Landscape-scale interactions between pastures, crops, trees and cattle in savanna grassland systems

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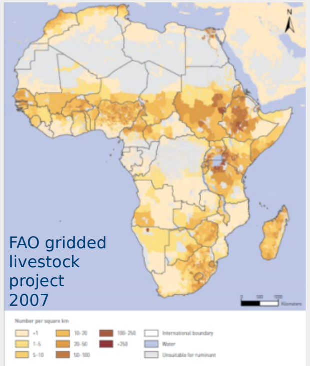
Land use in African savanna landscapes

- Savannas: 45% of land area in Subsaharan Africa (FAO 2011)
- Animal stocks increasing world-wide (Herrero et al. 2012) → ecological side-effects (FAO 2006)
- Rapid LUC during the last decades (Herrero 2010) pastoral → agricultural
- Call for intensification towards large-scale agriculture (World Bank 2009, Shankland & Conçalves 2016)
- Limited access and less area for increasing number of cattle → overgrazing, degradation (FAO 2006), aggravated by climate change
- Conflicts farmers vs. herders: Access to fields & paddocks (Tyrrell et al. 2017; Rohwerder 2015)



Research questions and approach

- Assess effects of large-scale land use change
- Assess alternative systems (e.g. integrated crop-livestock systems (Duncan et al., 2013))

Model approach:
Understand interactions:
Humans – herds – plants – environment (soil, hydrology, weather, topography)

Lack detailed process-based plant-animal interactions, economic accounting of animal products, selective grazing, herd mobility, consideration of whole farms (Snow et al. 2014; Rufino et al. 2014; Romney et al. 2003)

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Processes of interest

Man-Plant
LU & management decisions
Pasture & crop productivity

Man-Animal
Herd movement & management
Meat & milk yields

Plant-Plant
Competition
Facilitation
Bush encroachment

Plant-Animal
Pasture quantity & quality, (re)growth
Dung, urine, soil compaction

Landscape level:
Hydrology, soil properties → plant growth; herd mobility; locations of grazing grounds

Models involved

	MPMAS **Math. Programming - Multi Agent Systems**	**LUCIA** **Land use change impact assessment**	**LIVSIM** **Livestock Simulator**
Domain	Farmer agents	Soil, plants	Animal herds
Processes	Production decisions	Plants, soil & SOM, water	Feed-manure conversion, meat /milk production
Applications	Adoption of innovations	Environmental impacts of land use	Herd performance
Space	Explicit	Distributed	Non-spatial
Time step	1 month	1 day	1 month
Language	C++	PCRaster-Python	Python
Reference	mpmas.uni-hohenheim.de | lucia.uni-hohenheim.de Coupled: Marohn et al. 2013		models.pps.wur.nl/livsim Rufino et al. 2009

Model coupling

Grazing decisions:

Monthly (MPMAS): Determined grazing area

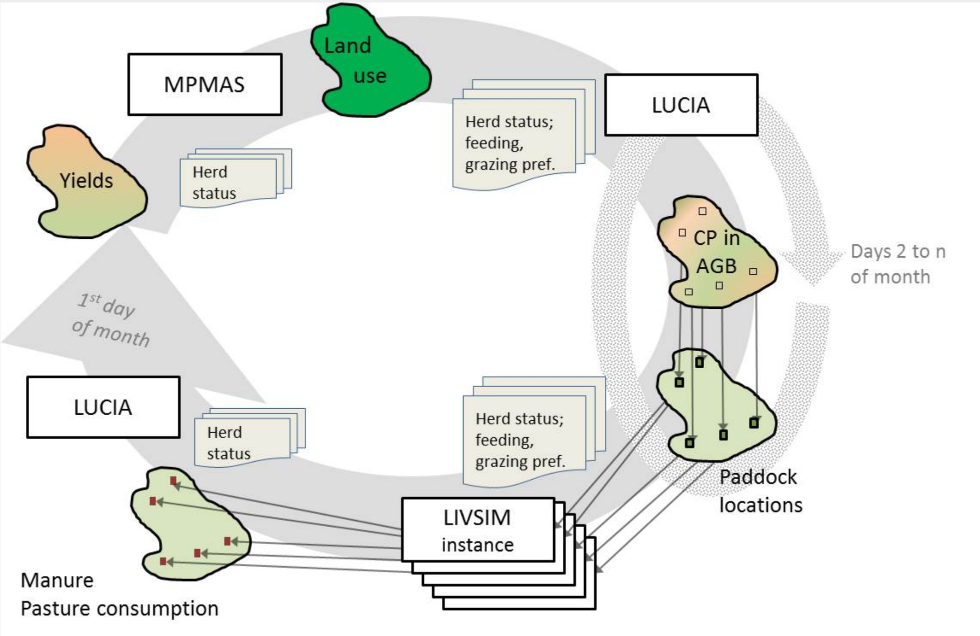
Daily (LUCIA): Movement acc. to crude protein (representing feed quantity and quality) once pasture is depleted

Grassland module:

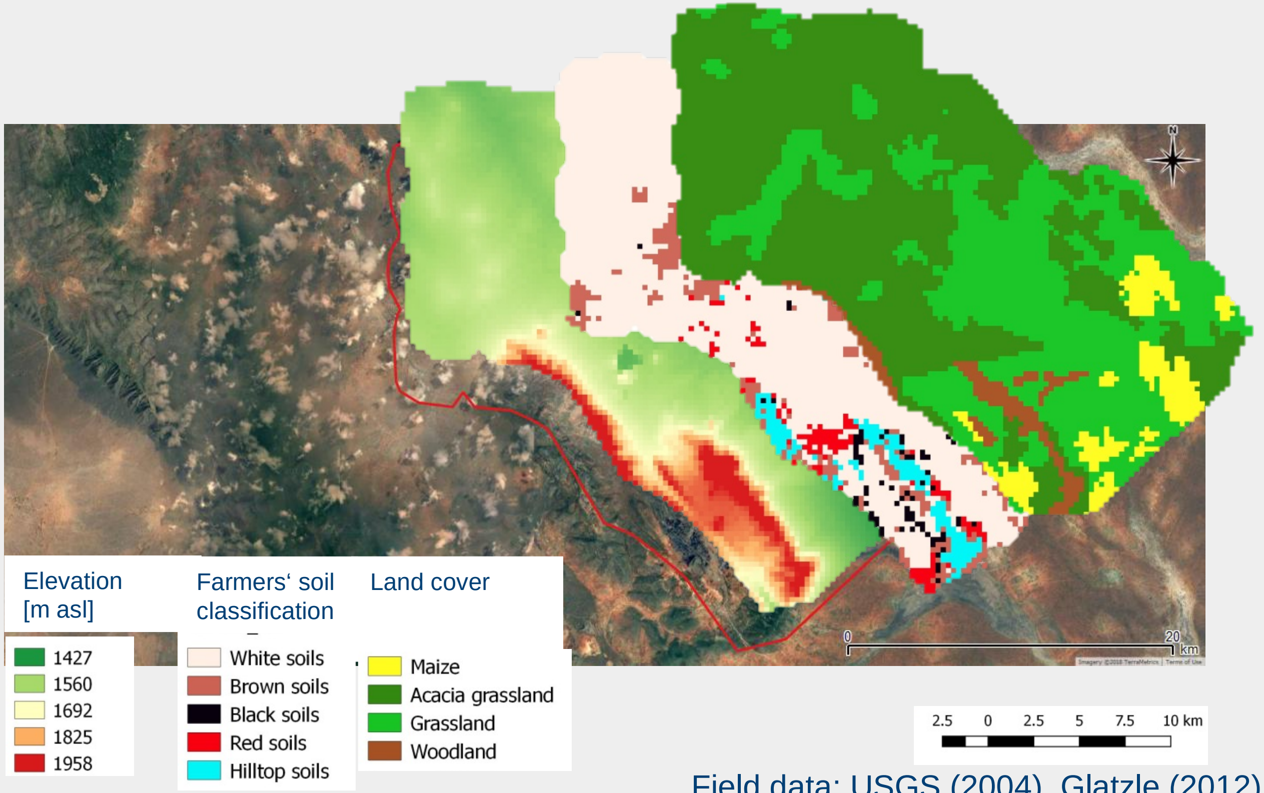
- Pasture quality
- Resprouting

LIVSIM:

- Multiple spatial instances



Research area

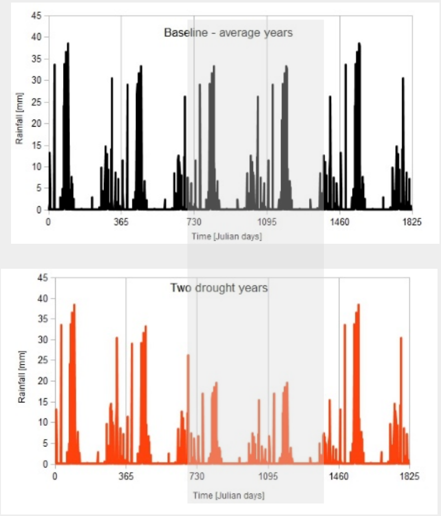


Field data: USGS (2004), Glatzle (2012)

Model scenarios

Parameterisation / calibration based on Tuffa & Treydte 2017 (rainfall), Hasen-Yusuf 2013 (biomass), Wario et al. 2016 (grazing grounds and herd movement)

Factor	Variation
Rainfall	Typical weather Drought
Access to paddocks wet / dry seasons [9 ha pixel]	20 / 20 ('small') 30 / 30 ('large') 16 / 30 ('set-aside')
Pre-emptive cattle selling (in case of expected feed shortage)	Yes No



5-yr loop typical / drought

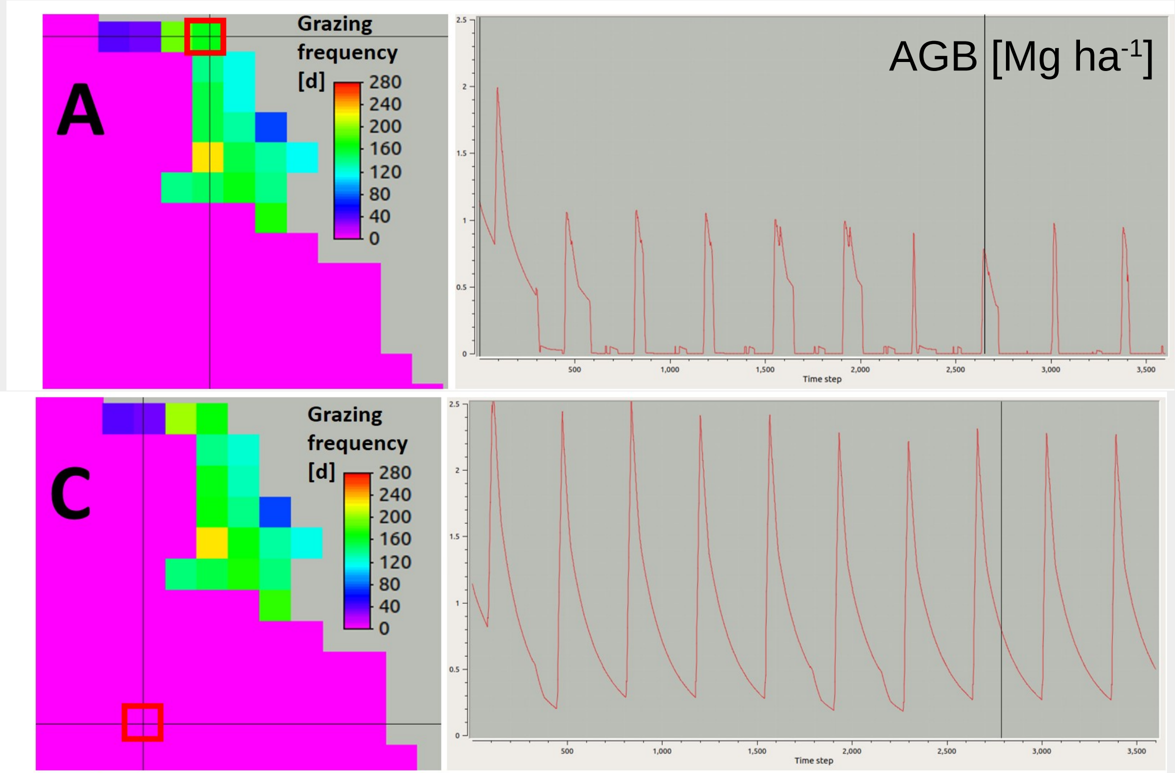
Results – grazing frequency and AGB

Scenario: Typical rain, access 20/20, no pre-emptive selling

A: Grazed pixel, C: Ungrazed pixel

Left: Grazing frequency [days / 10y] as affected by heterogeneity of soils and plant (re)growth.

Right: Aboveground biomass on the highlighted pixel

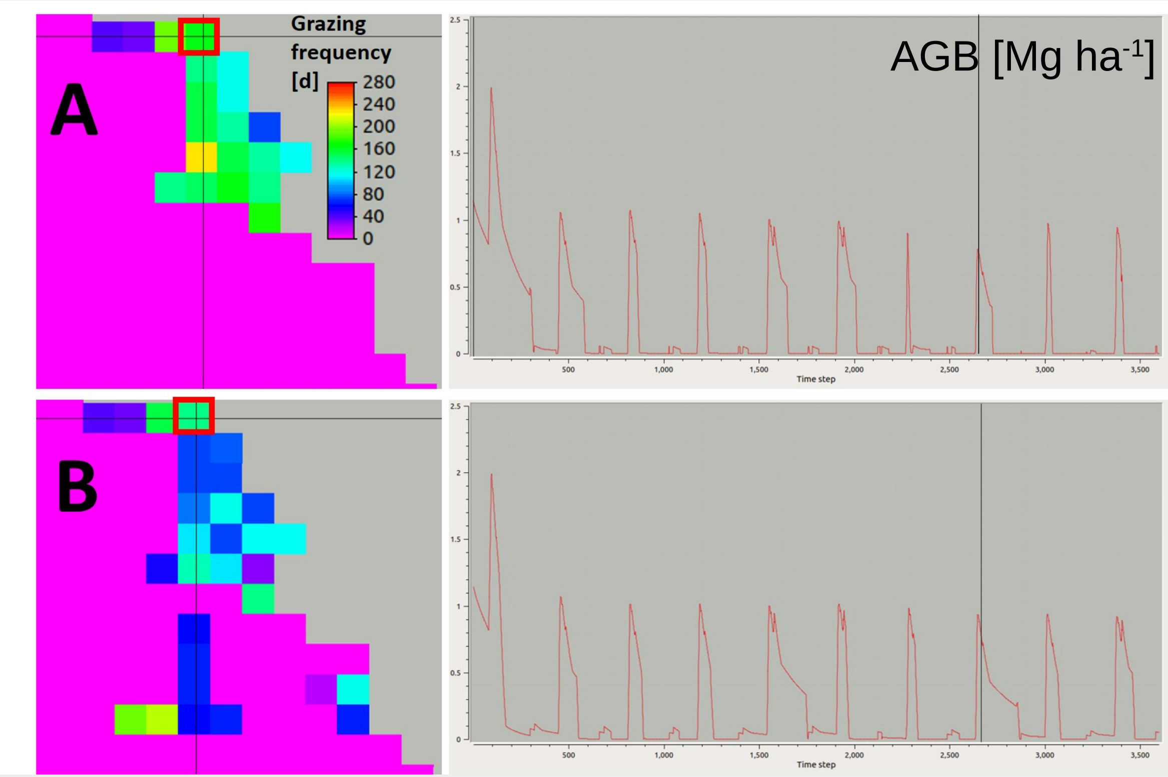


Results – grazing frequency and AGB

Scenarios:
A: Typical rain, access 20/20 pixels, no pre-emptive selling

B: Typical rain, access 16/30 pixels, pre-emptive selling.

Prolonged grazing times compared to A (mixed effects!).

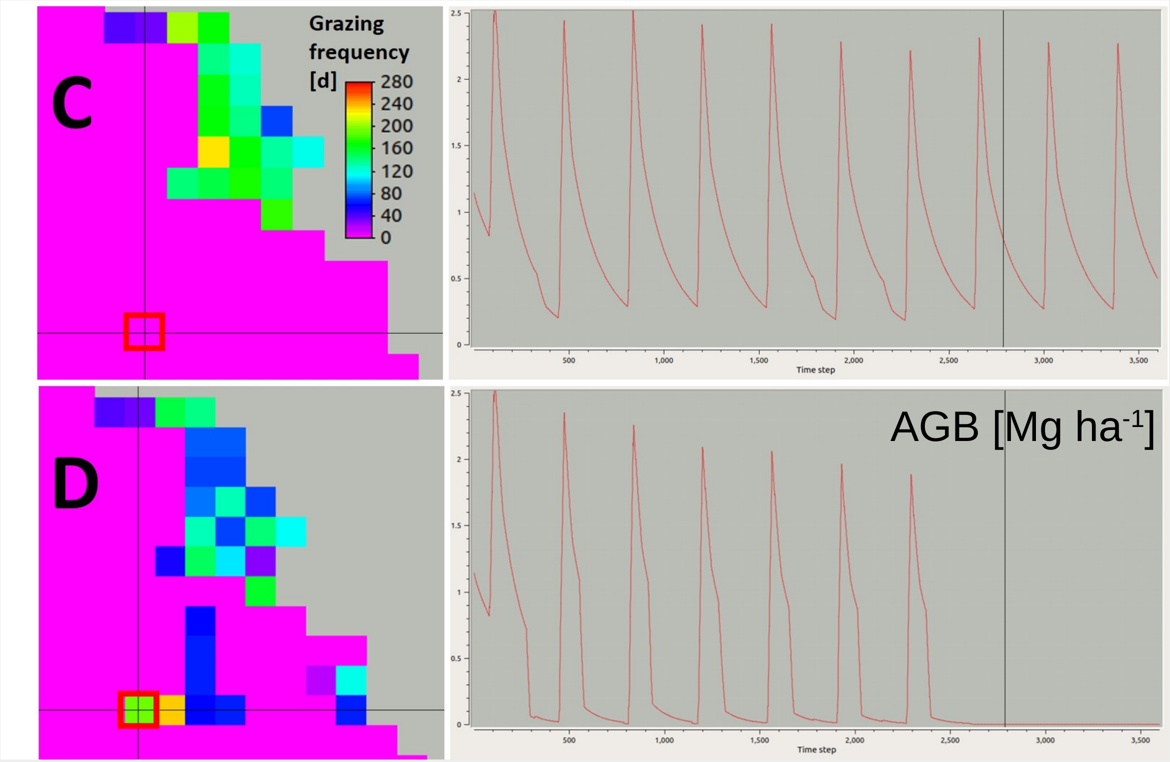


Results – grazing frequency and AGB

Scenarios:
C: Typical rain, access 20/20 pixels, no pre-emptive selling.
Ungrazed pixel.

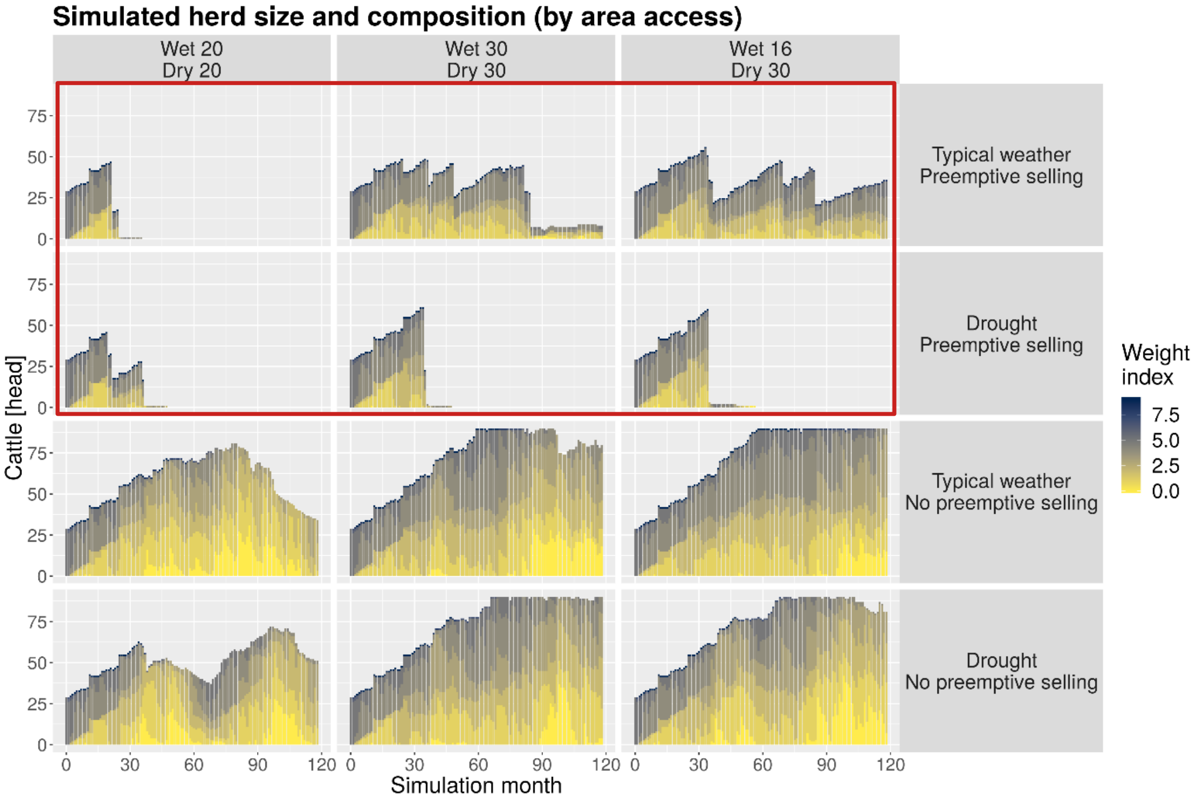
D: Typical rain, access 16/30 pixels, pre-emptive selling.

Overgrazing: Peak biomass decreasing from year to year, degradation after year 7.



Results- herd size and body weights

- Clear effect of all varied factors: Selling strategy, access, rainfall
- Drought effects not always as expected



Marohn et al., iEMSS 2020

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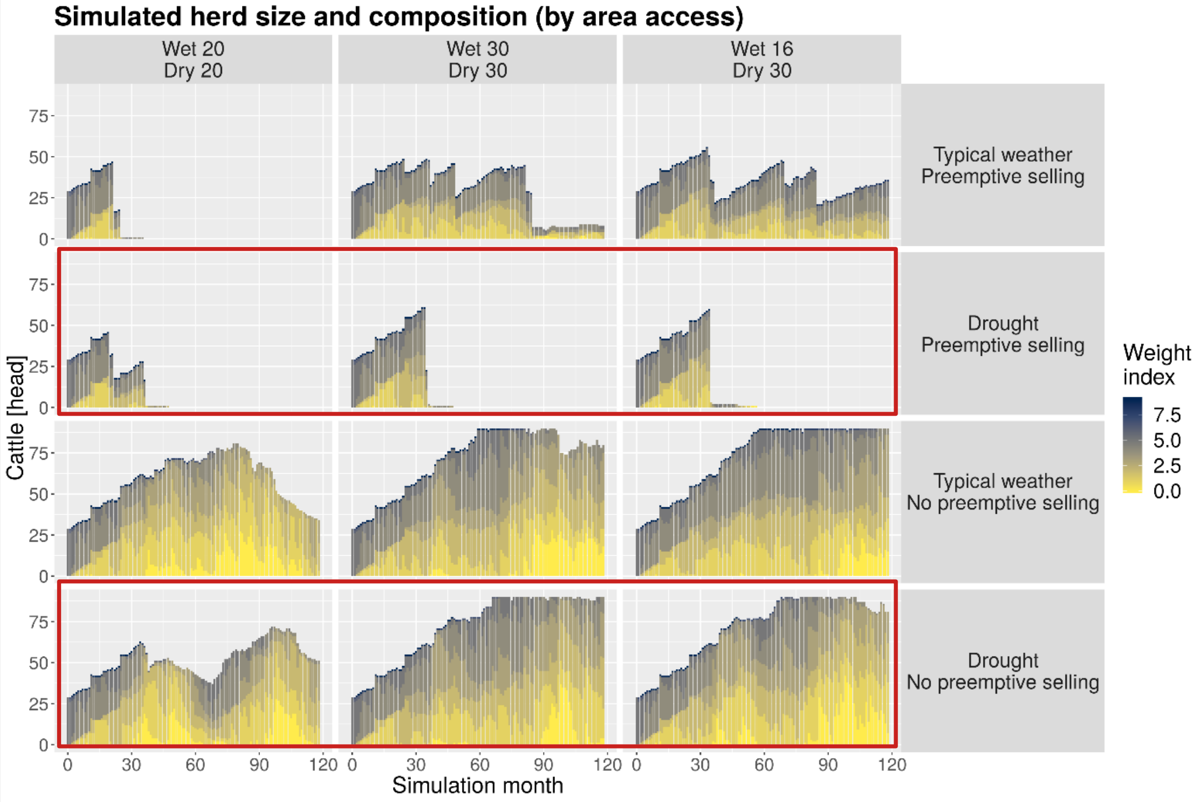

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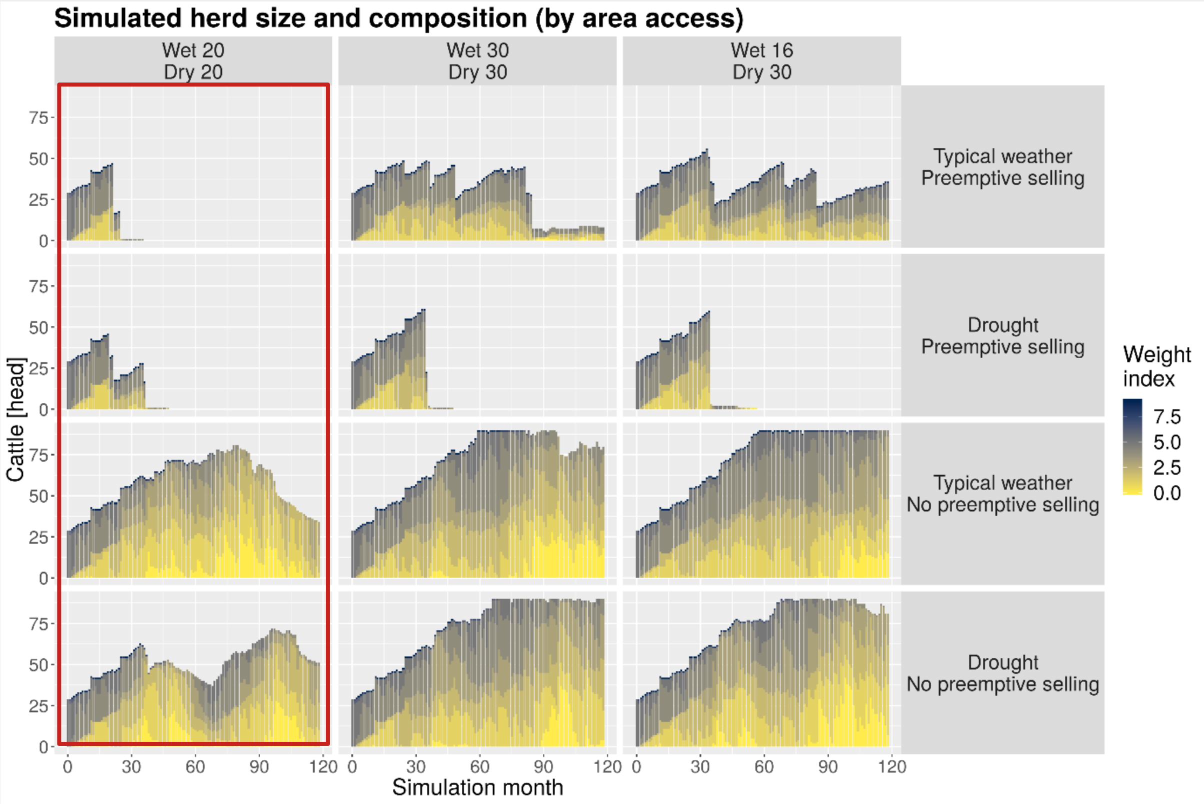

Discussion

- Marginal land use system → meticulous calibration needed
- Strong landscape effects (hydrology, soil fertility) on plant growth
- Drought exacerbates degradation (overgrazing earlier and on more pixels)
- Influence of dynamic pasture quality (seasonal / resprouting after grazing)
- Stress (access / drought) can be partly compensated by selling strategy

Work under development

- Pasture quality (role of standing litter)
- Rules for daily herd movement (how far can a paddock be grazed down before the herd moves?)

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Conclusions & Outlook

Achievements so far in coupling:

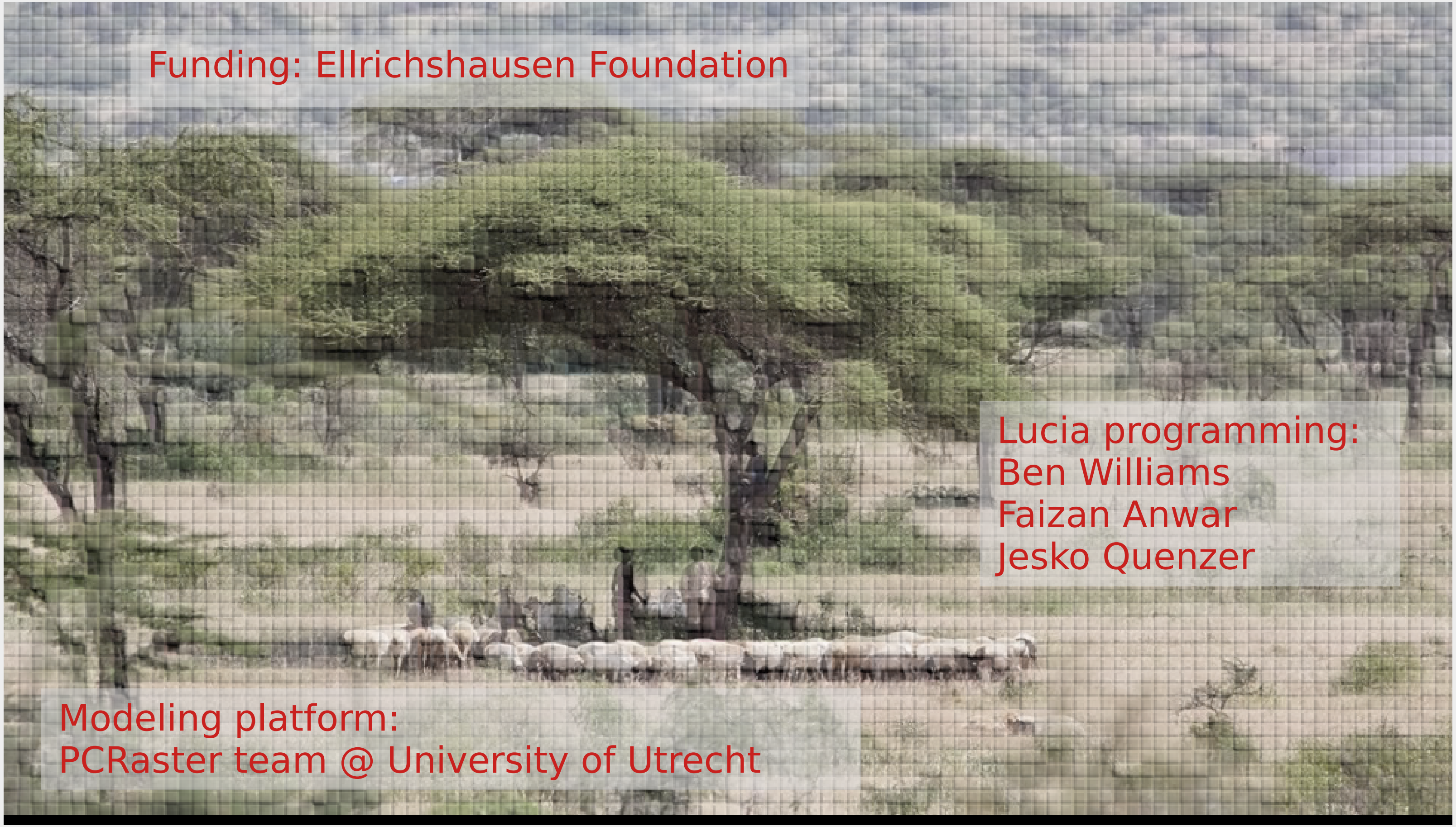
- Interactions plants – animals – humans – environment mostly plausible
- Effects of seasonal pasture quantity and quality underestimated before modelling

Next steps:

- Increase number of agents & herds
- Include LUC to agriculture
- Spatial herd movement patterns (walking distance, water holes, tenure, fragmentation)

SustainSahel: EU project 2020-2024: Crop – shrub – livestock systems in W-Africa

Acknowledgments



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