Mapping Soybean Expansion in South America and Modeling Socioeconomic Drivers

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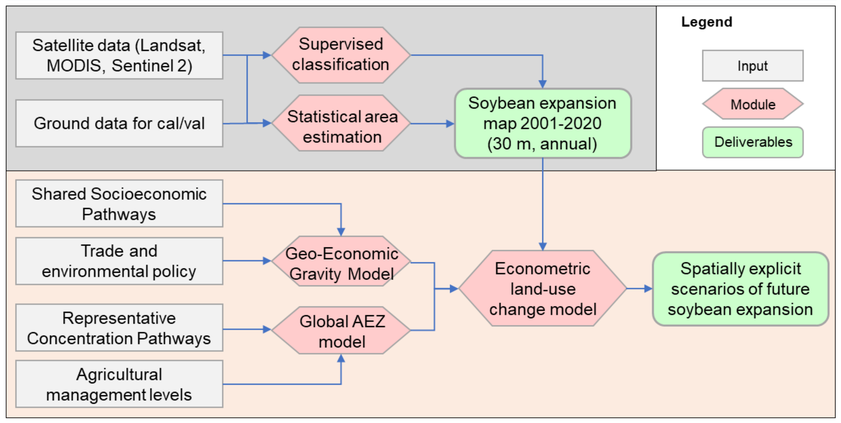
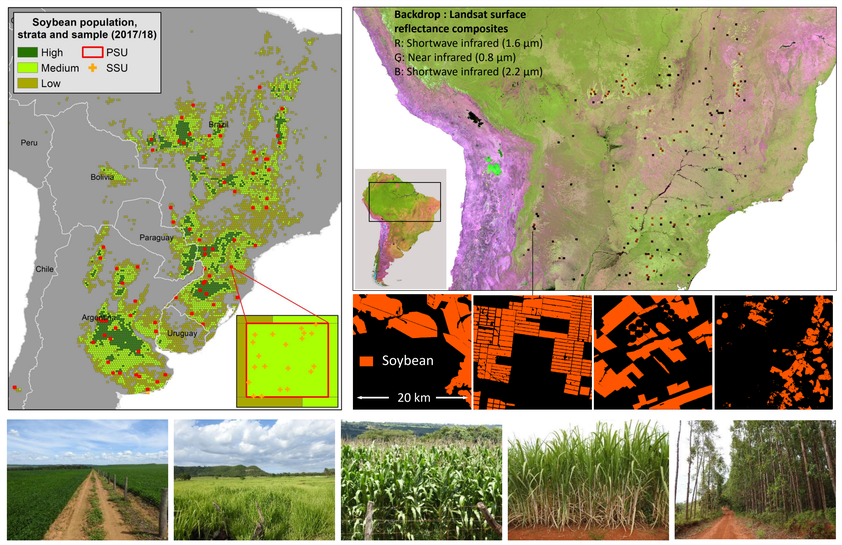
Research highlights

- Implemented an operational method for continental-scale crop area estimation and wall-to-wall mapping.
- Mapped soybean at 30 m over South America for every year between 2001 and 2022.
- Field data were collected over multiple years for training and map validation (92% OA).
- Mapped soybean yield at 30 m over Brazil 2001-2020.
- Simulated soybean expansion using a land-share model and a range of biophysical and socioeconomic variables.
- Amazon Soybean Moratorium reduced soy expansion in forests. Soybean expansion in the Cerrado is 3–8 times higher than a counterfactual control in the Amazon.

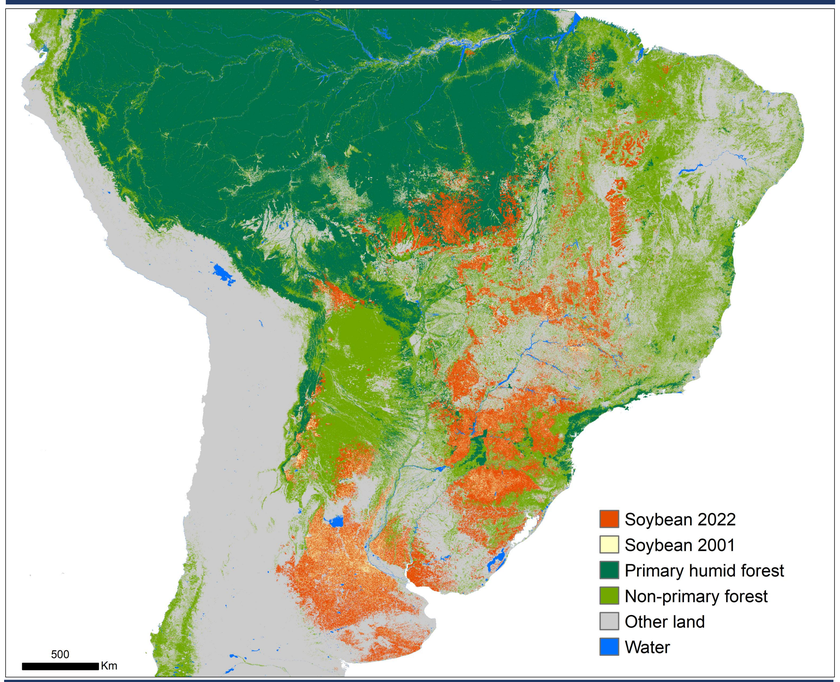
Overall method



Field data collection and mapping

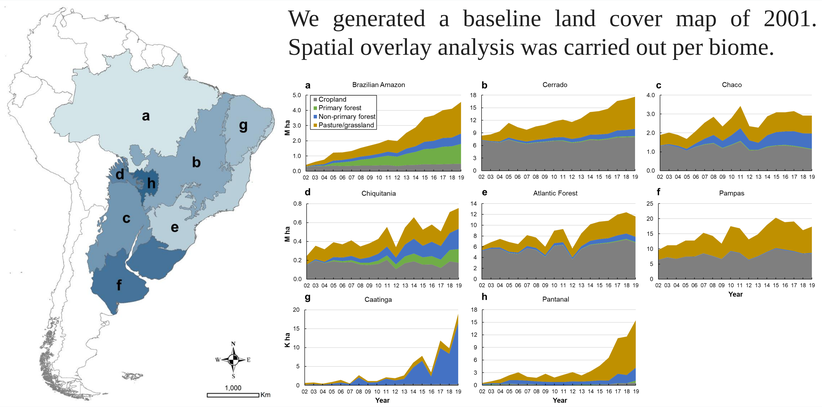


Annual Soybean Map 2001-2022



Land Source Attribution

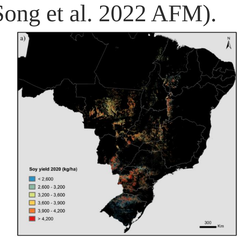
We generated a baseline land cover map of 2001. Spatial overlay analysis was carried out per biome.

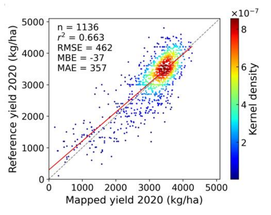


Soybean yield mapping

We used municipal yield statistics as reference for training. Landsat, MODIS data, topographic features, climate data (1971-2000), in-season weather data (2001-2019) and soil variables were used as inputs to random forests models. We applied the models trained on 2001–2019 data to 2020 data and produced a soybean yield map for 2020, demonstrating the predictive capability of trained machine learning models for operational yield mapping (Song et al. 2022 AFM).

Variable category	Importance in RF models
Landsat	0.1883
MODIS	0.4371
Climate	0.1037
Weather	0.2539
Topographic	0.0041
Soil	0.0128





Economic LUC Modeling

Satellite-based soybean expansion maps were aggregated to the municipality scale for land-use modeling. We collected various socioeconomic datasets including soybean and forest productivity return, population density, GDP per capita, road density, as well as biophysical datasets including elevation, slope, temperature, precipitation, and shortwave radiation. We run non-spatial, spatial lag and spatial error panel models to simulate soybean expansion in Brazil.

$$d_{it} = \exp(\beta_0 + \beta_1 RSoy_{it-1} + \beta_2 RF_{it-1} + \beta_3 C'_{it} + \beta_4 B'_i + \beta_5 E'_{it} + \lambda_t + \alpha_b + \varepsilon_{it})$$

(i) d_{it} is the area of soybean expansion into natural forest at municipality i over year t and $t+3$

(ii) $RSoy_{it-1}$ and RF_{it-1} are the soybean return and forest return

(iii) C'_{it} is a vector of climate factors which contribute to yearly variations in the crop yield

(iv) B'_i and E'_{it} are vectors of biophysical and socioeconomic variables respectively which characterize the biophysical and socioeconomic features of municipality i and jointly function as proxies of various costs

Major results: Soybean cultivation is significantly stimulated by the economic revenue of soybean; Amazon Soybean Moratorium decrease the soybean expansion in forests by 16.5%-27.6%; Soybean expansion tends to occur in municipalities with relatively high incomes; Soybean expansion in Cerrado is 3.3 – 8.3 times higher than a counterfactual control in the Brazilian Amazon.

Future work will be focused on applying the calibrated land-share models to project spatially explicit scenarios of future soybean expansion.

Acknowledgments

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Publications:

Song, X.-P., Hansen, M.C., Potapov, P.V., Adusei, B., Pickering, J., Adami, M., Lima, A., Zalles, V., Stehman, S.V., Di Bella, C.M., Conde, M.C., Copati, E.J., Fernandes, L.B., Hernandez-Serna, A., Jantz, S.M., Pickens, A.H., Turubanova, S., & Tyukavina, A. (2021). Massive soybean expansion in South America since 2000 and implications for conservation. *Nature Sustainability*, 4, 784-792

Song, X.-P., Li, H., Potapov, P., & Hansen, M.C. (2022). Annual 30 m soybean yield mapping in Brazil using long-term satellite observations, climate data and machine learning. *Agricultural and Forest Meteorology*, 326, 109186