et al., 2012).

Increases in production in MT stem from agricultural intensification and extensification, two ongoing processes that have both shared and distinct drivers. For example, novel crop varieties adapted to tropical conditions have enabled intensification of agricultural production and facilitated the establishment and expansion of farm holdings in the region (Chaddad and Jank, 2006). In recent years, changing land prices, anti-deforestation policies, and a scarcity of remaining high quality land have combined to cause agricultural intensification to comprise an increasing share of production growth relative to agricultural extensification (Hargrave and Kis-Katos, 2013; Nolte et al., 2013; Soares-Filho et al., 2006; Spera et al., 2014).

Pathways of agricultural intensification observed in MT include increased cropping frequency, increased yields in mechanized agriculture, cattle ranching intensification, integration of crop and livestock systems, and – the focus of this paper – conversion of cattle pastures to cropland (P2C). P2C may involve not only the

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landholder, but also a renter or potential buyer. It can happen through "self-conversion" (where a rancher undertakes the conversion herself); "renting" (a rancher rents all or part of his land to a farmer); and "selling" (a rancher sells all or part of her land to a farmer). P2C is conducted on entire farms or parts of them and can be reversed in response to changing conditions.

Typically, the value of production per hectare of crop farming in Northern Brazil is greater than the value of cattle ranching production (Richards et al., 2014). Thus, relative to cattle ranching, crop farming might promote regional economic development (VanWey et al., 2013). The higher value and heightened export orientation of soybeans vs. beef could also increase the value of Brazil's exports (Chaddad and Jank, 2006; VanWey et al., 2013; Weinhold et al., 2013). Agricultural expansion onto low-productivity pastures, might also help to restore soil fertility, impel neighboring pastures into more intensive cultivation, and spare land from deforestation (Gil et al., 2015). Critics have argued that P2C does not necessarily ensure economic development, that large-scale crop farming may foster local environmental degradation and social pressure, and that the effect of P2C on deforestation rates through land sparing is ambiguous.

P2C might indeed decrease deforestation provided that agriculture intensification leads to less agricultural land used elsewhere through an agricultural commodity price effect (Cohn et al., 2014). More P2C, however, might also increase deforestation through a farmer income effect—particularly if effective forest protection policies are not in place (Angelsen, 2010; Rudel et al., 2009).

Nevertheless, P2C is projected to deliver 10–90% of the GHG emission reduction target defined under Brazil's National Climate Action Plan (PNMC) (Cohn et al., 2011). For its potential contribution to climate change mitigation, P2C is also eligible for preferential loans under programs of Brazil's "Low-Carbon Agricultural Plan." Of the six loan categories in the plan, four are designated for activities associated with elements of P2C: nitrogen fixation, restoration of degraded pastures, low-tillage agriculture, and integrated crop, livestock, and/or forestry systems (Brazil, 2014).

Several recent studies find enormous agronomic potential for P2C across Brazil, including in MT (Alkimim et al., 2015; da Silva, 2014; Gibbs et al., 2015; Graesser et al., 2015; Martini et al., 2015). One study finds that of MT's 25 million hectares of cattle pasture, 11 million hectares have the potential to be converted to cropland (da Silva, 2014). If all pasture area classified as suitable were converted, the cropping area in MT would more than double. Another study suggests that as many as 13 million hectares of additional soy expansion could occur in MT on non-natively vegetated lands, a substantial share of which would likely be pasture (Gibbs et al., 2015).

The biophysical characteristics of recent cropland expansion in the state have been shown to be substantially less suitable for farming than those of previously converted lands (Morton et al., 2016; Spera et al., 2014). It appears that the decline in suitability is not strictly due to scarcity of remaining high quality lands (Morton et al., 2016; Spera et al., 2014) or land governance (Hargrave and Kis-Katos, 2013; Soares-Filho et al., 2014). A great deal of the converted land has been far less suitable than large areas of potentially available cropland in the state (Morton et al., 2016; Spera et al., 2014). This pattern is a departure from theory and is a key motivation for our analysis—if these lands are not highly agronomically suitable in either absolute or relative terms, what explains why producers are converting them as opposed to other lands? We hypothesize that socio-economic and institutional variation has played a critical role in explaining the pattern and rate of P2C. But, apart from certain socio-economic variables such as land prices (Richards et al., 2014) and market access (Pfaff, 1999), this role has largely been left unexplored in many studies of agricultural expansion. We thus have adopted a mixed methods approach designed to consider and compare a wide array of socio-economic and biophysical determinants of P2C in Mato Grosso.

Our research entailed four complementary data collection activities—a comparison of satellite maps of land use, a statistical analysis of the likelihood of pasture to crop conversion, cattle rancher and crop farmer focus groups, and qualitative interviews with agricultural experts. First, we assembled the most complete mapping of land that has undergone P2C in Mato Grosso. This mapping reveals the amount of P2C land, whether it has persisted as cropland, and how P2C lands compare to the rest of cattle pasture and cropland.

We next investigated the geographic drivers of the spatial patterns of P2C mapped. We adapted a statistical approach detailed in (Irwin and Geoghegan, 2001) which the decision to maintain cattle pasture or convert it to mechanized cropland is a discrete choice where each pixel is expected to have the profit maximizing land use, given a set of agronomic characteristics, centrality with respect to cities and agricultural infrastructure, the characteristics of neighboring pixels, and whether the pixel is found in a protected area. We examined the sensitivity of model results to controls for pasture to crop conversion costs, investigated the predictive skill of the estimated model, and mapped the likelihood that remaining pastures in MT would be converted to cropland.

The large and heterogeneous influence of variables not easily represented in this type of model, such as land institutions and rural producer characteristics, is likely to lead to discrepancies between observed P2C and the P2C likelihood modeled. Thus, in parallel, to further elucidate P2C mechanisms and patterns, we undertook farmer focus groups and semi-structured interviews with agricultural experts. We also conducted follow up quantitative analyses designed to further investigate key themes that emerged from the qualitative results. We close by addressing several of these themes as a way of comparing findings and claims from across research activities.

2. Material and methods

Our research sought to synthesize complementary quantitative and qualitative approaches to investigate the determinants of, and the potential for, P2C in Mato Grosso, Brazil. For some variables, we obtained results from multiple methods, enabling cross-comparison and assessment of the level of agreement or disagreement. Table 1 shows the variables on which each method focuses. Research for the paper was conducted over the period March 2014–September 2014 by the authors and by agricultural consultants trained by the authors.

2.1. Past P2C land map

We developed a land use dataset containing annual thematic land use maps for Mato Grosso State over the period growing year 2000–2001 (2000/01) to 2012/13. The dataset contains cattle pasture areas ("Past") for the years 2000/01 to 2003/2004, 2007/2008, and 2009/10; and mechanized cropland areas ("Crop") for the years 2001/02 to 2010/11 and 2012/13. We used ArcMap 10.2 to harmonize the projection and pixel size of the cropland and pastureland maps, exported them as ASCIIs, imported the ASCIIs into Stata, and created a Stata dataset containing one observation for each 250 m pixel-year (n = 16,007,297; t = 13). We used Stata to generate a new variable indicating pixels classified as cropland in year t and classified as pasture during one or more years during the period t-1 to 2000/01 ("P2C").

The pasture data merges three datasets. The first was released in 2002 as part of PROBIO, an effort organized by the Brazilian government to perform supervised classification of all land use and