The Environmental Impacts of Microfinance: An Empirical Study of Index-Based Livestock Insurance and East African Rangelands

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April 19, 2022 seminar at Texas A&M University

Motivation

- There has been considerable growth in micro-finance to induce investment and savings and to provide social protection in settings with missing or weak financial markets, incl. in agricultural index insurance.

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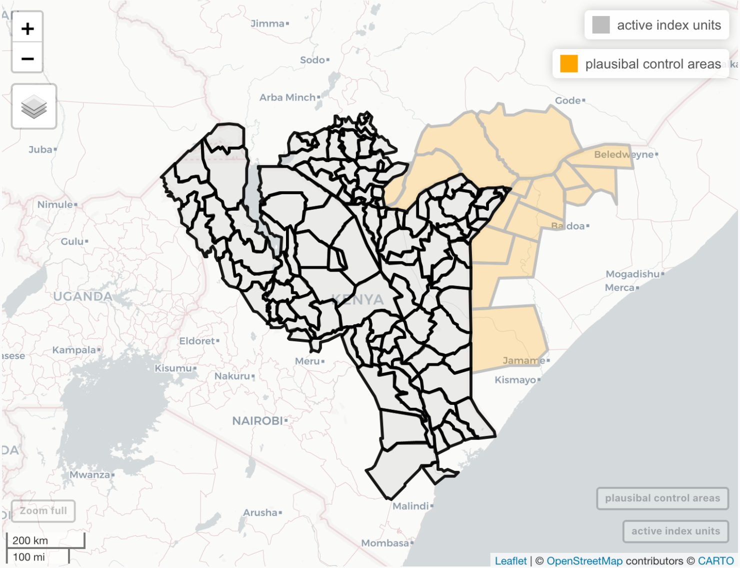
- There has been considerable growth in micro-finance to induce investment and savings and to provide social protection in settings with missing or weak financial markets, incl. in agricultural index insurance.
- An important, understudied issue: *Does microfinance lead to unintended environmental impacts?*
  If microfinance induces greater investment or production, it may generate important externalities that undercut MF's short-run gains.

Case study: IBLI

Index-based livestock insurance (IBLI) - developed by ILRI, Cornell, UC-Davis and partners - has won multiple major int'l awards.
IBLI has scaled out to multiple countries across Africa, as both a micro-scale commercial product and underpinning nat'l drought response.

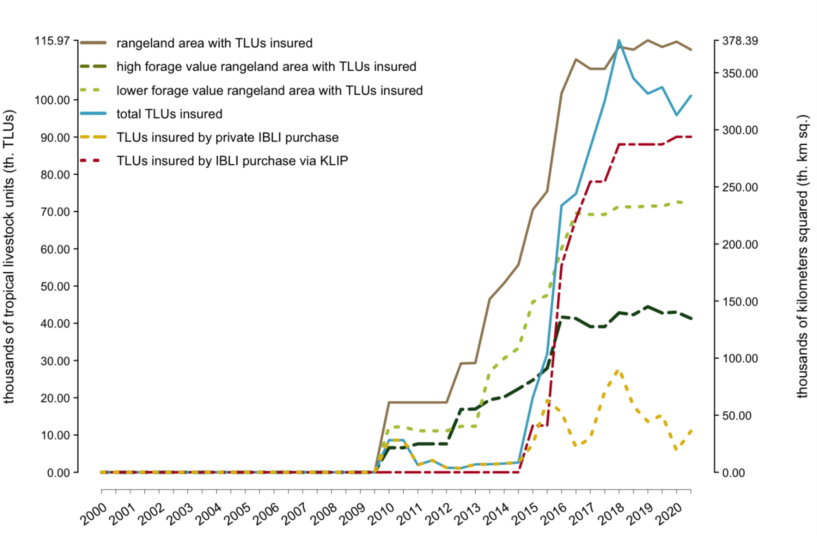
- Designed to address drought-related herd mortality, poverty traps (Lybbert et al.*EJ* 2004, Chantarat et al.*JRI* 2013).
- NDVI-based index designed around bimodal rainfall. 2 sales periods (LRLD = Mar-Sep; SRSD=Oct-Feb). Contracts last 1 year.
- Piloted in Marsabit in Jan 2010, in Borana from Aug 2012. Sharia-compliant Takaful began in Wajir in 2013. Kenya Livestock Insurance Program (KLIP) launched in 2015. Has expanded in Ethiopia, and now in Zambia, Mauritania, and soon Somalia, Sudan.

Case study: IBLI



Case study: IBLI

Effectively random, staggered roll-out, exogenous to rangeland conditions.



Case study: IBLI

IBLI's favorable impacts have been well established:

- Benefits to child nutrition, productivity, household income, drought response, informal insurance (Jensen et al. *JDE* 2017, Janzen & Carter *AJAE* 2019, Tafere et al. AJAE 2019, Takahashi et al. AJAE 2019, Matsuda et al. *GPRI* 2019).

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- Inconclusive impacts on livestock holdings and herding behaviors: herd size ($\uparrow$ Matsuda et al. *GPRI* 2019, $\downarrow$ Jensen et al. *JDE* 2017); herding effort ($\downarrow$ Toth et al. 2020 WP, $\uparrow$ Son 2021 WP).

Case study: IBLI

Even with clear impacts on stocking rate and herding behavior, theory is ambiguous on IBLI's environmental impacts.

- Reduced risk exposure could increase stocking rates, degrade rangelands, and thereby cause herd collapses (John et al. *EE* 2019, Bulte & Haagsma *ERE* 2021)

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- Insurance could reduce precautionary savings, reducing stocking rates and pressure on rangelands (Jensen et al. *JDE* 2017; Cisse & Barrett *JDE* 2018)

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- Insurance could reduce precautionary savings, reducing stocking rates and pressure on rangelands (Jensen et al. *JDE* 2017; Cisse & Barrett *JDE* 2018)
- Insurance could change herding behaviors generating spatially variation in induced changes in grazing pressure (Toth et al. 2020 WP; Son 2021 WP)

Our contribution and research questions

Our contribution: Study environmental (rangeland quality) impacts of a scaled microfinance product (IBLI) over an extended period (21 yrs' semi-annual data) and vast range ($\sim 600Kkm^2$).

Research Questions:

– *Does IBLI have a measurable impact rangeland quality?*

– *If yes, are the net-effects negative or positive for rangeland quality?*

Our approach

Staggered, roll-out of IBLI, plausibly conditionally exogenous to rangeland conditions, lends itself to differences-in-differences (DiD) estimation:

– use new non-parametric group-time DiD (gt-DiD) to address staggered rollout (Callaway & Sant'Anna *JE* 2021, Roth & Sant'Anna 2021 WP).

VERY preliminary results:

– *No clear evidence of any favorable or unfavorable effects of IBLI on RH. Mixed results across indicators:*
$\uparrow$ *bg*, $\downarrow$ *npv*, $\uparrow$ pv, $\uparrow$? vegetation productivity.

– *impacts appear heterogeneous by broad rangeland type: a bit better for lower quality rangelands than higher quality*

Lots to do still: other RH indicators (LAI, SIF), composite RH index, continuous exposure measures, placebo tests, etc.

Rest of this talk

(1) Spatial and temporal diffusion of IBLI

(2) Remote-sensing (RS) measurement of rangeland health (RH)

(3) Data: control variables

(4) Econometric methods for causal identification

(5) Preliminary results

(6) Conclusions and next steps

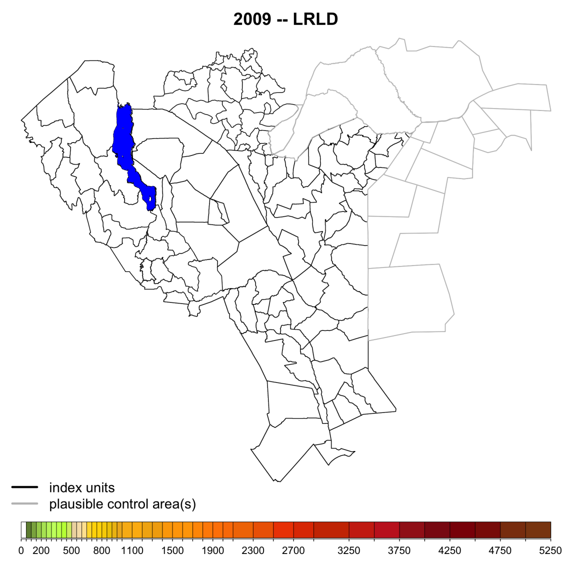
Data: Spatial and temporal diffusion of IBLI

Need to construct measure of inverse distance weighted binary exposure to the universe all IBLI contracts in force during a given season.

IBLI administrative data recorded from 'insurance unit' (IU) level sales. IUs reflect administative jurisdictions. Need to allocate across space and downscale to relevant physical geography.

Generate 21 yrs' semi-annual (LRLD; SRSD) seasonal data (2000-2020):

Data: Spatial and temporal diffusion of IBLI



Data: Spatial and temporal diffusion of IBLI

Constructing IBLI exposure measures

Challenge: *How to account for herder movement and downscale IBLI exposure to affected rangelands within each unit?*

Answer: *Use the all rangelands mask and define a "neighborhood" to inverse distance weight exposure from units j in unit i.*

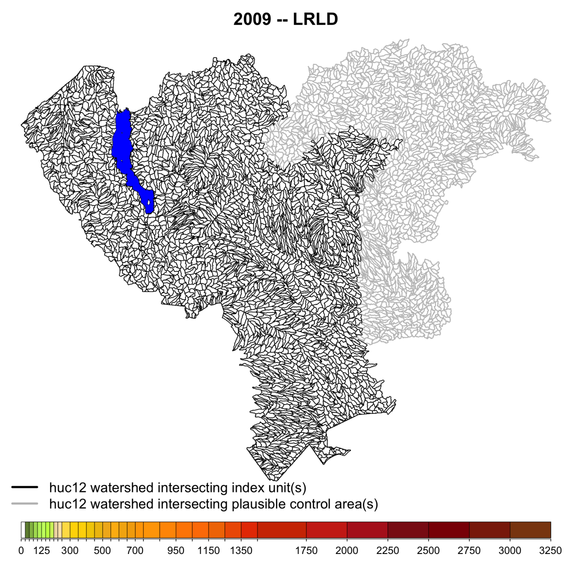
$$WIBE_i = IBE_i + \sum_{j^{-i}} \frac{(\mathbb{1}_j \; w_{ij} \; IBE_j)}{\sum_{j^{-i}} \mathbb{1}_j \; w_{ij}}$$

Define neighborhood, $\mathbb{1}_j$: SRSD grazing extent ≈ 63 km grz fig

Divide the neighborhood: split neighborhoods into buffers b_n buffer ; use distances to the boundary of unit i as building block for weights, w_{ij}.

Define exposure: *a unit becomes exposed to IBLI when* ≥ 1 *insured tropical livestock unit (TLU)* 1^{st} *observed.*
Use hydrological units (HUC) as relevant physical geography unit.

Data: down-scaled IBLI exposure



Remotely sensed (RS) rangeland health (RH) measurement

Rangelands are the dominant land type on Earth.

Definition (Pellant et al. 2020): "lands on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly".

Remotely sensed (RS) rangeland health (RH) measurement

- 1970s-Present: range science advanced theory and field-based assessment, RS-tools have matured & become more reliable.

  Two foundational concepts in range science:

  - state and transition models (STM) STM fig

  - rangeland health (RH): $RH = f(B, H, S)$ RH fig

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  Two foundational concepts in range science:

  - state and transition models (STM) STM fig

  - rangeland health (RH): $RH = f(B, H, S)$ RH fig

- Well-developed field-based methods for RH (Pellant et al. 2020); downward (upward) trend in more than 1 attribute likely implies declining (improving) RH.

Remotely sensed (RS) rangeland health (RH) measurement

Impossible to mirror field-based methods perfectly, but we can use direct and indirect, RS-based measures of RH:

- $30m^2$ fractional land cover of bare ground (bg), photosynthetic vegetation (pv), non-photosynthetic vegetation (npv)

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Impossible to mirror field-based methods perfectly, but we can use direct and indirect, RS-based measures of RH:

- $30m^2$ fractional land cover of bare ground (bg), photosynthetic vegetation (pv), non-photosynthetic vegetation (npv)
- $250m^2$ vegetation indices.

Remotely sensed (RS) rangeland health (RH) measurement

Impossible to mirror field-based methods perfectly, but we can use direct and indirect, RS-based measures of RH:

- $30m^2$ fractional land cover of bare ground (bg), photosynthetic vegetation (pv), non-photosynthetic vegetation (npv)
- $250m^2$ vegetation indices.
- And control for long-run RS time-series for baseline (e.g. anomaly detection), using 21 yrs' semi-annual (LRLD; SRSD) seasonal data (2000-2020).

Remotely sensed (RS) rangeland health (RH) measurement

Rangeland Health (RH) Attributes	RH Assessment Indicators (RHAI)	RS-based Estimates of RHAI
Biotic Integrity	dead or dying plants	non-photosynthetic vegetation via 30m fractional cover
	functional / structural group canopy cover	photosynthetic vegetation via 30m fractional cover
	functional/ structural groups, plant mortality and vigor	site potential deviations
		vegetation indices (e.g., EVI, NDVI, LAI, SIF) $^{++}$
Hydrologic Function	bare ground	bare ground via 30m fractional
Soil / Site Stability		

$^{++}$ denotes indirect estimates of RHAI.

Data: Rangelands and aggregation

- **Masking strategy: we use 30m^2 landcover (Soto et al. 2022) to form three rangeland masks for each 5-6 year span:**

  * all rangelands all

  * high forage value rangelands high

  * lower forage value rangelands low

  This strategy ensures data come from rangelands of interest and enables us to capture spatial heterogeneity.

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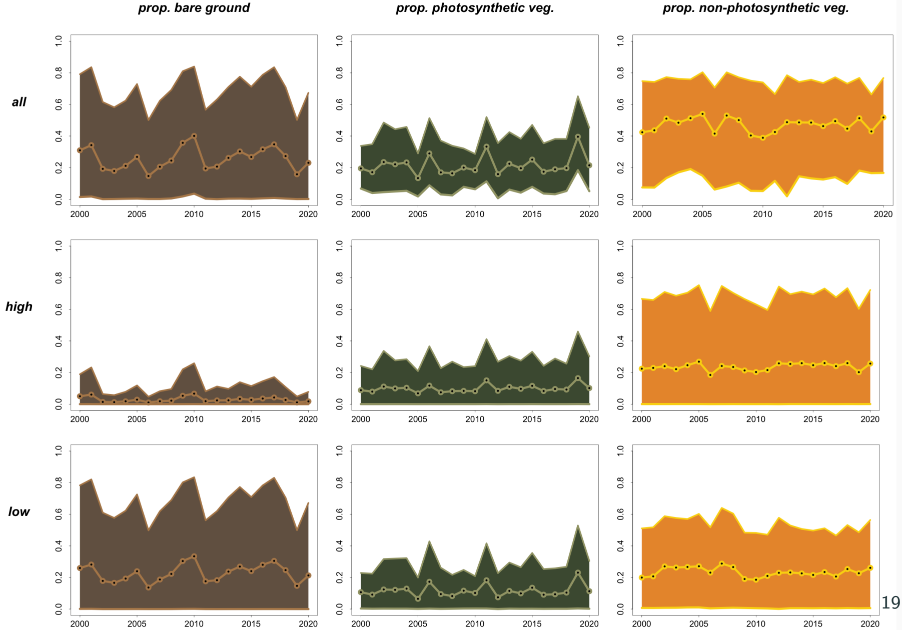
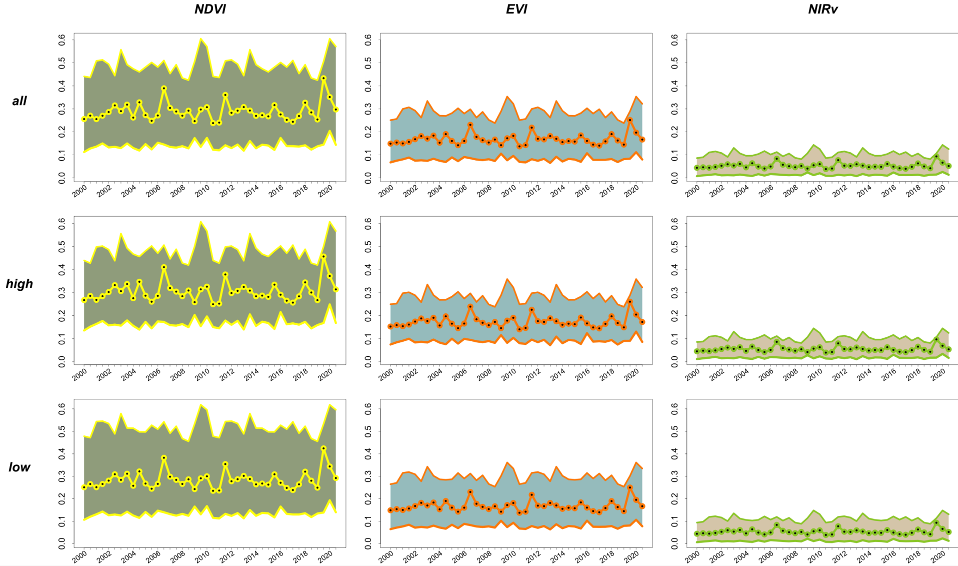
- **Units/levels of study:** index units and plausible control areas, and 3 sub-watershed levels (Lehner and Grill 2013)

  * matrices reflect summarized data of areal units (polygon); masks allow us to isolate particular kinds of information within areal units.

huc12 fractional cover



huc12 vegetation indices



Data: Control variables

Group-time treatment effects do not necessarily require or permit covariates; only Callaway and Sant'Anna JE 2021 permits conditional estimation, and only with pre-treatment covariates.

When we can use covariates, we use the following:

- fire incidence (monthly burned area, MODIS Fire-cci, 250m)
- temperature (hourly temperature data, ERA-Land5, 9km)
- precipitation (every 5 days, CHIRPS, 6km)

Econometric methods for causal identification

Plausibly exogenous rollout over space and time allows for DiD estimation. But as a rapidly emerging DiD estimation cautions, beware of conventional two-way fixed effects (TWFE) estimation when treatment timing and intensity vary among exposed units.

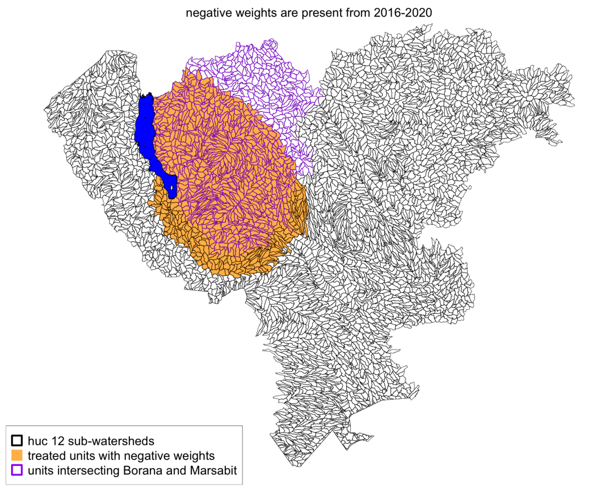
DiD via TWFE:

$$Y_{i,r,s,t} = D_{ist}\delta + \mathbf{X}'_{\mathbf{i,r,s,t}}\beta + \gamma_i + \sigma_t + \varepsilon_{i,r,s,t}$$

for unit i, rangeland type r, in season s, and year t

TWFE Jakiela (2021) test for negative weights

A risk of TWFE w/differential timing: neg. weights on treated units (de Chaisemartin & D'Haultfœuille *AER* 2020, Goodman-Bacon *JE* 2021, Sun & Abraham *JE* 2021, Jakiela 2021 WP). Applies here!:



Econometric methods for causal identification

So need to use an alternative approach:

Callaway and Sant'Anna 2020: allows for pre-treatment controls

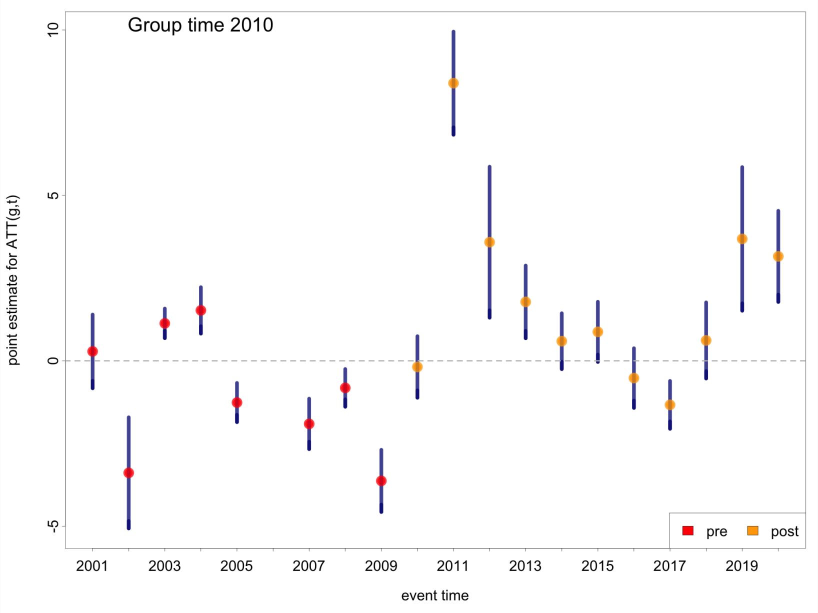
$$ATT(g,t) = ATT_{dr}^{ny}(g,t;\delta)$$
$$= \mathbb{E}\Big[\Big(\frac{G_{i,g}}{\mathbb{E}[G_{i,g}]} - \frac{\frac{p_{g,t+\delta}(X)\ (1-D_{t+\delta})\ (1-G_g)}{1\ -\ p_{g,t+\delta}(X)}}{\mathbb{E}[\frac{p_{g,t+\delta}(X)\ (1-D_{t+\delta})\ (1-G_g)}{1\ -\ p_{g,t+\delta}(X)}]}\Big)\big(Y_t - Y_{g-\delta-1} - m^{ny}_{g,t,\delta}(X)\big)\Big]$$

Roth and Sant'Anna 2021: greater efficiency, but no controls

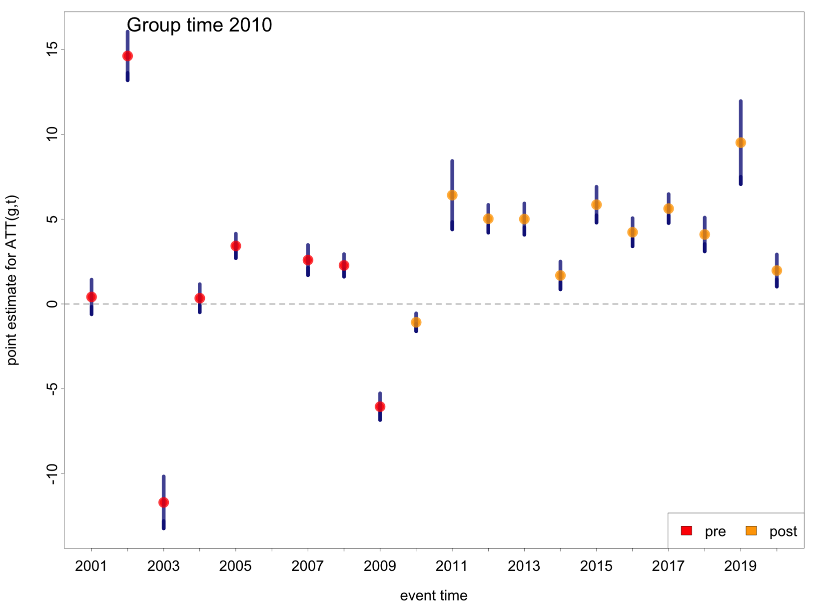
$$ATE(g,t) = \sum_{t,g,g'} a_{t,g,g'}\tau_{t,g,g'}$$

$$\text{estimator: } \hat{\theta}_\beta = \hat{\theta}_0 - \hat{X}'\beta, \quad \text{where: } \beta^* = Var[\hat{X}]^{-1}Cov[\hat{X},\hat{\theta}_o]$$

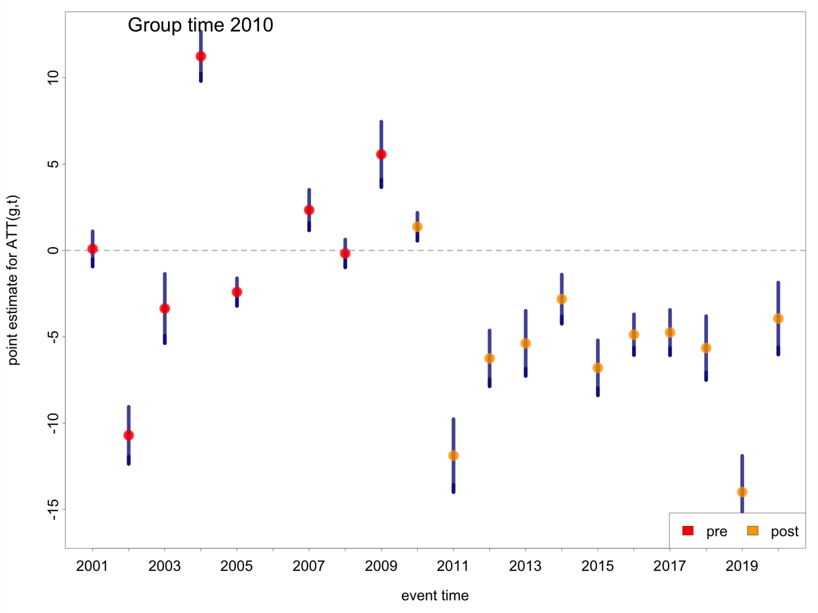
gt-2010, event-study type ATT: bg-all



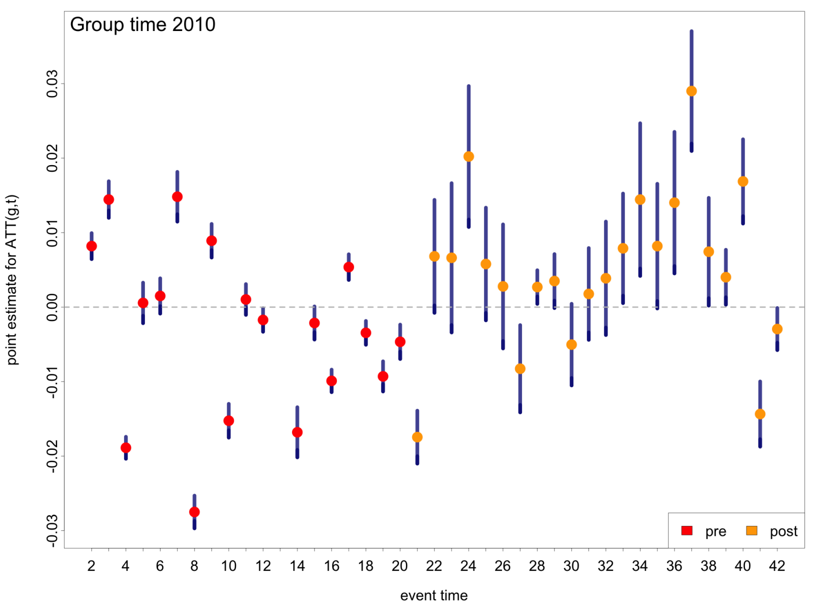
gt-2010, event-study type ATT: pv-all



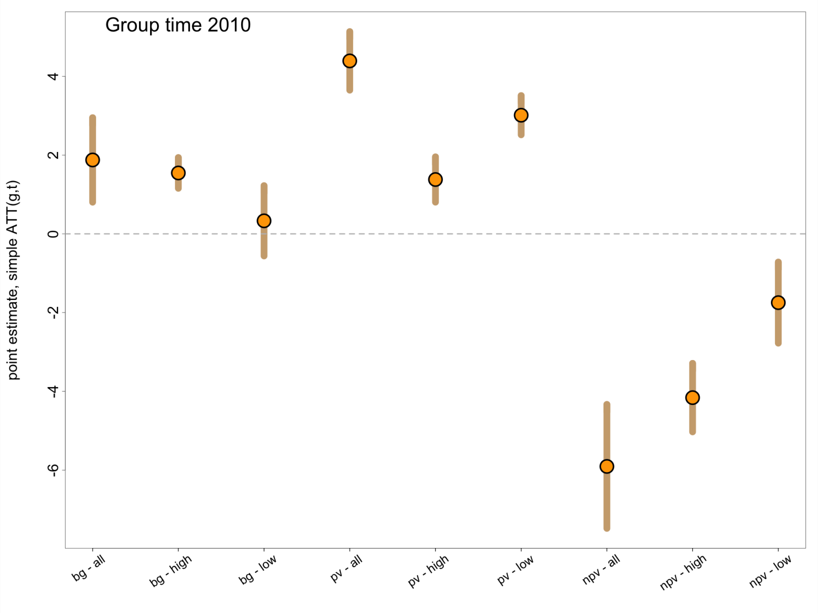
gt-2010, event-study type ATT: npv-all



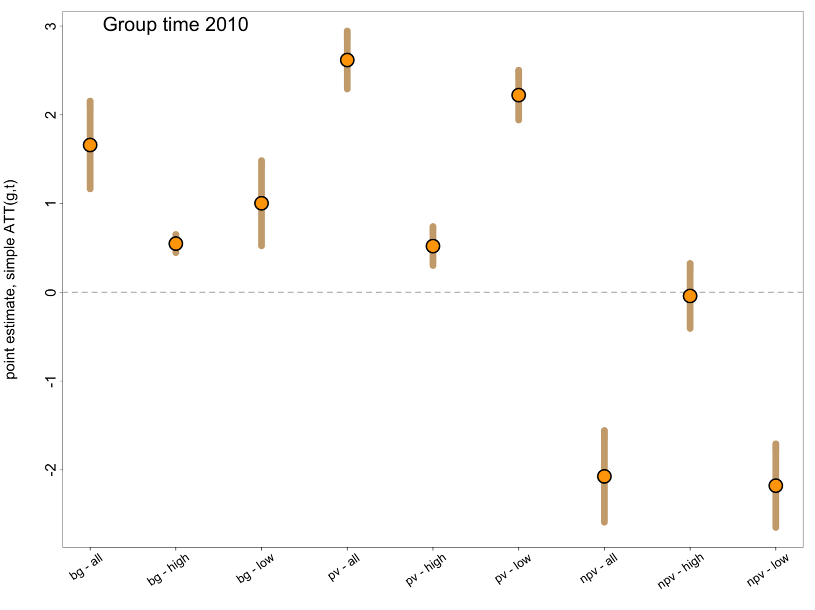
gt-2010, event-study type ATT: EVI-all



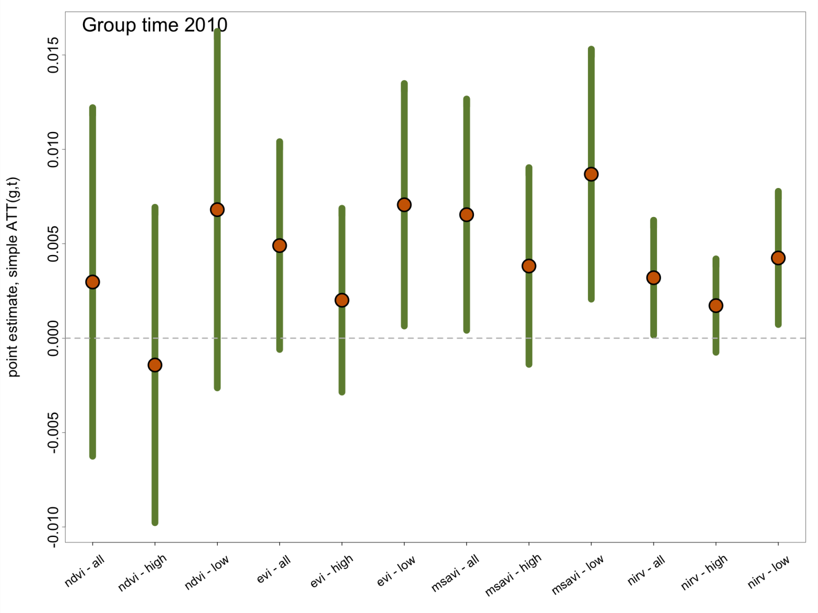
simple ATTs, gt-2010, fractional cover



simple ATEs, gt-2010, fractional cover



simple ATTs, gt-2010, vegetation indices



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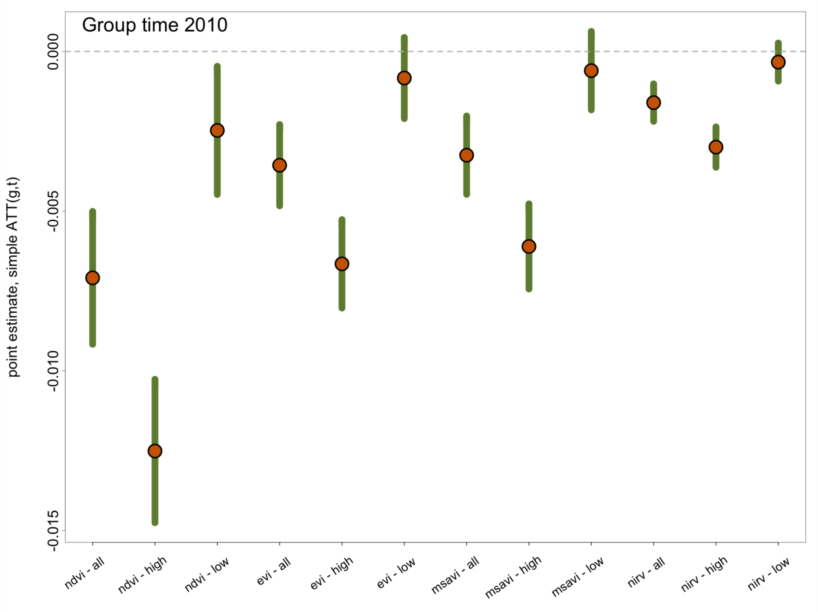


Preliminary findings

- Preliminary results reveal no clear pattern of RH impacts from IBLI.
- Varied impacts: $\uparrow$ bg, $\downarrow$ npv, $\uparrow$ pv, maybe $\uparrow$ productivity of vegetation.
- Mixed effects suggest potential need to look at composite RH index and look at other group-time cohorts.
- RH assessment principle: sustained decline (improvement) in $\geq$ one RH attribute over time suggests degrading (improving) RH. Trends inconclusive based on just one RH indicator.

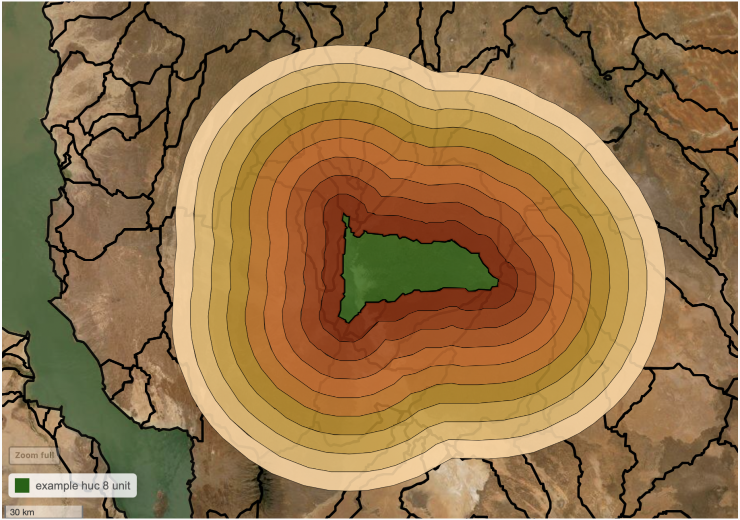
Next steps

- Look at additional RH indicators (e.g., LAI, SIF) and a PCA-based composite RH index.
- Explore potential for estimating at intensive margin based on growth in IBLI exposure intensity.
- Try to keep up w/ fast-changing DiD literature to pin down estimator best suited for this context ... parallel trends assumptions, time-varying confounders, endogenous uptake levels conditional on IBLI availability; identify key group-time cohorts to understand.

Thank you

Thank you for your time, attention and interest!

Questions/comments? Please contact Chris (cbb2@cornell.edu) or Steve Wilcox (sww62@cornell.edu)



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example STM (Liao & Clark 2017)

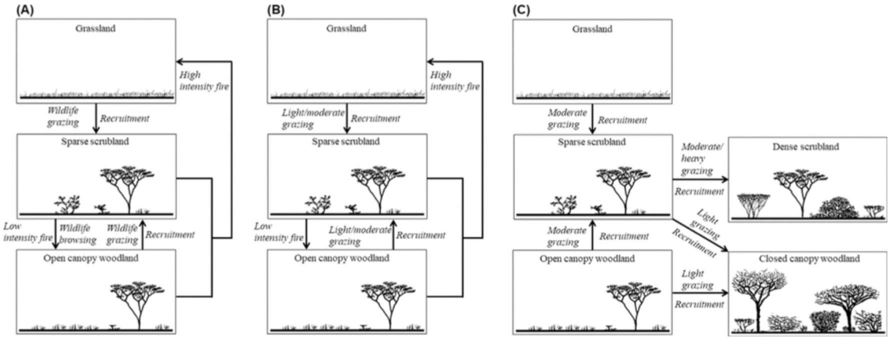


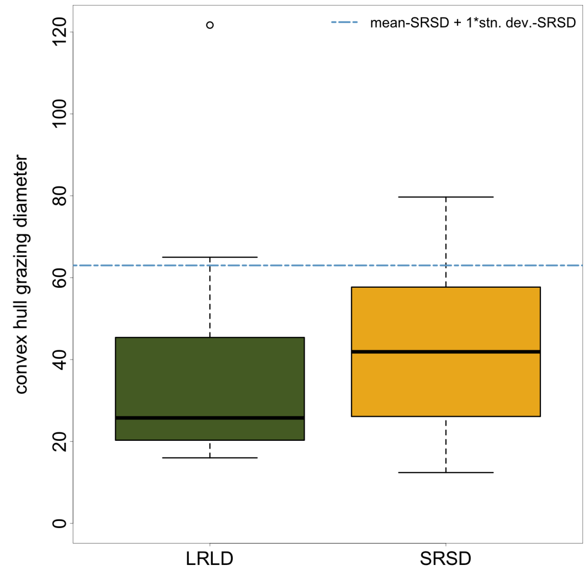
Fig. 5. Rangeland states and transitions with wildlife herbivory and fire (A), with livestock grazing and fire (B), and with livestock grazing but without fire (C).

back

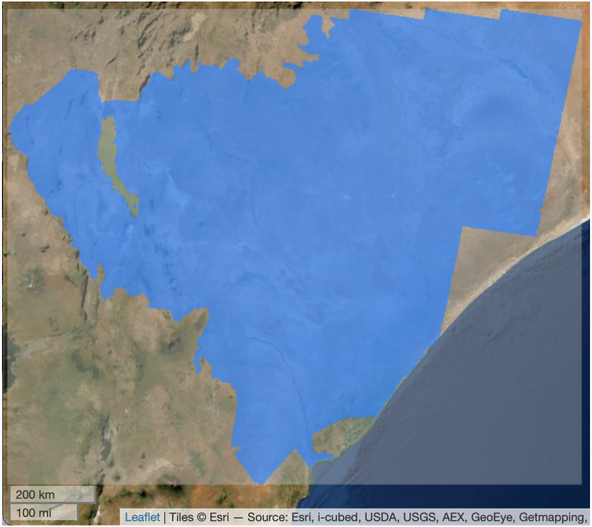
RH attributes & indicators (Pellant et al. 2020)

<table>
<tr><th>Soil/Site Stability</th><th>Hydrologic Function</th><th>Biotic Integrity</th></tr>
<tr><td colspan="2">1. Rills</td><td>12. Functional/Structural Groups</td></tr>
<tr><td colspan="2">2. Water Flow Patterns</td><td>13. Dead or Dying Plants or Plant Parts</td></tr>
<tr><td colspan="2">3. Pedestals and/or Terracettes</td><td>15. Annual Production</td></tr>
<tr><td colspan="2">4. Bare Ground</td><td rowspan="2">16. Invasive Plants</td></tr>
<tr><td colspan="2">5.Gullies</td></tr>
<tr><td>6. Wind-Scoured and/or Depositional Areas</td><td colspan="2">14. Litter Cover and Depth</td></tr>
<tr><td>7. Litter Movement</td><td>10. Effects of Plant Community Composition and Distribution on Infiltration</td><td>17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants</td></tr>
<tr><td colspan="3">8. Soil Surface Resistance to Erosion</td></tr>
<tr><td colspan="3">9. Soil Surface Loss and Degradation</td></tr>
<tr><td colspan="3">11. Compaction Layer</td></tr>
</table>

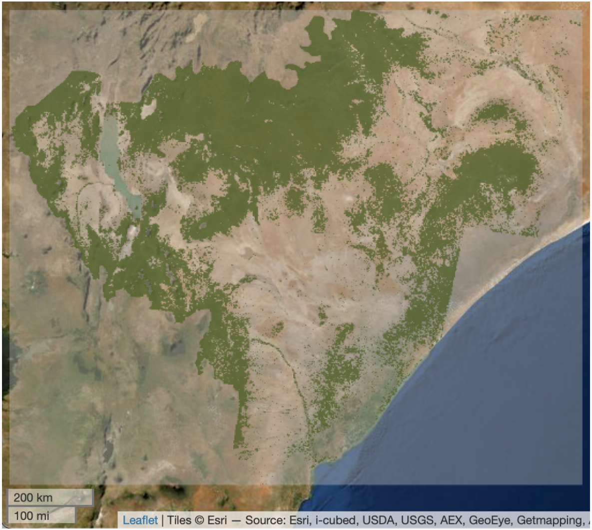
back


mean-SRSD + 1*stn. dev.-SRSD
convex hull grazing diameter
0
20
40
60
80
100
120
LRLD
SRSD

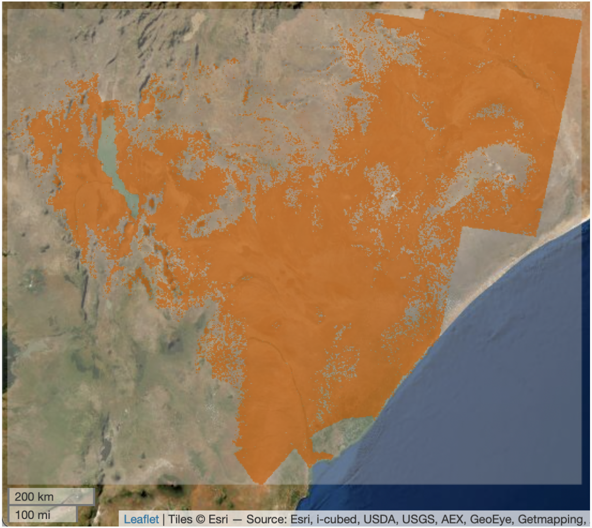
back



(only masks out water and impervious cover) back



(includes grassland, open canopy woodland, sparse scrubland, dense scrubland) back



(includes sparse vegetation, bushland, cultivated land, close canopy woodland) back

IBLI Down-scaling Work Flow

- Step 1: Rasterize index-unit-based AOI (index units + control areas) using one of our land cover rasters as template grid (i.e. 30m).
- Step 2: For each year, count the number of pixels within each IU and CA that comprise the two adopted definitions of rangeland.
- Step 3: For each year, season, IU and CA, divide *IBE* measures by number of rangeland pixels. Store the data from Steps 2 and 3.
- Step 4: For each year and season, rasterize the pixel-level rangeland-area-weighted data from Step 3 w/30m landcover.
- Step 5: Using data from Step 4, for each unit, in each year and season, sum across pixels within each unit, sum across pixels within each concentric buffer and weight by the inverse distance, add the two sums, and store the data.