A cross-scale approach to understand agricultural frontiers emergence in Southern and Eastern Africa

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Building on the work of the team of **MIDLAND** (2016-2022) **https://erc-midland.earth**

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UEM (Mozambique): Luis Artur, Julieta Jetimane, Sá Nogueira Lisboa, Natasha Ribeiro, Almeida Sitoe, Milton Tovele, Yara Ubisse

UCL – Earth & Life Institute

UCLouvain

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Outline

1. Introduction, the global picture and challenge (Patrick)

2. **Agents:** Commercial farmers and investors' decision-making: from the local to the meso-scale (Dilini)

3. **Land use patterns:** Mapping and explaining the land use dynamics (Patrick)

4. **Impacts:** of farm size dynamics and forestry investments (Cristina)

5. Future steps, prospects, engagement with GLASSNET community (Team)

>> Discussants statements

& Discussion.

Part 1. Introduction, the global picture and challenge

“Resource frontiers”: our working definition

Places with imbalance between **abundant natural resources / land** and **comparative lack of production factors (capital, labor) to exploit these resources**, and **rapid inflow of production factors & expansion of resource / land use**

>> **deforestation frontiers** & **commercial agriculture frontiers**

Contemporary: Commodity / commercial deforestation frontiers;
large-scale, capitalized actors

(Barbier 2011, le Polain de Waroux et al. 2018, Meyfroidt et al. 2018, Meyfroidt et al. in preparation)

Frontiers are marginal spaces globally…

Global extent: Cropland: 1562 Mha
Pastures: 3183 Mha

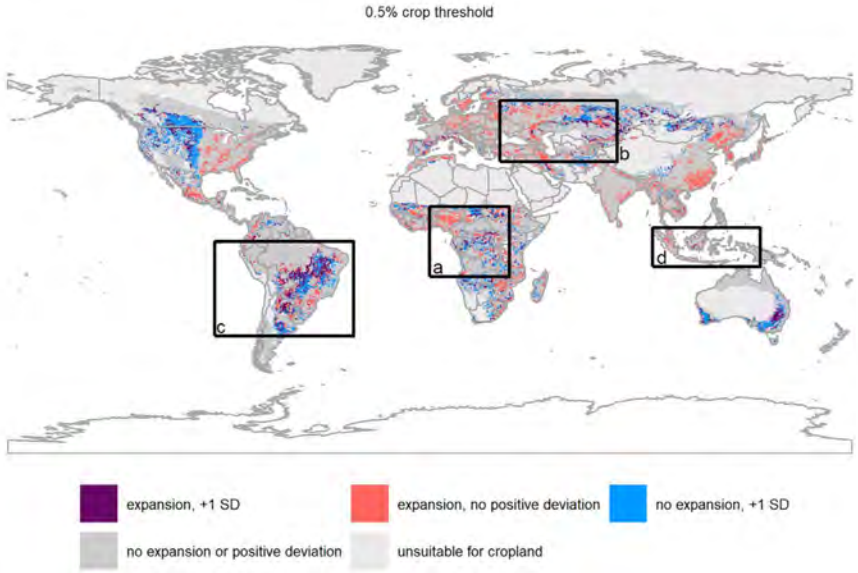
>< Agriculture-driven deforestation rate: ~6.4–8.8 Mha/y **~ 0.1-0.2%** !!

You can very well get global agricultural models 99% correct but miss these frontiers!

…But of high importance

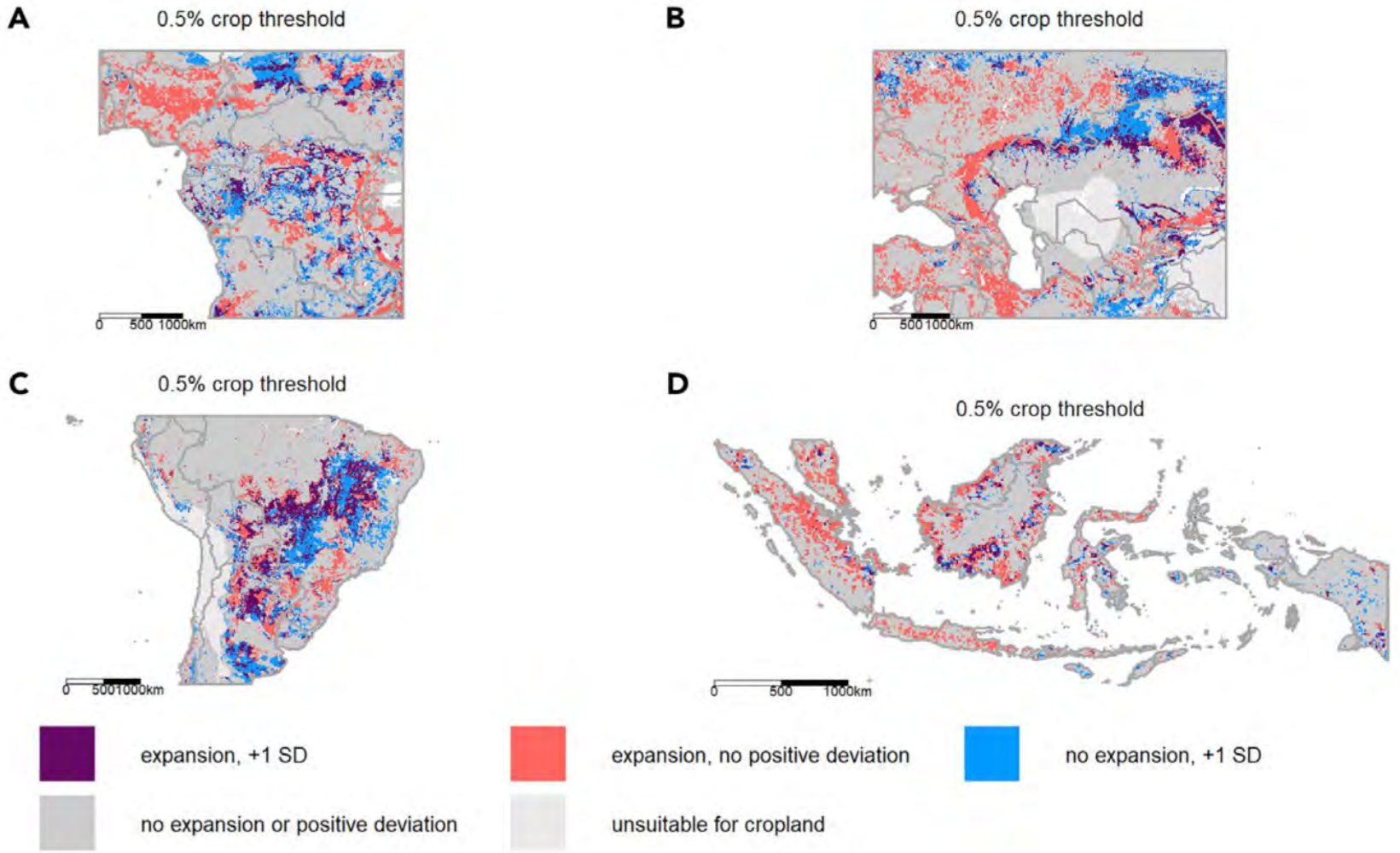
Why do we need a global-to-local approach ?

Global statistical model based on standard land rent theories (von Thünen, Ricardo) explain cropland *extent* better than *expansion*; but past **frontier dynamics** partly explain recent dynamics >> **land supply elasticity**

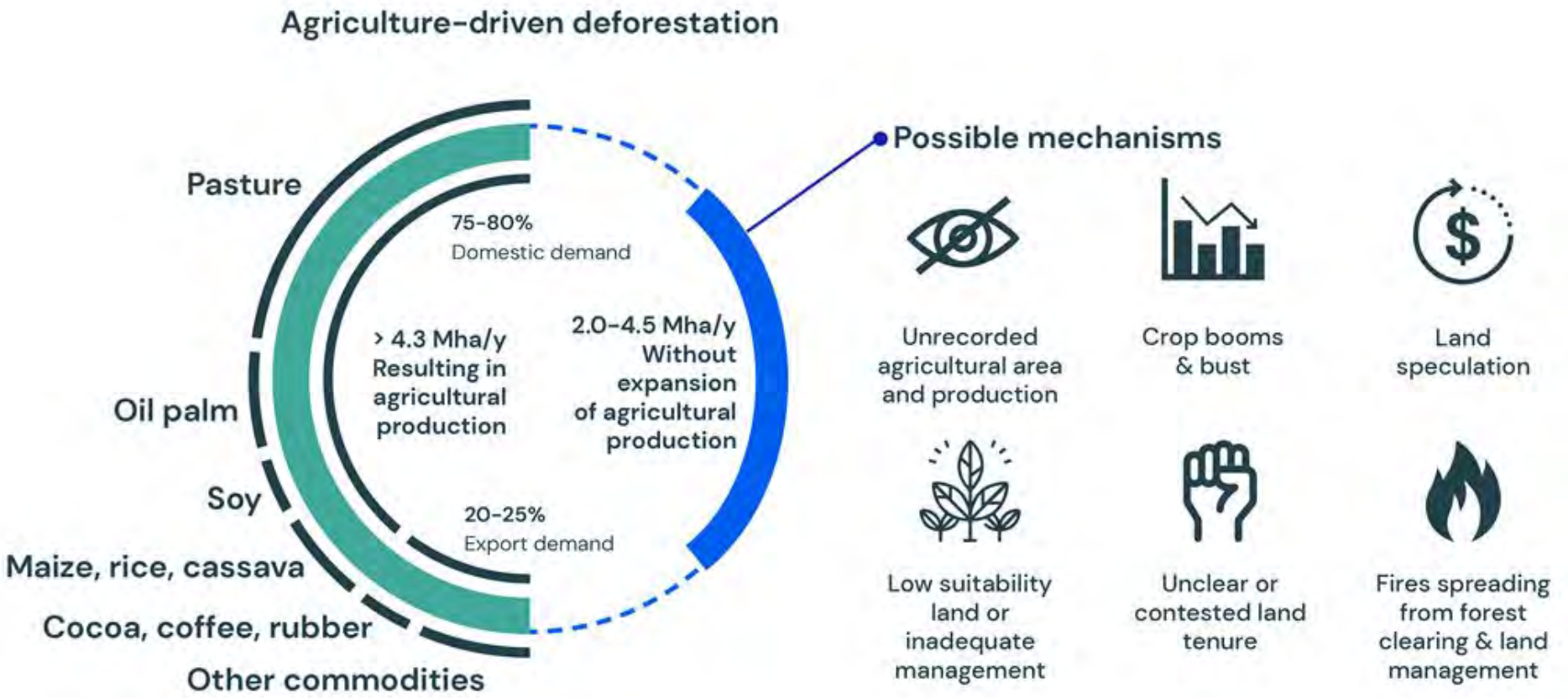


+ 1SD = more cropland in 1992 than predicted by economic model

Eigenbrod et al. 2020 (One Earth)



Messy dynamics don't easily fit in global modelling: ~ a third to half of tropical deforestation is "for nothing"



Pendrill et al. in review

Capturing rents drives frontiers

Resource frontiers are driven by "abnormal rents", created and captured by agents with heterogenous capacities

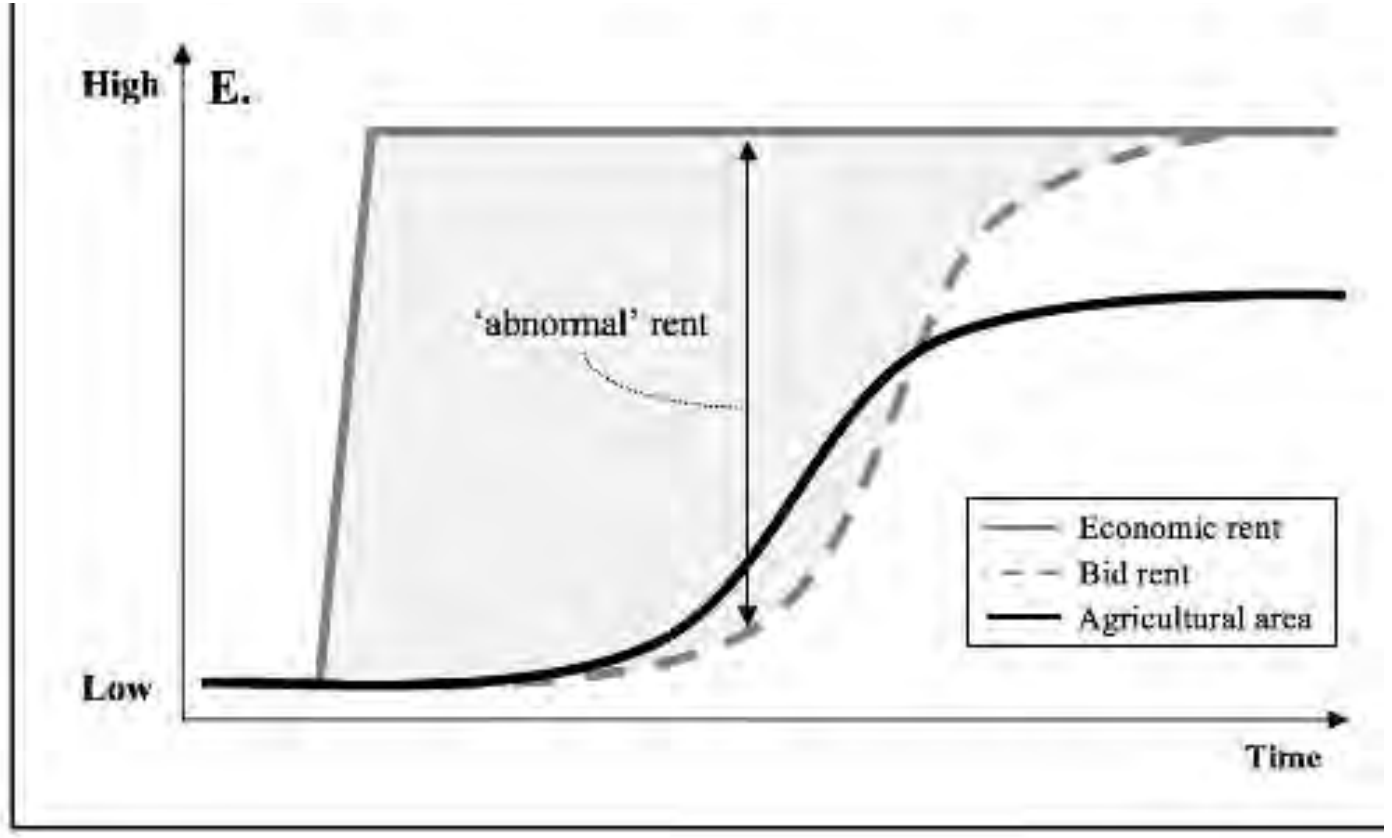


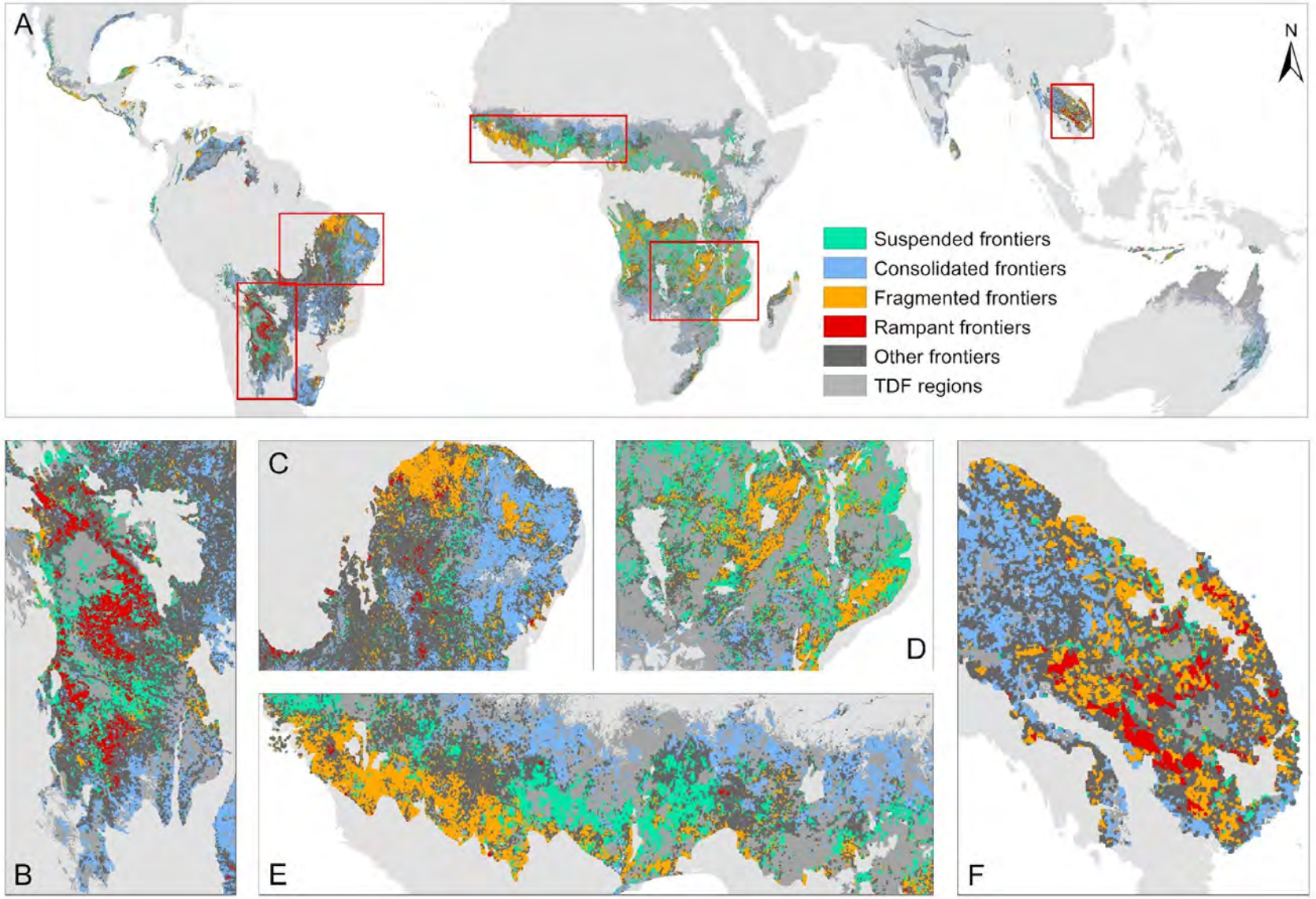
Figure 3

Sources of abnormal rent		Characteristics of actors		FRONTIER EXPANSION
• Change in accessibility • Change in environmental conditions • Change in technology • Change in producer prices and/or demand • Change in subsidies or other policies	X	• Access • Information • Preferences • Agency	=	• Location • Spatial patterns • Temporal dynamics

le Polain de Waroux et al. 2018 (AAAG)

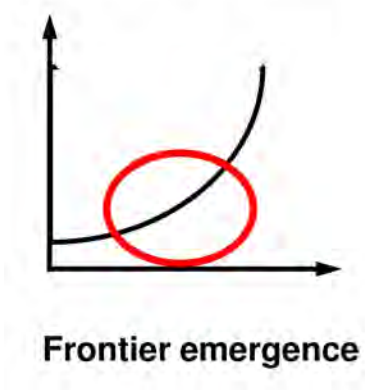
Why study frontiers in tropical dry forests ?

1/3 of tropical dry forests are in deforestation frontiers



Buchadas et al. 2022

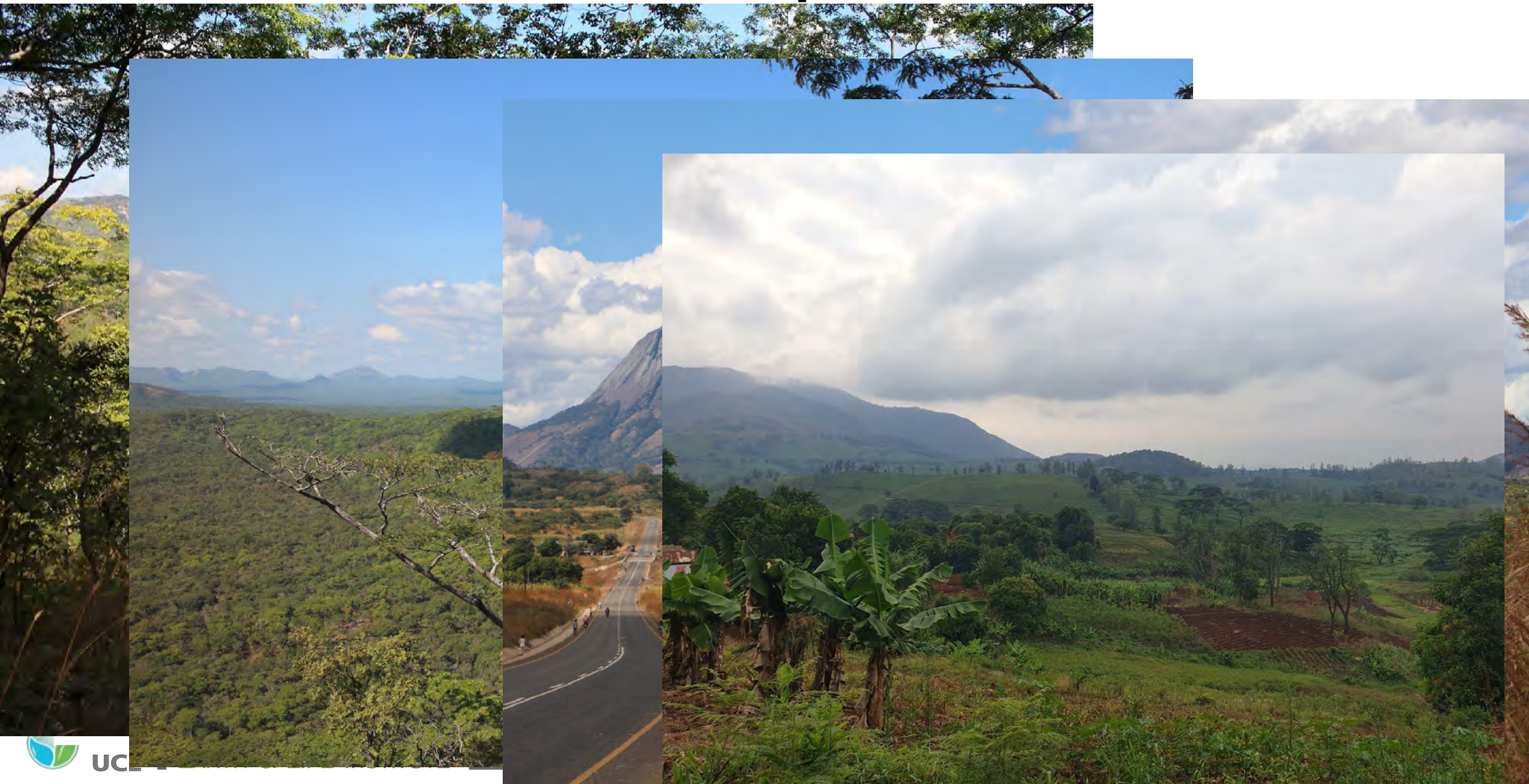
Questions



How do frontiers emerge?

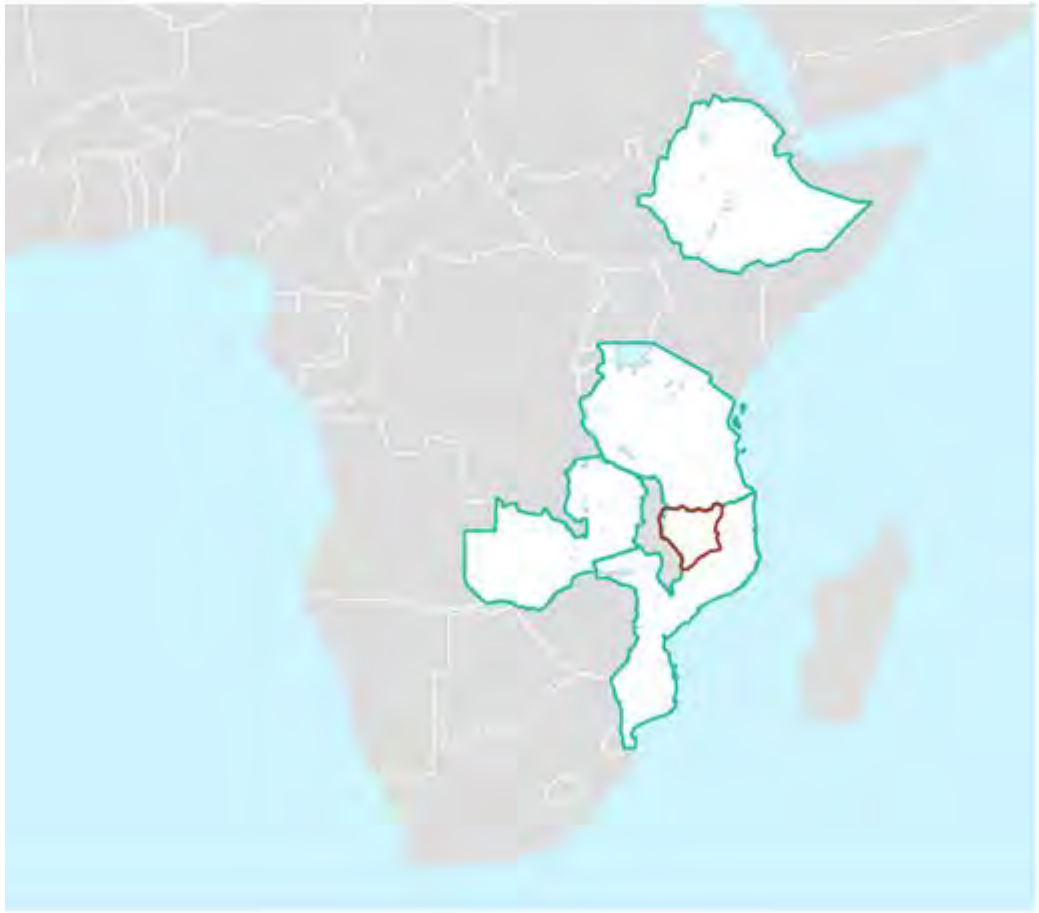
1. Why sometimes no change & then sudden acceleration?
2. Why do investors go where there is no commercial agriculture ?
3. How do deforestation frontiers & commercial agriculture frontiers interact?
4. How do these frontiers impact smallholders?

Case: Northern Mozambique and Southern Africa



Part 2. Agents: Commercial farmers and investors' decision-making: from the local to the meso-scale

Focus



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Waves and legacies: th… f an investment frontier in M…

FRONTIER MAKING HOW AND WHY?

https://doi.org/10.5751/…

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Resource fron… …conomies: The varied logics o… …land-based investing in Southern and Eastern Africa

WHO INVESTS WHERE AND WHY?

Dilini Abeygunawardane, Angela Kronenburg García, Zhanli Sun, Daniel Müller, Almeida Sitoe & Patrick Meyfroidt

Ambio **51**, 1535–1551 (2022) | Cite this article

Key Findings

- The making of frontiers (Kronenburg-García et al. 2022)
  - a protracted time period; multiple attempts to open the frontier; layering of social, human, and physical capital
- A range of investors with diverse track records and purposes (Kronenburg-García et al. 2022, Abeygunawardane et al. 2022)
- Much of Southern and Eastern Africa is in a pre-commercial emerging frontier state (Abeygunawardane et al. 2022)
- Location of agricultural production (Abeygunawardane et al. 2022)
  - market prices, money and market policies, resource availability, resource access, investor track record
  - Location determinants: the same old list more or less, but the priorities for different investors are different

Study Area

Country	GDP (USD billion)	Poverty headcount ratio at national poverty lines (% of population)	Rural population (%)	Average smallholder farm size (ha)	Forested Area in million ha (% of land cover)
Ethiopia	29.93	28.2	82.7	0.6	12.4 (11)
Mozambique	11.09	54.7	69.2	0.9	27.0 (34)
Tanzania	32.01	29.6	71.9	1.1	24.7 (26)
Zambia	20.27	54.7	60.6	0.9	22.4 (30)

Source: FAOSTAT, 2019; Hansen et al., 2013; Jayne et al., 2010; World Bank, 2014, 2020)

Abeygunawardane et al. 2022, Kronenburg-García et al. 2022

An ethnography of investors









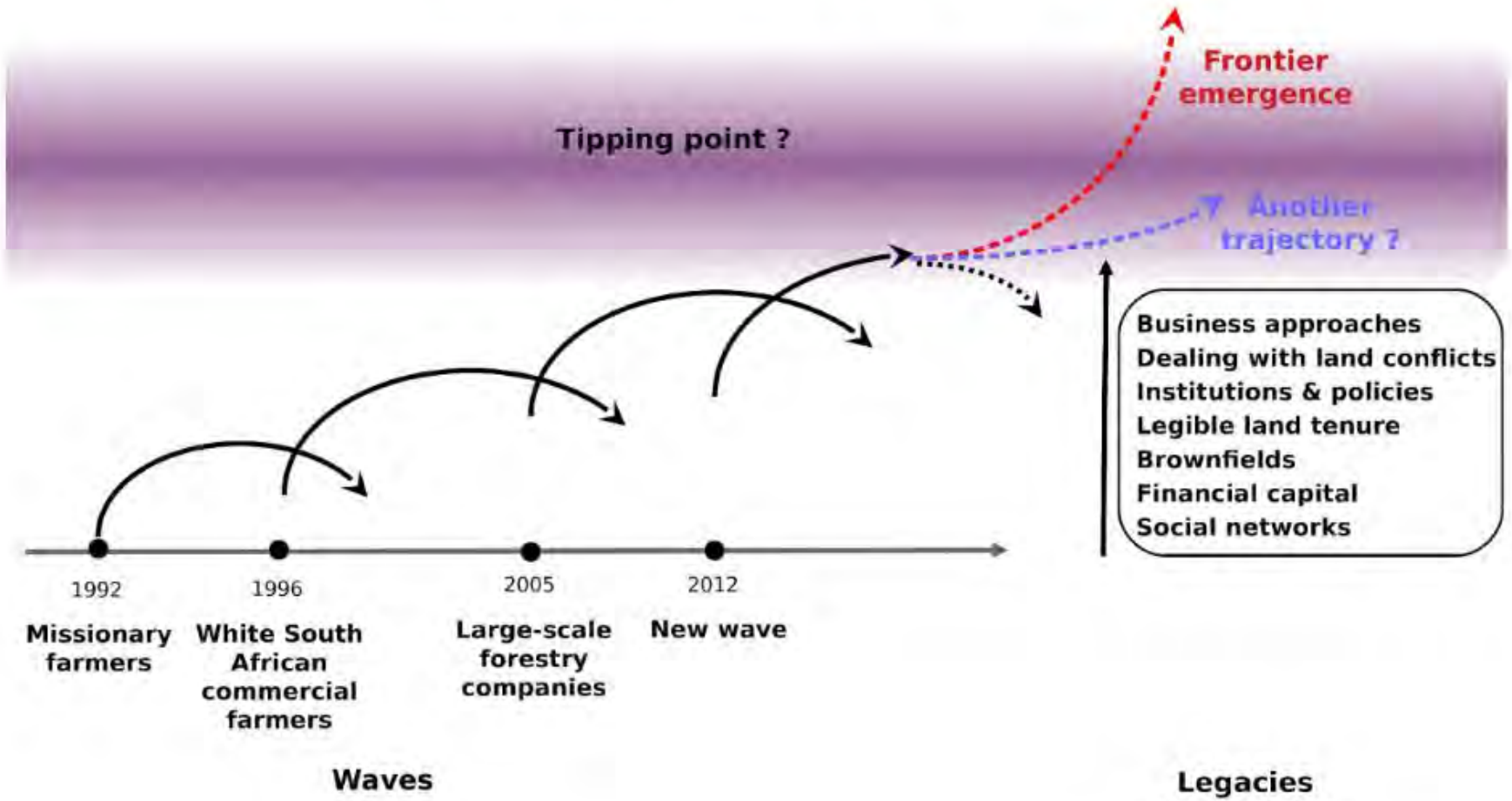


Kronenburg-García et al. 2022

1891	… 1934	… 1964	1975	1977	1992	1996	2005	2012 …
Niassa Company	• cotton • plantation agriculture	• War of independence • (Mozambican Liberation Front)	• Independence • socialist agri policy • state farms (Four Hundred Thousand Hectare Enterprise) • forest plantations, and projects • nationalization of abandoned farms	Civil war	• Christian missionaries	• Afrikaner farmers (Mosagrias Program)	• Large scale forestry companies • (Malonda Foundation) • National Reforestation Strategy	New wave
					• Faith • Isolation • Poverty • Land (availability)	• Independence • Land (availability) • Infrastructure (promised) • Financial capital (promised)	• Land (availability) • Land (access) • Infrastructure (promised) • Financial capital (promised) • Bureaucratic support (promised) • Forestry know-how (promised)	
• infrastructure • technical know-how	skilled labor	• farm abandonment • decline in infrastructure	• technology • accessible land tenure	• farm abandonment • decline in infrastructure • decline in population	• social networks	• social networks • technical know-how • skilled labor	• Brownfields • accessible land tenure • skilled labor • social networks • technical know-how	

Kronenburg-García et al. 2022

Waves and legacies



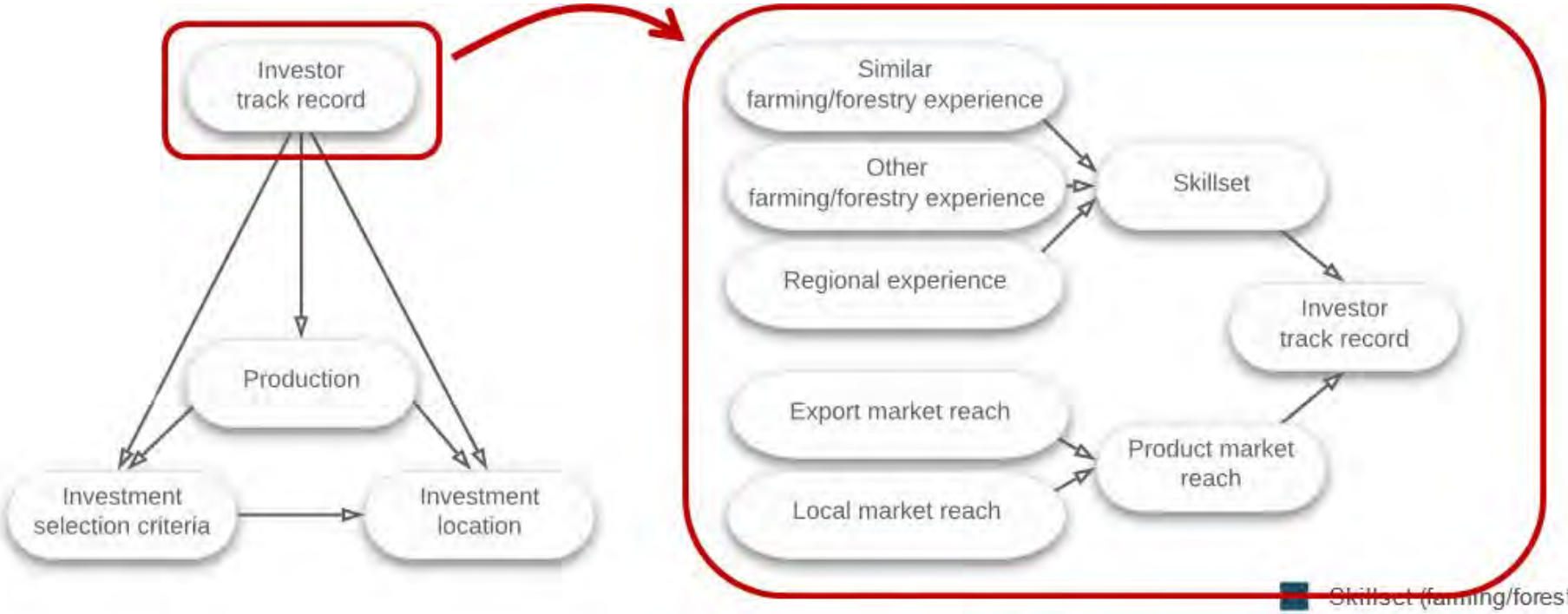
Kronenburg-García et al. 2022

Methods

- Mixed methods, semi-structured interviews with qualitative and quantitative data
- Interviews 94; farm and plantation locations 121; includes 37 investments operated by 29 investors
- The sample covers 11% of the total transnational agricultural and forestry investments made between 2000 and 2016 in Mozambique, Zambia, Tanzania, and Ethiopia
- The chain of managers - local farm managers, country managers, regional managers, CIOs, and CEOs

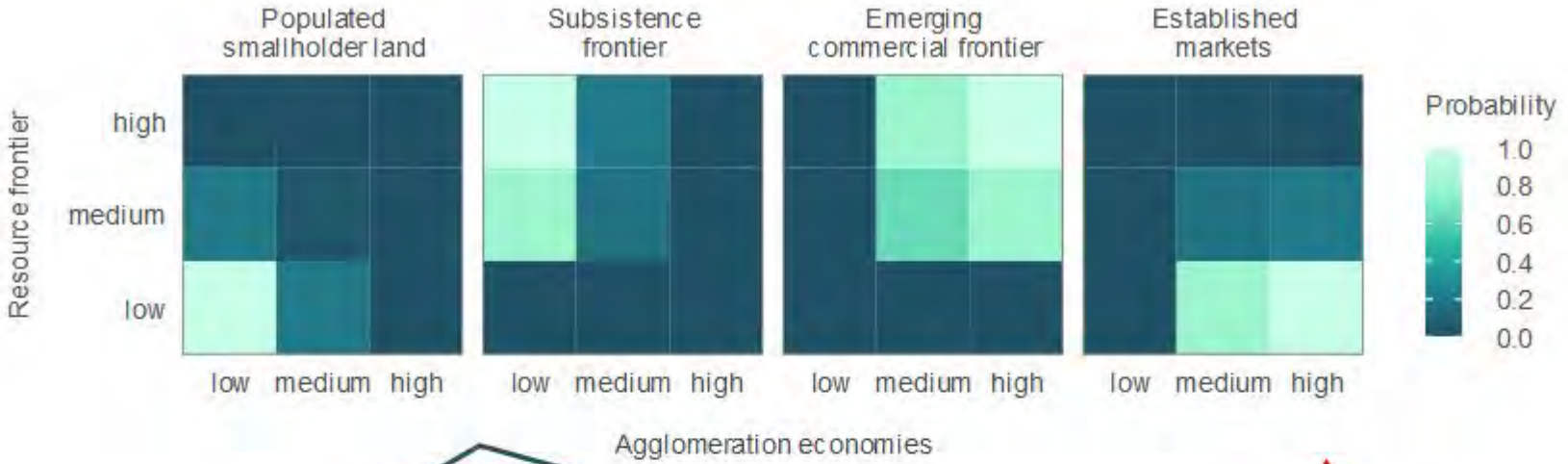
Abeygunawardane et al. 2022

The Model



Abeygunawardane et al. 2022

Land cover
Population density



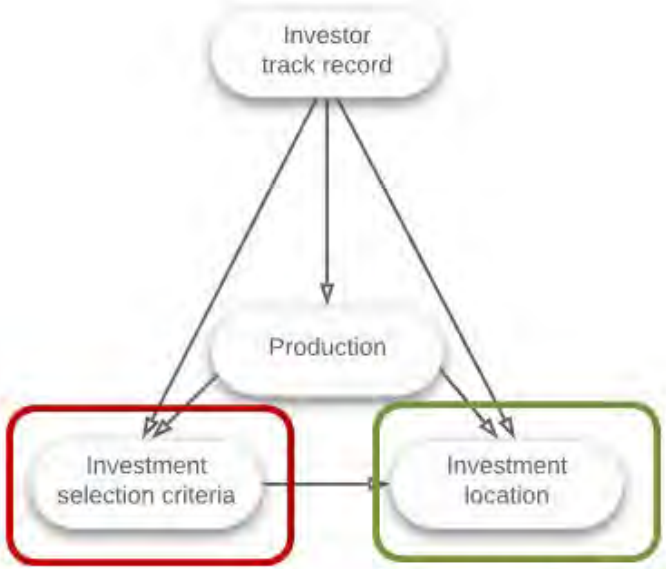
Field size
Market influence

$$\underbrace{P(H|E)}_{\text{Posterior}} = \frac{\overbrace{P(E|H)}^{\text{Likelihood}}\ \overbrace{P(H)}^{\text{prior}}}{\underbrace{P(E)}_{\text{evidence}}}$$

$P(X) = P(X_1, X_2, \ldots X_n) = \prod_{i=1}^{n} P(X_i | X_{pa(i)})$, where $X_{pa(i)}$ is the set of parent variables of X_i

Abeygunawardane et al. 2022

The Bayes Net



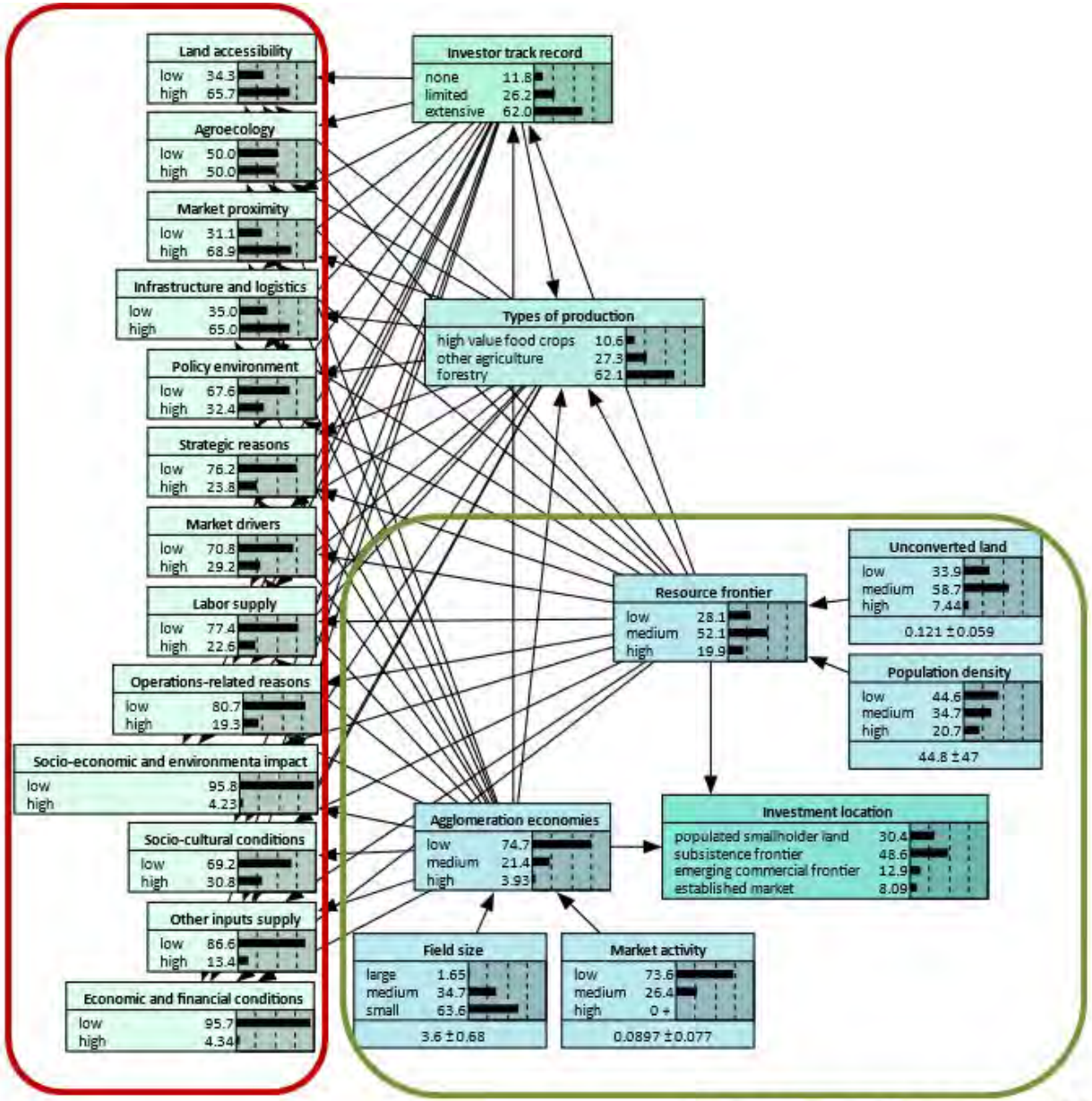
Secondary Data

Land cover (Li et al. 2018)

Population density (Lloyd et al. 2019)

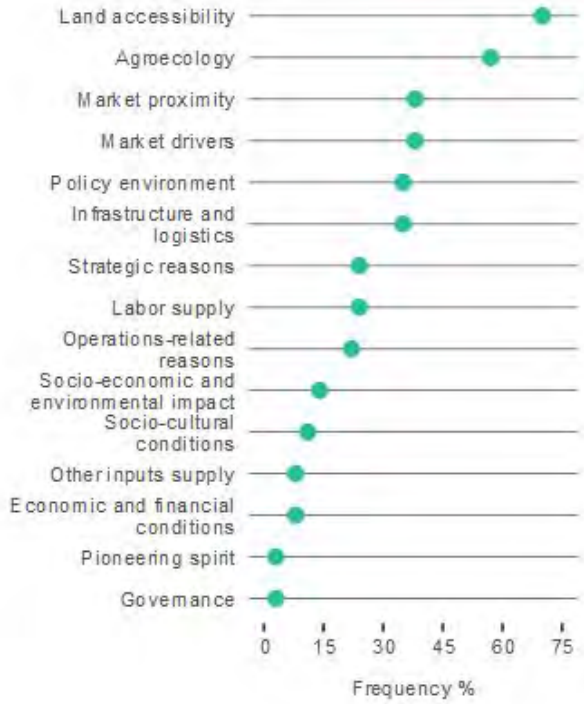
Field size (Lesiv et al. 2019)

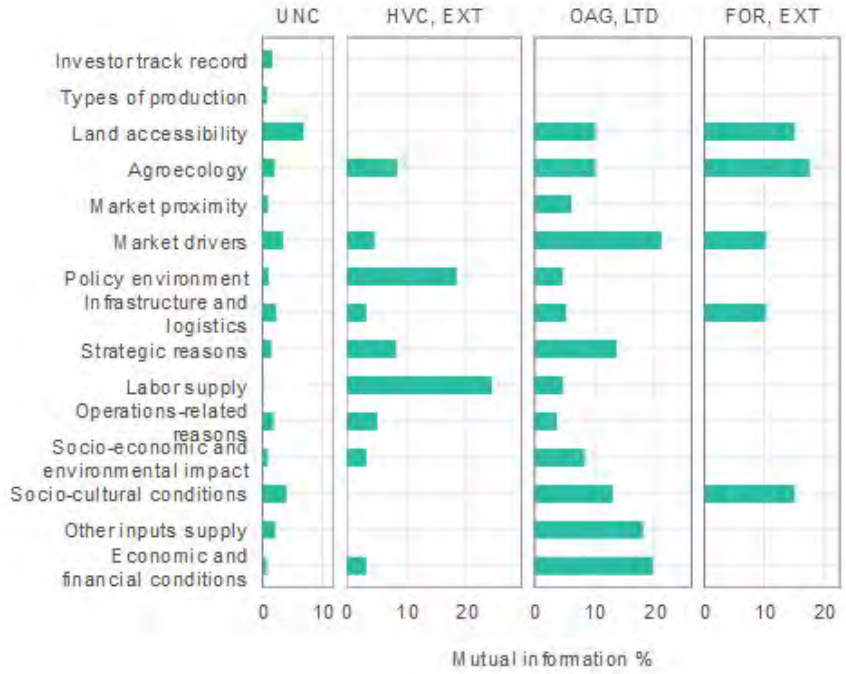
Market influence (Verburg et al. 2011)



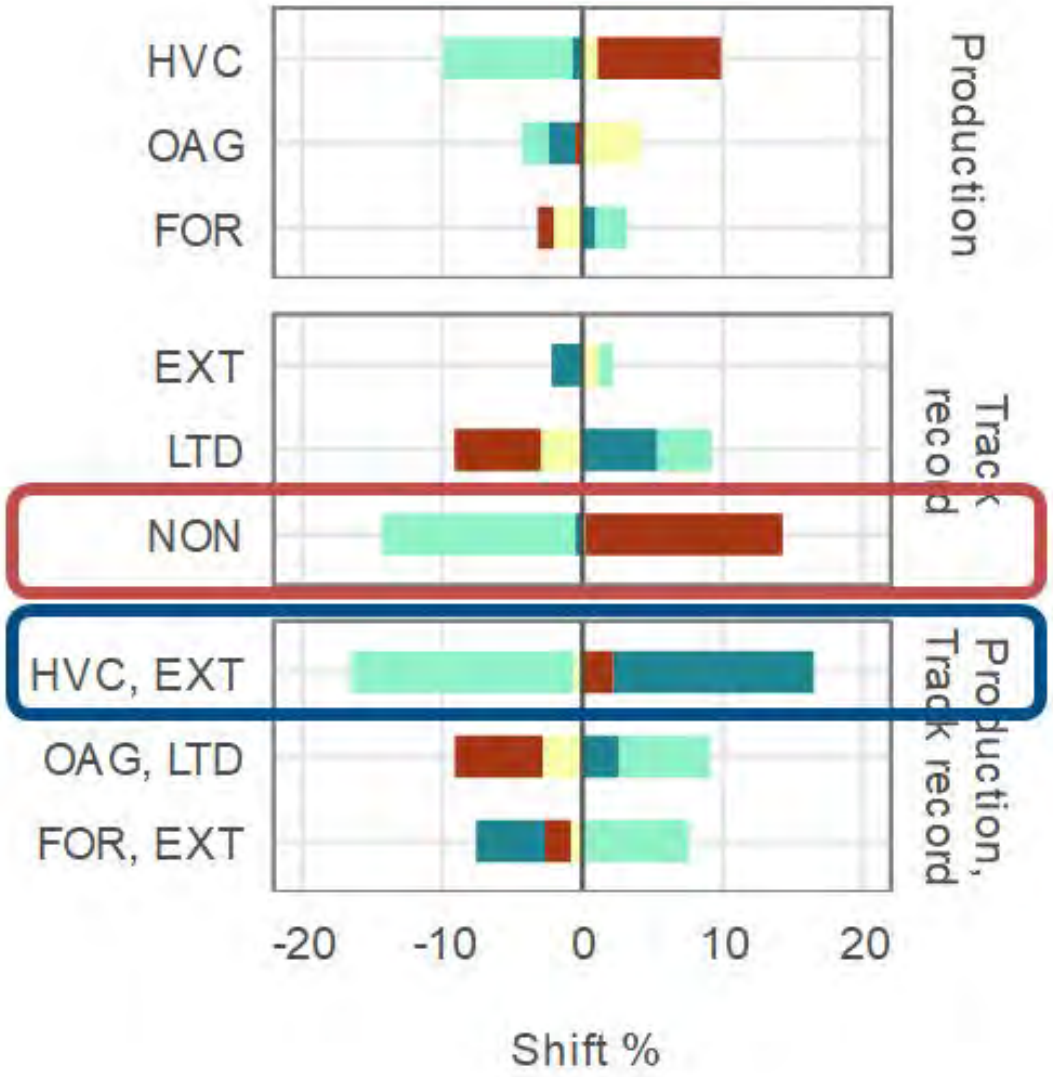
Abeygunawardane et al. 2022

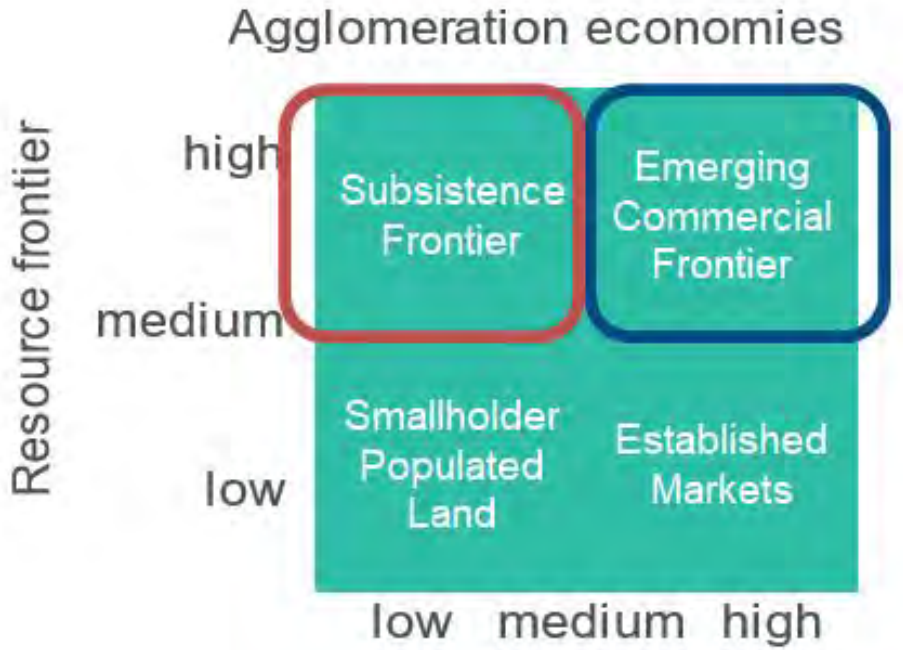
The Results



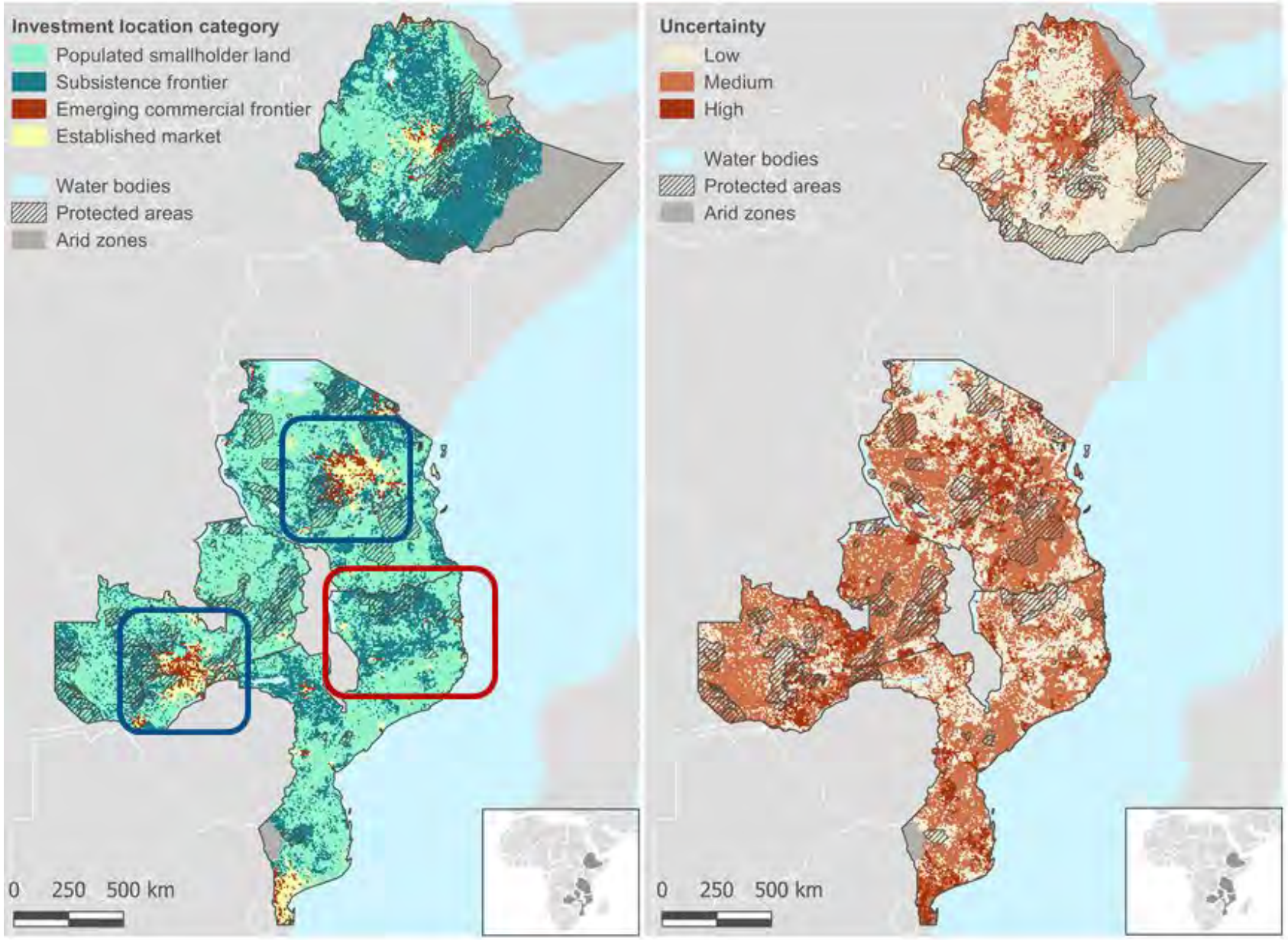


Abeygunawardane et al. 2022





Abeygunawardane et al. 2022



Abeygunawardane et al. 2022

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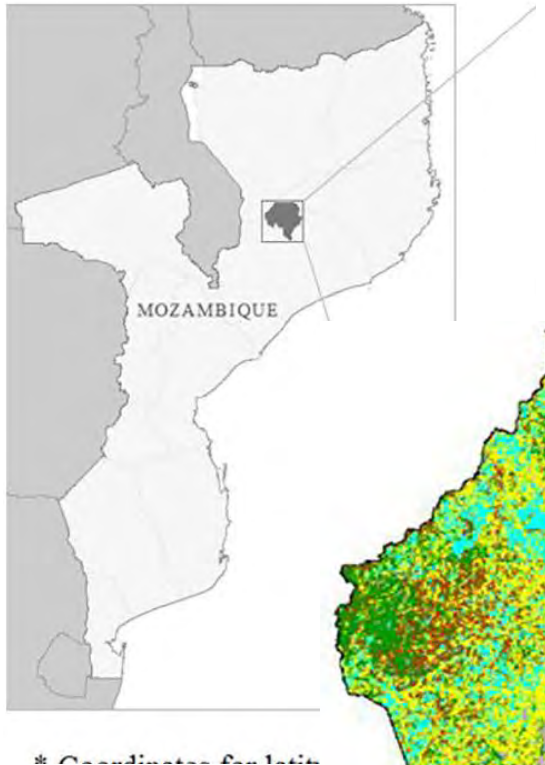
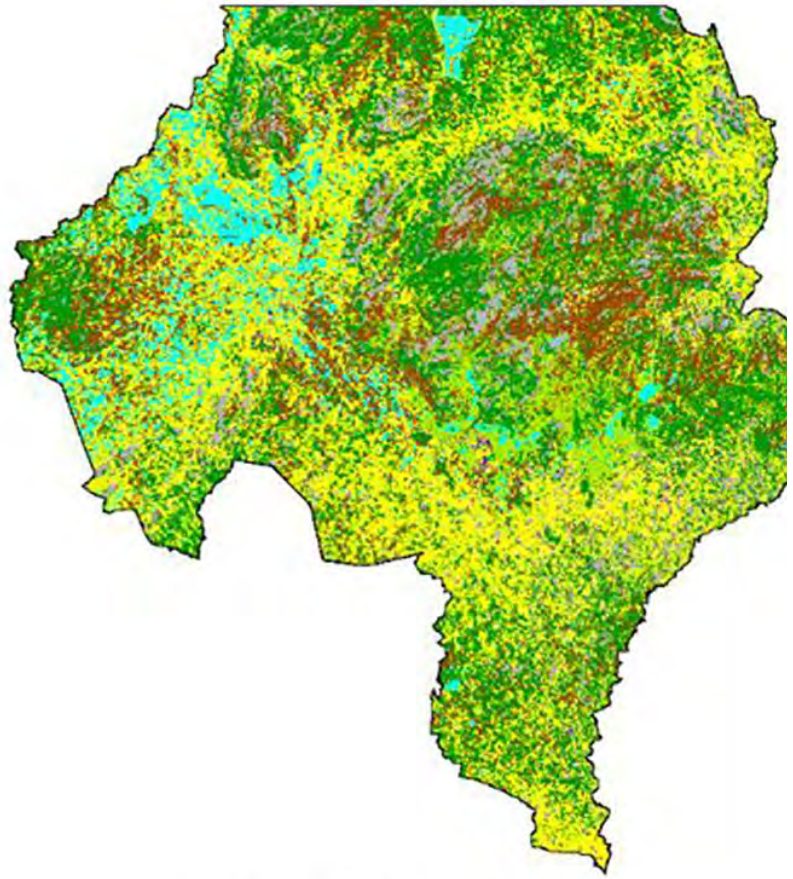
Part 3. Mapping and explaining the land use dynamics

Large-scale agricultural investments





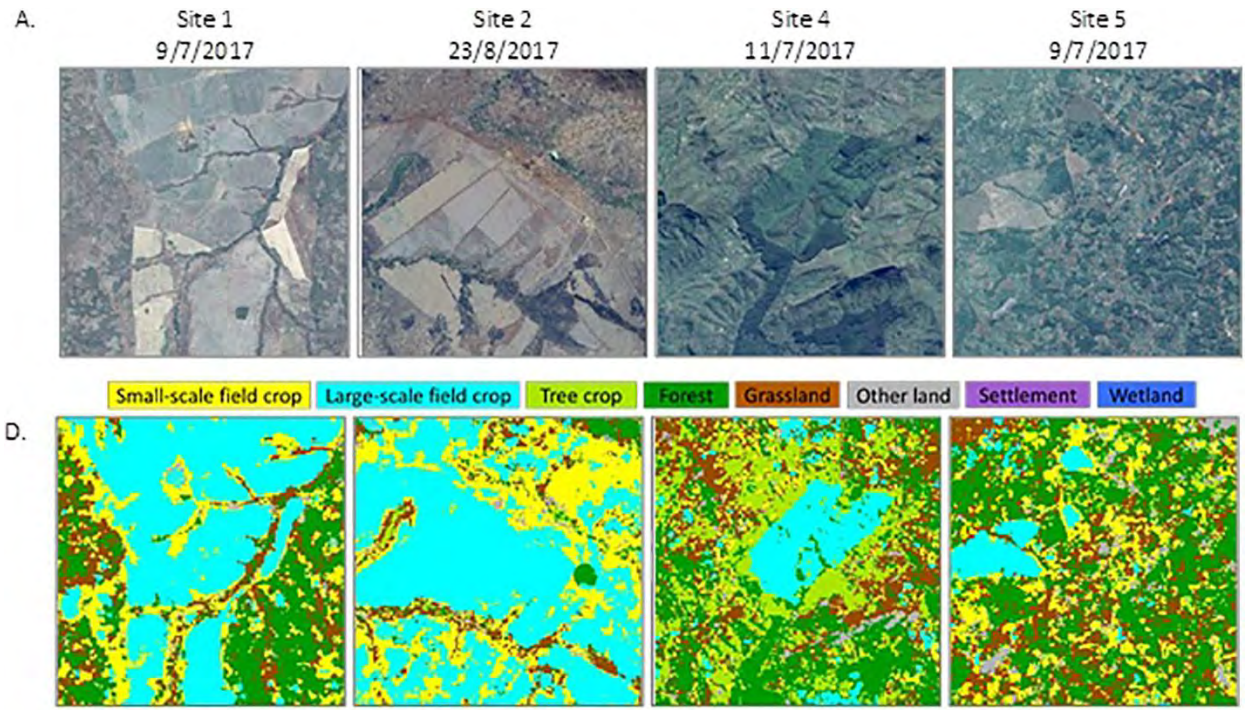
Period 3 (2016 ± 1)

Large-scale cropland

1.2 % of landscape

2006-2017: +1.0%, ~58 km² expansion

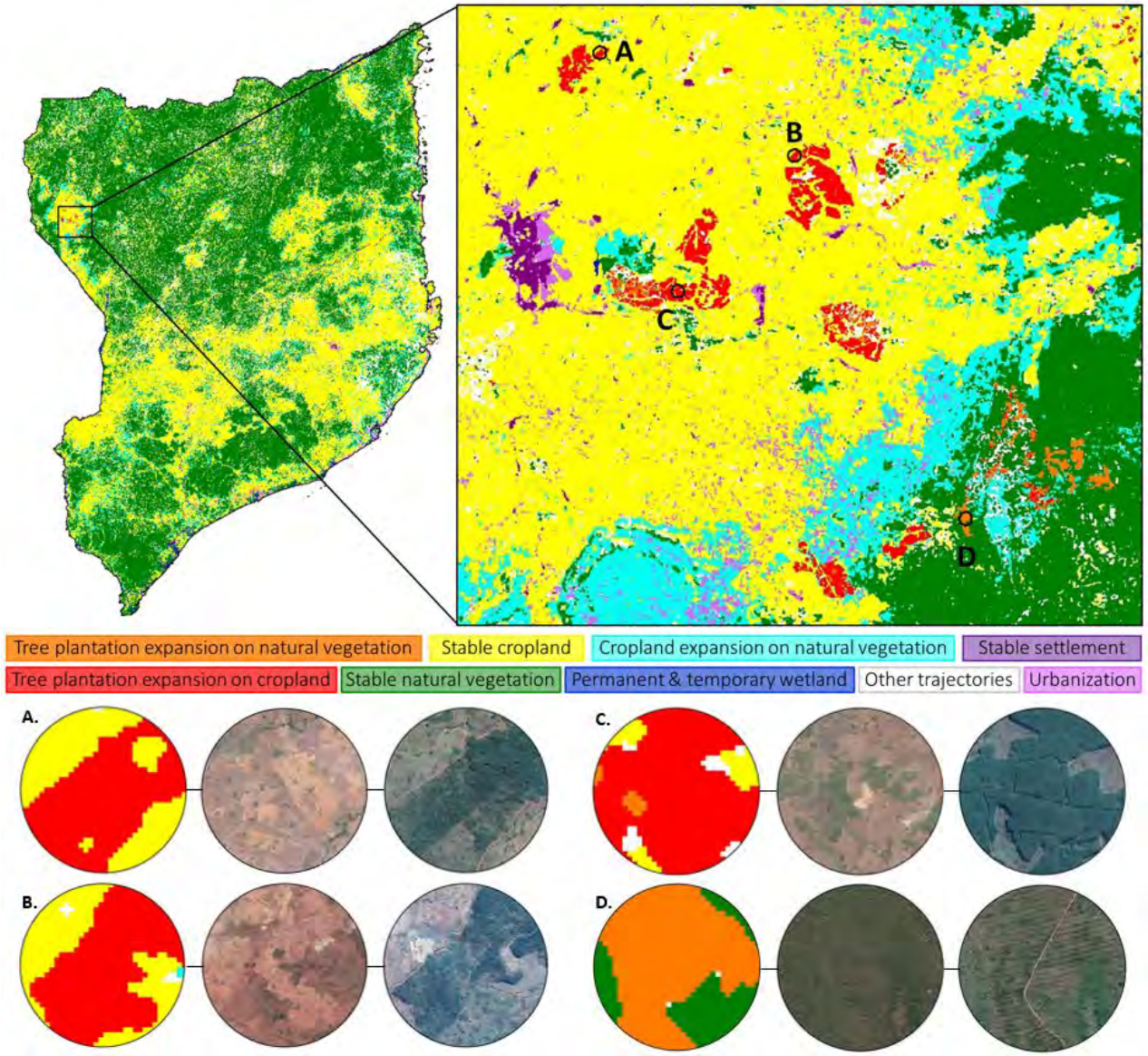
65 % expansion on smallholder cropland



Bey et al. 2020

UCL - E

Large-scale tree plantation investments

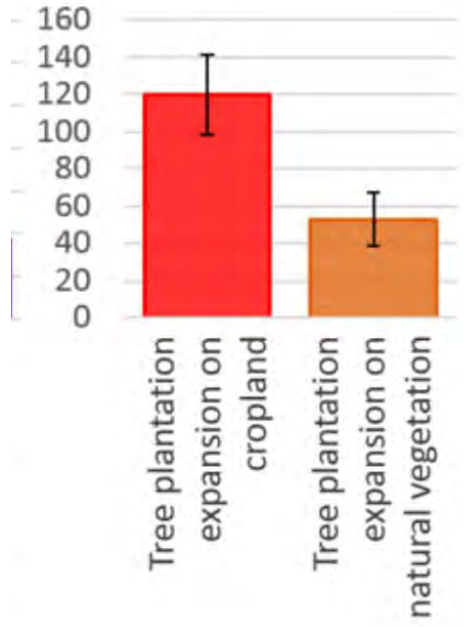


Large-scale tree plantations

0.5 % of landscape

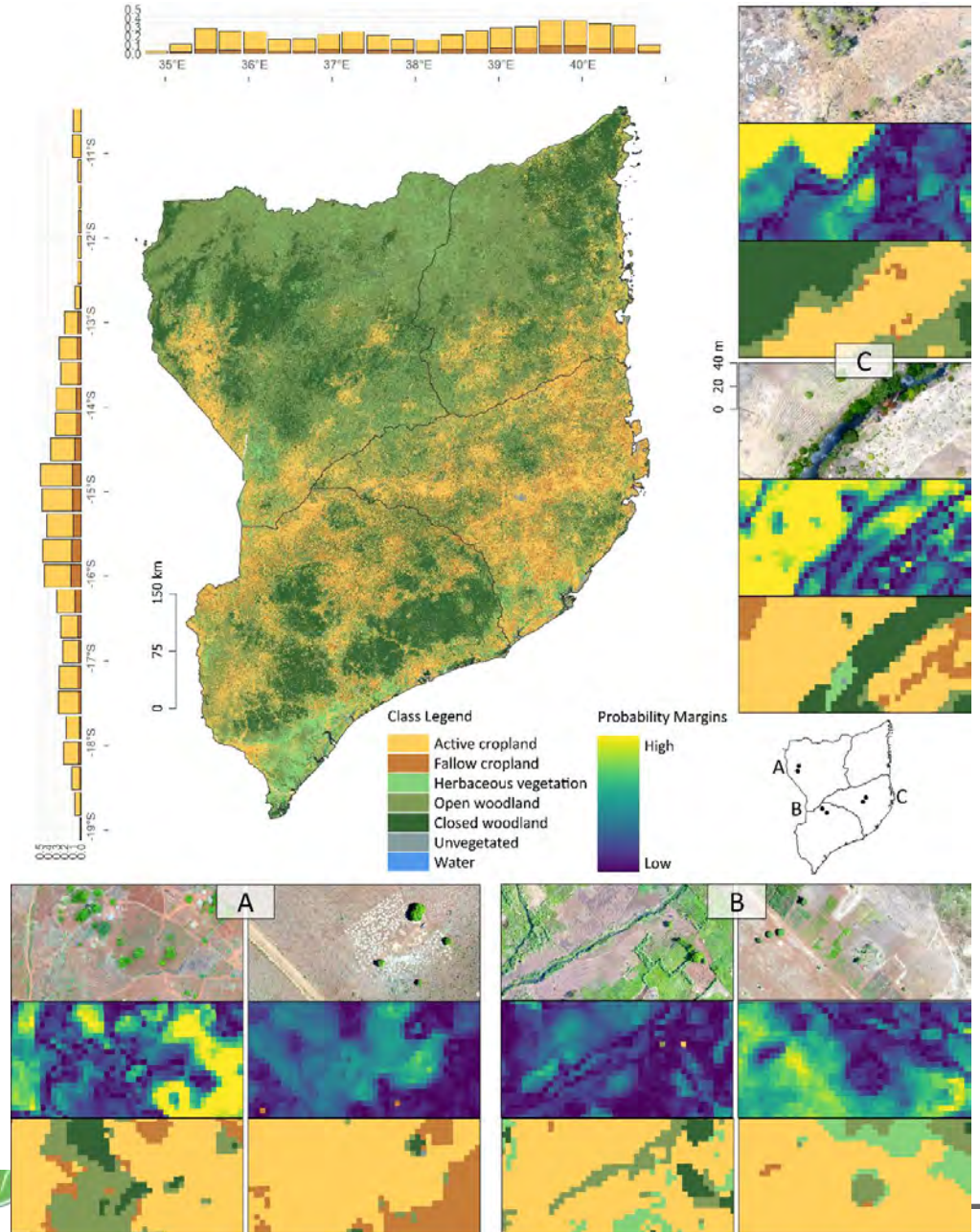
2001-2017 : ~175 km² expansion

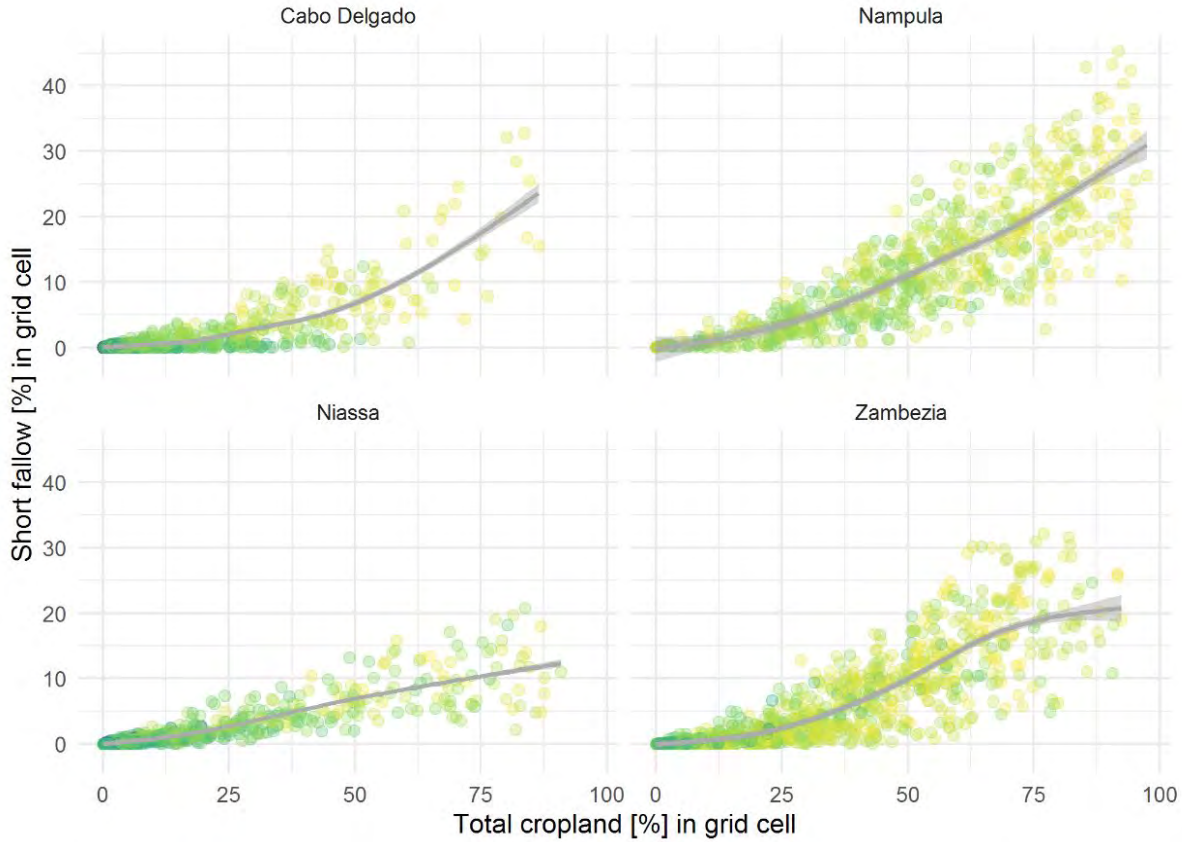
70 % expansion on cropland



Bey and Meyfroidt, 2021

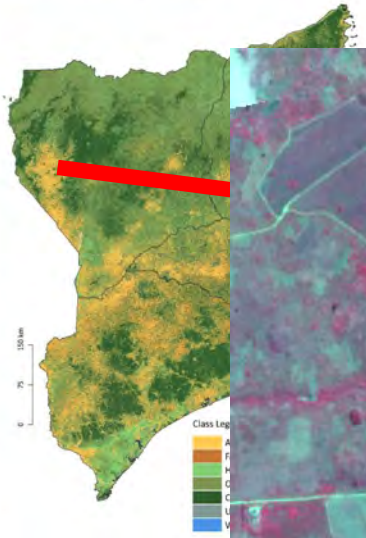
Active cropland & short fallows

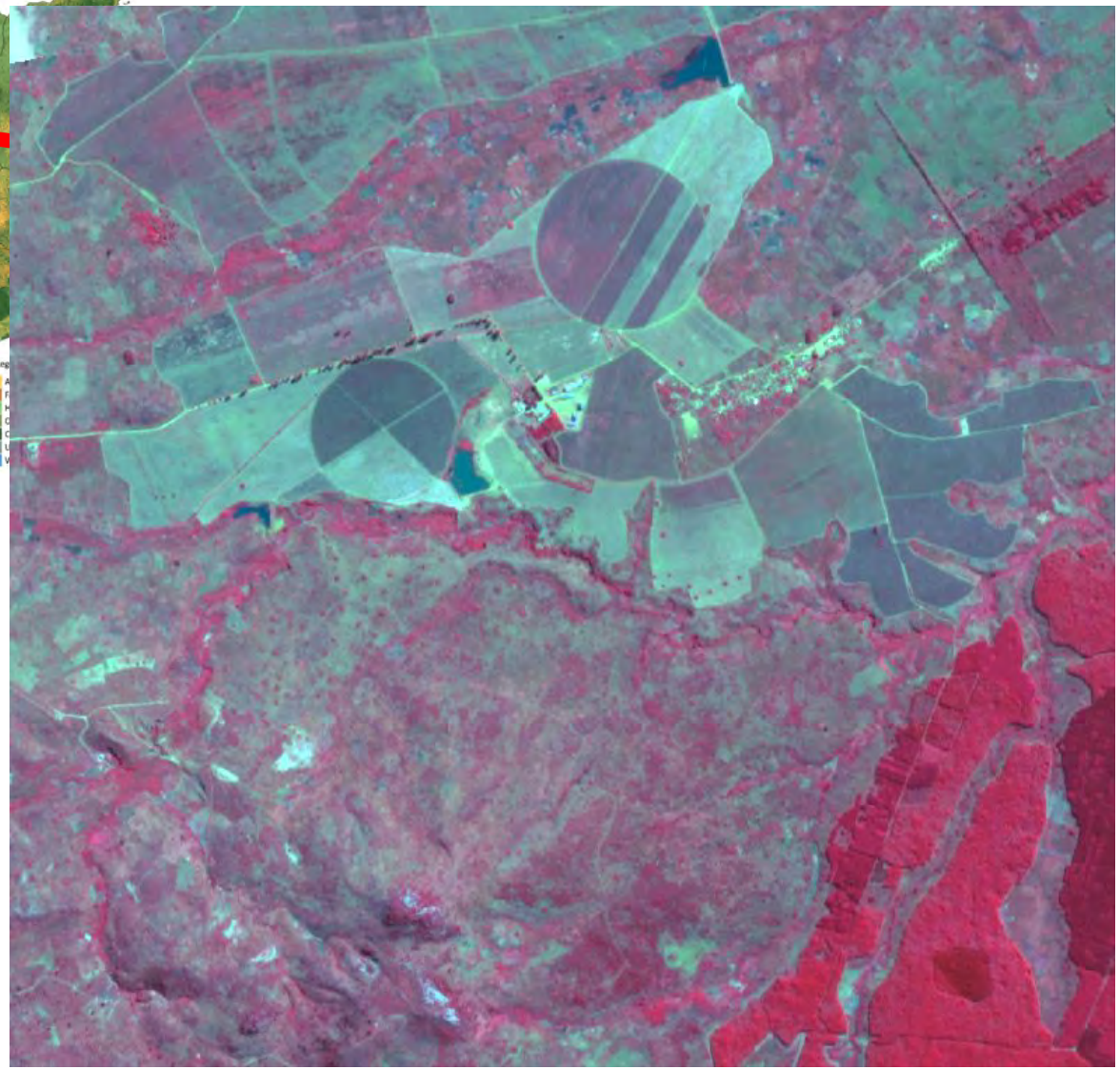


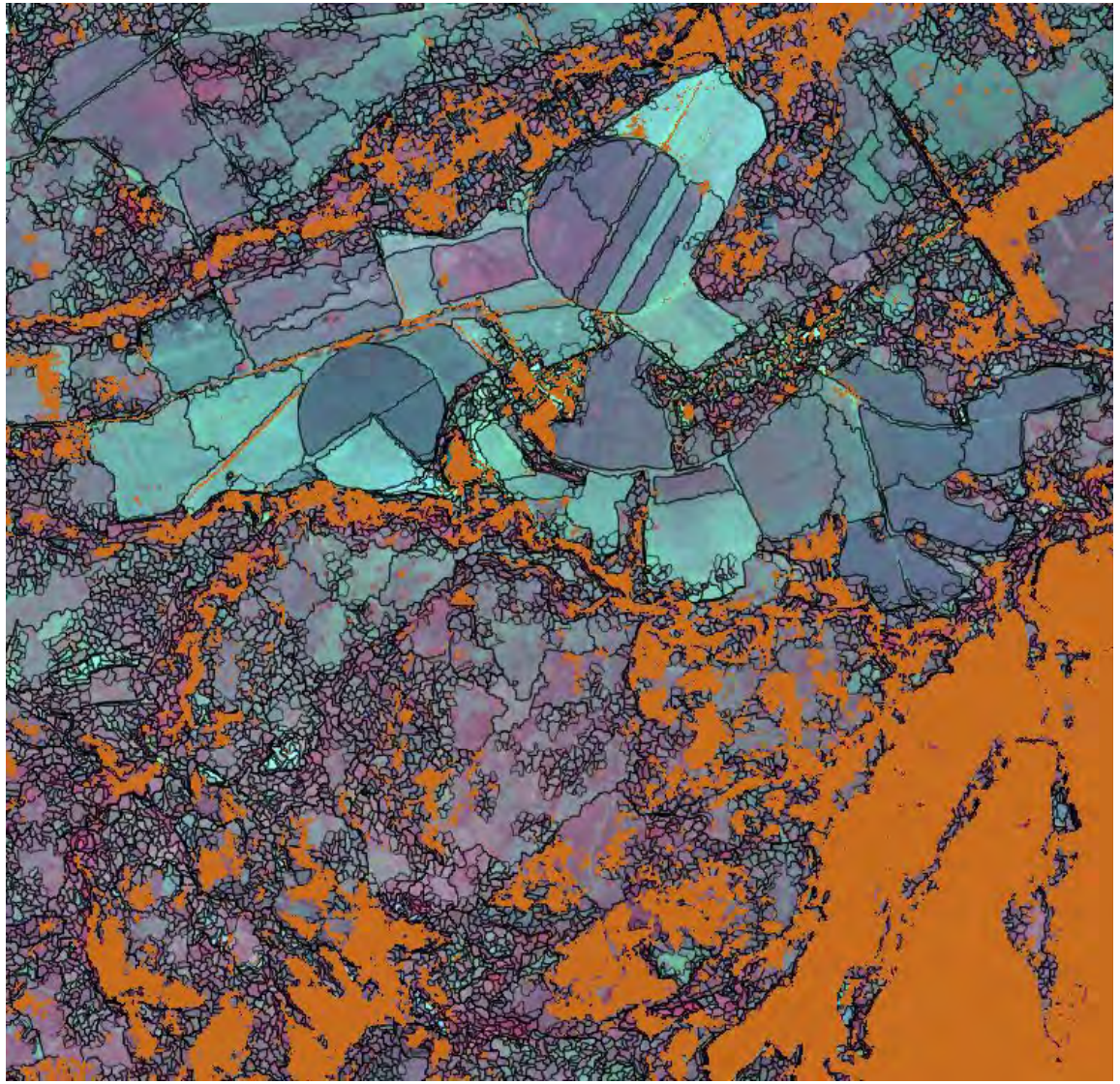


Rufin et al., 2022

Field segmentation of small, medium, large-scale agriculture (ongoing)







PlanetScope 2019 (R: nir, G: red, B: green)

crop fields

non-cropland mask

Picoli et al., in progress

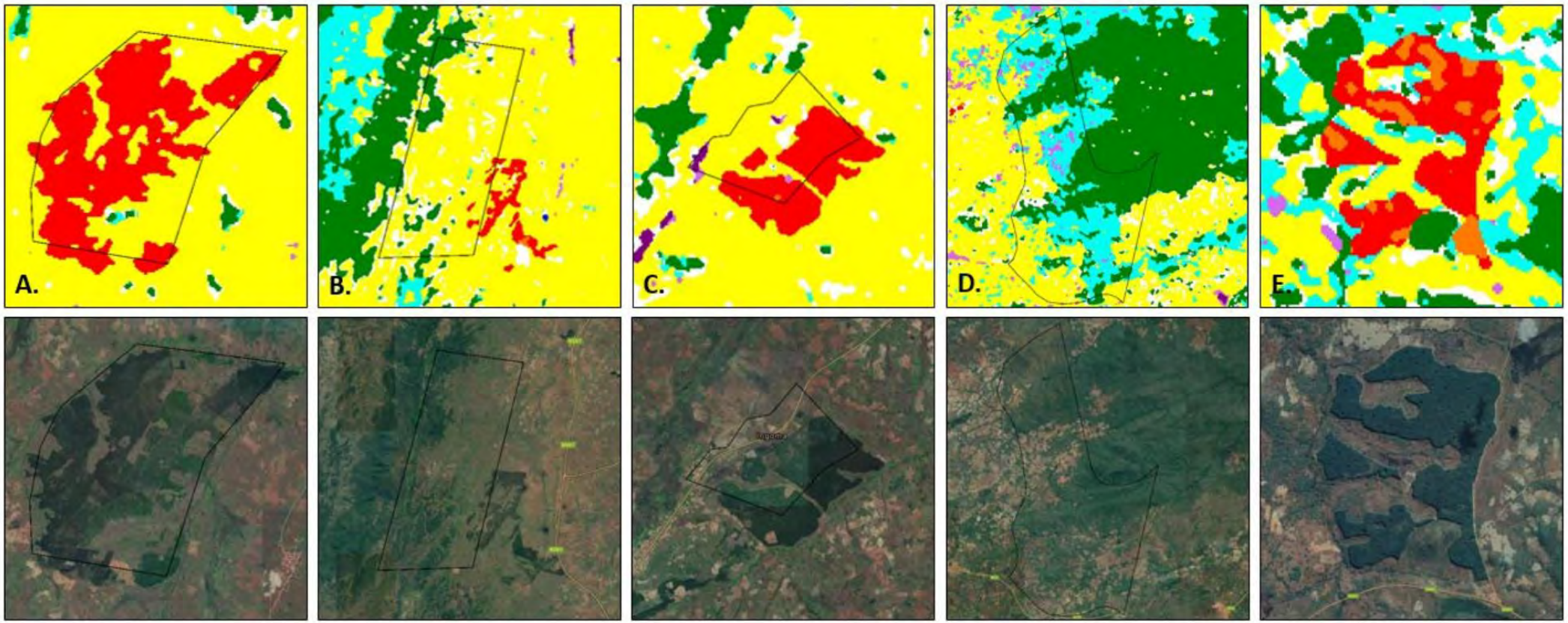
Field segmentation of small, medium, large-scale agriculture (ongoing)

Google Earth, Sep 2019

PlanetScope, 2019 (R: nir, G: red, B: green)

Picoli et al., in progress

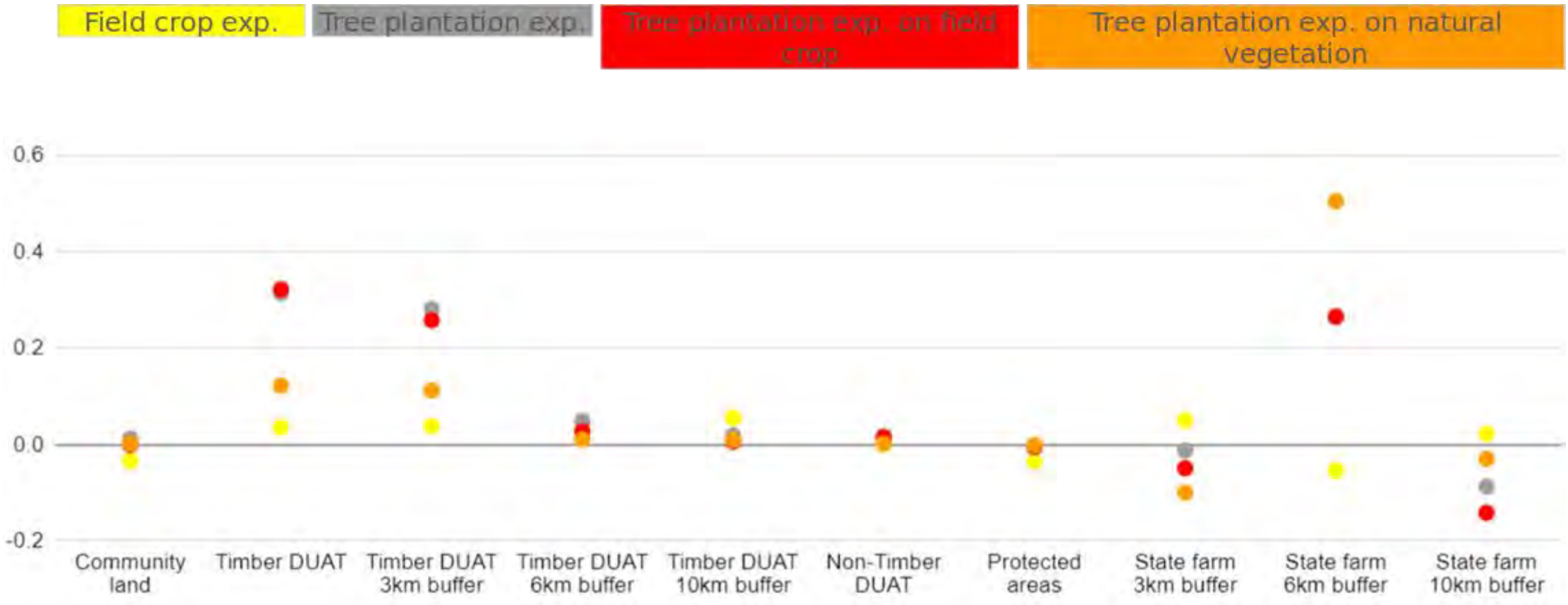
Multiple, overlapping, contested land tenure claims



Cadastral records can be inaccurate, imprecise, out of date, or simply non-existent. Only **59%** of the 17,500 hectares of tree plantations identified in 2017 fall within land title boundaries.

Bey and Meyfroidt, 2021

Effects of land tenure policies on plantations expansion



Community lands overall do not have a clear effect on large-scale tree plantations expansion; but proximity to former state farms appears to have an effect

Bey et al. in preparation

Part 4. Impacts of farm size dynamics and forestry investments

Balancing the trade-offs between land productivity, labor productivity and labor intensity

Land sparing - **land productivity**

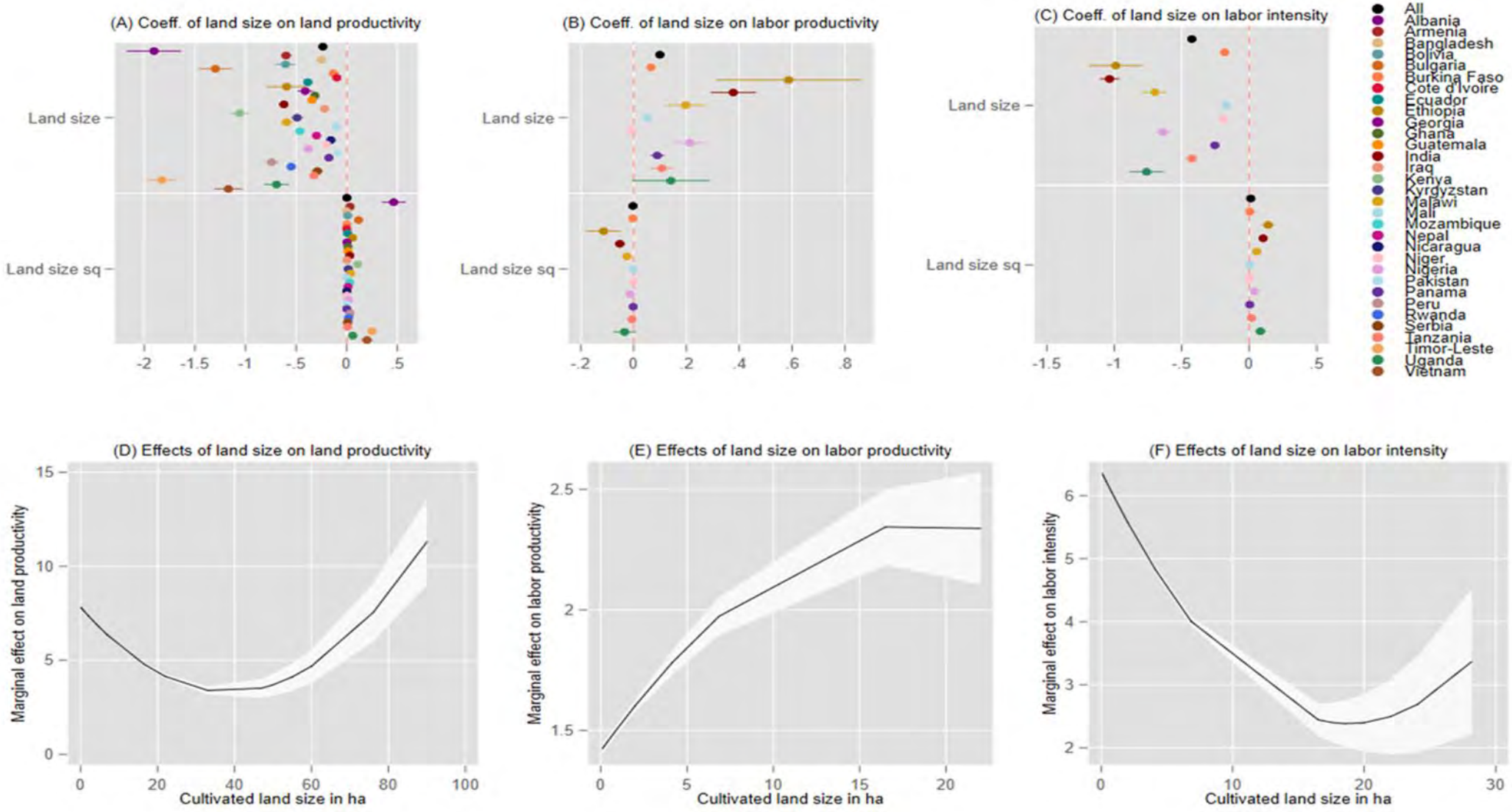
Often weighed in
Long-run analysis
And prioritized for
Sustainable Development

Social equity - **labor productivity**

Yet, when agriculture is the main source of livelihoods (and when nonfarm labor absorption is thin), spreading the benefits of farming with a larger number of people to sustain their livelihoods and lift them out of poverty is also a key sustainable development goal.

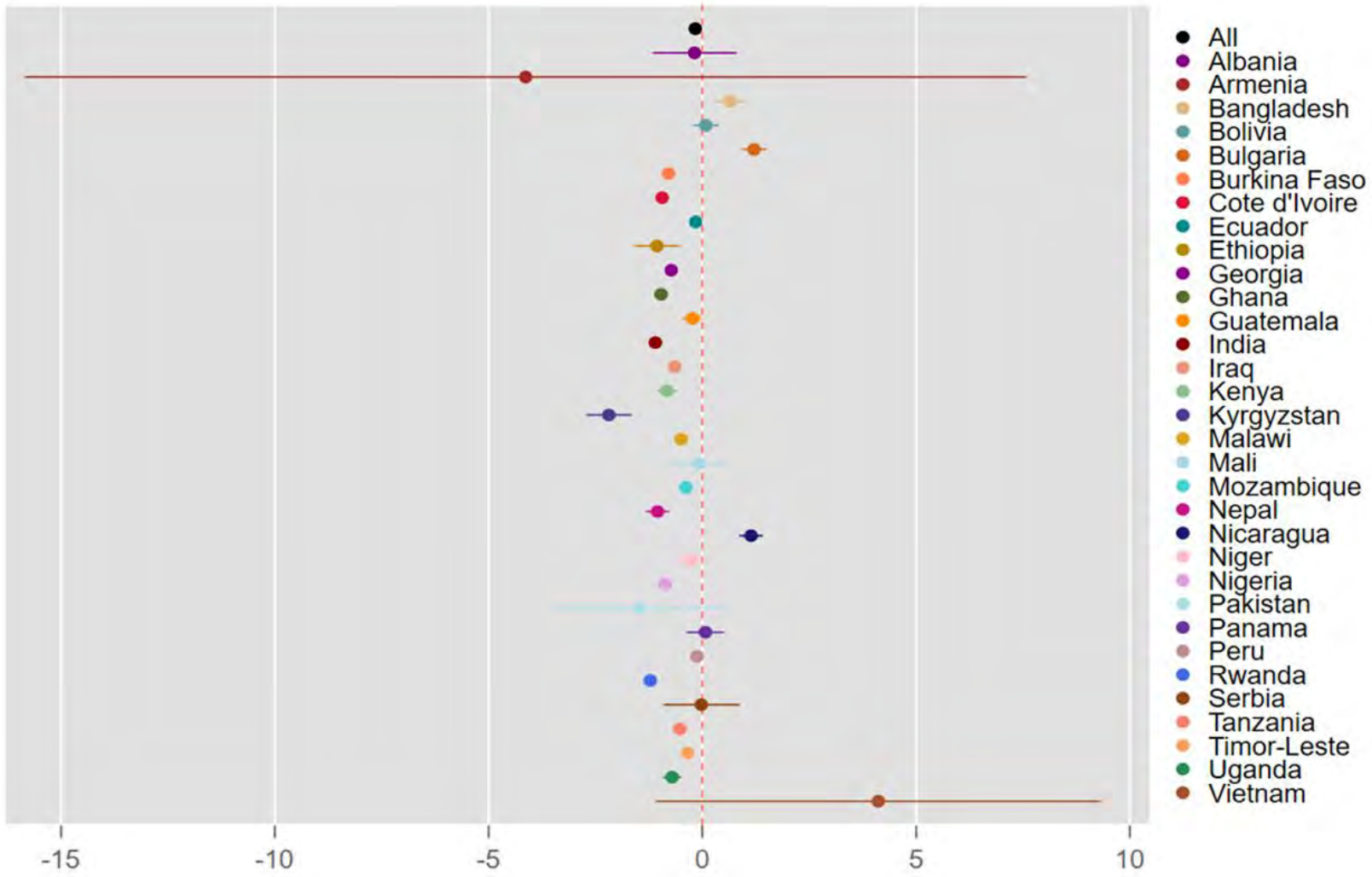
This goal can be captured effectively through:
Labor intensity (farm workers per ha)

The relationship between land productivity, labor productivity and labor intensity with farm size



Technical efficiency increases with farm size

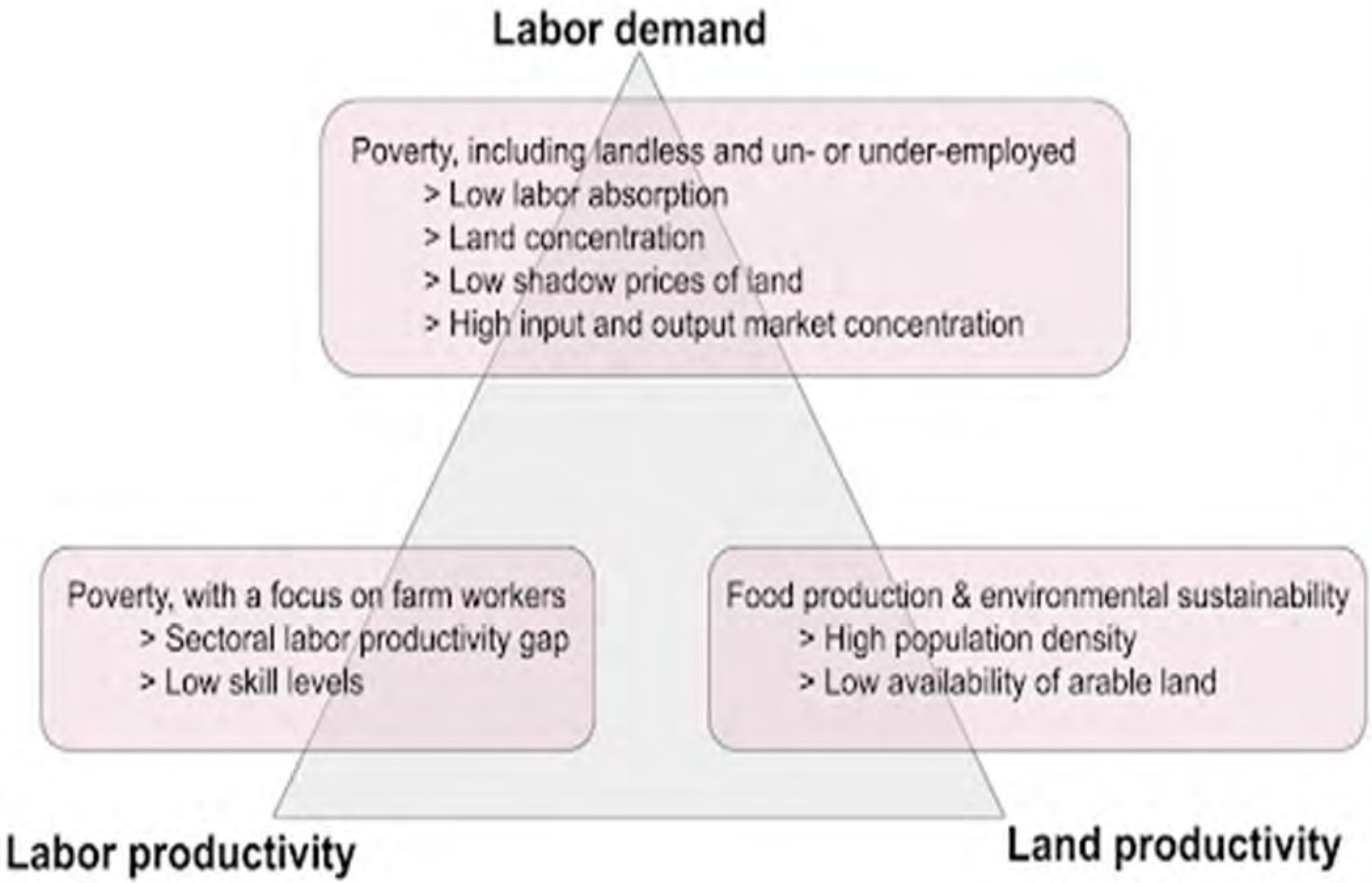
Beta coefficients of farm size on the inefficiency function



At the farm level…

- Smaller farms have greater land productivity and labor demand, but greater dispersion that bigger farms
- The IR only holds for farms below 11ha, after which the relationship becomes positive
- Smaller farms also significantly use more labor per ha, but are less productive per worker
- Technical efficiency of small farms is lower (with some variation across countries)

Moving beyond the farm level: Key factors when prioritizing between the trade-offs



Changing commercial agricultural dynamics and their relations with farm size has impacts on the outcome variables of the trade-off space: land productivity, labor productivity and labor demand

Focusing on Mozambique, what are the impacts of large-scale forestry investments on neighboring small-scale agriculture?

- Forestry plantations can foster rural development and mitigate land degradation and climate change, but their impacts on neighboring peoples' livelihood strategies are ambiguous.
- A National strategy in Mozambique aims to establish one million hectares of forests by 2030 (focused on Northern Moz).
- We aim to evaluate causal effects of large-scale forestry investments on smallholders' welfare, focusing on cultivated land area, crop productivity, and employment.

Possible positive effects:

- May employ local population
- Facilitate market access and market opportunities
- Spillovers for land area expansion, increased productivity, change in cultivated crops

Possible negative effects:

- No large employment effects
- Risk of higher land prices, premature displacement of smallholders

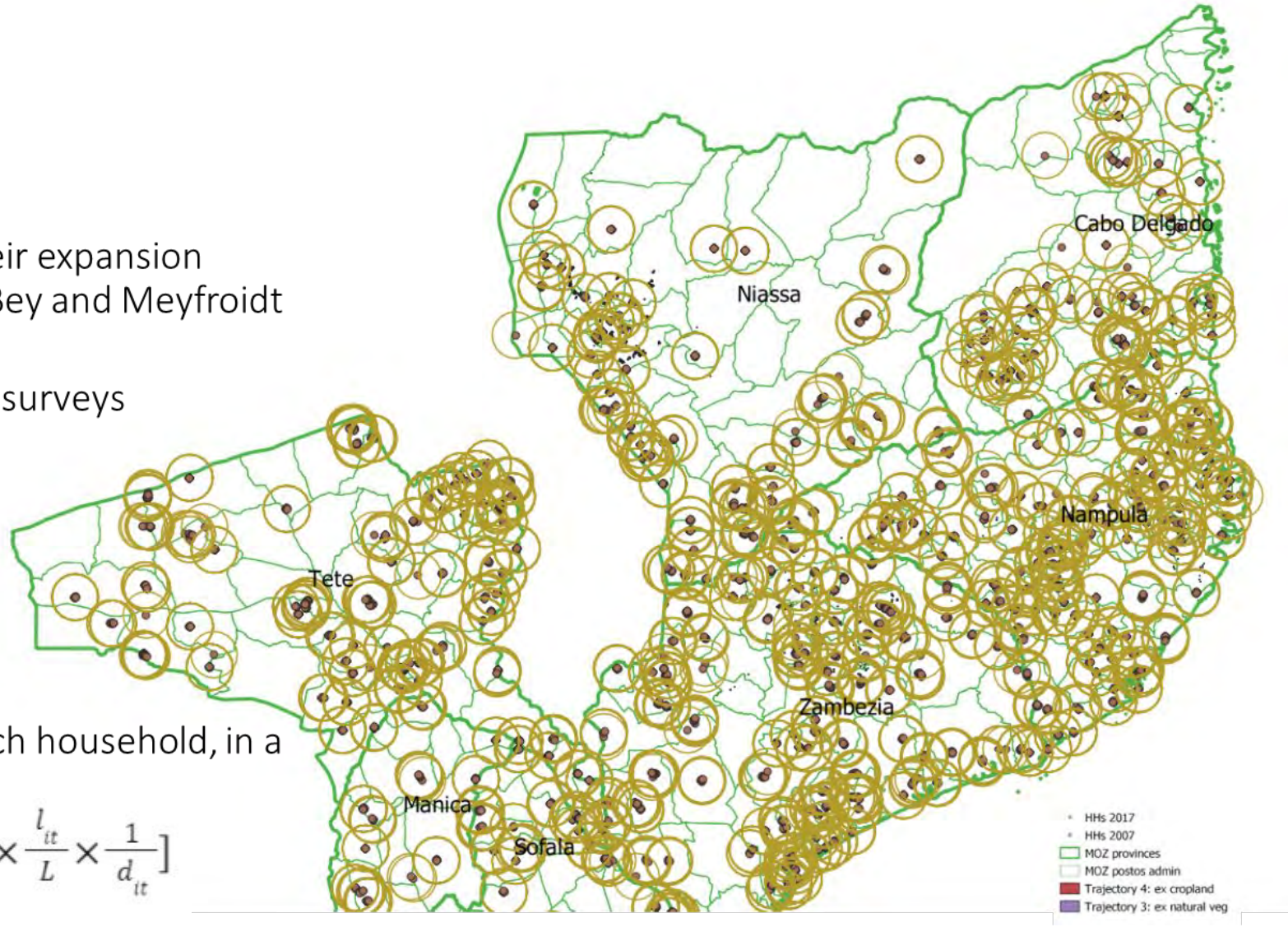
Methods

- Data
  - Census of forestry plantations and their expansion trajectories from 2001 to 2017 from Bey and Meyfroidt (2021) (shown above)
  - Nationally-representative agricultural surveys administered in 2007 and 2017
- Evaluation
  - Long-term effects of forestry investments in a 11-year horizon.
  - Regression Discontinuity Design
    - "Exposure" to plantations for each household, in a 20km buffer

$$Exp_{it} = I_{rit}\left[\frac{A_{it}}{A_r} \times \frac{l_{it}}{L} \times \frac{1}{d_{it}}\right]$$

  - Difference-in-Difference estimation

$$Y_{ivt} = \beta + \lambda_t + \delta Exp_{ivt} + \gamma Exp_{ivt} \times H_{ivt} + X_{ivt}\kappa + \alpha_v + \epsilon_{ivt}$$



Part 5. Future steps, prospects, engagement with GLASSNET community

Taking stock of what we have done already

How do frontiers emerge?

1. Why sometimes no change & then sudden acceleration?

>> Past waves & failures, legacies; agency & rents ; agglomeration economies

2. Why do investors go where there is no commercial agriculture ?

>> Various motivations & profiles, not only strict economic logic but can be described and linked to LU decisions

3. How do deforestation frontiers & commercial agriculture frontiers interact?

>> Direct (investors driving land use expansion into forest) and indirect (expansion into smallholder agriculture & possible displacement) ; current deforestation remains essentially smallholders

4. How do these frontiers impact smallholders?

>> Land use dynamics ; socio-economic impacts ; environmental / ecosystem services impacts

All papers on https://erc-midland.earth

What we could do next

- Build scenarios of future agricultural and forestry investments in the region, characterized by different types of investors with different assets, goals and logics
- Build on the Bayesian Network model to turn it into a land use change simulation model and model these investment scenarios at the scale of the region (meso-scale)
- Data limitation: Pooling similar investor data from different regions
- Mapping agglomeration economies at global scale
- Build on the land use/cover maps that we have to make a more fine-grained downscaling within Northern Mozambique to investigate detailed land use change and their impacts
- With proper field segmentation maps: investigate more precisely the land use/cover change dynamics of different types of actors (deforestation, etc); assess role of land tenure and land use policies in these dynamics; assess impacts of large and medium-scale farming on households…
- Discuss how labor demand at different farm scales could be incorporated into long-run assessments