INSIGHTS

# THE DYNAMICS OF AGRICULTURAL TECHNOLOGY ADOPTION IN BRAZIL

## EVIDENCE SHOWS THREE DISTINCT PATTERNS OF TECHNOLOGY UPTAKE

One of the most important issues for Brazil is how it will continue to meet the increasing demand for food while protecting its natural resources. Understanding which modern technologies and farming practices increase productivity without pressuring forests is key to resolve this tension. Nevertheless, **the absence of up-to-date information on the use of inputs and technologies at disaggregated levels has severely limited knowledge about how farming practices have evolved and what their relationship is with productivity and deforestation.**

This new report from INPUT researchers at Climate Policy Initiative (CPI/PUC-Rio) aims to fill this gap. It leverages recently released municipality-level information from Brazil's 2017 Agricultural Census to describe the evolution of three agricultural practices typically connected with processes of agricultural intensification: direct planting system (DPS, a modern soil conservation technique also known as direct seeding), tractors, and fertilizers.

Findings reveal a diverse pattern among farmers' use of the technologies throughout the country. While direct seeding remains concentrated in crop producing municipalities, its use is becoming more widespread throughout the country. The use of tractors has more become concentrated throughout the country. Finally, while fertilizer use has has dispersed throughout the county, its spatial concentration is neither increasing nor decreasing.

While the three technologies analyzed in this report are connected with processes of agricultural intensification, their determinants[1] and subsequent environmental consequences[2] vary. This report provides an initial look at the important questions surrounding the evolution of agricultural practices in Brazil and provides a better understanding of what might be needed to better tailor policies to promote sustainable growth in the country's agricultural sector.

1 Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. Annual Review of Economics, 2(1), 395-424.

2 Galloway, J. N., Townsend, A. R., Erisman, J. W., Bekunda, M., Cai, Z., Freney, J. R., ... & Sutton, M. A. (2008). Transformation of the nitrogen cycle: recent trends, questions, and potential solutions. Science, 320(5878), 889-892.

# UNDERSTANDING PRODUCTIVITY FROM THREE ANGLES

The increases in agricultural productivity observed in Brazil over the last decades have been accompanied by increases in the use of machines, fertilizers, herbicides, GMO seeds, and modern soil conservation practices. For instance, in the last decade, the sales of tractors and harvesters increased from 23,000 to 40,700 units per year while the consumption of nitrogen-based fertilizers increased from 24.4 to 34.4 million tons per year. Moreover, the area cultivated using the DPS increased from 17.8 to 32.8 million hectares.

Because differences in technology use are known to be a significant driver of differences in productivity across countries and regions, understanding the regional heterogeneity in these processes is important to explain the differences in agricultural productivity throughout the country.3 Moreover, understanding whether technology use is converging (i.e., becoming more widespread across municipalities) or diverging (i.e., becoming more concentrated across municipalities) helps to target policies aimed at promoting the diffusion of technology, such as technical assistance and dissemination of information. Thus, this report not only maps the diffusion of agricultural practices but it also studies whether their use is converging or diverging.

## 1. Direct Planting System (DPS)

The DPS is a no-till farming technology developed in south of Brazil in the 1970s. The limited use of tillage in this technology reduces soil degradation and the loss of nutrients, thereby increasing carbon sequestration, reducing costs and boosting productivity.[4] Despite these benefits, only 17.4% of the cropland was cultivated using the DPS in 2006. Moreover, most of the cropland cultivated using this technology was concentrated in selected municipalities located in the south of Brazil.

**In the country as a whole, the percentage of cropland cultivated using direct seeding increased from 17.4% to 38.8% between 2006 and 2017.**

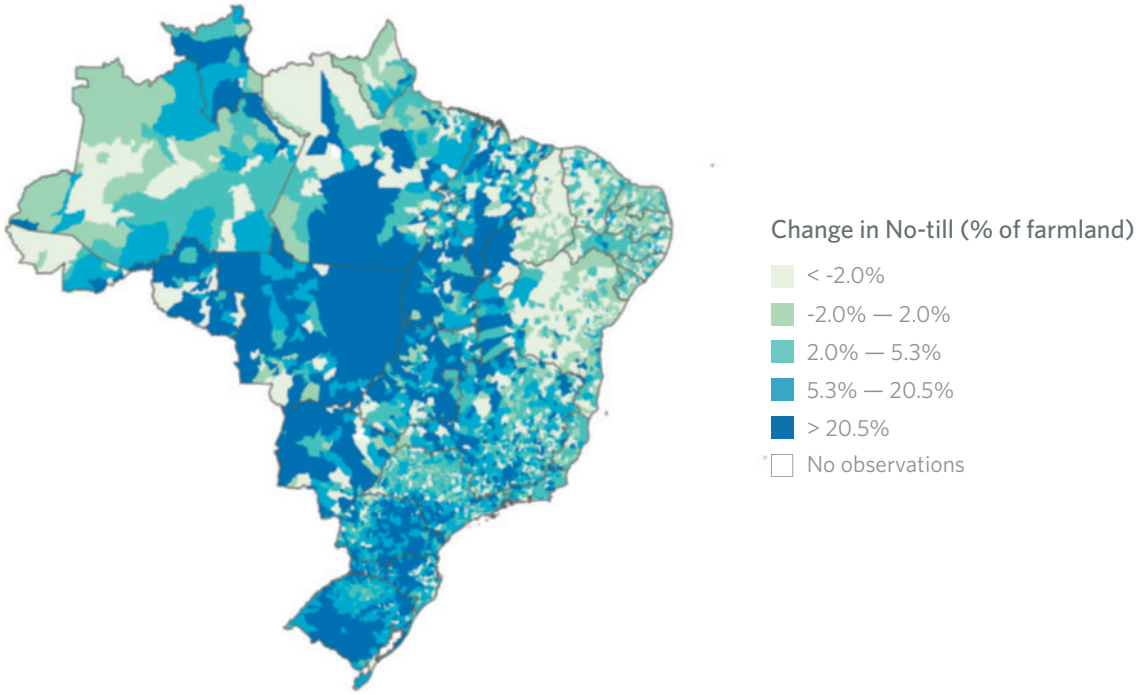
Figure 1 illustrates the evolution of DPS use in Brazil from 2006 to 2017. The dark blue municipalities show those where the growth in DPS use is highest while the light green municipalities represent those where the growth in DPS use is the lowest. In the country as a whole, the percentage of cropland cultivated using this technique increased from 17.4% to 38.8%. The largest increases in DPS use are concentrated in crop producing municipalities located in the Center-West and Matopiba regions. There were also strong increases in DPS use in the southern regions of Brazil that underused this technology in 2006 (e.g., the municipalities in the southern part of the state of Rio Grande do Sul). These patterns suggest that, while DPS remains concentrated in crop producing regions, it use is converging in the country. Indeed,

3 Comin, D., & Hobijn, B. (2010). An exploration of technology diffusion. American Economic Review, 100(5), 2031-59.

4 Baker, C. J., Saxton, K. E., Ritchie, W. R., Chamen, W. C. T., Reicosky, D. C., Ribeiro, F., ... & Hobbs, P. R. (2007). No-tillage Seeding in Conservation Agriculture. FAO, 2nd edition.

econometric analysis shows that the DPS intensity increases more in municipalities that had a lower DPS intensity in 2006. This suggests that producers are being able to overcome the informational barriers that are commonly perceived as the main constraint for the diffusion of this method.[5]

**Figure 1:** Change in the Use of Direct Planing Systems (DPS) in Brazil, 2006-2017




***Note:*** *The figure plots the change, between 2006 and 2017, in the share of farmland cultivated using DPS (Direct Planting System) computed using data from the Agricultural Census.*

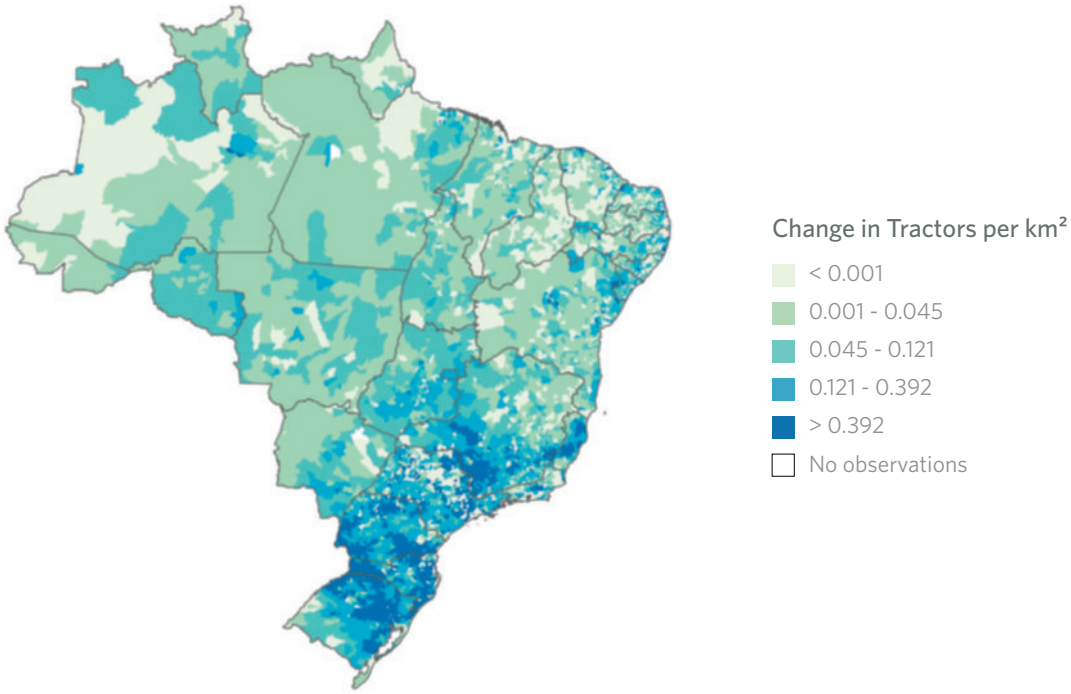
## 2. Tractors

The process of agricultural intensification is typically associated with increases in mechanization of agricultural activities. Because tractors are one of the most common machines used in farming activities, tractor use is an important proxy for the mechanization of agriculture. Over the period from 2006 to 2017, the density of tractors increased from 0.25 to 0.35 in the country as a whole, meaning that the average municipality experienced an increase from 315 to 500 tractors. Figure 2 shows the spatial distribution of the evolution of the number of tractors per square kilometers in this period. The municipalities from the richest and the more urbanized areas in the South and Southeast experienced the largest increases in tractor density.

5 Assunção, J., Bragança, A., & Hemsley, P. (2018). Geographic Heterogeneity and Technology Adoption. Working Paper. Available at https://www.dropbox.com/s/7hafjpcs1o0mqou/Geography_Adoption.pdf?dl=0

Nevertheless, these municipalities are exactly the ones where agriculture was already more mechanized to begin with. This indicates that tractor use is diverging (becoming more concentrated) across the country. **Using econometric models, researchers show that the difference in tractor use between municipalities with relatively high (75th percentile) and relatively low (25th percentile) tractor use increased in about 20% from 2006 to 2017.**

**Figure 2:** Changes in Tractor Density in Brazil, 2006-2017




***Note:*** *The figure plots the change, between 2006 and 2017, in the density of tractors computed using data from the Agricultural Census.*

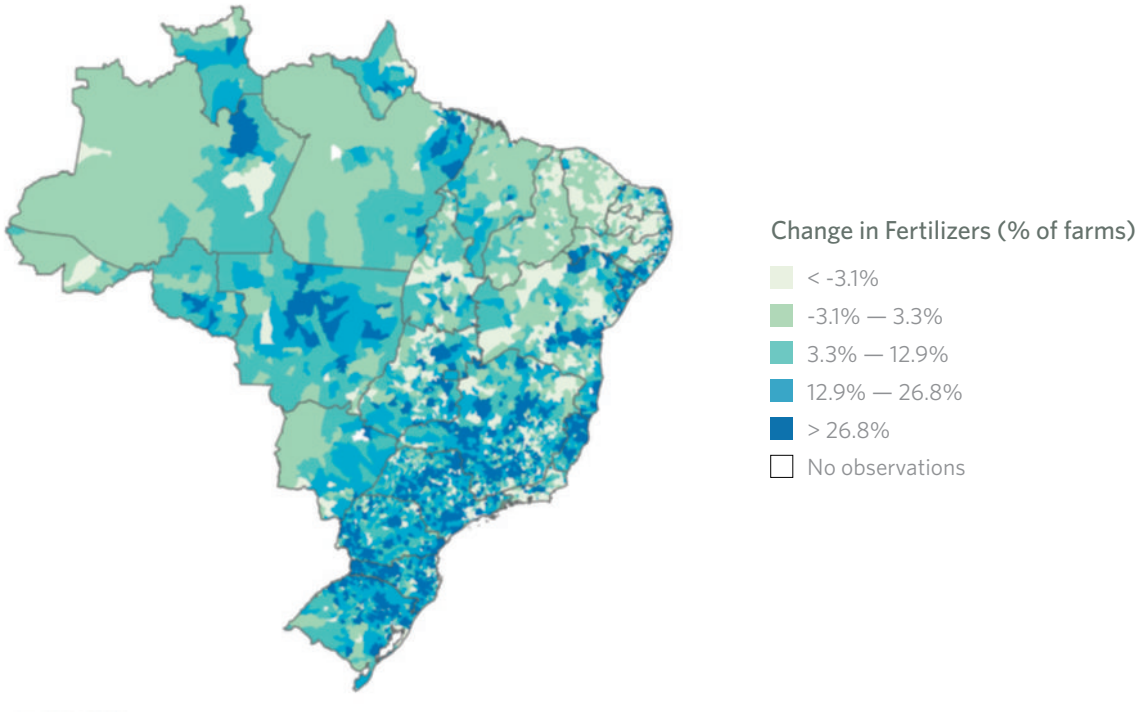
## 3. Fertilizers

**The share of farmers who use fertilizers increased from 25% to 35% over the study period. Its growth however does not have a clear spatial pattern.**

Fertilizer use also plays an important feature of agricultural intensification. In Brazil, specifically, the growth of modern agriculture to regions with poorer soils like the Cerrado is closely tied to increases in the use of fertilizers.[6] Figure 3 reports the evolution of the share of farmers who use fertilizers from 2006 to 2017. In the country as a whole, this share increased from 25% to 35%. However, in contrast to DPS and tractors, the growth in fertilizer use does not have a clear spatial pattern. Municipalities with the strong growth in fertilizer use are scattered in different regions of the country in areas as diverse and the Cerrado lands from the center of the state of Mato Grosso and in the irrigated Caatinga lands in the border of the states of Bahia, Pernambuco, and Sergipe. Furthermore, econometric models point out that fertilizer growth is not connected with initial fertilizer use.

6 Assunção, J., & Bragança, A. (2015). Technological Change and Deforestation: Evidence from the Brazilian Soybean Revolution. INPUT Working Paper. Available at https://www.inputbrasil.org/wp-content/uploads/2015/08/Technological_Change_and_Deforestation_Working_Paper_CPI.pdf

**Figure 3:** Changes in Fertilizer Use in Brazil, 2006-2017




***Note:*** *The figure plots the change, between 2006 and 2017, in the share of farms using chemical or organic fertilizers computed using data from the Agricultural Census.*

# DISCUSSION

## TECHNOLOGY USE AND PRODUCTIVITY

Although much is understood about the dynamics of land use and agricultural production in Brazil, the role technologies play in enabling farmers to increase their productivity remains unclear. This study shines light on farm-level technologies by tracking the adoption of three important technologies connected to high productivity agriculture: DPS, tractors, and fertilizers.

Using newly released data on agricultural practices from Brazil's 2017 agricultural census, this report documents completely different trends in the diffusion of these three technologies. These divergent trends raise important questions for policymakers. Which policies have enabled farmers to overcome the informational barriers that constrained the diffusion of the DPS until 2006? Which constraints have blocked the diffusion of tractors throughout the country? What is driving the increases in fertilizer us? Furthermore, it is important to understand the environmental impacts of these different practices in terms of soil degradation, fire incidence, and, ultimately, deforestation. Hence, this study opens up an important agenda for discussing agricultural practices and their relationship with sustainability in Brazil's agricultural sector.

# CONCLUSION

The use of technology can dramatically increase productivity, but little is known about how these technologies may be changing Brazil. This makes setting policy and improving conditions for farmers to boost productivity and protect Brazil's natural resources more difficult. This report provides first glimpses into the diffusion of important technologies throughout the country. The findings indicate very different patterns in the use of modern agricultural practices and inputs among farmers in Brazil.

While DPS is becoming more widespread used throughout the country, tractors are becoming more concentrated in the wealthier and more urbanized regions. These divergent patterns bring important questions for future research. With regard to DPS, it is important to understand which conditions helped DPS to diffuse throughout the country and which public policies might help to speed this diffusion process. With regard to tractors, it is important to understand whether the concentration of tractors is reflecting actual demand for mechanization or not. Finally, investigating the effects of these different patterns of agricultural intensification on productivity and deforestation is an important will surely highlight opportunities and tradeoffs for agricultural and environmental policies in Brazil.

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*The Land Use Initiative (INPUT – Iniciativa para o Uso da Terra) is a dedicated team of specialists who work at the forefront of how to increase environmental protection and food production. INPUT engages stakeholders in Brazil's public and private sectors and maps the challenges for a better management of its natural resources. Research conducted under INPUT is generously supported by the Children's Investment Fund Foundation (CIFF) through a grant to the Climate Policy Initiative. This work was supported in part by the World Wildlife Foundation (WWF).*
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