



Soybean Expansion in South America: Quantifying Historical Land-Use Change, Modeling Socioeconomic Drivers and Projecting Future Trajectories

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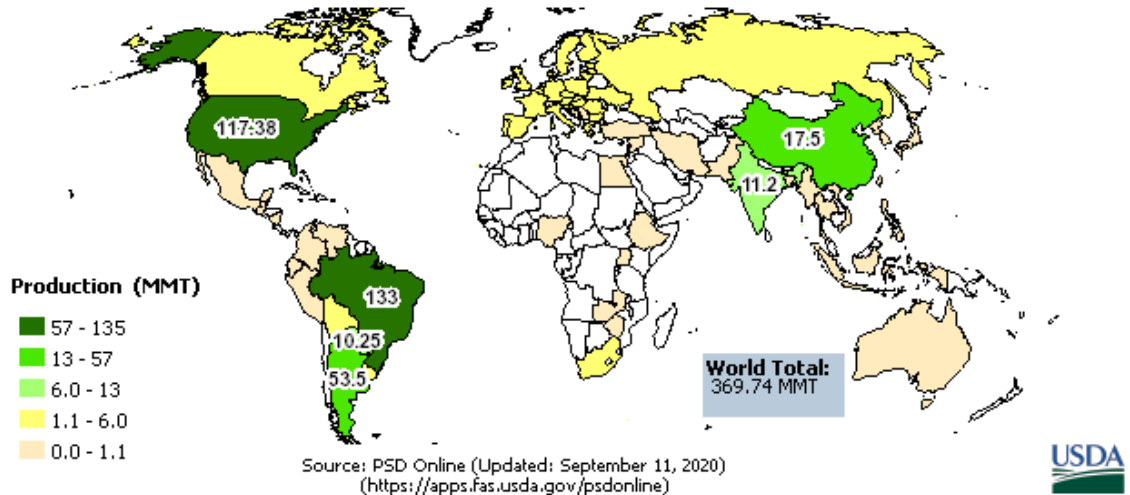
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Rapid Soybean Expansion in South America

53% of world's soybean production is in South America

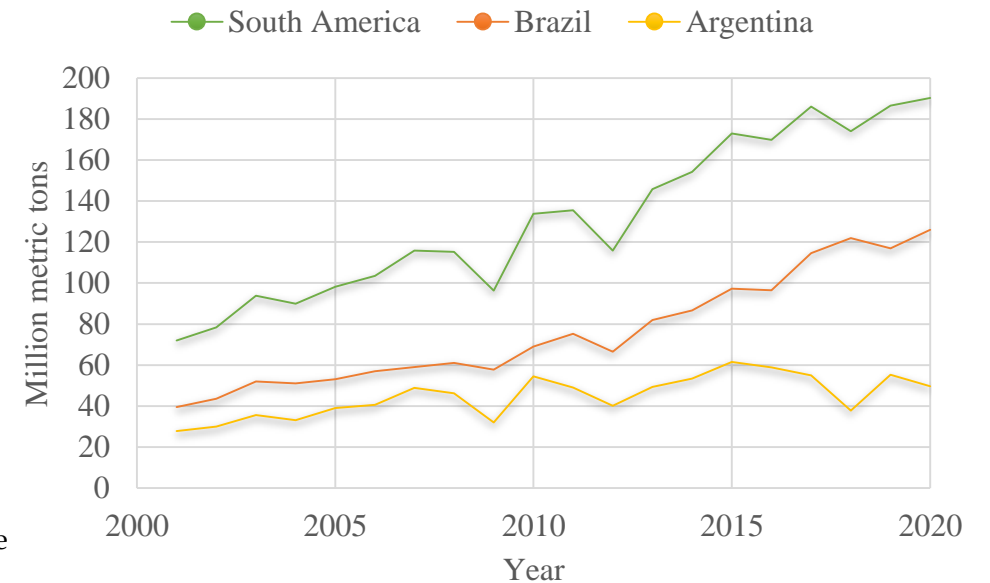
Soybean production in South America nearly tripled from 2000 to 2020

2020/2021 Oilseed, Soybean Production



Source: USDA Foreign Agricultural Service

Annual Soybean Production



Robust International Drivers

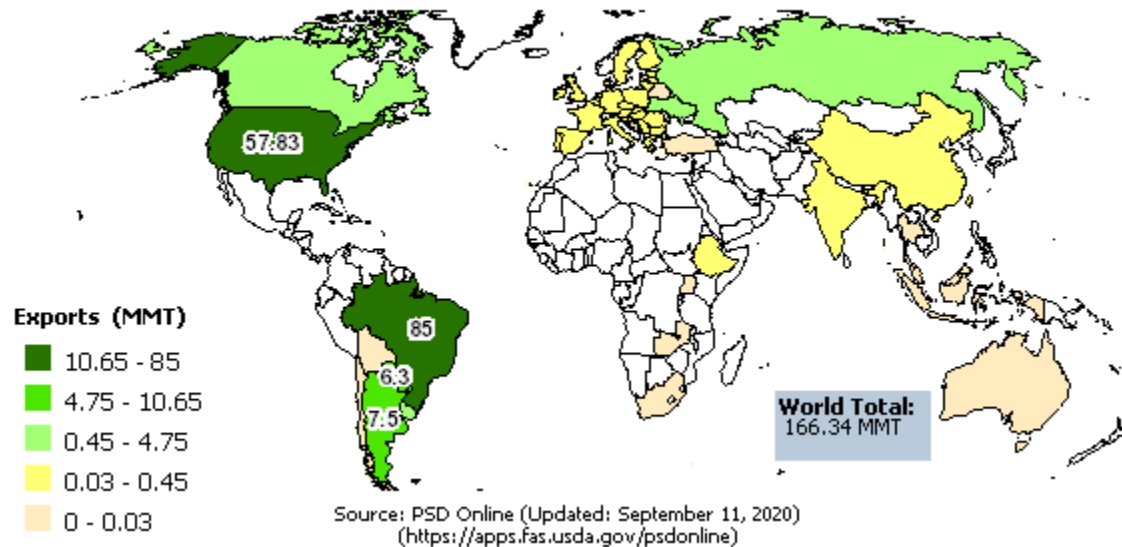
Exports

50% of USA soybean production
60% of Brazil soybean production

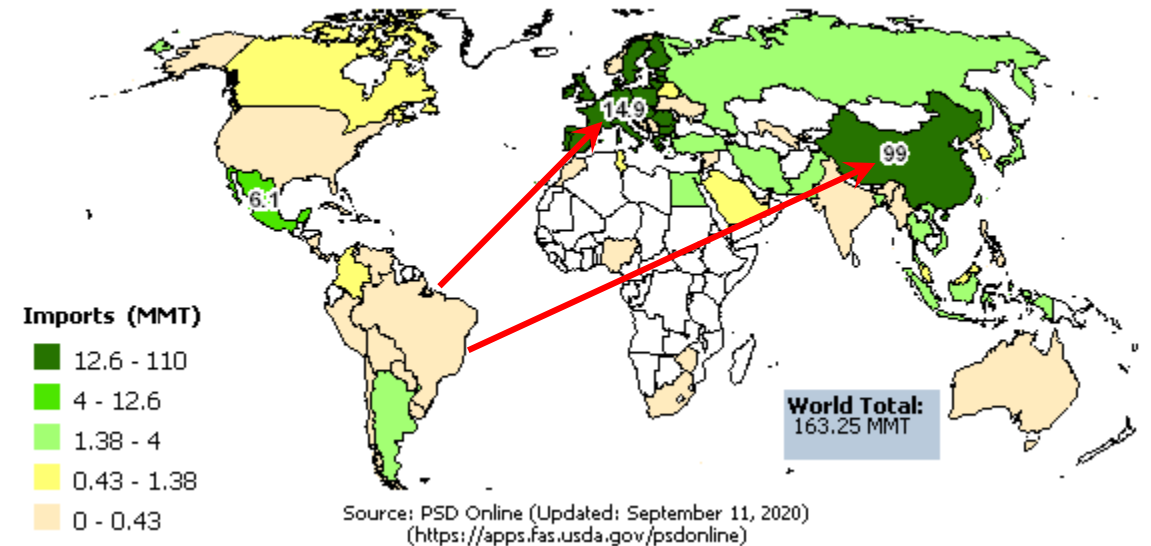
Imports

60% of USA soybean exports to China
80% of Brazil soybean exports to China

2020/2021 Oilseed, Soybean Exports

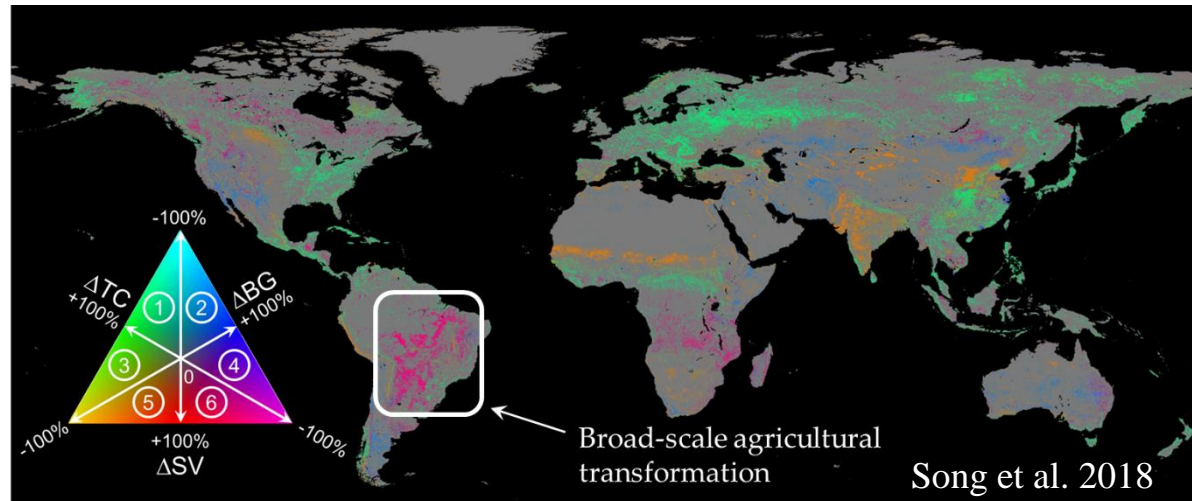


2020/2021 Oilseed, Soybean Imports



Consequences and Environmental Policies

Global land change from 1982 to 2016



TC: tree canopy cover; SV: short vegetation cover; BG: bare ground (BG) cover

- Loss of natural vegetation
 - Amazon, Atlantic Forests, Cerrado, Chaco, Pantanal
- GHG emissions
- Loss of biodiversity and ecosystem services
- Alters regional climate
- ...

Amazon Soy Moratorium

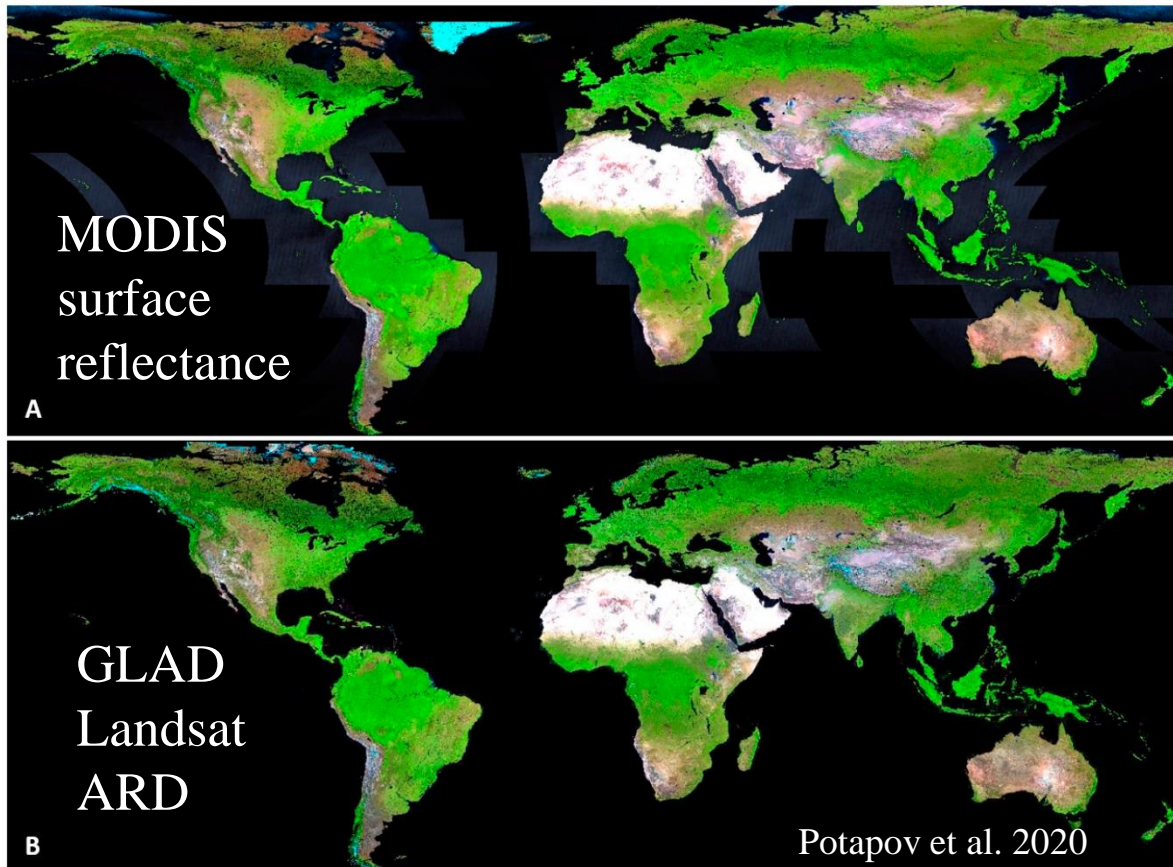
A voluntary agreement signed by traders who committed not to buy soybeans sowed on deforested lands in the Brazilian Amazon after 2008.



Project Objectives

- Overall Goal
 - Achieve a comprehensive understanding of soybean expansion in South America in the past and future.
- Specific objectives
 - Characterize the spatiotemporal patterns of soybean expansion at 30m resolution, annually, and over a long period (1985-2020).
 - Investigate the economic drivers of soybean expansion with a spatially and temporally explicit econometric model.
 - Project a range of scenarios of future soybean expansion under different socioeconomic, policy, technological and climate conditions.

Mapping Soy Expansion Using Satellite data



Ranking of 16-day observation time-series by spectral reflectance or index value

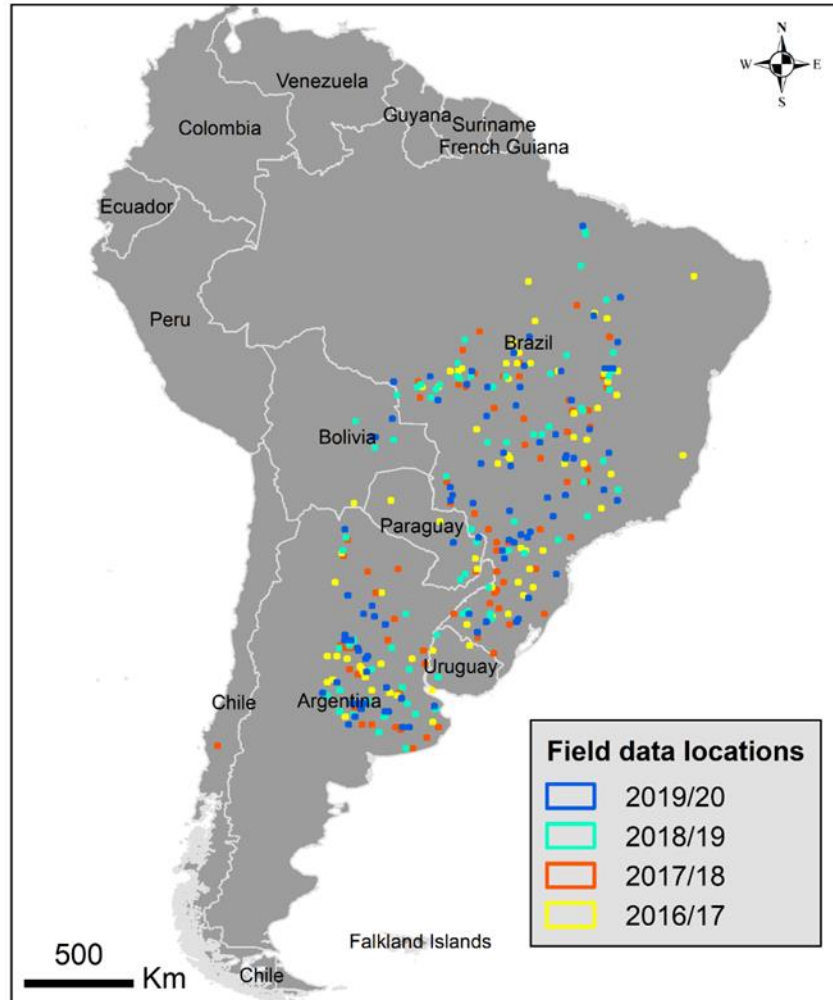
Spectral data and indices	Statistics	Amplitudes*
Spectral Bands	Minimum [min]	max - min
Blue	Maximum [max]	smax - smin
Green	Second lowest value [smin]	av50smax - av50smin
Red	Second highest value [smax]	av75smax - av75smin
NIR	Median [median]	
SWIR1	Average between smin and Q2 [av50smin]	
SWIR2	Average between Q2 and smax [av50smax]	
	Average between min and Q1 [avmin25]	
	Average between Q3 and max [av75smax]	
	Average between Q1 and Q3 [av2575]	
Derived Indices	Average of all values [avminmax]	
$(\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$ [RN]	Average of all values except min and max [avminsmax]	
$(\text{NIR} - \text{SWIR1}) / (\text{NIR} + \text{SWIR1})$ [NS1]		
$(\text{Blue} - \text{Green}) / (\text{Blue} + \text{Green})$ [BG]		
$(\text{Blue} - \text{Red}) / (\text{Blue} + \text{Red})$ [BR]		
$(\text{Blue} - \text{NIR}) / (\text{Blue} + \text{NIR})$ [BN]		
$(\text{Green} - \text{Red}) / (\text{Green} + \text{Red})$ [GR]		
$(\text{Green} - \text{NIR}) / (\text{Green} + \text{NIR})$ [GN]		
$(\text{SWIR1} - \text{SWIR2}) / (\text{SWIR1} + \text{SWIR2})$ [SWSW]		
Spectral variability index [SVVI]		

Phenological metrics

Ranking of 16-day observation time-series by the value of corresponding variable

Spectral data	Corresponding variable	Statistics	Amplitudes*
Blue	$(\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$ [RN]	Minimum [min]	max - min
Green	Spectral variability index [SVVI]	Maximum [max]	smax - smin
Red	Brightness temperature [LST]	Second lowest value [smin]	av50smax - av50smin
NIR		Second highest value [smax]	av75smax - av75smin
SWIR1		Average between smin and Q2 [av50smin]	
SWIR2		Average between Q2 and smax [av50smax]	
		Average between min and Q1 [avmin25]	
		Average between Q3 and max [av75smax]	

Calibration & Validation

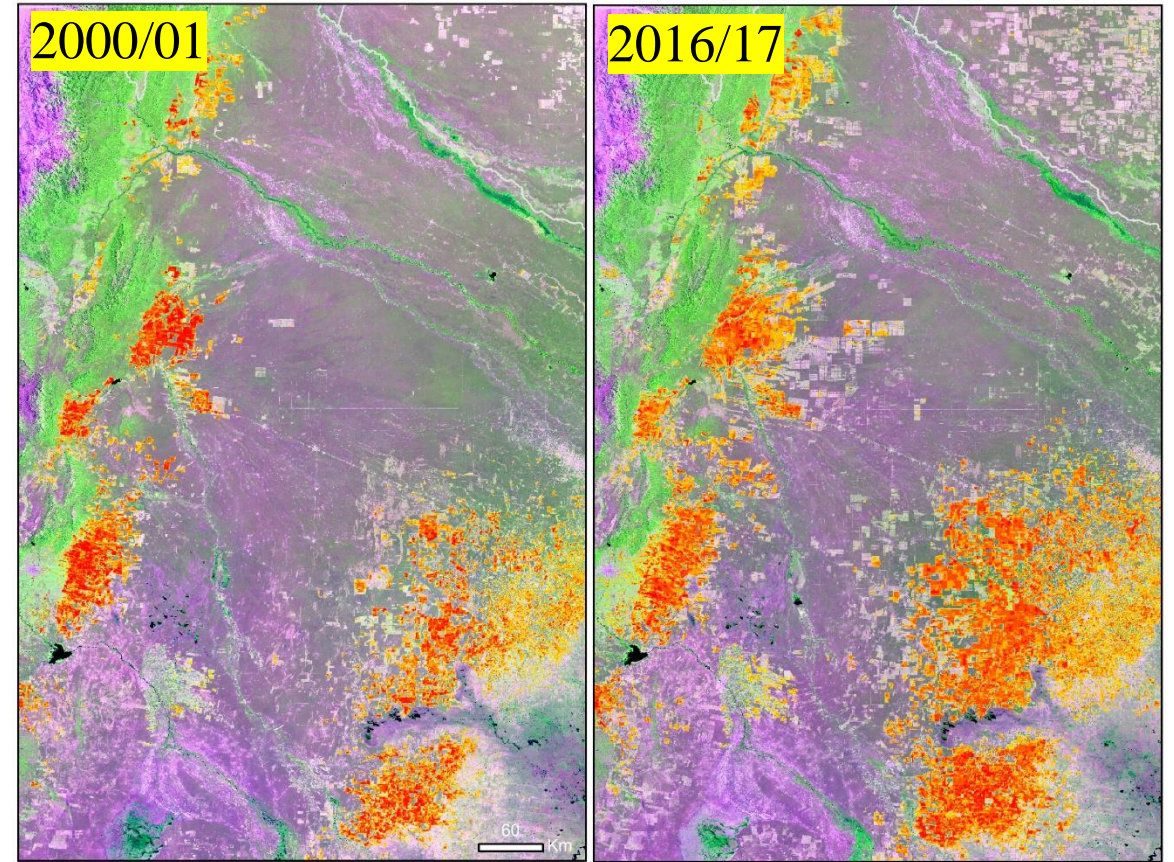
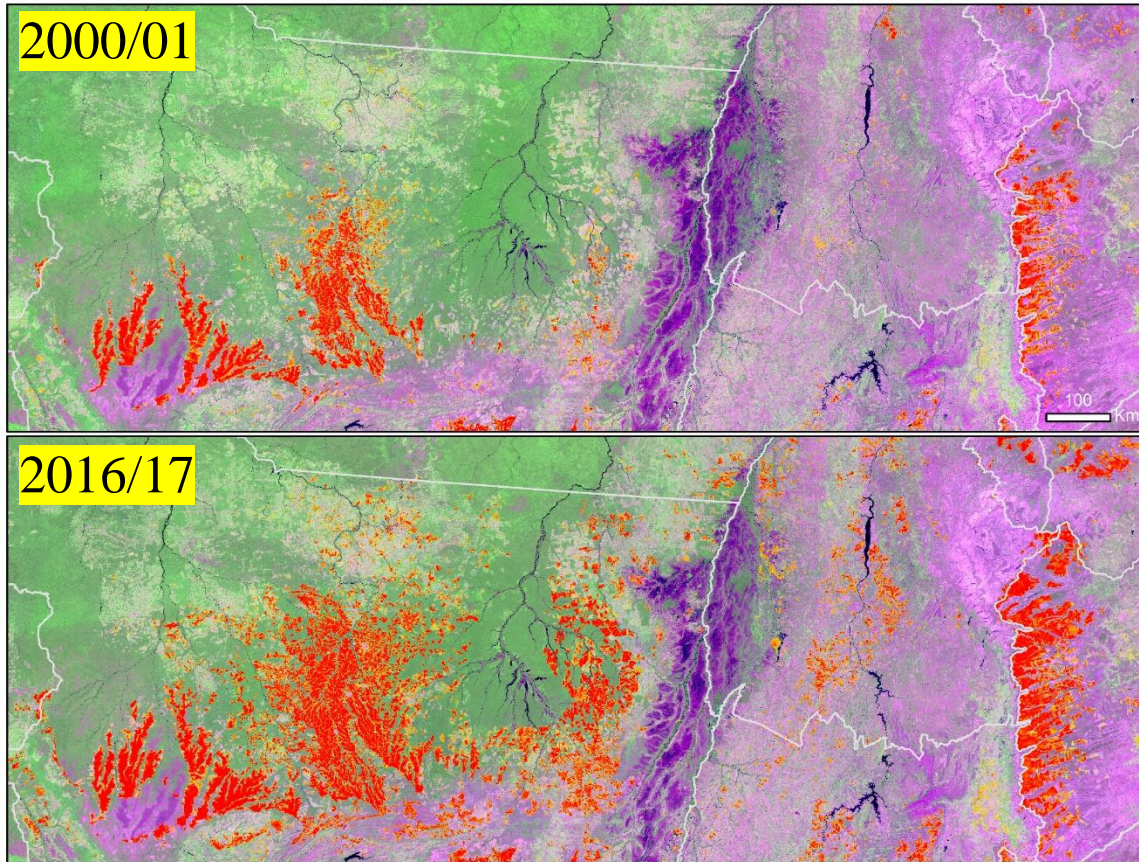


Preliminary Mapping Results

Amazon & Cerrado

■ Soybean

Chaco



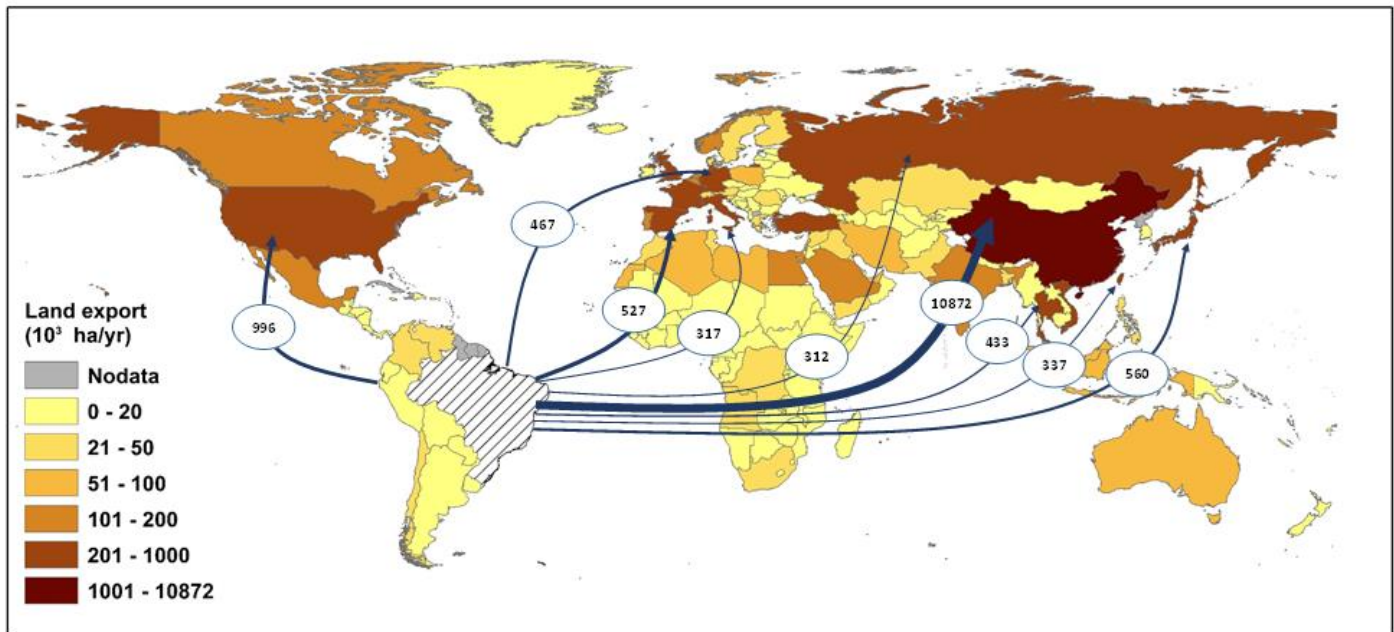
Economic Land-use Change Analysis

- Model soybean expansion using an econometric land-use change model (eLUC)
 - Risk-neutral landowner would choose the land-use type with the highest utility.
 - Data on competing land uses (soybean, non-soybean cropland, pasture and forest) are obtained from remote sensing-based map products.
 - Solve a logit-linear transformed share model using OLS (Ay et al. 2017).
 - $$\mathbf{S}_{gtl_1} = \frac{\exp(\mathbf{S}_{g(t-1)l_1}\boldsymbol{\beta}_{l_1}^S + \mathbf{R}_{gtl_1}\boldsymbol{\beta}_{l_1}^R + \mathbf{B}_{gtl_1}\boldsymbol{\beta}_{l_1}^B)}{\sum_{l_0=1}^L \exp(\mathbf{S}_{g(t-1)l_0}\boldsymbol{\beta}_{l_0}^S + \mathbf{R}_{g(t-1)l_0}\boldsymbol{\beta}_{l_0}^R + \mathbf{B}_{g(t-1)l_0}\boldsymbol{\beta}_{l_0}^B)}$$
 - Where, \mathbf{S}_{gtl_1} is the land-use share vector of land-use type l_1 in grid cell g at time t , a portion of which is converted from land-use type l_0 at time $t-1$.

Multi-Regional Input-Output Analysis

- Employ the MRIO analysis to establish the tele-connection (e.g. China consumption and Brazil production) through the whole economic supply chain.
 - Global Trade Analysis Project (GTAP) data, in which soybean is an independent sector.
 - Extend MRIO with land-use footprint (Yu et al. 2013).

Virtual soybean land export flow from Brazil to the rest of the world in year 2014



Global Agro-ecological Zones Analysis

- Employ GAEZ to simulate the production potentials of soybean and other crops under different climate conditions and agricultural management levels (Fischer et al. 2012).

Simulation factors

Climate

Soil

Cultivar

Planting and harvest dates

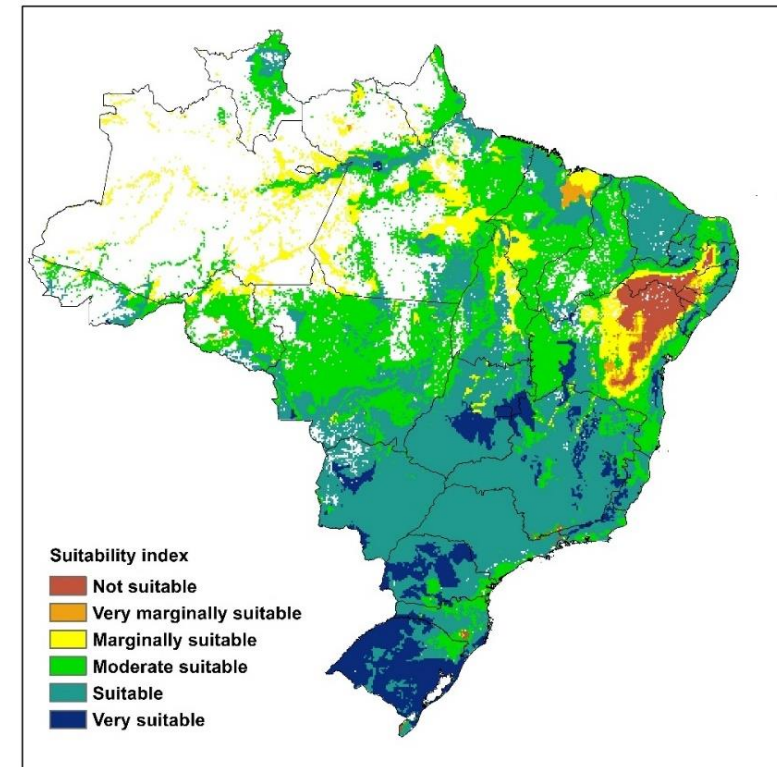
Irrigation

Fertilizer

Pesticide

CO₂ fertilization

*GAEZ-simulated
soybean suitability
under rainfed
condition in 2030s.*



Thank you!

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