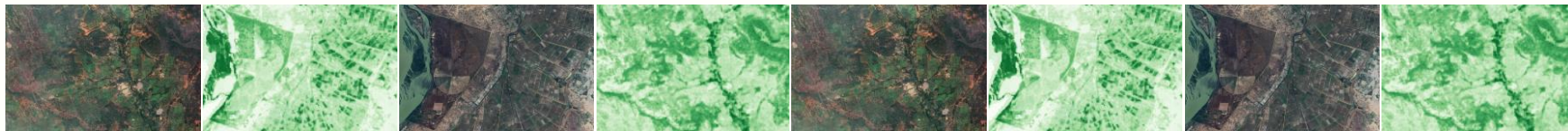


LULCC Impacts of Agricultural Intensification in Mali

Borlaug or Jevons?

Dilini Abeygunawardane

ICAE – SPIA Fest | New Delhi | August 2, 2024



A lot of wonderful people contributed!

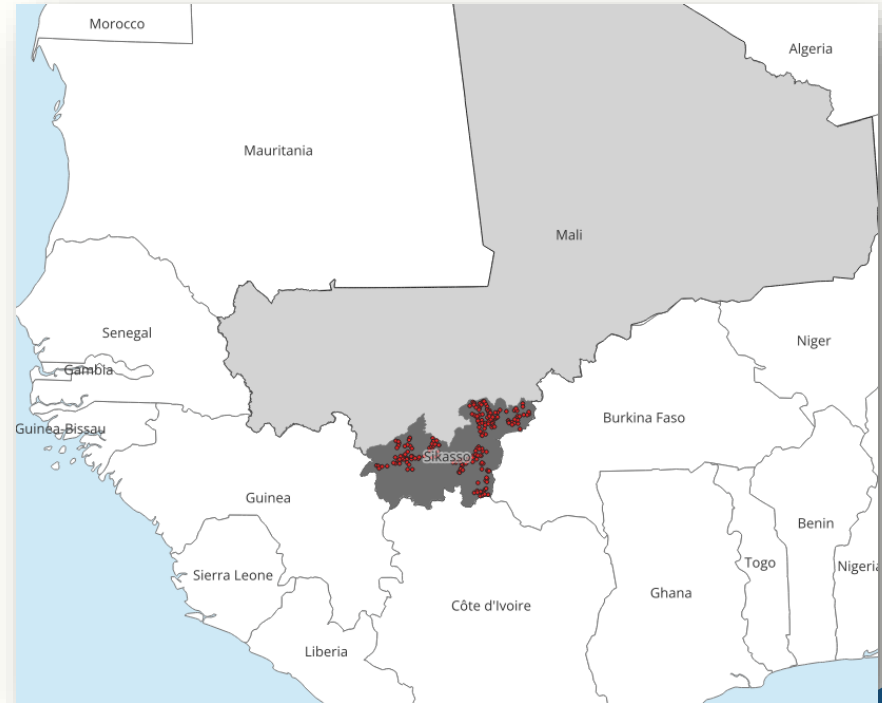


Souleymane Traore, Sibiry Traore, Vivian Kerubo, Steven Ngungu, Florian Reiner, Martin Brandt, Rasmus Fensholt, Pratik Kumar



ICRISAT's Large-scale Sorghum and Millet Intensification in Mali 2014-2020

- Intervention:
improved seeds, microdosing,
intercropping, seed treatment
- Farmer reach:
more than 100,000 sorghum and
millet farmers
- Geographic reach:
202 villages in Sikasso



USAID data; ARDT_SMS rollout data

Intensification Interventions Achieved 30-60% Yield Increases

- 30% yield increase in millet
- 60% yield increase in sorghum
- 24% economic rate of return
- 133% increase in household income

(Source: USAID Cost Benefit Analysis and ICRISAT M&E Data)



© ICRISAT

The Yield Improvements Generated Heterogeneous Impacts on Local LULCC

- Labor and capital reallocation: land sparing vs. land sharing
 - depends on local market conditions
 - e.g., opportunities to transition towards cash crops
- Land saving \neq Land sharing

Balmford 2021 *Journal of Zoology*
Rodríguez García et al. 2020 *Environ. Res. Lett.*
Balmford et al. 2019 *Journal of Applied Ecology*
Phalan et al. 2018 *Sustainability*
Phalan et al. 2016 *Science*
Hertel et al. 2014 *PNAS*
Stevenson et al. 2013 *PNAS*

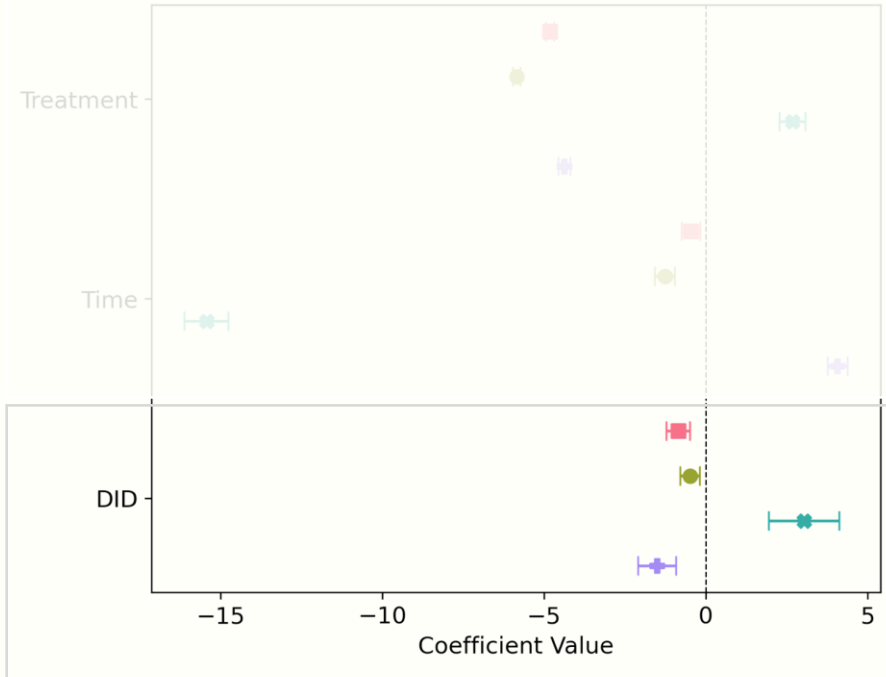
Research Questions



© Food Systems Caravan West Africa Project and
FAO/Swiatoslaw Wojtkowiak

1. What impact did ARDT_SMS have on LULCC in Sikasso region?
 - woody cover
 - cropland extent
2. How did the LULCC impacts of intensification vary across gradients of market access?
 - cotton area and yields

Key Findings

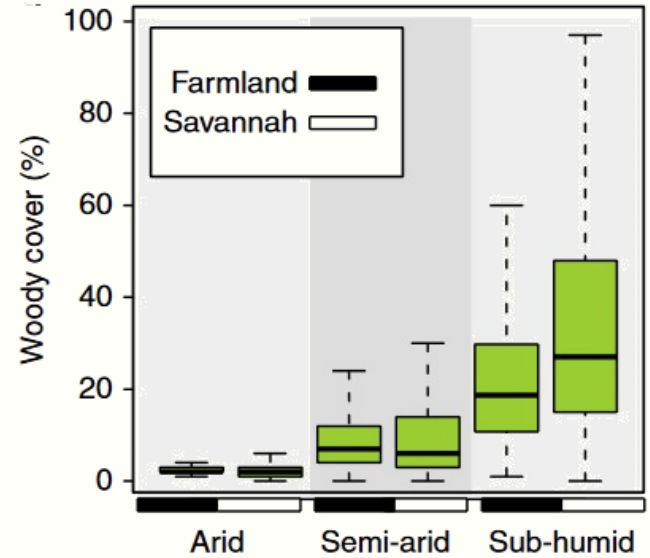
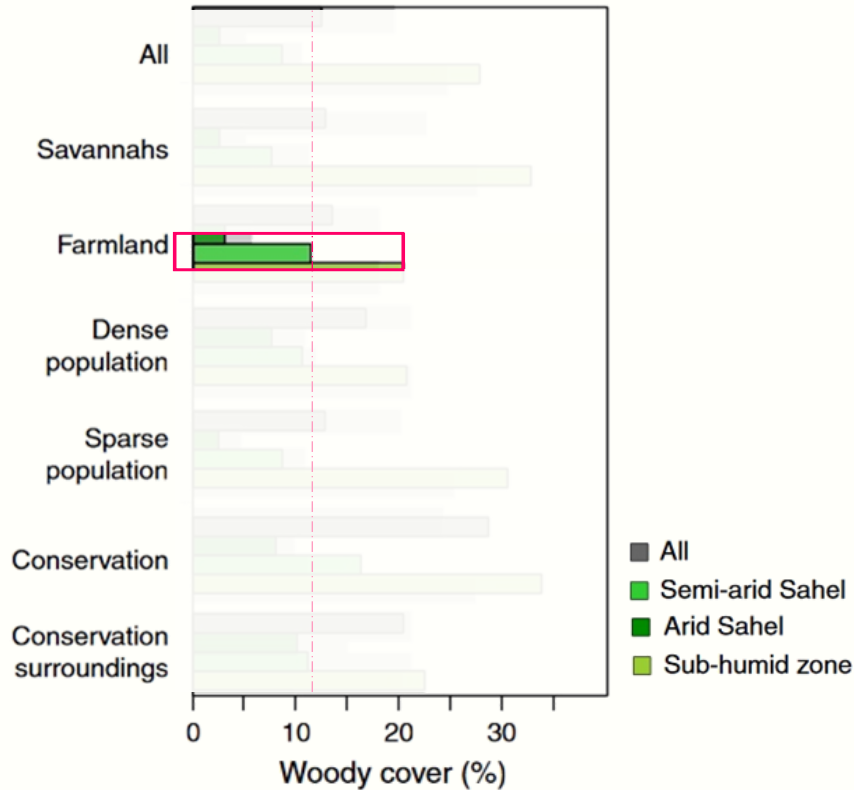


The average causal treatment effect on the treated villages (ATT):

- **woody cover decline 0.9%**
 - **within cropland 0.5% decline**
 - **outside cropland 1.5% decline**
- **cropland extent expansion 3%**

- mean woody cover
- mean woody cover within cropland
- * percentage cropland extent
- + mean woodycover outside cropland

Trees Outside Forest



Brandt et al 2018 Nature Geoscience

AFRICA / 22 SEPTEMBER 2017

The Sikasso paradox: Can the Mali miracle be repeated?

By Simon Allison



© Mali&Guardian

Two Stages of Non-random Selection - Endogeneity Concerns

Village selection

- presence of key project partners
- agricultural potential
- market access
- site accessibility

Beneficiary selection

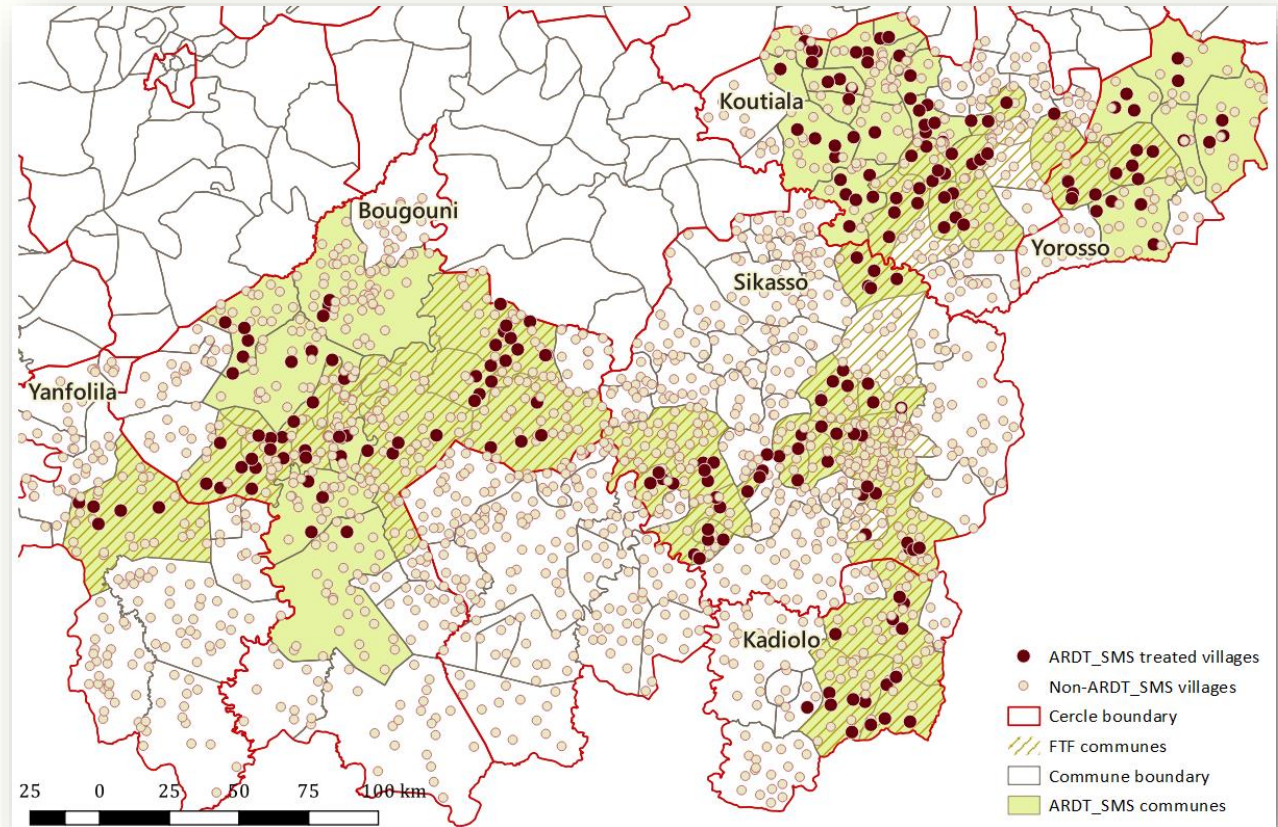
- within treated villages, beneficiaries self-selected into treatment

Treatment Timing

- Key technology dissemination to 202 villages was completed by the end of 2015
 - improved seeds
 - microdosing
 - intercropping
 - seed treatment
- 2016-2019 follow up interventions focus on project sustainability

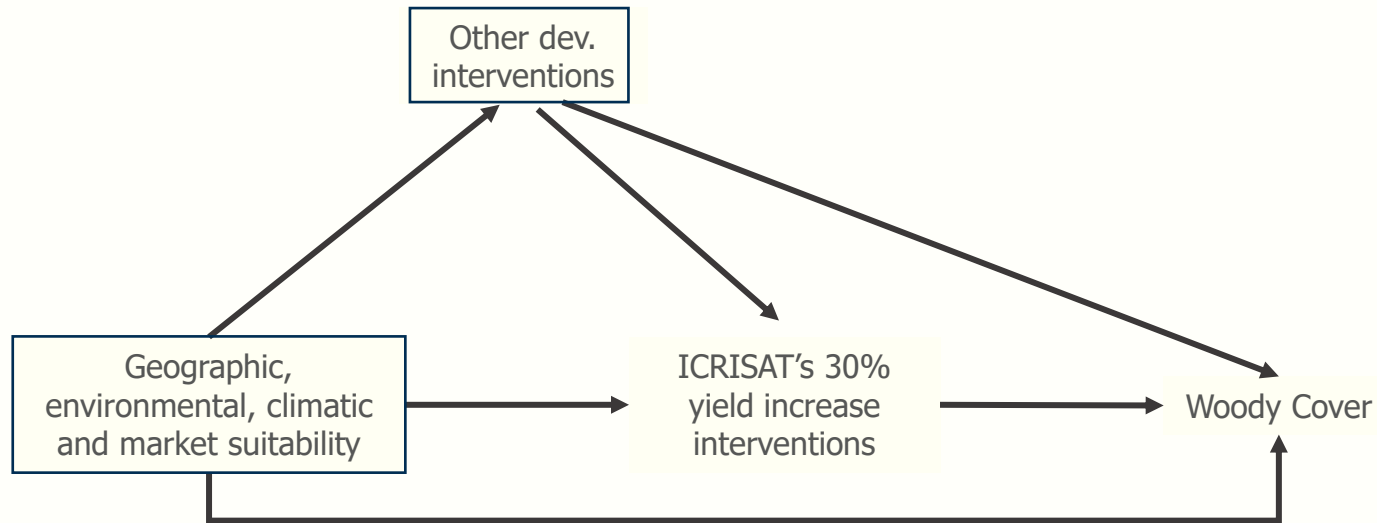
Intervention Year	No. of Villages	
	First Intervention	Second Intervention
2014	31	
2015	172	9
2016	10	3
2017	10	15
2018	4	30
Total	227	57

Treated Villages



USAID data; ARDT_SMS rollout data

Event Study: Matched Difference-in-Differences



Data

- Outcomes:
 - panel of remotely sensed (Landsat--derived) data on tree cover and total cropland area
- Treatment:
 - village-level treatment program data from ICRISAT
- Covariates:
 - time to city (Nelson 2019)
 - sorghum, millet, and cotton yields (MAPSPAM/IFPRI 2000-2020)
 - sorghum, millet, and cotton area (MAPSPAM/IFPRI 2000-2020)
 - Precipitation (CHRIPS)
 - season (ICRISAT)
 - Elevation (USGS)

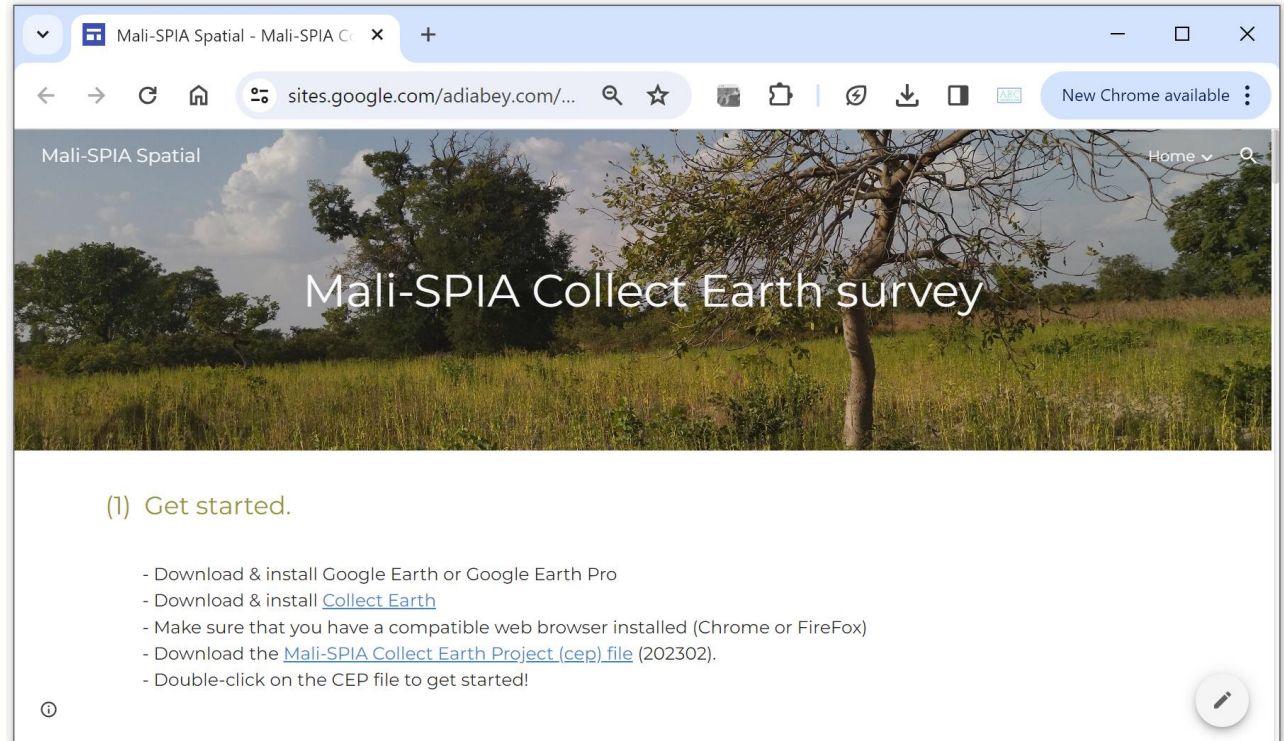
A Panel of Remotely Sensed Tree Cover Data from 2000 to 2023

- 2000-2023 Landsat images (30m)
- Multiple reference data: Brandt 2020; Brandt and Stolle 2021; CCI 2016



A Panel of Remotely Sensed Tree Cover Data from 2000 to 2023

- ~4600 ground validation points
- ~2500 collect earth points



Mali-SPIA Spatial

Home

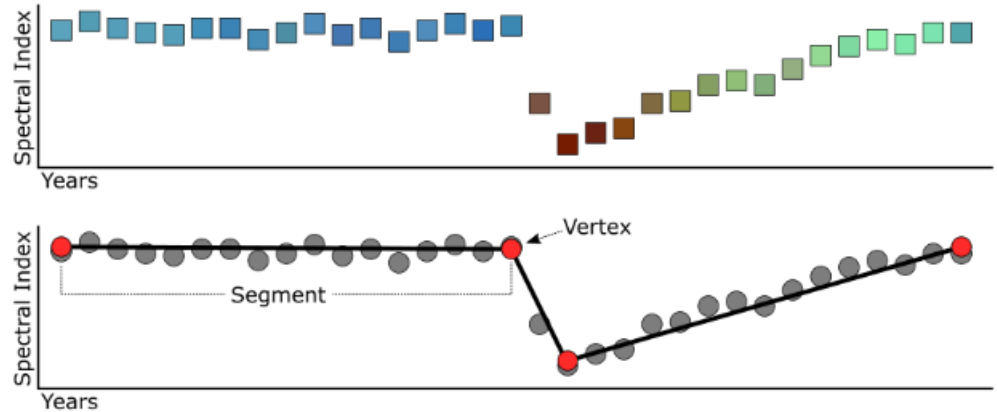
Mali-SPIA Collect Earth survey

(1) Get started.

- Download & install Google Earth or Google Earth Pro
- Download & install [Collect Earth](#)
- Make sure that you have a compatible web browser installed (Chrome or FireFox)
- Download the [Mali-SPIA Collect Earth Project \(cep\) file](#) (202302).
- Double-click on the CEP file to get started!

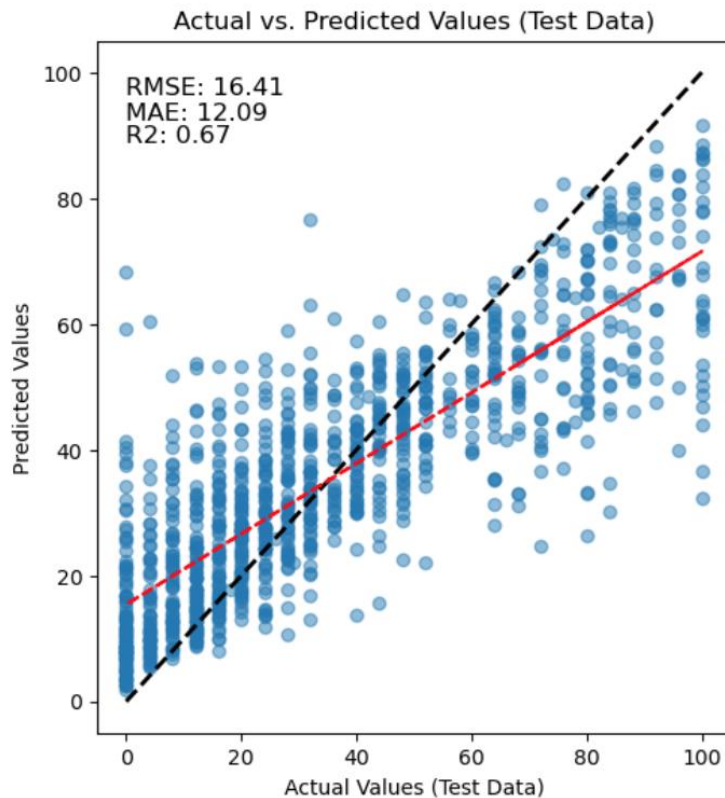
A Panel of Remotely Sensed Tree Cover Data from 2000 to 2023

- LandTrendr smoothing
- Random Forest Model
- Nested Cross Validation



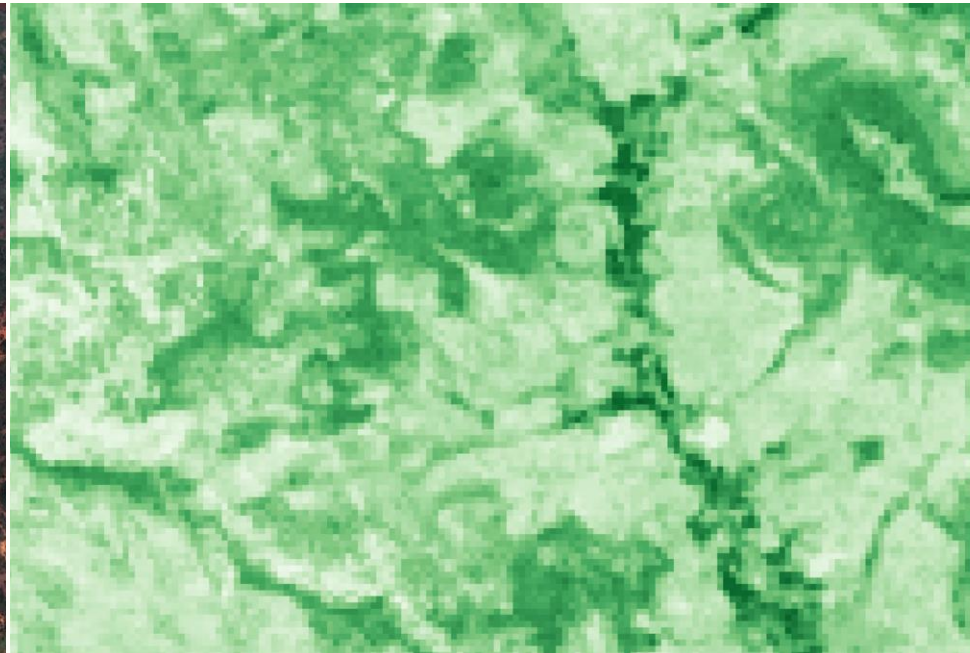
A Panel of Remotely Sensed Tree Cover Data from 2000 to 2023

- Error terms are relatively low
- Higher forest cover values are predicted (previously values never exceeded 60%)
- Model exhibits bias
 - Overprediction at low actual forest cover & underprediction at high cover with prediction over 80% being rare
 - May be a result of having class imbalances in the CE plots, with few high forest locations for training



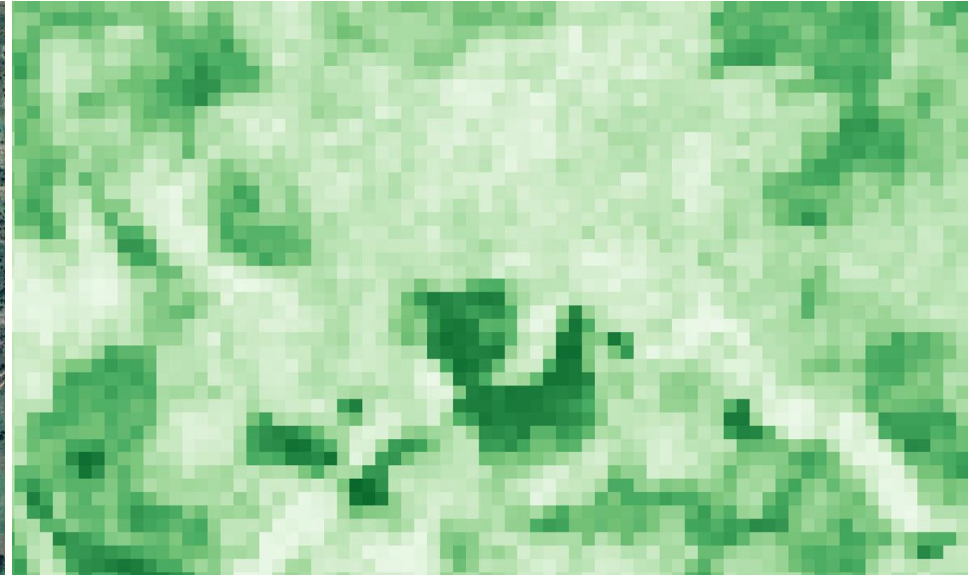
Visual Assessment of Predictions I: Forest Gradients

- Gradients in forest cover well represented
- Fields with intermediate tree cover are mapped with a rather low total woody cover
- Dark features such as the exposed soil on the top left and right of the image are not confused with forest



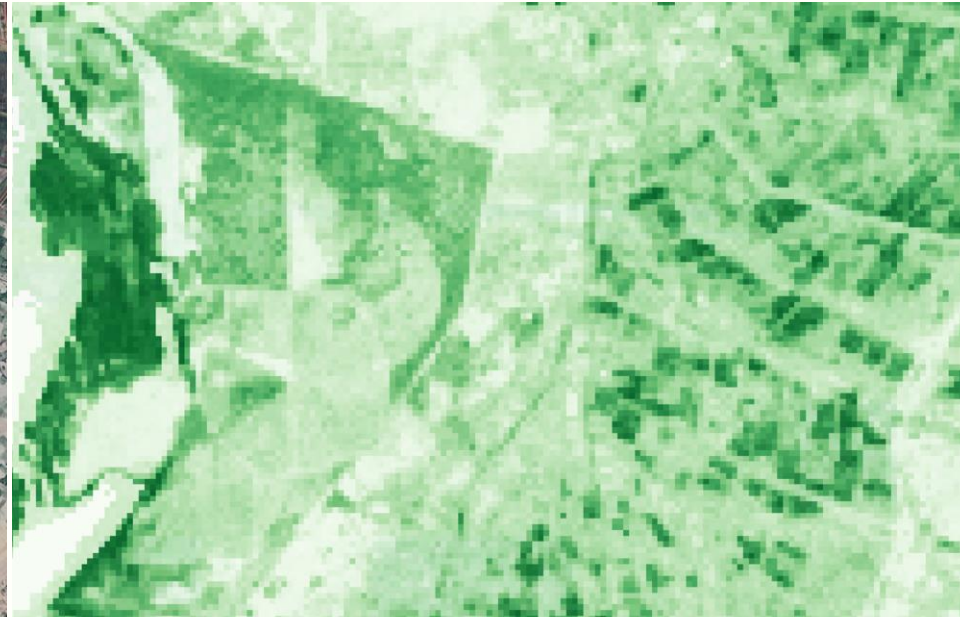
Visual Assessment of Predictions II: Agriculture

- Less intensive agriculture is mapped well
- Both gradual and sharp forest gradients are captured



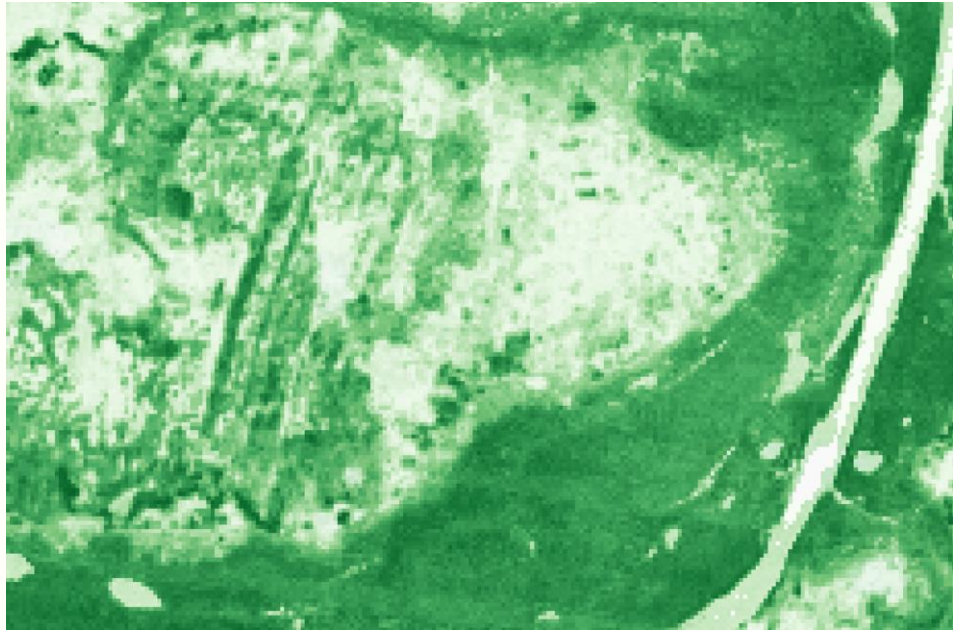
Visual Assessment of Predictions III: Intensive Agriculture

- Forested Islands are well represented, with little confusion with water
- Mixed results with high intensity agriculture
 - Confusion occurs depending on crop type



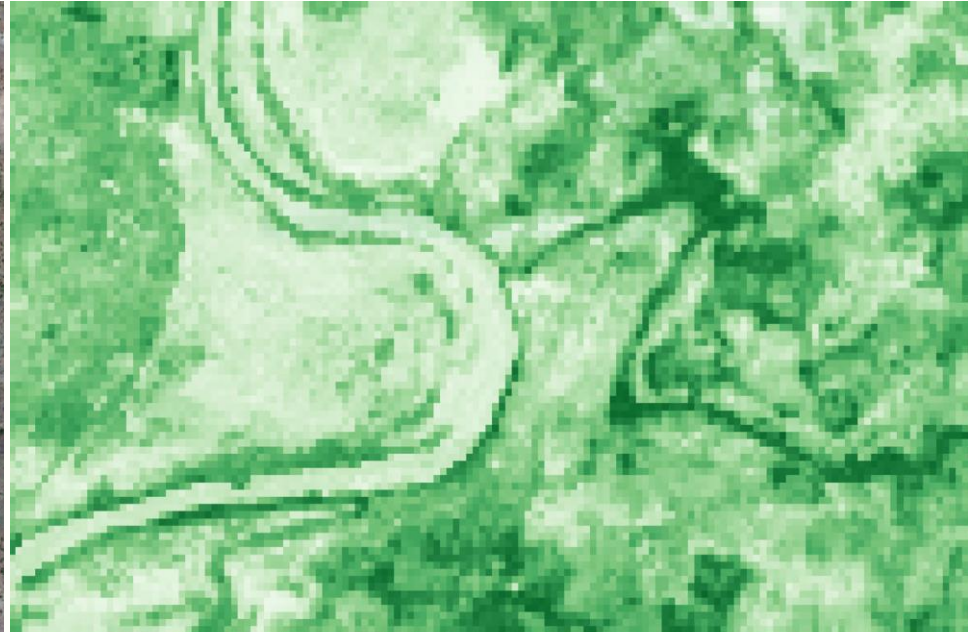
Visual Assessment of Predictions IV: Floating Vegetation

- Inconsistent but significant confusion between trees and floating vegetation
- Not present in river in slide above, or floodplain areas in the following two slides



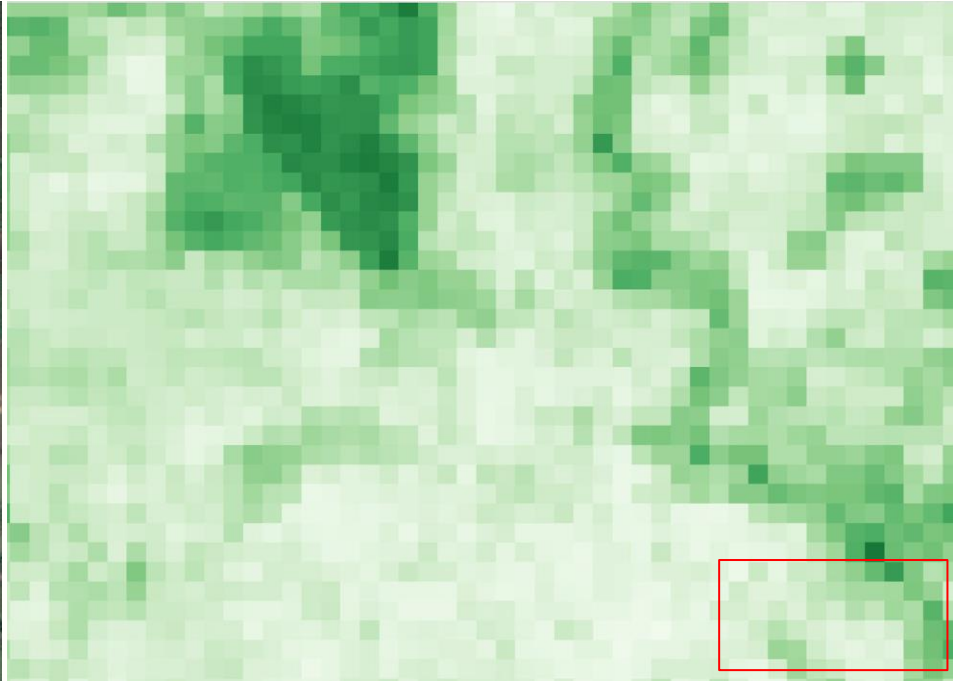
Visual Assessment of Predictions V: Floodplains

- Flood plain areas with seasonal floating vegetation mapped accurately
- Gradients in forest cover are well represented



Visual Assessment of Predictions VI: Floodplain Agriculture

- Flood plain areas with agriculture are mapped accurately
- Floating vegetation in bottom right is correctly mapped as non-forest



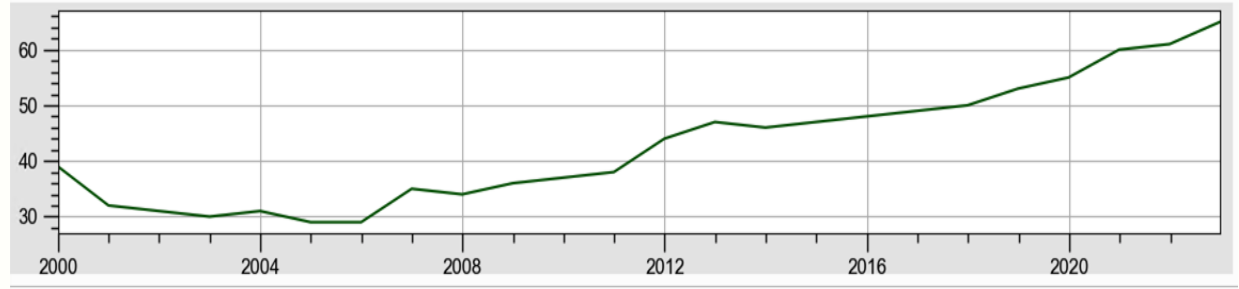
Temporal Dimension I

Sudden drops in fractional woody cover time series corresponds with VHR images



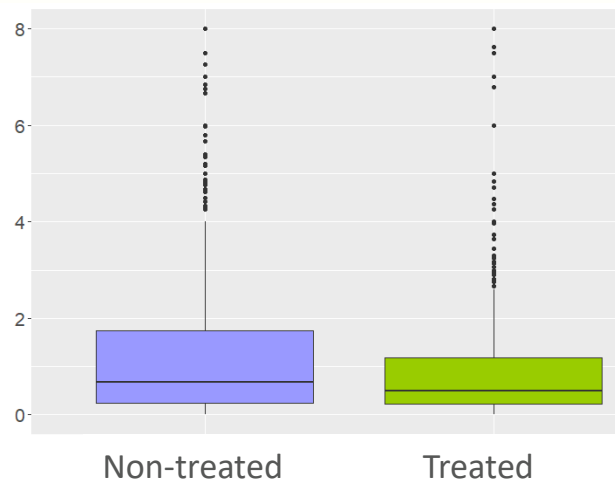
Temporal Dimension II

Canopy densification in plantation forest is also captured

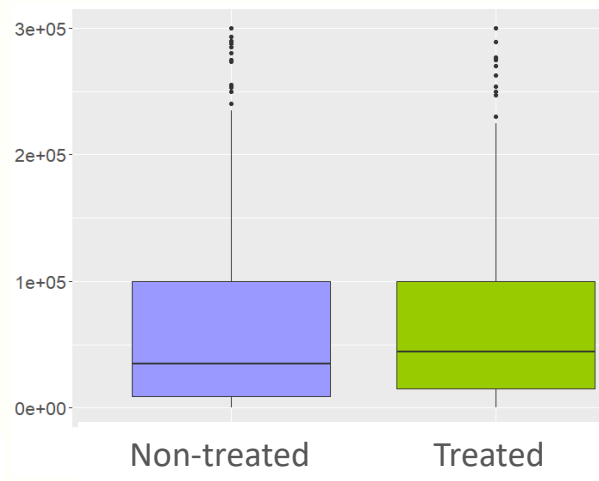


Balance Tables

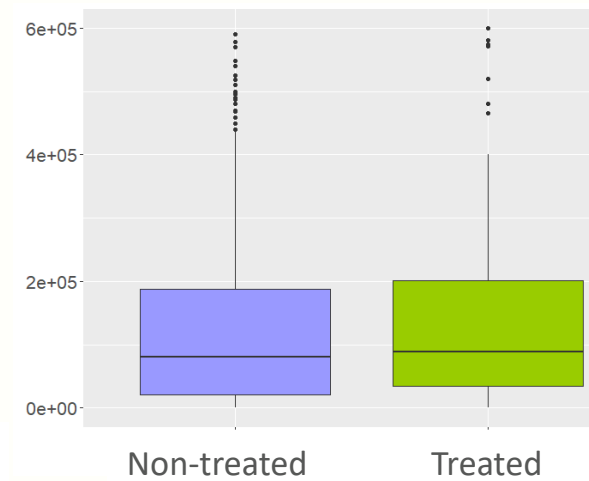
Area of cultivated land (ha)



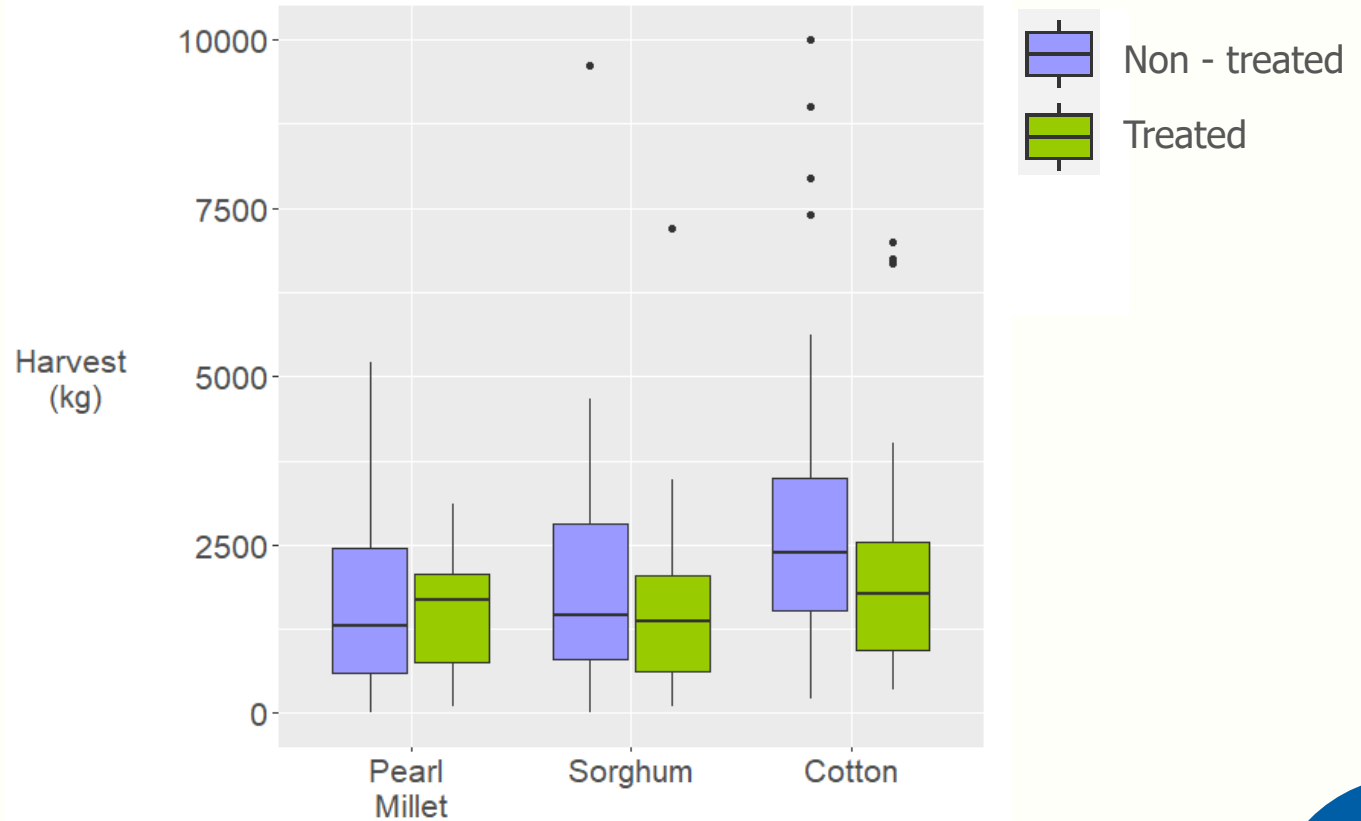
Total crop sales (local currency)



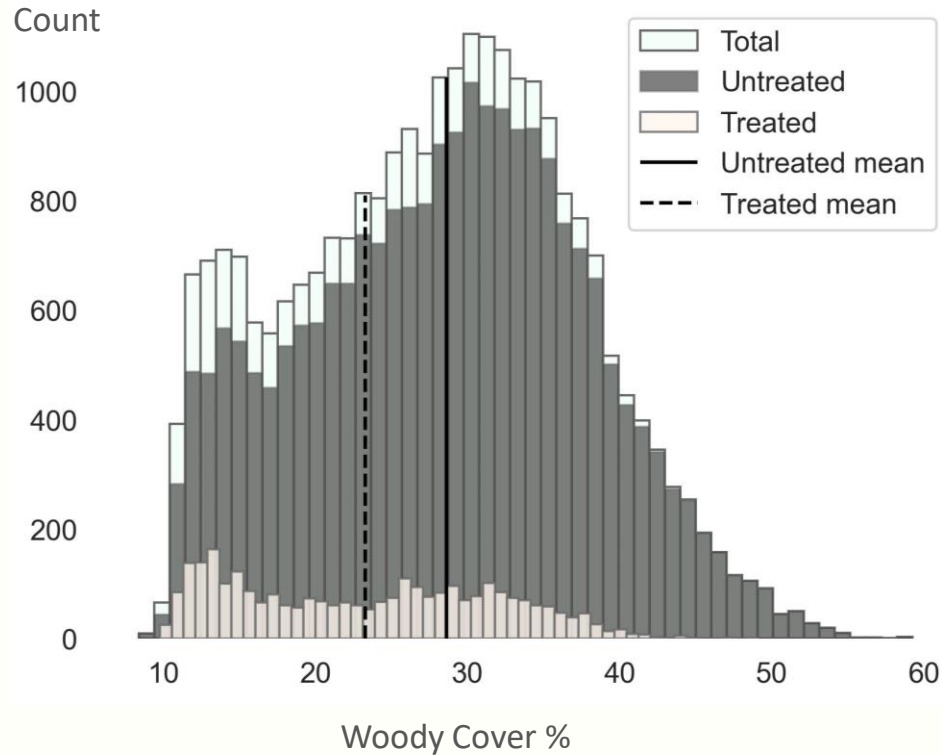
Crop sales (local currency / ha)



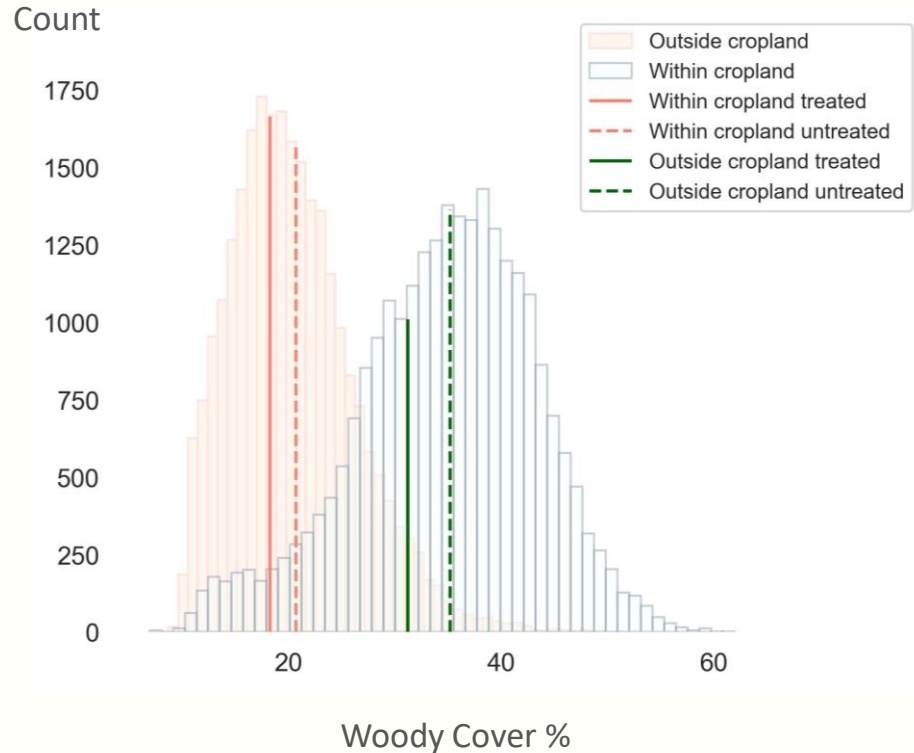
Balance Tables



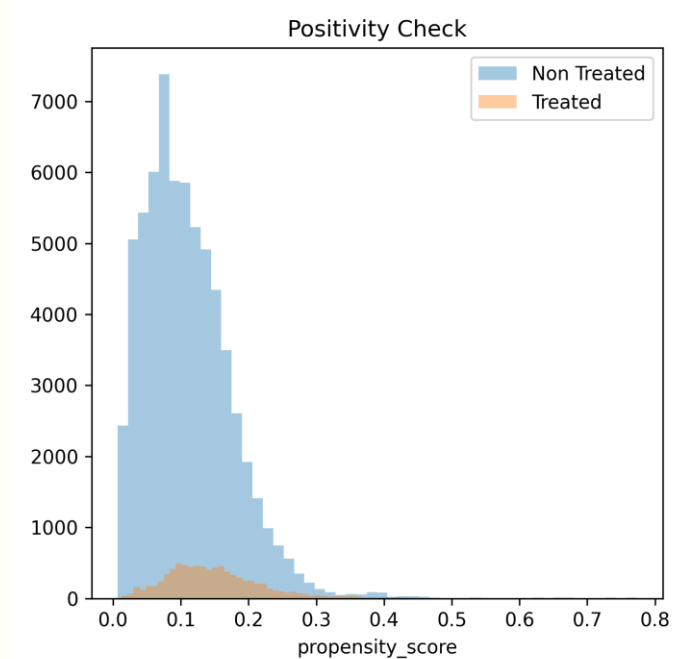
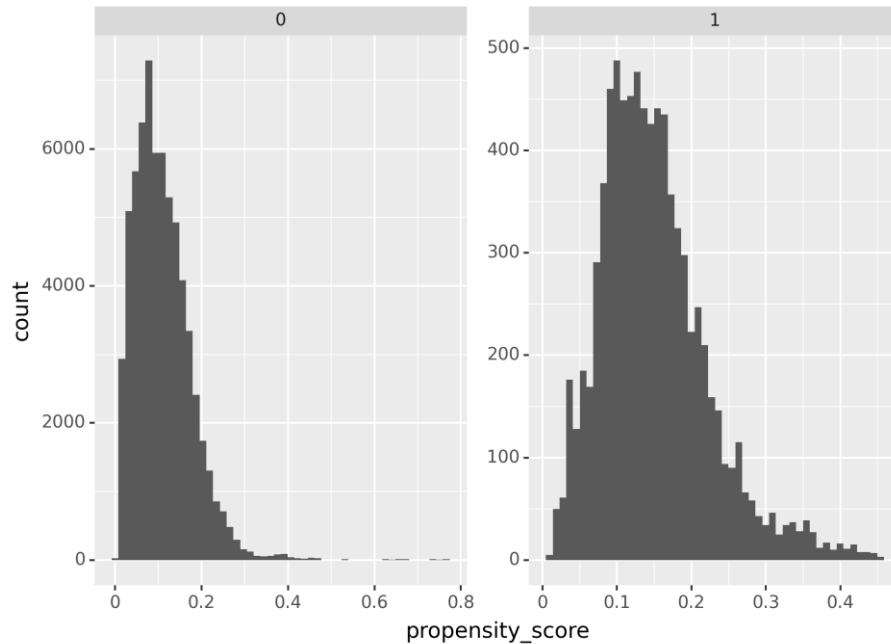
Before Treatment – Total Mean Woody Cover



Before Treatment – Woody Cover Within and Outside Cropland

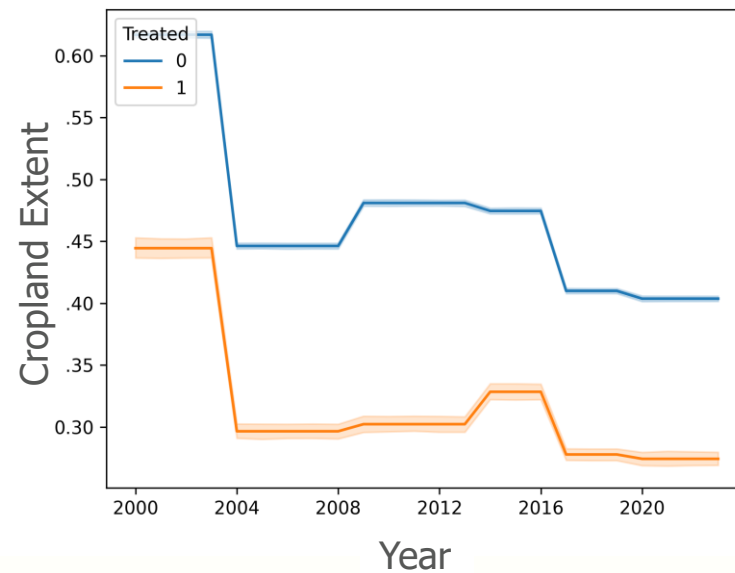
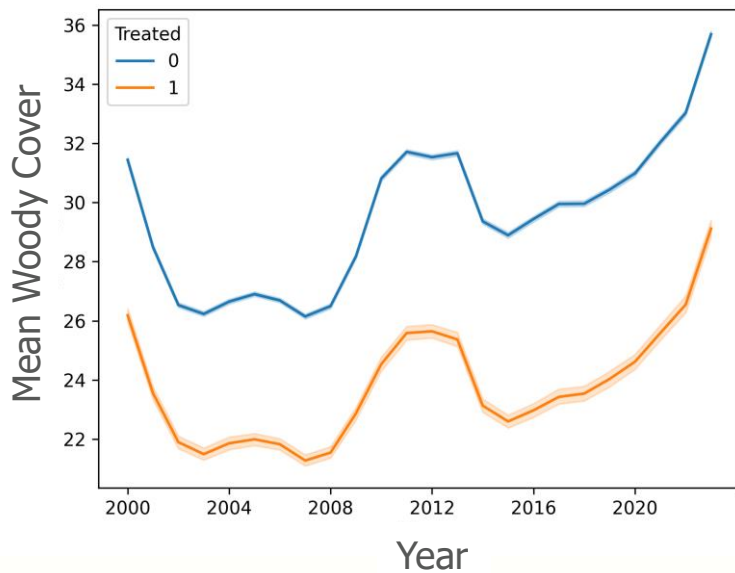


Propensity Score Matching

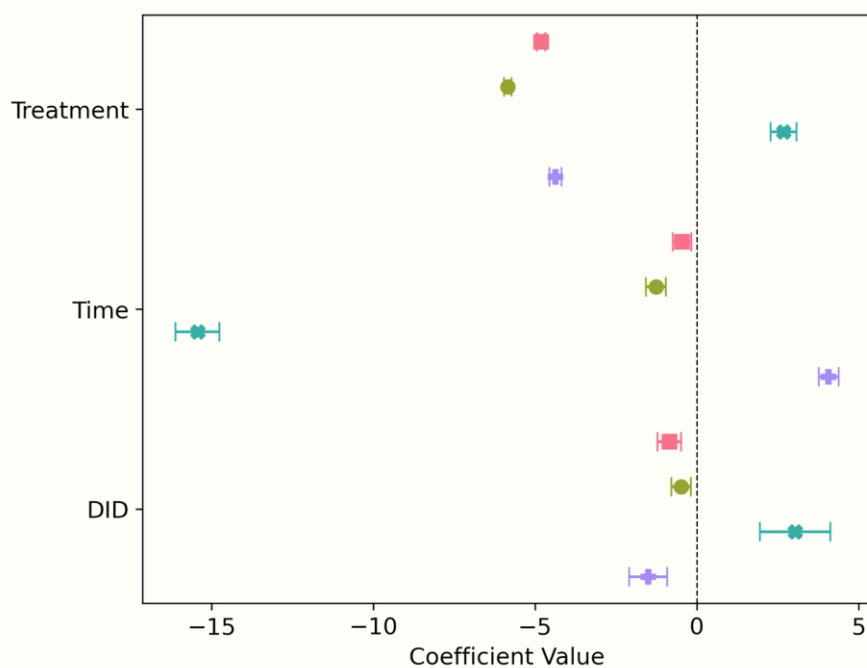


Matched covariates: cropland extent, sorghum yields, millet yields, travel time to cities, precipitation, elevation, and population

Before and After Treatment



Average Treatment Effect (ATT)



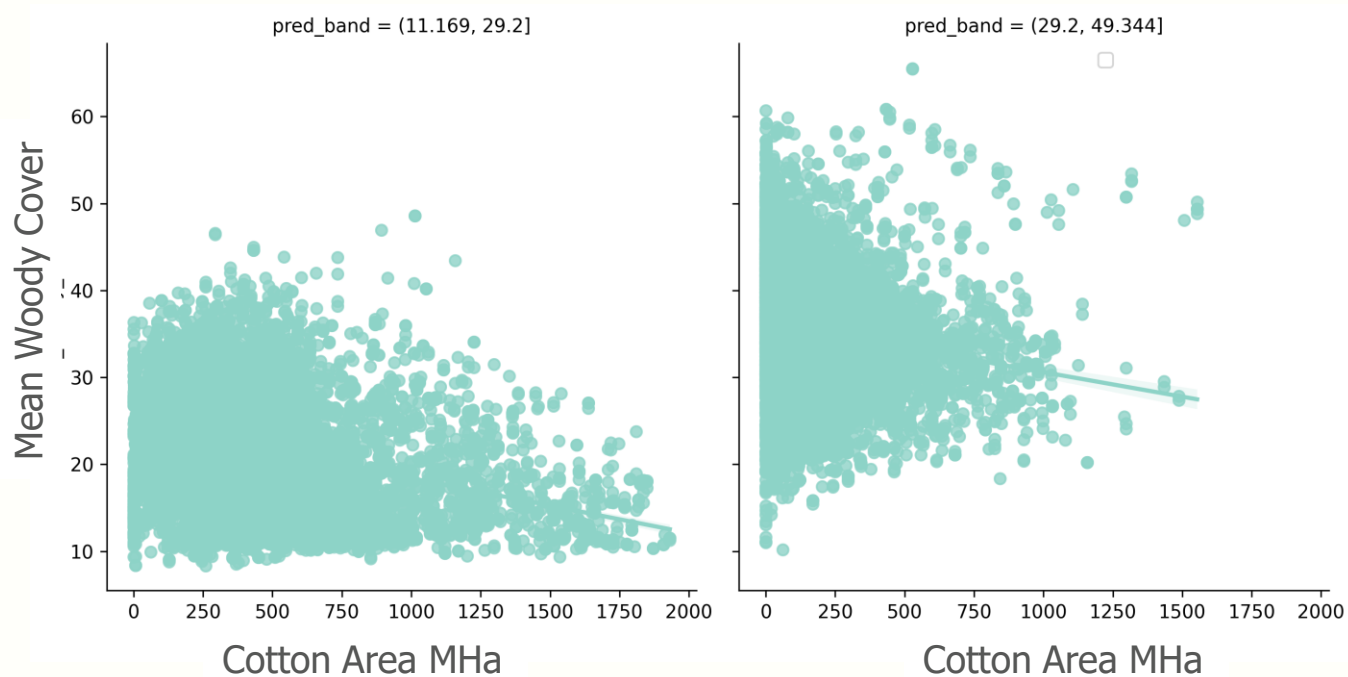
- mean woody cover
- mean woody cover within cropland
- * percentage cropland extent
- + mean woodycover outside cropland

The average causal treatment effect on the treated villages (ATT):

- woody cover decline 0.9%
 - within cropland 0.5% decline
 - outside cropland 1.5% decline
- cropland extent expansion 3%

Significant time effect indicates a 4% gain in woody cover outside cropland

Heterogeneous Treatment Effects (CATE)



Summary

- Sorghum and millet intensification efforts in the Sikasso region in Mali led to a **rebound effect** alias the case of **Jevons paradox**
- Significant heterogeneous treatment effects across market gradients of cotton

Thank you!



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Standing
Panel on
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