Climate and Weather Impacts on Agriculture: The Case of Brazil

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Outline

1. Introduction
2. Methodology
3. Climate Change and Brazilian Agriculture
4. Extreme Weather Events' Impact on Agriculture
5. Policy Discussion
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Brazilian Regions

Introduction: Motivation

- Brazil is one of the main grain producers and exporter.
  - No. 1: Sugar, Coffee, beef, tobacco, timber
  - No.2: Soybeans,
  - No. 3: Corn/Maize

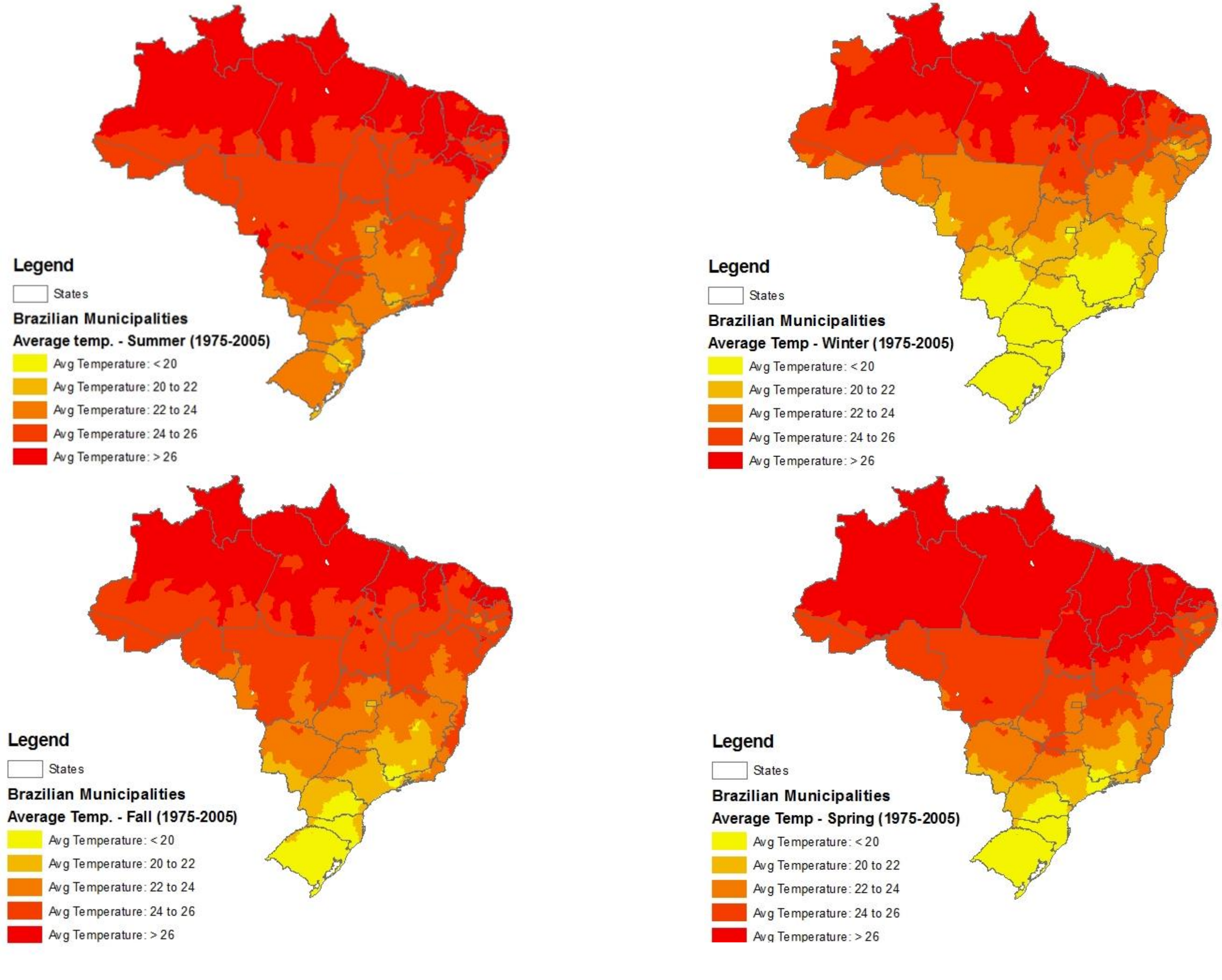
- The country has large climate variability.

- This article focuses on the measurement of specific climate effects on agriculture.

- Climate is an important factor influencing agricultural production.

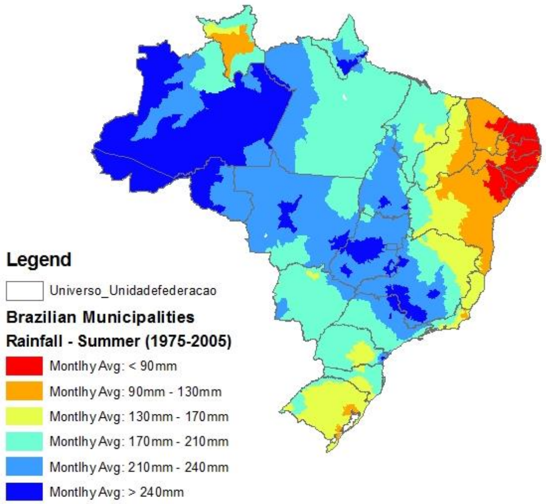
Introduction: Motivation

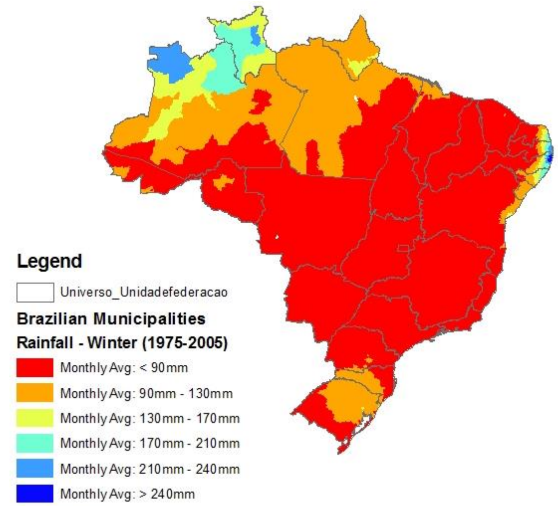
Average Temperature from 1975 to 2005 by season, in ^oC

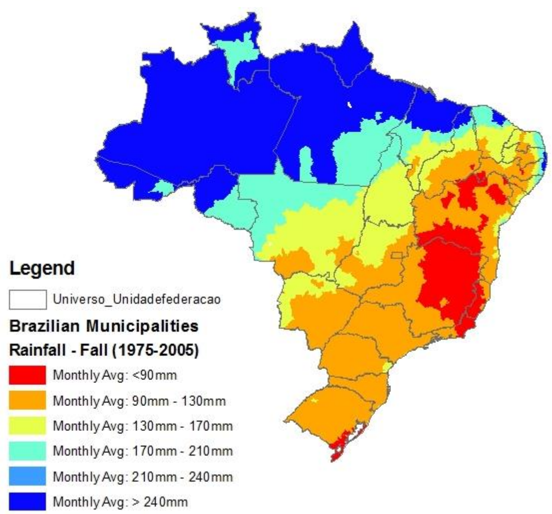


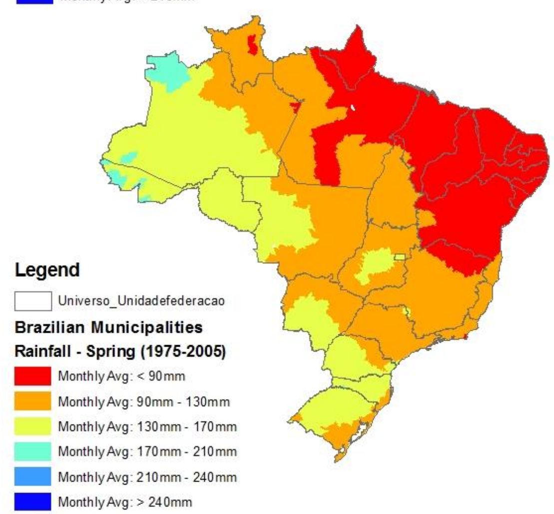
Introduction: Motivation

Average Monthly Rainfall from 1975 to 2005 by season, in mm



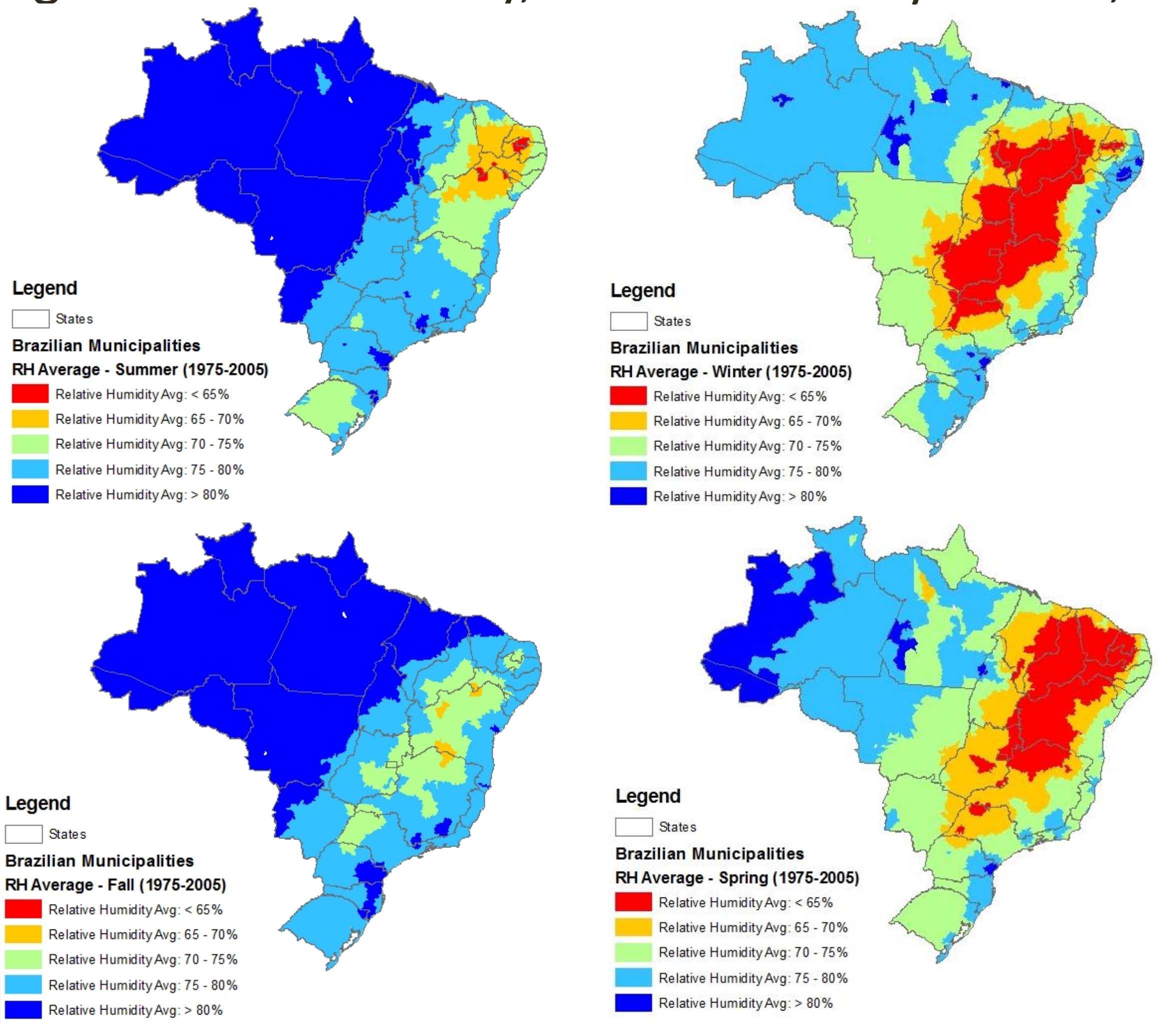






Introduction: Motivation

Average Relative Humidity, 1975 to 2005 by season, in %



Introduction: Motivation

Climate/Weather has important impacts on agricultural activities:

Climate might be a direct input for crop and animal production:

- planning decision of producers
- land use configuration

Climate can be a determinant of crop/livestock failure/loss of productivity:

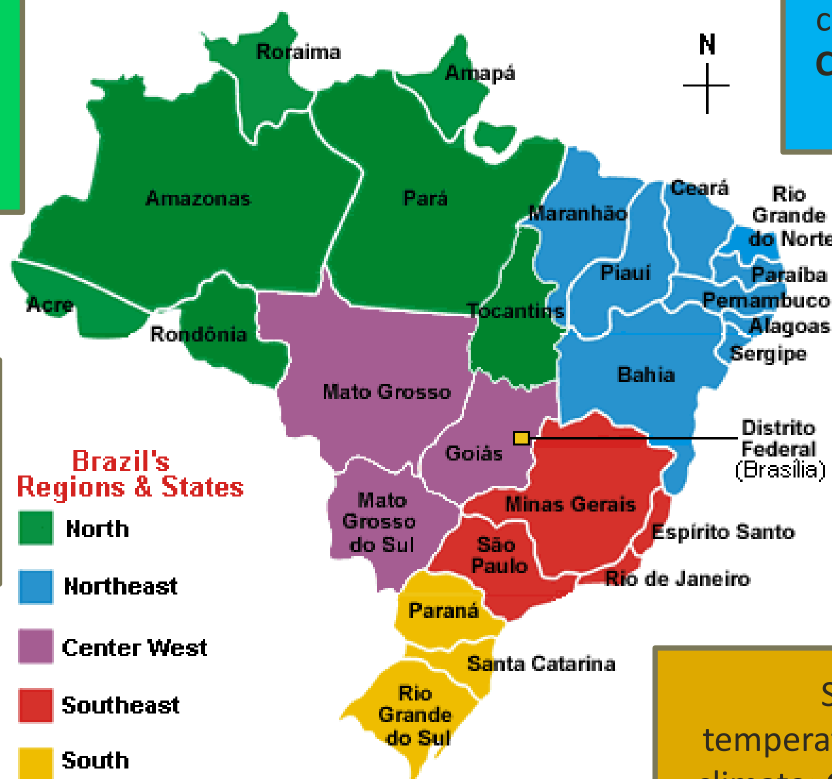
- RS and SC states calculated US$ 480 million of losses due to droughts in the summer of 2012 (maize, dairy products and beans)
- soybean production in South America fell 3% due to adverse weather in 2012
- contribute to the existence of rural poverty

Introduction: Motivation

Tropical and very humid climate: **Mainly Tropical fruits and Forest products.**

Tropical, but drier climate: **Tropical fruits, Cocoa, Forest products and subsistence**

Cerrado: **Pasture, exporting crops (soybens and maize)**



Tropical climate: **Sugarcane, Orange, crops (maize)**

Semi-temperate/moderate climate: **Grains, Crops and Oilseeds**

Introduction: Questions

Understanding Agriculture:
Relevant for food safety nowadays and in the future

Questions:

1. How will climate changes, if confirmed, affect farmers' profits and production in Brazil?
2. How can farmers adapt to deal with such possible changes?
3. Do extreme weather events divert Brazilian farmers from their optimal outcome?
4. What is the estimated magnitude of damages caused by extreme weather events?
5. How can farmers deal with extreme weather events?

Methodology

Main hypotheses:

I. Farmers observe the average climate of the region and use this information to decide production (optimally): Suggesting a <u>producer theory approach</u> (microeconomics)

II. Deviations from the average climate (such as extreme events) might deviate farmers from their above mentioned optimal choices: Suggesting the inclusion of an <u>efficiency analysis</u> inside the producer theory approach (market failure)

Methodology

Model: Profit frontier function

Producers maximize a profit function by choosing:
- Agricultural outputs (products)
- Production variable inputs (labor, fertilizers)

Producers are aware of the:
- **historical climate of the regions**
- Historical prices of the products and inputs
- Available technology
- Soil quality
- Production fixed inputs (capital and land)

Extreme events are one of the factors that frustrate the producers plans of producing by deviating them from the optimal

Methodology

Long-term approach: Translog profit frontier analysis

$$\ln\left(\frac{\Pi}{p_1}\right) = \beta_0 + \sum_{j>1} \beta_j ln(p_j/p_1) + \frac{1}{2}\sum_{j>1}\sum_{k>1} \beta_{jk} ln(p_j/p_1) ln(p_k/p_1) + \sum_{j>1}\sum_{r=1}^{f} \gamma_{jr} Z_{jr} ln(p_j/p_1) + \sum_{r=1}^{f} \delta_r Z_r + \frac{1}{2}\sum_{h=1}^{f}\sum_{r=1}^{f} \theta_{hr} Z_h Z_r - \tau$$

- *p*: is the vector of prices (output / input)
- *Z* denotes quasi-fixed factors (long-term climate / technology / soil quality other inputs)
- τ represents the inefficiency component

Methodology

Short-term approach:

Identify the factors leading to production failures (inefficiencies) in agriculture:

$$TE = \exp(-\tau) = \frac{\Pi(p, Z)}{\Pi^*(p, Z)}$$

$$TE_i = \mathrm{f}(C_i, X_i, D_i) + \varepsilon_i$$

- ε_i is a random shock with positive distribution for each farmer (represented by the representative farmer of municipality *i*);
- C_i is a vector of climate anomalies (extreme weather variables, for example) in the period for municipality *i*;
- X_i is a vector of farmer characteristics for municipality *i*;
- and D_i is a vector of other determinants.

Methodology

Data sources:

- 2006 Brazilian Agricultural Census (IBGE), INMET and INPE

Outputs:

- Annual crops: soybeans; maize; others
- Perennial crops: coffee; and others
- Livestock: milk and beef cattle
- Forest: wood; and other forest products

Inputs:

- Variable: Labor and fertilizers
- Quasi-fixed: Land and Capital (proxy: energy consumption)

Technological variables:

- Irrigation, mechanical harvesting, certified/transgenic seeds, confined cattle, art. insemination, tilled area, etc.

TE determinants:

- schooling, experience, memberships, crop diversification, climate, farm management, among others

LONG-TERM RESULTS: Analyzing historical climate

Climate change and Agriculture

LONG-TERM RESULTS

1st Results: Historical climate matters!
(imposing consistency of choice)

- Statistical relevance of average climate to explain farmers' profits
- Statistical relevance of technological variables
- Non-rejection of the inefficiency component in profits

Climate change and Agriculture

2nd Results: Expected climate change impacts

Expected loss/gain in thousand dollars, by product

Total impact (in thousand US$)	2070-2099 A2	2070-2099 B2	2040-2069 A2	2040-2069 B2
SOYBEANS	18,356,391	7,800,817	7,492,002	5,797,190
MAIZE	-32,405,954	-21,173,862	-16,616,423	-13,391,211
OTHER ANNUAL.	2,856,792	-468,878	1,449,614	1,414,939
COFFEE	-4,303,034	-4,374,969	-2,721,208	-2,758,696
OTHER PEREN.	2,483,300	-371,177	-717,465	-1,730,494
MILK	6,833,588	-1,331,718	2,492,212	-707,374
WOOD	865,875	676,169	673,609	715,158
BEEF	-3,657,008	-2,248,954	-2,128,847	-1,619,200
OTHER FOR.	-11,812	-12,157	-7,045	-12,700
Total	**-8,981,861**	**-21,504,728**	**-10,083,551**	**-12,292,387**
% of Agric. GDP*	**-8.7%**	**-20.9%**	**-9.8%**	**-12.0%**

Climate change and Agriculture

2nd Results: Expected climate change impacts

Expected loss/gain in thousand dollars, by region.

Total impact (in thousand US$)	2070-2099		2040-2069	
	A2	**B2**	**A2**	**B2**
North	4,099,362	3,080,740	1,871,070	984,517
Northeast	3,600,090	-6,703,599	-6,069,200	-5,103,463
Southeast	-9,218,995	-11,303,049	-6,653,777	-6,758,171
South	25,330,504	15,699,132	18,422,657	14,130,940
Midwest	-32,792,822	-22,277,952	-17,654,301	-15,546,211
Total	**-8,981,861**	**-21,504,728**	**-10,083,551**	**-12,292,387**

Climate change and Agriculture

3rd Results: Compensation measures for expected climate change

Variation in the technological variables (that compensate expected climate change losses in production, scenario B2 and forecast period 2040-2069)

Adaptation measures (in % of change)	Mechanical harvesting	Confined cattle	Irrigated area	Tilled area	Transgenic or certified seeds
Scenario B2 (2040-2069)					
beef	-	25.20%	-	-	*n.s.*
coffee	2.20%	-	0.70%	1.90%	4.90%
milk	-	3.40%	-	-	-
maize	6.00%	-	9.10%	44.60%	5.80%
other for	*n.s*	-	1.50%	4.80%	5.80%
other peren.	1.50%	-	0.70%	6.80%	5.50%
other annual	12.70%	-	1.50%	11.80%	10.30%
soybeans	27.40%	-	18.00%	55.80%	131.30%
wood	*n.s*	*n.s*	0.30%	*n.s*	3.60%

n.s. not statistically significant at 10%

Climate Change and Agriculture

Conclusions:

- Soybean production: positively affected by higher summer temperatures in most regions

- Expected climate changes (net losses in % of agricultural GDP, 2011):
  - 9.8 to 12% for 2040-2069 / 8.7 to 21% for 2070-2099
  - More damage in the Midwest, Northeast and Southeast regions
  - Positive effects: South and North regions

- Compensation/productivity measures:
  - Irrigation seems to be the most important compensation technique
  - Transgenic and certified seeds are relevant for crops in general
  - Cattle confinement to compensate milk and beef losses
  - Mechanical harvesting for maize and other annual crops, and tilled area for coffee and other annual and perennial crops

SHORT-TERM RESULTS: Analyzing extreme events

Extreme Weather and Agriculture

SHORT-TERM RESULTS

Climate anomaly data: climate information by season demeaned by the long-term climate data (30-year average). Four indexes are created to test their impact on profits:

- *Drought Index*: Observed rainfall below the long-term average rainfall in standard deviations;
- *Flood Index*: Observed rainfall above the long-term average rainfall in standard deviations;
- *Cold Stress Index*: Observed air temperature below the long-term average in standard deviations; and
- *Heat Stress Index:* Observed air temperature above the long-term average in standard deviations.

Extreme Weather & Agriculture

Results:

- Extreme weather events impact farmers’ outcomes

- The most relevant actions to increase farmers’ efficiency are:
  - membership in cooperatives or other associations;
  - local higher education;
  - credit access; and
  - crop specialization.

Extreme Weather & Agriculture

Estimated impact of weather anomalies on profits, Brazil.

Estimates	% of profits	Loss (-) or gain (+) in million reais (Dec-2006)	Loss (-) or gain (+) in million dollars (Dec-2011)
2005 and 2006 anomalies			
Rainfall	-5.60%	-21,440.7	-14,879.6
Temperature	3.34%	12,803.2	8,885.3
Drought or cold stress			
Drought	-30.50%	-116,689.1	-80,981.0
Cold stress	-13.19%	-50,474.2	-35,028.5

Percentage of profit losses due to climate anomalies, by region

Region	Cold stress	Drought
North	-13.1%	-30.3%
Northeast	-13.0%	-30.0%
Southeast	-12.8%	-29.5%
South	-13.6%	-31.4%
Midwest	-15.5%	-35.9%

Policy Discussion

Expected climate change

Policymakers are the only agents that can think about the sustainability of the country in the long run in order to plan specific actions.

Agriculture: Actions to build flexible production systems (technology)

- use of irrigation is the main compensation instrument
- transgenic/certified seeds, confined cattle and tilled area are also important adaptation measures to smooth the climate change effects.
- In particular, transgenic/certified seeds: sustainable way that serve as an insurance policy in response to potential changes in production conditions.

Policy Discussion

Short-term interventions

Monetary and social losses due to weather : equitable problem

Public intervention to stimulate the market to produce alternatives

In agriculture:

- cooperatives, crop specialization, credit access help farmers to be more efficient
- Discussion of insurance instruments: important actions to protect farmers from extreme weather harmful situations (max. farmer propensity to pay is 15 billion dollars due to the lack of rainfall)
- Weather index insurance mechanism: market-driven solution.
- Many barriers in the current Brazilian rural insurance market: mainly lack of information, data management, rural insurance consolidation

Future research and limitations

Future research:

- Agricultural studies:
  - Account costs and barriers of the adaptation measures (compare techniques)
  - Map investment need/penetration of each technique in the municipalities
  - Include new questions regarding those technologies (Agricultural Census)
  - Develop frost/hail index instead of cold stress index

Limitations:

- Method: Partial analysis
- Risk assess. in agriculture: lack of precision/ frequency of climate data for Brazil to implement better rural insurance.
- Time horizon of the analysis: data limitation

Obrigada.