More Than Just Carbon: The Socioeconomic Impact of Large-Scale Tree Planting

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Motivation

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The UN Sustainable Development Goals emphasize that ecosystem services and biodiversity conservation are essential to human well-being

- Defined an agenda where development targets for people and planet sit alongside each other

Current global enthusiasm around tree planting as a means of climate change mitigation and adaptation

- Raised several questions about the optimal project design and ancillary economic and ecological benefits

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Large-scale tree planting could jointly address poverty and environmental concerns

- Climate mitigation (sequestering carbon) (Bastin et al., 2019; Griscom et al., 2017; and Lewis et al., 2019)
- Climate adaptation (possibly reduce floods and landslides) (Tan-Soo et al., 2016; Van Noordwijk et al., 2016)
- **Poverty reduction** (through job creation and asset transfers)

Philippines' National Greening Program (NGP)

From 2011-2016, the program planted 1.6 Mha of land with over 1.4 billion trees, and **directly employed over 550.000 people**

- Expansion in forest cover of 11.4 percent over the 13.2 million hectares of natural forest in 2010
- Primarily a reforestation program, but further scope for poverty reduction, food security and ecosystem services

The DENR forms partnerships with local **People's Organisations (POs)**

- Payments for seedling production, site preparation and maintaining the projects for three years
- Plantation assets are transferred to POs
- Receive all profits from the plantations

Research Questions

1. Was the NGP effective in **increasing forest cover**?
2. Did the NGP **reduce poverty and increase economic activity**?
   - Were there spillover effects into surrounding villages?
   - Was the impact derived from the asset transfer (trees) or the payments (preparation/maintenance)?
3. Did the NGP induce **sectoral or labor reallocation**?
4. What are the **carbon sequestration benefits** of the NGP?
   - How much CO2 was sequestered?
   - What is the **economic value** of reducing CO_2 emissions through the NGP?

Preview of Paper

Exploit the staggered roll-out of the NGP by comparing earlier and later treated municipalities/villages

Main Findings:

Preview of Paper

Exploit the staggered roll-out of the NGP by comparing earlier and later treated municipalities/villages

Main Findings:

- **4% increase in forest cover**
- **6 p.p. reduction in poverty and 8 p.p. decrease in the share of unlit settlements**
- Reduction in **agricultural employment** and increases in **unskilled manual labor and services**
- No effect on **labor supply** (population change) $\rightarrow$ NGP created economic activity
- **Cost efficient** carbon sequestration: $2 - $10 per tCO_2

Contributions

Inherent trade-off between environmental quality and poverty alleviation (Jayachandran, 2023)

- Policies trying to maximizing economic prosperity alongside environmental quality rarely occur (Jayachandran, 2022)

Multifaceted interventions that grant productive assets along with cash transfers

- Large transfers, which create better jobs for the poor, are an effective means of getting people out of poverty traps and reducing global poverty (Balboni et al., 2022)

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Structural transformation and conservation programs

- NGP reduced employment in the agriculture sector, increased unskilled manual labor and services
- No evidence of changes in population and migration

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Context and Specifics of the National Greening Program

National Greening Program

The Philippines have seen continued forest loss since the 1930s

- From 2000 - 2022, lost 1.42 million hectares of tree cover, equivalent to a 7.6 percent decrease or 848 MtCO2

NGP launched in 2011 as an executive order to plant billions of trees across the Philippines

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NGP launched in 2011 as an executive order to plant billions of trees across the Philippines

- Budget of 31 billion PHP (~$721m), sought to plant 1.5 billion seedlings across 1.5 million hectares from 2011 - 2016
- Tree planting happens on degraded forestlands, mangrove, protected areas and mosaic cropland

National Greening Program (continued)

The DENR overseas nursery establishment, site identification, technical support and program monitoring

- Extension services, monitoring seedling suppliers and plantation sites

The DENR forms partnerships with People's Organizations (local associations / cooperatives)

National Greening Program (continued)

The DENR overseas nursery establishment, site identification, technical support and program monitoring

- Extension services, monitoring seedling suppliers and plantation sites

The DENR forms partnerships with People's Organizations (local associations / cooperatives)

- They receive payment for their role in
  - Seedling production
  - Preparing the sites
  - Planting seedlings
  - Maintaining and implementing protective measures for 3 years
- All profits generated from the plantation are directed towards the implementing PO

Survival rate goal was 85% $\rightarrow$ from 2011 to 2015 the survival rate was 83%

Data

National Greening Program: 2011 - 2016

Data on 80,522 individual tree planting plantations:

- Information on when a municipality/village received each plantation
- How many hectares were planted, commodity type and species planted
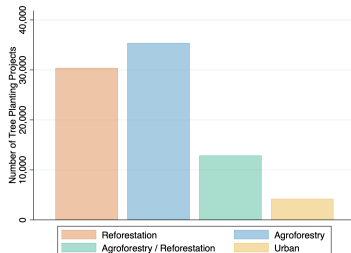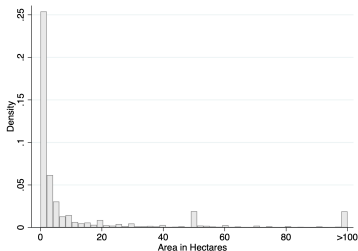
National Greening Program

National Greening Program Accomplishment Report

Year	Target Area	Area Planted	Seedlings Planted	Employed
2011	100,000	128,558	89,624,121	47,868
2012	200,000	221,763	125,596,730	55,146
2013	300,000	333,160	182,548,862	65,198
2014	300,000	334,302	205,414,639	152,008
2015	350,000	360,357	351,014,239	123,519
2016	247,683	284,089	415,564,211	114,584
NGP	1,497,683	1,662,229	1,369,762,802	558,323

Source: Department of Environment and Natural Resources (2022).

NGP: Municipality Level

NGP Treatment Timing
- Never Treated
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
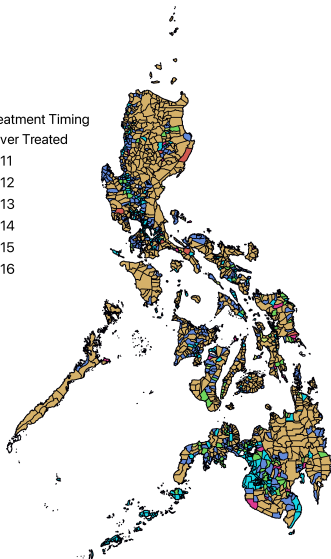
NGP Timing by Treatment Pool

NGP Treatment Timing	Frequency	Percent	Cumulative
Never Treated	322	19.77	19.77
2011	837	51.38	71.15
2012	301	18.48	89.63
2013	99	6.08	95.7
2014	27	1.66	97.36
2015	31	1.9	99.26
2016	12	0.74	100
Total	1,629	100	

(Number of Projects Implemented) (Number of Hectares Implemented)

NGP: Village Level
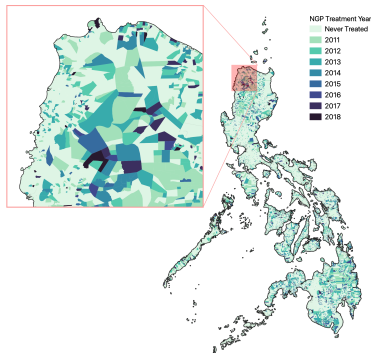
NGP Timing by Treatment Pool

NGP Treatment Timing	Frequency	Percent	Cumulative
Never Treated	32,472	78.75	78.75
2011	2,523	6.11	84.87
2012	2,427	5.89	89.24
2013	1,803	4.37	93.54
2014	721	1.75	95.26
2015	909	2.20	97.43
2016	378	0.92	100
Total	41,233	100	

Empirical Strategies

Empirics: Municipality Level

We leverage the **staggered roll-out** of the NGP to estimate a dynamic difference-in-difference specification following Callaway and Sant'Anna (2021):

$$Y_{m,t} = \sum_{\phi=-10}^{-1} \beta_{-\phi} NGP_{m,t-\phi} + \sum_{\phi=0}^{6} \beta_{+\phi} NGP_{m,t+\phi} + \tau_t + \gamma_m + \epsilon_{m,t}$$

- Outcome $Y_{m,t}$ is estimated separately for the log of forest cover, small area poverty estimates, and share of unlit settlements for municipality m at time t
  - Share of Unlit Settlements: combine night-time lights data with global human settlement data on building footprints

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We aggregate the coefficient of interest $\beta_{+\phi}$ in an event study-type ATT plot for each outcome

- Also estimate dynamic effects by cohort and average treatment effect by cohort

Empirics: Village Level

Replicate the main dynamic DID specification for unlit settlements at the village level

Estimate spatial spillovers:

- Ferraro and Simorangkir (2020): whether a never treated village shares an administrative boundary with a treated village
- Adopt similar strategy within dynamic DID framework to assess whether economic activity spills over into neighboring villages

Example map to assess economic spillovers

NGP Treatment Year
- 2011
- 2012
- 2014
- 2016
- Control

Neighbor Treatment Year
- 2011
- 2012
- 2014
- 2016
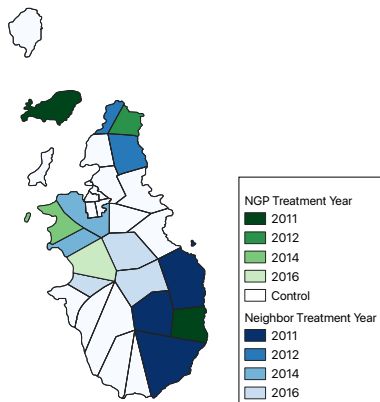
- Limit the sample to 32,472 **never treated** villages and exploit whether their neighbors are treated by the NGP

  - We consider a never treated village as **first treated** when one of its neighbors is treated by the NGP

Results

Forest Cover: ↑ 4%

Small Area Poverty Estimates: ↓ 6 p.p.

Percentage of Unlit Settlements: ↓ 8 p.p.
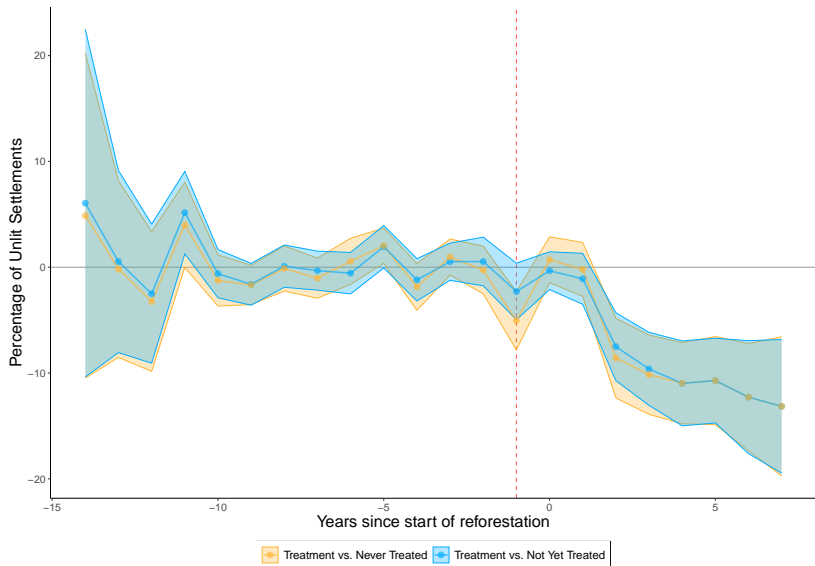
Village-level Percentage of Unlit Settlements
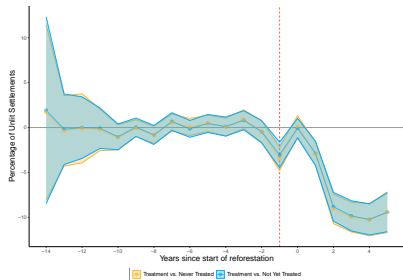
Direct effect: ↓ 6.7 p.p
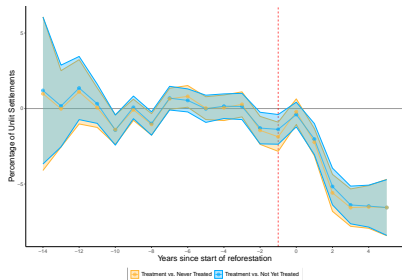
Spillovers: ↓ 4.5 p.p

- Dip: run procedure by Rambachan and Roth (2023) to adjust for significant pre-trend dip

Robustness

Run standard two-way fixed effect estimation: (Results)

Conditional parallel trends: (Results)

- Time-varying controls: population, precipitation, and maximum temperature
- Time-invariant controls: Slope, elevation, number of villages within a municipality that have access to the national highway, number of markets, number of commercial establishments, and number of bank establishments (interacted with time-trend)

Estimate Sun and Abraham (2021): (Results)

- Possibility that coefficients on a given lead or lag could be contaminated by the effects from other periods

Other outcome variables:

- Nighttime lights: proxy for economic activity (Results)
- Percentage of municipality and village populations living in unlit areas (Results)

Robustness

Haiyan Affected Municipalities
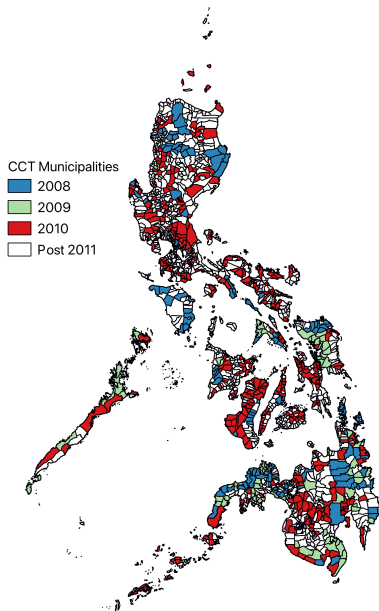☐ Not Affected
■ Affected Municipality
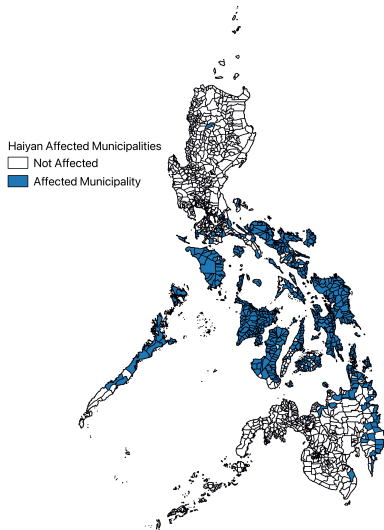
Typhoon Haiyan

- Category 5 typhoon hit in 2013 affecting 591 municipalities, 6,300 died, damage to physical assets of 3.7% of GDP

- Could impact ecosystems, poverty incidence and economic activity

Results for Small Area Poverty Estimates

Results for Unlit Settlements

Robustness

CCT Municipalities
- 2008
- 2009
- 2010
- Post 2011

Insurgency Violence

- Conflict affected areas: conflict stemming from the Moro Islamic Liberation Front, an Islamist separatist movement

Conditional Cash Transfer Program

- Provides cash-grants to families with children suffering from chronic hunger and provides incentives to access schooling and healthcare

(Results for Small Area Poverty Estimates)

(Results for Unlit Settlements)

Payment vs. Tree Planting Asset

Payment vs. Tree Planting Asset

Previous literature focused on multi-faceted interventions that grant productive assets along with cash transfers:

- An important next step is understanding which components of the bundle are necessary for generating large benefits (Sedlmayr et al., 2020)

Disentangle the effect between transferring productive plantation assets versus payments to produce seeds, prepare sites, plant trees and maintain sites

$$Y_{m,t} = \beta_0 + \beta_1 Payment_{m,t} + \beta_2 PlantationAsset_{m,t} + \tau_t + \gamma_m + \epsilon_{m,t}$$

Payment vs. Tree Planting Asset

Impact of Payment vs. Plantation Asset

	Small Area Poverty Estimates			Percentage of Unlit Settlements		
	(1)	(2)	(3)	(4)	(5)	(6)
Payment	-1.219***		-3.283***	-1.533***		-5.499***
	(0.241)		(0.383)	(0.512)		(0.671)
Plantation Asset		-3.919***	-5.783***		-7.550***	-10.77***
		(0.368)	(0.538)		(0.981)	(1.167)
Constant	34.33***	34.63***	35.34***	42.08***	42.82***	44.07***
	(0.0356)	(0.0452)	(0.119)	(0.0774)	(0.127)	(0.230)
Observations	26,009	26,009	26,009	24,182	24,182	24,182
R-squared	0.838	0.840	0.841	0.842	0.843	0.844
Control Mean	33.323	33.323	33.323	38.919	38.919	38.919

Sectoral and Labor Reallocation

Sectoral Reallocation

An increase in labor productivity could be achieved through (Diao et al., 2019):

- Existing economic activities capital accumulation or technological changes
- Labor moving from low-productivity to high-productivity activities

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- Labor moving from low-productivity to high-productivity activities

We employ a two period TWFE-DID specification:

$$Sector_{i,m,t} = \beta_0 + \beta_1 NGP_{m,t} + \tau_t + \gamma_m + \epsilon_{m,t}$$

- Where $Sector_{i,m,t}$ is estimated separately for the percentage of individuals not working, working in services, working in agriculture, working in unskilled manual labor, or working in skilled labor for municipality m, at time t

Sectoral Reallocation

Impact of NGP on Employment in Different Sectors

	(1) Not Working	(2) Services	(3) Agriculture	(4) Unskilled	(5) Skilled
NGP	0.0342	0.0258*	-0.0379*	0.0564***	0.00221
	(0.0259)	(0.0150)	(0.0198)	(0.0196)	(0.0127)
Observations	976	976	976	976	976
Treated Municipalities	370	370	370	370	370
Control Municipalities	118	118	118	118	118
R-squared	0.611	0.594	0.741	0.603	0.634

Sector definitions - <u>Services:</u> housekeeping and restaurant services, finance and sales associates and administrative professionals. <u>Unskilled manual labor:</u> manufacturing labor, building caretakers, mining and construction laborers. <u>Skilled:</u> textile, garment and related trades, assemblers, wood treaters and food processing.

Labor Reallocation

Did the NGP lead to broader changes in labor supply?

We investigate whether the increased economic activity is the result of population growth or migration

- Use high-resolution disaggregated census counts
  - Captures the full potential activity space of people throughout the course of the day and night (Sims et al., 2022)

Labor Reallocation

Impact of NGP on Population

Panel A: Municipality Level
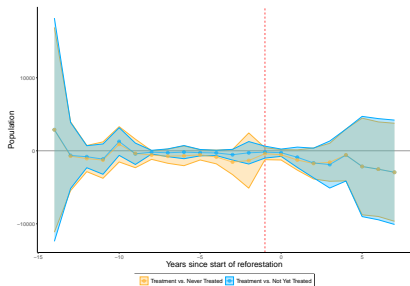
Panel B: Village Level
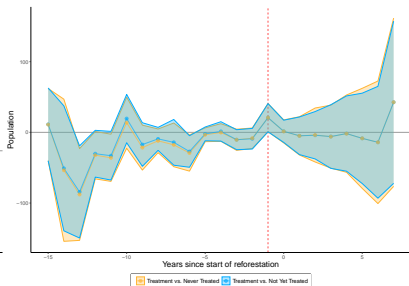
Valuing the Sequestration Benefits of the NGP

Calculations and Assumptions

Back-of-the-envelope-calculations:

- Goal is to estimate the total amount of CO_2 sequestered by the NGP and calculate the monetary benefit of sequestering CO_2
- Use all 80,522 tree plantations

Assumptions:

Calculations and Assumptions

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- Use all 80,522 tree plantations

Assumptions:

- Balangue (2016) calculates the annual carbon sequestration rate per hectare using a 99 hectare NGP plantation
  - Dominant tree species annual CO_2 sequestration rate per hectare (high sequestration)
  - Co-dominant tree species annual CO_2 sequestration rate per hectare (low sequestration)

CO_2 Sequestration
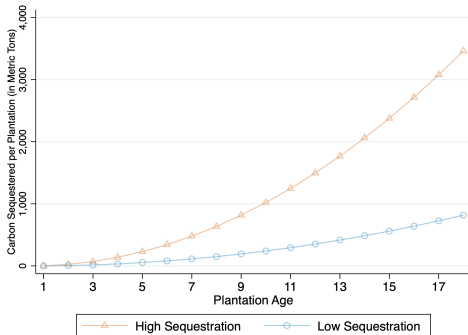
Sequestered Carbon per Plantation

CO$_2$ Sequestration
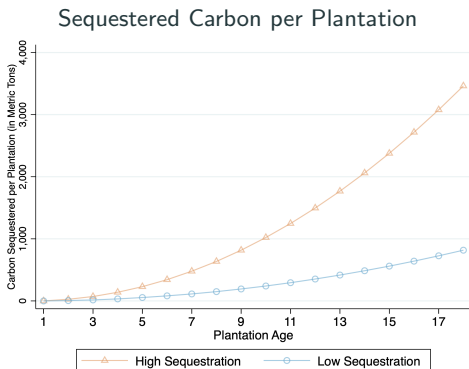
Sequestered Carbon per Plantation

The NGP sequestered between 73 MtCO$_2$ (low sequestration rate) and 308 MtCO$_2$ (high sequestration rate) over 10 years

- Equivalent to 16m gasoline-powered passenger vehicles driven in one year or 20 coal-fired power plants in one year

CO_2 Sequestration
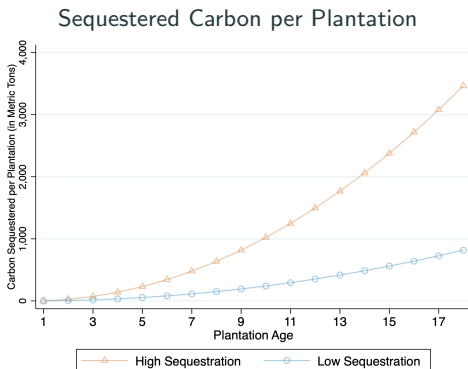
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- Equivalent to 16m gasoline-powered passenger vehicles driven in one year or 20 coal-fired power plants in one year

For policymakers focused exclusively on carbon emissions, the NGP reduces CO_2 emissions at a cost ranging from \$2 to \$10 per ton

CO_2 Sequestration

Economic value associated with a permanent reduction of CO_2 in the atmosphere - US EPA estimates (2016)

- Annual monetary benefits (sequestered CO_2) - annual costs (3 year payments)
- NGP sequestered CO2 valued between \$163 million and \$10 billion

Carbon Sequestration Benefits from the NGP
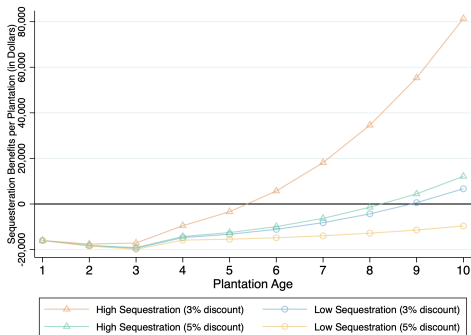
Discussion and Conclusion

Discussion: Valid Concerns Around Tree Planting

Scale of land required, the timing and permanence of the CO2 reductions and the potential ecological impacts (Grosset et al., 2023)

- May result in the loss of cropland and consequently compromise food security
- Permanence of tree planting due to the risk of large-scale mortality caused by drought, invasive species, cyclones, and wildfires (Leverkus et al., 2022)
- Planting across a broad spectrum of landscapes can provide a limited set of ecological services (Lamb et al., 2005) and reduces native biodiversity (Xu, 2011; Hua et al., 2016)

Discussion: Policy implications

NGP's design elements were crucial to its success:

- Engagement and planning with POs
- Long-term incentives to local organizations
    - Payments to POs over several years
    - Managerial control of plantation assets
- Transfer of plantation assets ensured economic benefits of the program were sustained beyond the initial payment phase

High survival rate of plantations

- Required continuous monitoring and support from both extension officers and local organizations

Conclusion

This study shows that it is possible for large-scale tree planting to align climate mitigation and poverty reduction policies

- The 2011 National Greening Program resulted in a significant **reduction in poverty** and **percentage of unlit settlements**
  - Significant **spatial spillovers**
  - Larger impact in poorer areas
  - Larger tree plantations have the largest impact
- Evidence of **sectoral reallocation** but no evidence of population/migration sorting
- Both the payment and plantation asset are important aspects of the bundle reducing poverty
- Important carbon sequestration benefits

Thank you for your attention!

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Number of Tree Planting Projects

Number of Tree Planting Projects
- Never Treated
- 1 - 119
- 119 - 272
- 272 - 569
- 569 - 1,132
- 1,132 - 2,083
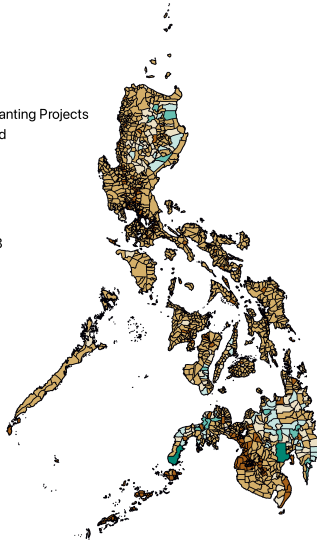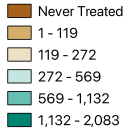
Return

Number of Hectares Planted

Number of Hectares Planted

	Small Area Poverty Estimates		Percentage Unlit Settlements	
	(1)	(2)	(3)	(4)
	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated
NGP	-5.759***	-5.981***	-8.209***	-8.169***
	(0.628)	(0.661)	(1.082)	(1.138)
Observations	27954	27954	24210	24210

Return

Robustness: two-way fixed effect estimation

Table 1: Impact of NGP on Socio-Economic Measures: Standard TWFE-DID

	Small Area Poverty Estimates		Percentage of Unlit Settlements	
	(1)	(2)	(3)	(4)
DID_{TWFE}	-4.636***	-3.522***	-8.301***	-5.301***
	(0.4602)	(0.4414)	(0.8810)	(0.9131)
Controls		✓		✓
Municipality FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Observations	28,907	25,827	29,322	26,028
Adjusted R^2	0.86529	0.86588	0.91762	0.91991

Return

Robustness: control for other covariates

Table 2: Impact of NGP on Socio-Economic Measures

| | Small Area Poverty Estimates | | Percentage of Unlit Settlements | |
| | (1) | (2) | (3) | (4) |
	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated
NGP	-3.125***	-2.861***	-4.348**	-5.583**
	(0.619)	(0.708)	(2.186)	(2.659)
Controls	✓	✓	✓	✓
Observations	24984	24768	21546	21546

Return

Robustness: Sun and Abraham (2021)

Table 3: Impact of NGP on Socio-Economic Measures: Staggered DID following Sun and Abraham (2021)

	Small Area Poverty Estimates		Percentage of Unlit Settlements	
	(1)	(2)	(3)	(4)
DID_{SA}	-6.388***	-5.685***	-7.542***	-5.772***
	(0.6056)	(0.6272)	(1.110)	(1.204)
Controls		✓		✓
Municipality FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Observations	28,907	25,827	29,322	26,028
Adjusted R^2	0.86695	0.86702	0.92043	0.92201

Robustness: De Chaisemartin and d'Haultfoeuille (2024)

Table 4: Impact of NGP on Socio-Economic Measures: Staggered DID following De Chaisemartin and d'Haultfoeuille (2024)

	Small Area Poverty Estimates		Percentage of Unlit Settlements	
	(1)	(2)	(3)	(4)
DID_{SA}	-5.412***	-4.738***	-7.317***	-6.405***
	(0.5239)	(0.5658)	(1.015)	(1.195)
Controls		✓		✓
Municipality FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Observations	12,040	10,719	11,325	10,135

Return

Impact of NGP on Nighttime Lights

Panel A: Municipality Level
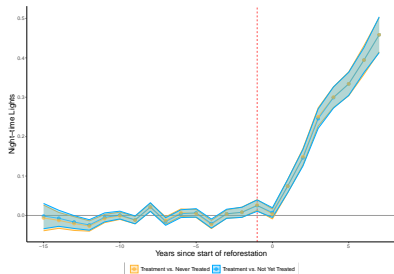
Panel B: Village Level

Impact of NGP on Unlit Population Percentage
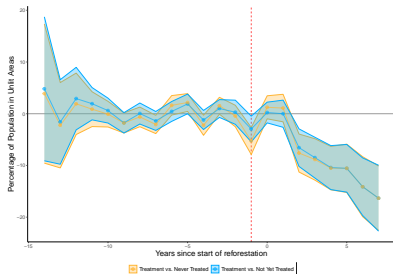
Panel A: Municipality Level   Panel B: Village Level
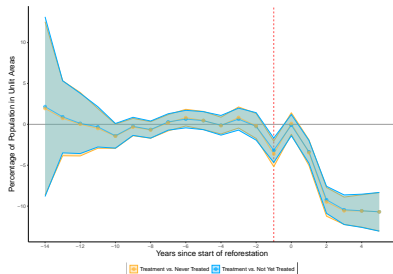
Return

Robustness: Changing Sample for Poverty Estimates

Table 5: Impact of NGP on Small Area Poverty Estimates: Robustness

	Excluding Haiyan		Excluding Mindanao		Excluding CCT	
	(1)	(2)	(3)	(4)	(5)	(6)
	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated
NGP	-6.892***	-7.063***	-2.048***	-2.051***	-5.421***	-5.582***
	(0.808)	(0.811)	(0.449)	(0.461)	(0.691)	(0.703)
Observations	17,010	17,010	21,780	21,780	17,910	17,910

Return

Robustness: Changing Sample for Unlit Settlements

Table 6: Impact of NGP on Unlit Settlements: Robustness

	Excluding Haiyan		Excluding Mindanao		Excluding CCT	
	(1)	(2)	(3)	(4)	(5)	(6)
	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated	Not Yet Treated	Never Treated
NGP	-8.633***	-8.453***	-9.657***	-9.791***	-7.485***	-7.499***
	(1.249)	(1.323)	(1.108)	(1.201)	(1.164)	(1.256)
Observations	14,562	14,562	19,098	19,098	15,984	15,984

Return

Dynamic Impact of NGP on Forest Coverage

Panel A: Treatment vs. Not Yet Treated
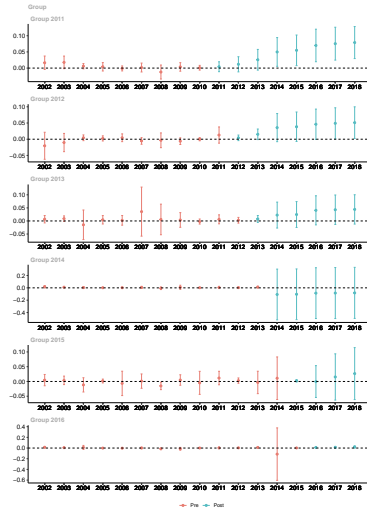
Panel B: Treatment vs. Never Treated
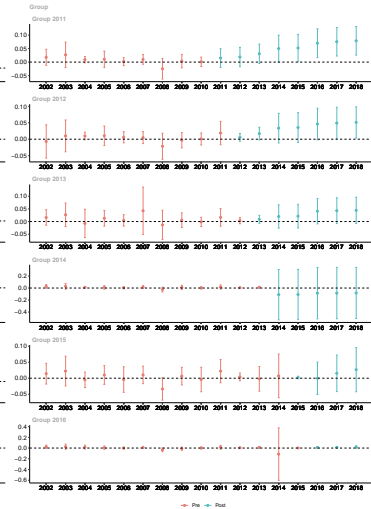
Average Cohort Impact of NGP on Forest Coverage

Panel A: Treatment vs. Not Yet Treated

Panel B: Treatment vs. Never Treated

Dynamic Impact of NGP on Small Area Poverty Estimates

Panel A: Treatment vs. Not Yet Treated
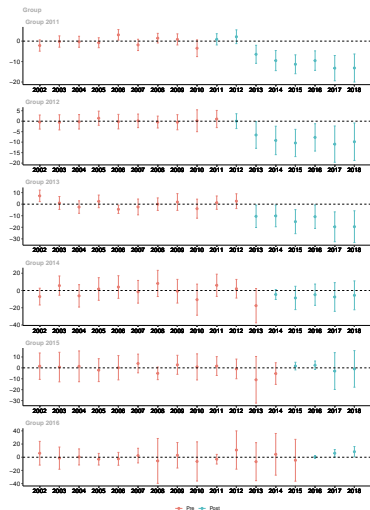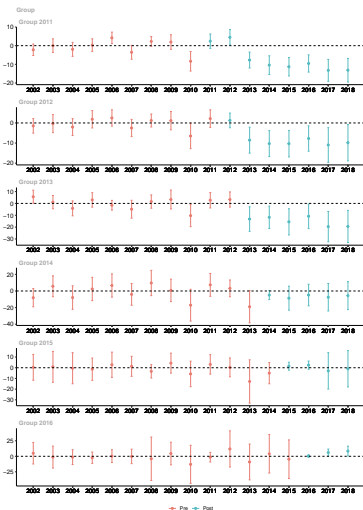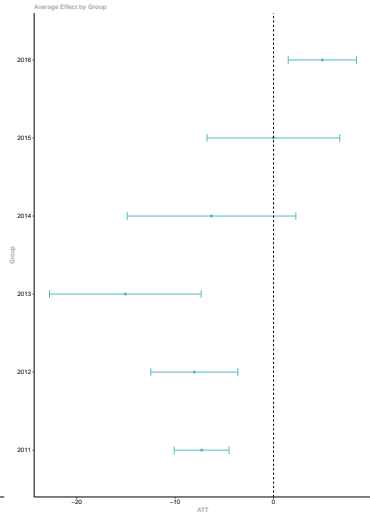
Panel B: Treatment vs. Never Treated

Average Cohort Impact of NGP on Small Area Poverty Estimates

Panel A: Treatment vs. Not Yet Treated

Panel B: Treatment vs. Never Treated

Dynamic Impact of NGP on Unlit Settlements
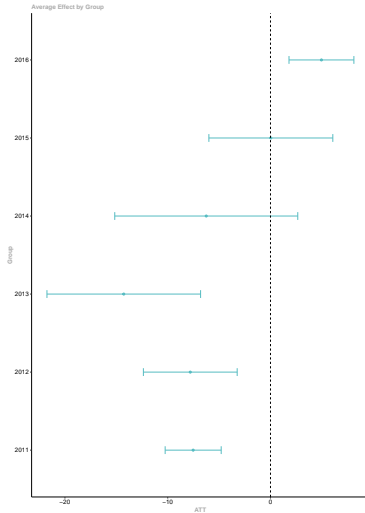
Panel A: Treatment vs. Not Yet Treated

Panel B: Treatment vs. Never Treated

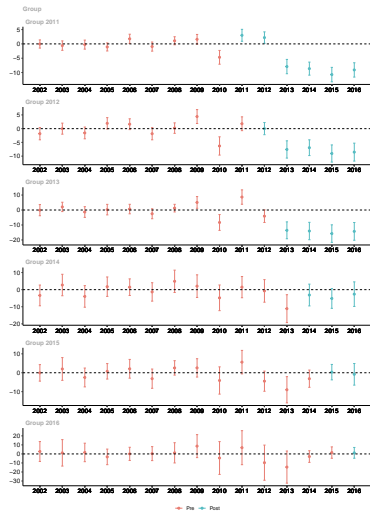# Average Cohort Impact of NGP on Unlit Settlements

Panel A: Treatment vs. Not Yet Treated
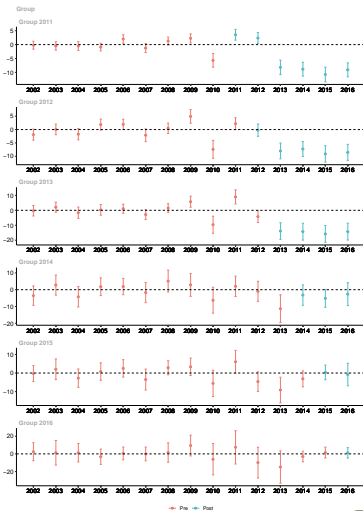
Panel B: Treatment vs. Never Treated

Dynamic Impact of NGP on Unlit Settlements at the Village Level

Panel A: Treatment vs. Not Yet Treated

Panel B: Treatment vs. Never Treated

Average Cohort Impact of NGP on Unlit Settlements at the Village Level

Panel A: Treatment vs. Not Yet Treated   Panel B: Treatment vs. Never Treated