Assessing the Impact of ENSO events on the Brazilian Agricultural Productivity

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El Niño Southern Oscillation (ENSO)

- Quase-periodic redistribution of heat across the tropical Pacific
- Three phases
  - El Niño: heating of the sea surface temperature in the Pacific Ocean (deviation from reference temperature > + 0,5ºC)
  - La Niña: cooling of the the sea level temperature in the Pacific Ocean (difference from reference temperature > - 0,5ºC)
  - Neutral: sea level temperature close to reference temperature

Weather related ENSO effects in Brazil

- Distinct regional effects

- Northeast region:
  - El Niño – severe droughts
  - La Niña – increased precipitation

- South region:
  - El Niño – increased precipitation and higher temperatures
  - La Niña – severe droughts

Weather-related ENSO effects: Northeast region

Northeast	Neutral	El Niño 1982-83	El Niño 1997-98	La Niña 1973-76	La Niña 1986-89
Precipitation (mm)					
Summer	91,80	84,13	74,23	95,37	108,08
Fall	139,23	94,23	110,51	163,16	185,81
Winter	66,05	47,96	56,23	70,53	78,45
Spring	38,4	25,30	25,67	52,96	38,96
Temperature (^{o}C)					
Summer	26,27	26,52	27,08	26,13	26,39
Fall	25,41	25,70	26,07	25,12	25,79
Winter	23,80	24,31	24,45	23,48	23,75
Spring	25,78	26,11	26,66	25,41	26,05

Economic-related ENSO effects

- El Niño 1982-83
  - South region: production loss aprox. 5 M t, 35% of total production (Berlato et al. 2005)
- El Niño 1997-1998 (Teracines, 2011)
  - Production loss: R$ 3,5 billion
  - Northeast: 15 million t.

Objective and methodology

- Assessing the impact of weather-related ENSO effects on the agricultural productivity of the Northeast and South regions
- Methodology: three-stage approach (Deng et al., 2010)
  - First stage: relationship between sea surface temperature in the Pacific and climatology of Brazilian municipalities
  - Second stage: reduced-form equations to assess how temperature and precipitation are related to crop productivity
  - Third stage: simulation of El Niño effects on agricultural productivity

First stage: specification

- Non-linearities: spline function
  - piecewise linear with respect to sea level temperature in the Pacific
  - Knots: thresholds for ENSO regime switch

$$weather_{it} = \beta_0 + 1\!\!1_{LaNiña}\beta_1 SSTA_t + 1\!\!1_{neutral}\beta_2 SSTA_t + 1\!\!1_{ElNiño}\beta_3 SSTA_t + 1\!\!1_{LaNiña}\beta_4 SSTA_{t-1} + 1\!\!1_{neutral}\beta_5 SSTA_{t-1} + 1\!\!1_{ElNiño}\beta_6 SSTA_{t-1} + \beta_7 latit_i * SSTA_t + \beta_8 longit_i * SSTA_t + \mu_i + \varepsilon_{it}$$

Second stage: specification

- Crop productivity in municipality i at period t as a (non-linear) function of temperature and precipitation

$$yield_{sit} = \gamma_0 + \gamma_1 temp_{it} + \gamma_2 temp_{it}^2 + \gamma_3 prec_{it} + \gamma_4 prec_{it}^2 + \gamma_5 T + \mu_i + \eta_{it}$$

Third stage: simulation

- ENSO effects captured as the difference of estimated average climate during El Niño/La Niña and neutral period (first stage) multiplied by γ (second stage)

$$E(\Delta yield)_{\text{El Niño}} = \hat{\gamma}' \left[E[\hat{weather}_{ElNiño}] - E[\hat{weather}_{neutral}] \right] \quad (3)$$

$$E(\Delta yield)_{\text{La Niña}} = \hat{\gamma}' \left[E[\hat{weather}_{LaNiña}] - E[\hat{weather}_{neutral}] \right] \quad (4)$$

Results: first stage

	Precipitation (mm)				Temperature (^{o}C)			
	summer	**autumn**	**winter**	**spring**	**summer**	**autumn**	**winter**	**spring**
$SSTA_{LaNiña.\ t}$	4.12*** (0.1813)	9.836*** (0.3278)	-6.70*** (0.3643)	-1.385*** (0.3633)	-0.0154*** (0.0023)	-0.065*** (0.0032)	0.1948*** (0.0069)	0.479*** (0.0083)
$SSTA_{neutral.\ t}$	-3.74*** (0.1882)	1.040*** (0.2418)	-1.48*** (0.1968)	-4.98*** (0.1392)	-0.0118*** (0.0024)	-0.007*** (0.0023)	0.1421*** (0.0038)	0.171*** (0.0031)
$SSTA_{El\ Niño.\ t}$	-0.557*** (0.1412)	1.81*** (0.2319)	-5.54*** (0.2132)	-0.362* (0.2028)	0.0587*** (0.0018)	0.1022*** (0.0022)	0.214*** (0.0041)	0.214*** (0.0046)
$SSTA_{LaNiña.\ t-1}$	-5.49*** (0.1583)	-40.47*** (0.9012)	-6.49*** (0.2202)	-0.1370 (0.2388)	0.0347*** (0.0020)	0.2710*** (0.0088)	0.0736*** (0.0042)	-0.323*** (0.0054)
$SSTA_{neutral.\ t-1}$	4.63*** (0.1689)	-12.34*** (0.3046)	3.083*** (0.1643)	4.084*** (0.1353)	0.0014*** (0.0022)	0.096*** (0.0029)	-0.095*** (0.0031)	-0.120*** (0.0030)
$SSTA_{ElNiño.\ t-1}$	-3.36*** (0.1279)	-19.61*** 0.5249	-2.936*** (0.1725)	-3.847*** (0.1294)	0.0488*** (0.0016)	0.0302*** (0.0051)	0.140*** (0.0032)	-0.032*** (0.00293)
Latitude	-0.050*** (0.0006)	-0.0538*** (0.0001)	-0.048*** (0.00008)	-0.045*** (0.00004)	-0.0518*** (0.00007)	-0.046*** (0.00005)	-0.0458*** (0.00006)	-0.0474*** (0.00005)
Constant	15.77*** (0.3234)	13.47*** (0.5141)	3.01*** (0.3139)	11.553*** (0.1459)	4.122*** (0.0276)	6.27*** (0.0209)	6.35*** (0.0198)	6.088*** (0.0180)

Note: *.** and *** indicate statistical significance at 10%. 5% and 1% level. respectively. Standard errors in parenthesis

Results: second stage

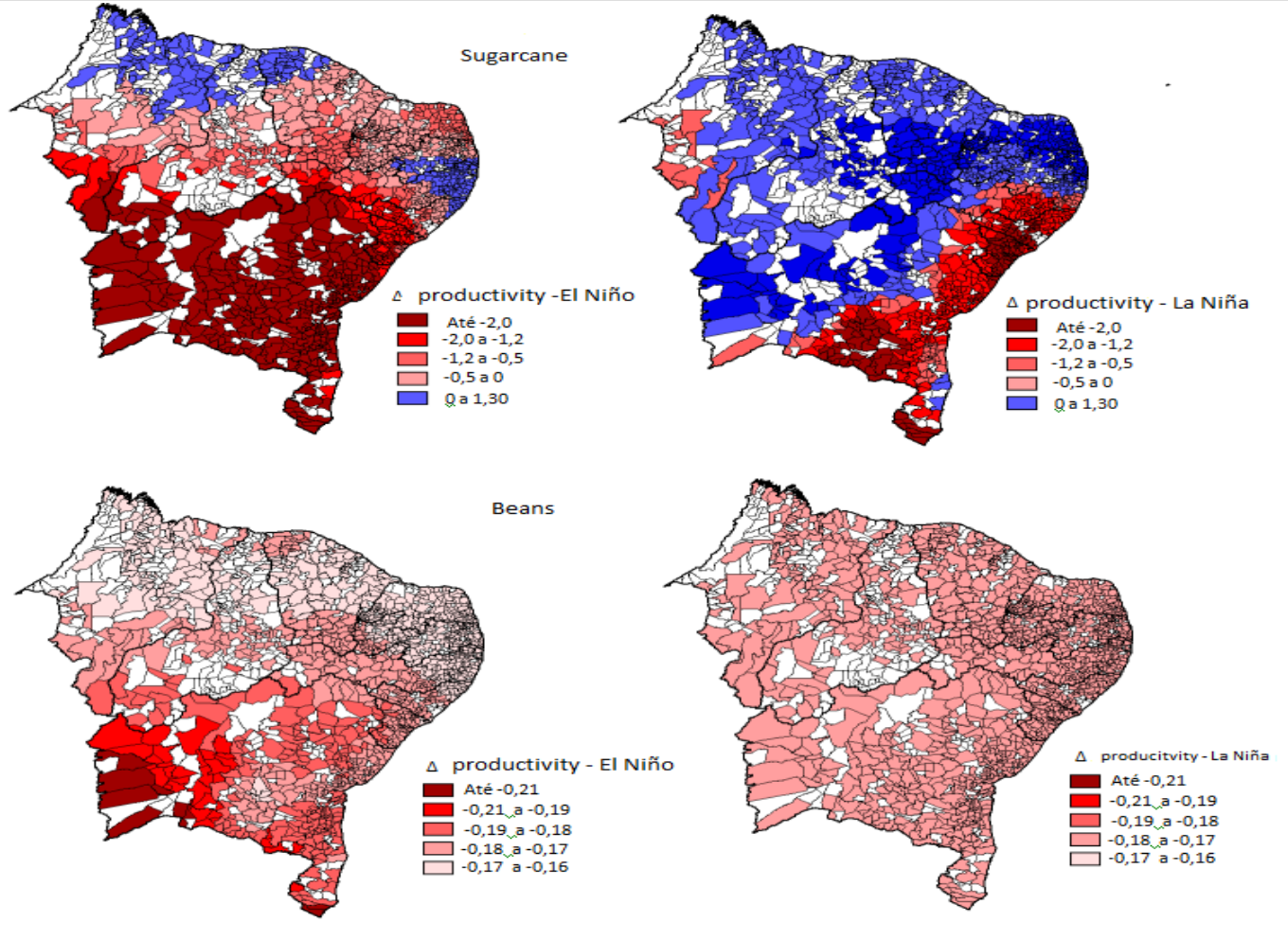
theast	El Niño				La Niña			
	Corn	Sugarcane	Beans	Manioc	Corn	Sugarcane	Beans	Manioc
summer	0.0028***	0.0243***	-0.00021*	0.0015	-0.0013***	0.0175**	-0.0025	0.0025
	(0.0002)	(0.0132)	(0.00014)	(0.0013)	(0.0007)	(0.0228)	(0.00028)	(0.00247)
ımmer ^2	0.0000006***	-0.00007***	0.0000	0.000006	0.0000006***	-0.0001***	0.0000	-0.0000009
	(0.00000005)	(0.0000057)	(0.00000)	(0.000003)	(0.0000005)	(0.000068)	(0.0000)	(0.000007)
autumn	0.0013***	-0.0108**	-0.00013*	-0.00027	0.0034***	0.0186***	0.0002**	-0.00002
	(0.00019)	(0.0108)	(0.00012)	(0.00086)	(0.0002)	(0.0120)	(0.0001)	(0.0014)
utumn ^2	-0.00000002***	0.0000147***	0.00000	-0.000003	-0.0000007***	-0.00005***	0.0000	-0.0000006
	(0.00000007)	(0.0000054)	(0.0000)	(0.00002)	(0.0000005)	(0.000029)	(0.0000)	(0.000003)
_winter	0.0012***	0.0143**	-0.00018	0.0025*	-0.0010***	0.0320***	-0.00005	0.0013**
	(0.00016)	(0.0127)	(0.00015)	(0.0014)	(0.0003)	(0.0205)	(0.00015)	(0.017)
winter^2	-0.00000003***	-0.000041***	-0.0000	-0.000005**	0.0000002***	-0.000072***	0.0000	-0.000003***
	(0.00000004)	(0.000039)	(0.00000)	(0.00006)	(0.00000007)	(0.0051)	(0.00000)	(0.000051)
_spring	0.0011***	0.0121**	-0.0001	-0.00311	0.0013***	-0.04125*	0.00003	-0.0002
	(0.0004)	(0.0272)	(0.000218)	(0.0022)	(0.0005)	(0.0303)	(0.00003)	(0.0029)
spring^2	-0.0000006***	-0.000008***	0.0000	0.0000	0.0000009***	0.0002***	0.0000	0.000002**
	(0.0000003)	(0.000156)	(0.00000)	(0.00000)	(0.0000005)	(0.00017)	(0.0000)	(0.00005)
_summer	0.7244	11.96	0.1161*	0.1227	0.1156	-16.39	0.0665	0.1532
	(0.1958)	(9.2034)	(0.0907)	(0.6830)	(0.1451)	(10.327)	(0.1230)	(0.9059)
_summer ^2	-0.0148**	-0.21006	-0.0023	-0.0027	-0.0037***	0.3153*	-0.0014	-0.0019
	(0.0037)	(0.17772)	(0.0017)	(0.0128)	(0.0027)	(0.1945)	(0.0023)	(0.0172)
_autumn	-1.0245	-23.3244**	-0.0733	-0.6379	-1.3444	5.4601	0.0642	-0.3499
	(0.1822)	(12.366)	(0.1214)	(1.0711)	(0.3199)	(14.603)	(0.1542)	(1.269)
_autumn ^2	0.0217**	0.4406**	0.0016	0.0133	0.0259**	-0.1147	-0.3016	0.0063
	(0.0035)	(0.2422)	(0.0023)	(0.0210)	(0.0060)	(0.2804)	(0.1011)	(0.0247)
_winter	0.7407	-6.2212	0.0397	0.6236	1.5187	-1.8122	0.00083	-0.8812
	(0.1284)	(7.05388)	(0.0710)	(0.5966)	(0.2005)	(8.0370)	(0.0019)	(0.9486)
winter^2	-0.01982**	0.1231	-0.0006	-0.0110	-0.0321**	0.0421	0.0025	0.00171**
	(0.0026)	(0.1460)	(0.0014)	(0.0125)	(0.0037)	(0.1606)	(0.0811)	(0.019)
_summer	-0.9834	2.406	-0.1743*	-0.6817	-0.809	16.5272	-0.00004	0.1432***
	(0.1436)	(8.306)	(0.0953)	(0.7332)	(0.2000)	(10.025)	(0.0015)	(0.849)
ummer^2	0.02137**	-0.04006	0.0029*	0.0102	0.01769***	-0.3373	-0.00004	-0.027*
	(0.0027)	(0.1587)	(0.00177)	(0.0140)	(0.0040)	(0.1975)	(0.0015)	(0.0169)
ıstant	8.318	20.1613	1.7164	8.9255	8.4431*	-16.04	-0.9671	-3.76
	(2.4915)	(10.849)	(1.1614)	(10.73)	(4.3348)	(161.24)	(2.0304)	(18.81)
ny_1970	1.086***	-1.2201***	0.510***	0.058*	0.054*	-0.012***	0.012**	0.0174***
	(0.049)	(1.193)	(0.0019)	(0.509)	(0.0286)	(0.0286)	(0.0003)	(0.0549)
ny_1980	0.673***	-10.202***	0.621***	0.0459	0.259***	-0.037***	0.034***	0.0014**
	(0.039)	(1.975)	(0.089)	(0.189)	(0.3195)	(0.0032)	(0.0129)	(0.0109)
ny_1990	0.210***	-0.460***	0.771***	0.026***	0.4691***	-0.1945***	0.0815**	0.0141***
	(0.052)	(1.541)	(0.120)	(0.238)	(0.372)	(0.00344)	(0.0512)	(0.341)
ny_2000	0.359***	-0.0945***	0.9311***	0.0629**	1.342***	-0.2021***	0.1301***	0.051***
	(0.047)	(0.02886)	(0.0987)	(0.0255)	(0.062)	(0.0161)	(0.0023)	(0.321)

Note: *.** and *** indicate statistical significance at 10%. 5% and 1% level. respectively. Standard errors in parenthesis

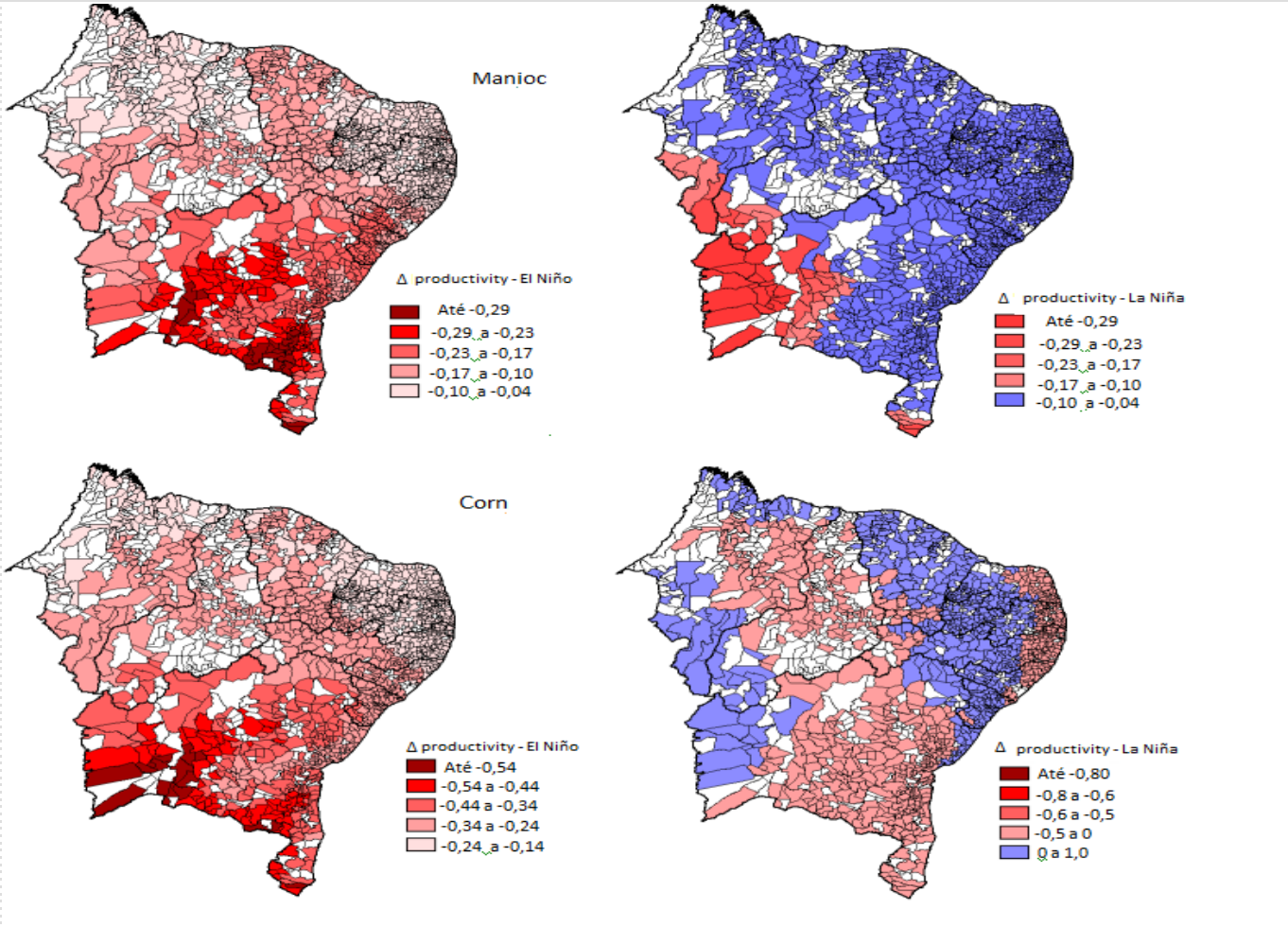
Simulation results: Northeast

Crop	Average Productivity (tons/ha)	El Niño		La Niña	
		Δ productivity (tons/ha)	Percentage change	Δ productivity (tons/ha)	Percentage change
Sugarcane	21.29	-0.91	-4.3%	-0.07	-0.3%
Manioc	1.88	-0.10	-5,3%	-0.01	-0.5%
Corn	0.52	-0.28	-53,8%	-0.03	-5.7%
Bean	0.37	-0.18	-48.6%	-0.15	-40.5%

Simulation results Northeast: sugarcane and black beans



Simulation results Northeast: manioc and corn



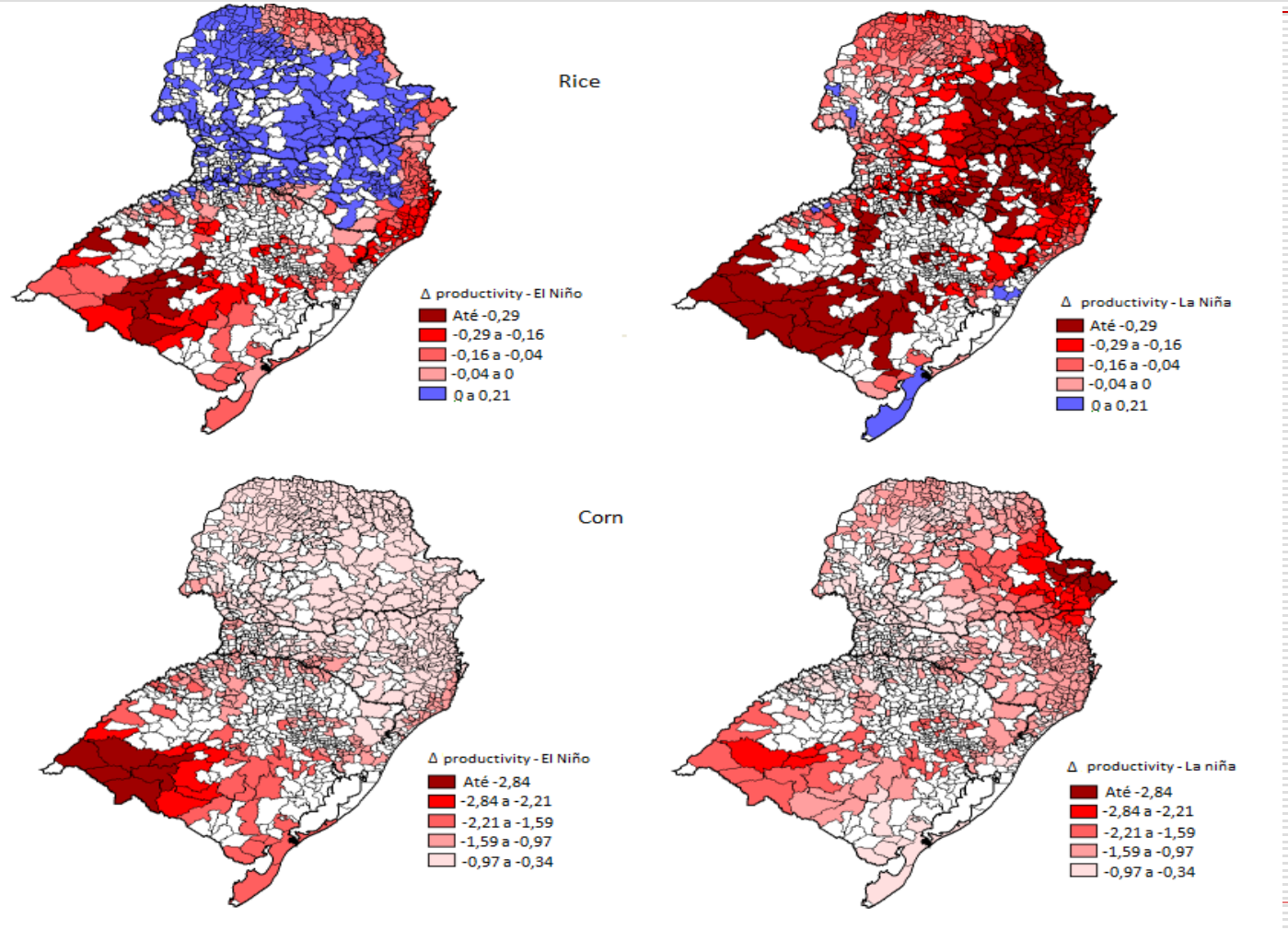
Simulation results: south

Crop	Average Productivity (tons/ha)	El Niño		La Niña	
		Δ productivity (tons/ha)	Percentage change	Δ productivity (tons/ha)	Percentage change
Corn	2.37	-0.96	-40.5%	-1.23	-51.9%
Rice	2.14	-0.01	-0.4%	-0.25	-11.7%
Wheat	0.78	-0.05	-6.4%	-0.67	-85.9%
Soybean	1.22	-0.96	-78.7%	-0.32	-26.2%

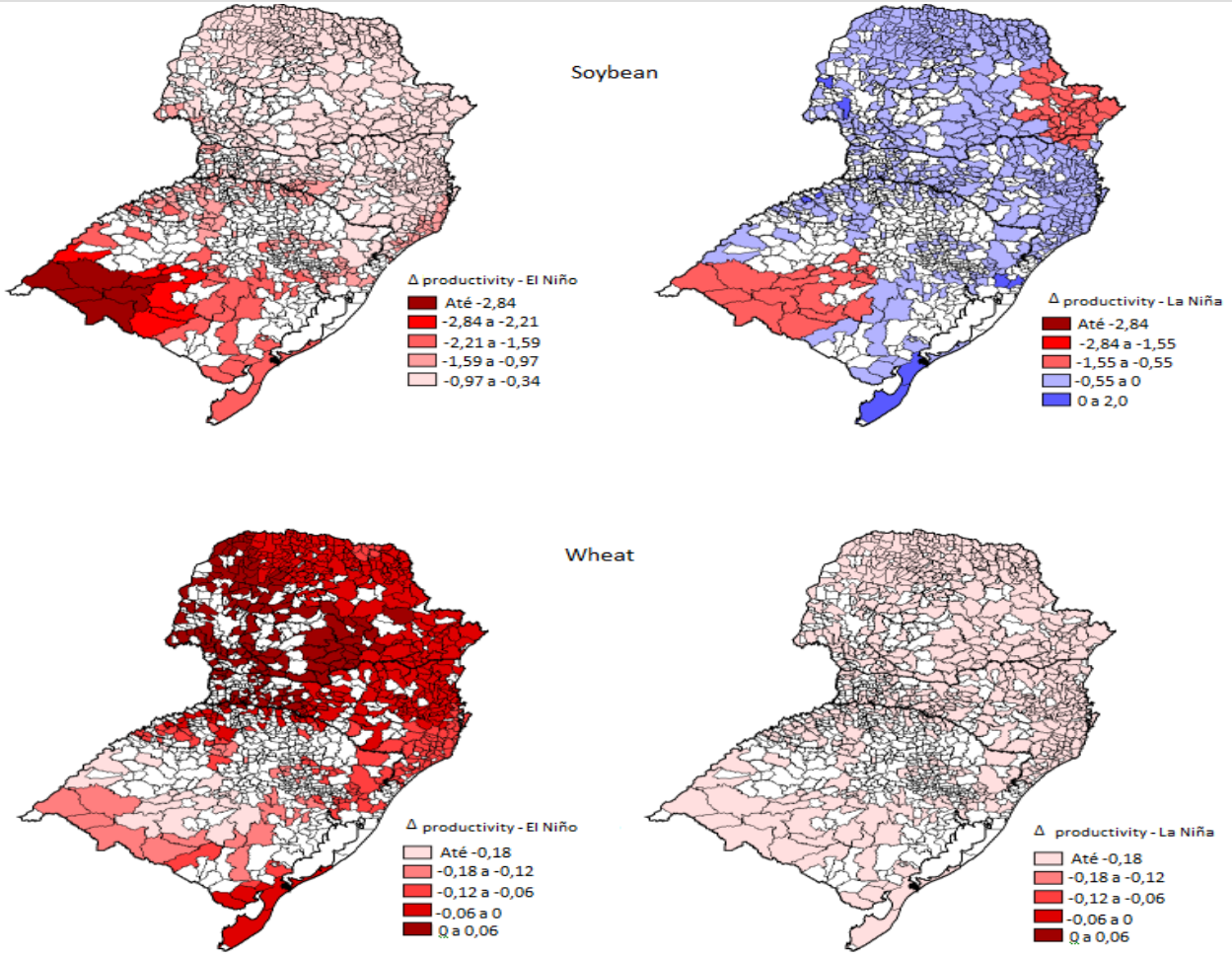
Simulation results: South

- Negative impacts in both El Niño and La Niña years
  - Rio Grande do Sul: Most vulnerable state in El Niño years
    - Corn: -83%; rice: -6%; wheat: -13%

Simulation results South: rice and corn



Simulation results: South region – soybean and wheat



Conclusions

- El Niño/La Niña: important regional impacts, especially on water-intensive, rainfed crops
- Need to invest in irrigation methods
- Further investigation: accounting for irrigated crops