UNIVERSITÉ DE LORRAINE

BETA Bureau d'économie théorique et appliquée

CEC Dauphine | PSL

May 16th, 2024

Forest Cover and Weather Shocks:

Land Use on the Quest For Adaptation and Conservation

PhD Candidate

Giulia Vaglietti

Supervisors

Delacote,P., Leblois, A.

Jury

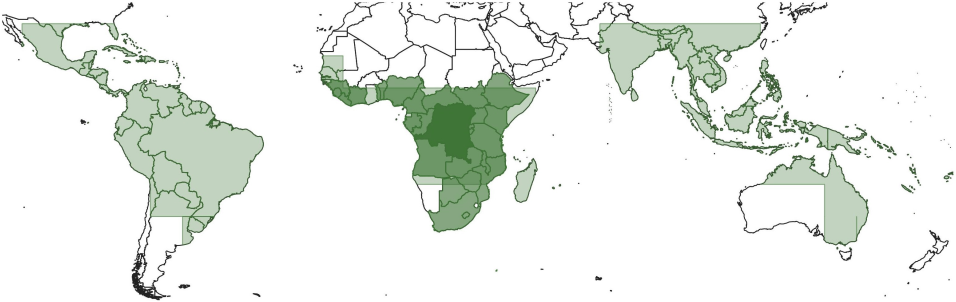
President - Chakir, R.

Reviewers - Di Falco, S., Strobl, E.
Examiner - Boltz, M.

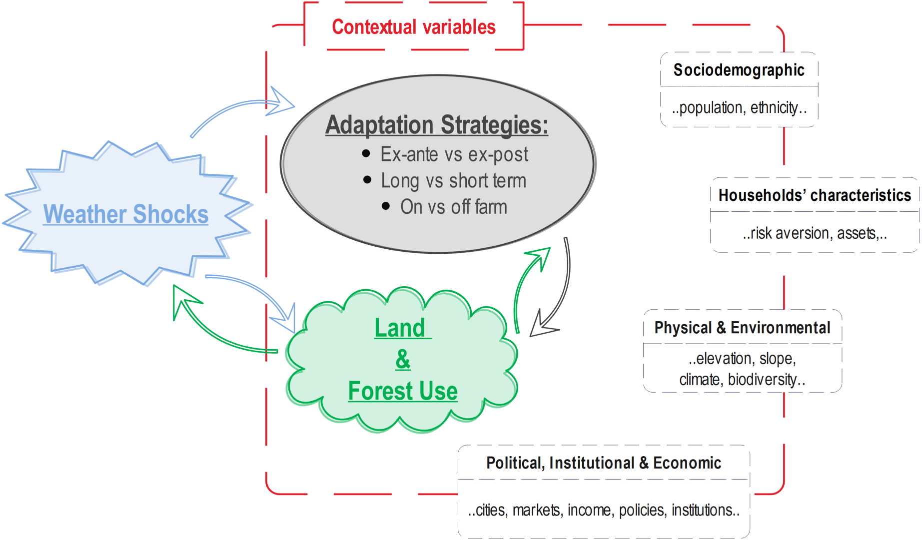
Chapter 1

Introduction

Investigating the relations between **drought** and **land use** at different **time** and **geographical** scale.

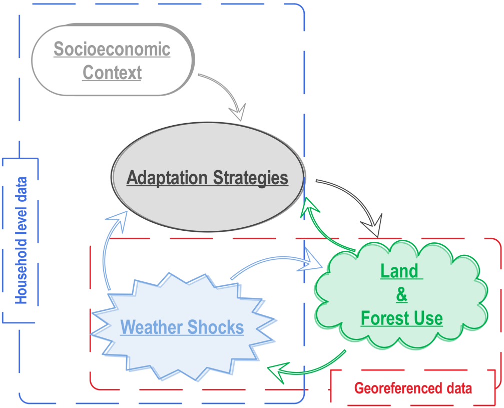


Deforestation and Adaptation Strategies



Literature's research methods

- Households surveys
  (Rodriguez-Solorzano, 2014; Tsegaye *et al.*, 2010; Roncoli, Ingram & Kirshen, 2001)
- Satellite and georeferenced data
  (Desbureaux & Damania, 2018; Leblois, 2021; Zaveri, Russ & Damania, 2020)



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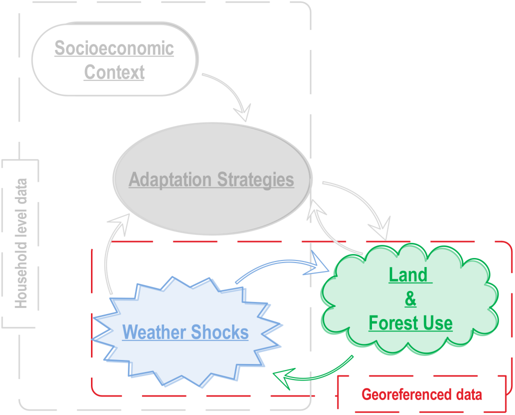


Research Questions

1. Is there a common response to **droughts** in **tropical** areas determining **forest cover change** or degradation? (Ch. 2)

2. Does the **timing** of agricultural droughts matter in determining forest cover loss? (Ch. 3)

3. Is the impact of drought on forest loss and degradation inhibited within **protected areas** (PA), **Indigenous Lands** (IL)? (Ch. 2 & Ch. 3)

4. Does **dam construction** and consequent changes in water distribution affects LUC? (Ch. 4)

Key Takeaways

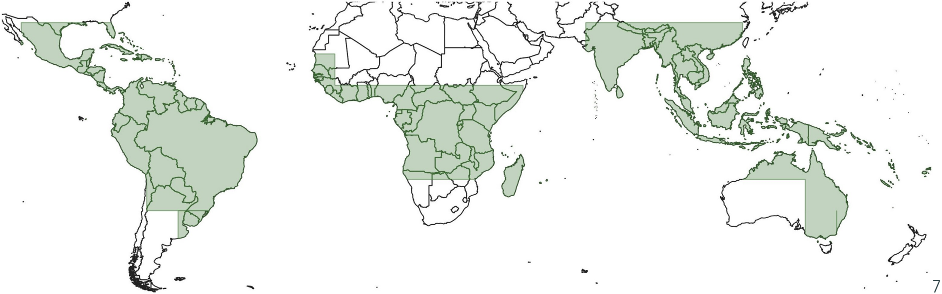
1. Deforestation and degradation as globally adopted responses to droughts - the case of tropical areas; (Ch. 2)
2. Responses may be context dependent - the case of agricultural seasonality in DRC; (Ch. 3)
3. Investments as a driver of land use change - the case of dams in Sub-Saharan Africa (SSA); (Ch. 4)

CHAPTER 2

PANTROPICAL DEFORESTATION AND DEGRADATION

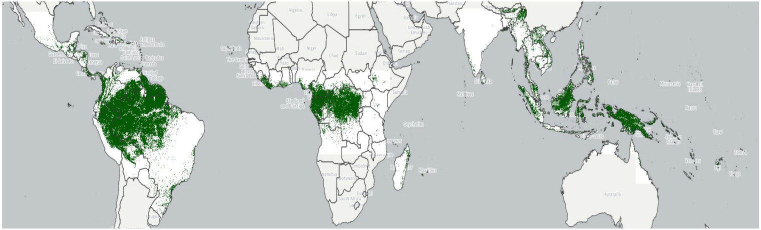
Vaglietti G., Leblois A. & Delacote P. - Working Paper

1. Is there a common response to **droughts** in **tropical** areas determining **forest cover change** or degradation? Discussing the influence of spatial & temporal heterogeneity and precipitation endowment.
2. Is the impact of drought on forest loss and degradation inhibited within **PA**, **IL**, **agricultural** or **urban areas**?



Data Availability & Processing

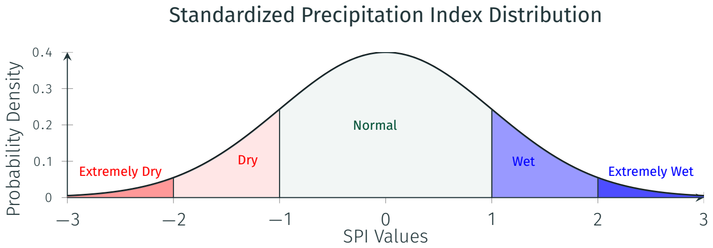
Deforestation and degradation



Source: Tropical Moist Forest Explorer

- **Data**: TMF, long-term deforestation and degradation in tropical moist forests; (Vancutsem *et al.*, 2021)
- **Period**: 1990-2020;
- **Resolution**: Georeferenced, 30x30m pixel → 5x5km pixel;
- **Output**: Panel, **dependent variable** indicating the share of deforested or degraded area as % of total pixel mapped area;

Data Availability & Processing



- **Data**: Monthly precipitations CHIRPS; (Funk *et al.*, 2015)
- **Period**: 1990-2020;
- **Resolution**: Georeferenced, 5x5km pixel;
- **Processing**: Creation of a Standardized Precipitation Index (SPI) for assessing and quantifying meteorological drought; (McKee *et al.*, 1993)
- **Output**: Independent variable dummy, $SPI_{it} \leq -1$ at year t and pixel $i \Rightarrow D_{it} = 1$;

Identification Strategy

1. **Global and regional impact:**

$$Log(L_{it} + 1) = \beta_0 + \beta_1 D_{it} + \gamma_i + \delta_t + u_{it}$$

2. **Sources of heterogeneity:**
    - Shock intensity;
    - Interactions with **Protected Areas** and **Indigenous Lands**
    - Time trends;

Identification Strategy

1. Global and regional impact;

2. **Sources of heterogeneity:**
   - **Shock intensity** - low, medium, average, high

$$Log(L_{it}+1) = \beta_0 + \beta_1 \mathbf{Dl}_{it} + \beta_2 \mathbf{Dm}_{it} + \beta_3 \mathbf{Da}_{it} + \beta_4 \mathbf{Dh}_{it} + \gamma_i + \delta_t + u_{it}$$

   - Interactions with land policies treatment (Tr), **PA** and **IL**

$$Log(L_{it}+1) = \beta_0 + \beta_1 D_{it} + \beta_2 D_{it} * \mathbf{Tr}_{it} + \gamma_i + \delta_t + u_{it}$$

   - **Time trends** over pentads, *e.g.*, $1990 \leq \boldsymbol{t} < 1995$, ..., $2015 \leq \boldsymbol{t} < 2020$

$$Log(L_{it}+1) = \beta_0 + \beta_1 D_{it} + \gamma_i + \delta_t + u_{it}$$

Global and Regional Impacts

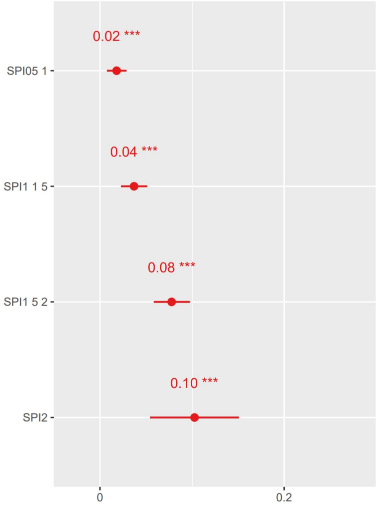
Global and regional deforestation in droughts eventuality, 1990-2020

	Dependent variable:				
	Deforestation				
	(1)	(2)	(3)	(4)	(5)
Sub-basin	Global	Africa	Americas	Asia	Oceania
Year SPI $\leq$ -1	0.051***	0.032*	0.027**	0.040***	0.059**
	(0.007)	(0.019)	(0.011)	(0.010)	(0.027)
Time and pixel FE	Yes	Yes	Yes	Yes	Yes
Observations	27,441,293	7,585,731	12,595,238	5,854,474	769,234
R^2	0.865	0.822	0.890	0.887	0.870
Adjusted R^2	0.860	0.816	0.886	0.884	0.866
Residual Std. Error	1.025	1.167	0.893	0.946	0.921

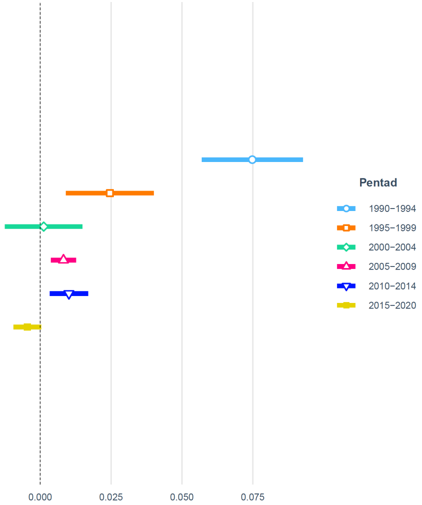
Note: *$p<0.1$; **$p<0.05$; ***$p<0.01$

Sources of Heterogeneity

Drought intensity



Impacts of droughts by pentad



CHAPTER 3

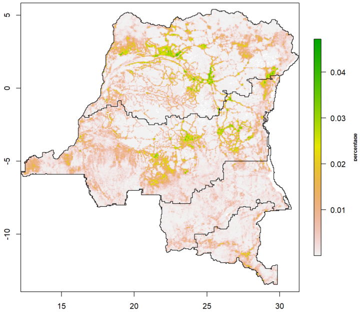
DROUGHTS AND DEFORESTATION: DOES SEASONALITY MATTER?

Vaglietti G., Leblois A. & Delacote P, 2022. *Plos One*

1. Does the **timing** of agricultural droughts matter in determining forest cover loss? Discussing the influence of previous *vs* current experience and agricultural cycle.
2. Is the impact of drought on forest loss and degradation inhibited within **PA**, **IL**, **agricultural or urban areas**?

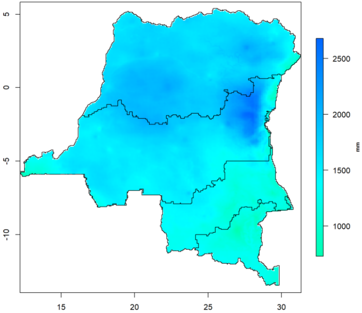
Data Availability & Processing

Forest Loss



- **Data**: Global Forest Change;
  (Hansen *et al.*, 2013)
- **Panel**: 2001-2020;
- **Output**: 5*5km cell, total ha deforested in year *t* and cell *i*;

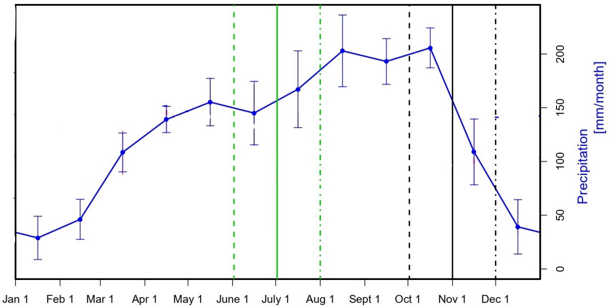
Precipitations



- **Data**: Monthly precipitations CHIRPS;
  (Perterson *et al.*, 2014)
- **Output**: $SPI \leq -1$ at season t, drought $D_{it} = 1$; (McKee *et al.*, 1993)

Data Availability & Processing

Agricultural Cycle



- **Data**: Crop Calendar Dataset; (Sachs *et al.*, 2010)
- **Crops and Cycle**: Maize, Cassava;
- **Crops and Cycle**: Planting (PL), Growing (GR), Harvesting (HA);
- **Independent variable**: $D\_Maize\_PL1,2_{it}$.

Identification strategy

Forest loss & droughts seasonality, both for **past** and **present** events:

$$Log(L_{it}+1) = \beta_0 + \beta_1 D\_Cassava\_PL_{it} + \beta_2 D\_Cassava\_HA_{it} \\ +\beta_3 D\_Maize\_PL1,2_{it} + \beta_4 D\_Maize\_GR1,2_{it} \\ +\beta_5 D\_Maize\_HA1,2_{it} + \gamma_i + \delta_t + u_{it}$$

Droughts & the Agricultural Cycle

	Dependent variable:	
	Log of deforested hectares + 1	
	(1) Experienced Droughts	(2) Current Droughts
Cassava		
Planting	-0.0186 (0.0248)	0.0569** (0.0249)
Harvesting	-0.0597 (0.0441)	-0.0636 (0.0535)
Maize		
Planting 1,2	0.0150 (0.0172)	−0.0304** (0.0136)
Growing 1,2	−0.0256* (0.0150)	−0.0689*** (0.0199)
Harvesting 1,2	−0.0194* (0.0115)	0.0592*** (0.0129)
Observations	519,160	519,160
F Statistic (df = 5; 493178)	37.6635***	73.8697***
Note:	*p<0.1; **p<0.05; ***p<0.01	
	Time and cell fixed effect, clustered at the sector administrative level	

Deforestation in response of experienced and current droughts. Analysis in areas with at least 50% forest cover in year 2000.

Chapter 4

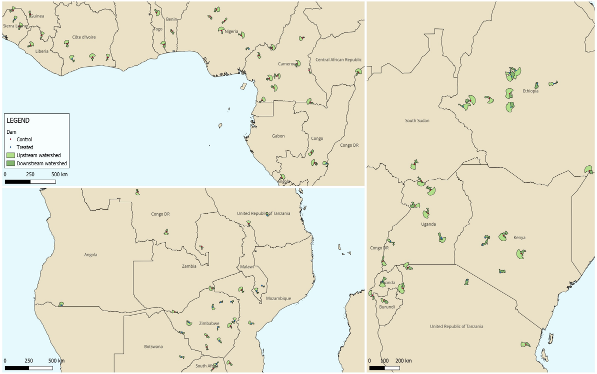
Dams construction, land productivity, forest cover and land use change

Vaglietti G. & Noack F. - Working Paper

1. Does **dam construction** and consequent changes in water distribution affect LUC?
   - Agricultural & irrigated lands;
   - Forests extension;
   - Flooded areas;
   - Productivity & economic activities.

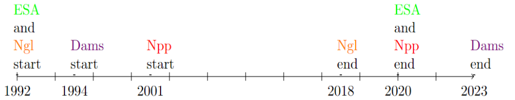
Data Availability & Processing

SSA Dams: treated and controls, watersheds and command areas

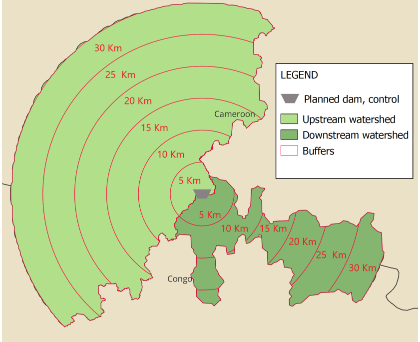


Source: Personal elaboration of GADM, Hydrosheds sub-basin (level 9) and DEM)

Data



Data Availability & Processing



Source: Personal elaboration of **Hydrosheds** sub-basin (level 9), integrated with a **hydrological modelling** (Whiteboxtool R) based on a DEM and dams location

1. **Dams**: FAO AQUASTAT African Dams database, 37 built and 55 planned;
2. **Land Use**: ESA Copernicus (1992-2020), unit of analysis pixels (300x300m) inside the dams' watershed
   - Agriculture;
   - Irrigated agriculture;
   - Forest;
   - Waters.
3. **Economic activities**:
   - Nightlights; (Li *et al.*, 2020)
   - Net Primary Productivity; (Running *et al.*, 2015)

Identification Strategy

Estimate the causal effect of dam construction over time by **staggered difference-in-difference** (Sun & Abraham, 2021):

$$LUC_{it} = \mu_i + \eta_t + \sum_{k=-L}^{-1} \tau^k Tr_{it}^k + \sum_{k=0}^{K} \tau^k Tr_{it}^k + \epsilon_{it}$$

Where *LUC* is a dummy indicating Land Use Change (e.g., if investigating agriculture $LUC_{it} = 1$ if the pixel has agricultural lands and 0 otherwise), while *Tr* a dummy indicating the treatment.

Land Use

Upstream	5 Km	10 Km	15 Km	20 Km	25 Km	30 Km
Waters	0.0188***	0.0164***	0.0040***	0.0004	1.51×10^{-5}	0.0002
Agriculture	−0.0150***	−0.0158**	−0.0017	0.0008	−0.0097***	−0.0249***
Forest	0.0135	0.0016	−0.0064	0.0007	0.0152***	0.0309***
Irrigation	8.71×10^{-5}	−0.0002	-7.02×10^{-5}	2.52×10^{-5}	1.37×10^{-5}	−0.0002*
Downstream	5 Km	10 Km	15 Km	20 Km	25 Km	30 Km
Waters	0.0009**	−0.0015*	−0.0008	0.0008	−0.0024	0.0005
Agriculture	−0.0114*	−0.0165**	0.0040	0.0068	0.0092*	0.0026
Forest	0.0470***	0.0402***	0.0129*	0.0117**	0.0009	−0.0066
Irrigation	−0.0027	−0.0040	−0.0013	0.0007	−0.0002	0.0001

Clustered at dam watershed. * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Average effect of Treatment on the Treated (ATT) by land use and distance, upstream and downstream watershed.

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Clustered at dam watershed. * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Average effect of Treatment on the Treated (ATT) by land use and distance, upstream and downstream watershed.

Economic activities and productivity

Upstream	5 Km	10 Km	15 Km	20 Km	25 Km	30 Km
NPP	−0.1211	−0.1119**	−0.2736***	−0.0783	−0.1871**	−0.3034***
Urban	−0.0003	0.0003	0.0014*	0.0007***	7.96×10^{-5}	−0.0005
Nightlights	−1.319***	0.0967	0.0346	0.0083	−0.0437	−0.0323
Downstream	5 Km	10 Km	15 Km	20 Km	25 Km	30 Km
NPP	−0.1351	−0.0336	−0.0877	0.0048	0.1220	−0.0207
Urban	−0.0026	0.0027***	0.0037**	0.0097***	-4.72×10^{-5}	0.0018
Nightlights	−0.9228***	0.5483***	0.7431***	0.5645**	0.1748	0.0949

Clustered at dam watershed. * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Average effect of Treatment on the Treated (ATT) by land use and distance, upstream and downstream watershed.

Discussion

- Human-induced global **deforestation increases** when droughts occur. Although sources of spatial, climate and temporal **heterogeneity** exist:
    - Drought-response **decreases over time**;
    - Deforestation is influenced by **droughts' intensity**;
    - Shocks experience and protection policies influence land use-choices with potential **policy implications**.
- Investments may lead to unintended redistribution of land uses;
- Potential interplay between mitigation tools (forests) and adaptation strategies (land use choices): **what are the implications for public policies?**

Discussion

Thanks for listening! Any question?

Acknowledgments

I would like to extend my heartfelt gratitude to the esteemed members of the jury - Pr. Chakir, Pr. Di Falco, Pr. Strobl & Dr. Boltz - for their time, expertise, and rigorous evaluation throughout this journey. I am thankful to the reviewers - Pr. Di Falco & Pr. Strobl - for the valuable contributions shared so far.

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Extreme weather events (EWE)

Occurrence of a weather variable value above (below) a threshold value near the upper (or lower) 'tails' of the observed values range. (IPCC, 2012)

EWE & agriculture, effects:

- **Direct**: Yield, Livestock (Thornton and Cramer, 2012; Mbilinyi *et al.*, 2013; Fitchett and Grab, 2014; Guan *et al.*, 2015; Herrero *et al.*, 2009; Thornton and Cramer, 2012)
- **Indirect**: Ecosystem services (Rosenzweig *et al.*, 2001; Thornton and Cramer, 2012)

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Farmer responses to EWE

Short term:

- collection of forest products (wood and NTFP), agroforestry (Noack *et al.*, 2019; Delacote, 2007)
- selling assets / livestock (Carter & Zimmerman,2006)
- looking for off-farm work (Millock *et al.*, 2015)

Long-term:

- activity portfolio diversification (Girard *et al.*, 2019)
- migration and remittance use (Duval & Wolff, 2009)
- building asset stocks (Wunder *et al.*, 2014)
- land reallocation and farming practices (Wunder *et al.*, 2014)

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Alternatives to the SPI?

Future robustness check may include alternatives calculation of the SPI or more elaborated drought indexes:

- *"The Standardized Precipitation Index (SPI) is widely used as drought meteorological index, to identify the duration and/or severity of a drought. The SPI is usually computed by fitting the gamma probability distribution to the observed precipitation data. [...] It is concluded that for SPI of 12 or 24 months, the log-normal or the* ***normal probability*** *distribution can be used for simplicity, instead of gamma, producing almost the same results."* Angelidis *et al.*, 2012
- **Standard Precipitation and Evapotranspiration Index (SPEI)**: both precipitation and **temperature**, thereby considering the influence of global warming.
- There is a degree of **agreement between SPI and SPEI** at all time scales (Tefera *et al.*, 2019).

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Table 1: Time trends of the deforestation-response to droughts, across continents and rainfall endowments

Continent:	*Rainfall endowment:*		
	Low	Mid	High
Africa	+ to -	- to + to -	- to + to -
Americas	+ to + (decreasing)	+ to - to +	+ to -
Asia	- to +	+ to -	+ to 0
Oceania	+ to + (decreasing)	+ to + (decreasing)	0 to +

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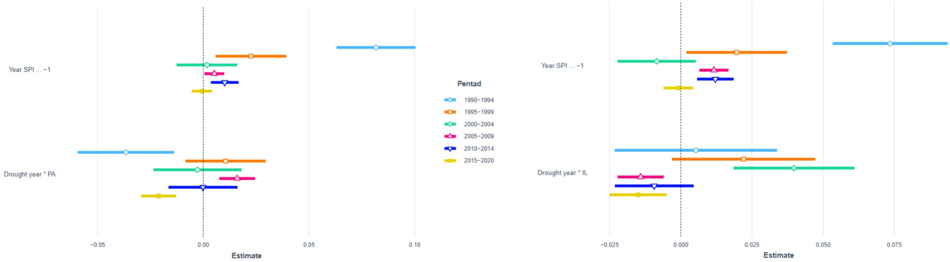
Results: land policies



(a) Protected areas (b) Indigenous lands

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Time interaction

HDFE Linear regression	
Number of obs	27,441,293
Absorbing 2 HDFE groups	$F(3, 18861) = 22.09$
Statistics robust to heteroskedasticity	$Prob > F = 0.0000$
R-squared	0.8648
Adj R-squared	0.8603
Within R-sq.	0.0006
Number of clusters (admin_2)	18,862
Root MSE	1.0251

	Dependent variable:					
	Log of L + 1					
	Coef.	Std. Err.	t	$P > \|t\|$	[95% Conf.	Interval]
D	.1151	.0149	7.74	0.000	.0859	.1442
D P2	-.0977	.0163	-5.99	0.000	-.1297	-.0657
D P3	-.1042	.0141	-7.40	0.000	-.1318	-.0766
Constant	4.6873	.0012	3910.02	0.000	4.6849	4.6896

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Identification strategy

1. **Forest loss & droughts seasonality**, both for **past** and **present** events.

2. Interactions with land policies treatment (Tr), **PA** and **proximity to cities**:

$$Log(L_{it}+1)=\beta_0+\beta_1 D\_Cassava\_PL_{it}+\beta_2 D\_Cassava\_HA_{it}+\beta_3 D\_Maize\_PL1,2_{it}+\beta_4 D\_Maize\_GR1,2_{it}$$
$$+\beta_5 D\_Maize\_HA1,2_{it}+\beta_6 D\_Cassava\_PL_{it}\mathbf{*Tr}+\beta_7 D\_Cassava\_HA_{it}\mathbf{*Tr}+\beta_8 D\_Maize\_PL1,2_{it}\mathbf{*Tr}$$
$$+\beta_9 D\_Maize\_GR1,2_{it}\mathbf{*Tr}+\beta_{10} D\_Maize\_HA1,2_{it}\mathbf{*Tr}+\gamma_i+\delta_t+u_{it}$$

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Yearly aggregation

	Dependent variable:
	Log of deforested hectares + 1 Yearly aggregation
Experienced, y	-0.0180
	(0.0115)
Current, y	-0.0005
	(0.0110)
Observations	519,160
F Statistic	27.8757***
	(df = 2; 493181)
Note:	*p<0.1; **p<0.05; ***p<0.01;
	Time and cell fixed effect, clustered at the sector administrative level

Deforestation and both experienced and current droughts, yearly aggregation.

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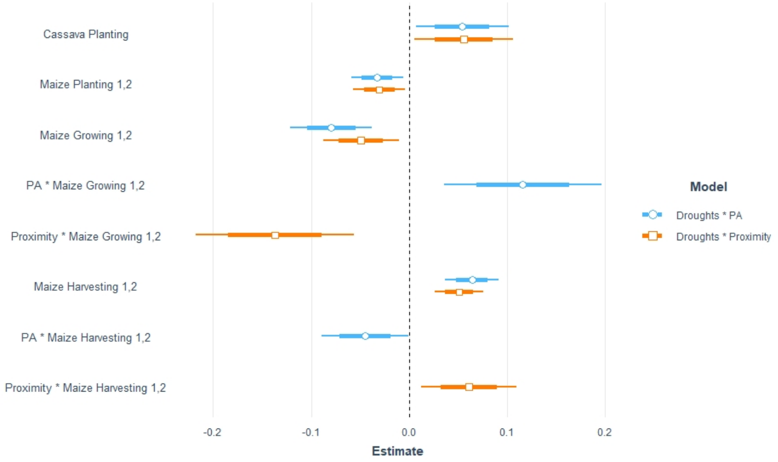
RESULTS: SOURCES OF HETEROGENEITY

Interactions with **protected areas** and **proximity to cities**:



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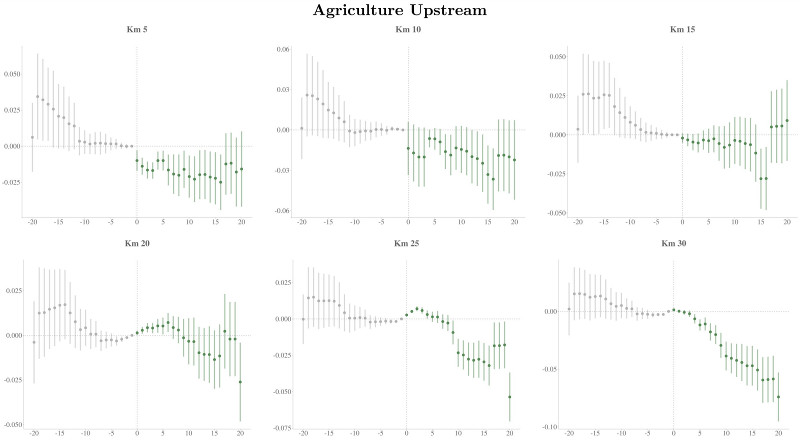

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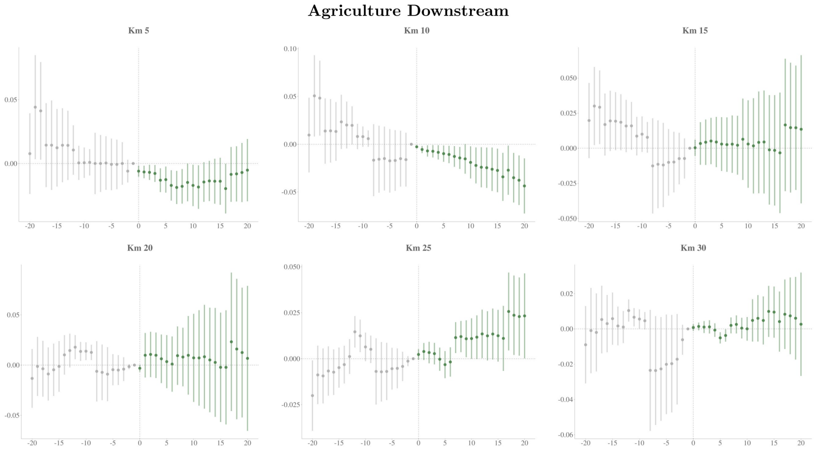
DiD Agriculture downstream



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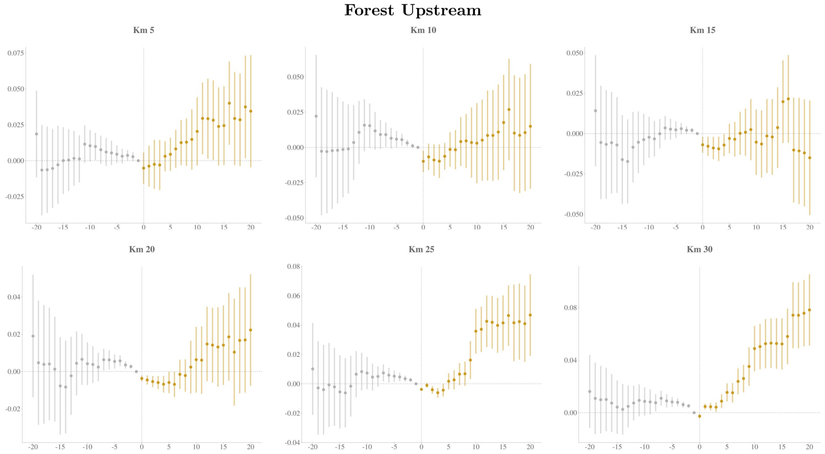
DiD Forest upstream



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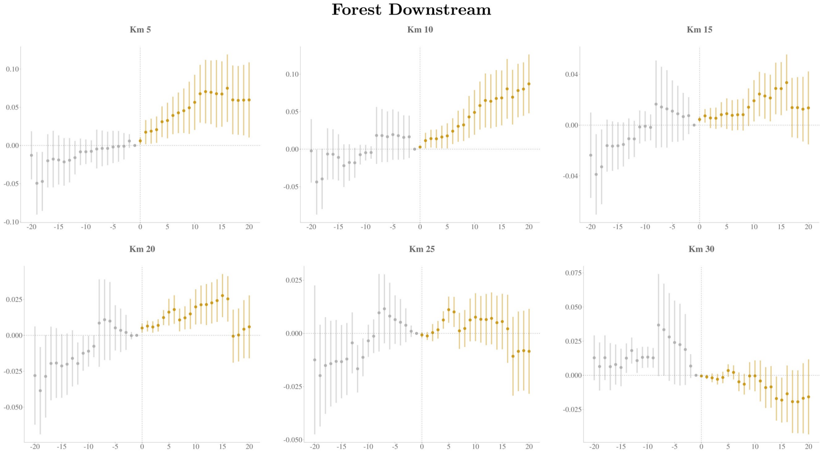
DiD Forest downstream



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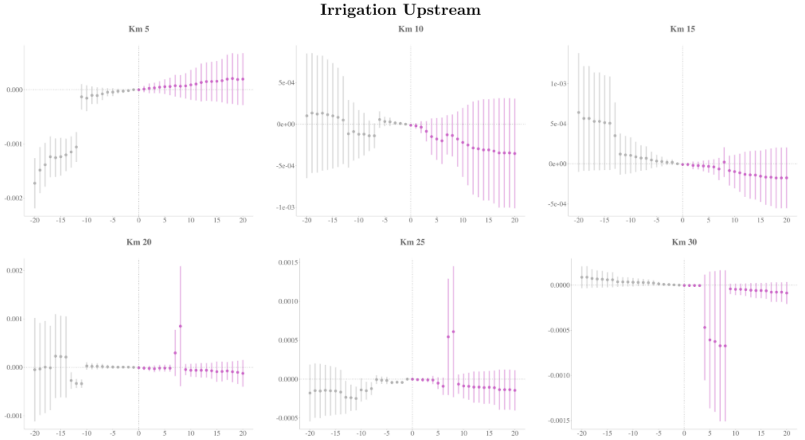

Figure A3: Event study, change in irrigated land in the upstream watershed by distance from the dam

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DiD Irrigation downstream

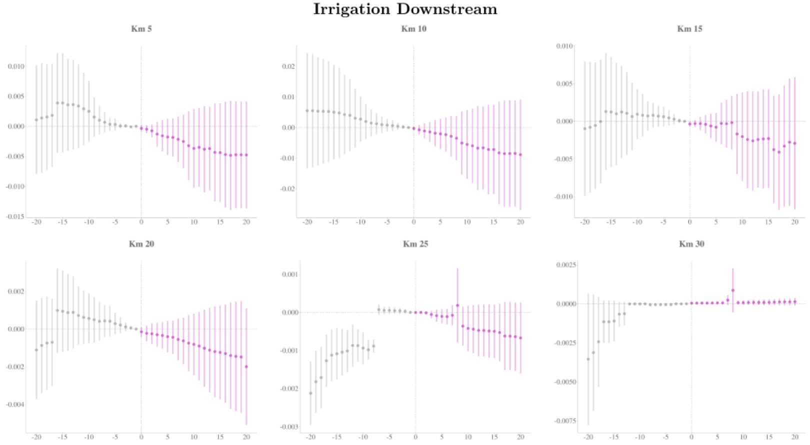

Figure A4: Event study, change in irrigated land in the downstream watershed by distance from the dam

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DiD Urban downstream

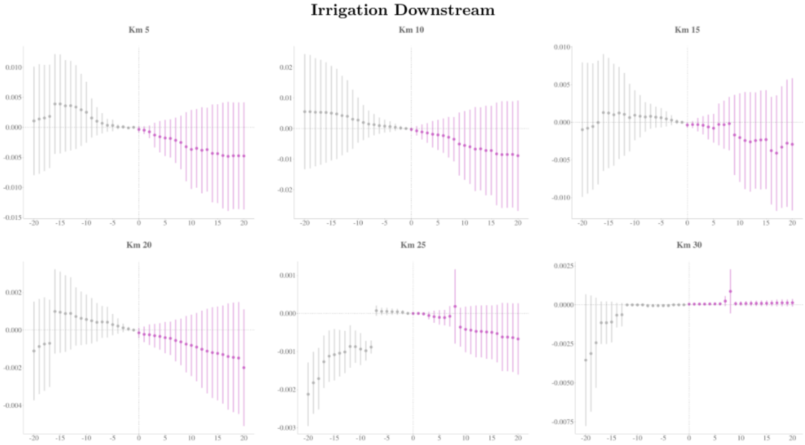

Figure A4: Event study, change in irrigated land in the downstream watershed by distance from the dam

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DiD Nightlights downstream

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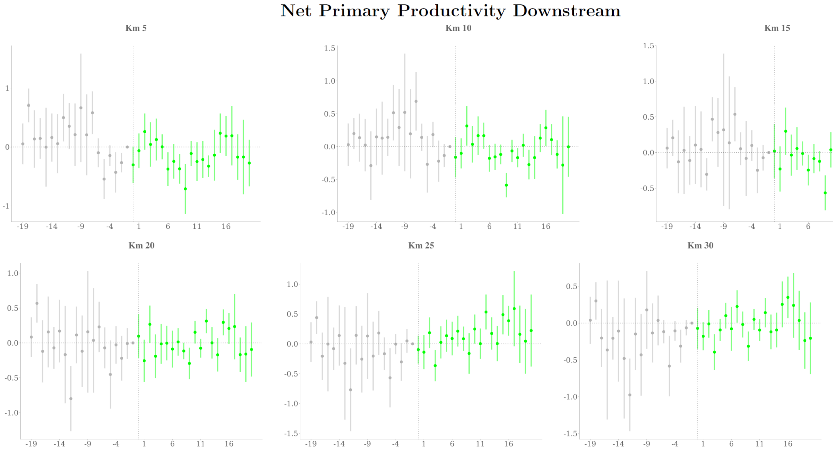
DiD Net Primary Productivity downstream



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Operative Next Steps

- **Pantropical - Data comparison**: comparing deforestation outcomes at tropical level between Hansen *et al.* (2013) and Vancutsem *et al.* (2021)
- **Dams - Aggregated effects**: at basin level to compare with milestones of the literature such as Duflo & Pande (2007) and Strobl & Strobl (2011)

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Limitations & Further Work

Limitations:

- **Adaptation practices** are not explicitly considered here (households' surveys)
- **Database reliability** specially for LU is highly debated

Next steps:

- Socioeconomic environment
- Resilience

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ECONOMIC INSIGHTS

What can we learn from an economic perspective?

- As **afforestation is a globally adapted mitigation tool**, therefore **global results** were necessary for the **generalisation of local or climate results** highlighted so far by the academic literature (Desbureaux and Damania, 2018; Leblois, 2021; Staal *et al.*, 2020);
- We underline that **private adaptation** may have an **impact on public goods**;
- If the impacted public goods are also a mitigation tool, as forest are, the risk is to **fuel a vicious circle** undermining mitigation tools efficiency ;
- Therefore, our results are a starting baseline to **orient policies towards equitable and sustainable adaptation strategies** that are not at detriment of those goods used as a tool for mitigation such forests.

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