Assessing Local Vulnerability to Climate Change in Agriculture for Tocantins, Brazil

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Assessing Local Vulnerability

to Climate Change in Agriculture for Tocantins, Brazil

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We propose a reliable indicator of vulnerability to climate change in agriculture that allows measuring in data intensive climate environments of reduced GPC of a local level: climate exposure (Ei), climate sensitivity (Si), and adaptive capacity (Ai).

Objective

To develop a reliable indicator of local vulnerability that captures its dynamics and the criterion of tractability and comparability across time and location. This indicator will allow identifying main vulnerability drivers and planning policies to increase system resiliency as well as designing climate change adaptation policies at the local level.

Methodology

This indicator combines the methodology of Lobell et al. (2005) and the estimates a fixed effects model at the county-level to measure how climate stressors (growing degree days, GDD_{it} and accumulated precipitation, $Prec_{it}$) influence agricultural systems (yields) using information on geographical, geomorphological, socioeconomic and temporal characteristics of local systems.

$$Y_{it}=\alpha_i Prec_{it}+\alpha_2 GDD_{it}+\gamma Y_t+\psi Y_t+\theta Y_{it}+\beta_1 Prec_{it}^2 Y_{it}+\beta_2 GDD_{it}^2 Y_{it}+d t+\varepsilon_{it}$$

We define a set of outcome variables that represent a system to define a fractional indicator of local vulnerability.

$$\text{Exposure } (E) = Pr_E\, dS \quad (1)$$

E is a frequency measure of climate adverse events for the crop development at municipality level.

Stressor sensitivity (Si)

$$SS = f\left(\frac{\Delta \text{output}}{\Delta \text{stressor's intensity}}\right) = f\left(\frac{\partial Yield_{ij}}{\partial Stressor_{ij}}\right) \quad (2)$$

The SS captures the system response to changes in stressors, where $\partial Yield_{ij}$ is the estimated response of yields to stressor i; $Yield_{ij}$ is the observed yield in a given system (county) and $Yield_{threshold}$ represents the point of reference for a given system below which the agricultural sector becomes "damaged".

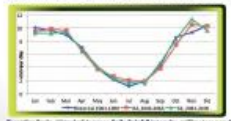
Vulnerability measure is defined as the expected value of the ratio of the system's sensitivity to a given threshold.

$$V = Expected\ Value(SS) = \int \left(\frac{\partial Yield_{ij}}{\partial Yield_{threshold}}\right) Pr_S\, dS \quad (3)$$

Case of Study

We applied this methodology for measuring local vulnerability of the municipalities where the Development Program for the Southwest region of the state of Tocantins (PRODOESTE, BIR-11170) is operating in Brazil. This project is an Inter-American Development Bank's agricultural project for expand irrigation area in the region and improve the productive conditions of the region.

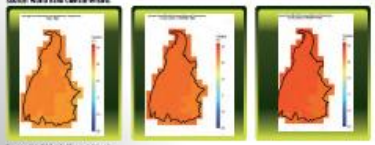
PRODOESTE is being implemented in Tocantins basin, one of the Brazil's agricultural frontier regions, specialized in the production of soybean, corn, rice, beans and watermelon. Most of the region is dryland; so, growing season is largely determined by occurrence of the rainy and dry seasons of the region (May to September), when drought is usually the main factor responsible for crop losses.



Tocantins Basin, Historical Average Daily Rainfall Intensity, millimeters per day.

Tocantins, Growing degree days per year.

Source: World Bank Climate Wizard.



Source: World Bank Climate Wizard.

It is projected that Climate Change will affect Tocantins by decreasing the average daily precipitation during wet season and increasing the minimum and maximum temperatures, affecting the growing degree days for the region. This research is focused in the period of study 1961-2001.
The sources used for the study were: NOAA for climate data, Ministério da Agricultura, Pecuária e Abastecimento for yield information and the Instituto Brasileiro de Geografia e Estatística for socioeconographic data at municipality level. Climate change data were obtained from the Climatic Research Unit (CRU) at the University of East Anglia (UEA).

Estimation and Results

Econometric estimation

Independent variables	Yield
Accum. Prec(t-1)	0.0041277 (0.0074859)
Accum. Prec(t-1)^2	2.000000 (0.0130697)
Growing degree days	-0.0000000 (1.5663336)
Growing degree days^2	(0.7687359) -0.0744428
	0.0457762

Sensitivity to Stressor Indicator*

Municipalities	Exposure Index*
1. Aliança do Tocantins	0.217
2. Almas	0.174
3. Araguaçu	0.174
4. Chapada de Tocantins	0.174
5. Chapadinha (2nd Stage)	0.217
6. Chapada do Tocantins	0.261
7. Dueré	0.217
8. Figueirópolis	0.174
9. Formoso do Araguaia	0.217
10. Lagoa da Confusão (2nd Stage)	0.261
11. Pium (2nd Stage)	0.304
12. Santa Rita do Tocantins	0.174
13. Santa Tereza do Tocantins	0.217
14. Talismã	0.174
Tocantins Average	0.228

* Indicators normalized with the Tocantins Average

Sensitivity to Stressor Indicator*

Municipalities	Precipitation	GDD**	Municipalities	Vulnerability
1. Aliança do Tocantins	0.00	0.91	1. Aliança do Tocantins	1.243
2. Almas	0.00	0.45	2. Almas	1.032
3. Araguaçu	0.02	1.94	3. Araguaçu	1.217
4. Carrilo do Tocantins	0.05	2.08	4. Carrilo do Tocantins	1.819
5. Chapadinha (2nd Stage)	0.10	0.00	5. Chapadinha (2nd Stage)	1.084
6. Chapada do Tocantins	0.10	3.65	6. Chapada do Tocantins	0.762
7. Dueré	0.07	0.55	7. Dueré	1.002
8. Figueirópolis	0.06	0.97	8. Figueirópolis	0.969
9. Formoso do Araguaia	0.00	0.21	9. Formoso do Araguaia	4.525
10. Lagoa da Confusão (2nd Stage)	0.00	0.32	10. Lagoa da Confusão (2nd Stage)	1.454
11. Pium (2nd Stage)	0.04	0.72	11. Pium (2nd Stage)	1.491
12. Santa Rita do Tocantins	0.02	1.47	12. Santa Rita do Tocantins	1.078
13. Santa Tereza do Tocantins	0.00	1.34	13. Santa Tereza do Tocantins	0.803
14. Talismã	0.10	1.21	14. Talismã	0.721
Tocantins Average	1.00	1.00	Tocantins Average	1.000

* Indicators normalized with the Tocantins Average

Conclusions

- Local vulnerability to climate change in agriculture in Tocantins will diverge according to drier locations.

This research was carried out with the financial support of the Inter-American Development Bank.