Semi-arid Savanna rangeland degradation and management: a landscape scale model

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Introduction

- Extensive grazing by *livestock and/or game* is the most common and widespread land-use form in arid and semi-arid savanna rangelands in Southern Africa
- Grazing causes changes in the *vegetation structure* and *composition*
- Land degradation processes include *woody encroachment, loss in vegetation cover* and *soil erosion*
- Most work is concentrated around *short-term* responses to the changes occurring at *community* (e.g. cover, richness, floristic composition) or *individual-levels* (e.g. individual growth-rate)

Introduction

Appropriate assessment of sustainable grazing management in rangelands is difficult, mainly due to 4 reasons:

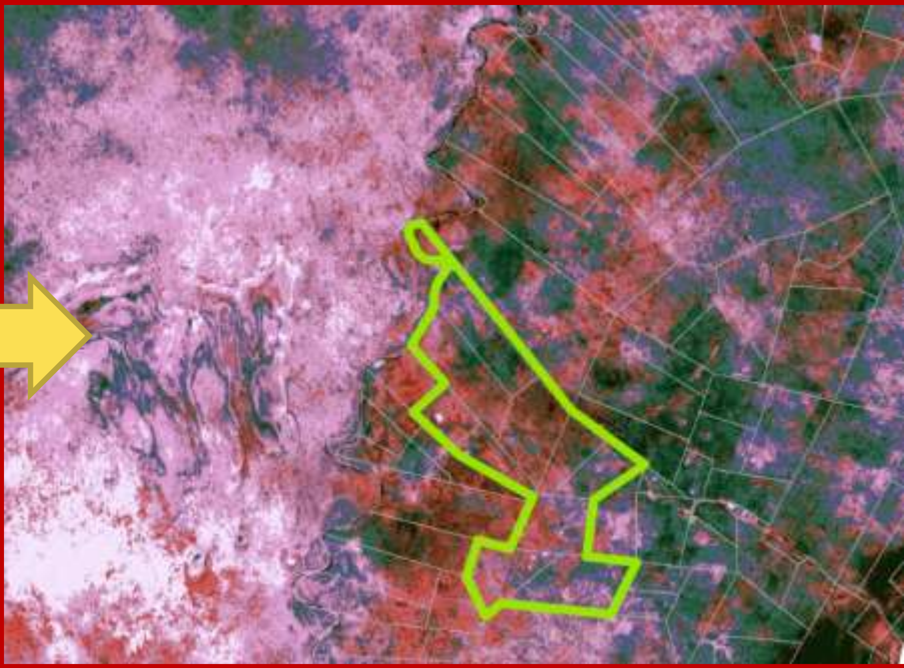
a) mismatch between time scales for observation and time scales of vegetation change;
b) differences in the relevant spatial scales;
c) complex non-equilibrium rangeland dynamics; and
d) potential conflicts between resource conservation and production.

Purpose

- Use data from individual plant dynamics on micro-scale scale and up-scale it to landscape and regional scales

- Understand how different management measures
  - lead to overall recovery or degradation of the vegetation condition at the landscape scale, and
  - affect the condition of the animal herds

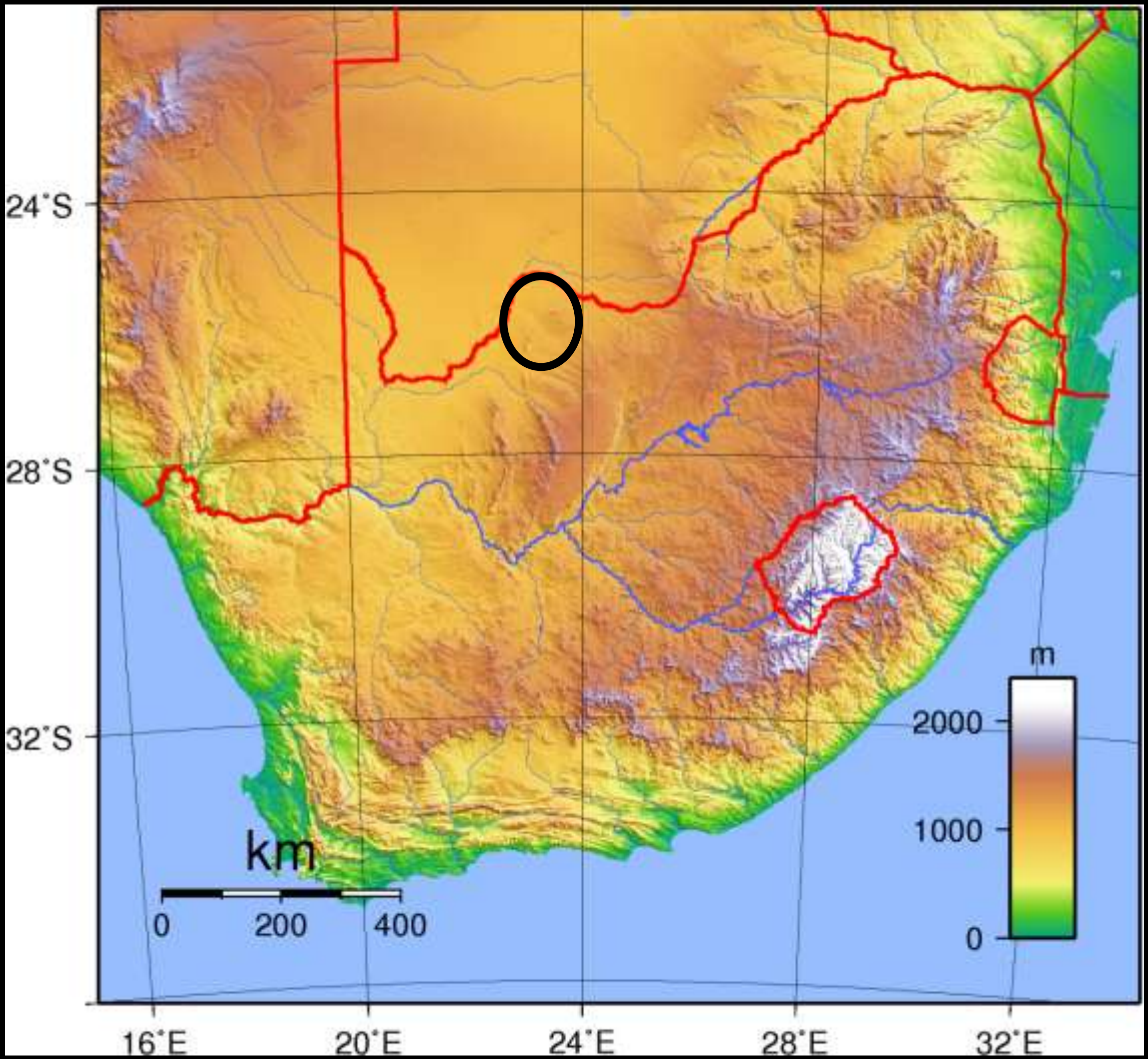
Plant (micro-scale) Landscape (macro-scale)



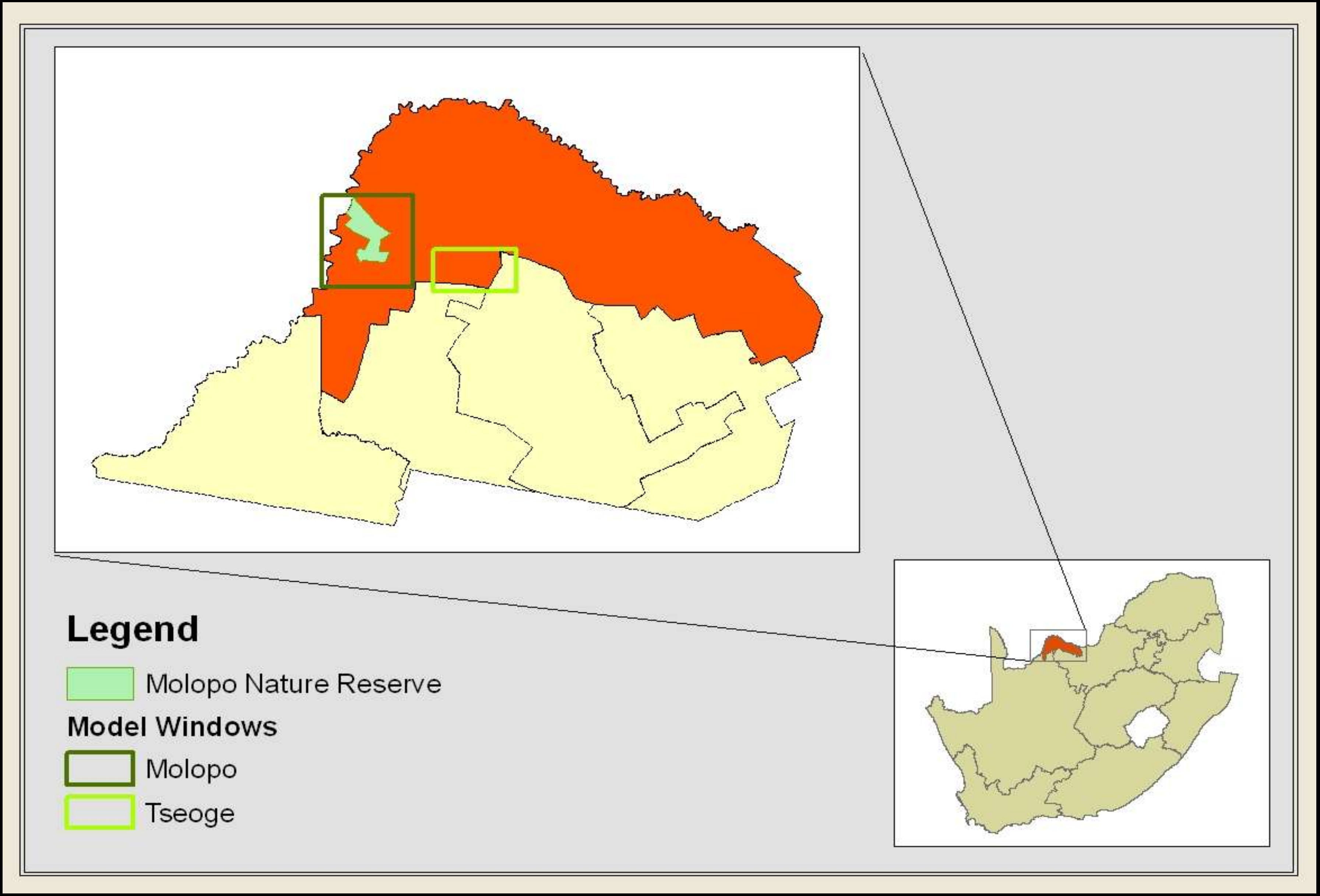
- Fenced and not fenced plots
- Proportion of rainfall and biomass production
- Effect of grazing on vegetation dynamics
- Use as benchmark sites for the model

Study area

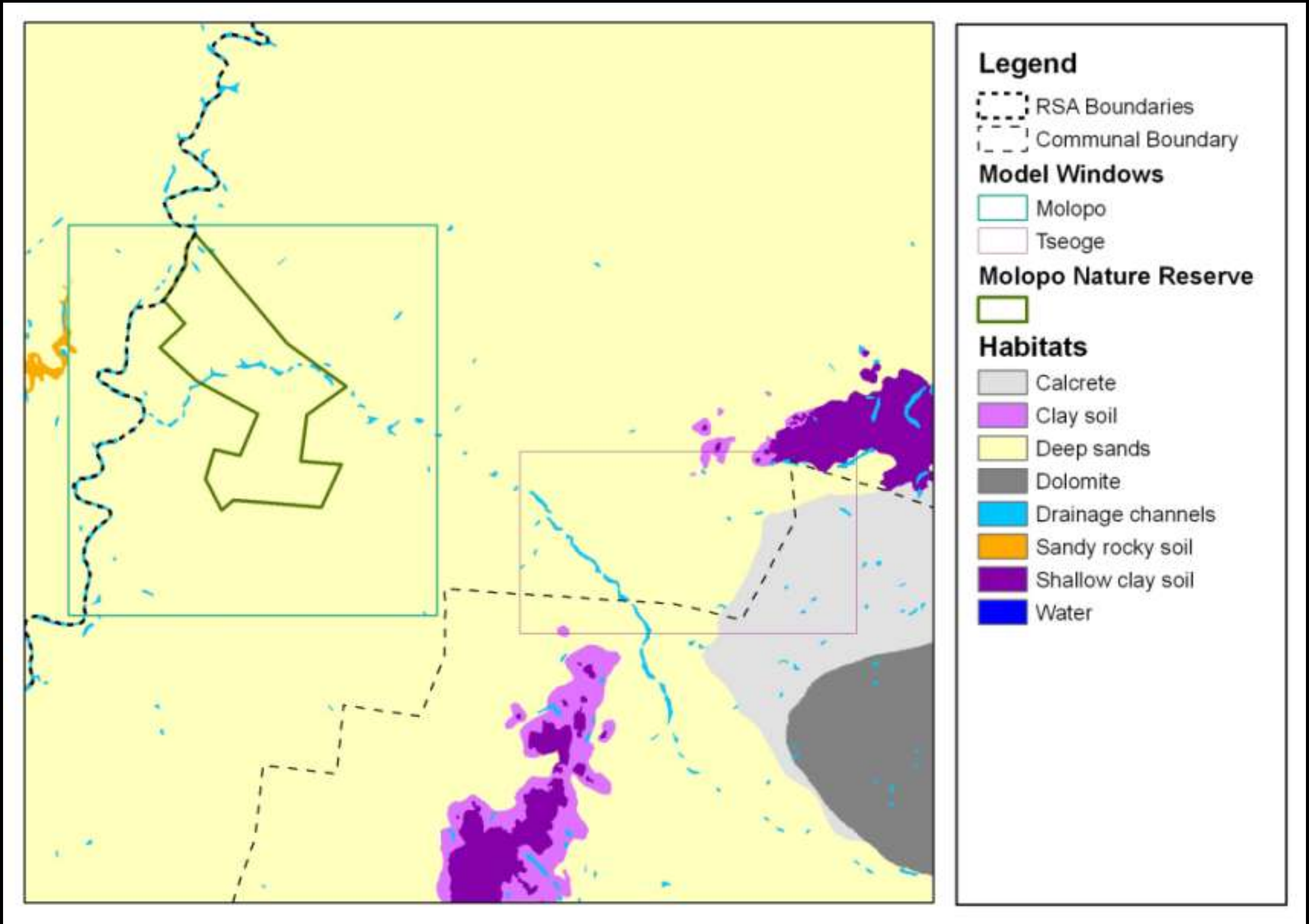
- Molopo Nature Reserve at Botswana border
- Surrounding commercial and communal farmland
- Only deep sandy soils
- Uniform rainfall zone (approx. 300mm p.a.)



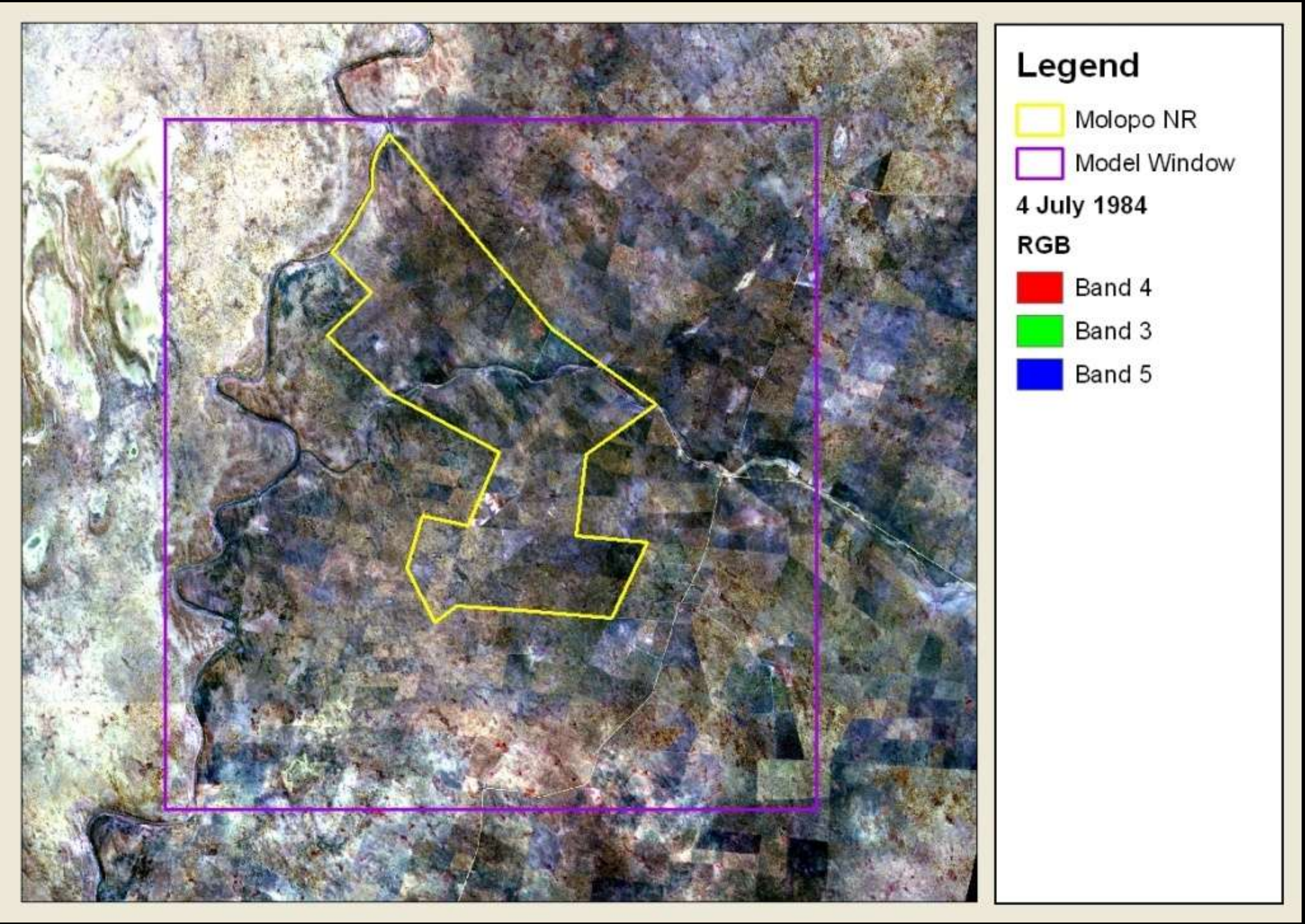
Study sites



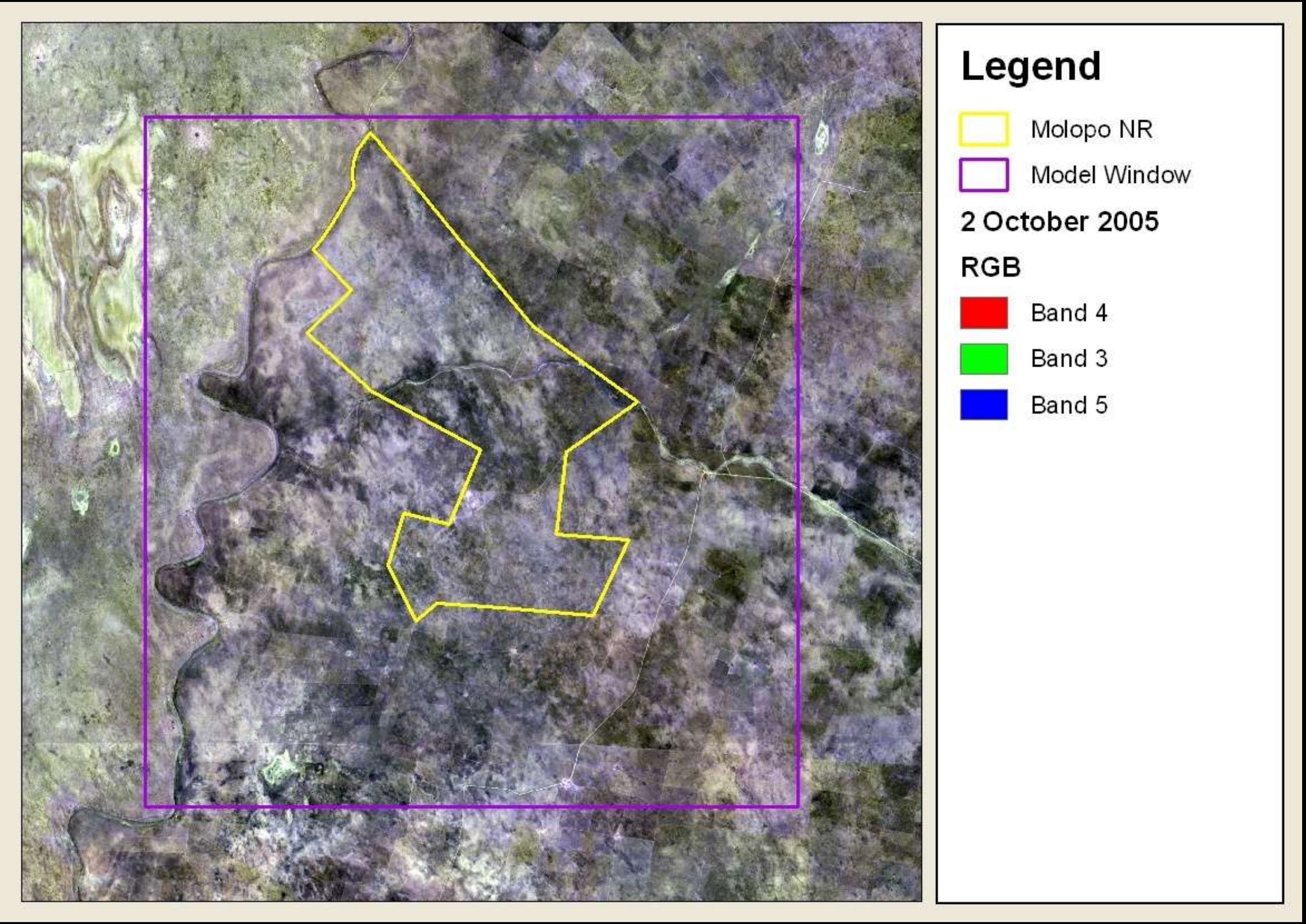
Study sites


Legend
RSA Boundaries
Communal Boundary
Model Windows
Molopo
Tseoge
Molopo Nature Reserve
Habitats
Calcrete
Clay soil
Deep sands
Dolomite
Drainage channels
Sandy rocky soil
Shallow clay soil
Water

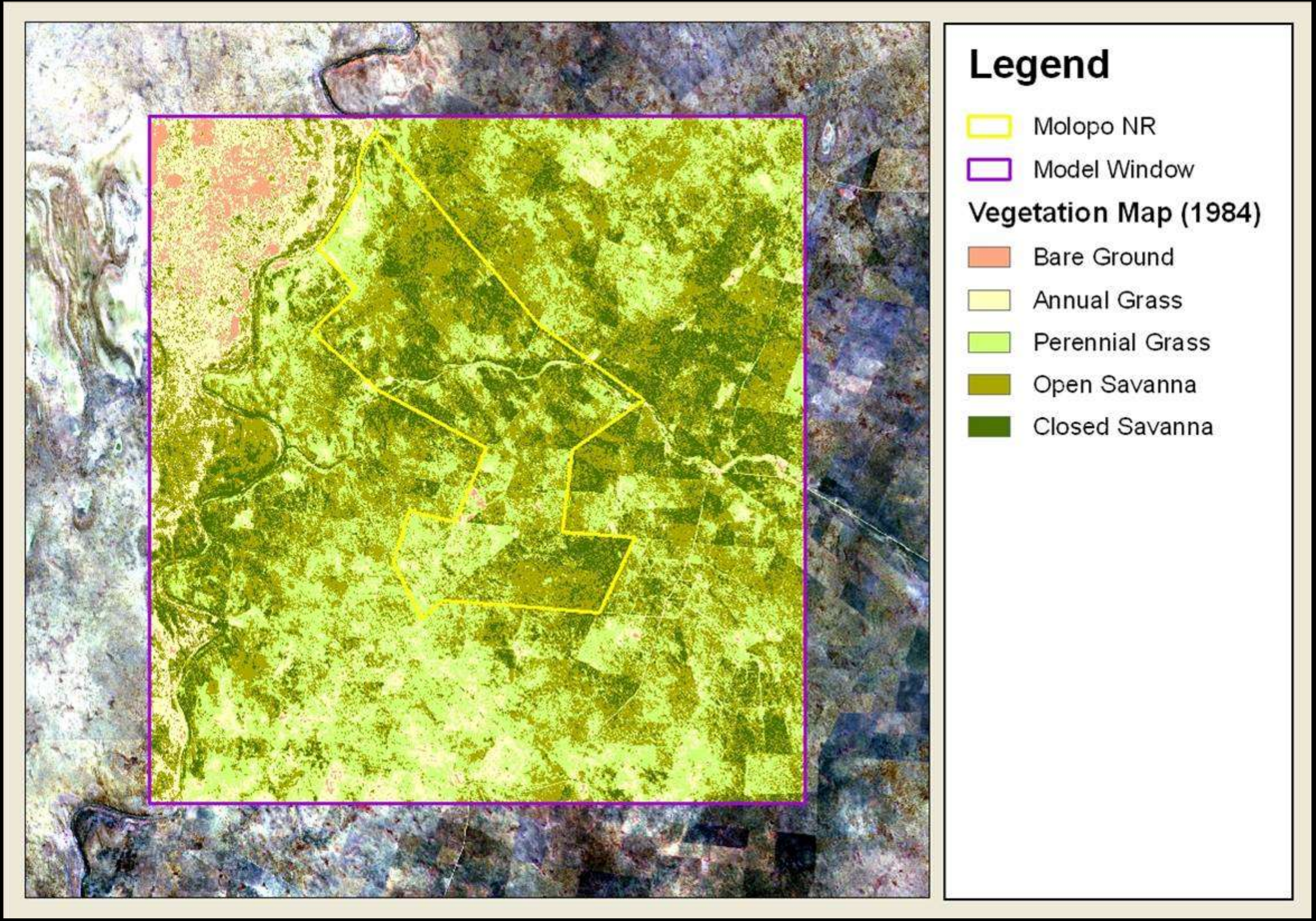
Landsat : 1984 – Molopo NR and surrounding areas



Landsat : 2005 – Molopo NR and surrounding areas



Landsat image : 1984 - Vegetation



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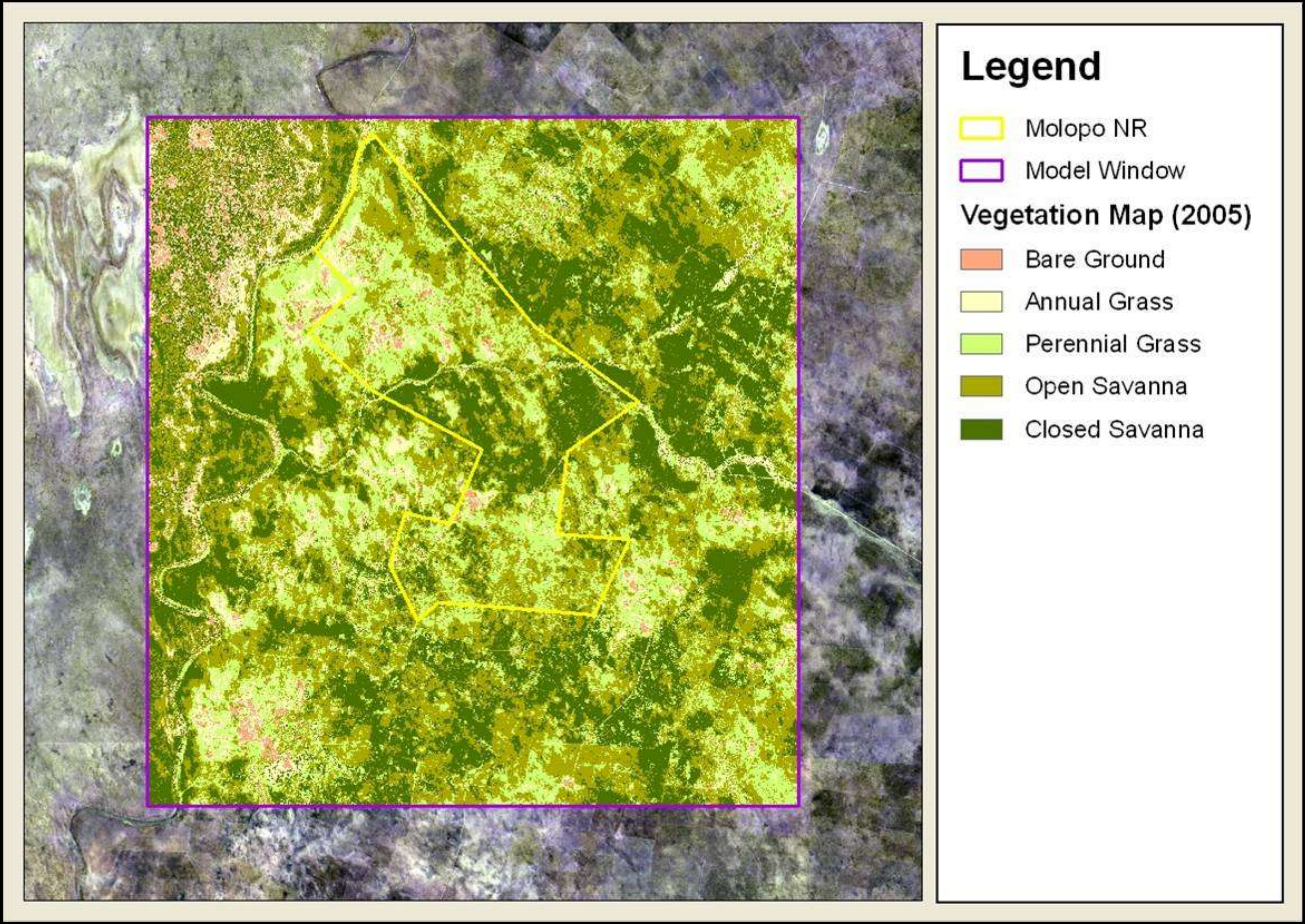

Model parameterization

- Ground-based data with a hierarchy of three sets of variables described by the *environment, vegetation and management*
- Data will be compared to classified LANDSAT 4 and 5, SPOT 5 images and NDVI data derived from NOAA (AVHRR), and MODIS, covering different temporal and spatial scales from 1984 till 2007
- Spatio-temporal dynamics of the vegetation due to impacts of
  - climatic conditions (temperature and precipitation),
  - soil moisture,
  - management (fire, wood removal, grazing/browsing),
  - demographic and phenological aspects of dominant plant types (unpalatable, palatable perennial and annual grasses and woody plants).

Spatial Extent

- Resolution
  - Input: 30m x 30m (Landsat pixel sizes)
  - Output: 90m x 90m
- Dimension
  - Approx. 512 x 512 cells (~ 25,000 ha)

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Temporal Extent

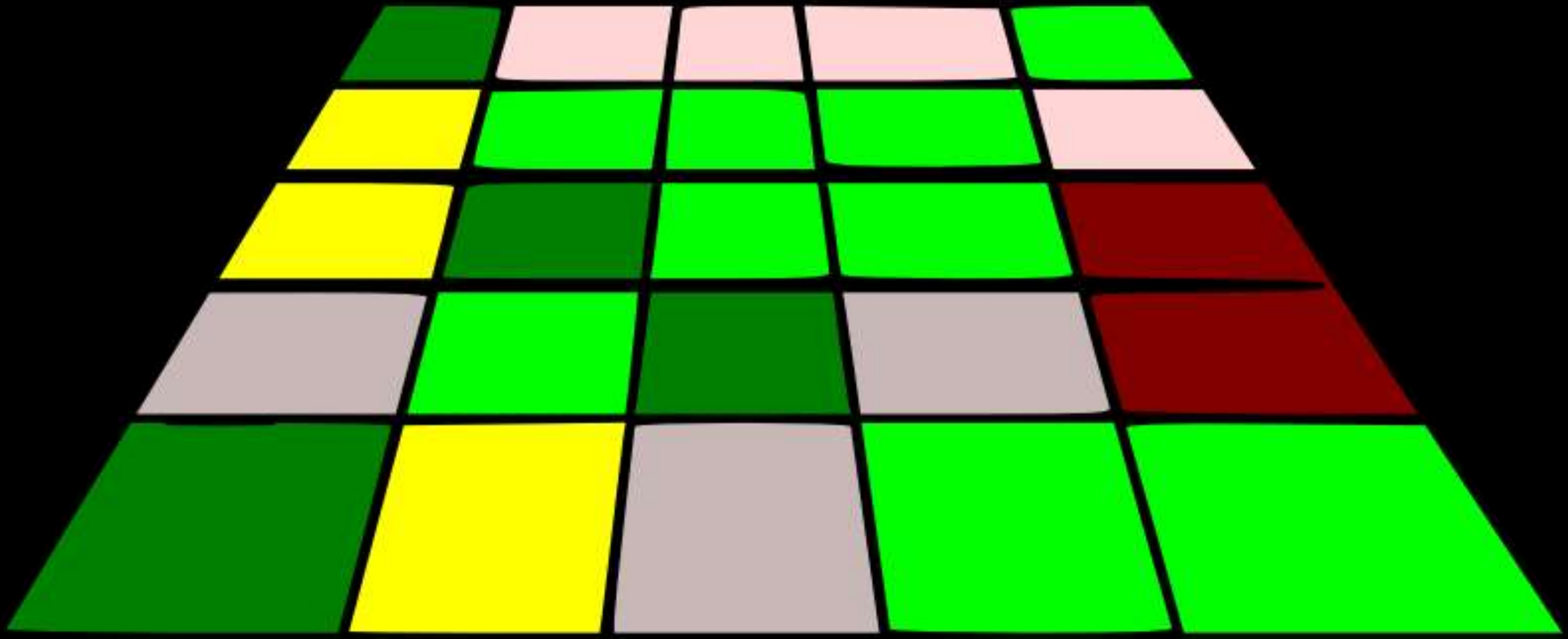
- Resolution - Monthly time steps
- Daily rainfall
- Management - annual time steps
- Dimension - usually 20 – 25 years

Modeling Approach

- Rule-based model
  - No complex differential equations
- Driven by sub-models
  - Like growth, grazing, fire ...
- Interaction of sub-model dynamics will lead to emergent effects in overall dynamics

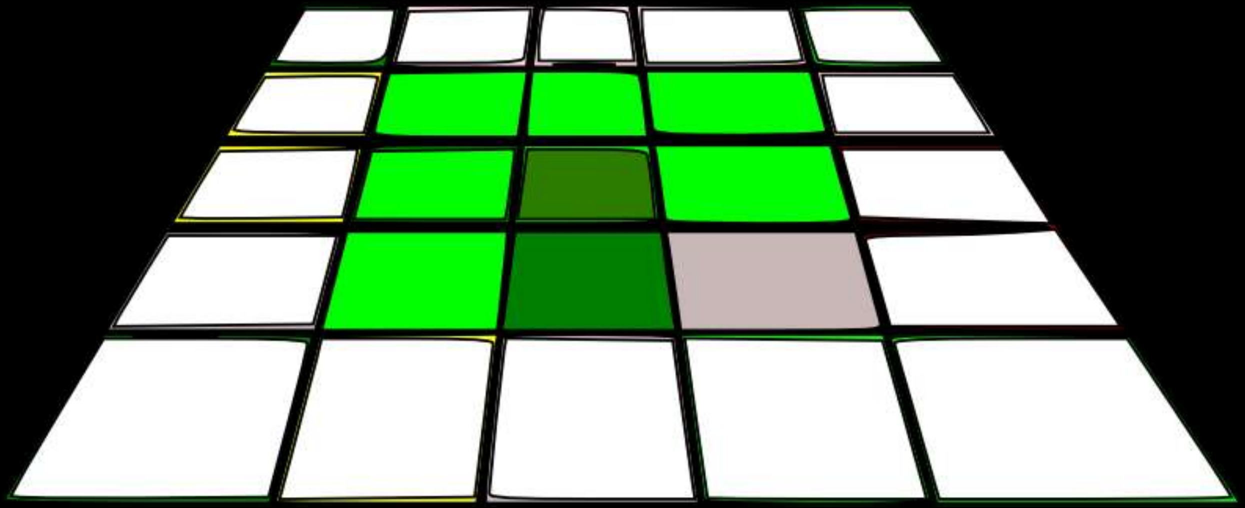
Modeling Approach

- Cellular automaton model – grid based
- Spatial explicit approach

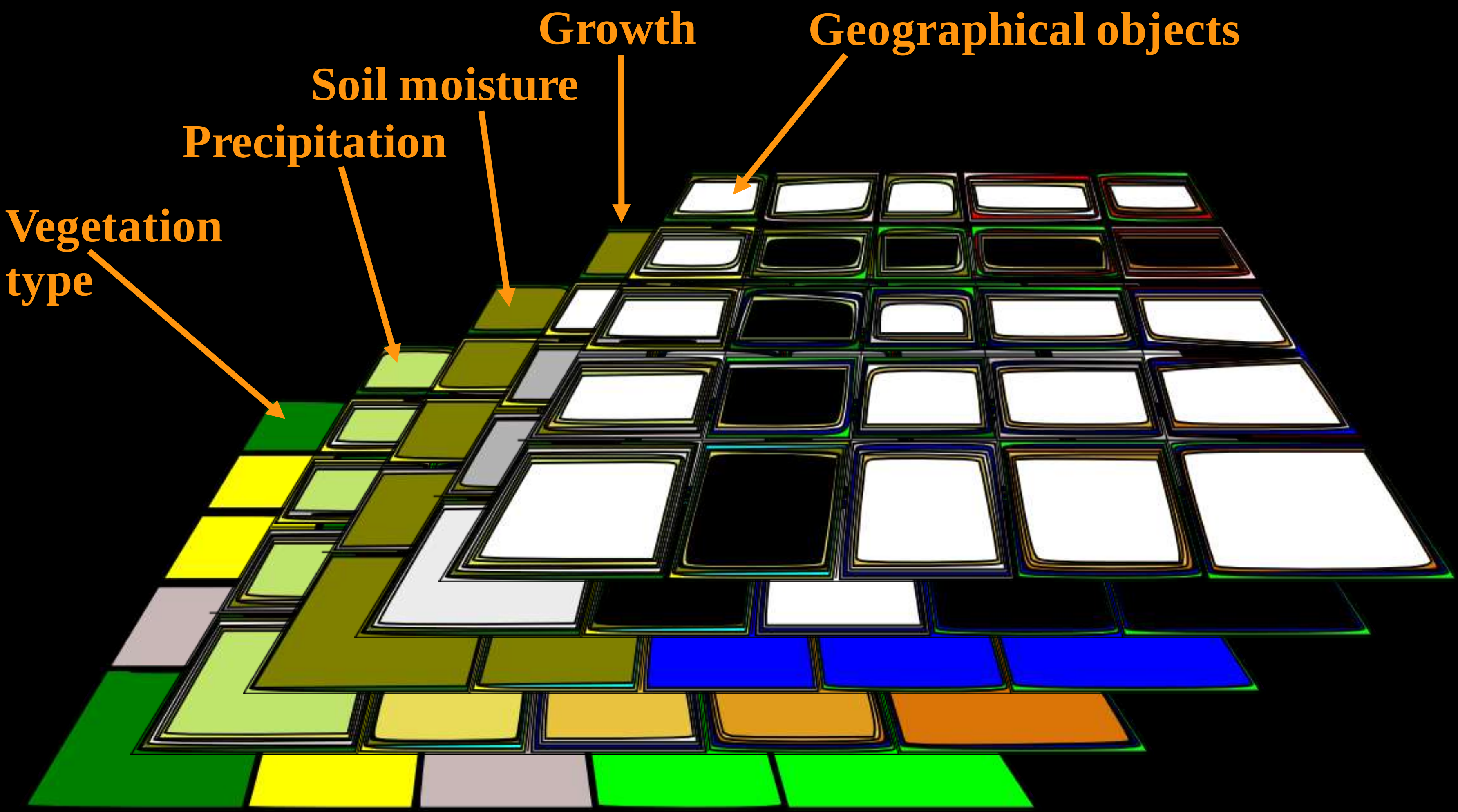


Spatial Transition Rules

- If cell is dominated by an other vegetation type
- Considering annual or longer time step

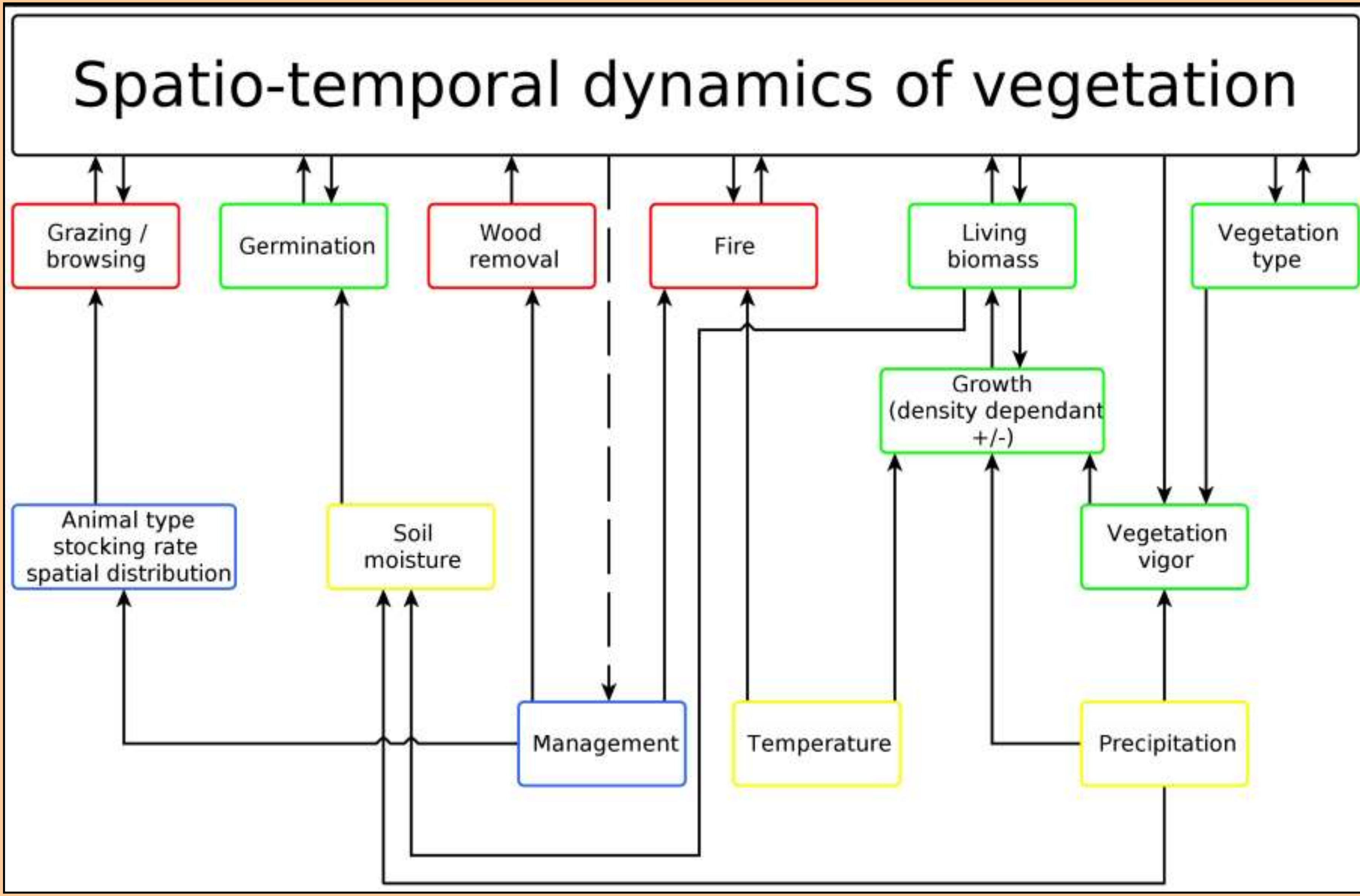


Cellular Layers

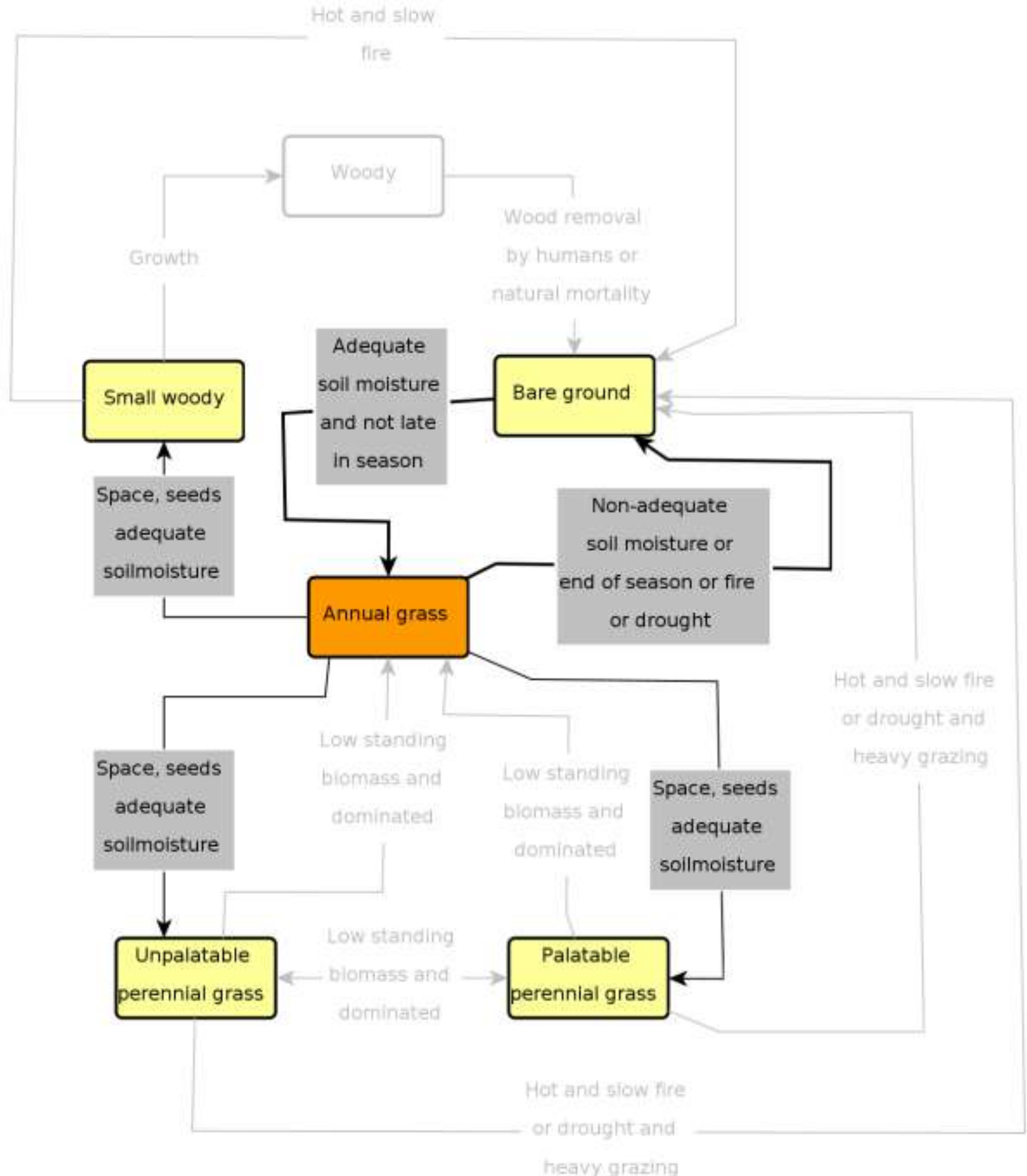


Vegetation transition

- Changes - cause degradation or recreation.
- Transition can either be a "temporal" (monthly) or a "spatial" (annual) procedure depending on the rules and requirements (environment) set for each vegetation type in the model that will lead to the "switching-on" (establishment) or "switching-off" (non-survival) of the vegetation type.



Spatio-temporal dynamics of vegetation
Grazing / browsing
Germination
Wood removal
Fire
Living biomass
Vegetation type
Growth (density dependant +/-)
Animal type stocking rate spatial distribution
Soil moisture
Vegetation vigor
Management
Temperature
Precipitation


Hot and slow fire
Woody
Growth
Wood removal by humans or natural mortality
Adequate soil moisture and not late in season
Small woody
Bare ground
Space, seeds adequate soilmoisture
Non-adequate soil moisture or end of season or fire or drought
Annual grass
Hot and slow fire or drought and heavy grazing
Low standing biomass and dominated
Low standing biomass and dominated
Space, seeds adequate soilmoisture
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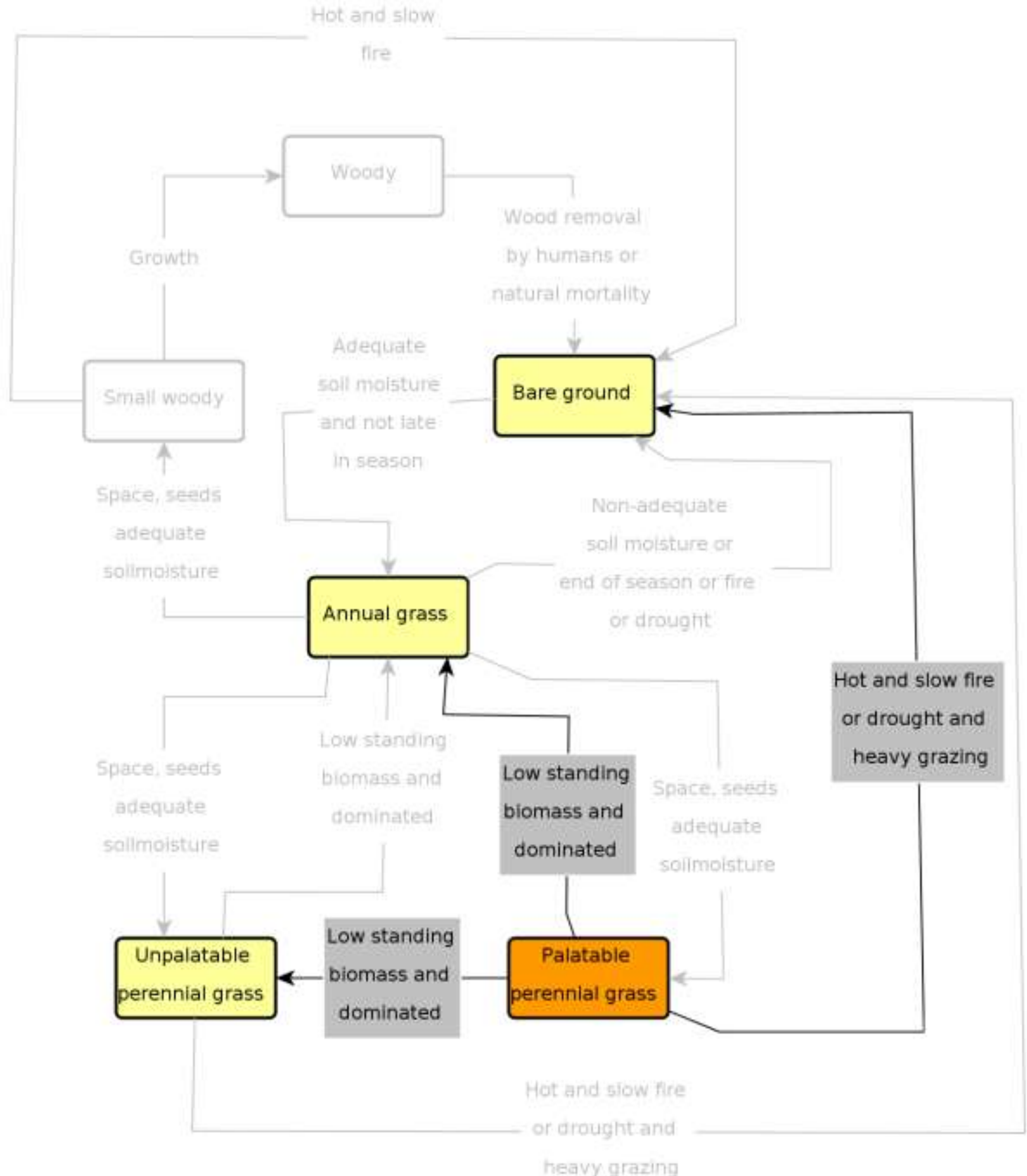
Unpalatable perennial grass
Low standing biomass and dominated
Palatable perennial grass
Hot and slow fire or drought and heavy grazing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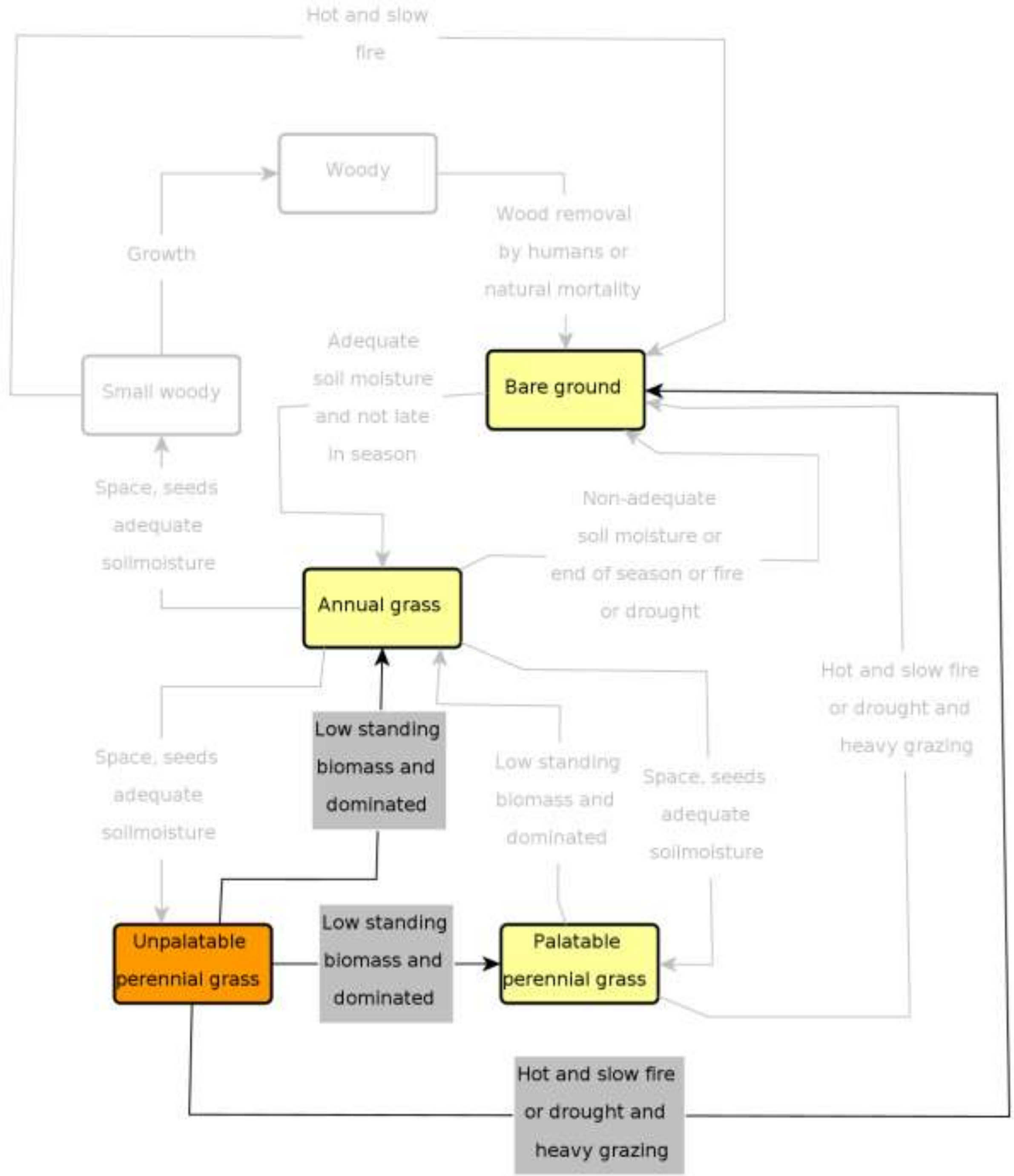
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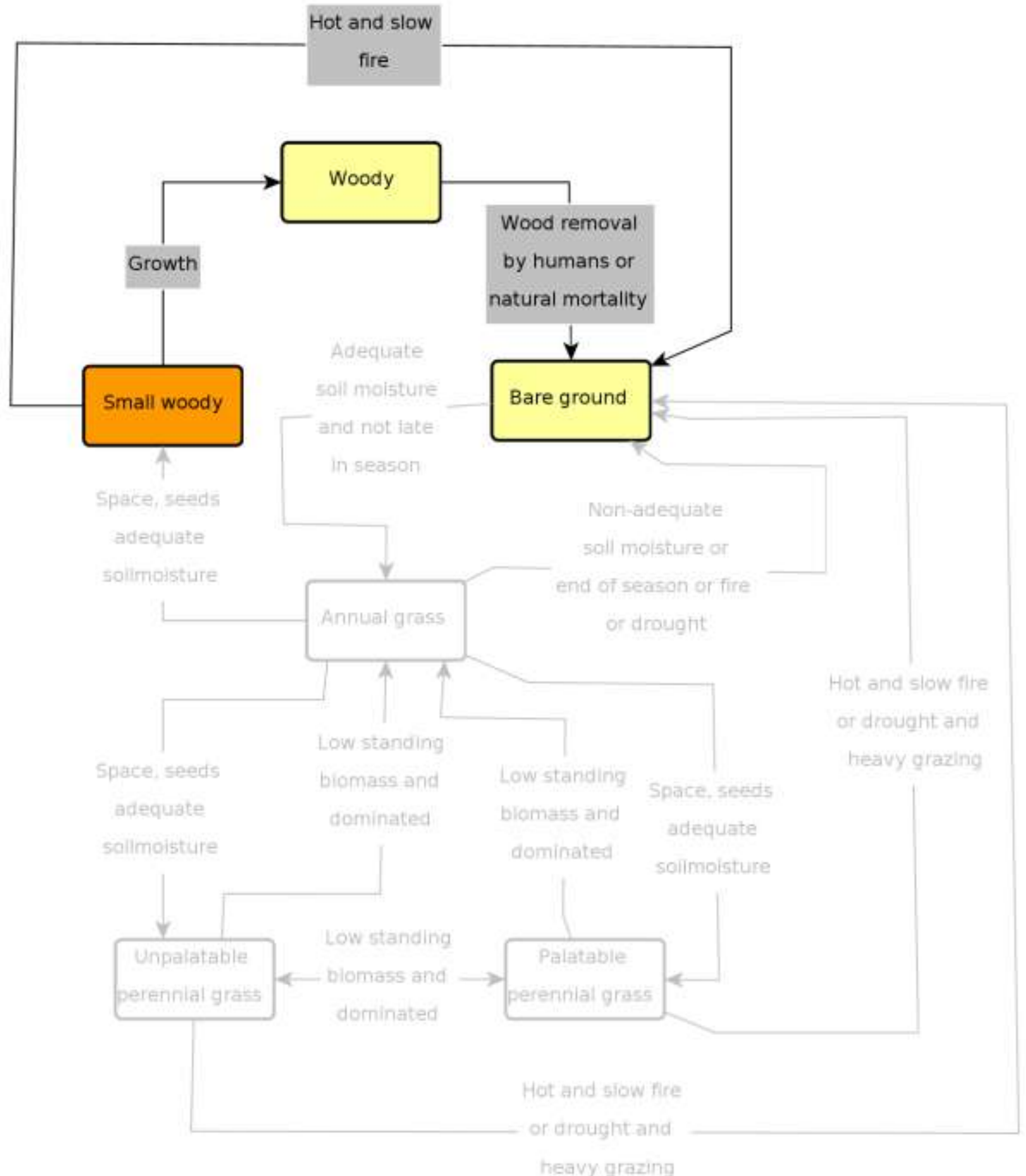
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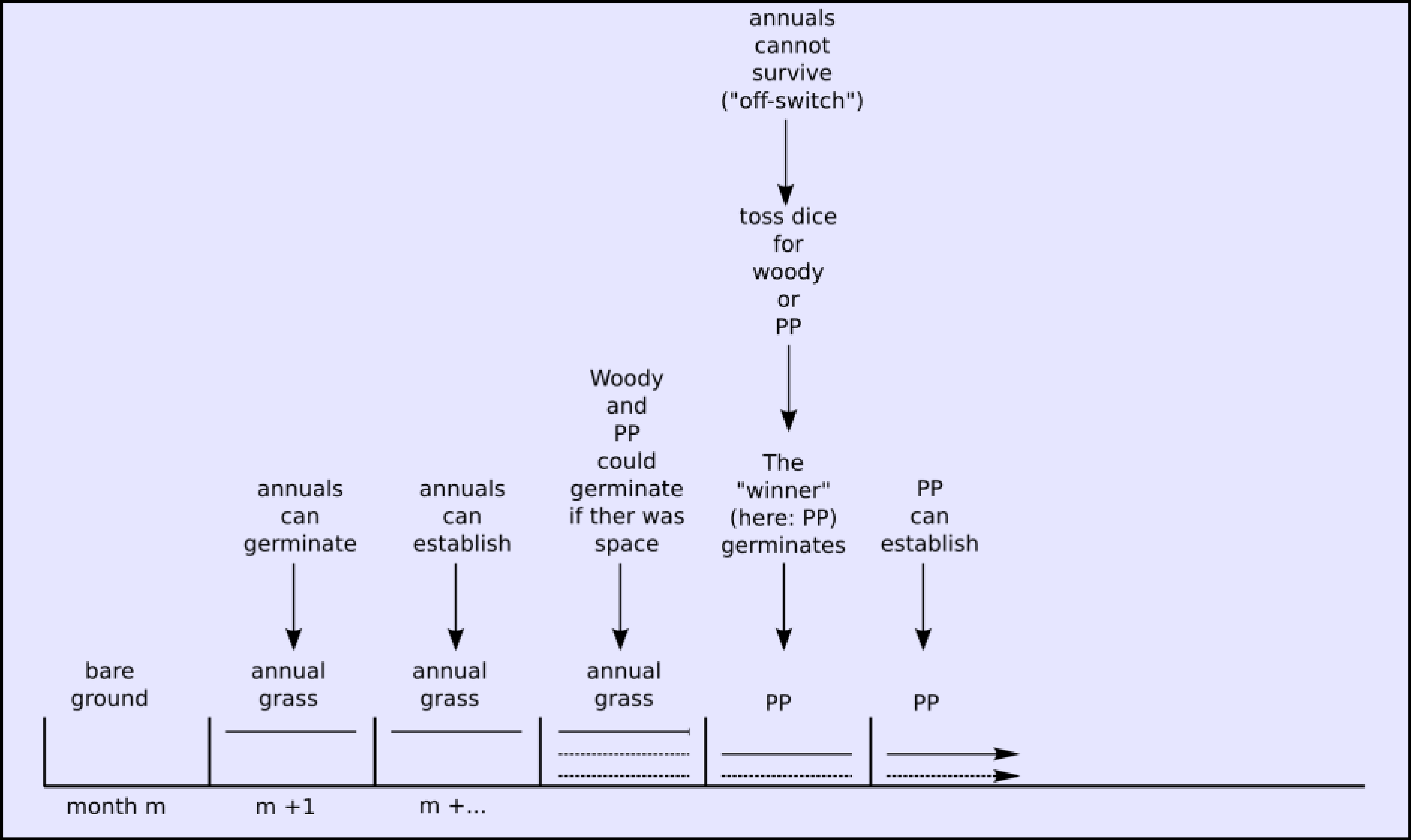
Transition: Example over different time steps



Outputs

- Improve the understanding and make predictions of possible vegetation dynamic changes (e.g. degradation, recovery, bush encroachment) due to environmental, climatic and management impacts from 30 up to 200 years.
- Apply sustainable management practices in the semi-arid Savanna over the long-term.

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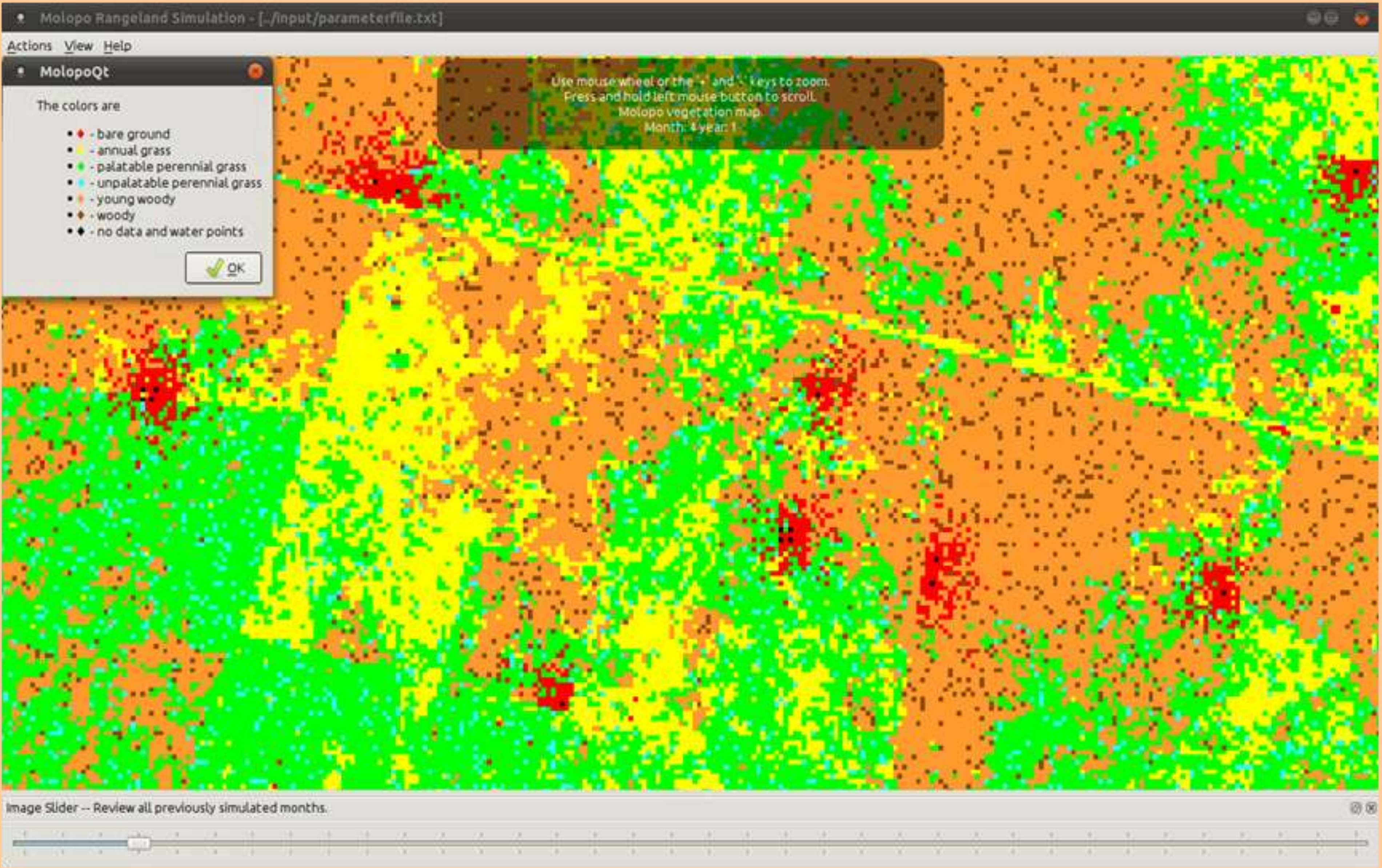
Molopo Rangeland Simulation - [../input/parameterfile.txt]
Actions View Help
MolopoQt
The colors are
- bare ground
- annual grass
- palatable perennial grass
- unpalatable perennial grass
- young woody
- woody
- no data and water points
OK
Use mouse wheel or the '+' and '-' keys to zoom.
Press and hold left mouse button to scroll.
Molopo vegetation map
Month: 4 year: 1
Image Slider -- Review all previously simulated months.

Project Partners and Funders

- Farmers of Molopo
- Hennie van den Berg
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Eastern Cape Agric

Friedrich-Schiller University of Jena

DACE

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Thank you

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Temporal Transition Rules

- ON and OFF switches for annual grass

Event	Rules	
Establishment ("on switch")	Germination:	Soilmoisture minimum 30%
	Survival for one month:	Soilmoisture for at least 20 days
	Assumption:	Seeds are everywhere freely available
Non-survival ("off switch")	Soilmoisture less than 10%	for more than ten days
	or	"cold" fire
	or	"hot" fire
	or	end of growing season

Implementation Temporal Transition

- ON and OFF switches for perennial plants

Event	Rules	
Establishment ("on switch")	Germination:	Soilmoisture minimum 50%
		Availability of space
		Availability of seeds
	Survival for one month:	Soilmoisture for at least 30 days
Non-survival ("off switch")		"hot" fire

Implementation Spatial Transition

- **Possible assumptions**

Five or more neigb. cells\Biomass	Low	Medium	High
Bare Ground	B	B/UP	UP
Palatable Perennial	PP	PP/UP	PP (?)
Unpalatable Perennial	UP	UP	UP
Woody	W	W/UP	UP
Else	UP	UP	UP

Vegetation Types

Vegetation type	Representative species	Precipitation memory index	Palatability index
Bare ground	--	--	--
Annual grass	*Schmidtia kalihariensis*	**Low**	**Low, medium when dry**
Perennial grass, palatable	*Schmidtia pappophoroides*	**High**	**High**
Perennial grass, non-palatable	*Aristida stipitata*	**High**	**Low**
Small woody	*Acacia mellifera*	--	**Low ?**
Woody	*Acacia mellifera*	--	**Low ?**