Modelling impacts of climate change and alternative management interventions on the multi-functionality of agricultural landscapes in southern Africa

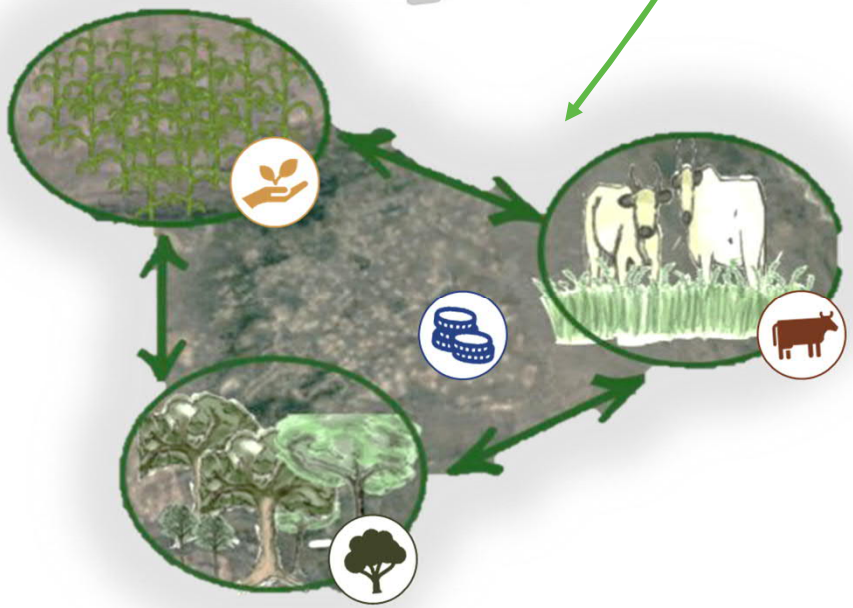

Arable - crop model


Rangeland – vegetation model


Orchard – crop model


Agent-based economic model

Content



1 Introduction to SALLnet

Modelling impacts of climate change and alternative management interventions on the multi-functionality of agricultural landscapes in southern Africa

Rötter, R.P.[1] , Nelson, W.C.D.[1], Isselstein, J.[1], Scheiter, S.[2], Pfeiffer, M.[2], Hoffmann, M.P.[3,1], Ayisi, K.[4], Lindstädter, A.[8], Behn, K.[8], Westphal, C.[1], Grass, I.[9], Feil, J.H.[1], Odhiambo, J.[5], Taylor, P.[5], Twine, W.[6], Merante, P.[1], Bracho Mujica, G.[1], Bringhenti, T. [1], Lamega, S.[1], Yazdan Bakhsh, S.[1], Krieger, W. [1], Linden, V.[5] and Erasmus, B.[7]

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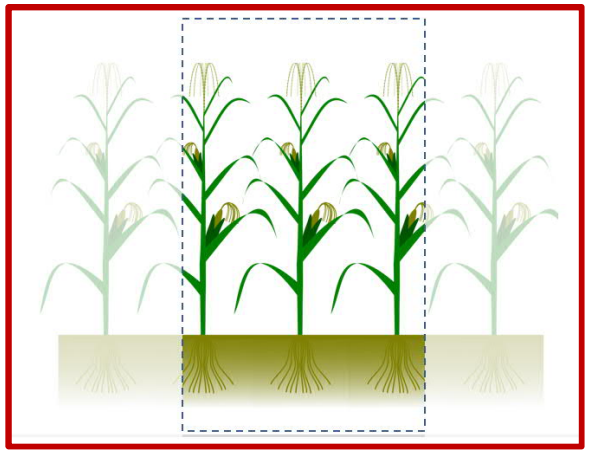
South African Limpopo Landscapes network SALLnet



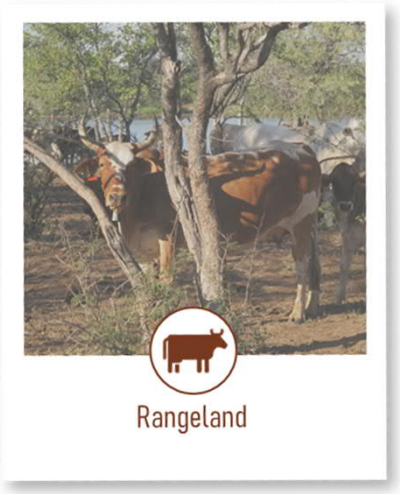
Field observations

Modelling

Complex reality & scales

Linking groundwork and modelling to understand complex realities at different scales

Multifunctional landscapes



Provide essential ecosystems services & functions

- Plant production: food - feed - fuel
- Biodiversity & habitat quality
- Pollination & natural pest control
- Soil conservation: carbon - erosion nutrients - water

SALLnet	Modelling impacts of climate change and management interventions on the multi-functionality of agricultural landscapes in southern Africa
Motivation	Threats climate change, soil degradation & population pressure Aim enhance functionality and resilience of multifunctional landscapes, food security, livelihoods
Linking model output	Linking model output (crop - rangeland - economic) Case study & stakeholder involvement in Limpopo, South Africa
Findings so far	Sustainable intensification closed livestock feed gap, but reduced soil organic carbon. Linking model output can highlight adaptive management options

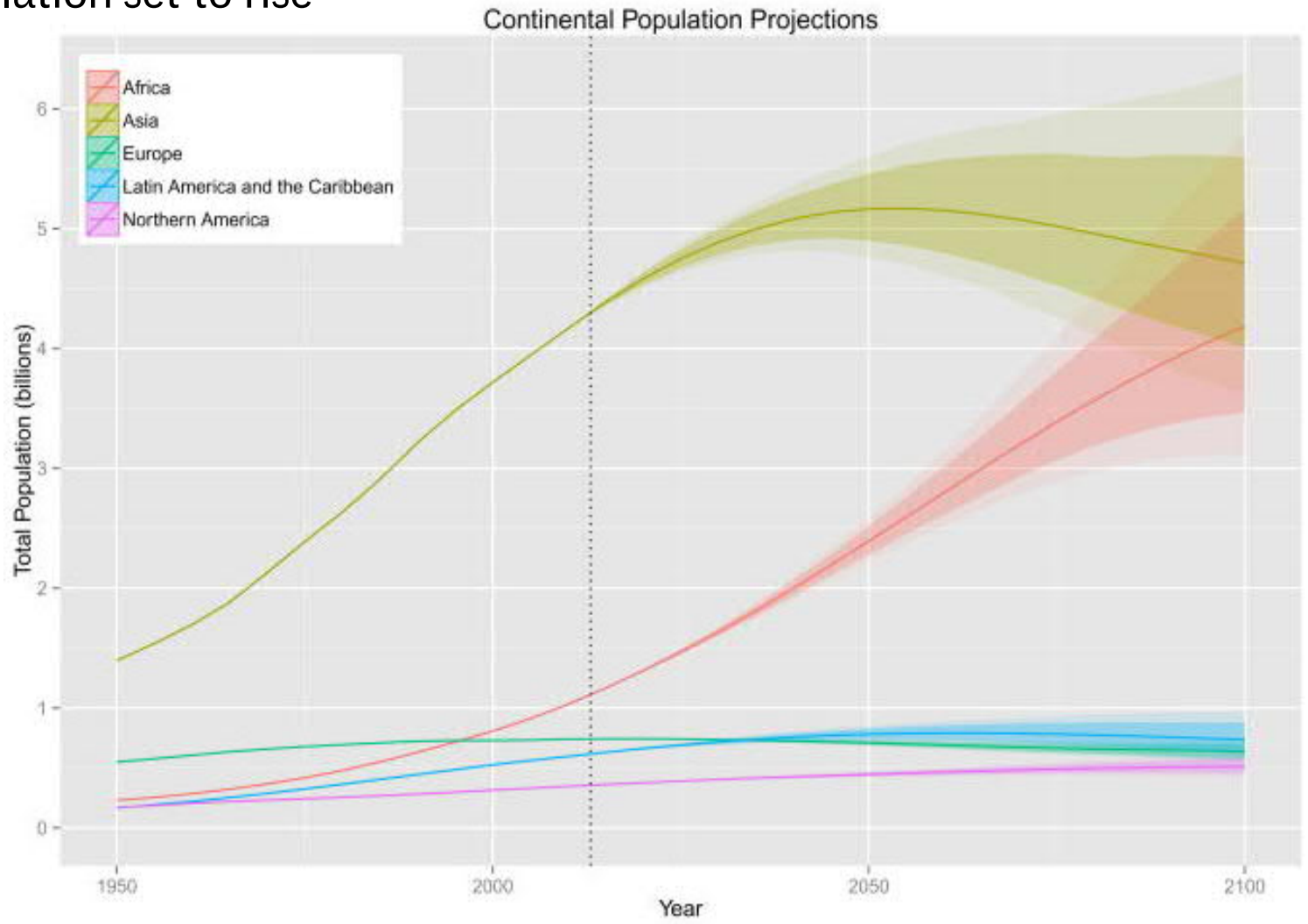
2 Motivation

Climate change and population pressure threaten the functionality and resilience of the multifunctional landscapes in southern Africa

Smallholder maize field & cob example, Limpopo Province, RSA, May 2019

Increasing pressure on land and other natural resources due to increasing welfare and population growth

African population set to rise

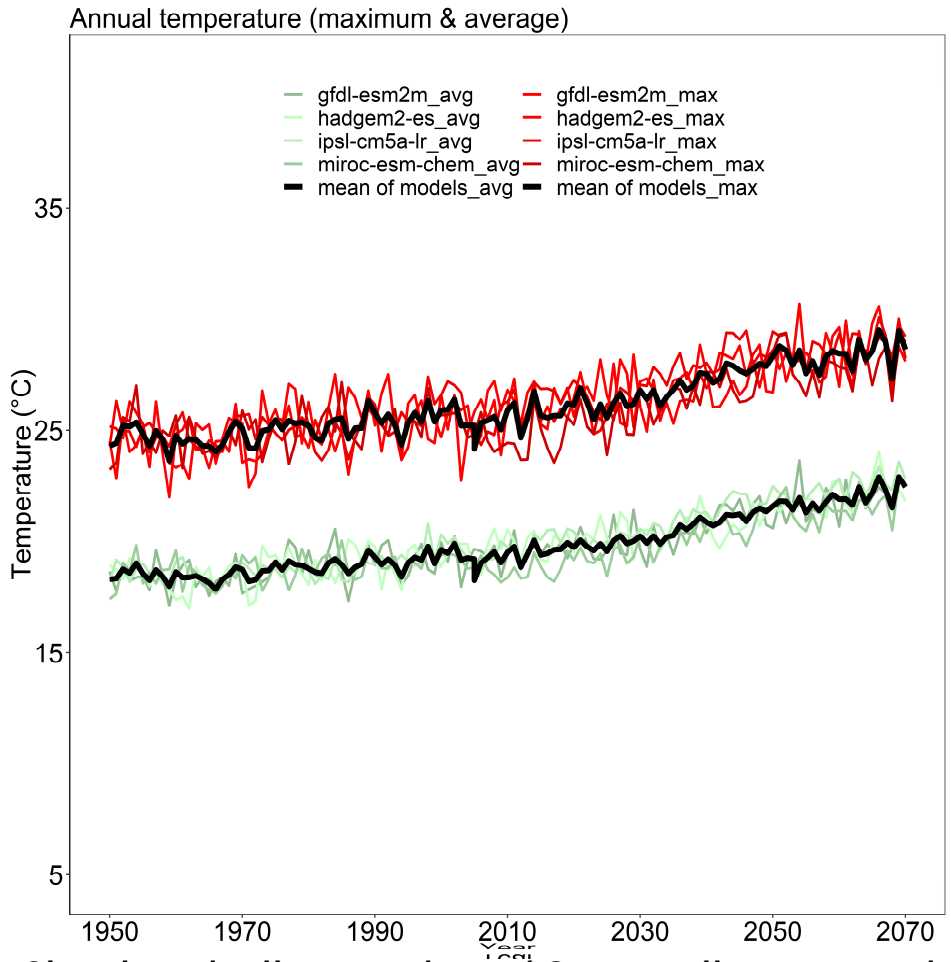


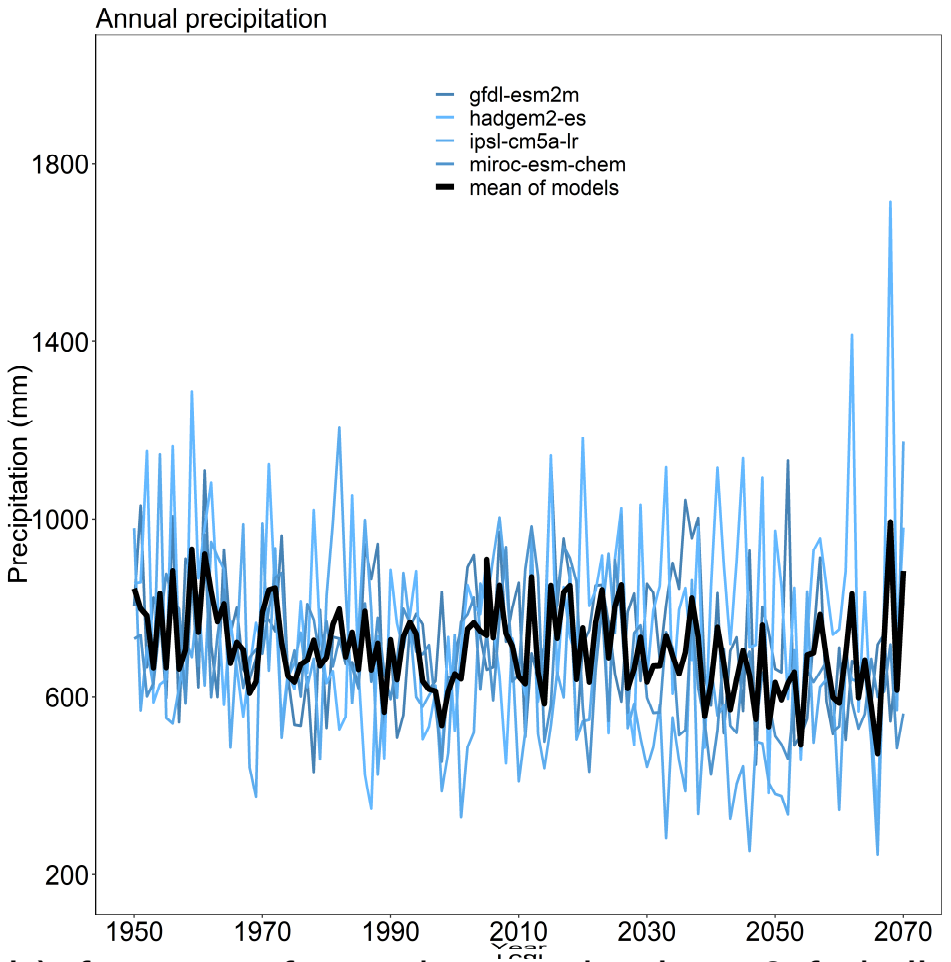
Gerland et al., 2014:
DOI: 10.1126/science.1257469

Climate change and population pressure threaten the functionality and resilience of the multifunctional landscapes in southern Africa

- Threats in southern Africa:
  - Land-use change (agriculture, tourism, mining and other sectors)
  - Environmental change (climate change and soil degradation)

  → Particularly severe in the drylands of Sub-Saharan Africa
- Projections of climate models:
  - Drought risk will increase considerably

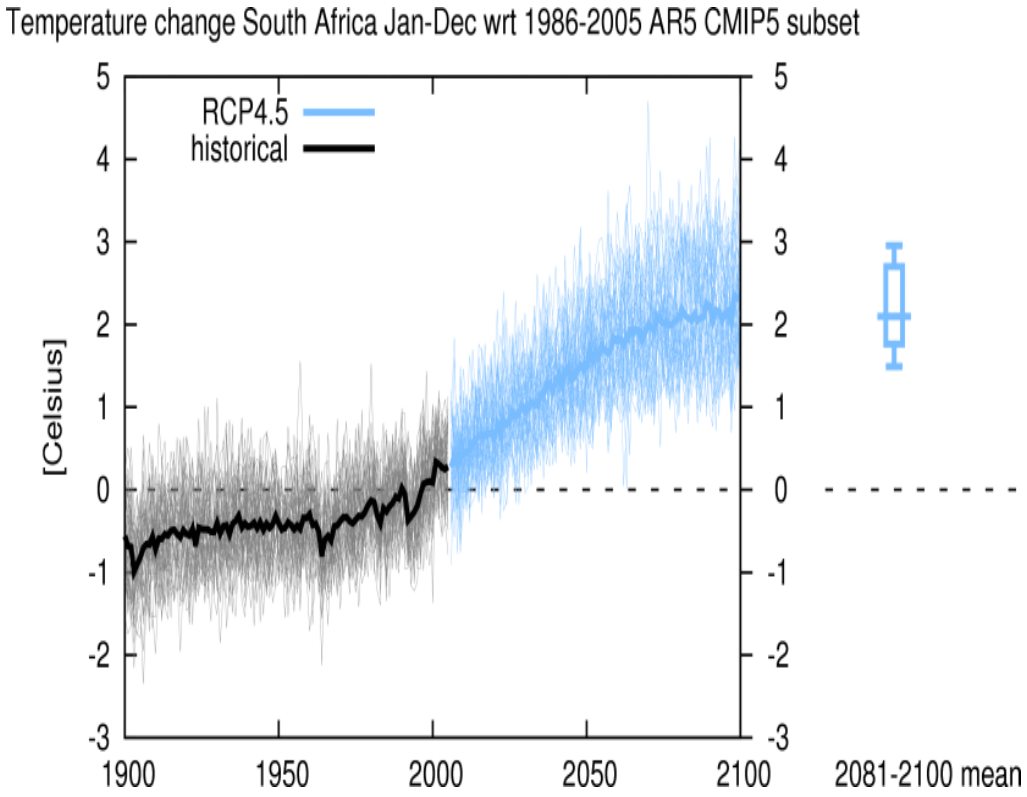


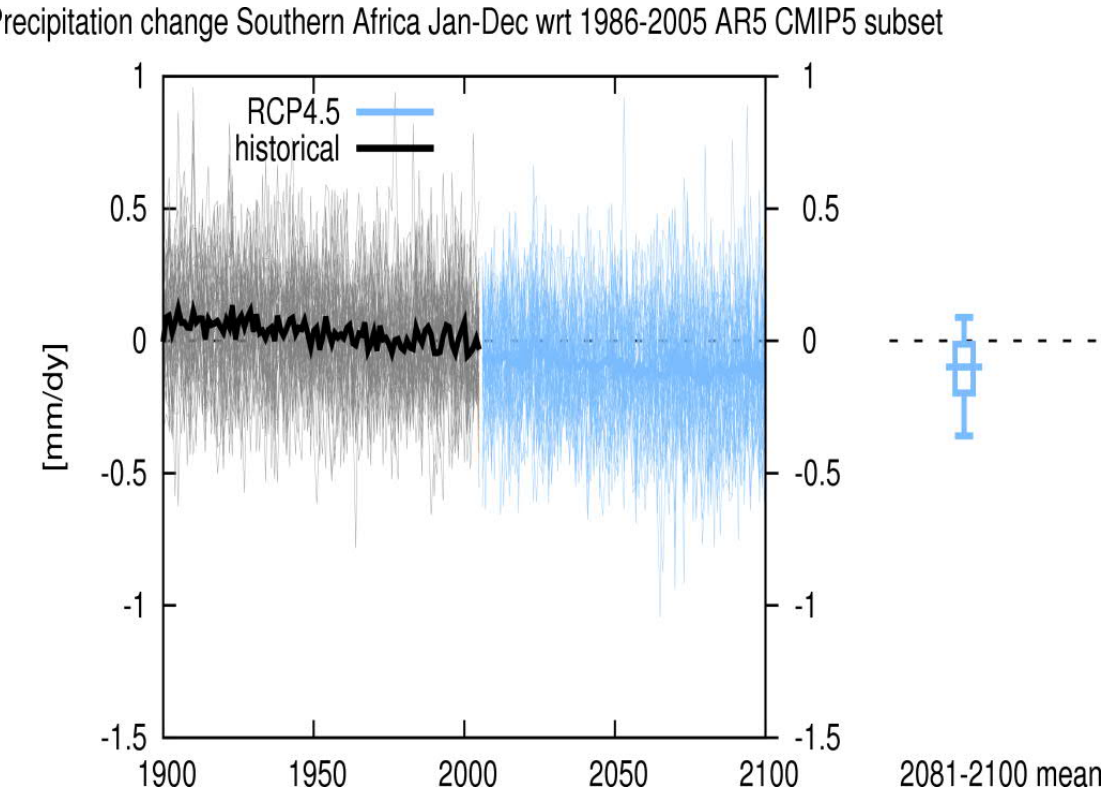


Nelson et al.
(in prep. - not for citation)

Simulated climate data (ISIMIP climate models) for one of two key study sites, Syferkuil (presented), & Univen, Limpopo Province, South Africa. Simulated historical data runs from 1950 to 2005, RCP8.5 from 2006 to 2070.

Climate change scenarios for South Africa, 1900 to 2100

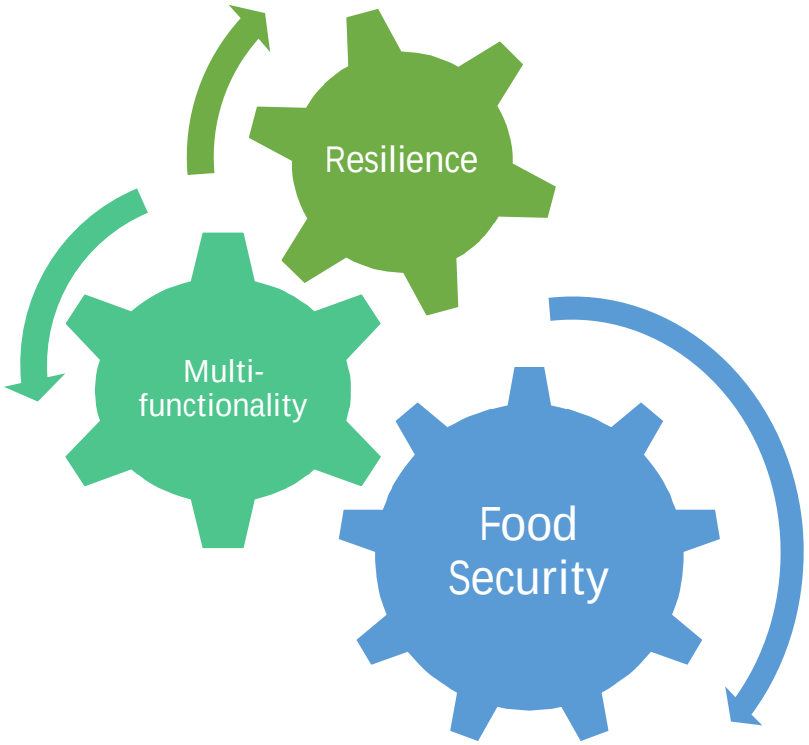




Source: plotted from KNMI Climate Explorer website - http://climexp.knmi.nl/plot_atlas_form.py - CMIP 5 multi-model ensemble – 42 models, using one ensemble member per model.

3 How - overview

How to enhance the multi-functionality and resilience of savannah landscapes in southern Africa under climate change and autonomous socio-economic developments with particular focus on food security and biodiversity?



- Evaluate ecosystem services in Southern Africa:

Provision of food, feed and fuel	Soil and water conservation	Recycling, restoring soil C and nutrients

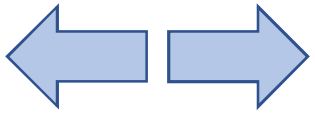
- Linking model output to assess the impact of management x environment interactions on various ecosystem functions of the agroecosystems

Scenarios: changes in climate, land-use and resource management

Scale: field -> farm / village -> landscape / region

We apply

- Vegetation model aDGVM
- Crop models APSIM, DSSAT, WOFOST
- Integrative farm and regional level agent-based economic models for different farming systems with geo-referenced databases



Adaptive Dynamic Vegetation Modeling

SALLnet: six German; five South African partner institutions cooperate with different disciplines:

- Agroecology
- Agronomy
- Soil Science
- Agricultural Economics
- Agricultural Systems Modelling
- Ecology

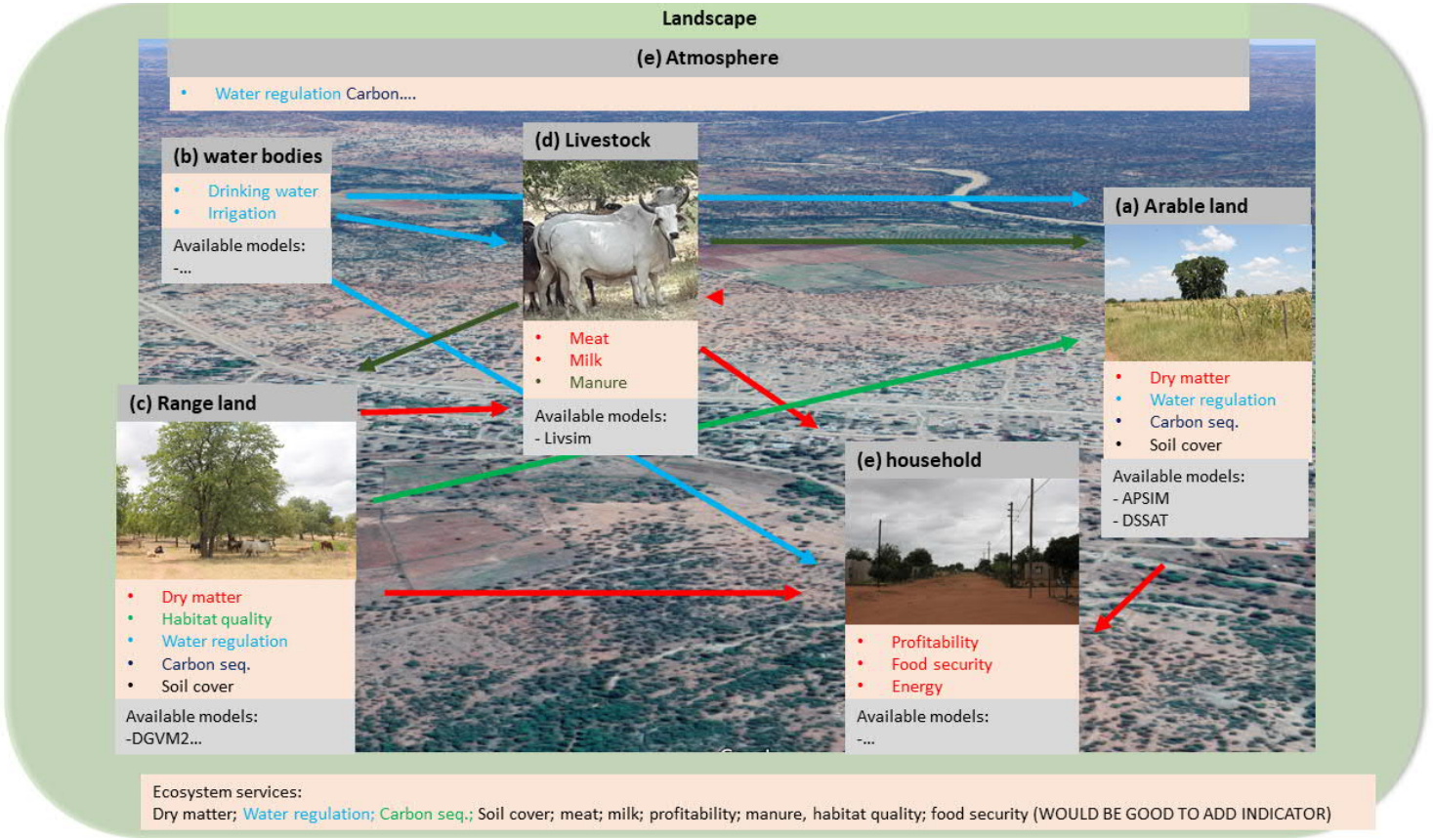
SALLnet is part of the SPACES 2 programme
Funded Federal Ministry of Education and Research (BMBF)
Project Management Agency DLR
Additional funding German Academic Exchange Service (DAAD)

Follow link for training we offer: https://www.spaces-training.org/

Find ways to sustainably manage land and enhance the resilience and multifunctionality of landscapes in southern Africa – in particular food security, biodiversity and rural livelihoods

SALLnet First Annual Meeting, Sept. 2019

Framework for integrative modelling and assessment of land-use scenarios



Assessment and modelling tools needed for the integrative analysis of land-use scenarios for southern African landscapes.

Source: Roetter et al. In prep.: Towards integrated approaches to assess the multi-functionality of landscapes in a changing climate

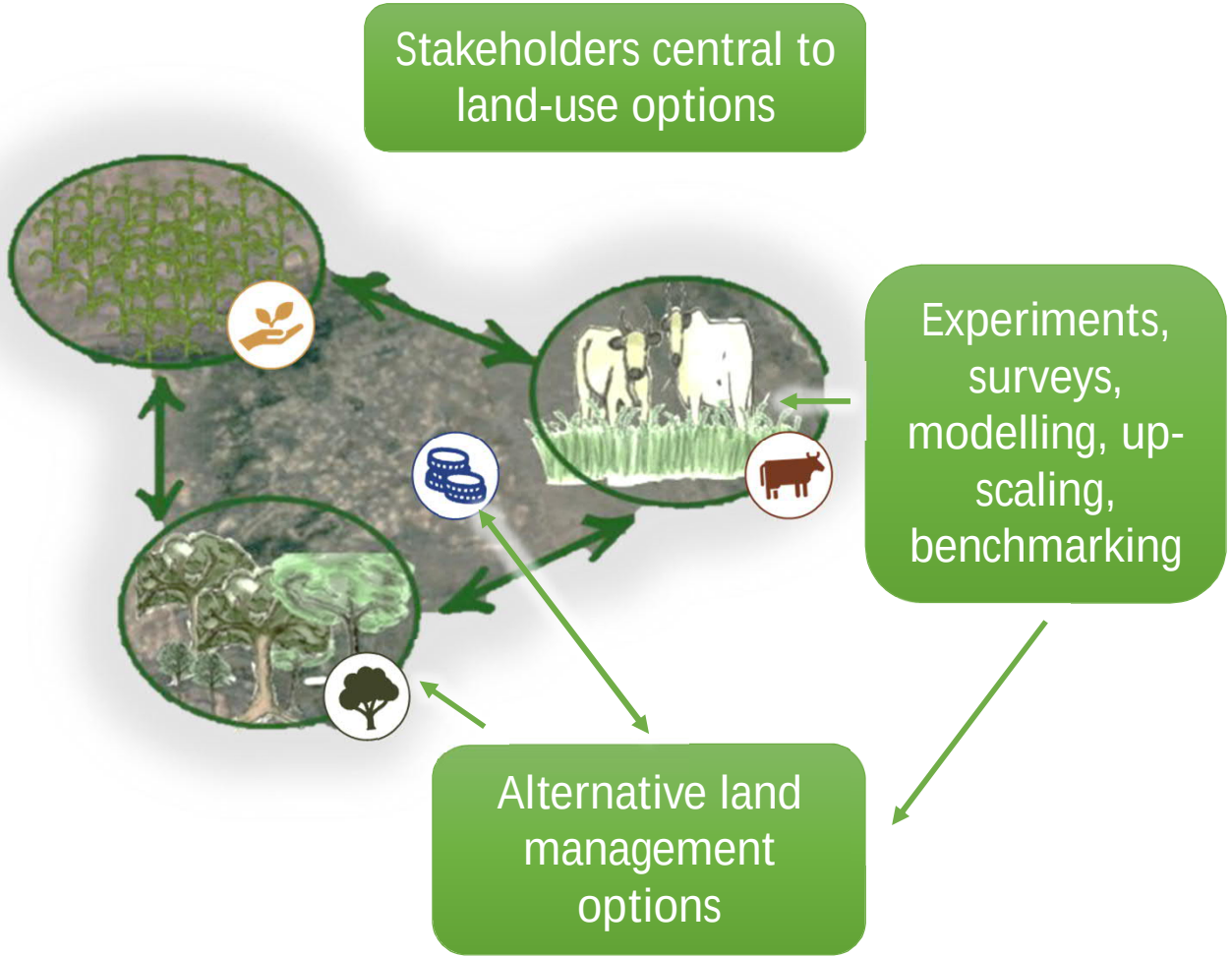
Roetter et al., (in prep.
- not for citation)

Aims

- Develop and test new approaches and methods of land use:
  Focus: interactions between connected land use types

- Provide integrative tools and modelling platforms to:
  Develop land-use scenarios and management options that enhance ecosystem resilience

- Involve stakeholders in the research process to develop overall risk evaluation, risk management strategies, and policy recommendations for sustainable land use



Why Limpopo?

- Diverse land use and biodiversity
- High spatio-temporal climatic variability
  - Helps to generalise findings for a larger domain in southern Africa
- Well-known, competent collaborative research partners

Aeral view of Limpopo province

Ongoing case studies

One	Management of smallholder crop-livestock (presented)
Two	Intensification of maize production for emerging farmers
Three	Sustainable management of macadamia orchards
Four	Introducing new crops to fill winter feed gap

Linking model output: Limpopo case study

Publications (selected)

Scheiter, S., Schulte, J., Pfeiffer, M., Martens, C., Erasmus, B.F., Twine, W. (2019). How does climate change influence the economic value of ecosystem services in savanna rangelands? Ecological Economics 157, 342-356. https://doi.org/10.1016/j.ecolecon.2018.11.015.

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J., Higgins, S., Mudongo, E., Scheiter, S. (2019). Grazing and aridity reduce perennial grass abundance in semi-arid rangelands - insights from a trait-based dynamic vegetation model. Ecological Modelling 395, 11-22. https://doi.org/10.1016/j.ecolmodel.2018.12.013

Rapholo, E., Odhiambo, J.J.O., Nelson, W.C.D., Rötter, R.P., Ayisi, K., Koch, M., Hoffmann, M.P. (2019). Maize lablab intercropping is promising in supporting the sustainable intensification of smallholder cropping systems under high climate risk in southern Africa. Experimental Agriculture. https://doi.org/10.1017/S0014479719000206

Conference contributions (selected)

Hoffmann, M., Scheiter, S., Pfeiffer, M., Nelson, W.C.D., Feil, J.H., ... & Rötter R.P. (2019). Coupling crop and vegetation modelling to quantify impact of cattle and crop management on ecosystem services in southern African landscapes. ISEM 19, Vienna
Invited Session 19: Modelling the multi-functionality of landscapes

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4 How – work packages

The SALLnet project is implemented through seven work packages:

1. Arable lands
2. Rangelands and agroforestry
3. Orchards
4. Economic modelling
5. Ecosystem services change: arable land and macadamia plantations
6. Climate change, land-use and nitrogen dynamics
7. Integration and synthesis

The SALLnet project is implemented through seven work packages:

1

Arable lands

- Assess the spatio-temporal variability of available feed resources and diversify farm management
- Overcome regular fodder shortages (gaps)
- Improve on-farm fodder resources
- Explore the potential of cover and neglected forage crops to sustain on-farm ruminant livestock production
- Soil fertility assessment and determine production potential of the arable land

Work package details

The SALLnet project is implemented through seven work packages:

2

Rangelands & Agroforestry

- Evaluation of ecosystem services and ecosystem stability in the face of climate change
- Explore suitable management options
- Understand the synergies and trade-offs between critical ecosystem services delivered by Limpopo‘s multi-functional landscapes

Work package details

The SALLnet project is implemented through seven work packages:

3

Orchards

- Examine the ecosystem services pollination and biocontrol and their potential trade-offs in macadamia systems
- Quantify the ecosystem services of predators and pollinators
- Determine the maximum potential yield and related yield gaps

Work package details

The SALLnet project is implemented through seven work packages:

4

Economic modelling and assessment of different scenarios and risk management options for agriculture in Limpopo

- Investigate the effects of agri-relevant risks on the production and economic performance of different farm types in the Limpopo region
- Develop farm type specific and spatially explicit risk management options
- Assess effectiveness of new risk management options under different land use and policy scenarios

Work package details

The SALLnet project is implemented through seven work packages:

5

Effect of climate change and management interventions on ecosystem services of arable land and macadamia plantations in Limpopo region

- Explore how intensification and diversification in arable land and orchards potentially impact important ecosystem functions (e.g. carbon sequestration, productivity)
- Upscale findings from farms and village settings to a regional level
- Consider current and possible future climate conditions

Work package details

The SALLnet project is implemented through seven work packages:

6

Climate change, land use and nitrogen dynamics in rangelands/ shrubs

- Project impacts of biophysical (climate, CO_2, nitrogen) and socio-ecological factors on the provision of multiple ecosystem services and functions
- Coupling aDGVM & N-model
- Use of improved vegetation model aDGVM2
- Model simulation for an integrated multiple-risk assessment to develop guidelines for decision-making

Adaptive Dynamic Vegetation Modeling

Work package details

The SALLnet project is implemented through seven work packages:

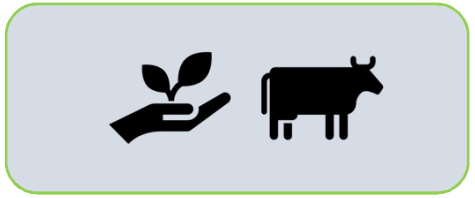
7

Integration & Synthesis

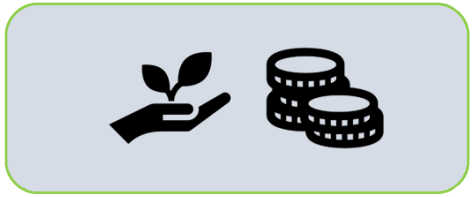
- Integrate the results of work packages 1-6
- Compliment data to ensure overarching project goals are fulfilled
- Develop integrative framework for data synthesis
- Include local scientists and stakeholders in the design and development of model questions / simulation scenarios
- Train local scientists and stakeholders
- Support knowledge-based strategic and practical land-use decisions

Work package details

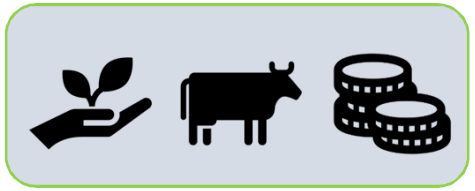
5 Linking model output: Limpopo case study



crop & rangeland – case study presented
WP7 & WP6



crop & economic
WP7 & WP4



crop, rangeland & economic
WP7, WP6 & WP4

Linking crop and vegetation model output to quantify the impact of cattle and crop management on ecosystem services in southern African landscapes

Objectives

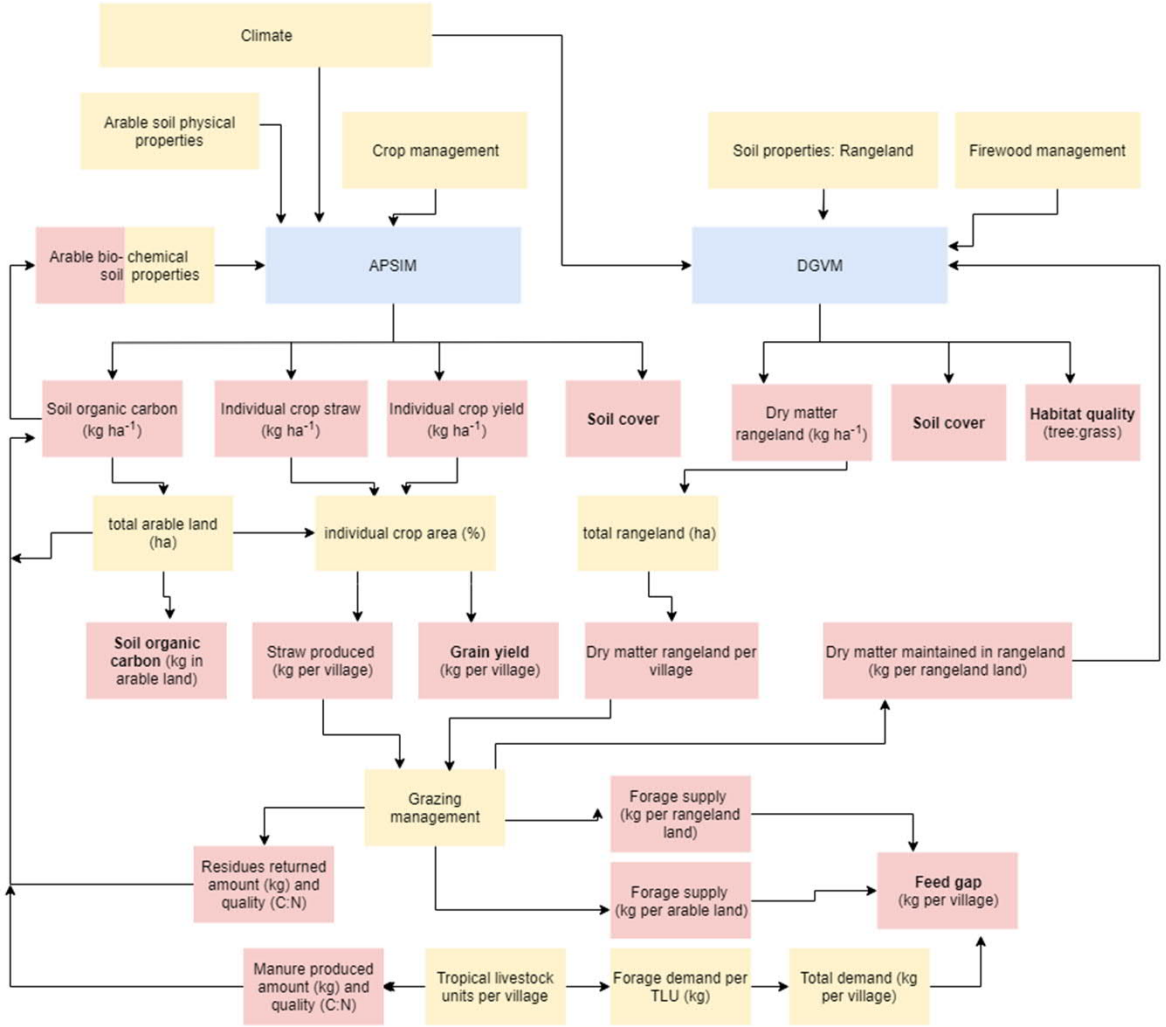
Link process-based model output APSIM for arable land and aDGVM2 for rangeland to investigate:

a) effects of current management practices

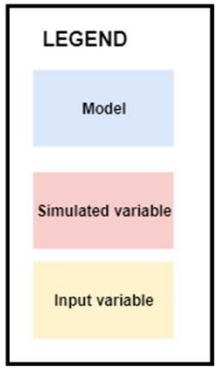
b) an intensification scenario

How do these affect SOC, soil erosion, productive water use, biomass production, monthly feed gaps, and rangeland habitat quality of the entire smallholder farming system over a period of ten years (from 2000-2010) at landscape level.

5 Linking model output - crop and rangeland - WP7



Adaptive Dynamic Vegetation Modeling



Conceptual framework linking crop (APSIM) & rangeland model (aDGVM) output

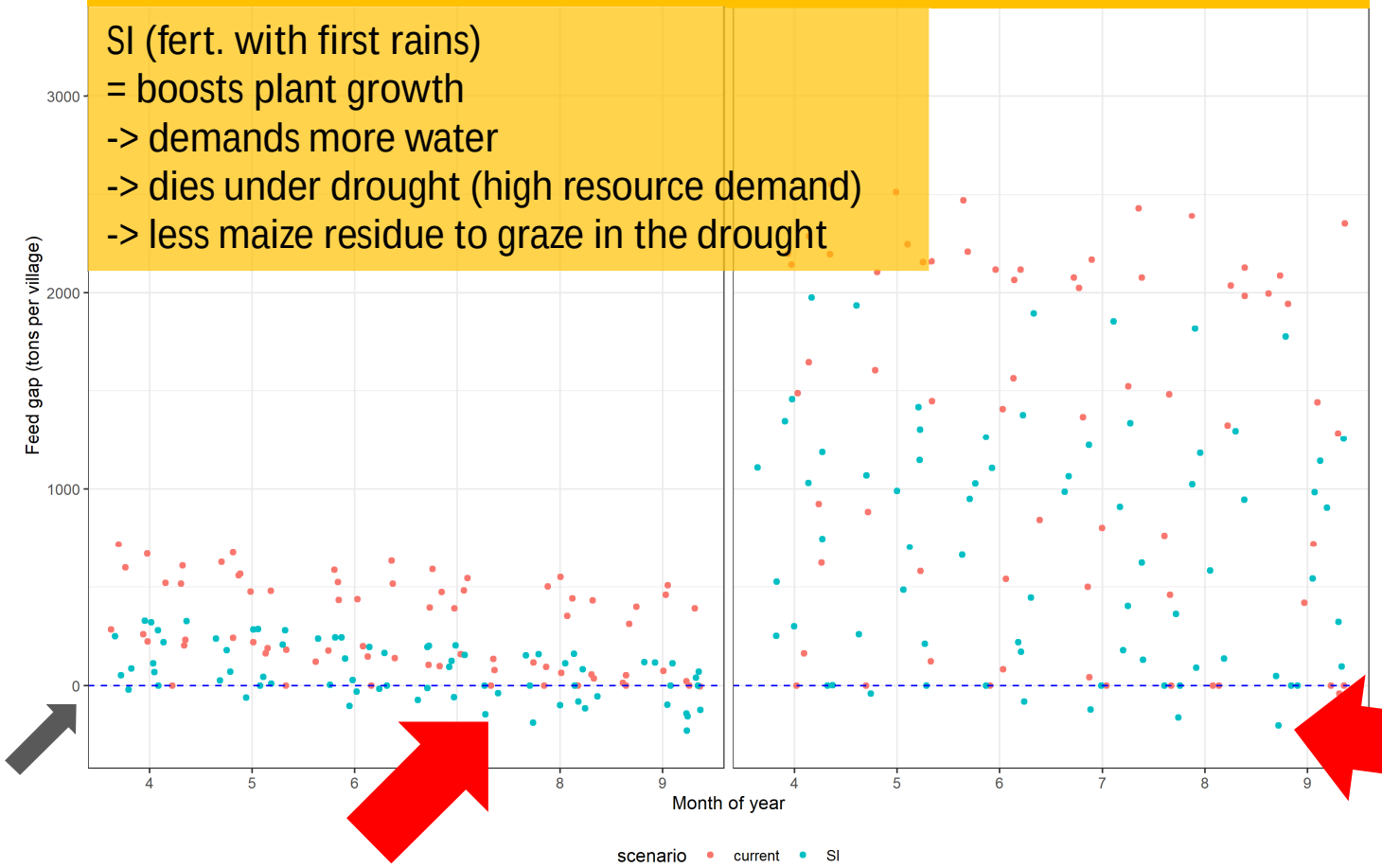
(in prep. - not for citation)

Output Feed gap of current management vs. sustainable intensification (SI) scenario

Selwane
Sandy soil (poor)

Mafarana
Higher SOC & clay soil (more fertile)

SI (fert. with first rains)
= boosts plant growth
-> demands more water
-> dies under drought (high resource demand)
-> less maize residue to graze in the drought



Feed production need met / balanced

SI under performs in dry years

(in prep. - not for citation)

Summary

Increased fertiliser → increased production risk

→ increasing pressure on grazing area in dry years with SI

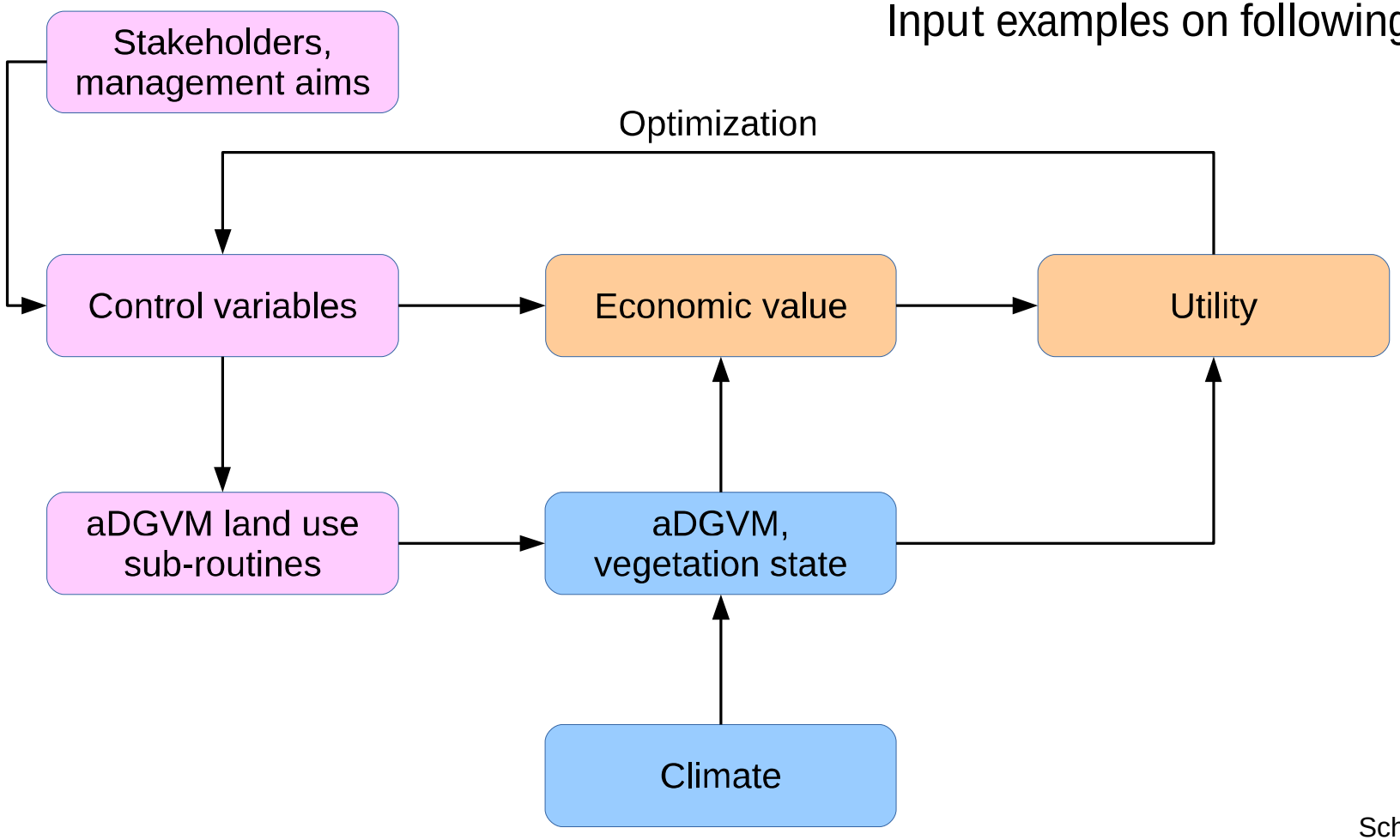
- Higher SOC levels due to SI, at least in favorable site
- Framework development in-progress (livestock)
- Knowledge-intensive (quantitative, systems-approach)

Outlook

‘Landscape surveys‘ → combine remote sensing (vegetation types) & low cost measurements (from plot to field up to landscape level) to enable ‘landscape-level‘ data collection

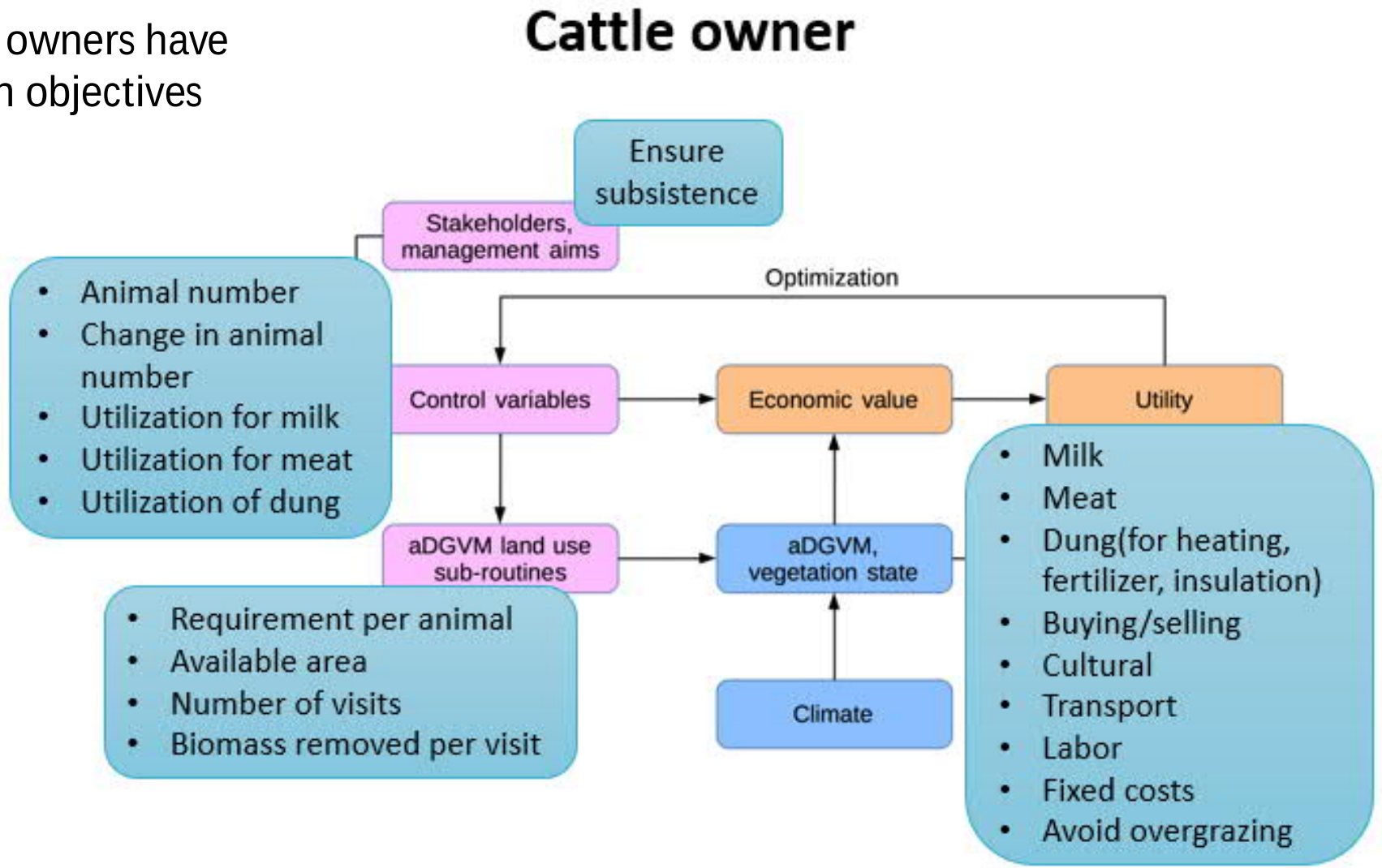
Linking vegetation and economic model output

Input examples on following slide



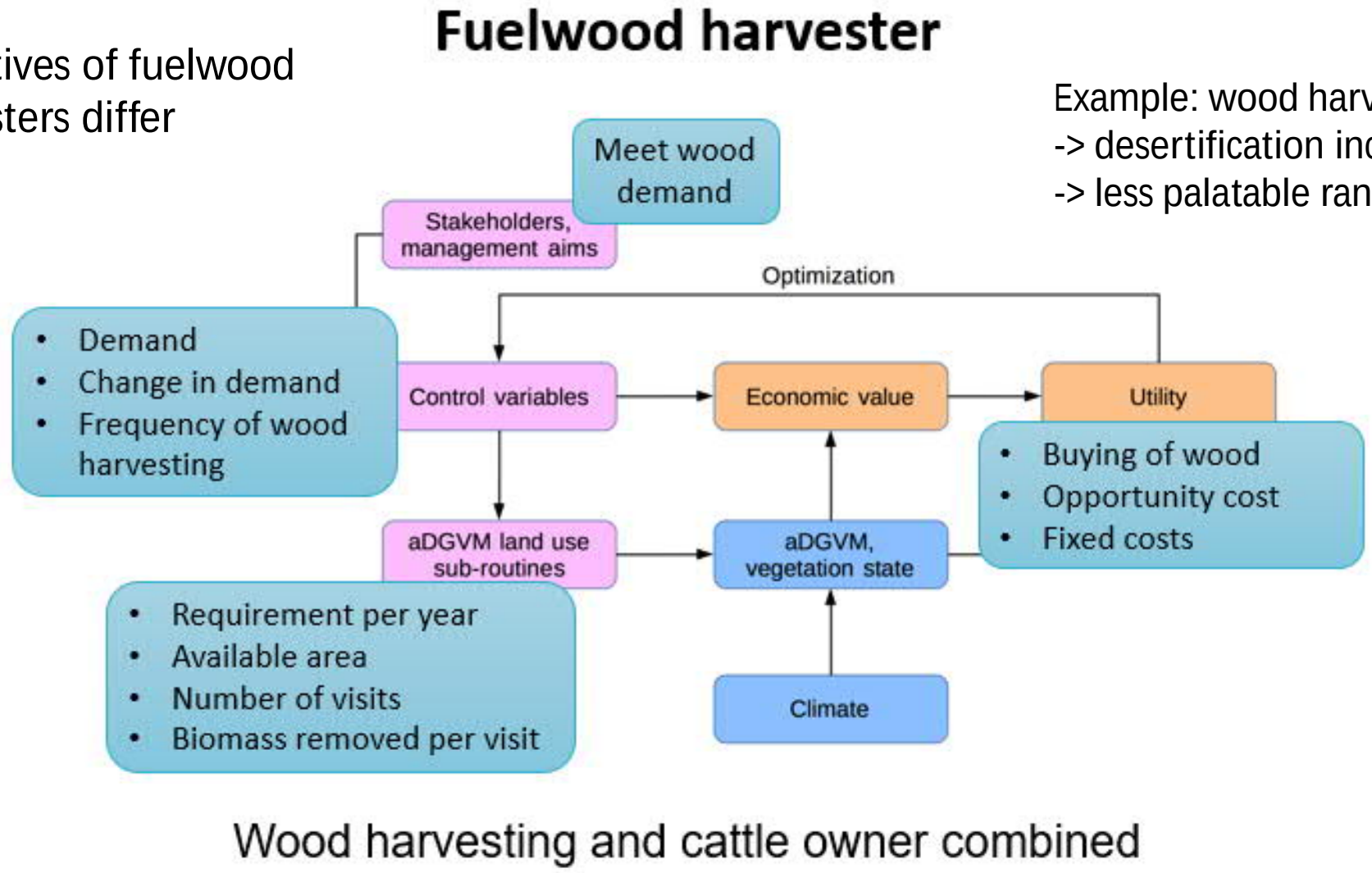
Scheiter et al. (2019) Ecological economics

Cattle owners have certain objectives



Scheiter et al. (2019) Ecological economics

Objectives of fuelwood harvesters differ



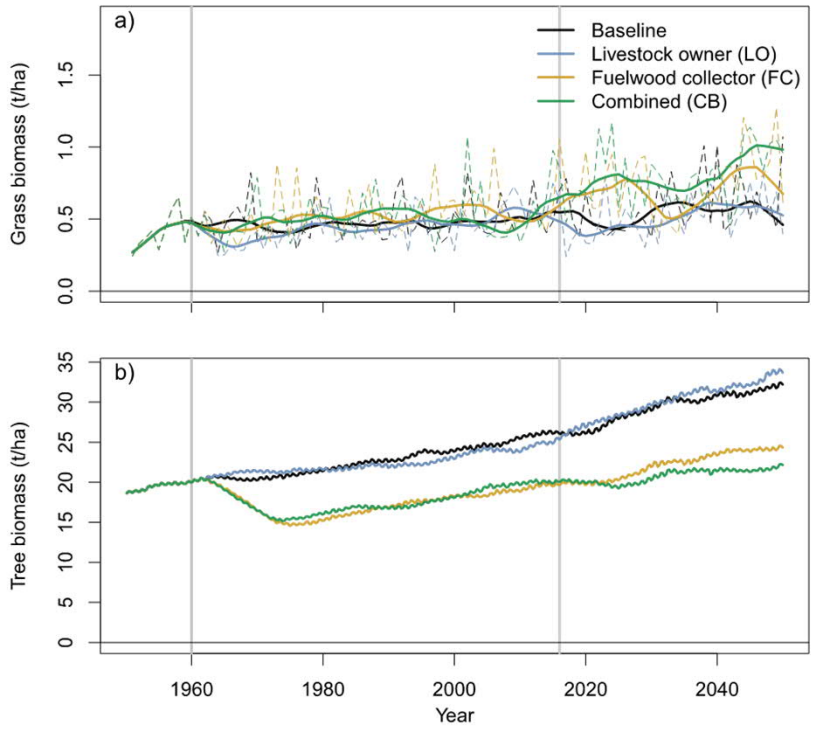
Example: wood harvesting increase
-> desertification increase
-> less palatable rangeland for grazers

Scheiter et al. (2019)
Ecological economics

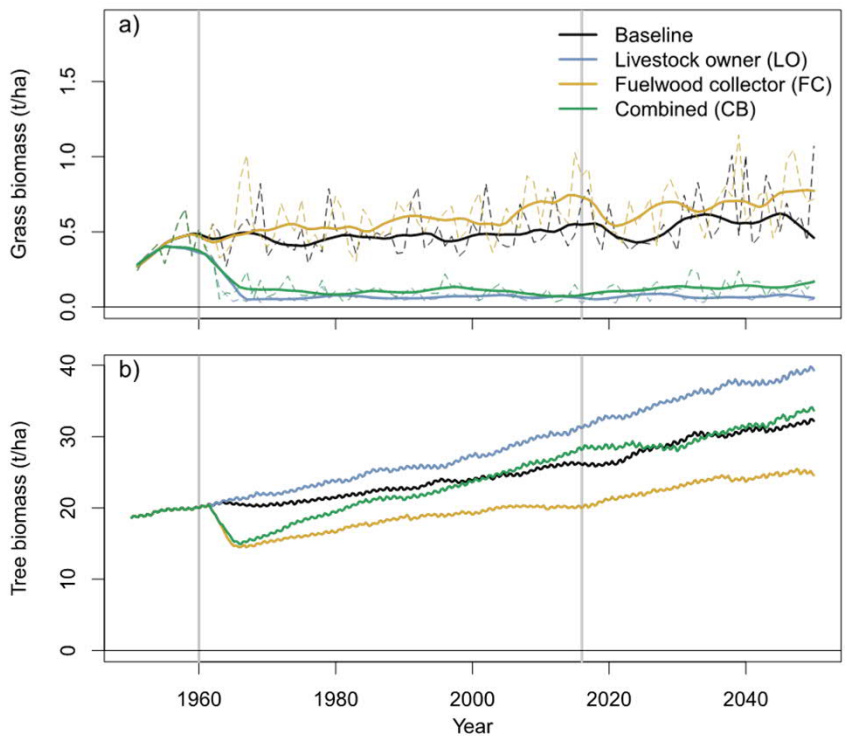
Model set-up and scenarios

- Parameterisation for Bushbuckridge Municipality, Mpumalanga, South Africa
- Two scenarios:
  - Optimisation of land-use that maximize economic value to stakeholders:
    Animals/ha: 0.1; fuelwood collected daily: 1.5 t/yr/household
  - Realistic intensities:
    Animals/ha: 0.9; fuelwood collected daily: 3.5 t/yr/household
- Planning horizon until 2050 for RCP 8.5; NOTE animals used primarily for milk

Optimised land-use strategy



Realistic land-use strategy



Scheiter et al. (2019)
Ecological economics

Impacts of grazing & fuelwood harvesting on grass (a) and tree (b) biomass, optimised and realistic, respectively. For grass biomass, dashed lines represent annual maximum grass biomass values, bold lines represent smoothened time series (locally-weighted polynomial regression). Gray lines indicate the introduction of management in 1960 and the start of the planning horizon in 2016.

Optimised land-use intensities are lower than realistic intensities

Recovery of ‘natural’ vegetation is slow after reduction of fuelwood harvesting intensities

Conclusions & outlook: rangeland model specific

- Model framework was developed to aDGVM, which links vegetation dynamics, climate change and different land-uses
- Model considers economic aspects
- Model projects woody encroachment under future conditions
- Optimised land use intensities are lower than realistic intensities
- Recovery of ‘natural’ vegetation is slow after reduction of fuelwood harvesting intensities
- Linking biophysical model output to agent-based economic models could help understand and plan additional land use activities

Preliminary conclusions: linking model output case study

- Tentative results: sustainable intensification closed the livestock feed gap
  - > But further reduced soil organic carbon
- Linking rangeland and crop model output promising to provide insights to complex interconnections of different ecosystem services at a landscape level
  - > However, model output needs to be further, regionally calibrated with sound ground/ experimental data – not yet thoroughly examined

Challenges ahead: linking model output case study

- Livestock element: elaboration to properly link arable and rangeland model output and their management
- Open question remains -> good estimates on how much manure can be expected from cattle per village for the arable simulation input
- Better estimates of forage demand per cattle - livestock units per village difficult to quantify
- Better understanding of estimate plausibility regarding: estimated livestock number vs. rangeland area

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Work package details …

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Arable lands

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- Explore the potential of cover and neglected forage crops to sustain on-farm ruminant livestock production
- Soil fertility assessment and determine production potential of the arable land

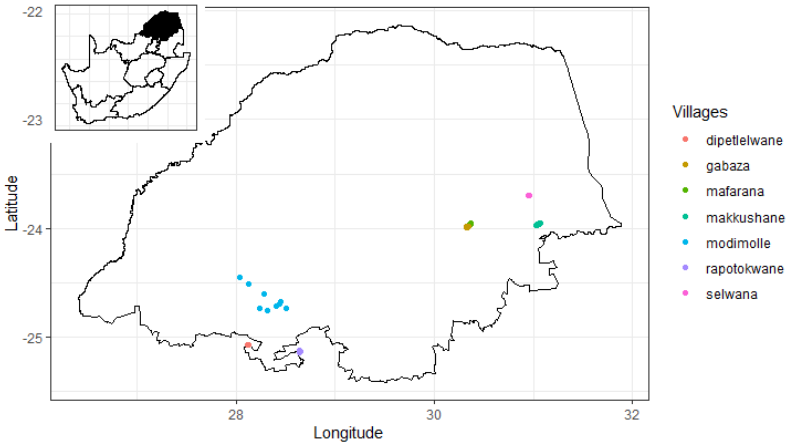
Back to WP overview

Key activity so far

Arable lands

- Conducted survey in seven villages:
  arid, semiarid, and semihumid
  90 individual farms: June – September 2019

- Collected data on:
  - Production systems and strategies – interviews
  - Arable land: soil, crop residues used as feed
  - Rangeland: grass, soil
  - On-farm: cattle tail hair, dung, feed supplement

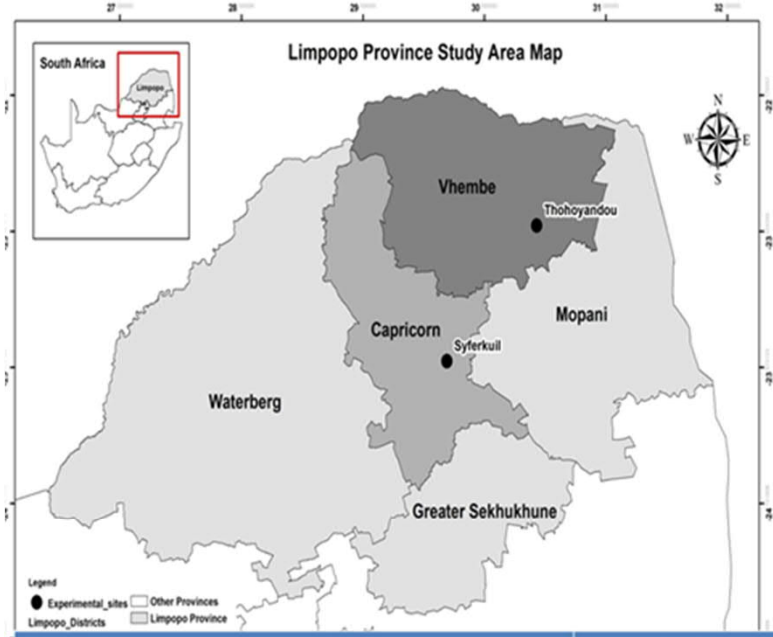


Key activity so far

Arable lands

- Field experiments, April 2019
  Cool-season forage crops mitigate feed-gap in winter months?

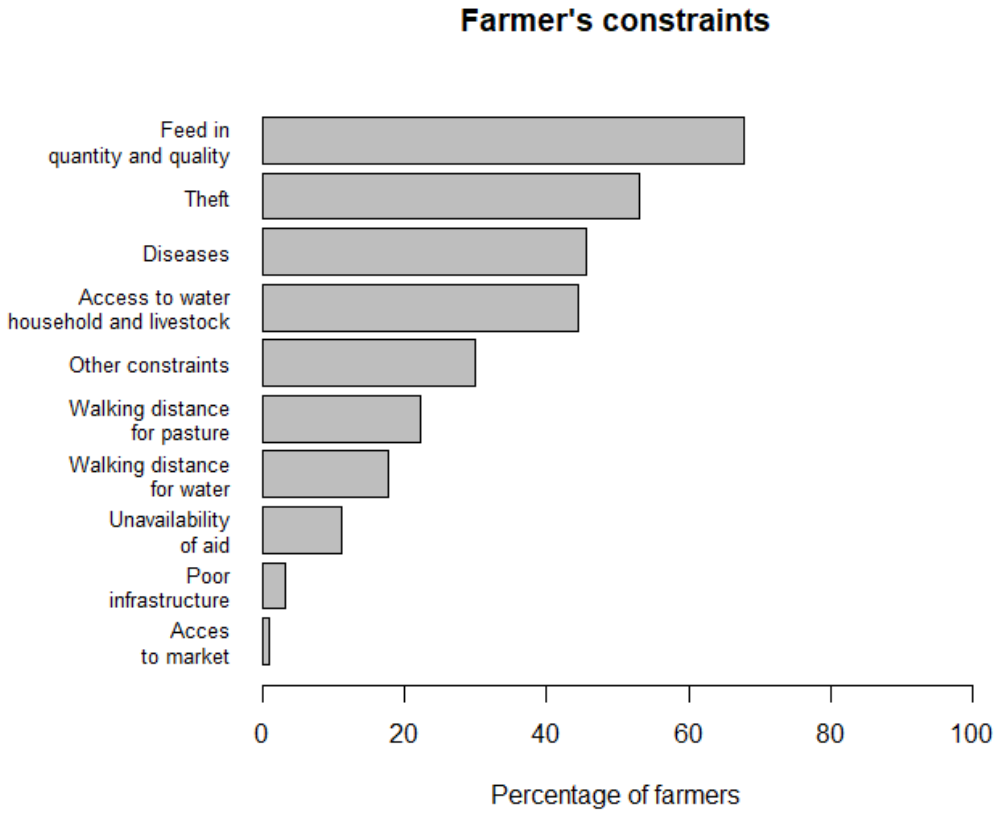
- Field-experiments conducted for APSIM parameterlisation and calibration
- Data collected:
  - Aboveground biomass
  - Biomass N
  - Soil water
  - Height, LAI



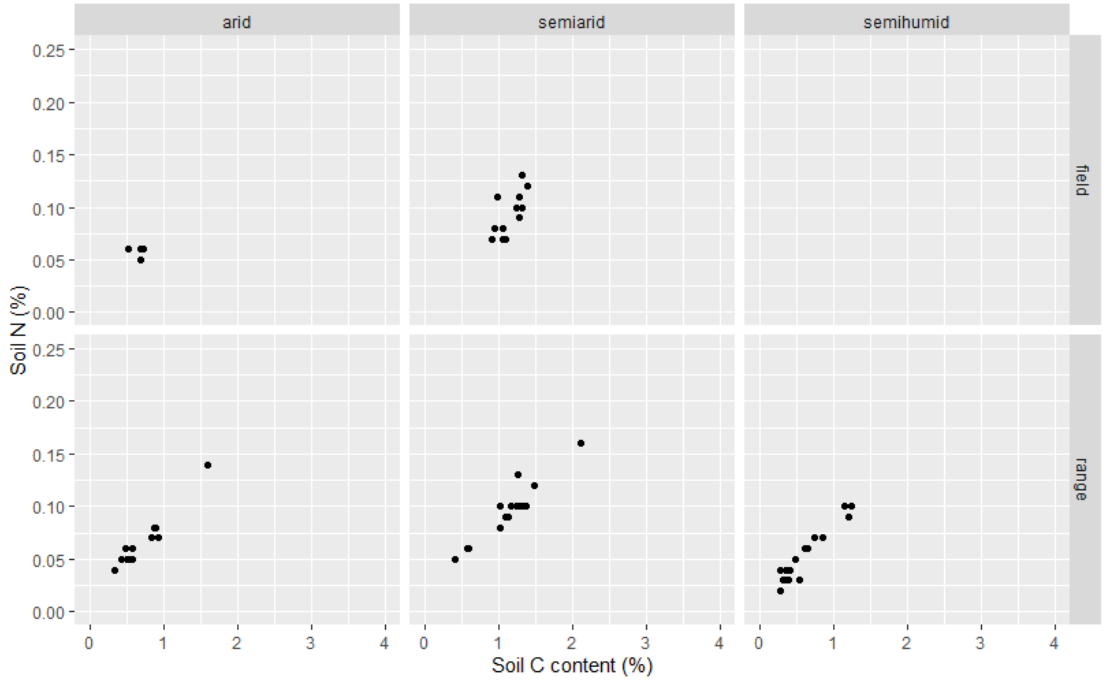
- 2 sowing dates
- 2 N levels for the non – legumes
- 4 replications/site
- 144 plots (including fallow plots)

Species	Cultivar	Sowing density kg ha^{-1}
Secale cereale (RYE)	Bonfire	100
Brassica napus (winter) (WRAP)	Gorilla	20
Trifolium alexandrinum (TAL)	Alex	35
Vicia villosa (VV)	Dr.B	30
Mixture 1	TAL + Rye	18 + 50
Mixture 2	TAL + WRAP	18 + 10

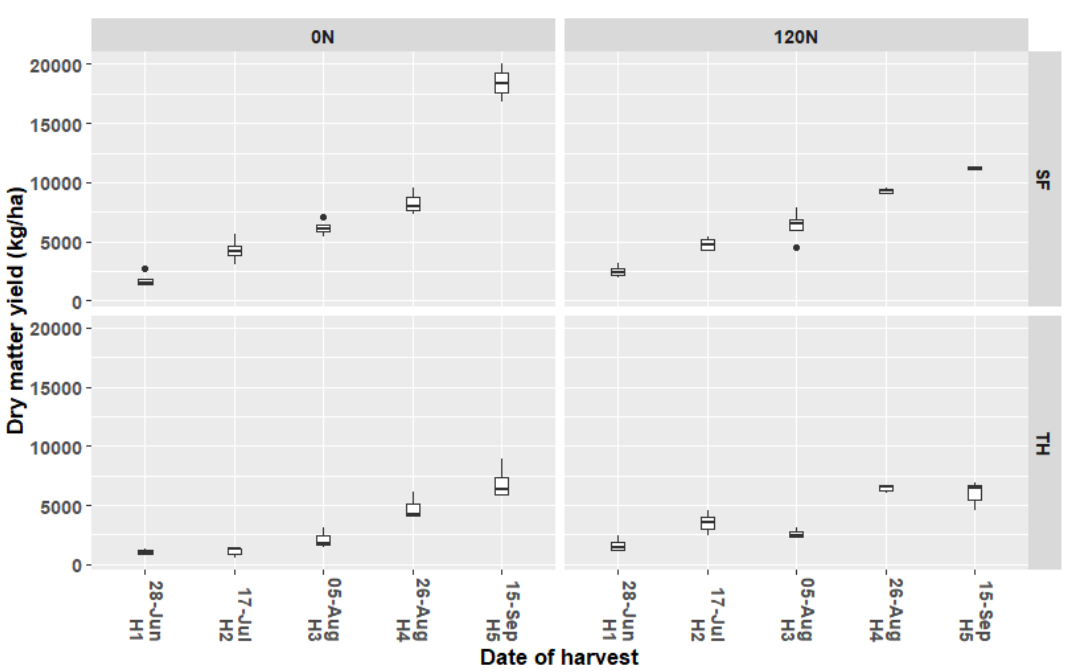
Key activity so far

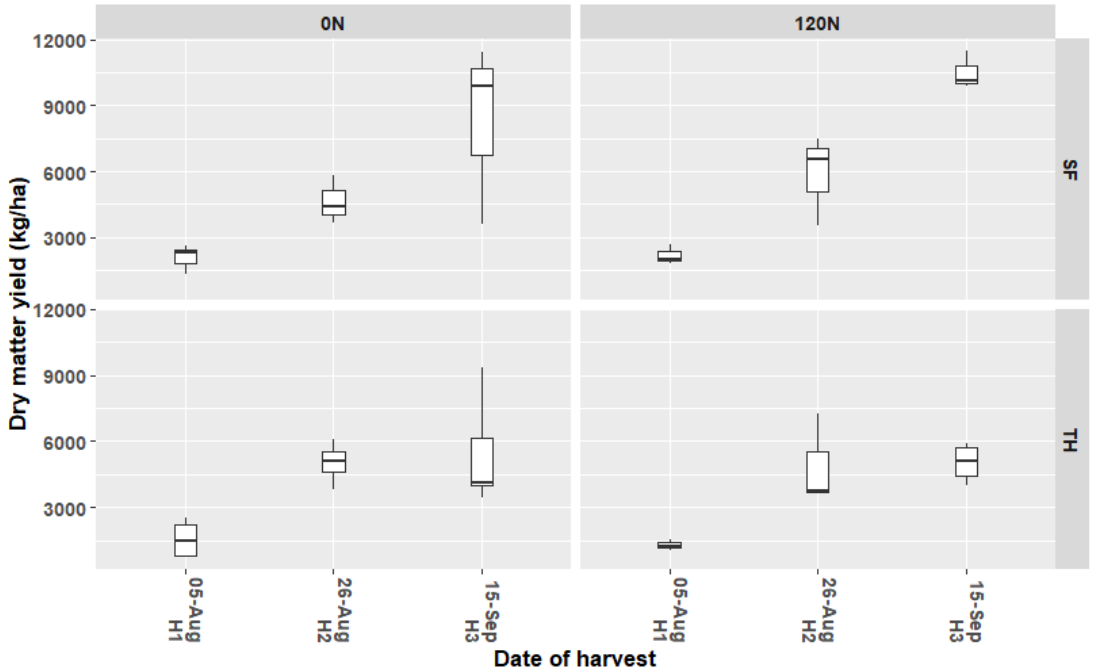


Overview of soil N and C content across land use and agroecological zones



Filling the feed gap with alternative crops

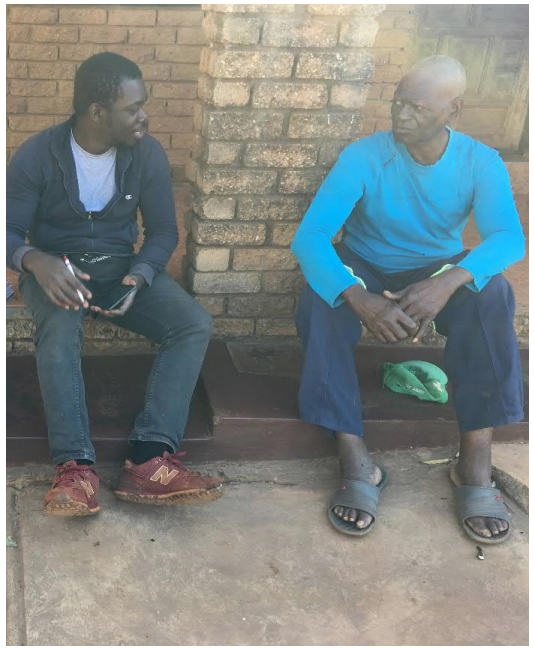




Aboveground dry matter of winter rye sowing date 1 and 2 - second y-axis: sites.

- forage trials show promising results for biomass production when irrigated
- cover crops could serve as an option for both crop and livestock systems, strengthen the nutrient pools of the arable lands and additional forage resource when deficits occur
- rangeland man. with intro. of new forage species, or rotational grazing to avoid overgrazing – linked to CSM (APSIM) sim. scenarios

Stakeholder involvement



Workshop planned

- Knowledge exchange – feedback from results highlighting potential options

The SALLnet project is implemented through seven work packages:

2

Rangelands & Agroforestry

- Evaluation of ecosystem services and ecosystem stability in the face of climate change
- Explore suitable management options
- Understand the synergies and trade-offs between critical ecosystem services delivered by Limpopo‘s multi-functional landscapes

Back to WP overview

Key activity so far

Rangelands and agroforestry

- DroughtAct: combined drought & grazing
  - On-going experiment since 2015
  - Data:
    - Vegetation: annual biomass, veg. Composition, plant functional traits
    - Environ. variables: soil properties, soil-moisture
- Seasonal variation in cattle diet composition (species level) via DANN from cow dung
- Collaboration: international networks (DroughtNet)

Sixth Observation Year in the DroughtAct Experiment

Drought is simulated by passive rainout-shelters that reduce the rainfall by about 66 % percent compared to non-drought treatments.

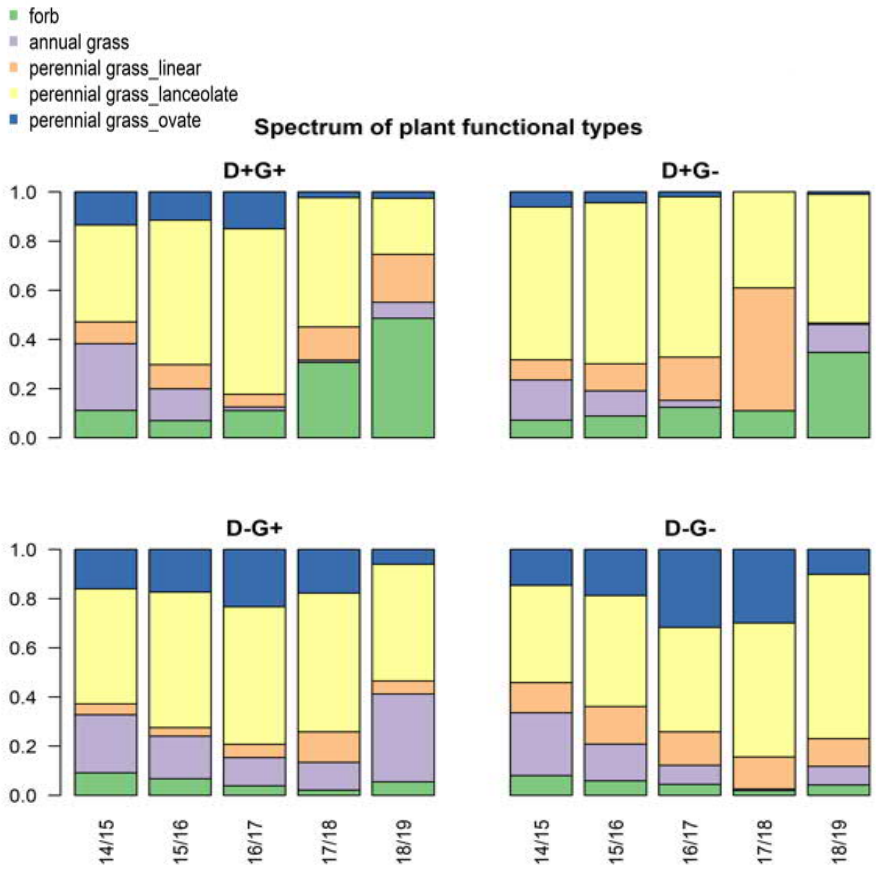
Key findings so far

Rangelands and agroforestry

- Drought changes composition of plant functional groups
  - Sig. changes from 3rd year of drought
  - Relative increase of forbs & linear-leaved perennial grasses (higher stress-tolerance)
- Relative decrease of ovate- and lanceolate grasses (competitors)
- Grazing under drought conditions may accelerate changes

-> Reduced forage provision:

- Lower biomass production
- replacement of highly palatable grasses by forbs and grasses with lower palatability

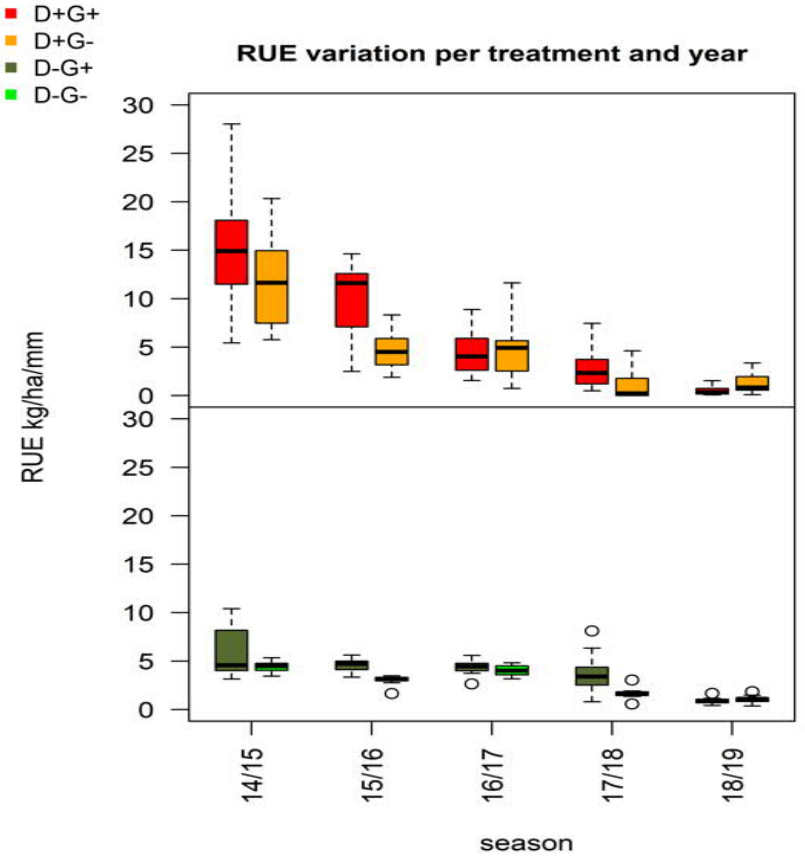


Changes in the spectrum of functional plant groups over the course of the DroughtAct experiment for the different treatments (D + drought, D - no drought, G + grazing, G - no grazing).

Key findings so far

Rangelands and agroforestry

- Rainuse efficency (RUE; biomass production per rainfall) relatively stable under non-drought conditions
- RUE under drought conditions initially higher - legacy effect? Plants may have reserves
- Continuous decrease under prolonged drought conditions due to reduction in vegetation cover and changes in species composition
- Grazing can initially increase biomass production but has negative effects under prolonged drought
- Reduction in RUE can indicate desertification tipping p.
- Management needs to be adapted to prevent tipping of the ecosystem to a desertified state



Change in biomass production in relation to rainfall (rain use efficiency; RUE) over the course of the DroughtAct experiment for the different treatments (D + drought, D- no drought, G + grazing, G- no grazing).

Land management options: diversification // specialisation

Rangelands and agroforestry

- DroughtAct:
  - Understand combined effects (drought & grazing)
  - Monitor gradual changes in vegetation structure and composition
  - Develop early warning indicators for desertification
  - Data used for calibration & validation of aDGVM (rangeland model)
- Management options:
  - Adapt land use management (stocking density and resting periods) to capacity of ecosystem to prevent degradation

Cattle on rangeland with high grazing pressure at the end of the rainy season in Octorber 2019.

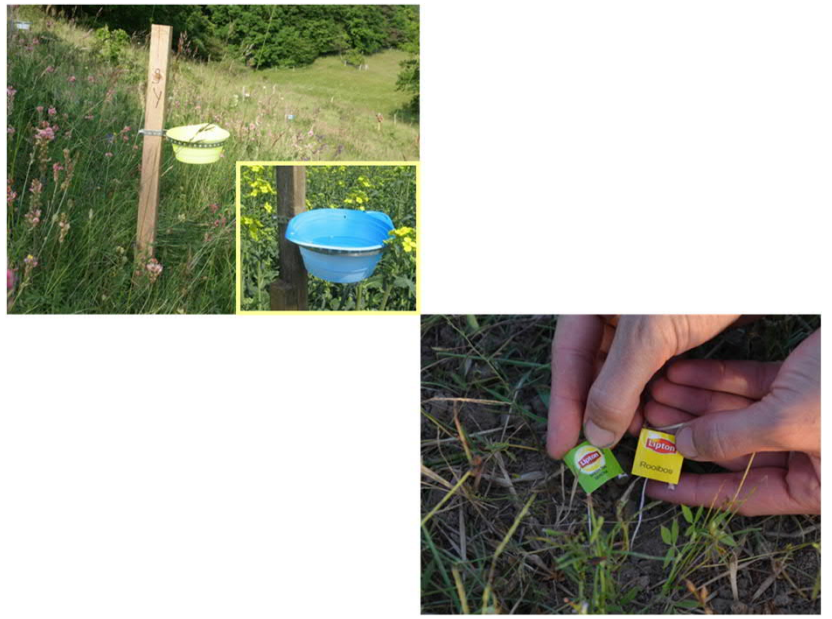
Stakeholder involvement through Rapid Ecosystem Function Assessment Coordinated by both WP2 (lead) and WP3

Rangelands and agroforestry

Challenge
- How do ecosystems respond to environmental change?
- How are they influenced by socio-economic developments?

-> ecosystem function data collection methods need to be faster & low tech.

How
- Sampling along climatic & socio-economic gradient
- Arable land / home gardens / rangeland
- Use of 'toolbox' of standardised methods to assess e.g. biomass production, pollinator activity or herbivory
- Combined with interviews with smallholder farmers



Application of REFA methods.

The SALLnet project is implemented through seven work packages:

3

Orchards

- Examine the ecosystem services pollination and biocontrol and their potential trade-offs in macadamia systems
- Quantify the ecosystem services of predators and pollinators
- Determine the maximum potential yield and related yield gaps

Back to WP overview

Key activity so far

Orchards – large vertebrate exclusions

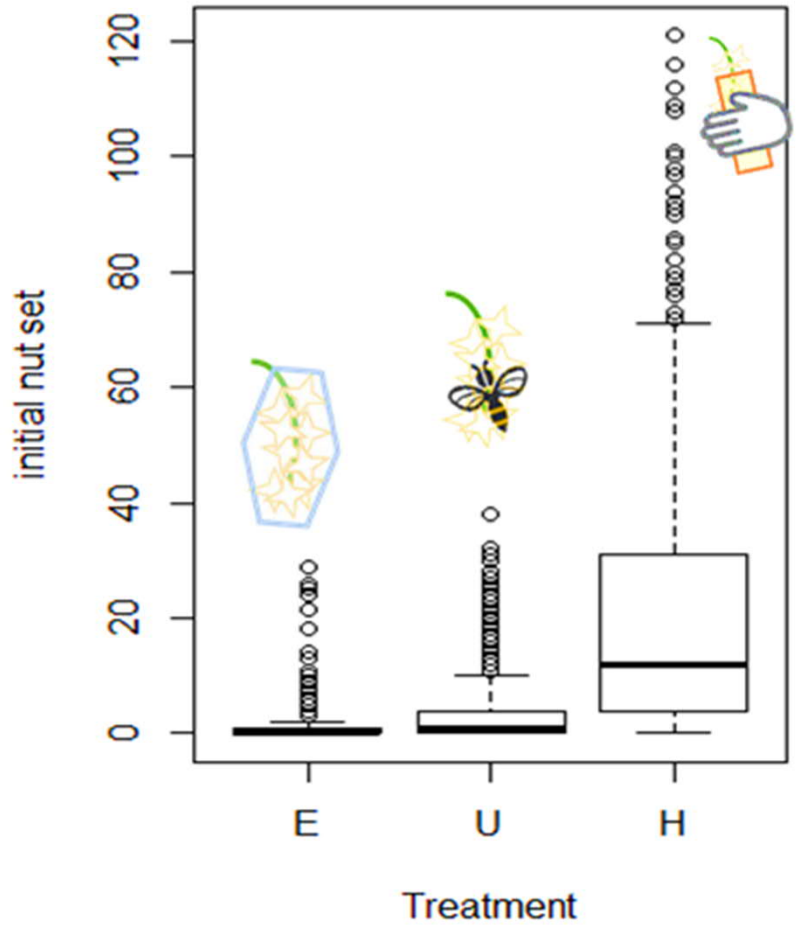
- Exclusion of large vertebrates through cages around macadamia trees
- Exclusion aimed at bats and birds (biocontrol)
- Effects on crop raiding species (monkeys)
- Species richness, diversity and activity assessed through monthly acoustic monitoring and camera traps
- Analysis of yield and nut quality (Feb. -> May 2020)

Key activity so far

Orchards – pollination service

- Macadamia pollination
  - Monitoring of flower visitors
  - Pollinator exclusion and hand pollination (July -> September 2019)

  - Hardly any nuts are formed after pollinator exclusion, but significantly more nuts are formed after pollination by animals/insects and a significantly larger initial nut set after hand pollination



The initial set of nuts per inflorescence after different treatments (E: pollinator exclusion, U: open pollination, H: hand pollination)

Key activity so far

Orchards – modelling (water use & productivity)

- Physiological, soil, and weather data collection for APSIM-macadamia model development
  - Two plots x two farms: MacLands & Neuhof - various: ages, soils, topologies

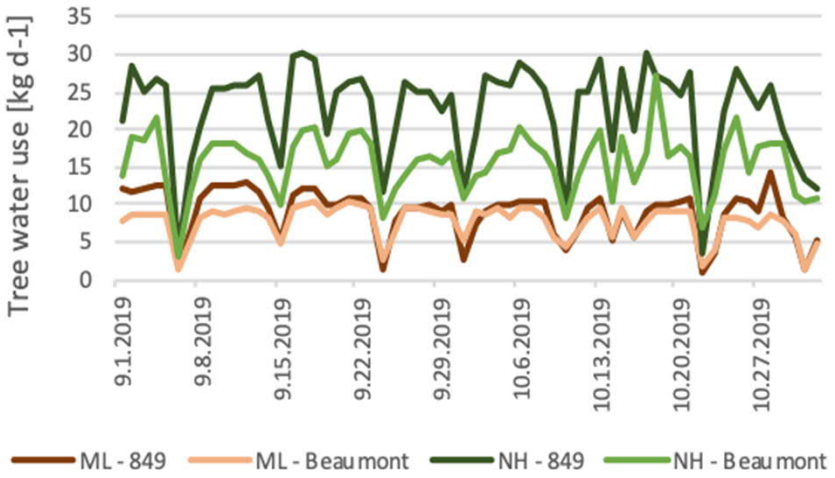
Aerial photograph of experimental sites: MacLands at 750 m a.s.l. (A) and between row photograph of Macadamia stand Neuhof at 850 m a.s.l.(B).

Key activity so far

Orchards – modelling (water use & productivity)

- Very detailed data collection: daily water use
- Water use varying depending on:
  - Genotype x
  - Environment (soil & weather) x
  - Management

Protected sap-flow sensor on a macadamia tree.

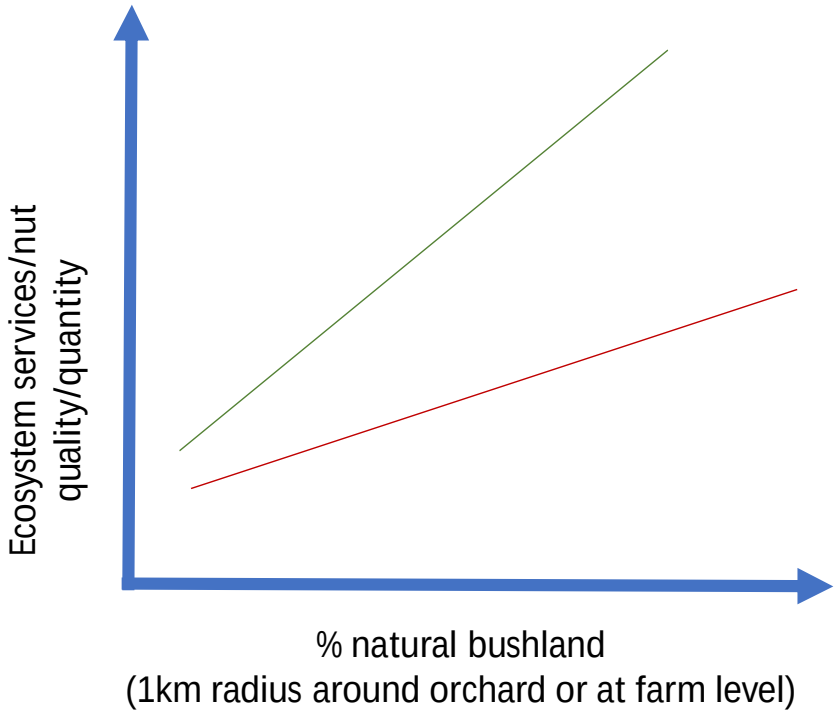


Daily water use of macadamia trees in four plantations – two plantations per site (MacLands and Neuhof).

Land management options: diversification // specialisation

Orchards

- With increasing proportions of natural bushland within the orchards increasing
  - Pollination services (red)
  - Biological control services (green)



The SALLnet project is implemented through seven work packages:

4

Economic modelling and assessment of different scenarios and risk management options for agriculture in Limpopo

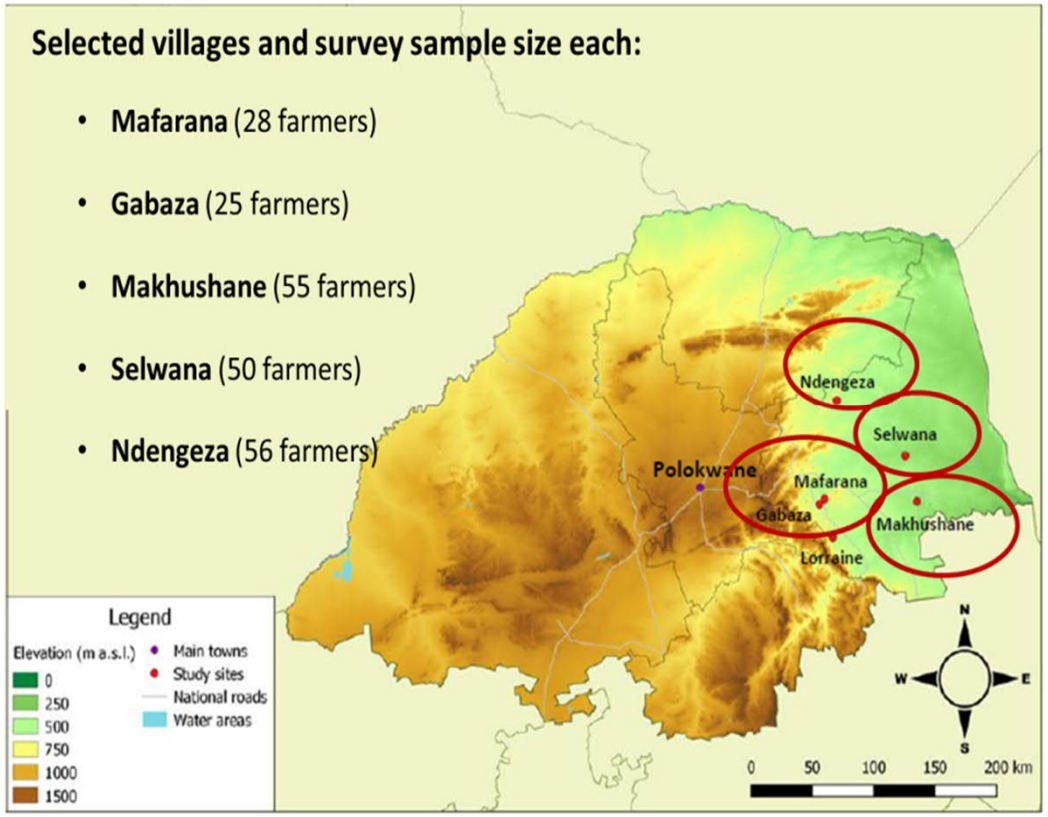
- Investigate the effects of agri-relevant risks on the production and economic performance of different farm types in the Limpopo region
- Develop farm type specific and spatially explicit risk management options
- Assess effectiveness of new risk management options under different land use and policy scenarios

Back to WP overview

Key activity so far

Economic modelling

- Socio-economic surveys to help set-up economic agent-based model: smallholder & commercial (e.g. avocado & macadamia) farmers
- Specifically:
  - Assessment of inputs, such as fertiliser, irrigation, and other investments
  - Farmer perceptions help to shape scenario development for simulation

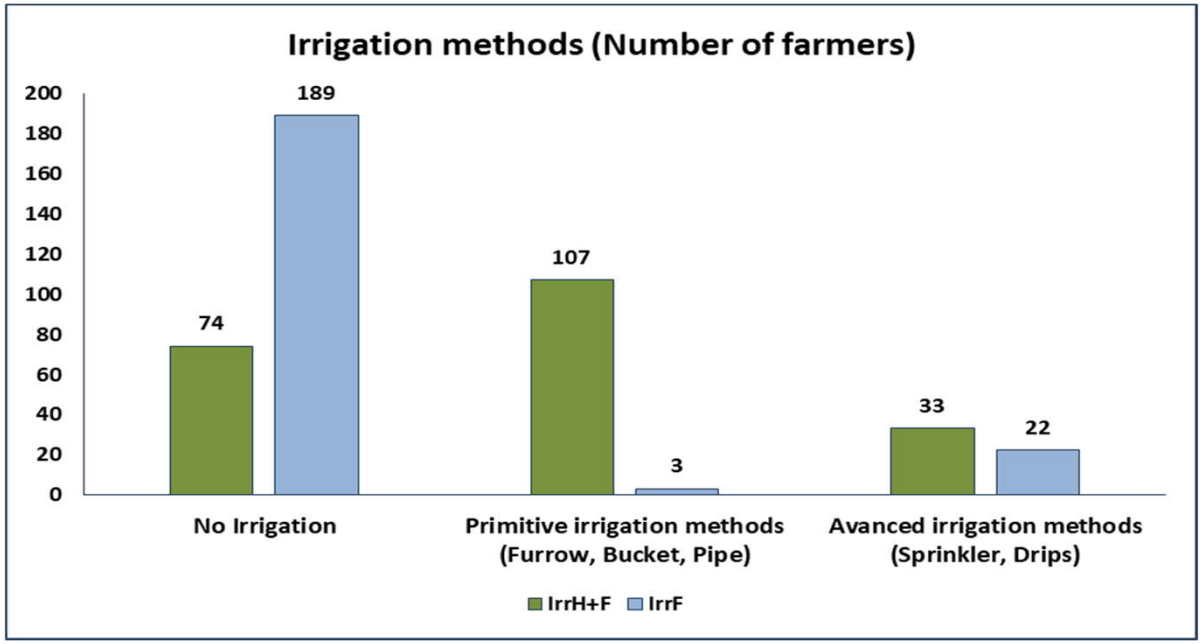


Key findings so far

Economic modelling

Smallholder farmer survey
-> Irrigation not used much among smallholder farmers
-> room for investment and improvement

- Key risks (scored):
  1. Drought
  2. Pests & diseases
  3. Storm/ wind
  4. Theft (livestock)
  5. Capital constraints



Number of smallholders in Limpopo from the survey who use different irrigation methods for the entire farm (green) and in their fields outside the villages (blue); left no active irrigation methods, middle primitive irrigation methods, right advanced irrigation methods.

Agent-based model objectives

Economic modelling

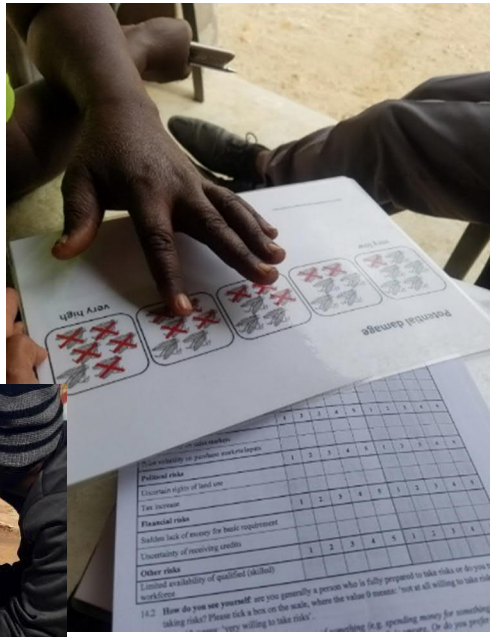
Analyse investment decisions of smallholder farmers: irrigation systems at farm and community levels

Model structure

- Farmers (agents) of various structural characteristics (e.g. efficiency, risk attitudes) try to satisfy external demand for crop production (maize)
- Decisions on cultivation based on: land size, irrigation investment
- Market intervention impacts
  - Subsidies, price regulation, water & land rights
- Agent based real option analysis of:
  - Stochastic simulations & genetic algorithms

Output

- Optimal investment trigger prices
- Sector & farm level output volumes



Model scenario questions

Economic modelling

- How efficient are different farm types in Limpopo and to what degree is the presence of agri-relevant risks the reason for efficiency shortfalls?
- Can risk management options be developed to improve long-term efficiency of farms and/ or resilience under different land use management scenarios?
- How can the effectiveness of different policy options to promote potential land use management scenarios and agricultural risk management be measured and, through this, spatially explicit policy implications derived?

The SALLnet project is implemented through seven work packages:

5

Effect of climate change and management interventions on ecosystem services of arable land and macadamia plantations in Limpopo region

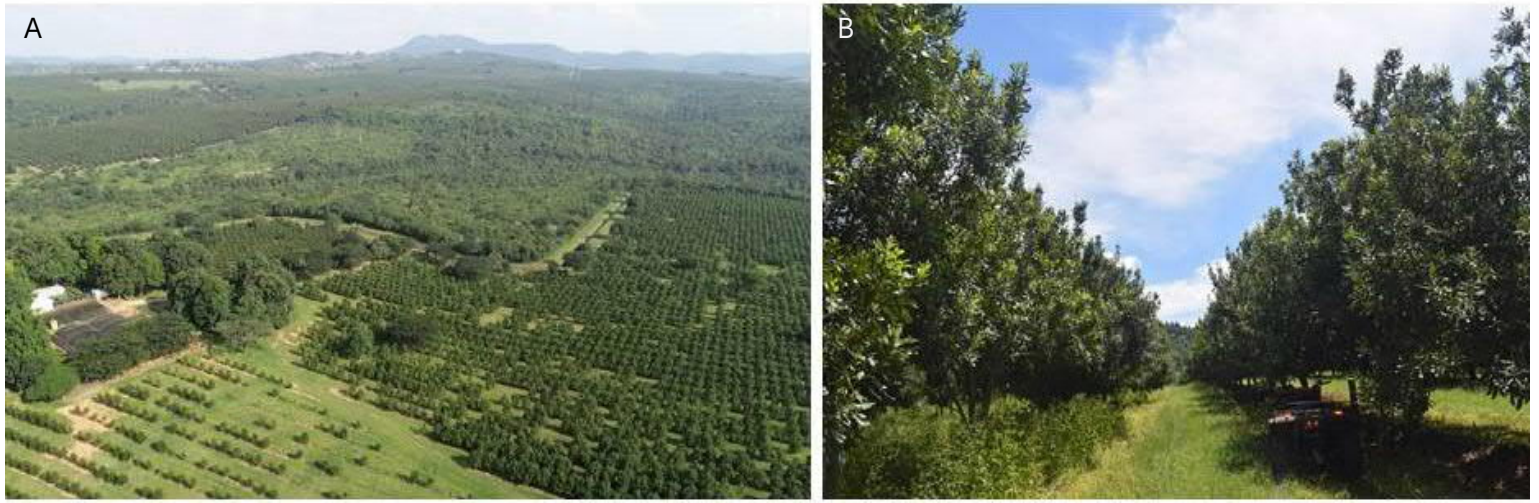
- Explore how intensification and diversification in arable land and orchards potentially impact important ecosystem functions (e.g. carbon sequestration, productivity)
- Upscale findings from farms and village settings to a regional level
- Consider current and possible future climate conditions

Back to WP overview

Key activity so far

Ecosystem service change: arable land and macadamia plantations

- Physiological, soil, and weather data collection for APSIM-macadamia model development
- Two plots x two farms: MacLands & Neuhof - various: ages, soils, topologies



Aerial photograph of experimental sites: MacLands at 750 m a.s.l. (A) and between row photograph of Macadamia stand Neuhof at 850 m a.s.l.(B).

Key activity so far

Ecosystem service change: arable land and macadamia plantations

- S.holder maize farmers far from achieving pot. yields
- Climate change projections: low and vari. yields to be exacerbated, calling for adaptation
- Culivar choice, balanced, site-specific management to reduce yield gaps and improve crop system resilience
- We study various sustainable intensification (SI) options in the Limpopo, Province, Republic of South Africa (RSA)
- To what extent can combining irrigation, fertilier & cultivar choice reduce risk in southern Africa?

VARIABLE		LEVELS				
Sites (2)		Syferkuil (Polokwane)			Venda (Thohoyandou)	
Baseline periods (2)		1985-2010 (Observed weather data)			1985-2010 (Observed weather data)	
Crop (1)		Maize				
Cultivars (5)		East Timor	Katumani	B130	B120	Hybrid614
Soils (3)		Syferkuil		Univen		Smallholder sample sites
Water treatments (3)		Rainfed		Deficit irrigation		Full irrigation
Fertilisation treatments (4)	Amounts	0 kg/ha	50 kg/ha	90 kg/ha	180 kg/ha	
	Splits	Sowing & top-dress				
Future climate	Period(s)	2011-2070				
	RCPs	4.5		8.5		
Models		APSIM				

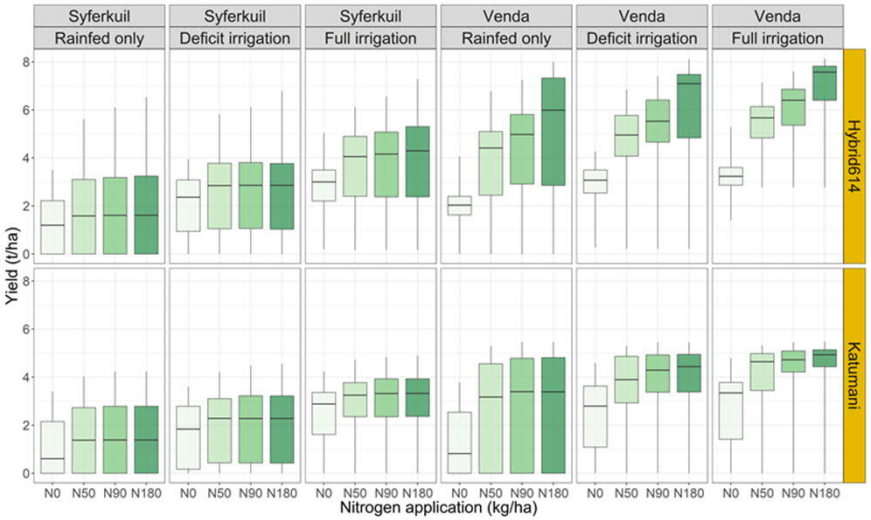
Simulation set-up including: sites, climate periods, cultivars tested, soil / sites, water and fertiliser treatments.

Nelson et al., (in prep. - not for citation)

Key activity so far

Ecosystem service change: arable land and macadamia plantations

- Model results from two contrasting sites show combination of sustainable intensification (SI) options reduced yield variability. Deficit irrigation, and N 50 kg/ha reduced maize production risks & increased grain benefits – additional irrigation and N lead to limited further yield gain
- Combinations of SI options led to cultivar specific thresholds at which maize production risks can be minimised
- Such thresholds should be identified and promoted for site-specific scenarios.
- There is potential for SI maize production - SI indicators more affected by SI options than projected climate



Simulated maize yields (t/ha), two cultivars: Hybrid 614 (late maturing, high yielding); and Katumani (early maturing, drought resistant); Syferkuil (PAWC = 55 mm) & Venda (PAWC = 143 mm); irrigation: rainfed, deficit & full; N application (0, 50, 90, and 180 kg/ha mineral N as urea); applied for projected (GFDL-E2M2M, RCP 8.5) weather data (2011-2070). The three horizontal lines indicate the 75th percentile (upper), median (solid line across boxes) and 25th percentile yield (lower). Upper and lower whiskers show the maximum and minimum values respectively.

Nelson et al., (in prep. - not for citation)

Key activity so far

Ecosystem service change: arable land and macadamia plantations

Arable field experimentation, University of Limpopo, Venda

Experiment topic Thabelo Musumuvhi PhD candidate
Cowpea-maize rotation; continous maize effect on productivity, residue quality: 2018-19 & 2019-20

Experiment topic Sophy Thaba MSc candidate
Effect of lablab varieties in rotations with maize on yield, soil water content and N: 2018-19 & 2019-20

Experiment topic Rose Ntakadzeni MSc candidate
Peanut diversity for CC resilience: 2018-19 & 2019-20

Lablab-maize crop stand w bird protection net.

Peanut field experimental plots.

Key activity so far

Ecosystem service change: arable land and macadamia plantations

Arable field experimentation, University of Limpopo, Polokwane

Experiment topic Elisabeth Mogale PhD candidate
Cowpea-sorghum intercropping as a climate-smart option for improved productivity; two sites: 2018-19 & 2019-20

Overall
Field experimental data to be used to calibrate and validate the crop model APSIM

Detailed soil, climate, and plant physological parameters therefore taken for all experiments

Sorghum-cowpea intercrops, Ofcolaco (a) und Syferkuil (b), 2018-19.

The SALLnet project is implemented through seven work packages:

6

Climate change, land use and nitrogen dynamics in rangelands/ shrubs

- Project impacts of biophysical (climate, CO_2, nitrogen) and socio-ecological factors on the provision of multiple ecosystem services and functions
- Coupling aDGVM & N-model
- Use of improved vegetation model aDGVM2
- Model simulation for an integrated multiple-risk assessment to develop guidelines for decision-making

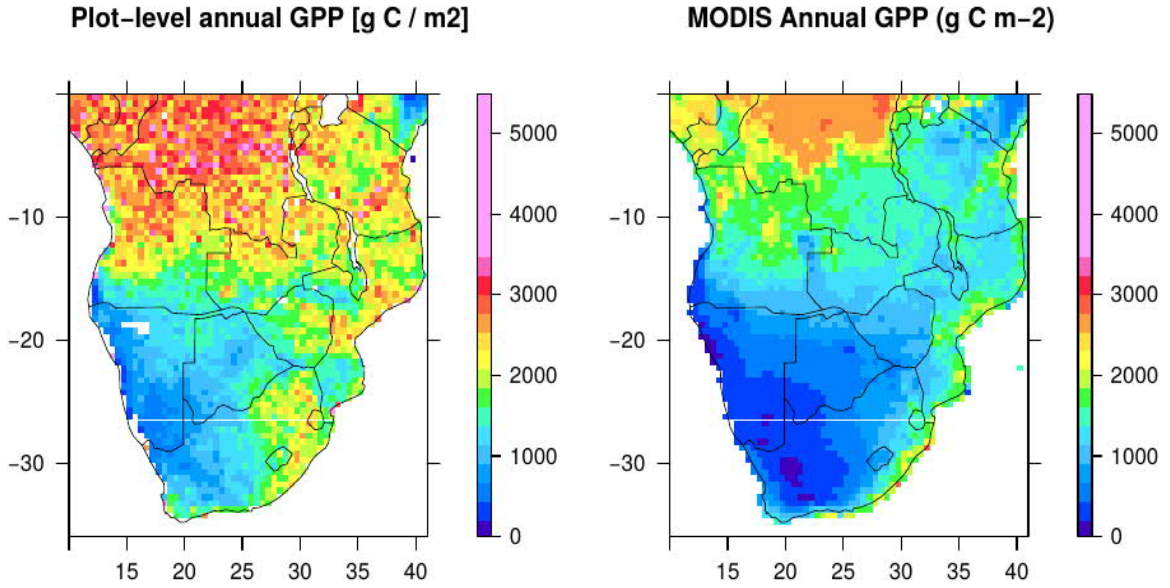
Adaptive Dynamic Vegetation Modeling

Back to WP overview

Key activity so far

CC land use & N dynamics in range/ shrublands

- Numerous simulations for southern Africa carried out with the improved model and with climate data from model ensembles
- Model results compared with various benchmarking data sets to ensure thorough validation

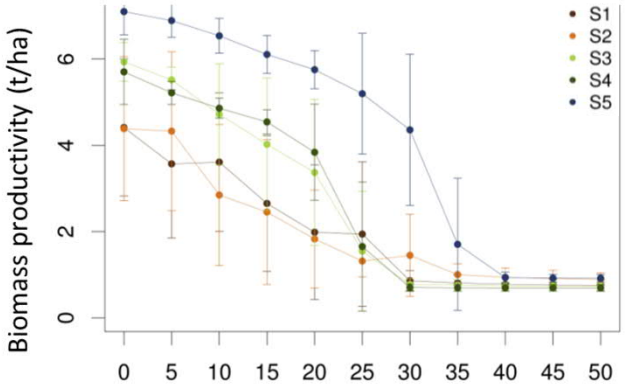


Annual gross primary production (GPP) simulated with aDGVM2 (left) based on AgMERRA climate input data compared to the average annual GPP derived from MODIS (right)

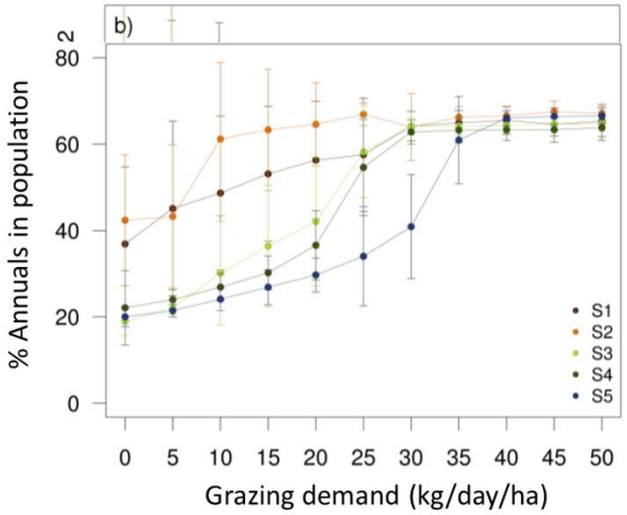
Pfeiffer et al. (2019)
Ecological economics

Legend: Aridity scale
S1 (most arid) – S5 (most humid)

a



b

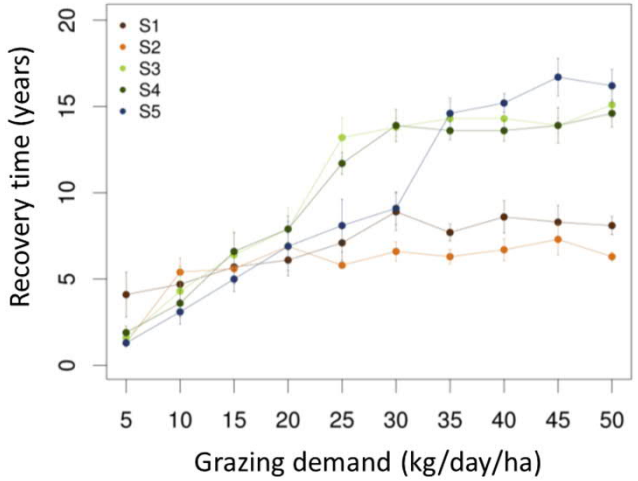


aDGVM2 model was updated to distinguish between annual and perennial grasses based on traits

Increasing grazing intensity reduced productivity (a) and perennial grass abundance (b) - annual grasses less palatable than perannial grasses.
Taking care of perannial grass % in population key!

Heavy grazing & drought: similar effects on simulated grass communities.
Vegetation recovery after degradation possible but slow & site-specific (c)

c



Pfeiffer et al. (2019)
Ecological economics

Work of WP6 is best seen through the following, which highlight key developments of rangeland vegetation model aDGVM within SALLnet

How - overview

Linking model output: Limpopo case study

The SALLnet project is implemented through seven work packages:

7

Integration & Synthesis

- Integrate the results of work packages 1-6
- Compliment data collection to ensure overarching project goals are fulfilled
- Develop integrative framework for data synthesis
- Include local scientists and stakeholders in the design and development of model questions / simulation scenarios
- Train local scientists and stakeholders
- Support knowledge-based strategic and practical land-use decisions

Back to WP overview

Key activity so far

Integration & synthesis

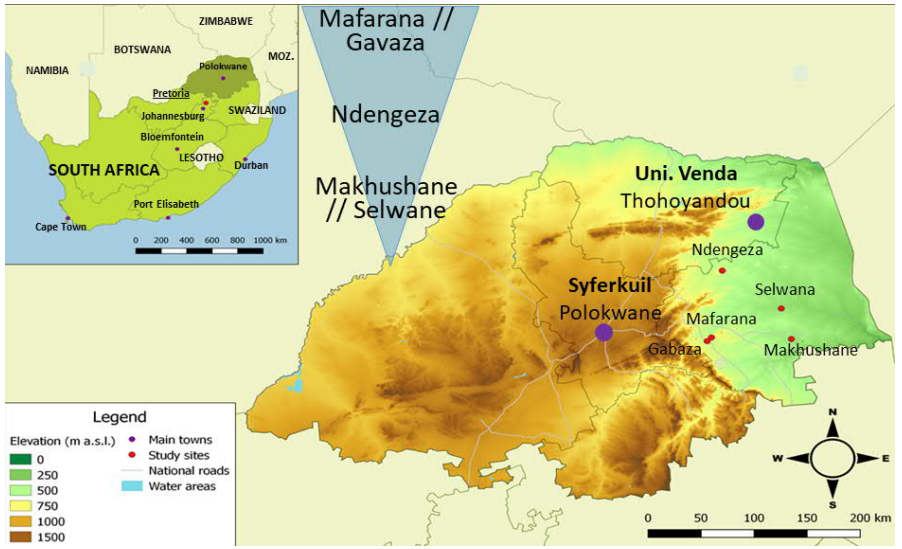
Groud truthing to support model input
April – May 2019 across climate gradient

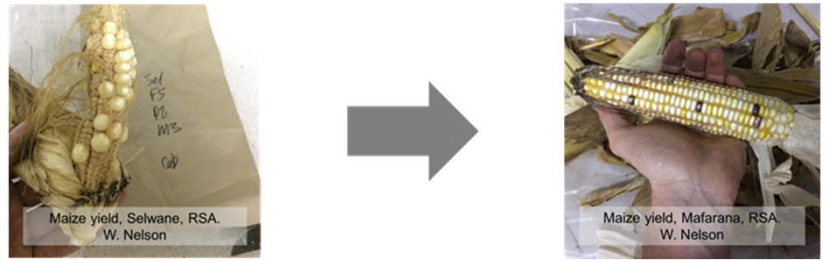
Soil (geo-referenced) cores from each harvest site: 0-30, 30-60, 60-90 cm: OC, total N

Livestock herd management captured as well as grazing intensity

Crop harvest (maize & legumes) survey conducted, including:
- 2 x 1m2 maize stands (geo-referenced)
- Plant observations: leaf no., height, cob no. & assessment
- Harvests: biomass & cobs / grain; dried & weighed
- Management survey: e.g. sowing date, weeding intensity, fert. …

Nelson et al., 2020: iCROPM conference contribution. How much can irrigation reduce climate-induced risk to sustainably intensifying maize production in southern Africa?





Climate gradient (precipitation) map of study area & maize yield survey examples.

Key activity so far

Integration & synthesis

This work packages puts a great amount of emphasis on stakeholder integration, through:

- Days of stakeholder interaction have been included / are planned for each annual project meeting
- Facilitation of stakeholder integration throughout each work package

Stakeholders are the target ‘end-users‘ of an integrative framework / prototype of an integrative analysis platform

Stakeholder discussion as part of the September 2019 annual workshop. Topic: resource management options

Work of WP7 (integration & synthesis) is best seen through the following, which highlight linkages between model output and the agricultural systems studied within SALLnet

How - overview

Linking model output: Limpopo case study