Rates and Drivers of Land Use Land Cover Change in the Agricultural Frontier of Mato Grosso, Brazil

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What are the spatially and temporally variable drivers of intensification in Mato Grosso State, Brazil?

1) Detection and characterization of land cover and land use change with remotely sensed data
2) Explaining and attributing the observed changes through socioeconomic analyses.
3) New directions and hypotheses

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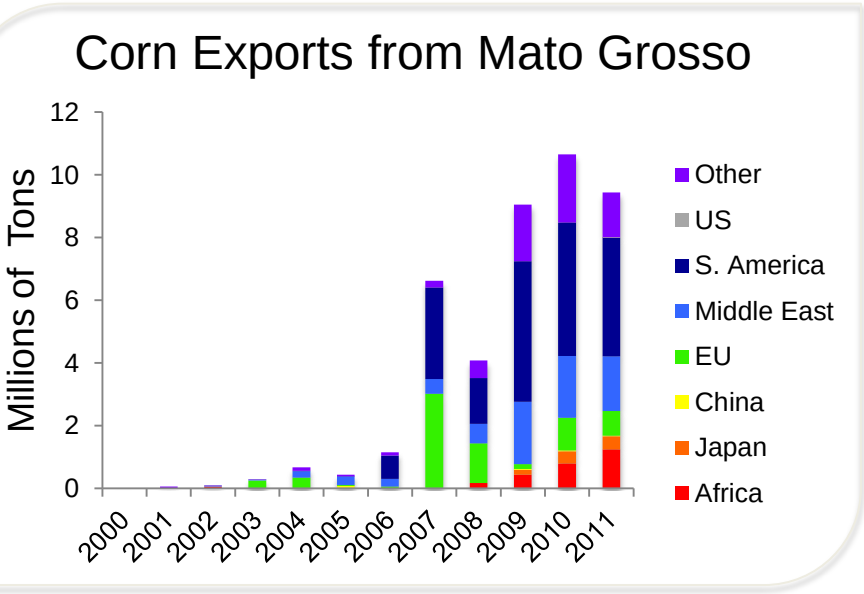
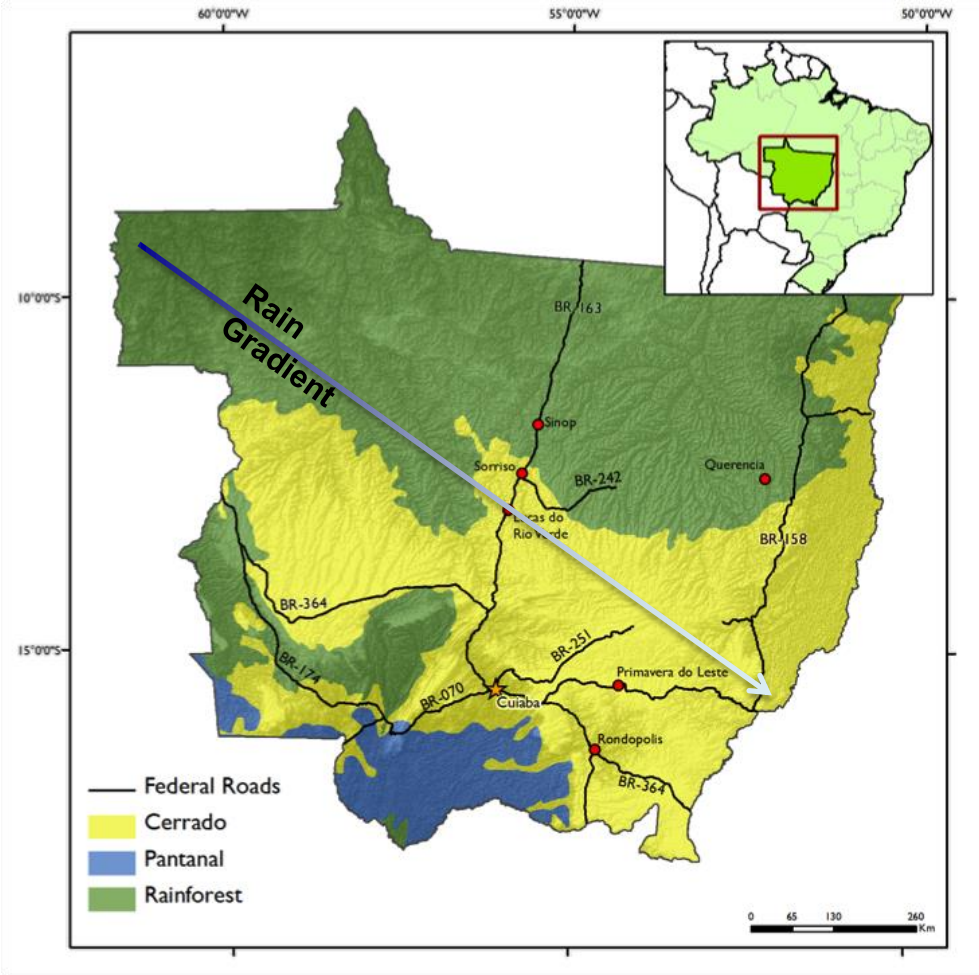
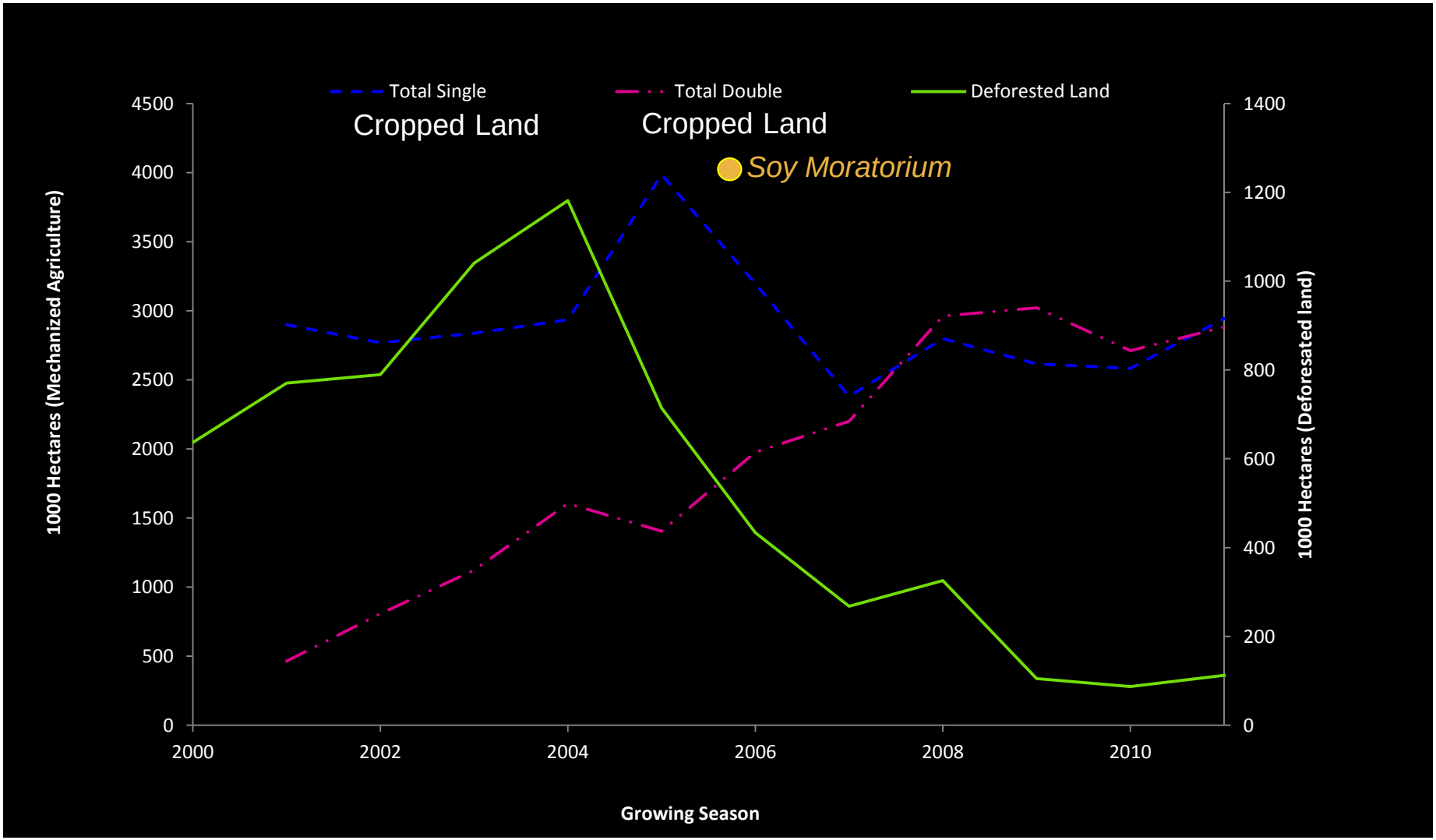
Mato Grosso, Brazil

- Nexus of environmental conservation efforts and agricultural production
- Brazil's leader in soy, corn and cotton exports
- Wet season/growing season: Sept. – Apr.
  - Northwest to southeast precipitation gradient



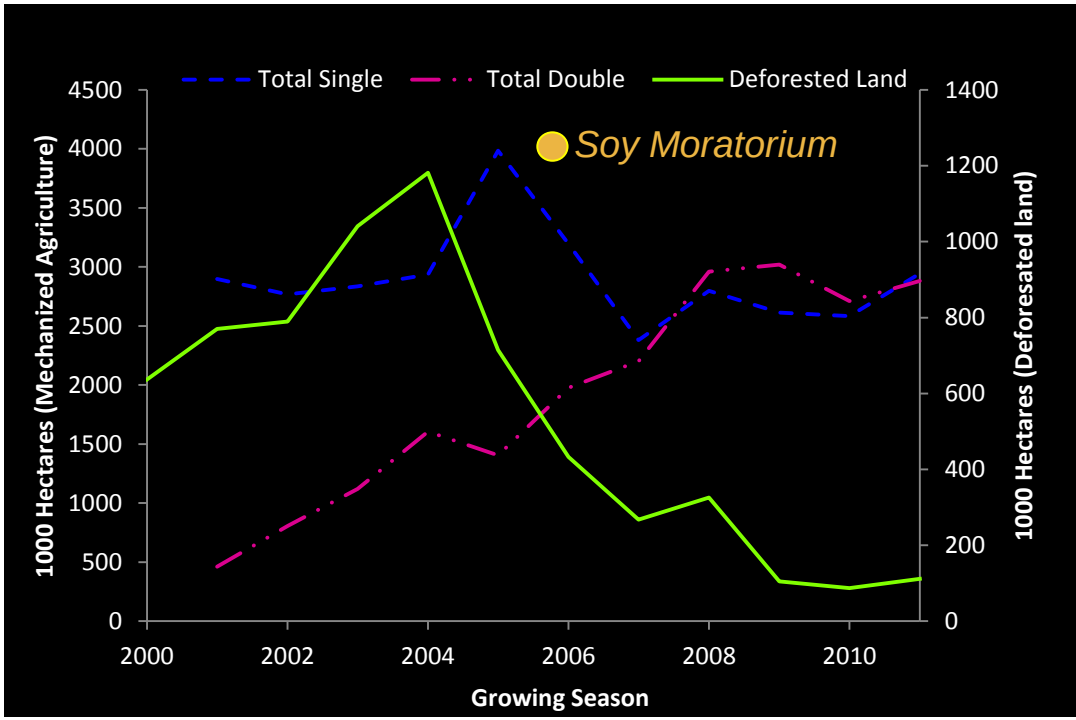


Trends


Total Single
Cropped Land
Total Double
Cropped Land
Deforested Land
Soy Moratorium
1000 Hectares (Mechanized Agriculture)
1000 Hectares (Deforesated land)
Growing Season
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1400
1200
1000
800
600
400
200
0
2000
2002
2004
2006
2008
2010

What are the spatially and temporally variable drivers of intensification in Mato Grosso State, Brazil?

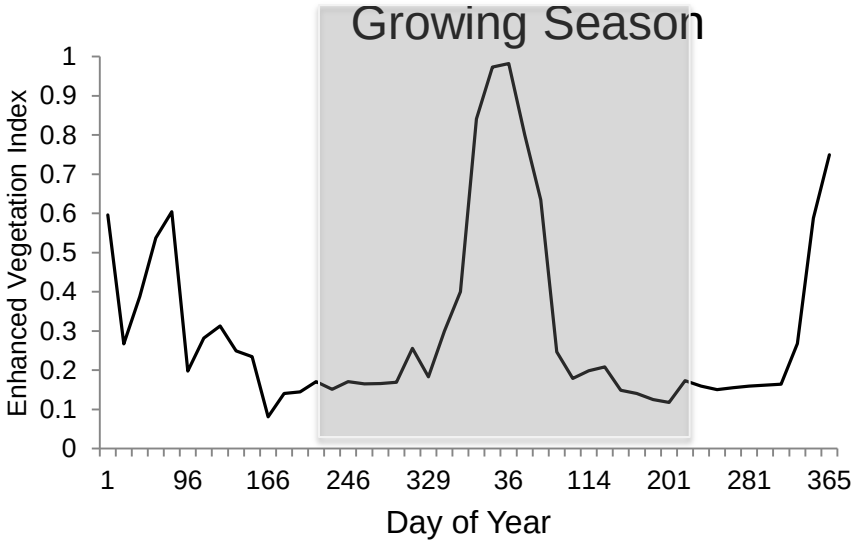
1) Detection and characterization of land cover and land use change with remotely sensed data
2) Explaining and attributing the observed changes through socio-economic analyse
3) New directions and hypotheses

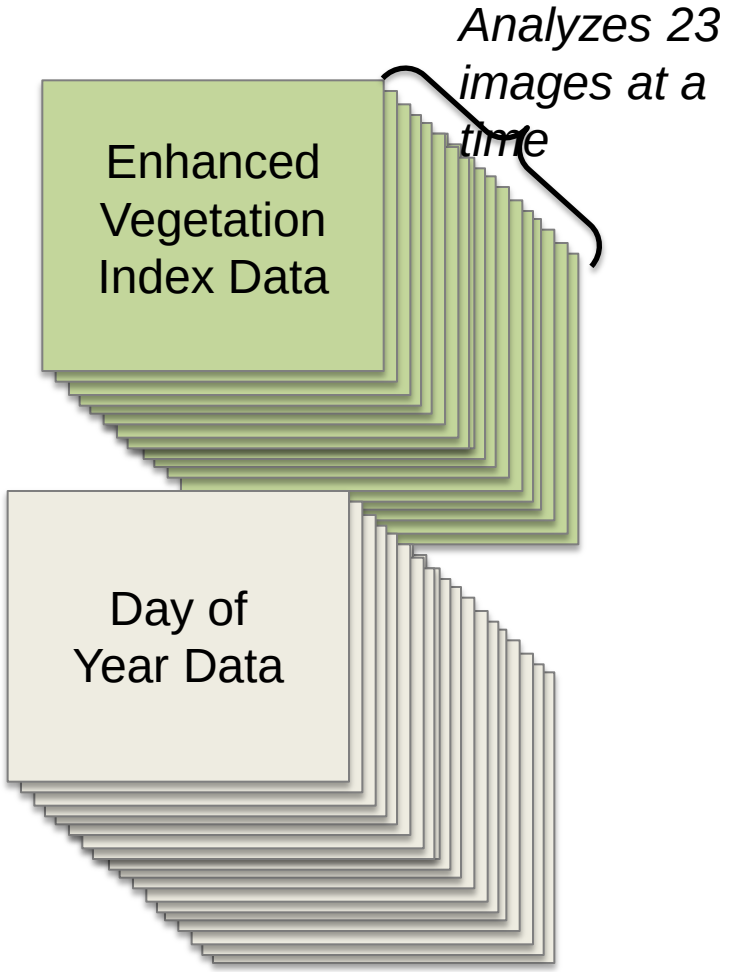


Spera et al. (in review) Rem. Sens. Envi.
Galford et al. (2008) Rem. Sens. Envi.
Brown et al. (2012) Rem. Sens. Envi.

Crop Classifying Algorithm

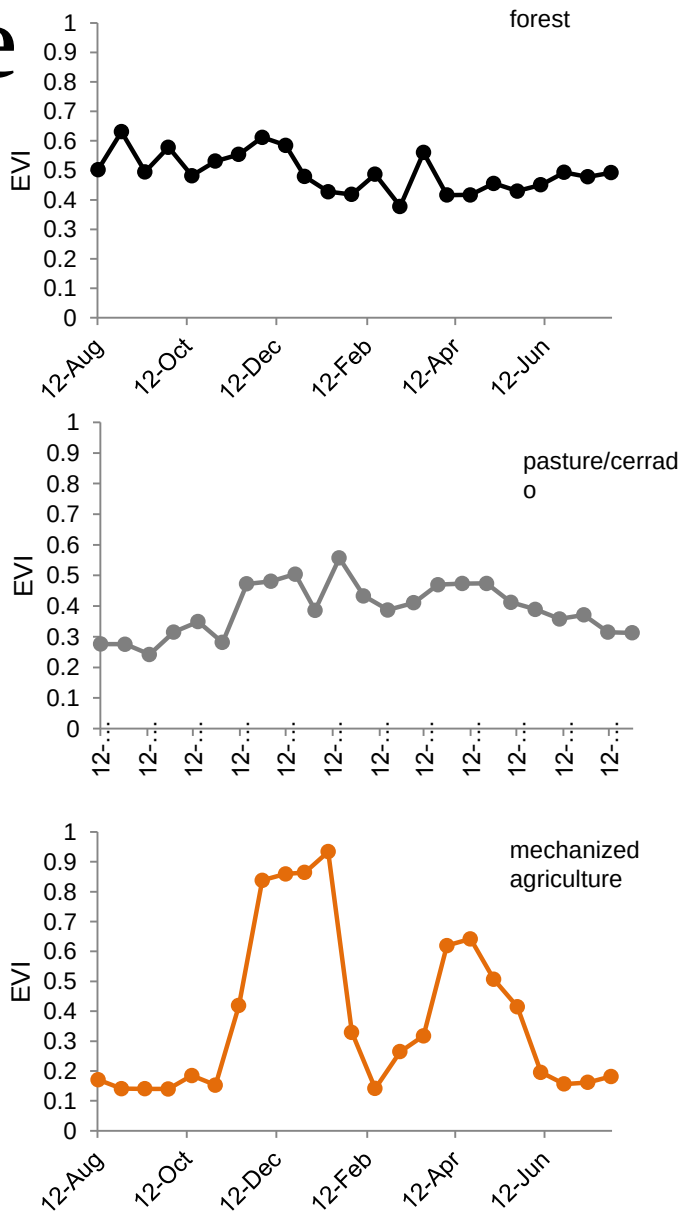
- Field data used as training data
- 11 growing seasons between 2000-2011
- 23 observations per growing season
- 253 total observations





Forest, Pasture/Cerrado, Mechanized Agriculture

- Standard deviation of EVI over growing season
- EVI value of first and last date of the growing season

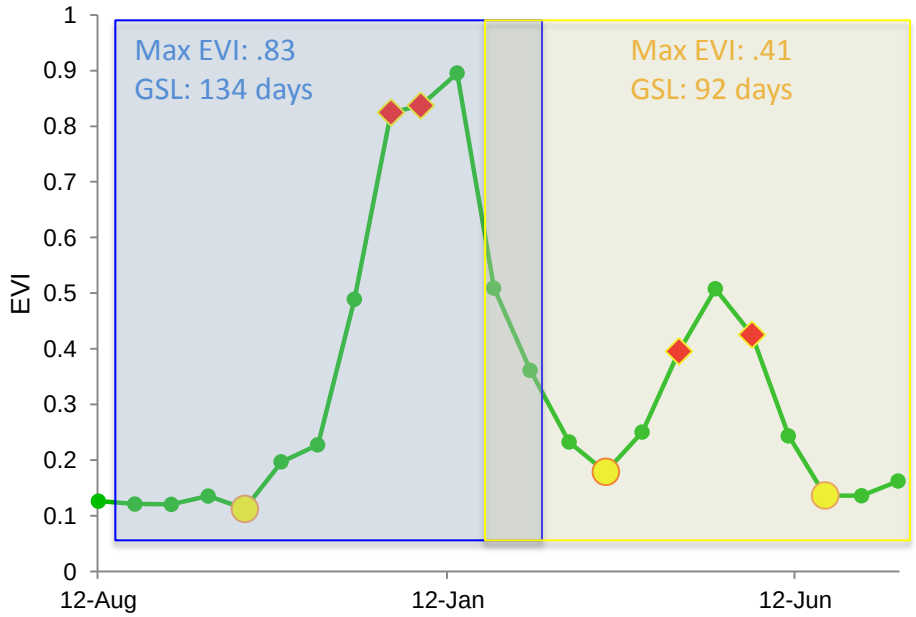


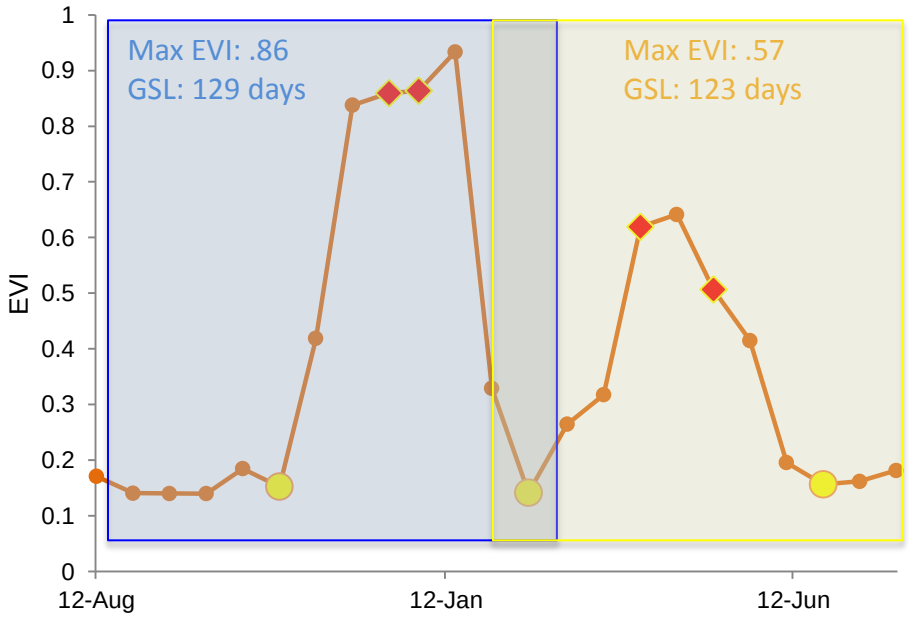
Specific Crop Type

- Halves growing season
- Average ‘maximum’ EVI values
- Growing season length

Dates of transition

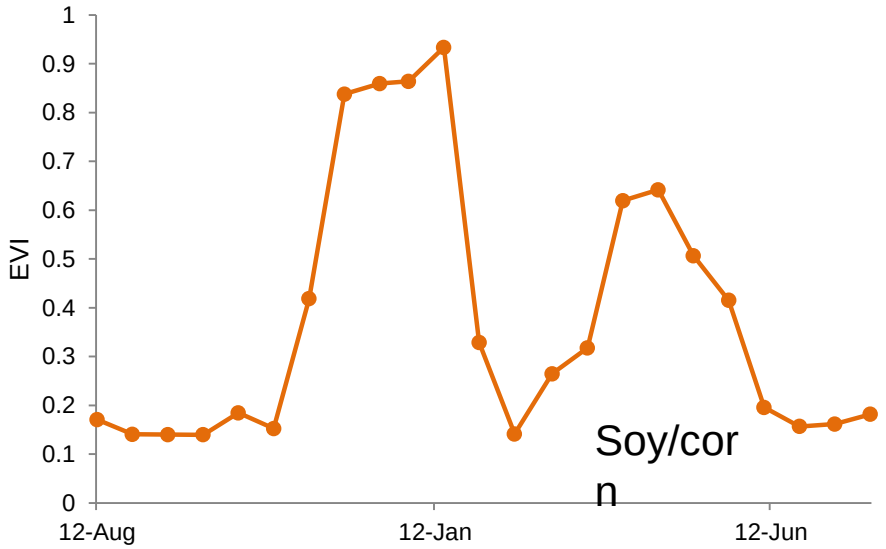
EVI ‘maxima’

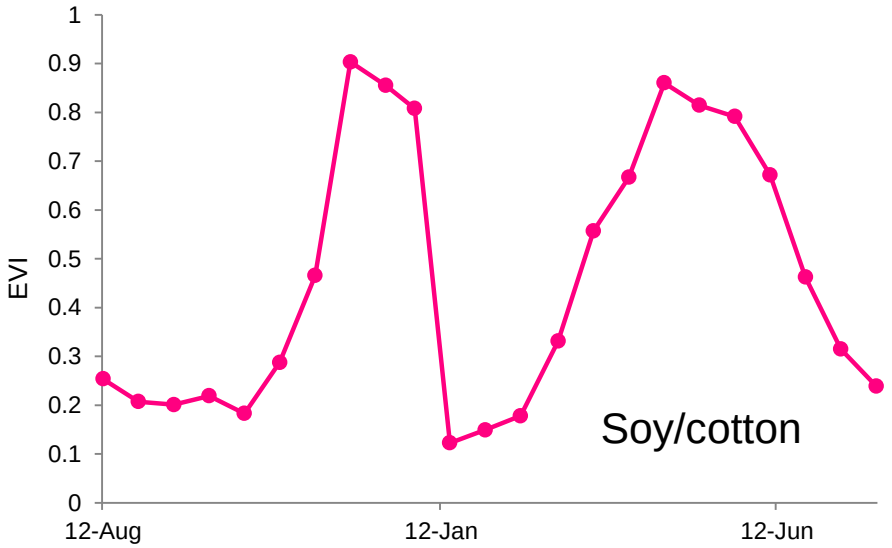




Specific Crop Type

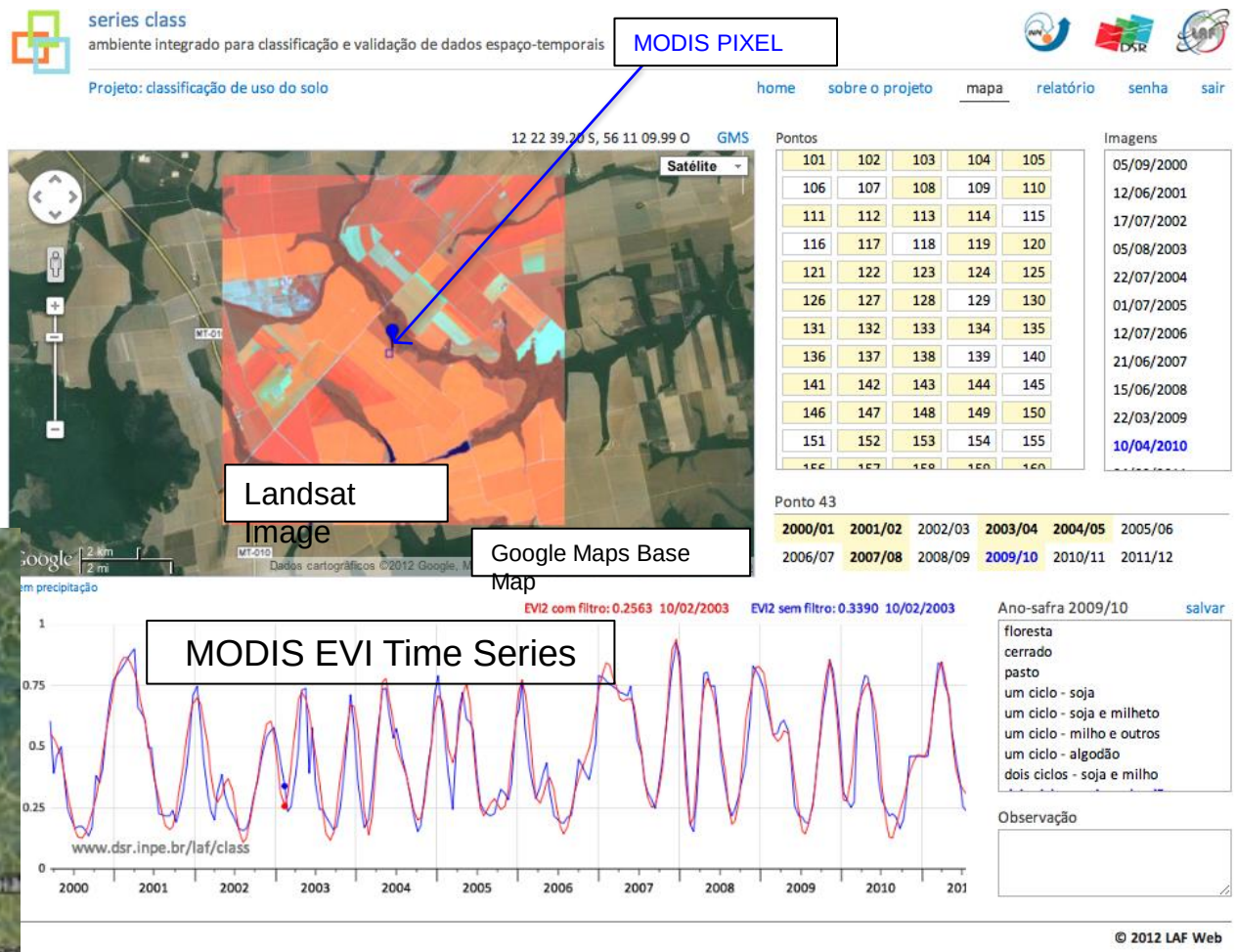
Algorithm Criteria for Crop Discrimination				
Land Cover	1st Half of Growing Season (DOY 225-81)		2nd Half of Growing Season (DOY 353-209)	
	Minimum-Maximum EVI	Growing Season Length (days)	Minimum-Maximum EVI	Growing Season Length (Days)
Soy	0.6	78-155		
Soy/Corn	0.6	78-155	0.45	78-155
Cotton			0.6	116-240
Soy/Cotton	0.6	78-155	0.6	116-240





Validation

- Sophisticated web-tool designed by INPE (Adami et al. 2012)
  - Soy Moratorium
  - Sugarcane monitoring
- 6600 potential points

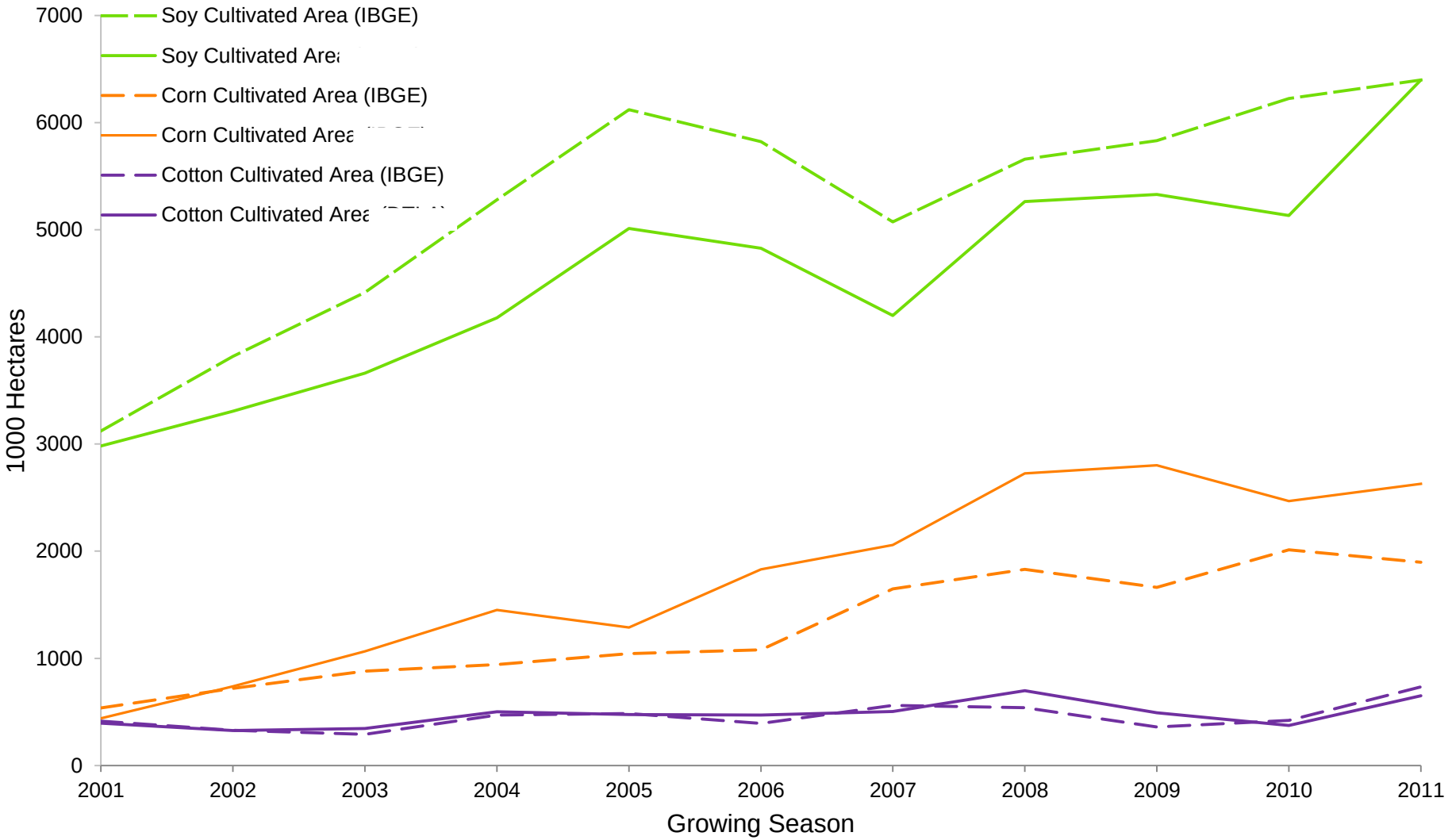


Accuracy Assessment

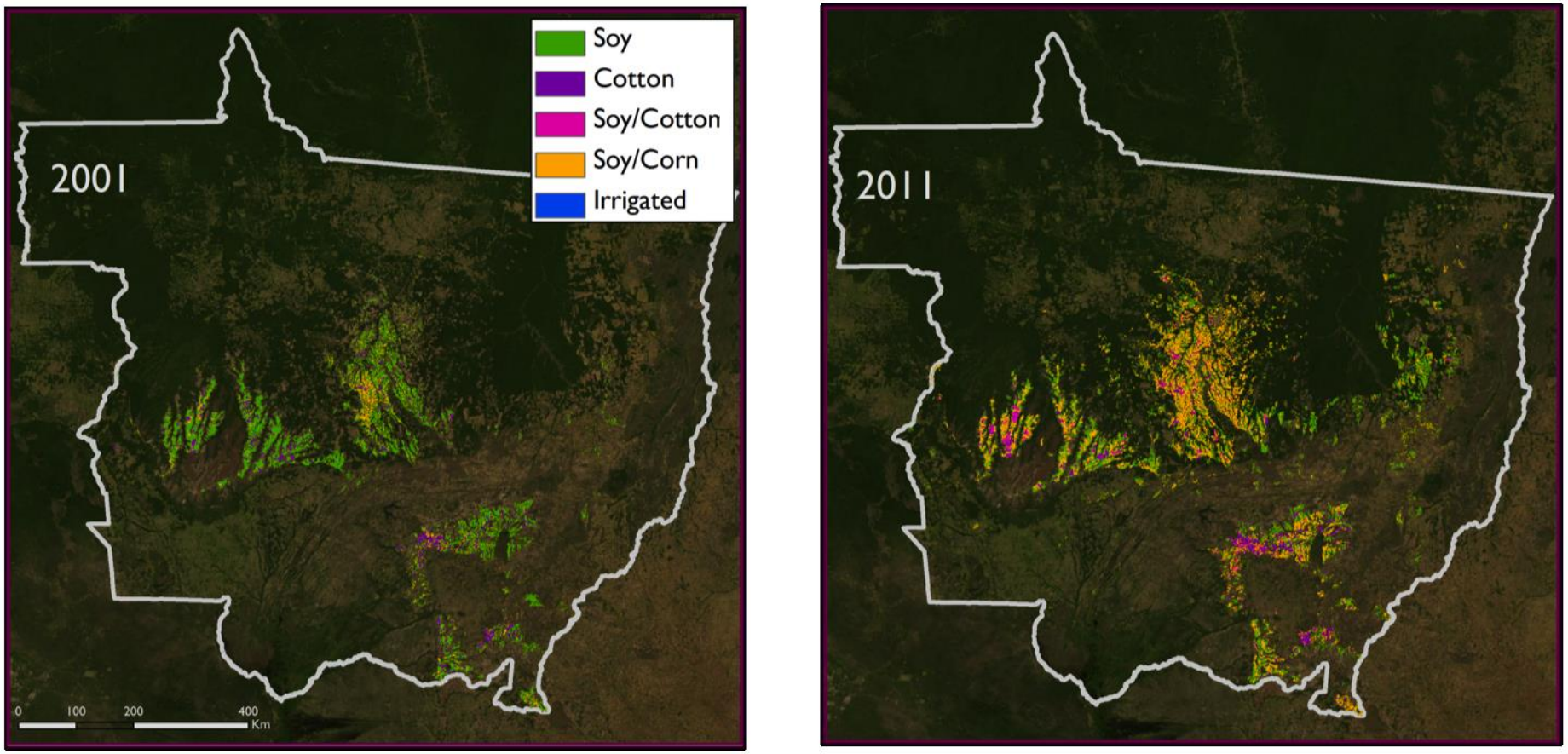
Classification	Ground Cover Validation Data			
	Mechanized Ag	*Pasture/Cerrado /Forest*	*Row Total*	*User's Accuracy*
Mechanized Ag	1608	16	1625	.99
Pasture/Cerrado/Forest	49	1272	1321	.96
Column Total	1657	1288	2945	
Producer's Accuracy	0.97	0.99		
Overall Accuracy	**0.98**			

Classification	Ground Cover Validation Data							
	Soy	*Cotton*	*Soy/Corn*	*Soy/Cotton*	*Pasture/Cerrado/ Forest*	*Irrigated*	Row Total	User's Accuracy
Soy	752	10	34	1	12	1	810	0.93
Cotton	10	165	4	1	0	0	180	0.92
Soy/Corn	41	3	502	4	4	3	557	0.90
Soy/Cotton	3	2	11	40	0	3	59	0.68
Pasture/Cerrado/Forest	38	3	2	9	1272	6	1321	0.96
Irrigated	0	0	0	0	0	18	18	1.00
Column Total	844	184	553	46	1288	31	2945	
Producer's Accuracy	.89	.90	.91	.87	.99	.58		
Overall Accuracy	**0.93**	**K_{hat}=.90**						

Comparison to government statistics



Expansion of Mechanized Agriculture Increase in Double Cropping



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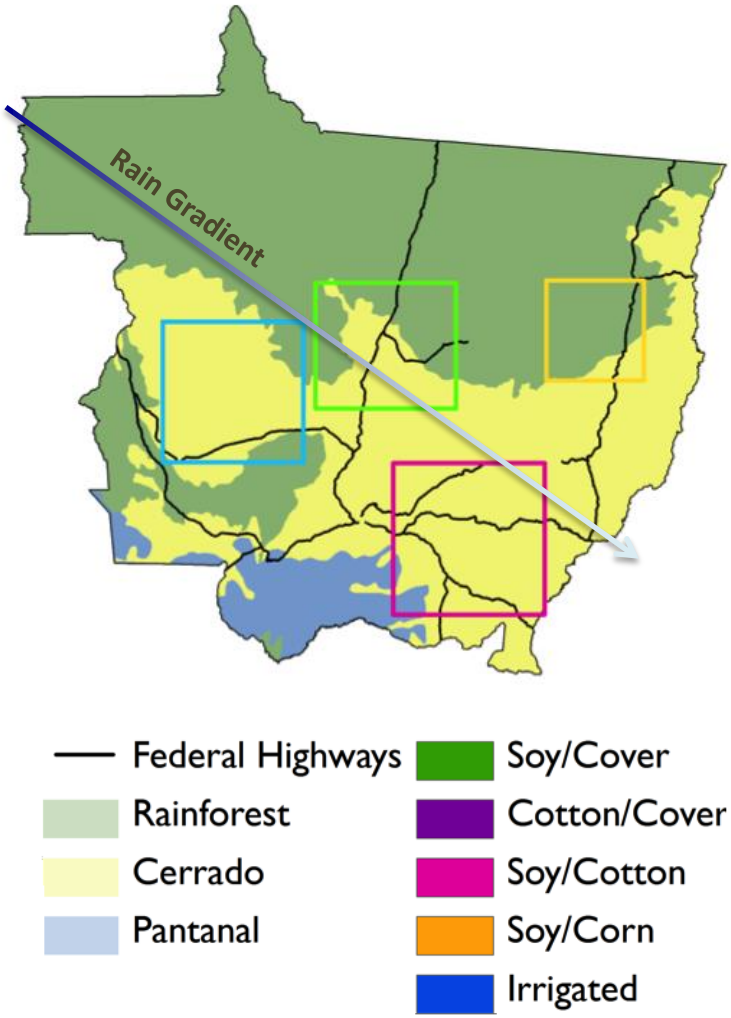
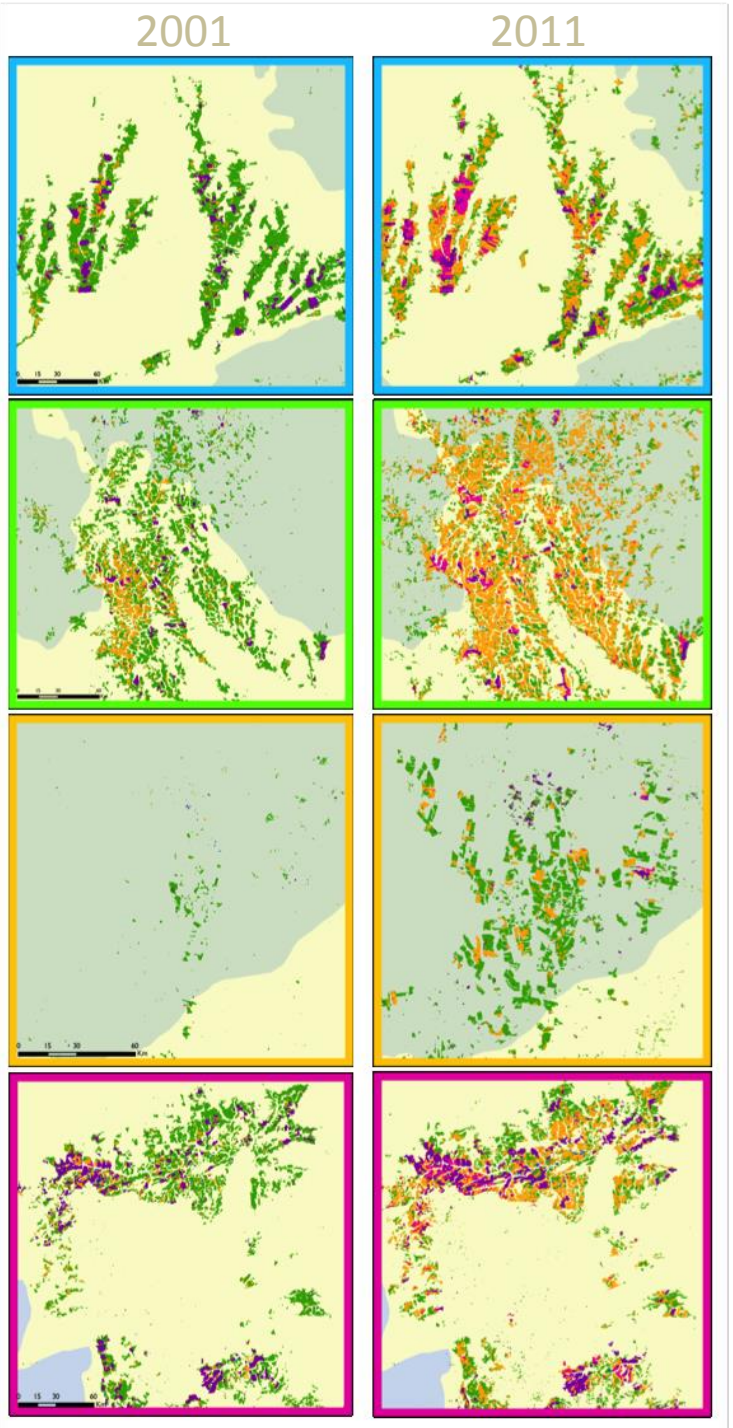
Patterns





Spera et al. (in review) Remote Sens. Envi.

Markov Transition Matrices

Time Period: 2000-2011

	Not Mech. Ag.*	Single Cropping	Double Cropping
*Not Mech. Ag.**	0.988	0.009	0.003
Single Cropping	0.196	0.546	0.259
Double Cropping	0.098	0.306	0.595

Time Period: 2000-2006

	Not Mech. Ag.	Single Cropping	Double Cropping
Not Mech. Ag.	0.988	0.010	0.002
Single Cropping	0.178	0.606	0.216
Double Cropping	0.108	0.383	0.509

Time Period: 2006-2011

	Not Mech. Ag.	Single Cropping	Double Cropping
Not Mech. Ag.	0.989	0.008	0.004
Single Cropping	0.216	0.477	0.307
Double Cropping	0.094	0.274	0.632

**Not Mech. Ag. class includes forest, pasture, cerrado*

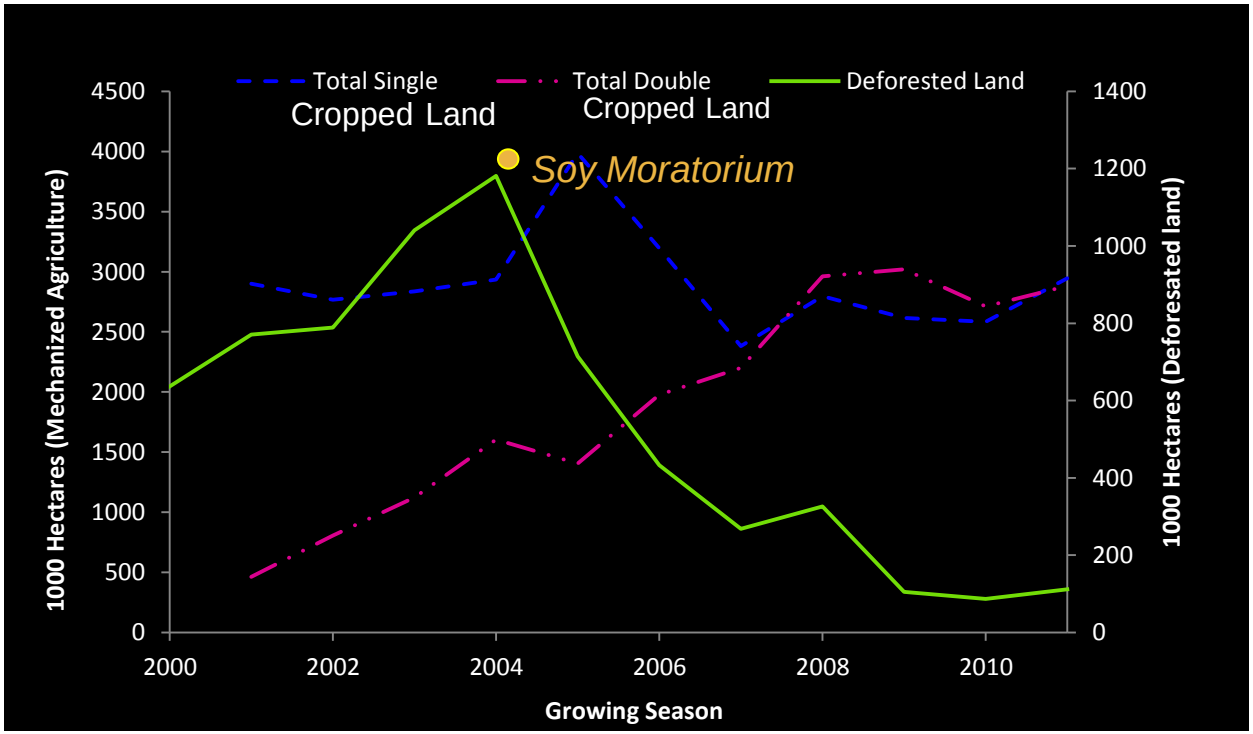
Strong trend to intensification

- Hugh increase in intensification through double cropping correlated to the Soy Moratorium and decline in deforestation: ***Spatial and temporal variance***
- Decoupling of deforestation and increases in production (Macedo et al, PNAS 2012)

- Land Sparing?

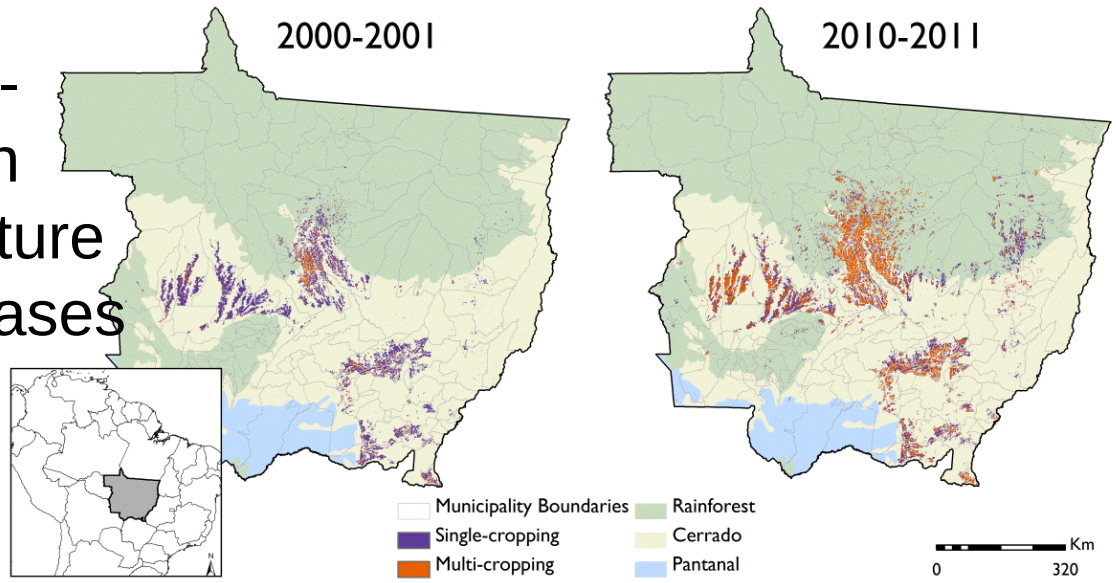
- Consequences
  - Biogeochemisty
  - Socioeconomic

- Drivers



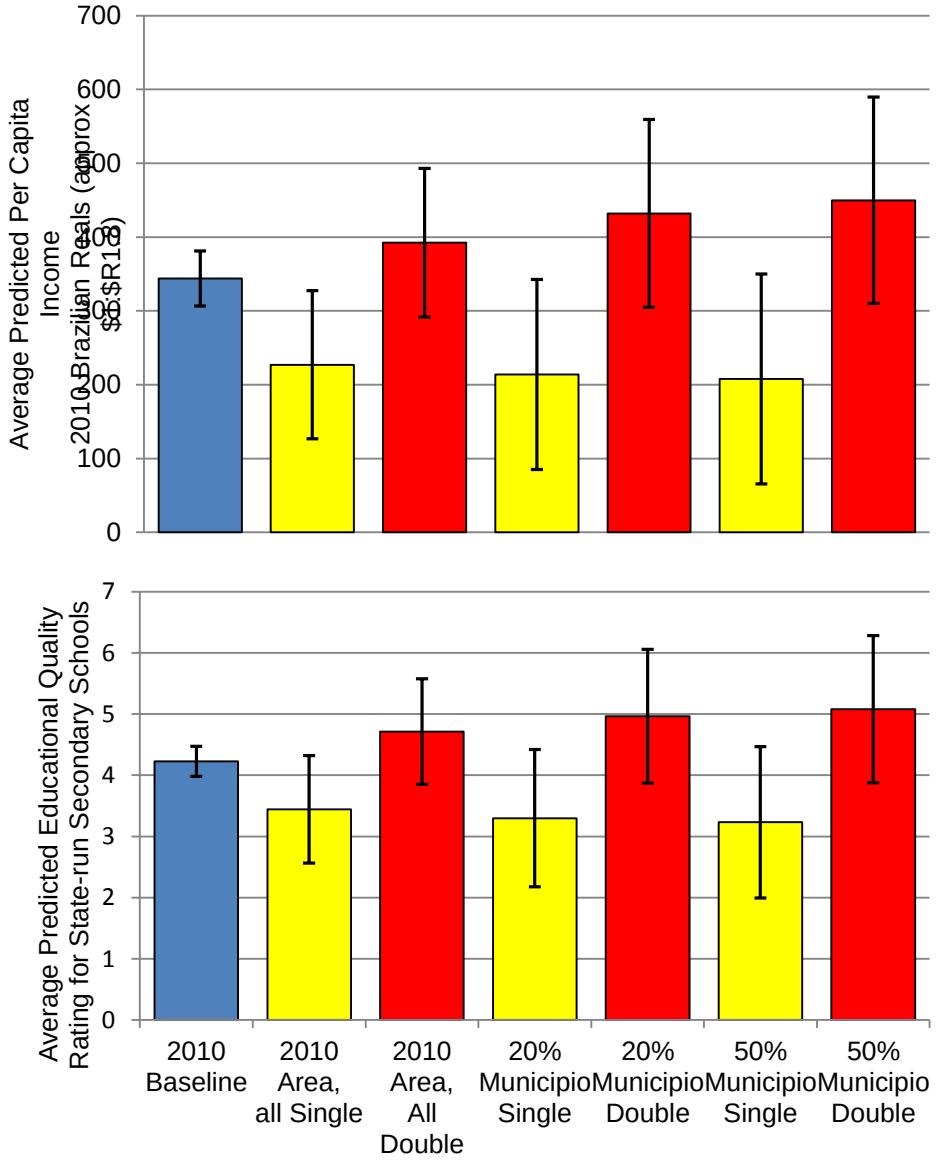
Socioeconomic Development and Agricultural Intensification in Mato Grosso (In Press, PTRS-B)

- Assessing the socioeconomic correlates of spatial-temporal variation in mechanized agriculture
- Intensification increases agricultural profits, demand for skilled labor, and complementary service sector employment
- Does double cropping do more than single cropping?



Leah K. VanWey, Stephanie Spera, Rebecca de Sa, Dan Mahr, and John F.

- Regression of socioeconomic outcomes in 2010 on single and double cropping in 2010, with controls for biophysical and socioeconomic characteristics, and for spatial autocorrelation
- ***Double cropping*** (not single cropping) associated with ***higher GDP, higher average incomes, and better schools***



The Uncertain Future for Tropical Agricultural Intensification Under Climate and Market Volatility

- We use our MODIS-derived agricultural management dataset to develop a model of drivers of Mato Grosso agricultural development
- Analysis indicates that ***double cropping*** helps farmers hedge against ***low soy prices***
- But climate change threatens double cropping
- How persistent are these risks?
- Can improved seeds, infrastructure, and institutions be sufficient for system resilience?


Photo: Kory Melby


Photo: moneymavens.com

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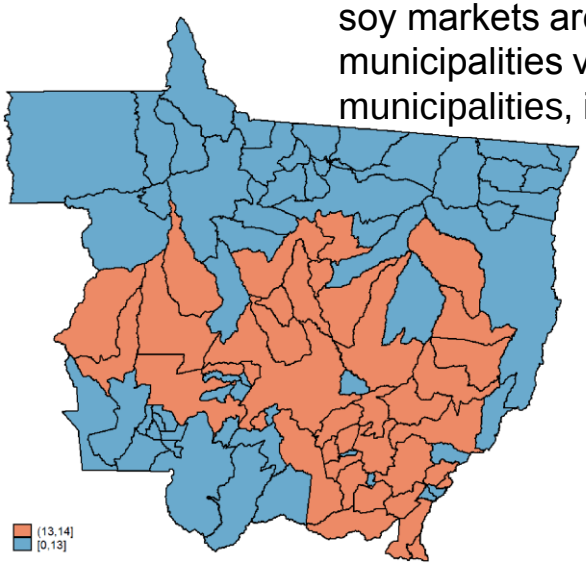
[4]Department of Geological Sciences, Brown; [5]National Center for Atmospheric Research

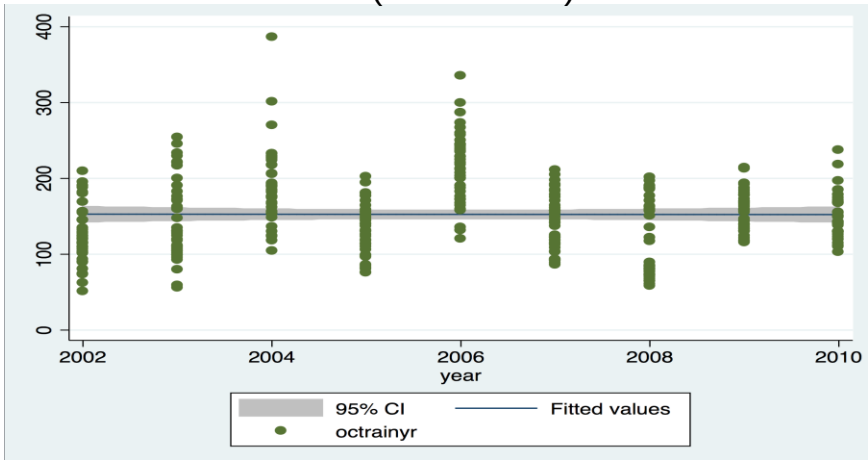
The Uncertain Future of Intensive Tropical Agriculture: Methods

- Used panel data regression analysis on double and single cropping acreage in 95 regions of MT from 2002 to 2010
- ***Hypothesis:***
  - Growing season length, biophysical suitability, isolation from markets (core vs. periphery) and commodity prices will determine land use outcomes
- Implemented spatio-temporal autocorrelation model to account for clustering and interdependence

Municipalities with persistent local soy markets are in red, "Core" municipalities vs. "Periphery" municipalities, in blue.



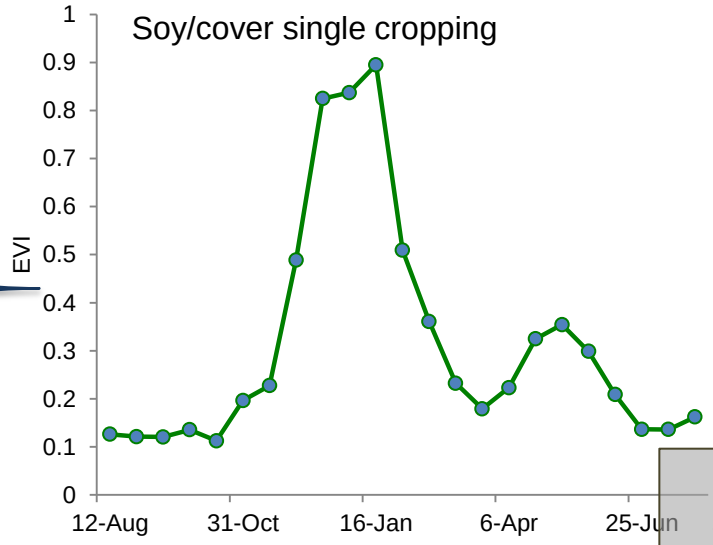
Rainy Season Start (mm rain in Oct) By MCA over time (TRMM data)



The Uncertain Future of Intensive Tropical Agriculture: Results

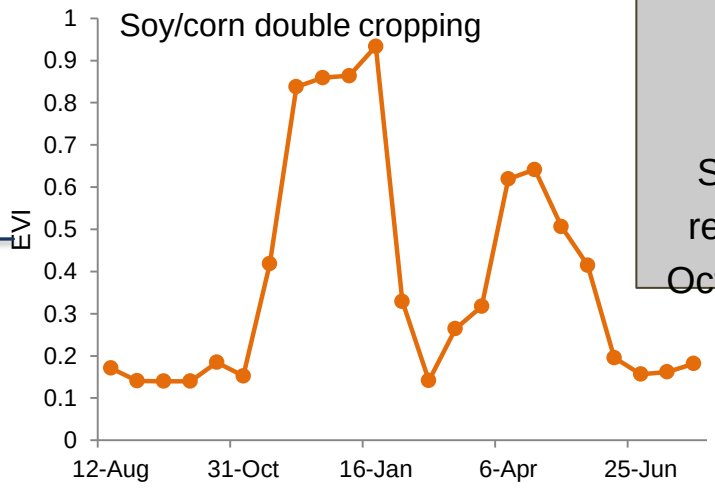
National soy prices ↑

Oct. precipitation ↓



National soy prices ↓

Oct. precipitation ↑

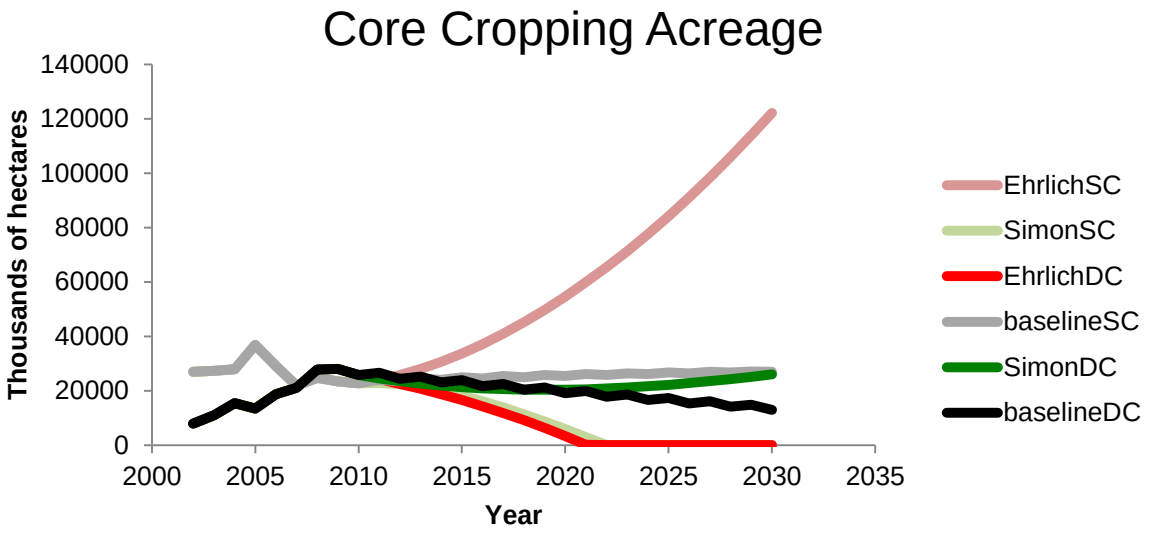


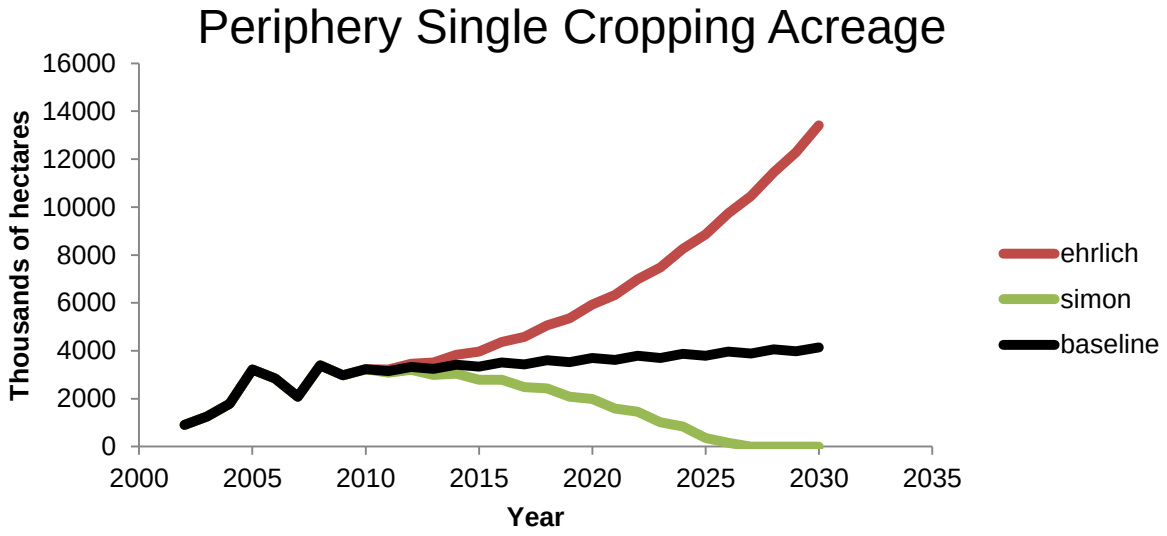
Significant positive relationship between soy price and single cropping

Significant negative relationship between October rain and single cropping

The Uncertain Future of Intensive Tropical Agriculture: Results

Remarkably different futures under increasing and decreasing agricultural prices





Malthus/Ehrlich
20 year doubling of soy and corn prices

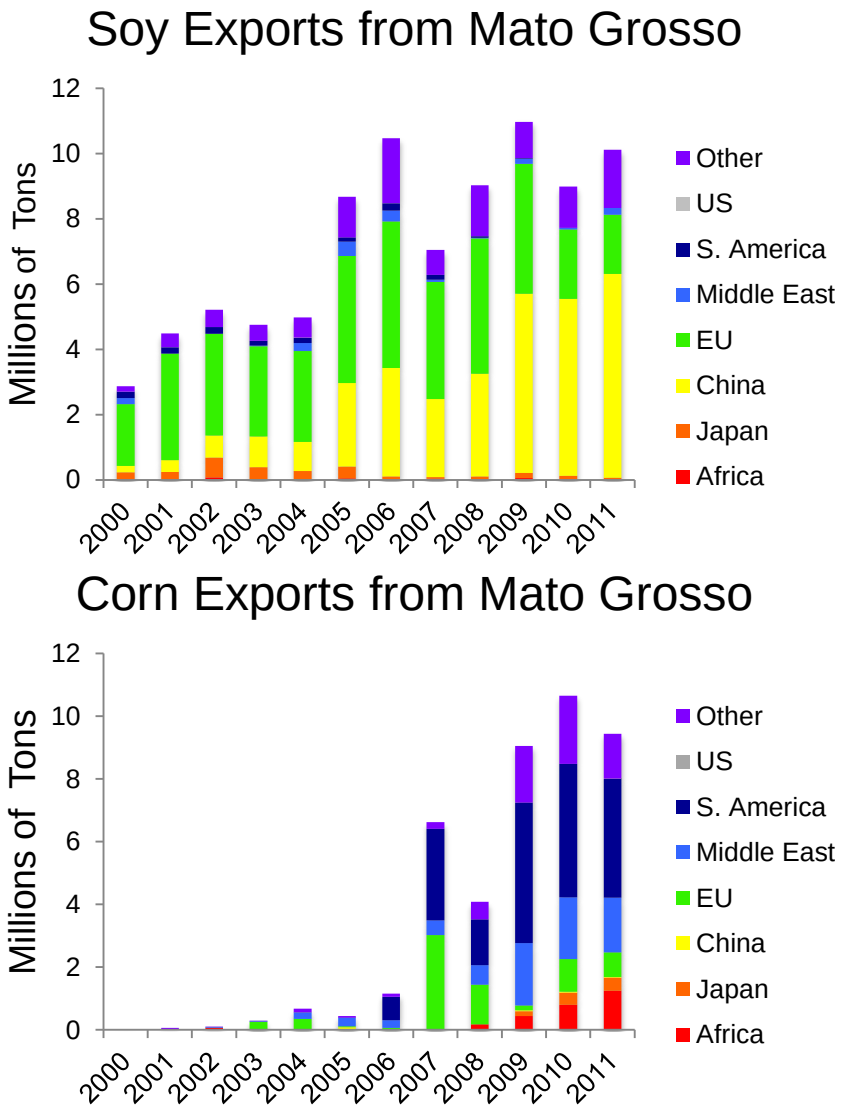
Borlaug/Simon
20 year halving of soy and corn prices

The Uncertain Future of Intensive Tropical Agriculture: Next Steps

- Combine with survey data
- Investigate yield tradeoffs
- Growing cycle length
- Other agricultural development processes
  - Pasture to crop
  - Pasture to intensive pasture
  - Double cropping to sugar

Results of LCLUC Analysis

- **6-fold** increase in soy/corn double cropping
- **11-fold** increase of soy/cotton double cropping
- Both mostly in the **cerrado region**



Preliminary Results of Drivers Analysis

- Price of Soy:
  - There is a significant correlation with single cropping and soy prices
    - Longer growing season soy varieties provide higher yield
  - Low soy price is correlated with double cropping with corn
    - Advantage to using short cycle soy and hedge with a rotation of corn
- Timing of Rains
  - Early wet season rains significantly correlated with double cropping
  - Late or weak early rains then single cropping is more likely
- Double cropping associated with higher GDP, higher average incomes, and better schools

Publications

- Spera et al. (in review) Remote Sensing Environment
- VanWey et al, Phil. Trans. Roy. Society B (2013)
- Cohn et al. (in prep) PNAS

Thank you