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A framework for modelling spatio-temporal competition and spread of invasive plant species in South Africa

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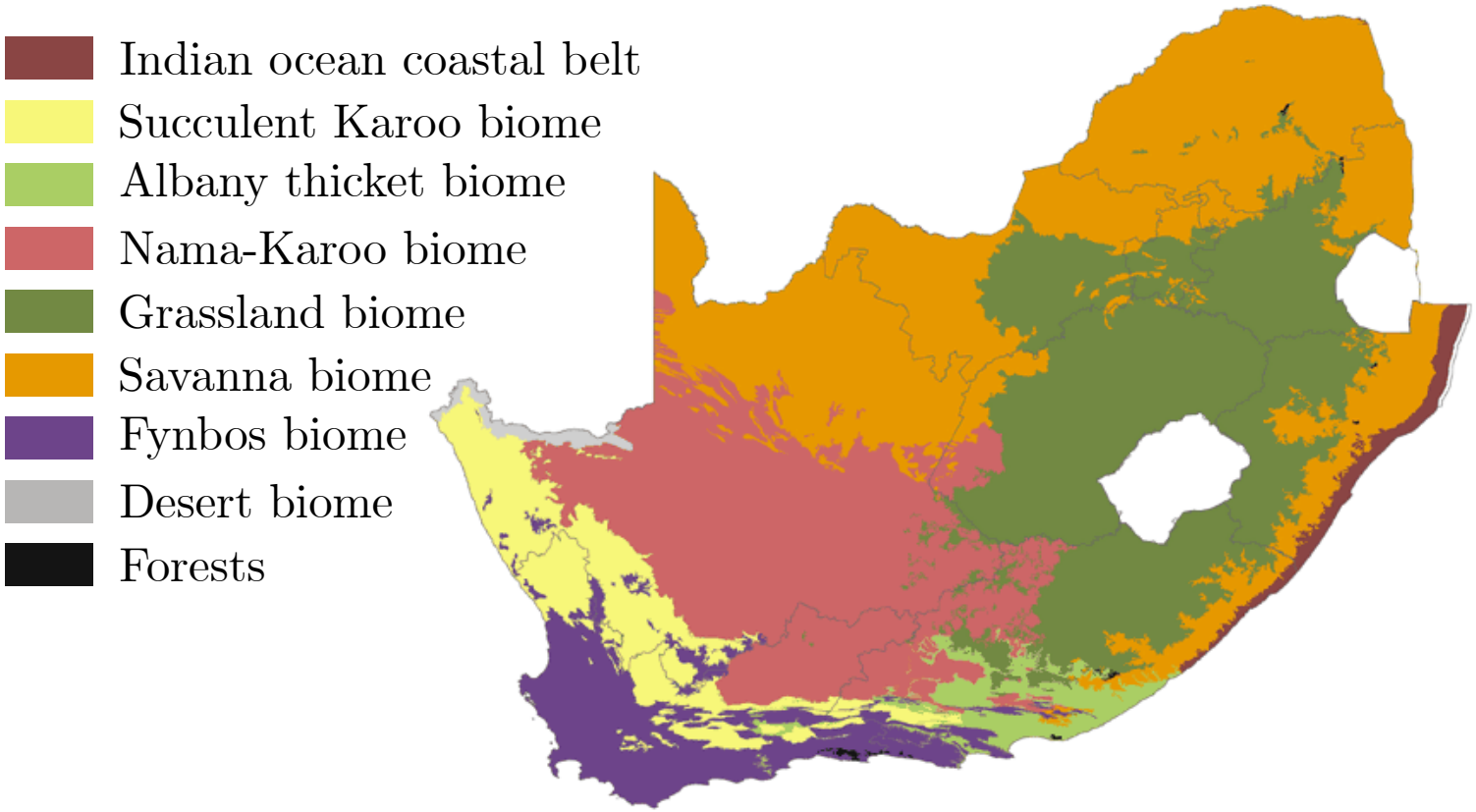
7 December 2022

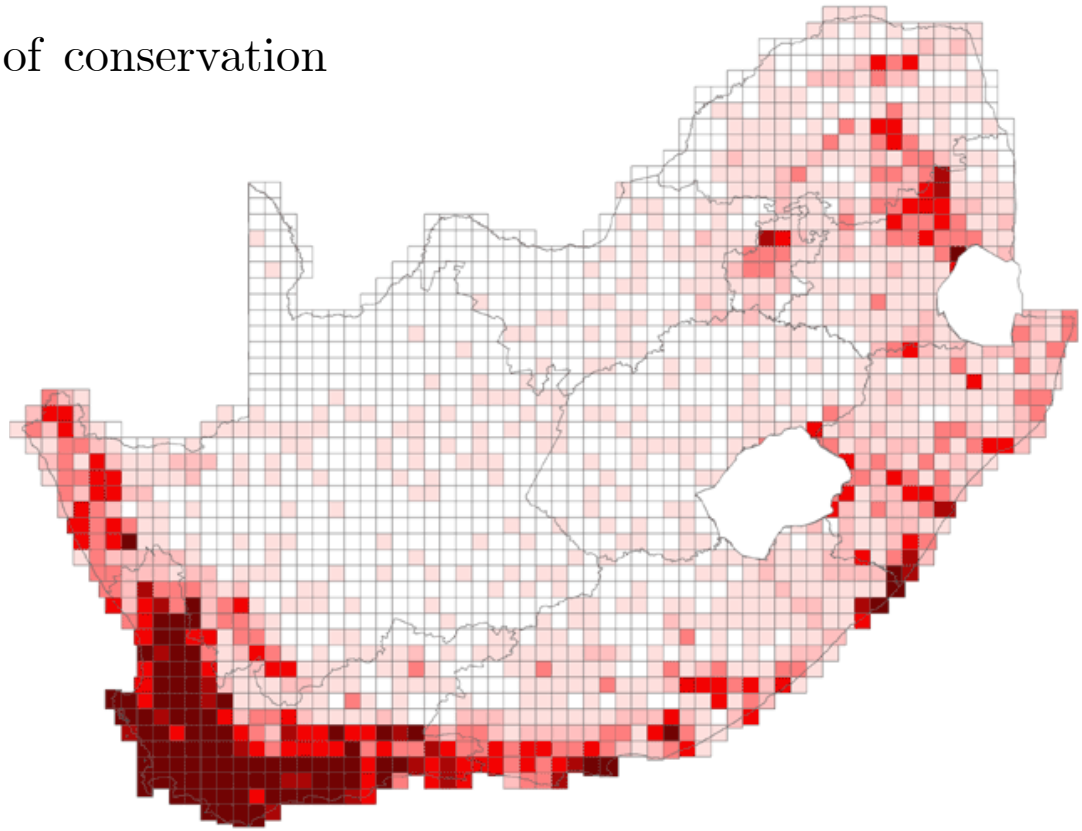
Introduction



Introduction

Number of species of conservation concern per QDS

- 0
- 1–5
- 6–10
- 11–20
- 21–30
- 31–40
- 41–50
- >50



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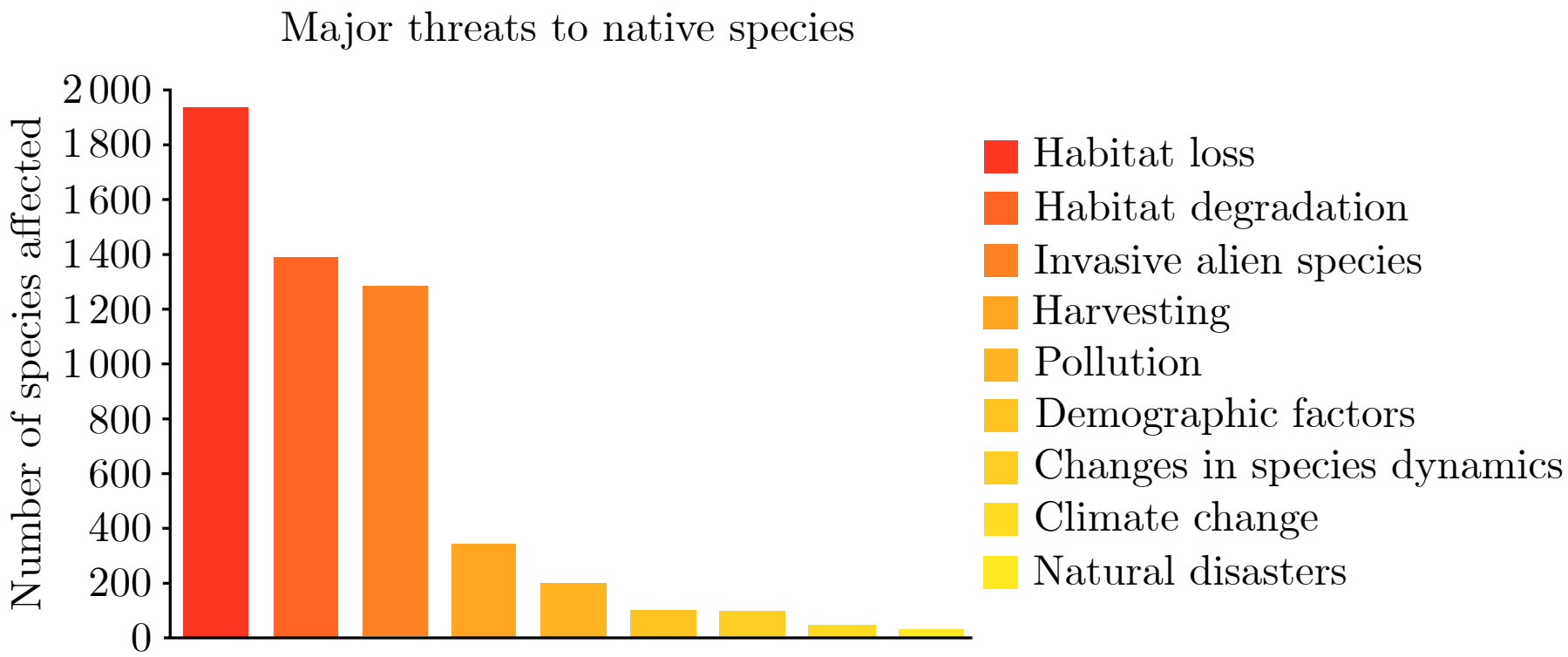

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Introduced species

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Species that become established and spread beyond the place of introduction

Invasive species

A sub-category of naturalised species that exhibit the potential to cause harm to the ecologies into which they are introduced

Introduction

National Environmental Management: Biodiversity Act (NEM:BA)

Invasive species regulations

1. Reducing the risk of introducing species or having those already introduced become invasive
2. Limiting the invasion extent and impact.

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Categories

1a. Species targeted for national eradication

1b. Controlled as part of a national management programme, trading and spread prohibited

2. An extension of category 1b, but permits may be issued for the species' usage

3. Species that may be kept without permits, that may not be traded or further propagated.

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Design and develop a generic framework capable of creating high-quality models to predict the spatio-temporal competition between, and spread of, invasive species

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Important objectives

- Rank environmental parameters that correlate with the current distribution of an invasive species
- Identify regions of study prone to invasive outbreaks
- Simulate potential future spread and ecological influence
- Recommend suitable management and control methods to inhibit their spread.

Agenda

- Case study background

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- SPACSIS framework
  Spatio-temporal Competition and Spread of Invasive Species

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  - Cellular automata (CA) component
  - Adaptive management component

Australian Acacias

Australian Acacia species are some of the most widespread invasive plants globally and have been documented very well in South Africa.

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South African context

- 71 species have been introduced to South Africa
- 23 are considered invasive
- Similar reproductive and physiological traits
- High-quality population distribution data.

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- Acacia *baileyana*
- Acacia *binervata*
- Acacia *crassiuscula*
- Acacia *cultriformis*
- Acacia *cyclops*
- Acacia *dealbata*
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- Acacia *stricta*
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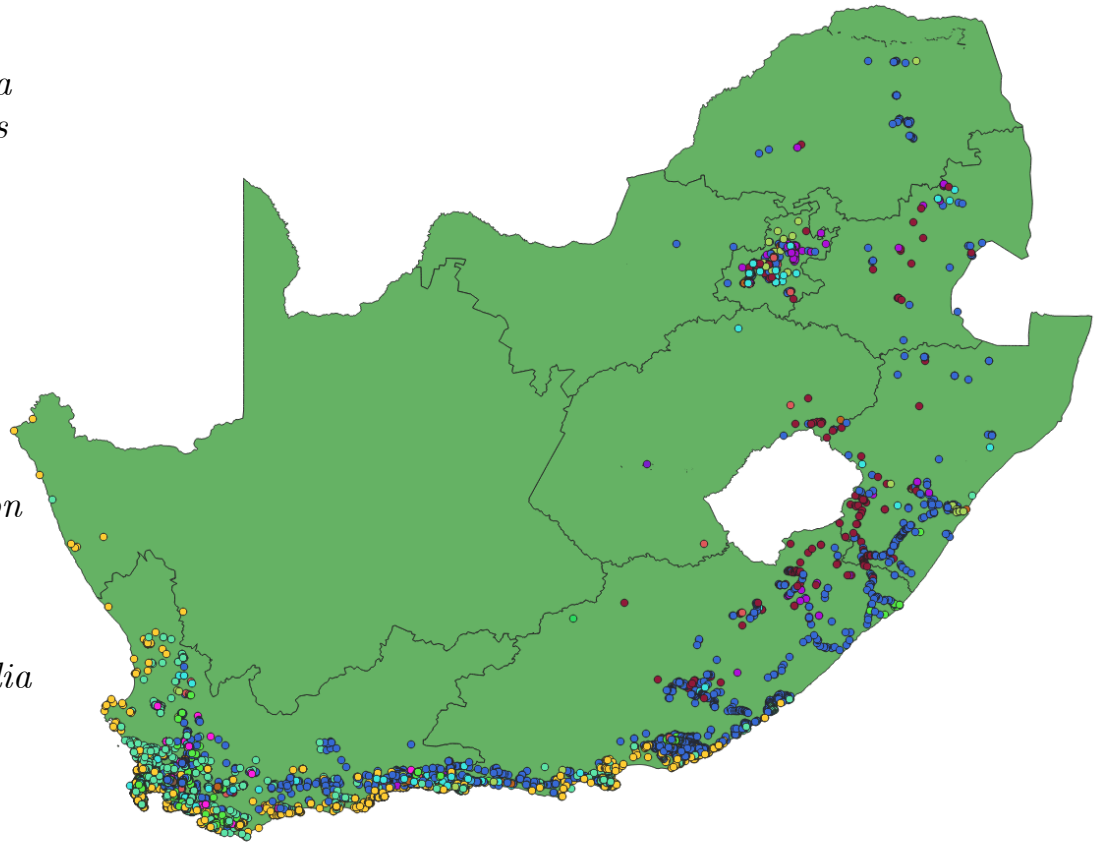

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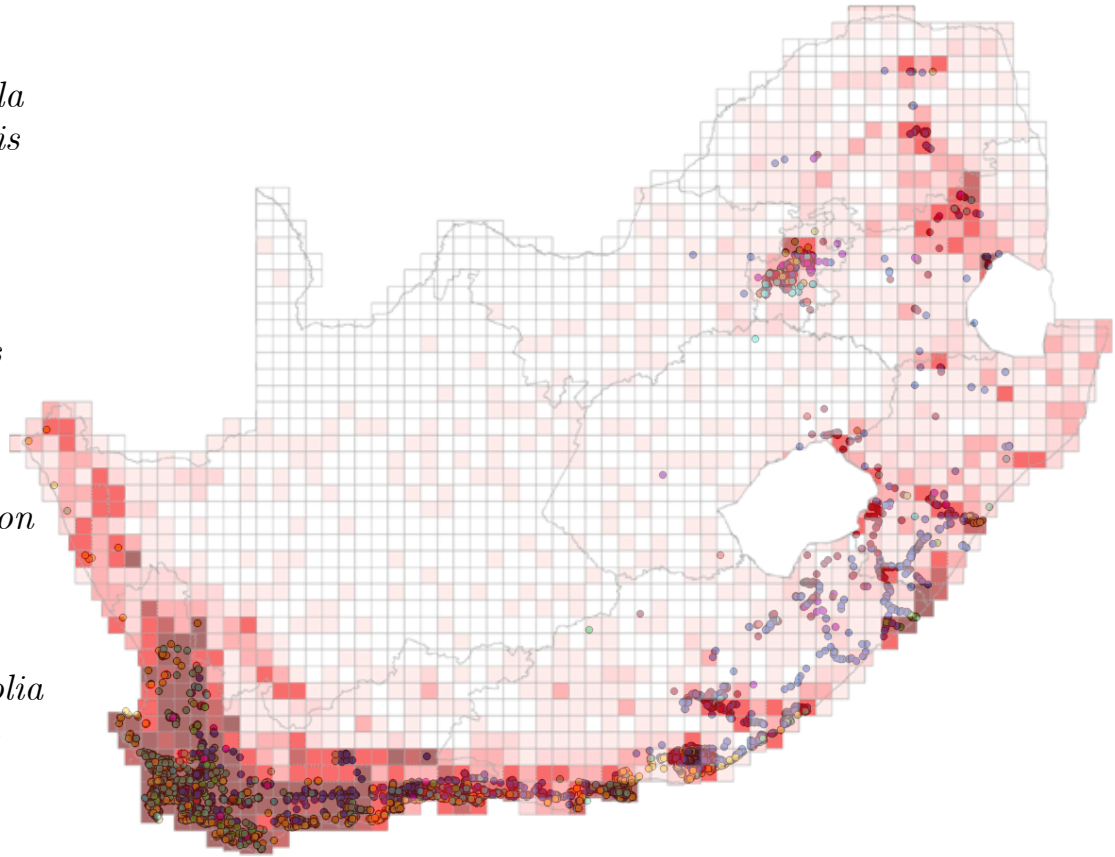

SPACSIS Framework overview

Spatial analysis component

- Select study region and create a spatial grid

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Adaptive management component

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- Apply and evaluate management strategies.

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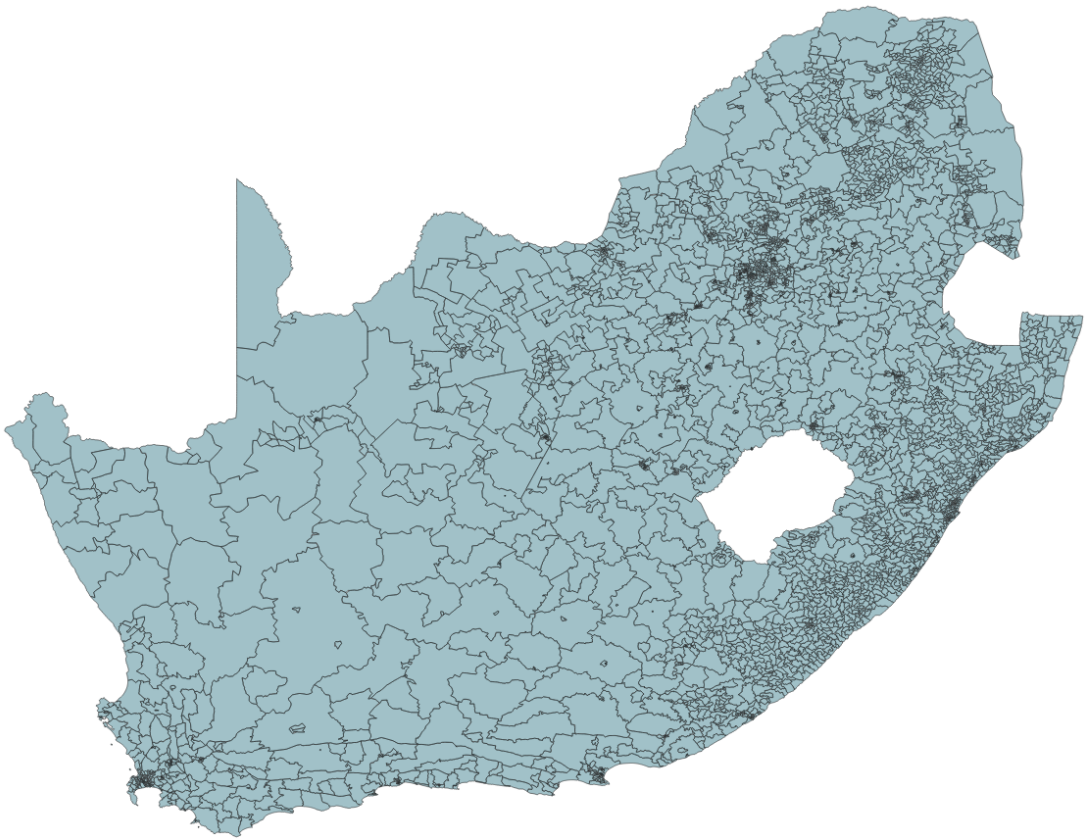

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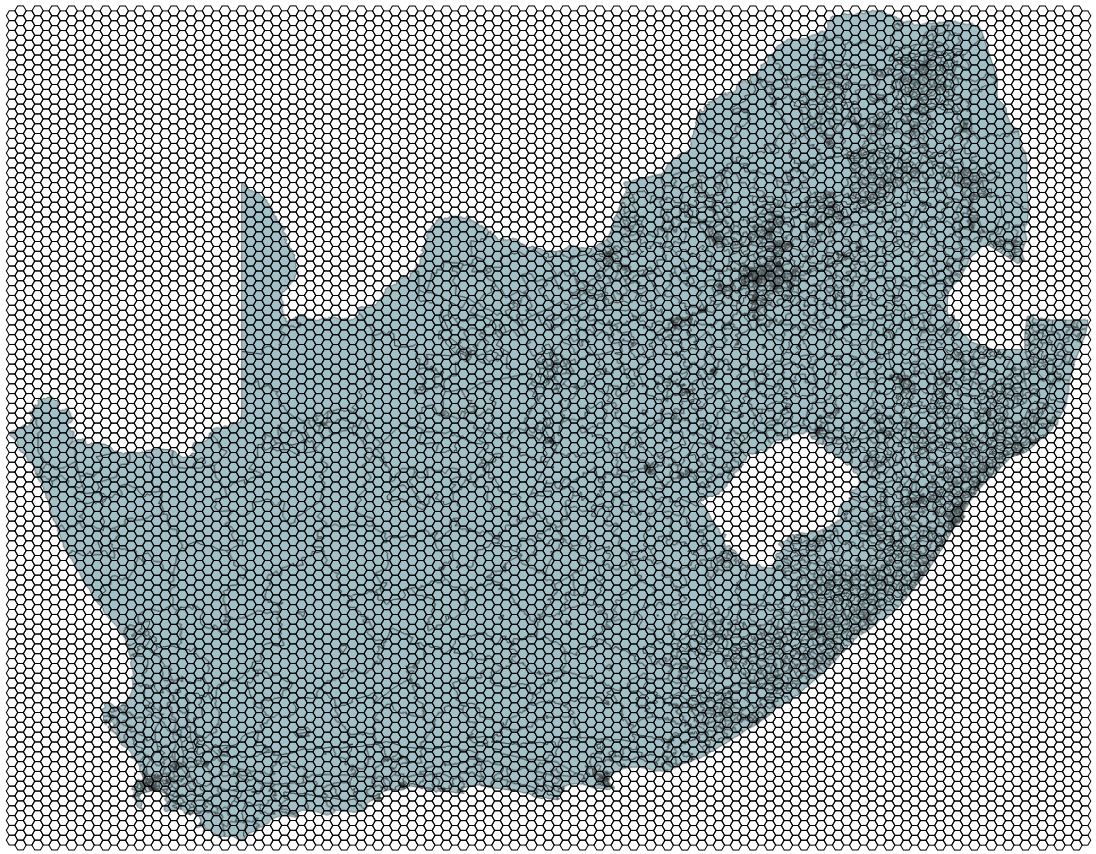

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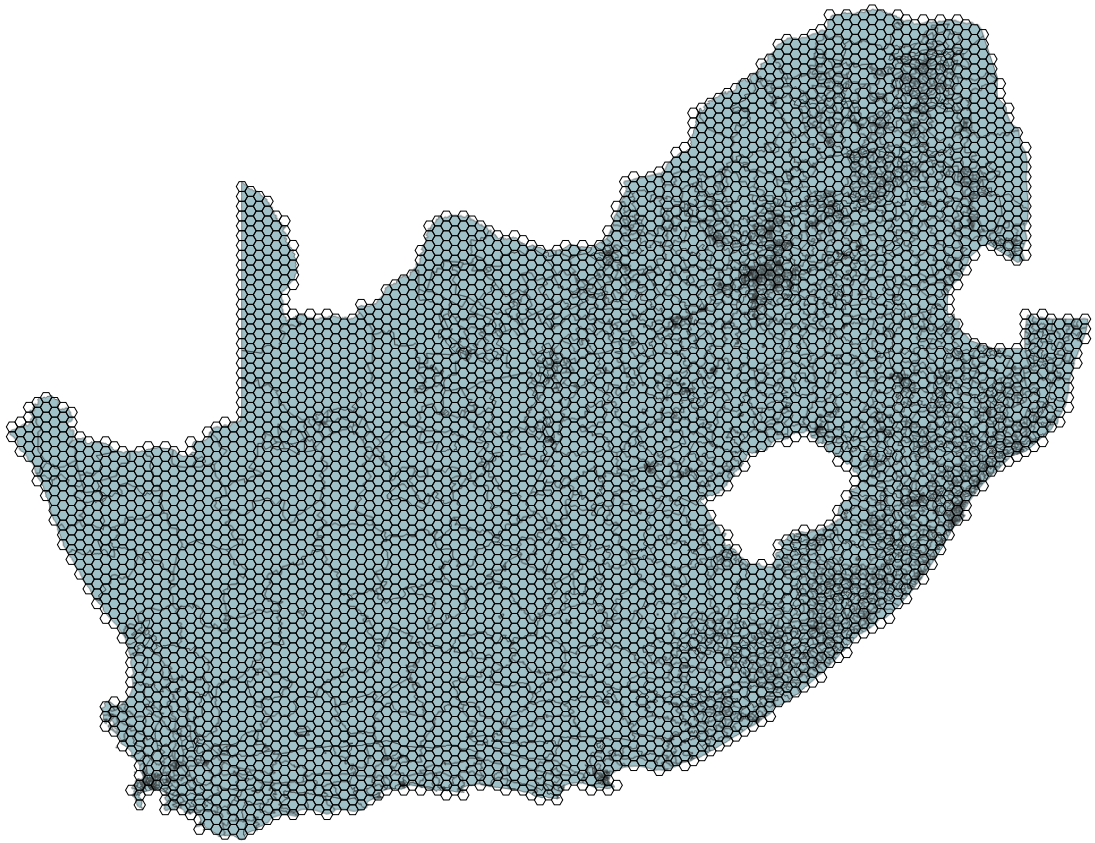

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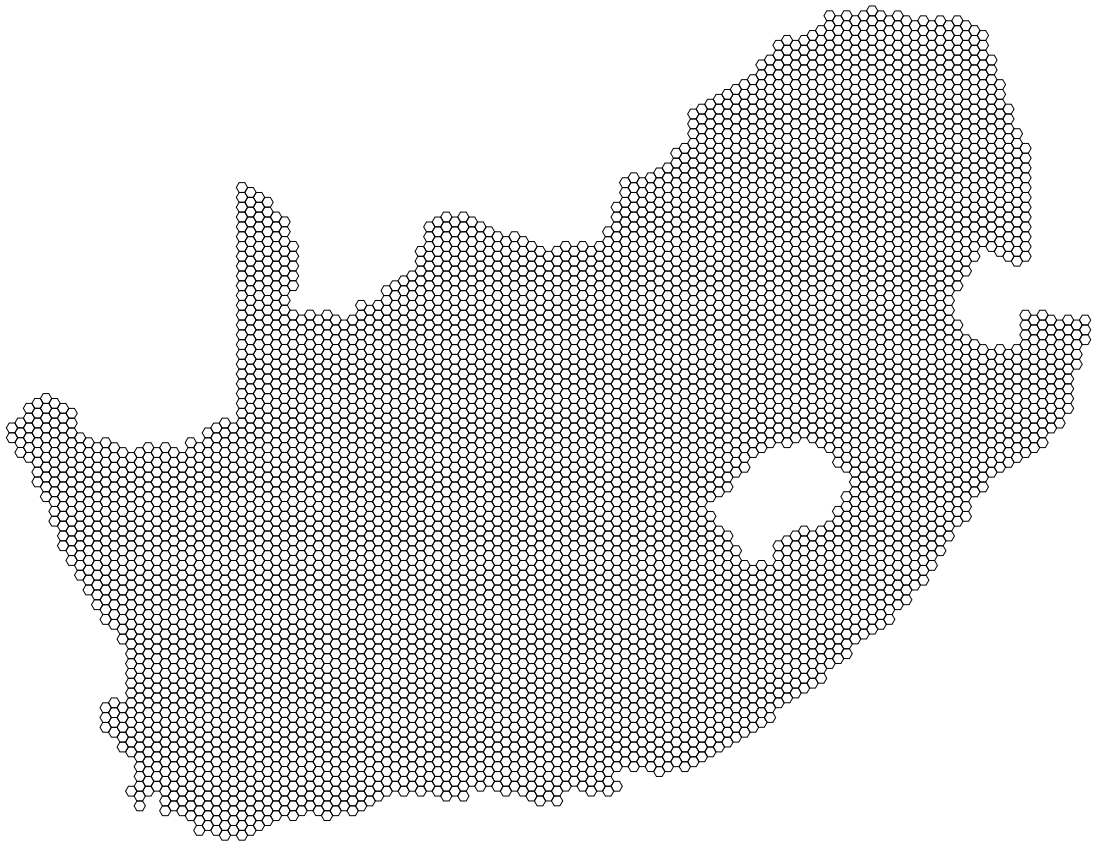

Environmental parameters

Environmental parameters (EPs) that define the environmental characteristics of study region.

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EP data types examples

- Continuous (numerical) data
  - Temperature
  - Precipitation
  - Slope and elevation
  - Distance from water sources

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EP data types examples

- Continuous (numerical) data
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  - Precipitation
  - Slope and elevation
  - Distance from water sources
- Categorical data
  - Land cover
  - Soil types
  - Water drainage

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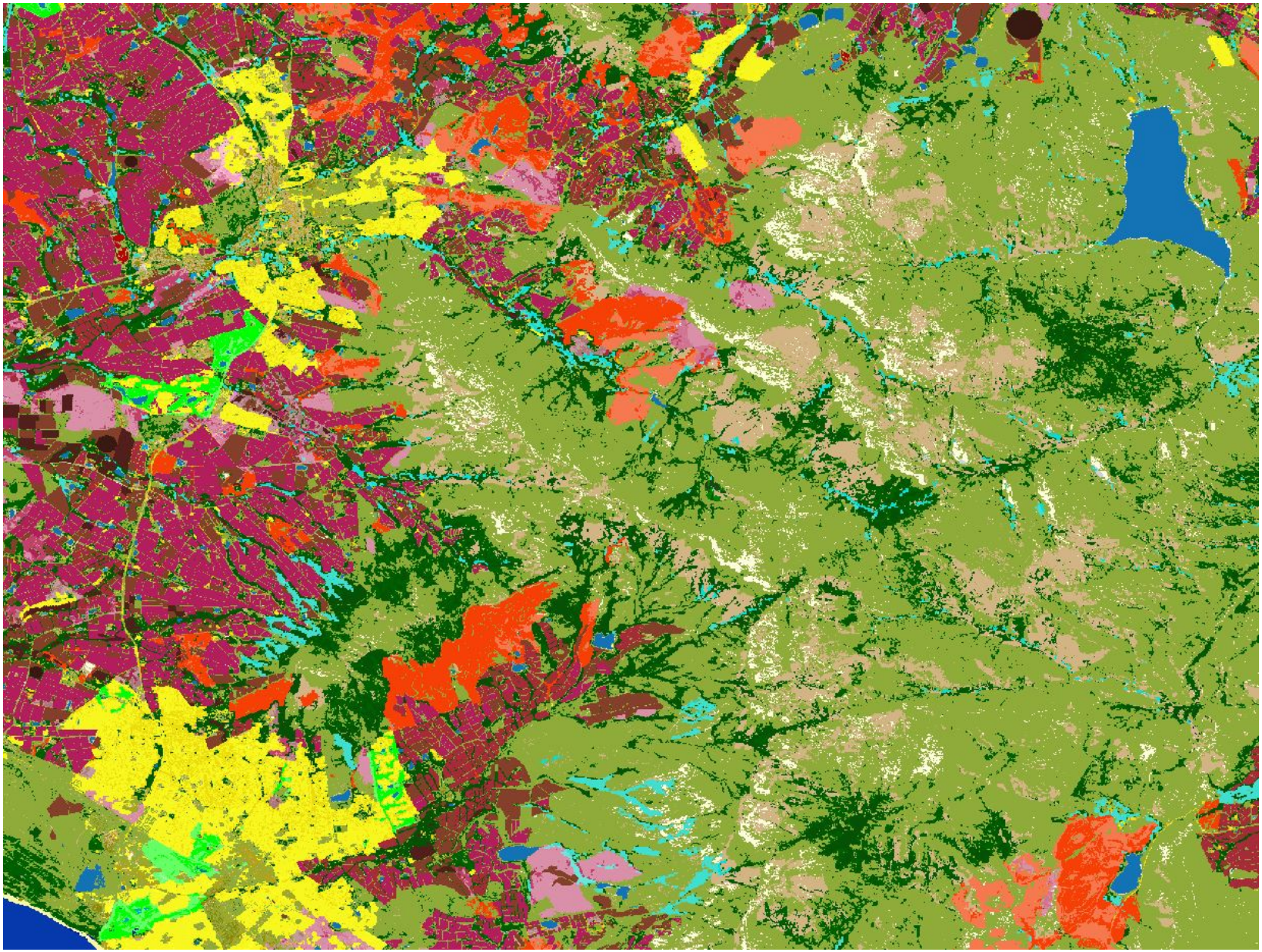

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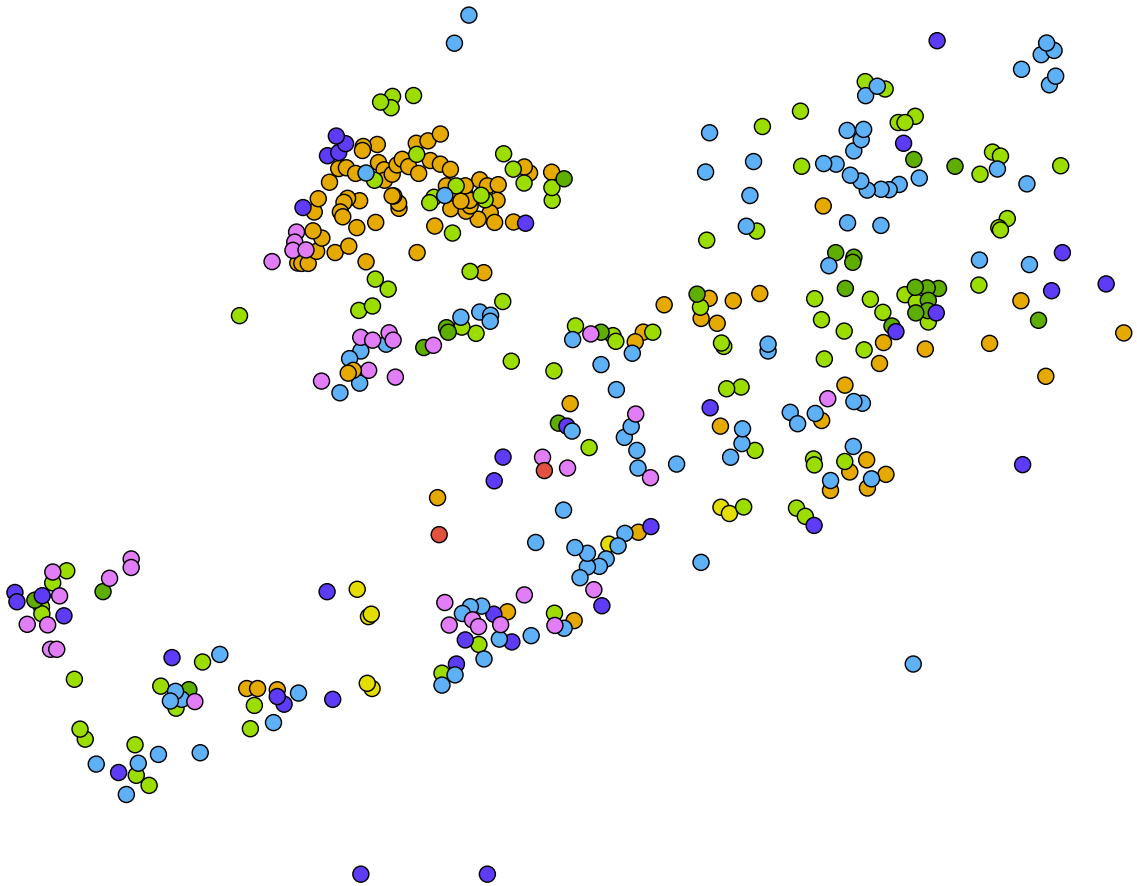

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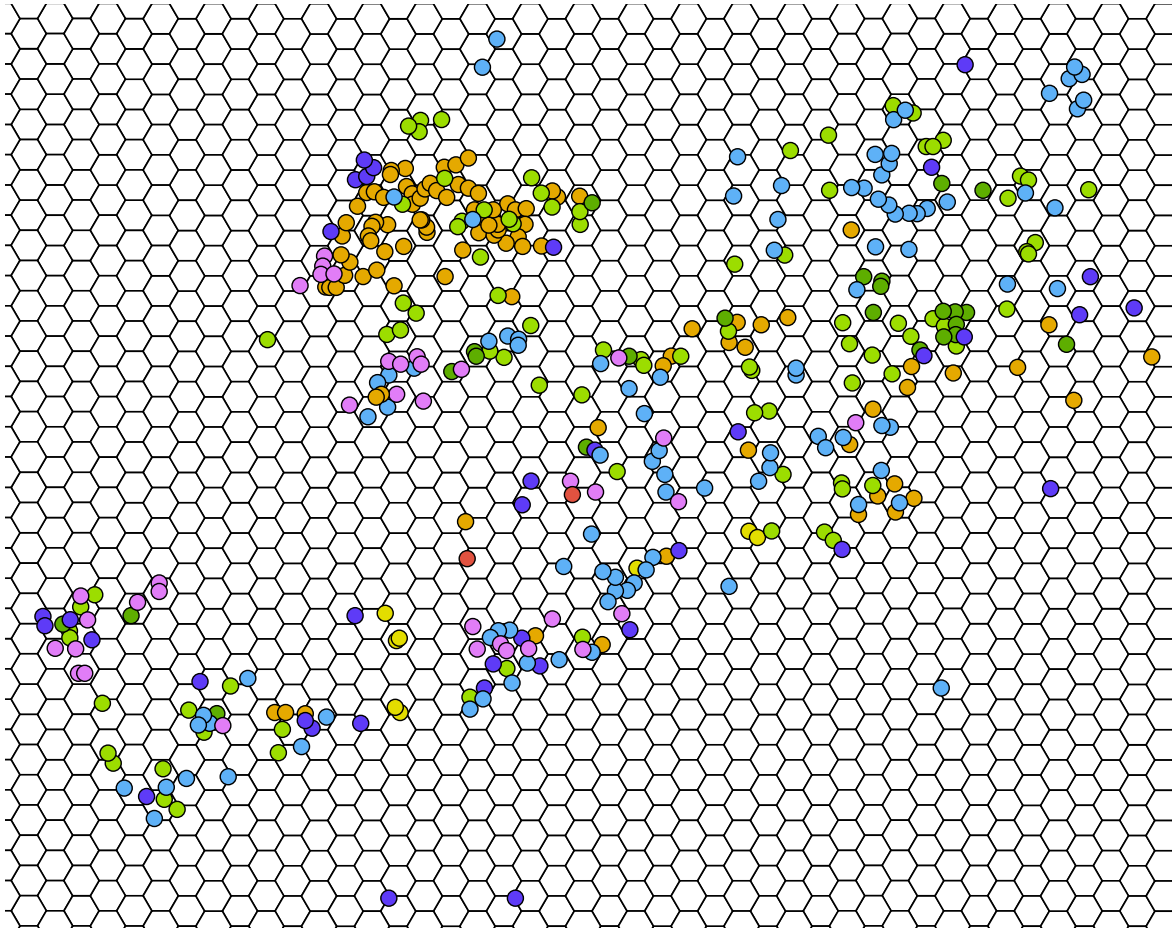

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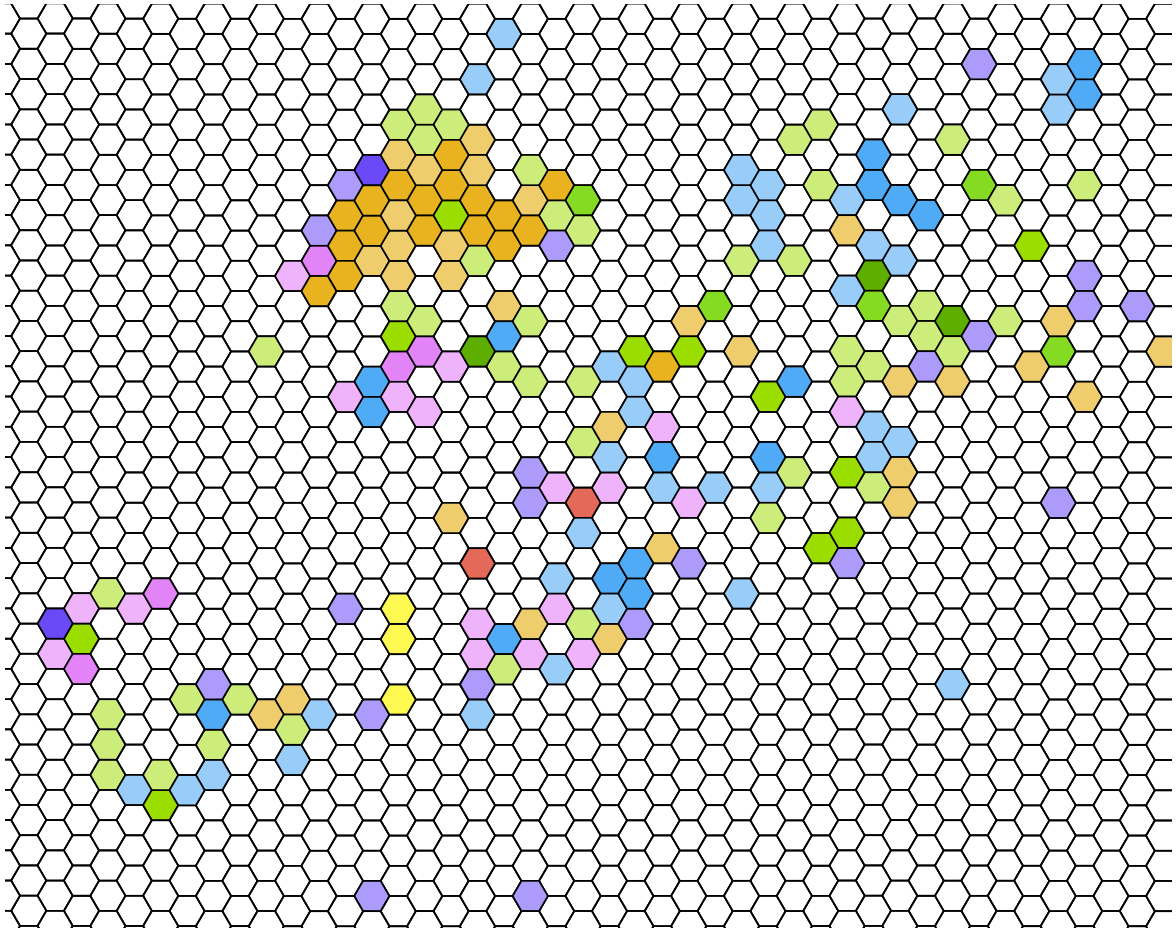

Spatial analysis component: Data set construction

Table: A representation of the populated spatial grid data set.

ID	$\cdots$	**Lat**	**Long**	$\cdots$	**EPs**				**Unique species**			
					EP$_1$	**EP$_2$**	**EP$_3$**	$\cdots$	**S$_1$**	**S$_2$**	**S$_3$**	$\cdots$
0	$\cdots$	-34.052	18.435	$\cdots$	35	121	1	$\cdots$	1	0	0	$\cdots$
1	$\cdots$	-34.054	18.422	$\cdots$	35	105	1	$\cdots$	1	2	0	$\cdots$
2	$\cdots$	-34.062	18.421	$\cdots$	42	302	2	$\cdots$	0	0	0	$\cdots$
3	$\cdots$	-34.059	18.425	$\cdots$	43	294	4	$\cdots$	1	0	3	$\cdots$
4	$\cdots$	-34.056	18.437	$\cdots$	55	178	4	$\cdots$	0	2	1	$\cdots$
5	$\cdots$	-34.051	18.422	$\cdots$	9	145	7	$\cdots$	0	0	0	$\cdots$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\ddots$

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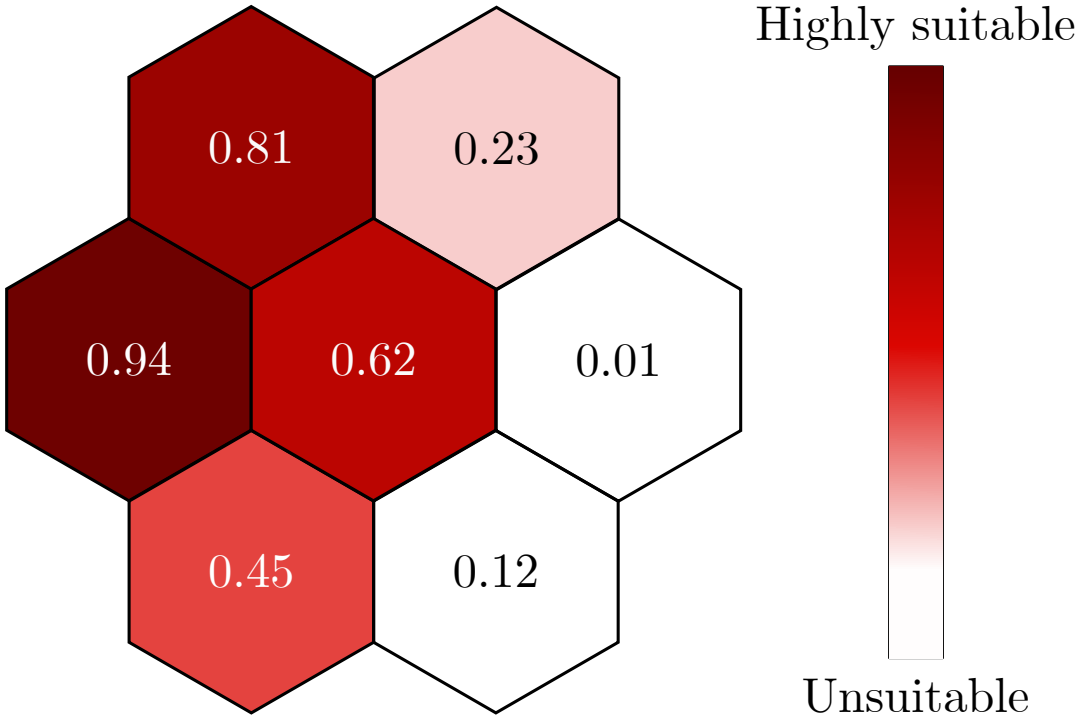

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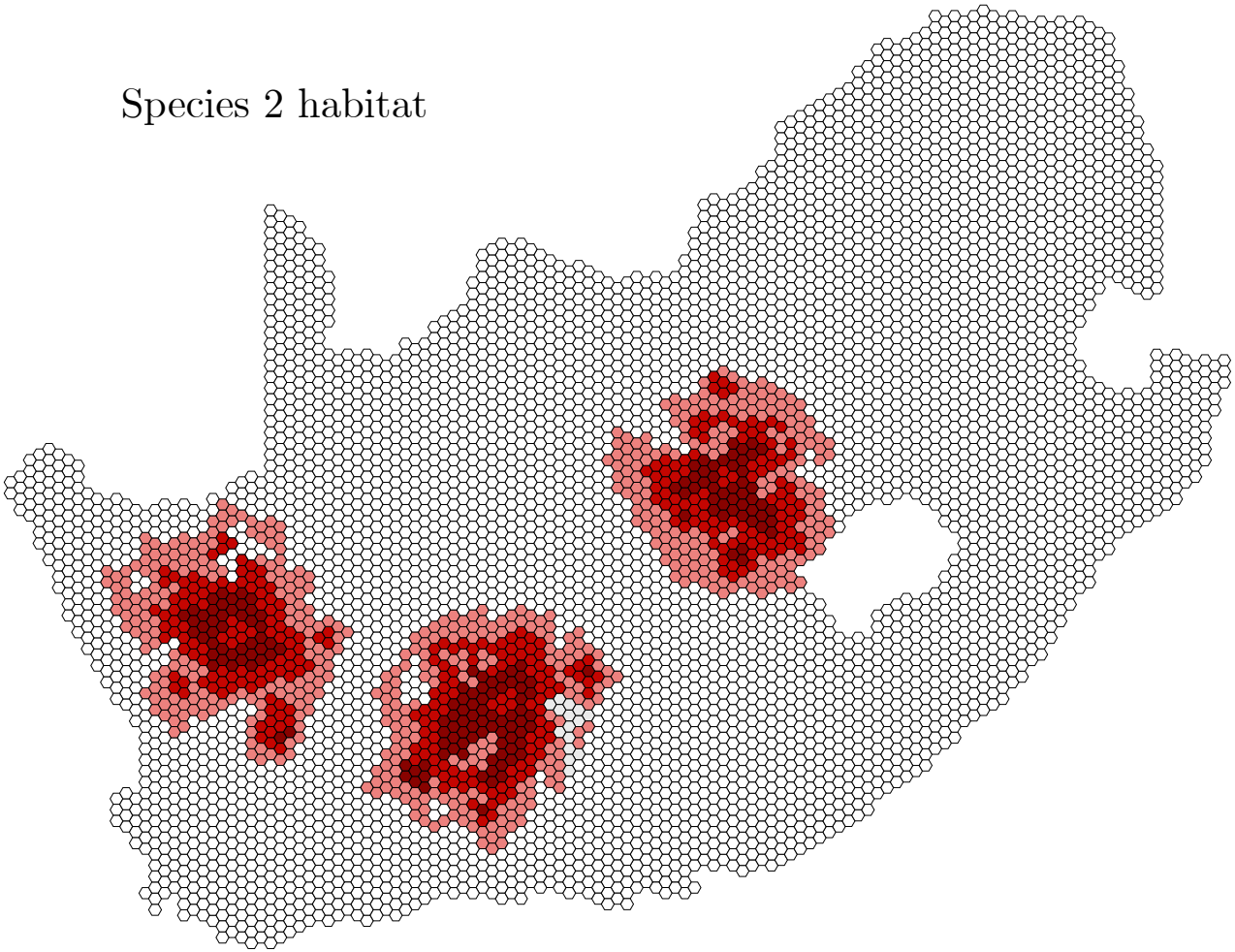
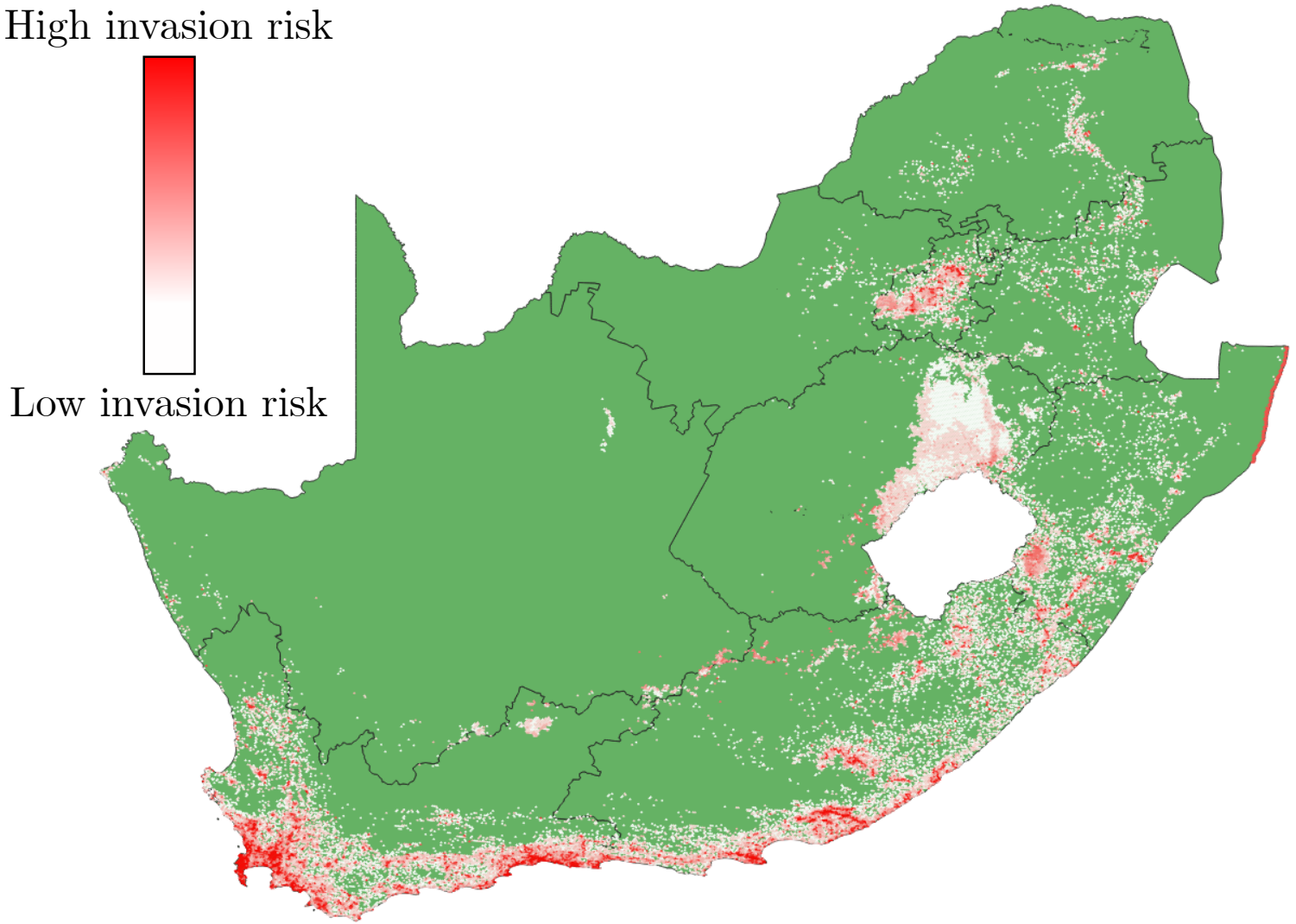


Selecting a suitable case study region



Selecting a suitable case study region

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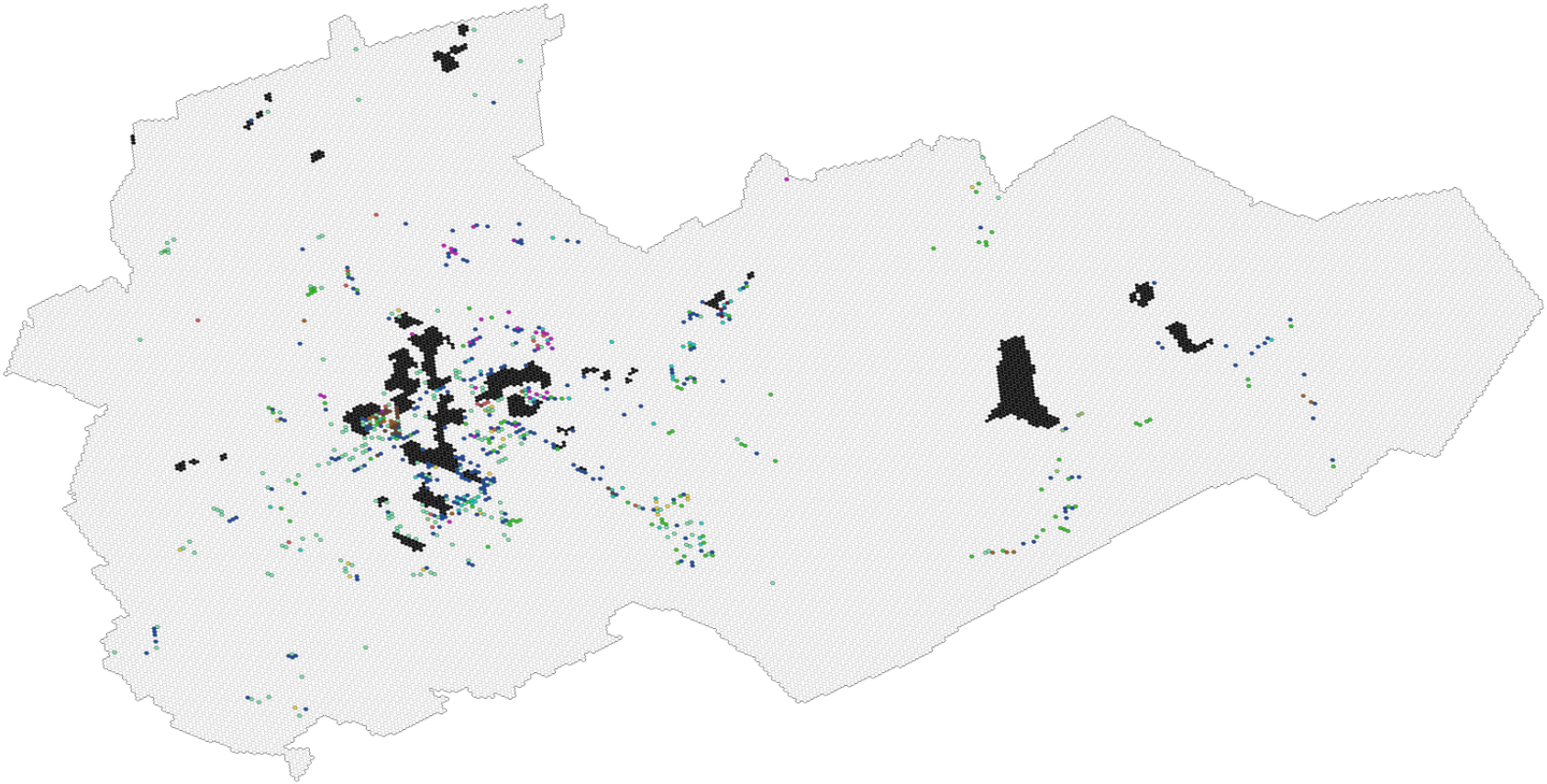
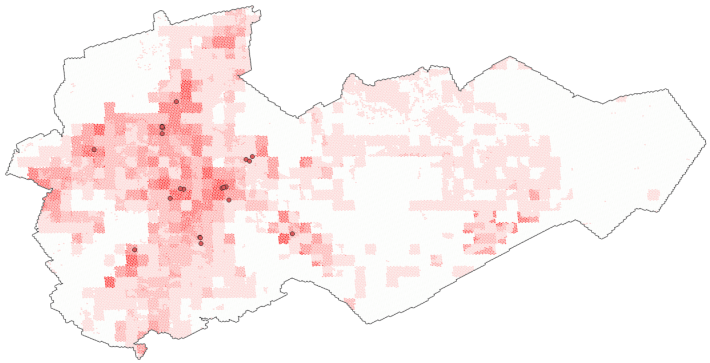
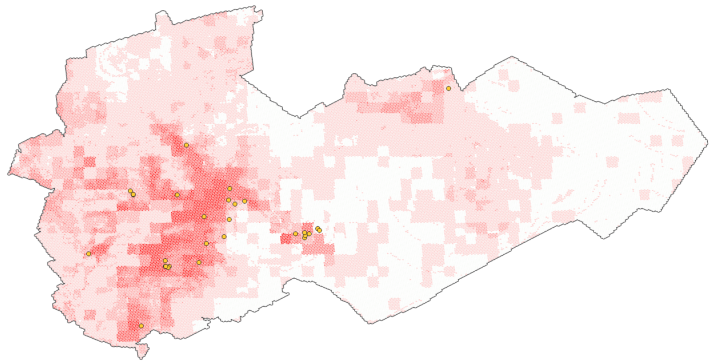


ML component: Habitat prediction

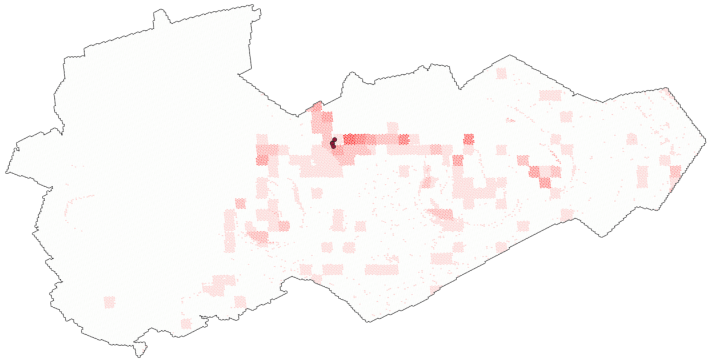
Acacia *baileyana*



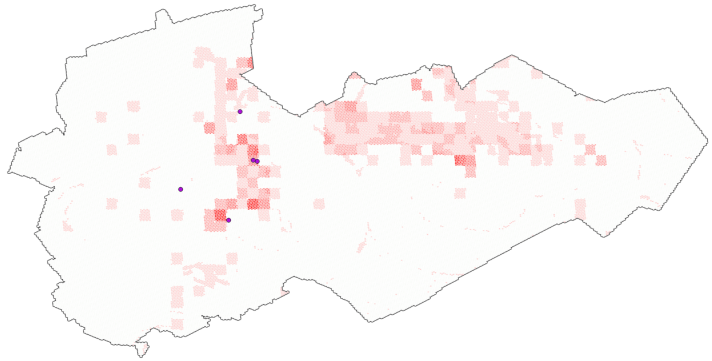
Acacia *cyclops*



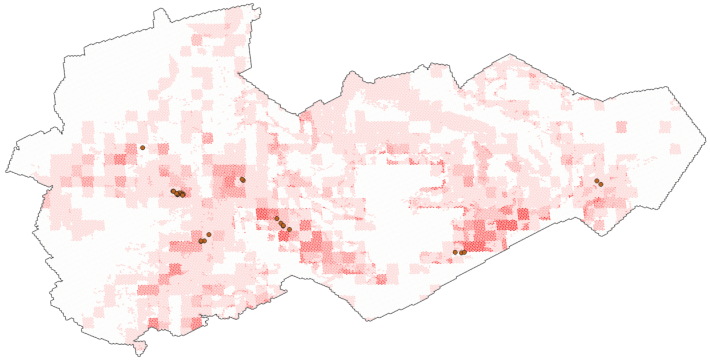
Acacia *dealbata*



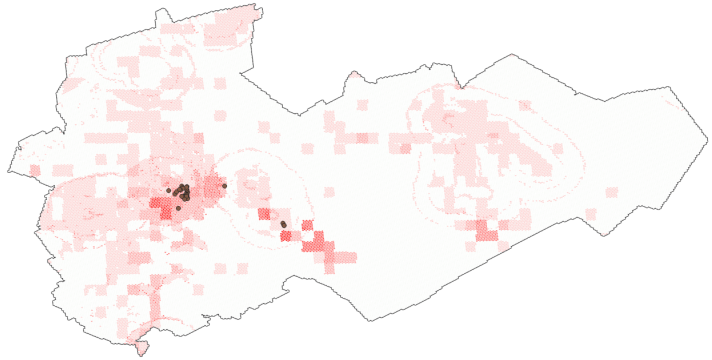
Acacia *decurrens*



Acacia *elata*



Acacia *implexa*



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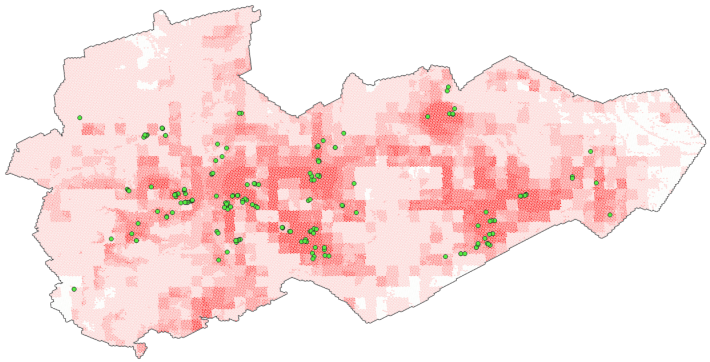
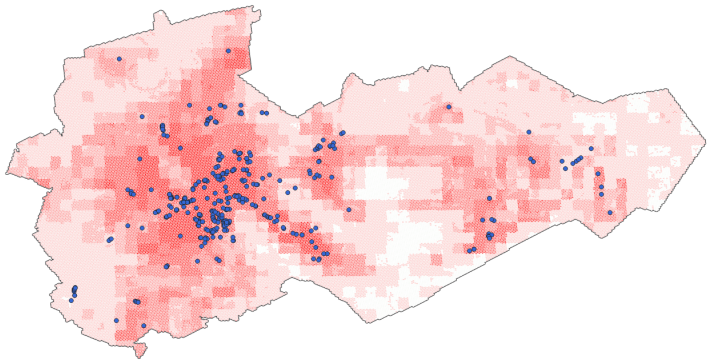
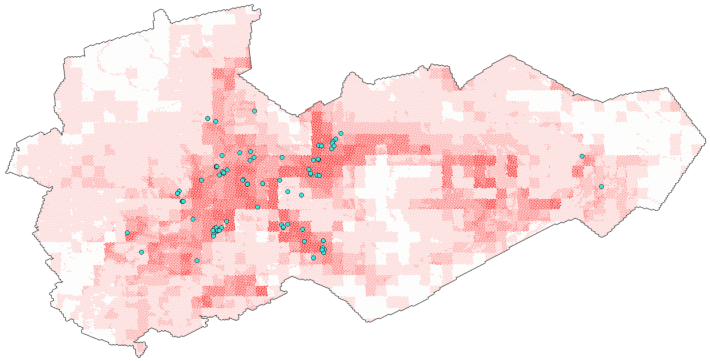


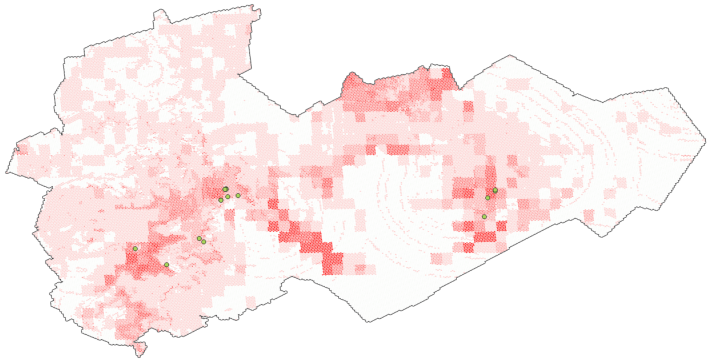
Acacia *mearnsii*



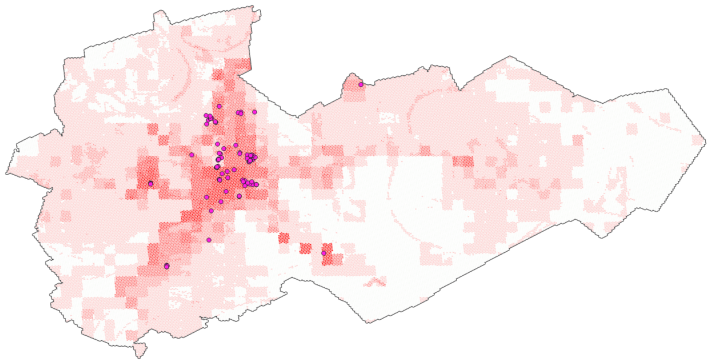
Acacia *melanoxylon*



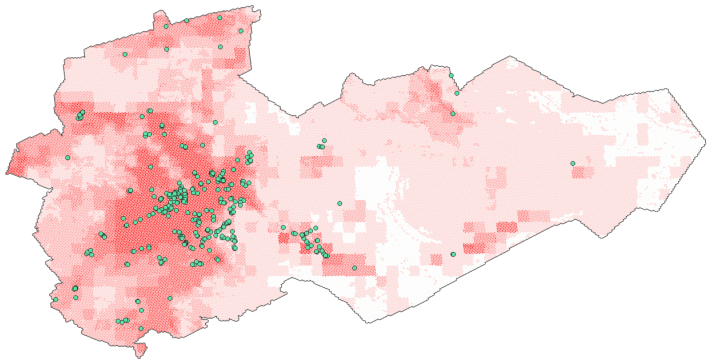
Acacia *podalyriifolia*



Acacia *pycnantha*



Acacia *saligna*



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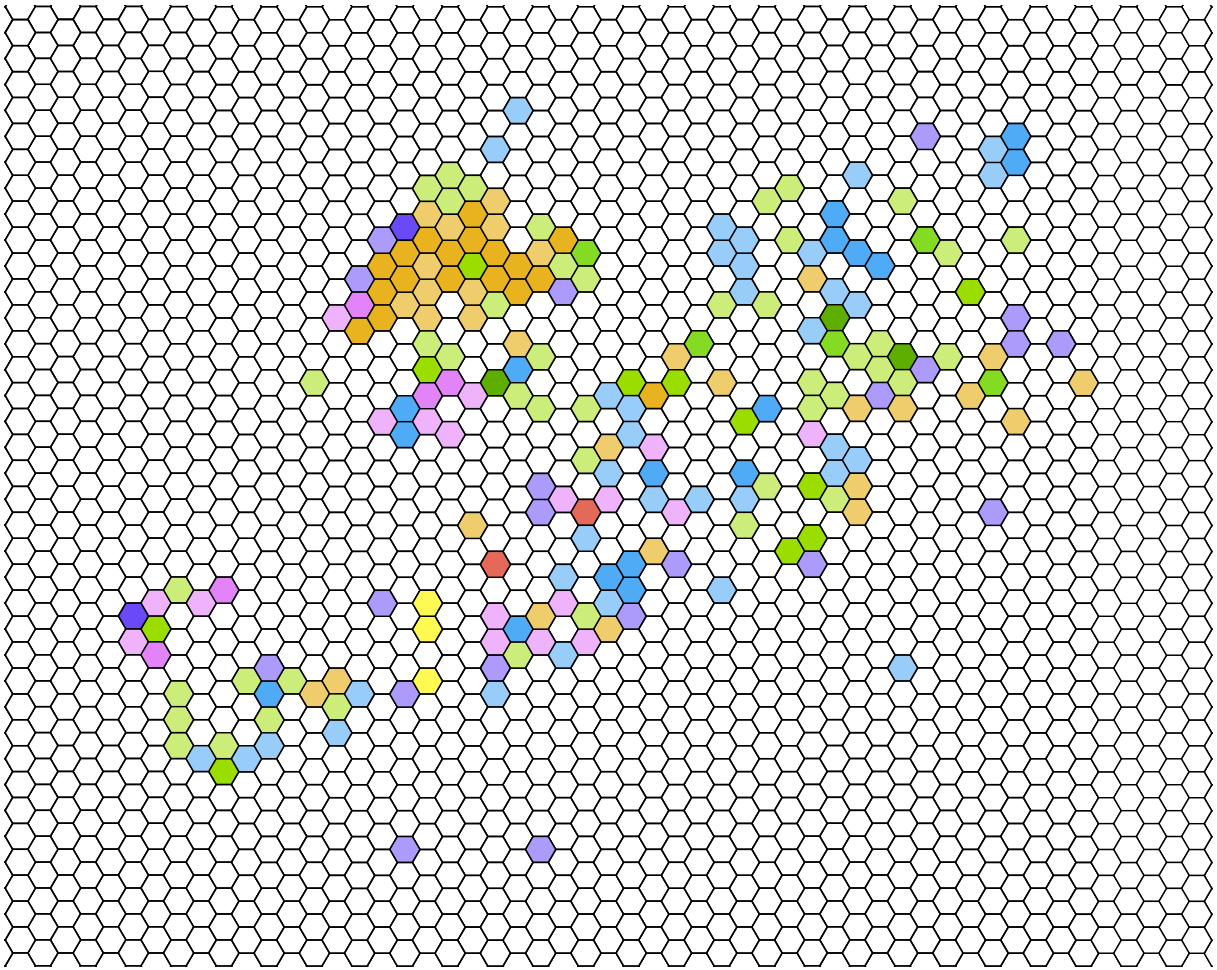

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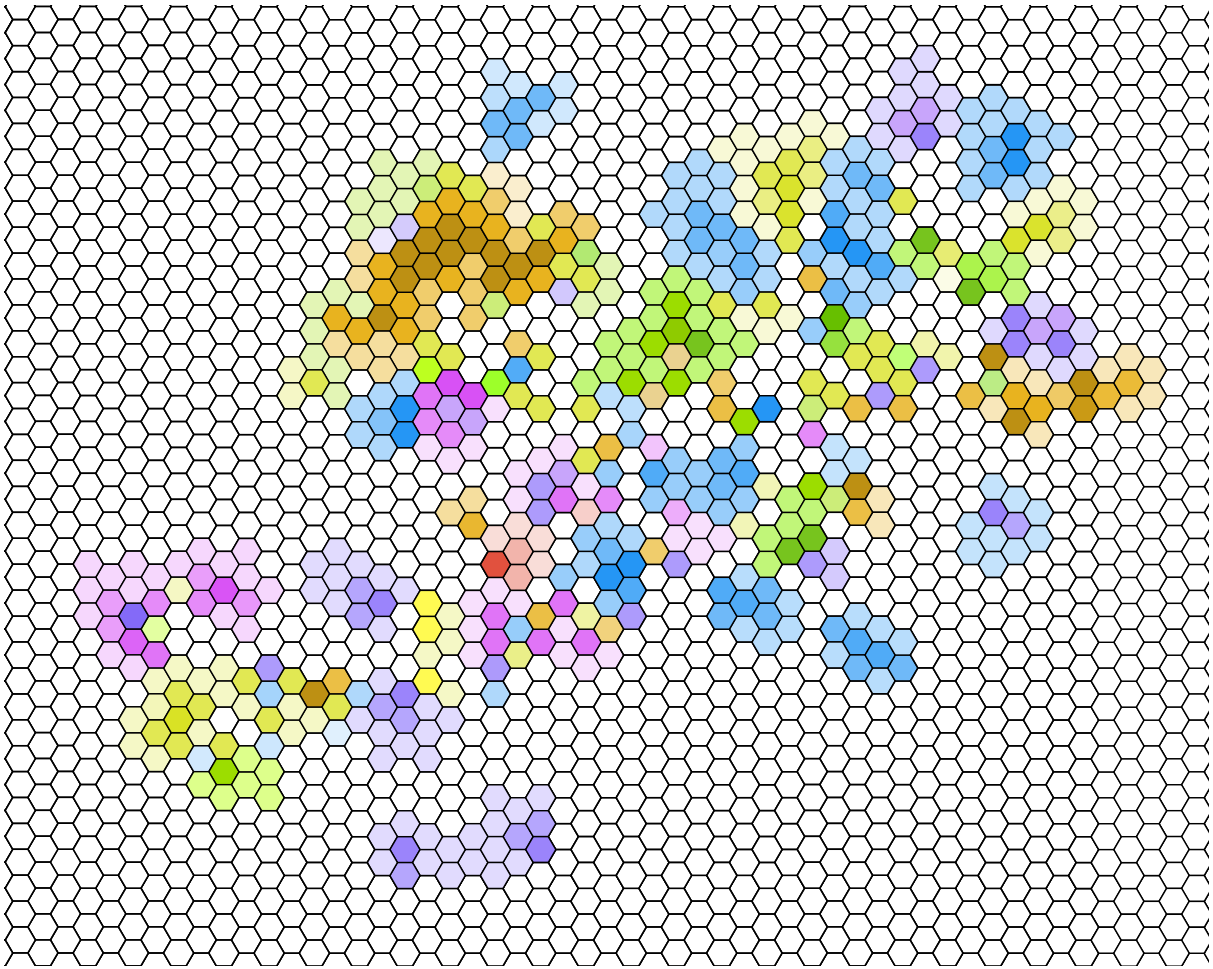

CA component: Cell states

Population dynamics governed by a Lotka-Volterra competition reaction-diffusion system.

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Population dynamics governed by a Lotka-Volterra competition reaction-diffusion system.

Vacant. A species population does not exist within the cell.

Populated. A species population exists within the cell.

Saturated. The species population has reached its carrying capacity.

Restricted. A cell cannot facilitate the population of a species.

CA component: Cell states

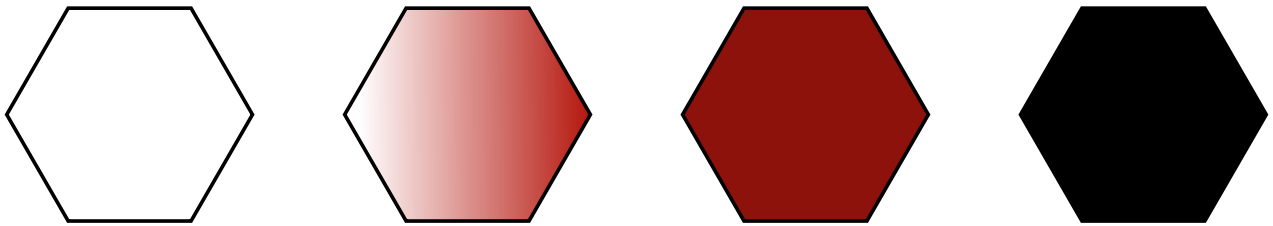
Population dynamics governed by a Lotka-Volterra competition reaction-diffusion system.

Vacant. A species population does not exist within the cell.

Populated. A species population exists within the cell.

Saturated. The species population has reached its carrying capacity.

Restricted. A cell cannot facilitate the population of a species.



Vacant Populated Saturated Resticted

CA component: Transition rules

Population growth. If a species population is present in a cell, that population size will increase subject to other species' presence.

CA component: Transition rules

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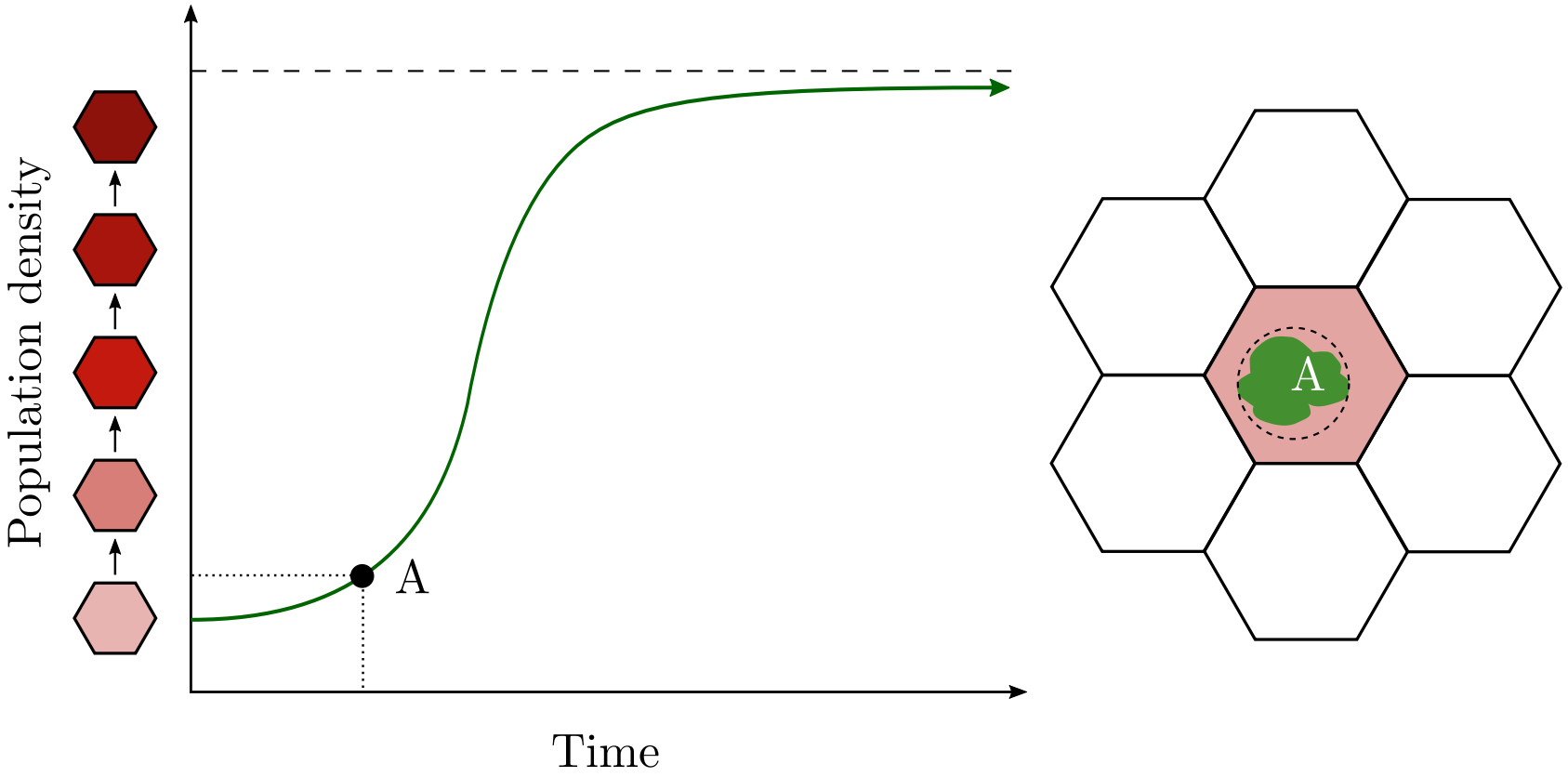

CA component: Transition rules

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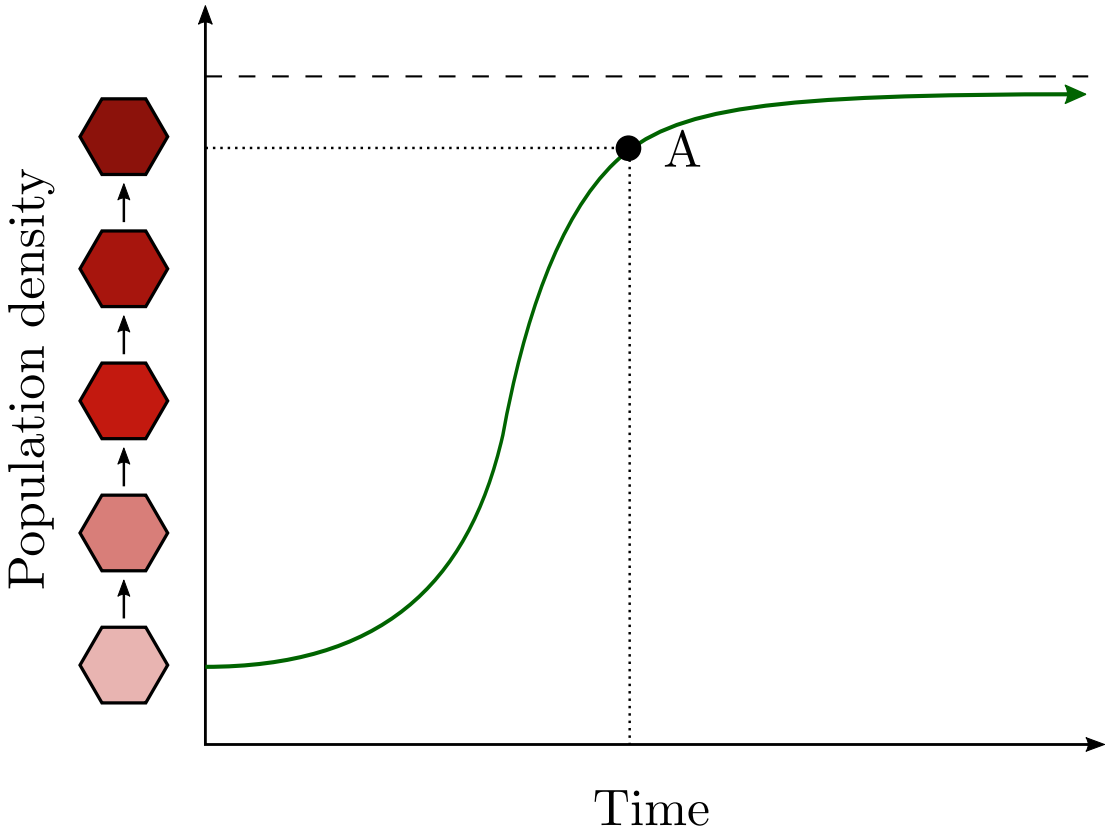

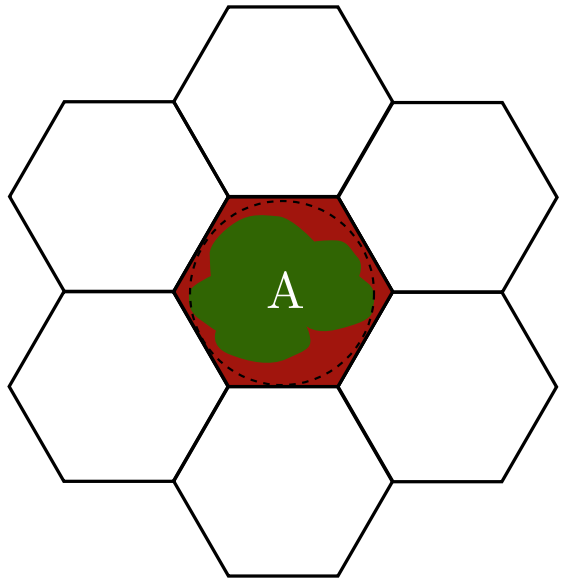

CA component: Transition rules

Population dispersal. If a species is old enough to produce offspring, the offspring will disperse among neighbouring cells.

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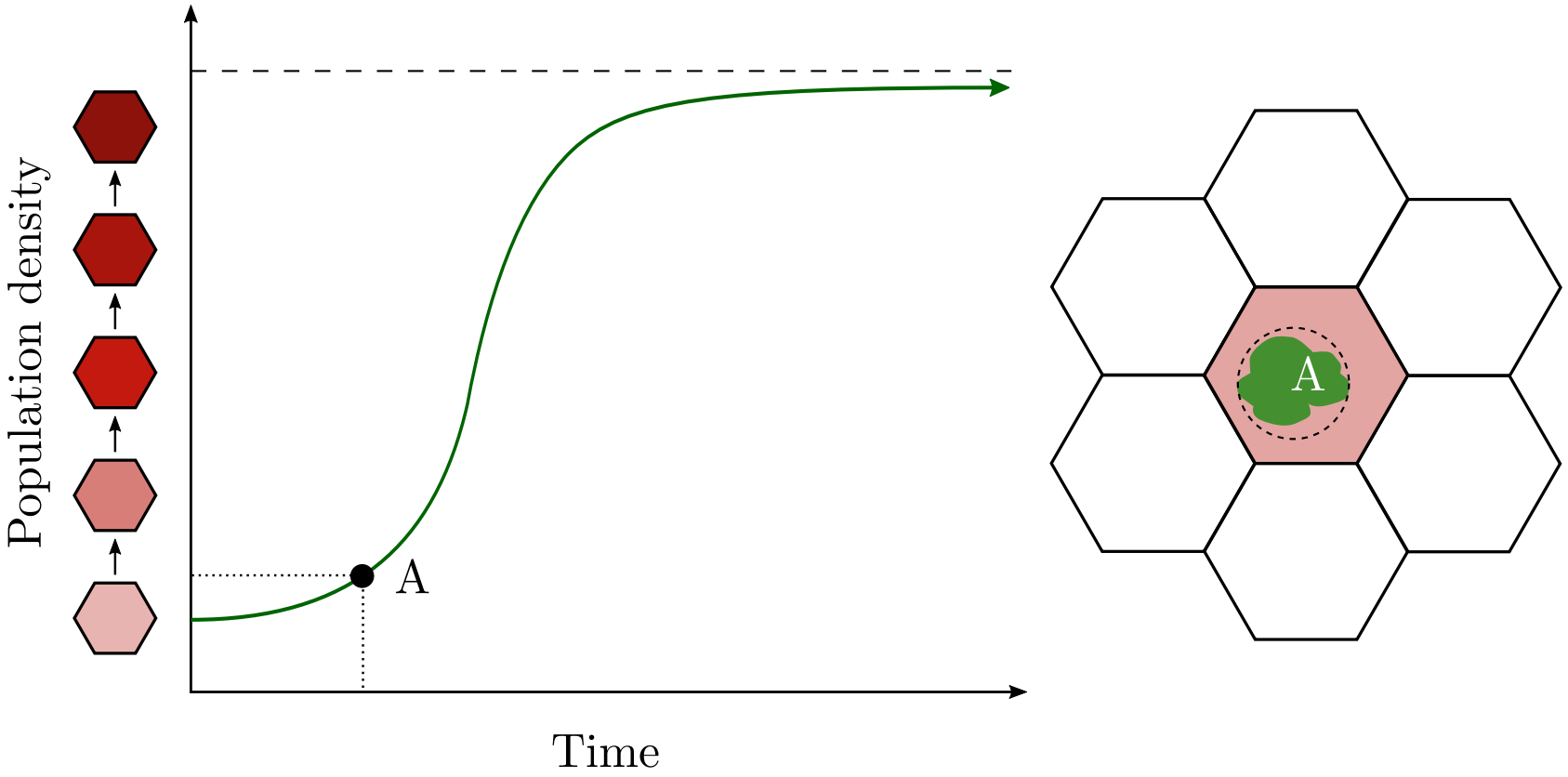

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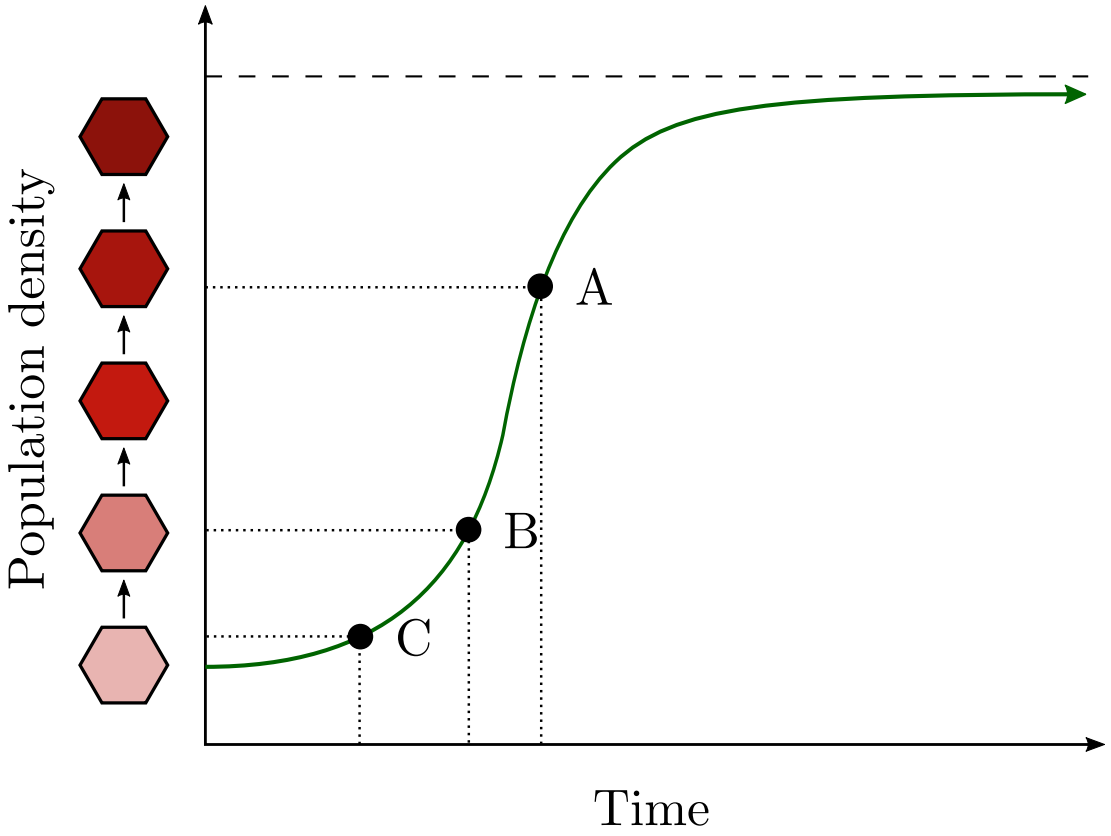

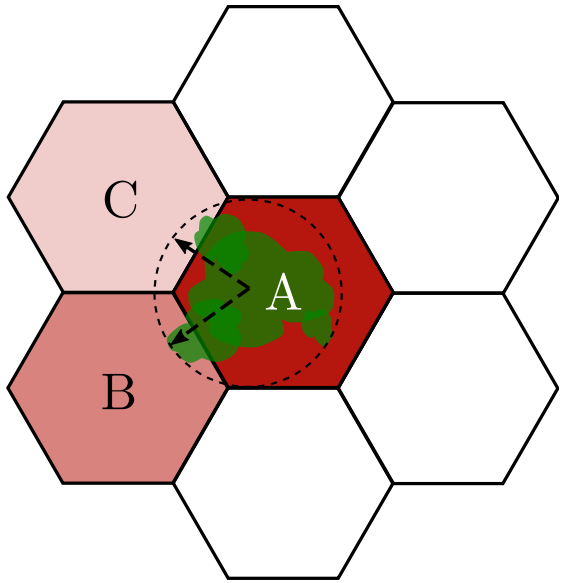

CA component: Transition rules

Population extintion. If the population density of a species in a cell decreases to zero due to competition with other species or insufficient population growth.

CA component: Transition rules

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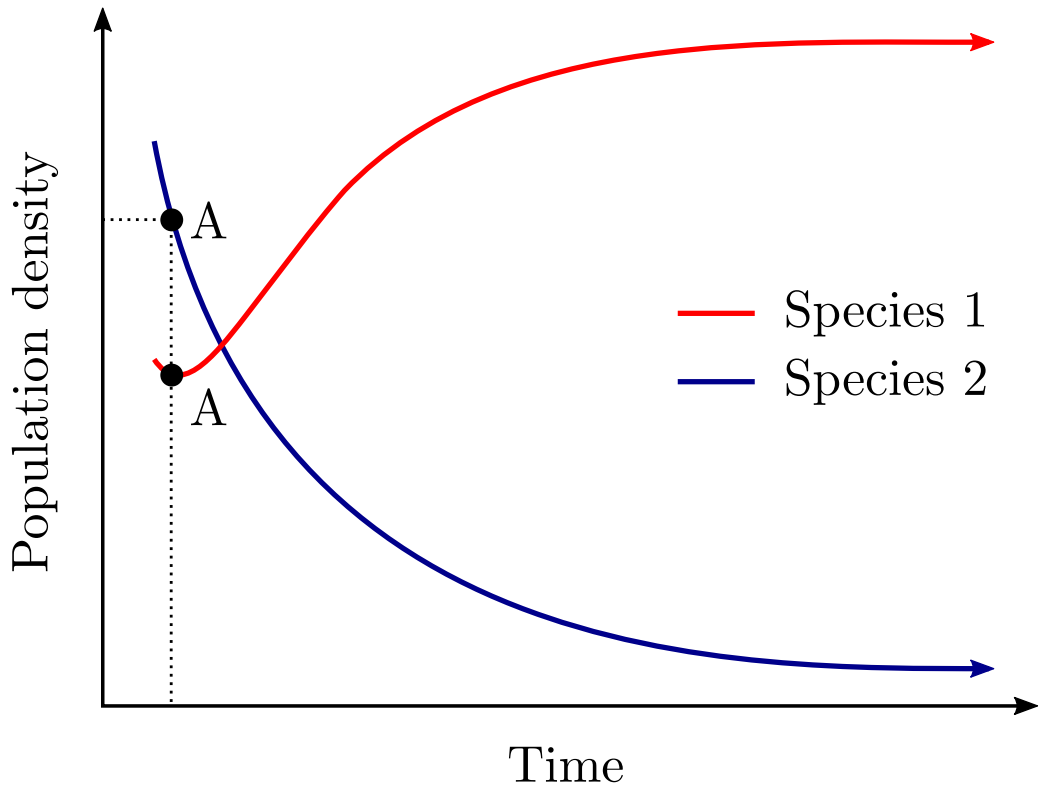

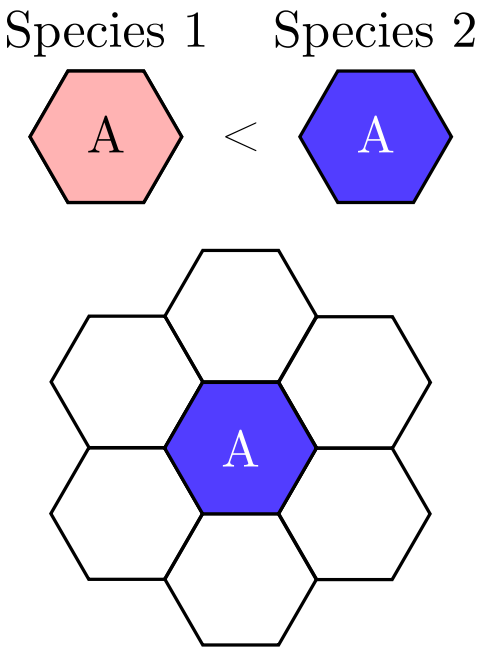

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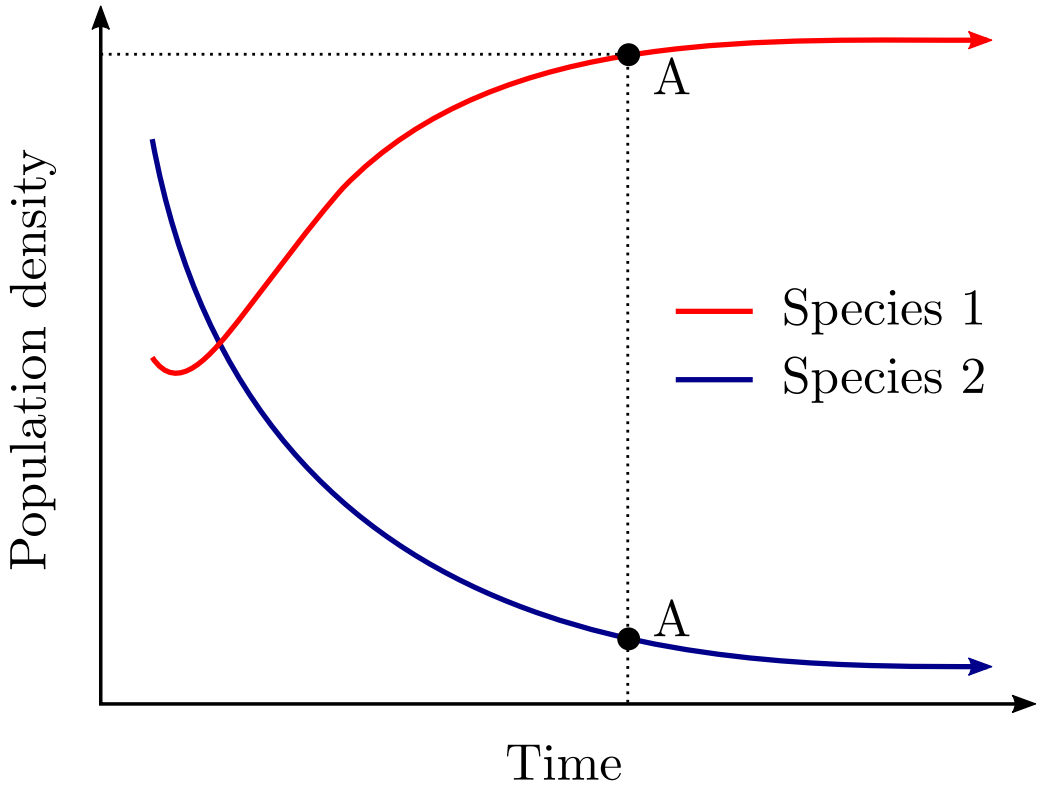
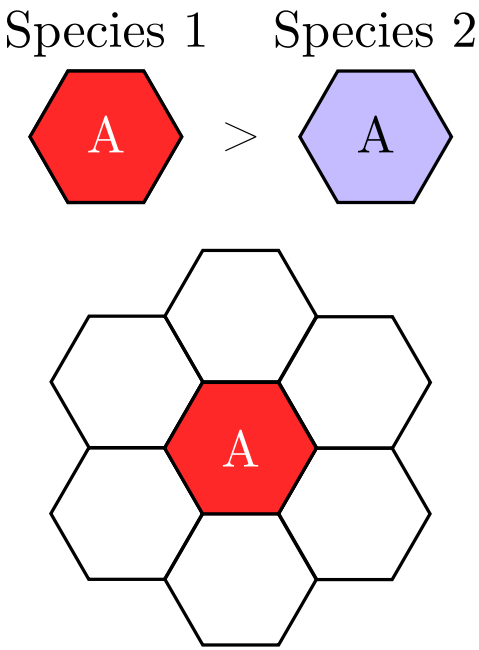
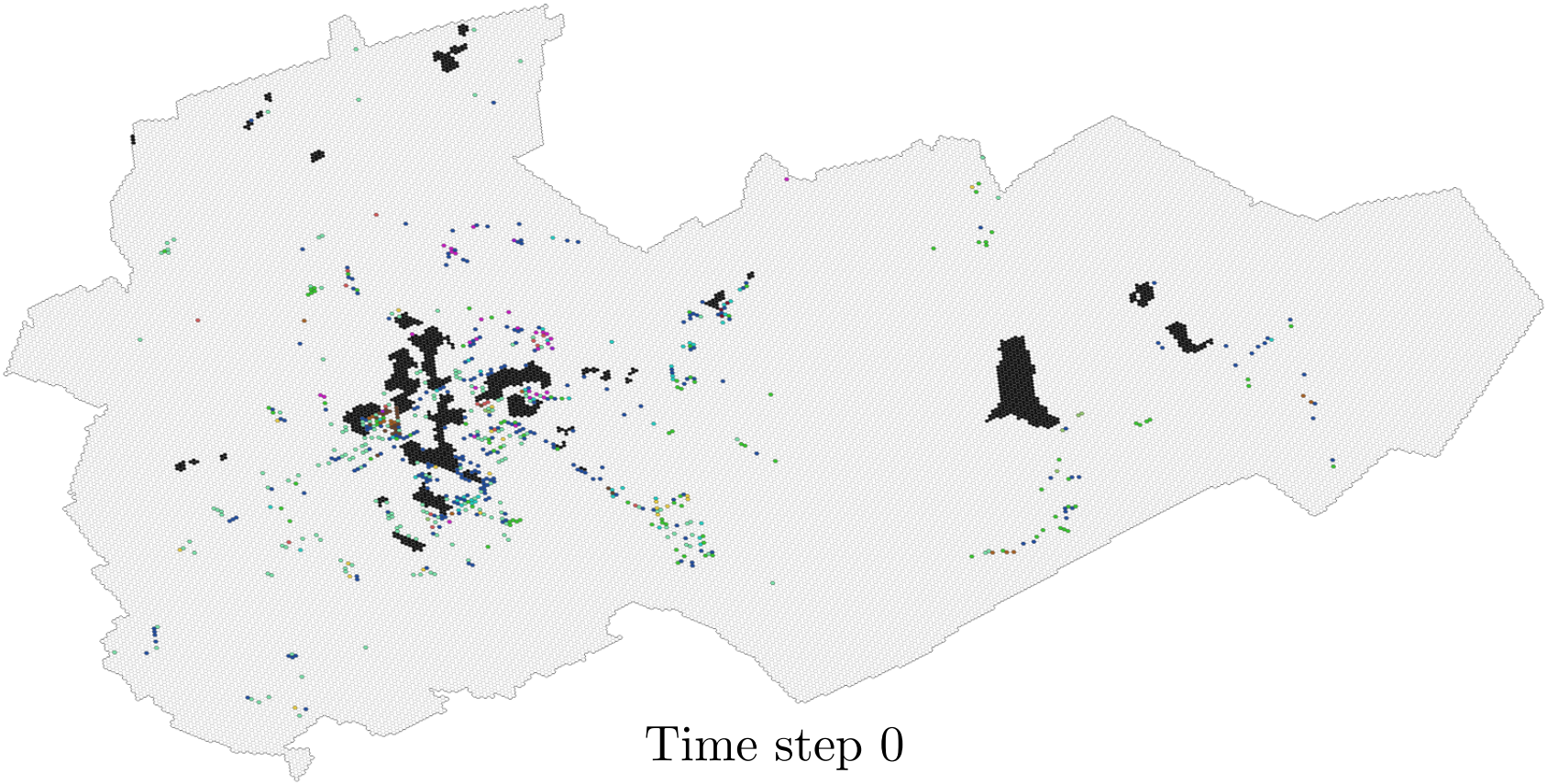




Predicting competition and spread

- Acacia *baileyana*
- Acacia *cyclops*
- Acacia *dealbata*
- Acacia *decurrens*
- Acacia *elata*
- Acacia *implexa*
- Acacia *longifolia*
- Acacia *mearnsii*
- Acacia *melanoxylon*
- Acacia *podalyriifolia*
- Acacia *pycnantha*
- Acacia *saligna*



Time step 0

Predicting competition and spread

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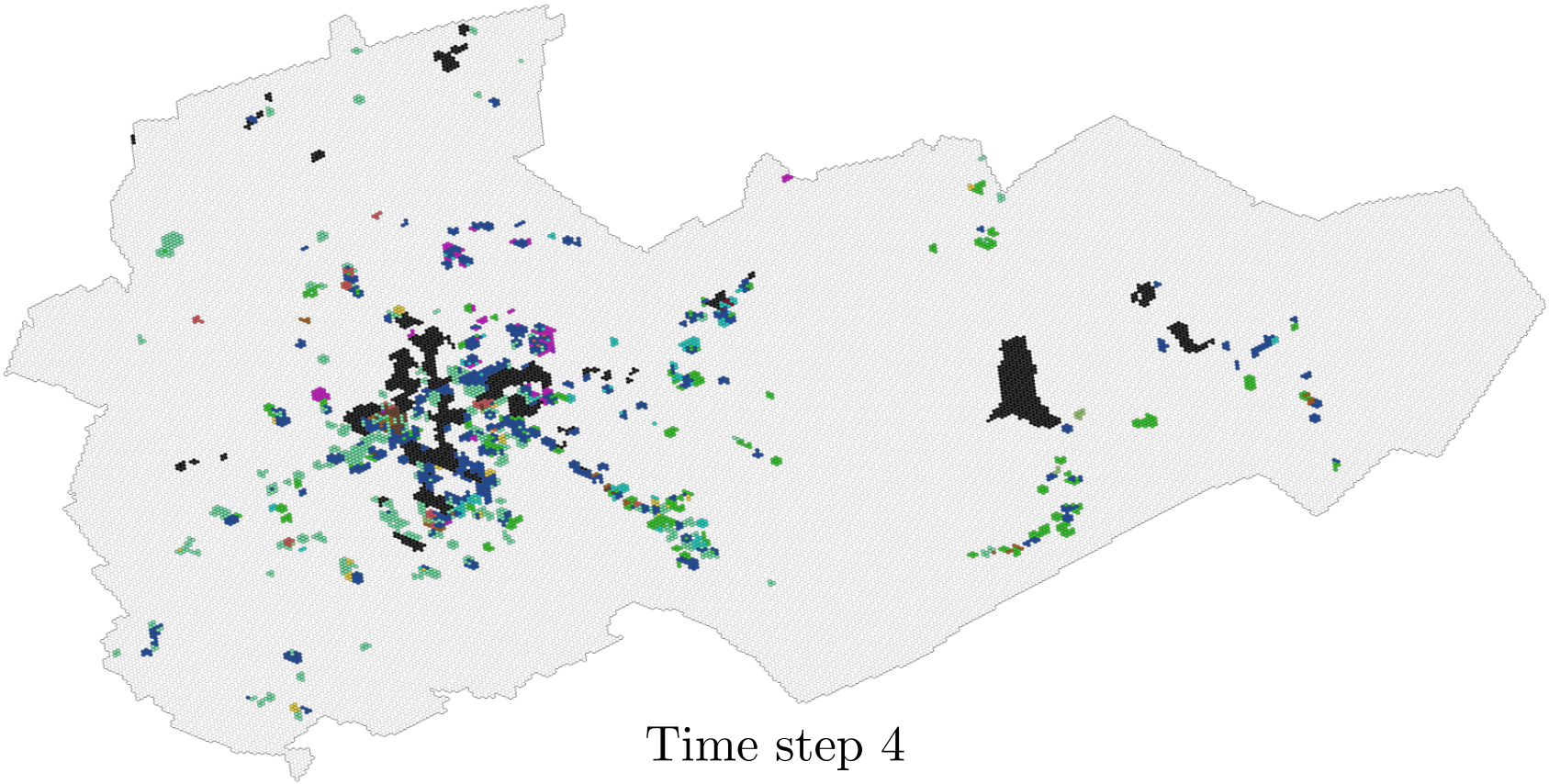

Time step 4

Predicting competition and spread

- Acacia *baileyana*
- Acacia *cyclops*
- Acacia *dealbata*
- Acacia *decurrens*
- Acacia *elata*
- Acacia *implexa*
- Acacia *longifolia*
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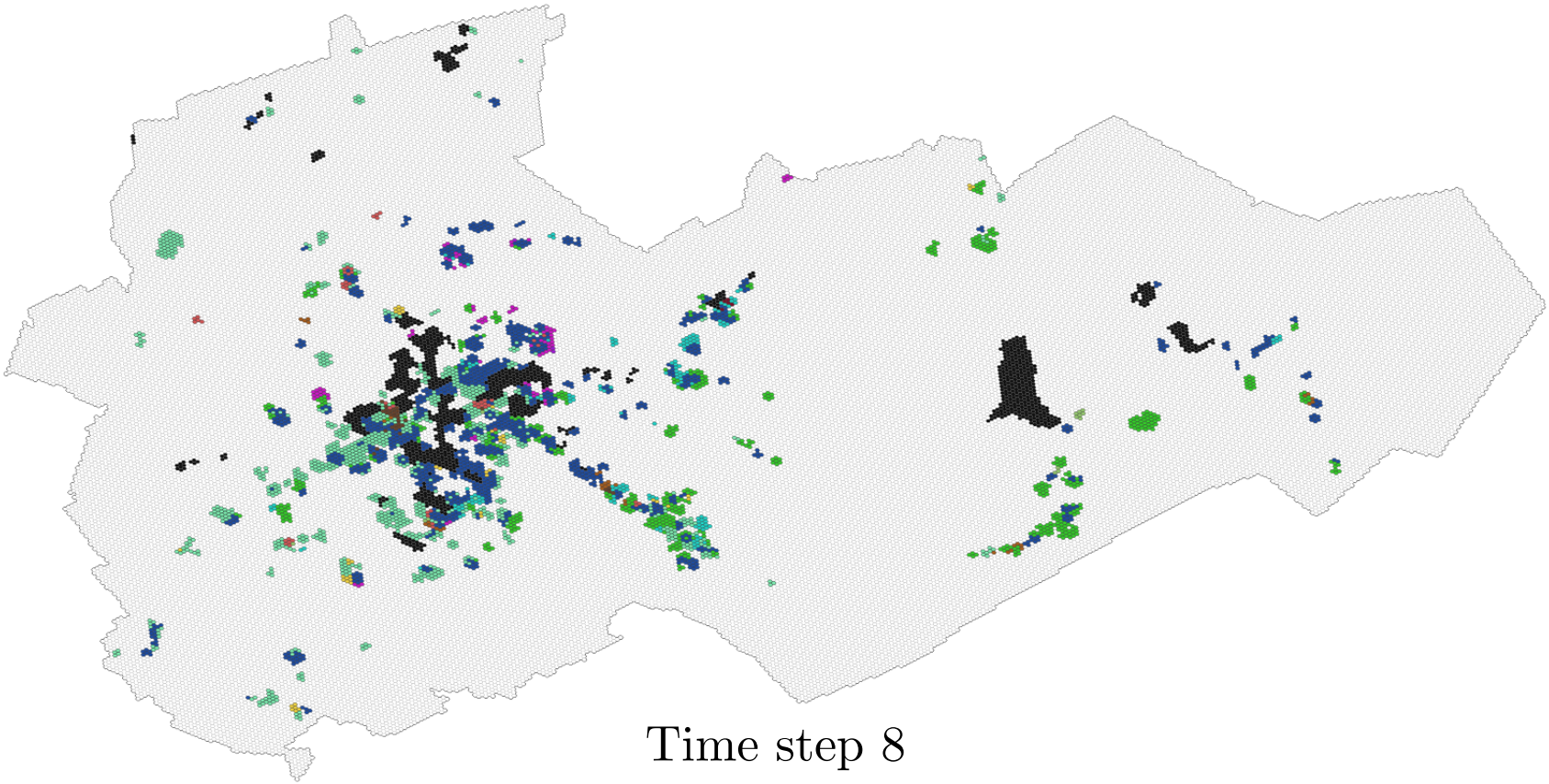
- Acacia *saligna*



Time step 8

Predicting competition and spread

- Acacia *baileyana*
- Acacia *cyclops*
- Acacia *dealbata*
- Acacia *decurrens*
- Acacia *elata*
- Acacia *implexa*
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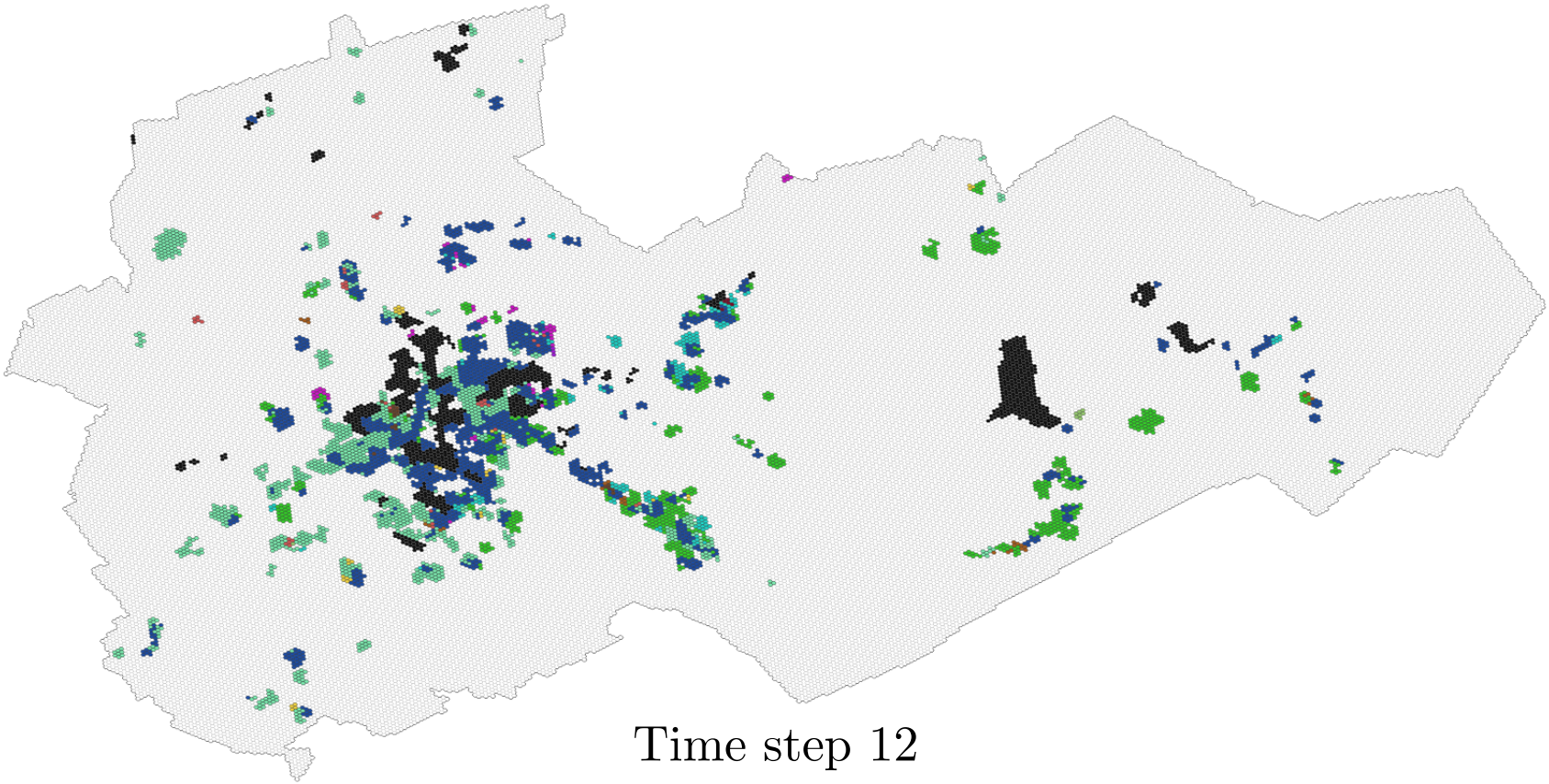
- Acacia *saligna*



Time step 12

Predicting competition and spread

- Acacia *baileyana*
- Acacia *cyclops*
- Acacia *dealbata*
- Acacia *decurrens*
- Acacia *elata*
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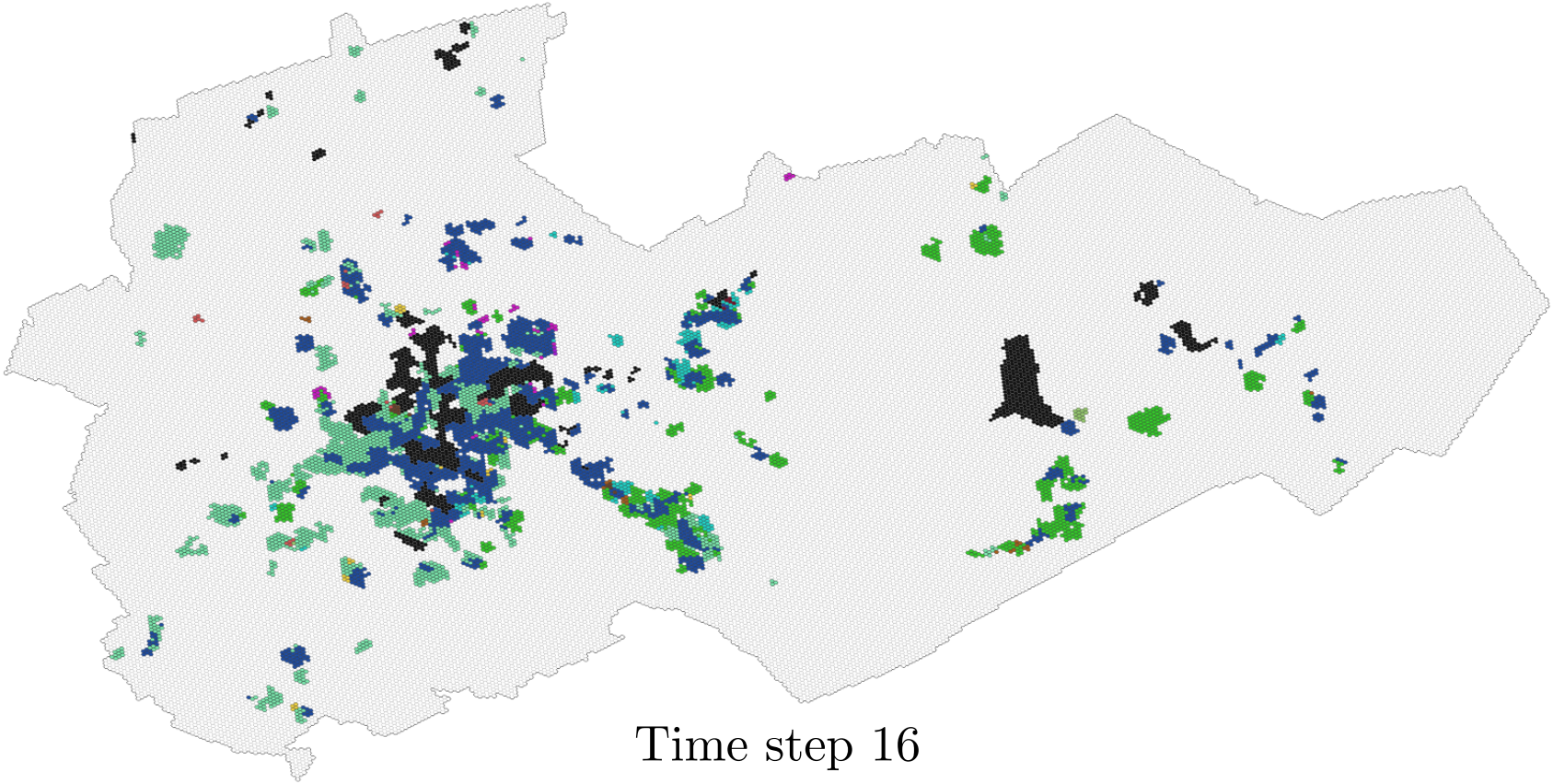

Time step 16

Predicting competition and spread

- Acacia *baileyana*
- Acacia *cyclops*
- Acacia *dealbata*
- Acacia *decurrens*
- Acacia *elata*
- Acacia *implexa*
- Acacia *longifolia*
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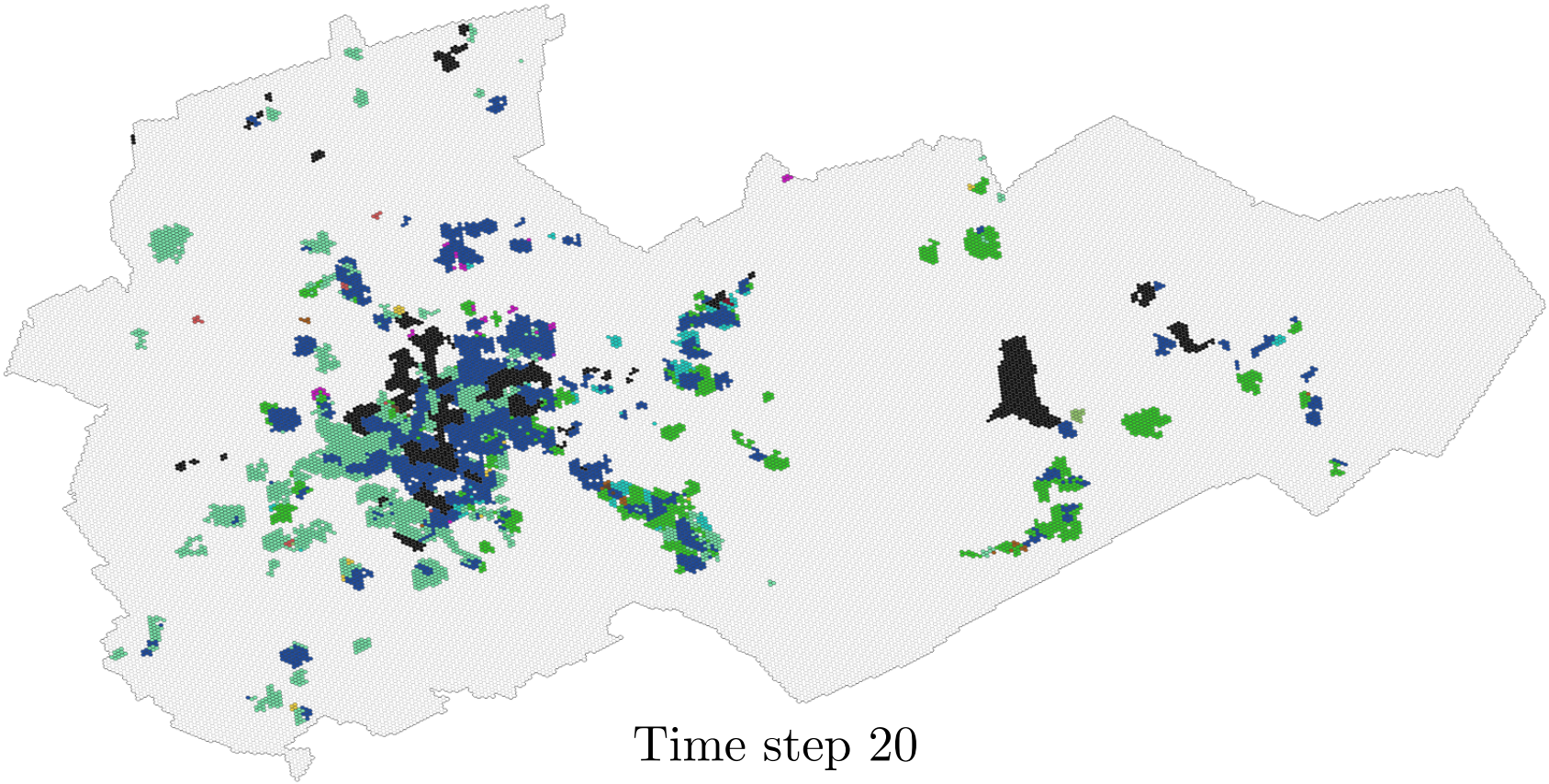
- Acacia *saligna*



Time step 20

Management of invasive species spread

Adaptive management component

- Categorise invaded regions for management and control
- Apply and evaluate management strategies.

Management of invasive species spread

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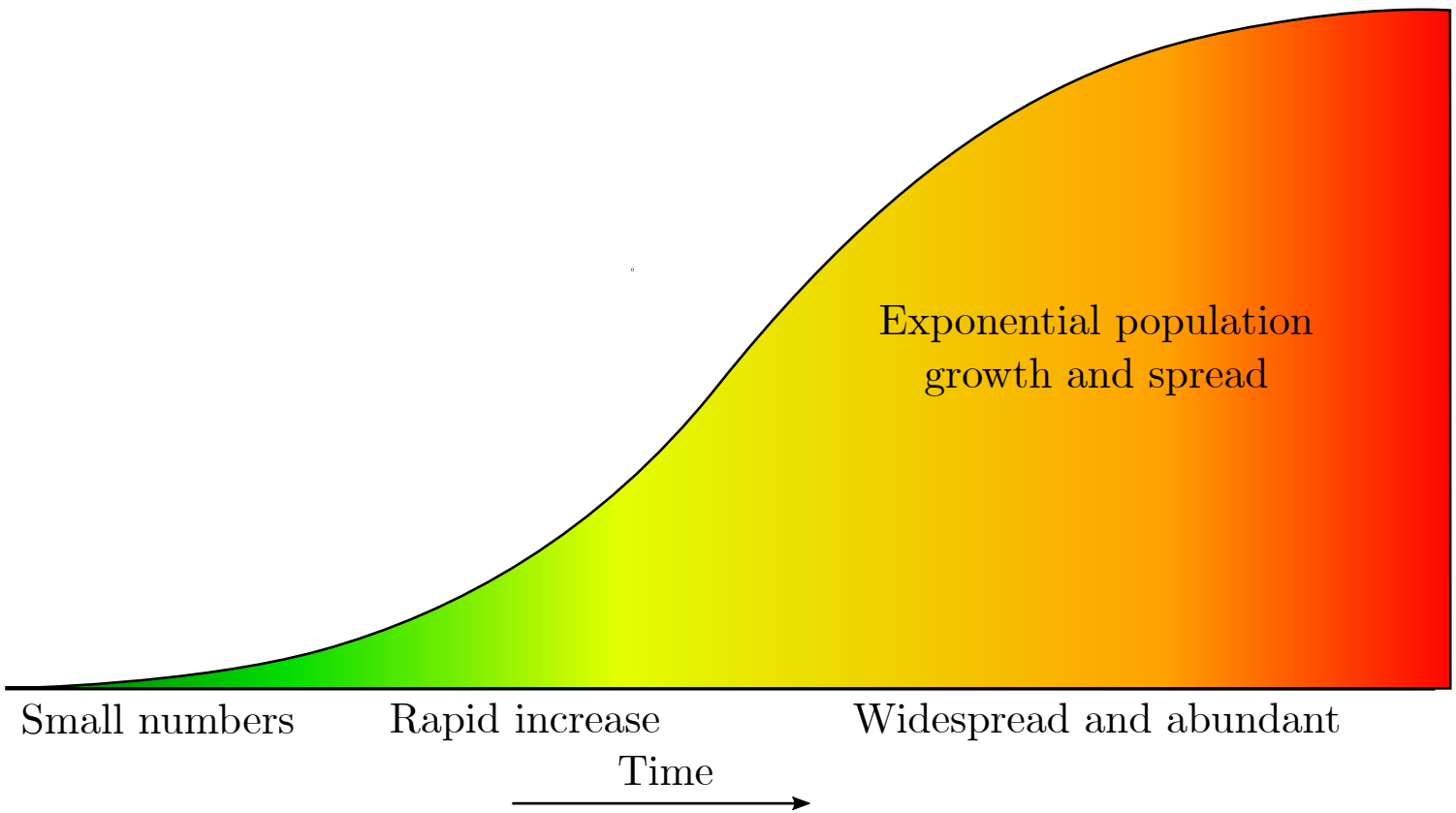

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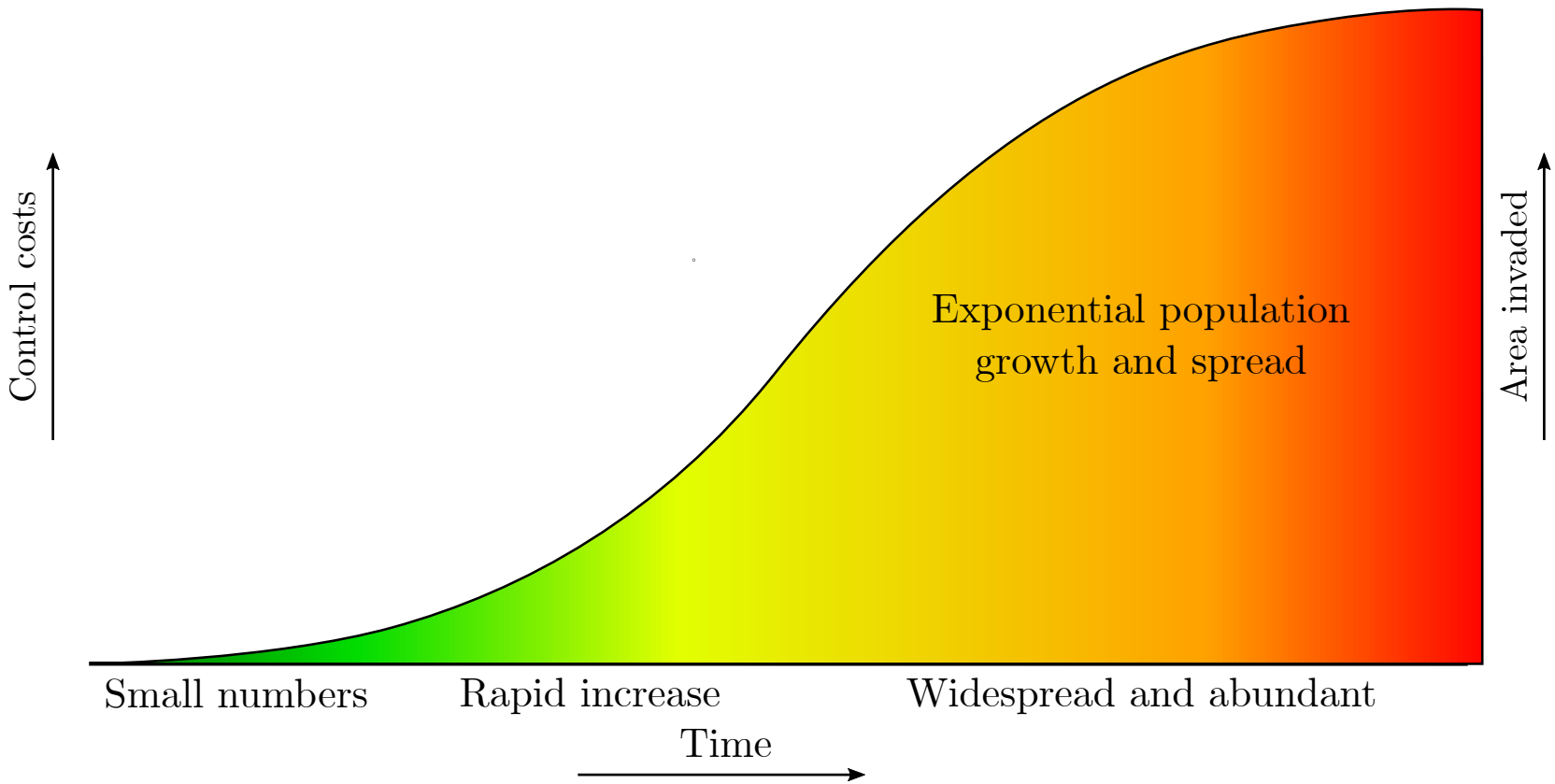

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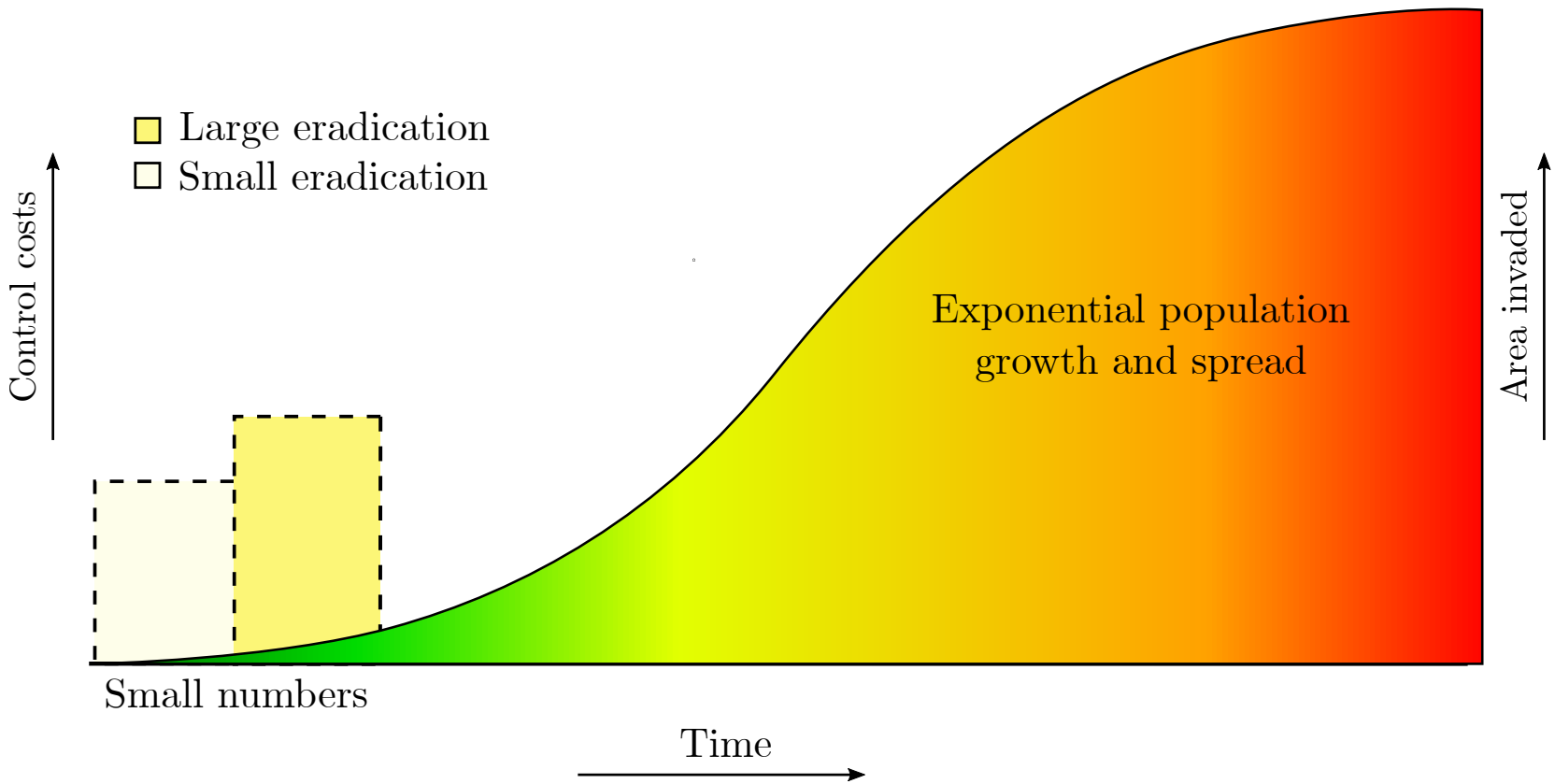

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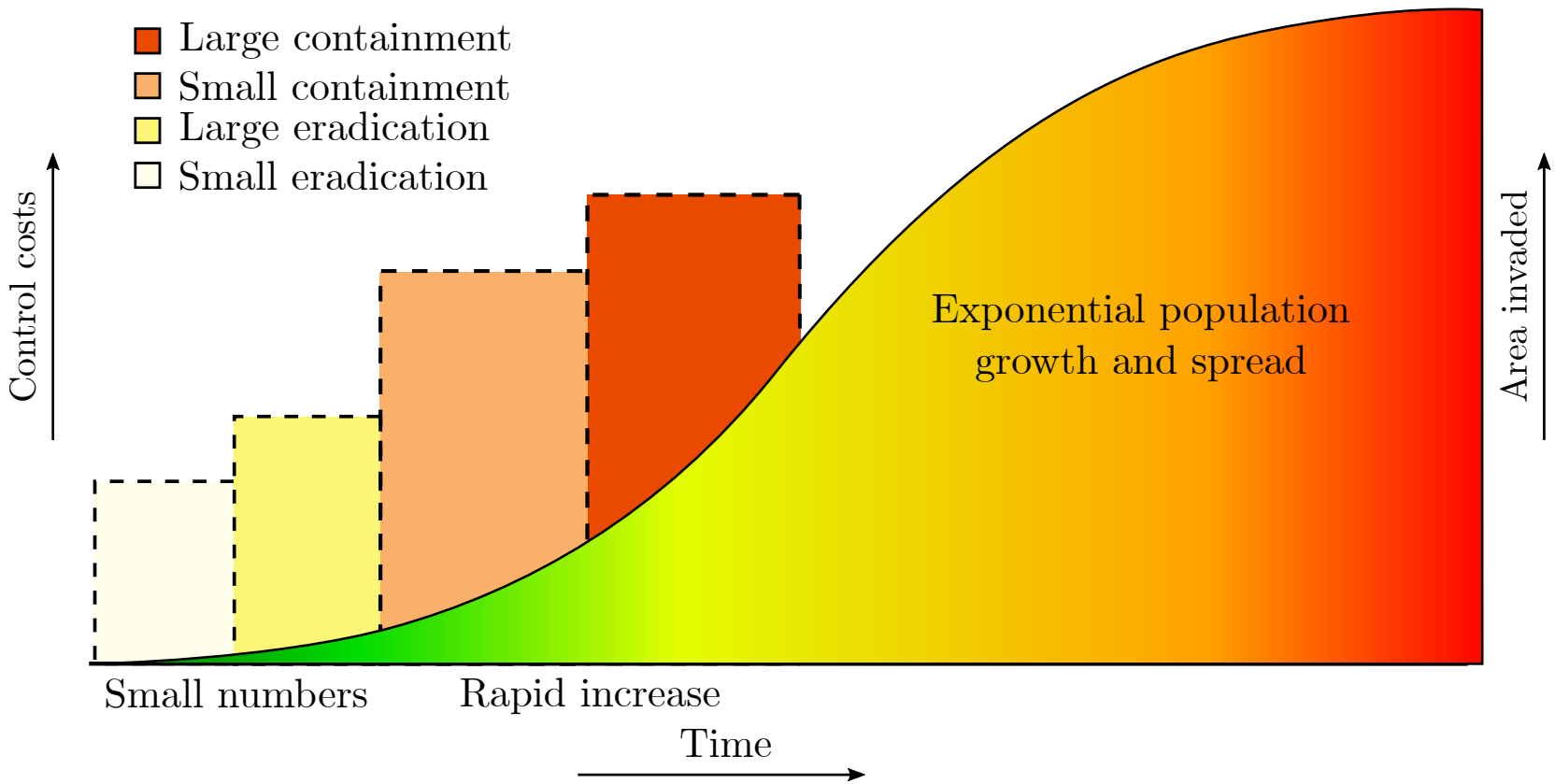

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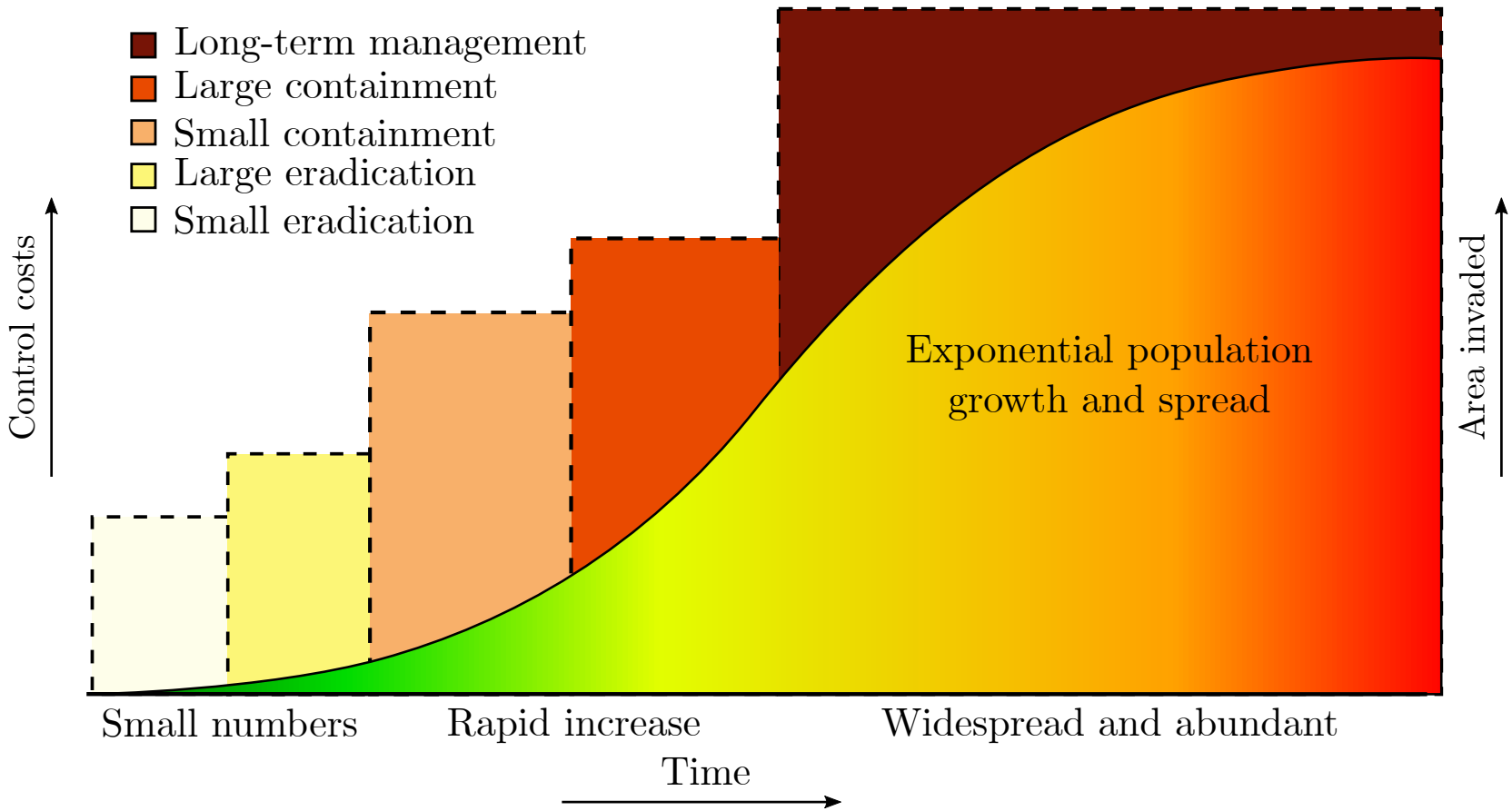

Applying management strategies

- Acacia *baileyana*
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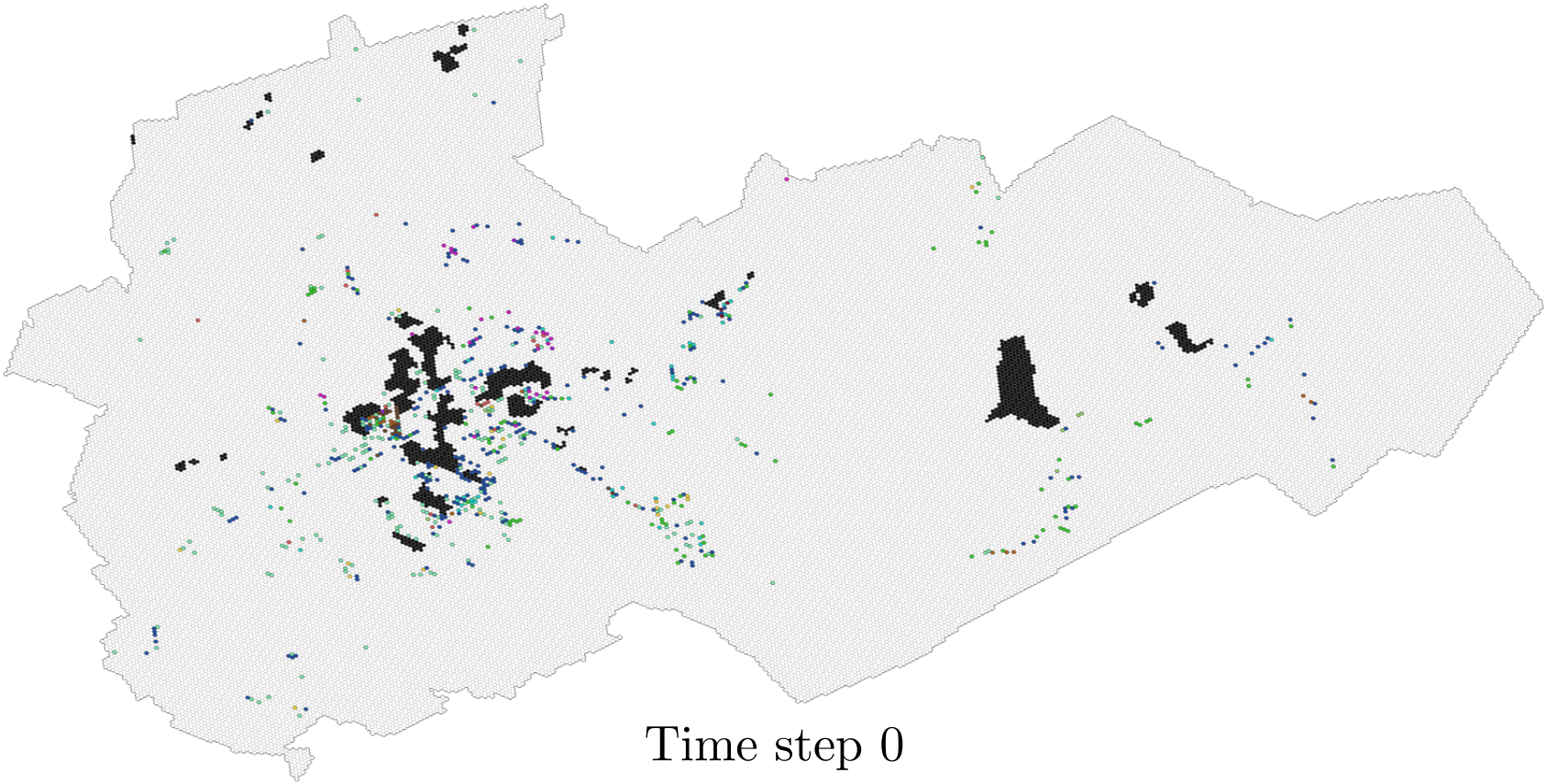

Time step 0

Applying management strategies

- Acacia *baileyana*
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- Acacia *elata*
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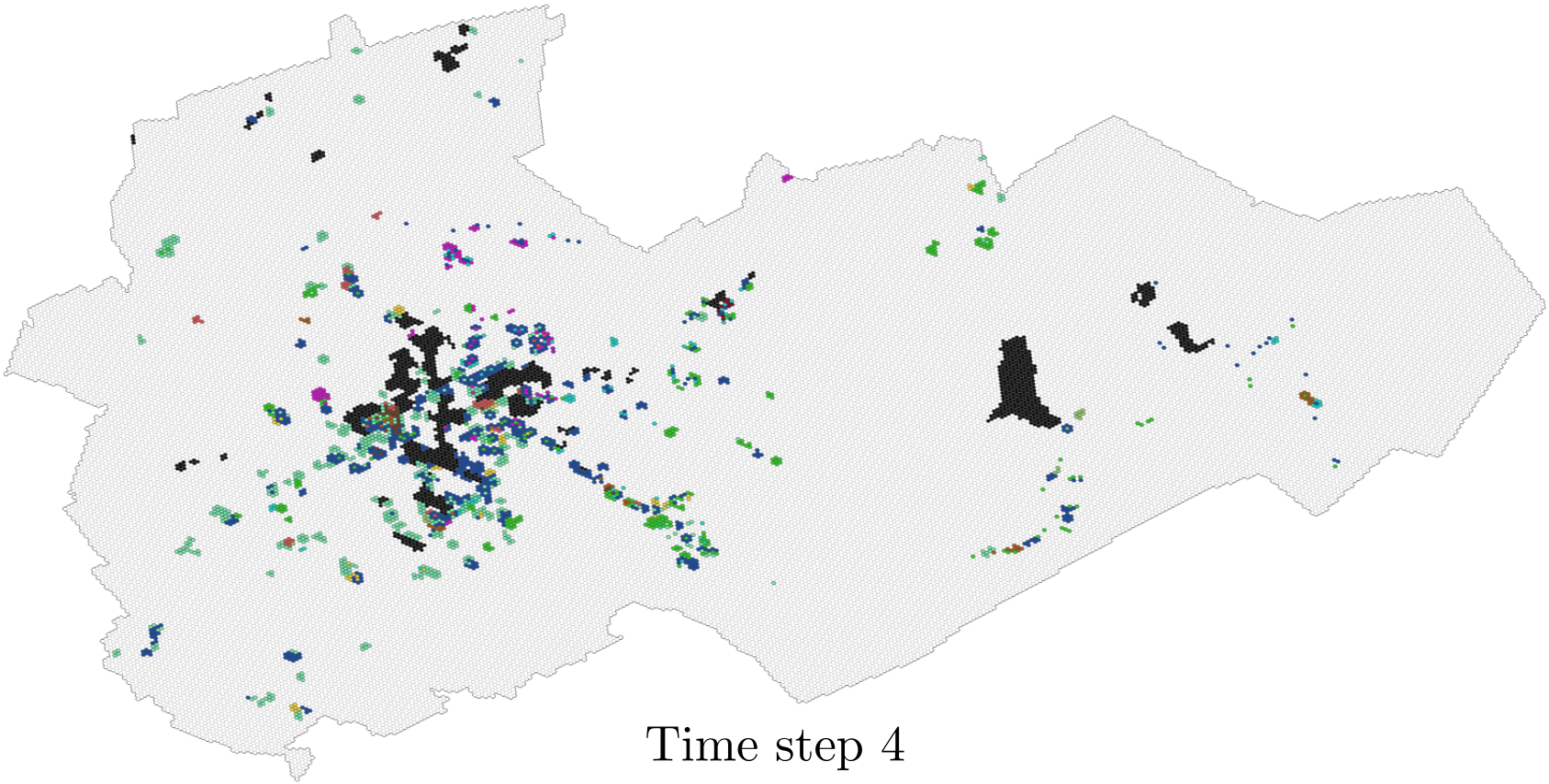

Time step 4

Applying management strategies

- Acacia *baileyana*
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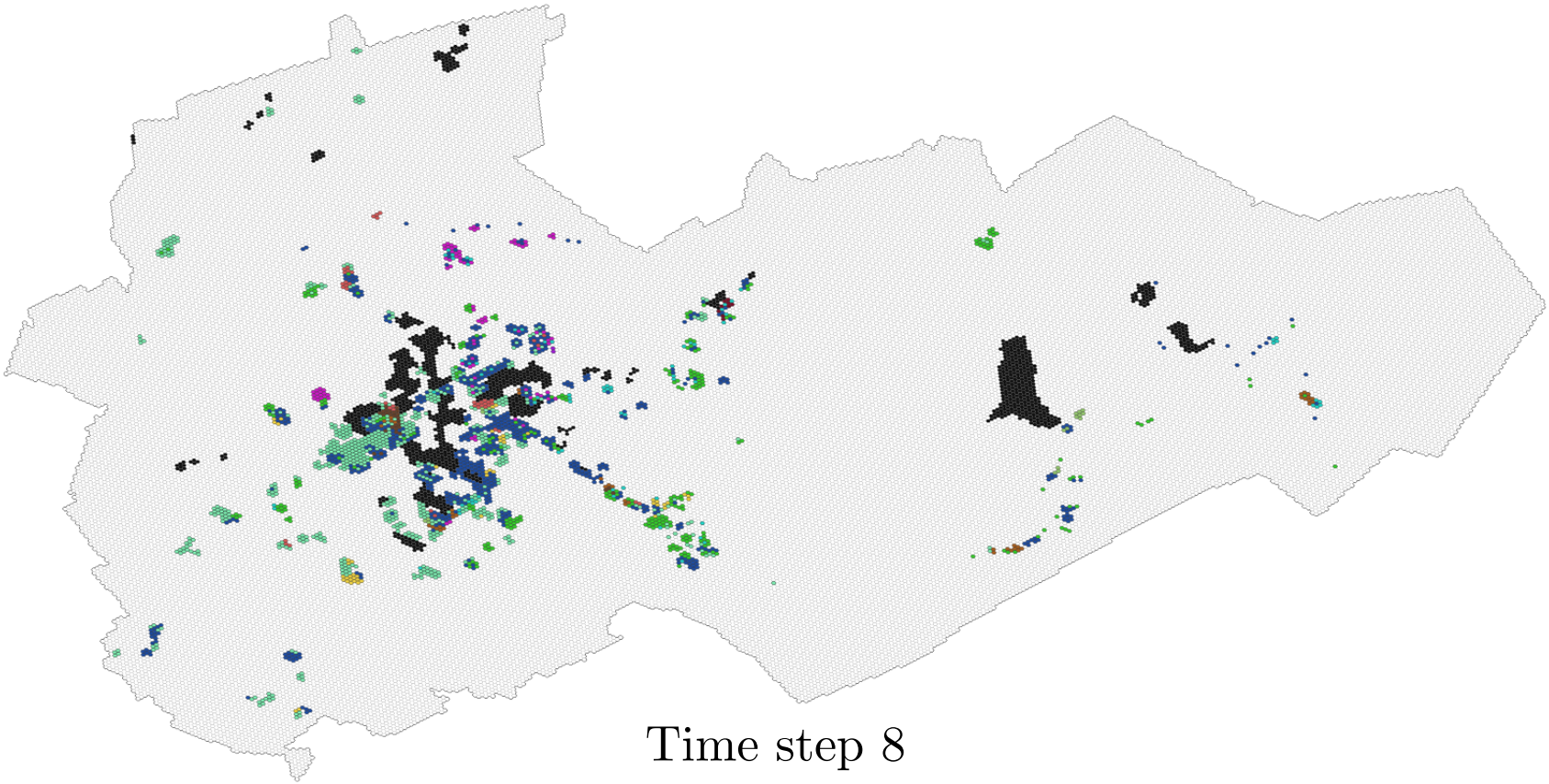

Time step 8

Applying management strategies

- Acacia *baileyana*
- Acacia *cyclops*
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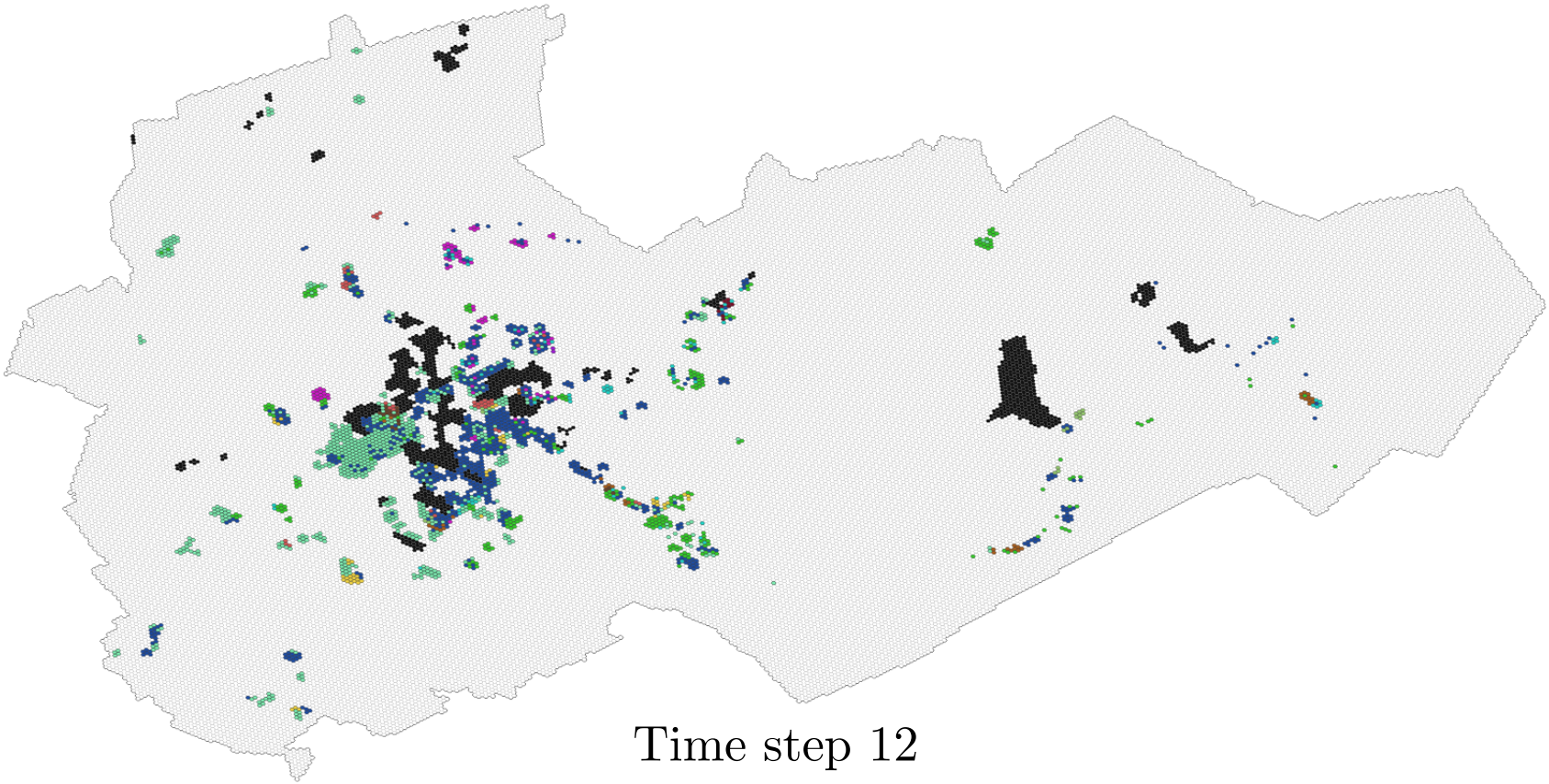

Time step 12

Applying management strategies

- Acacia *baileyana*
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- Acacia *decurrens*
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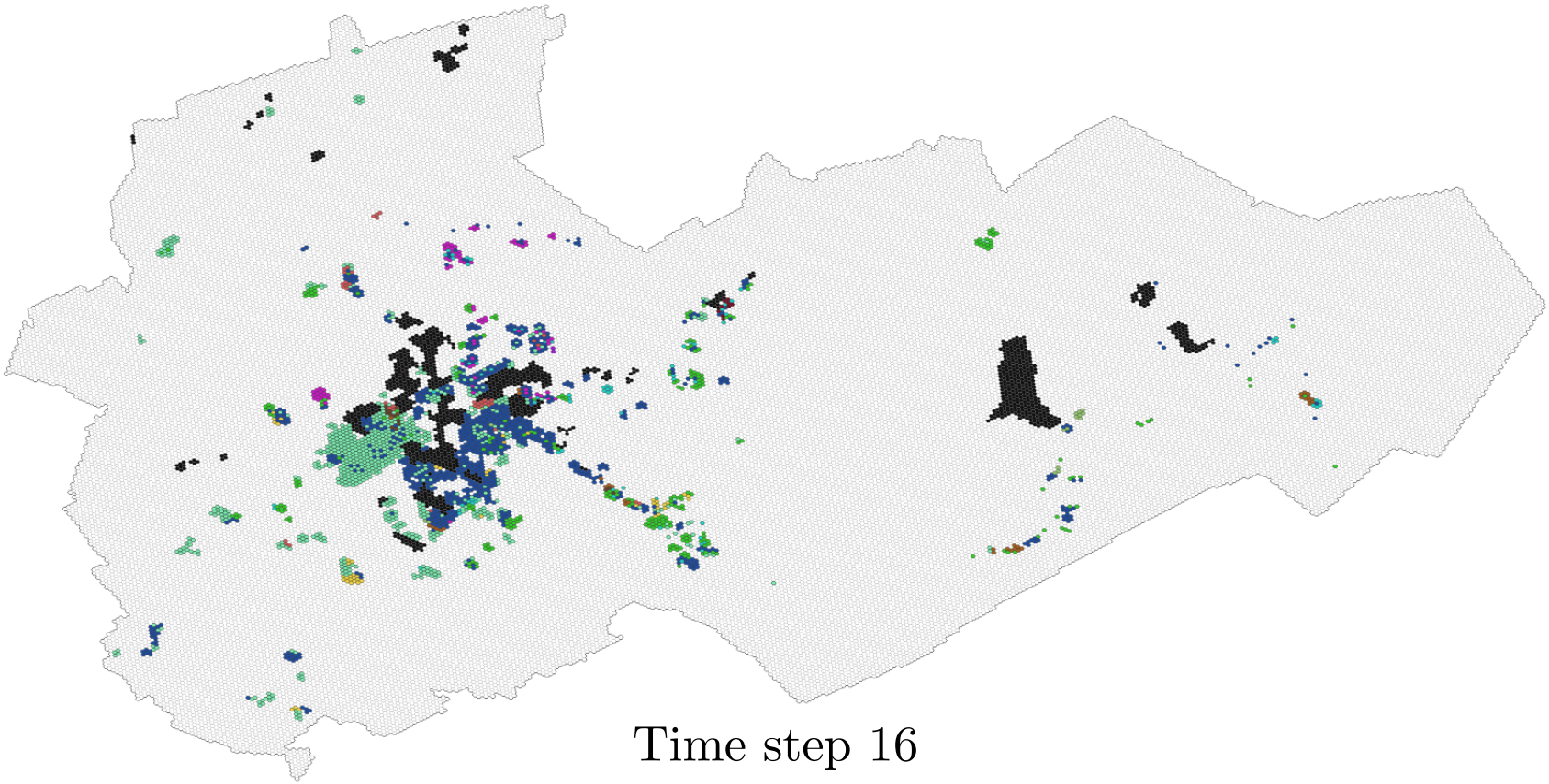

Time step 16

Applying management strategies

- Acacia *baileyana*
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- Acacia *decurrens*
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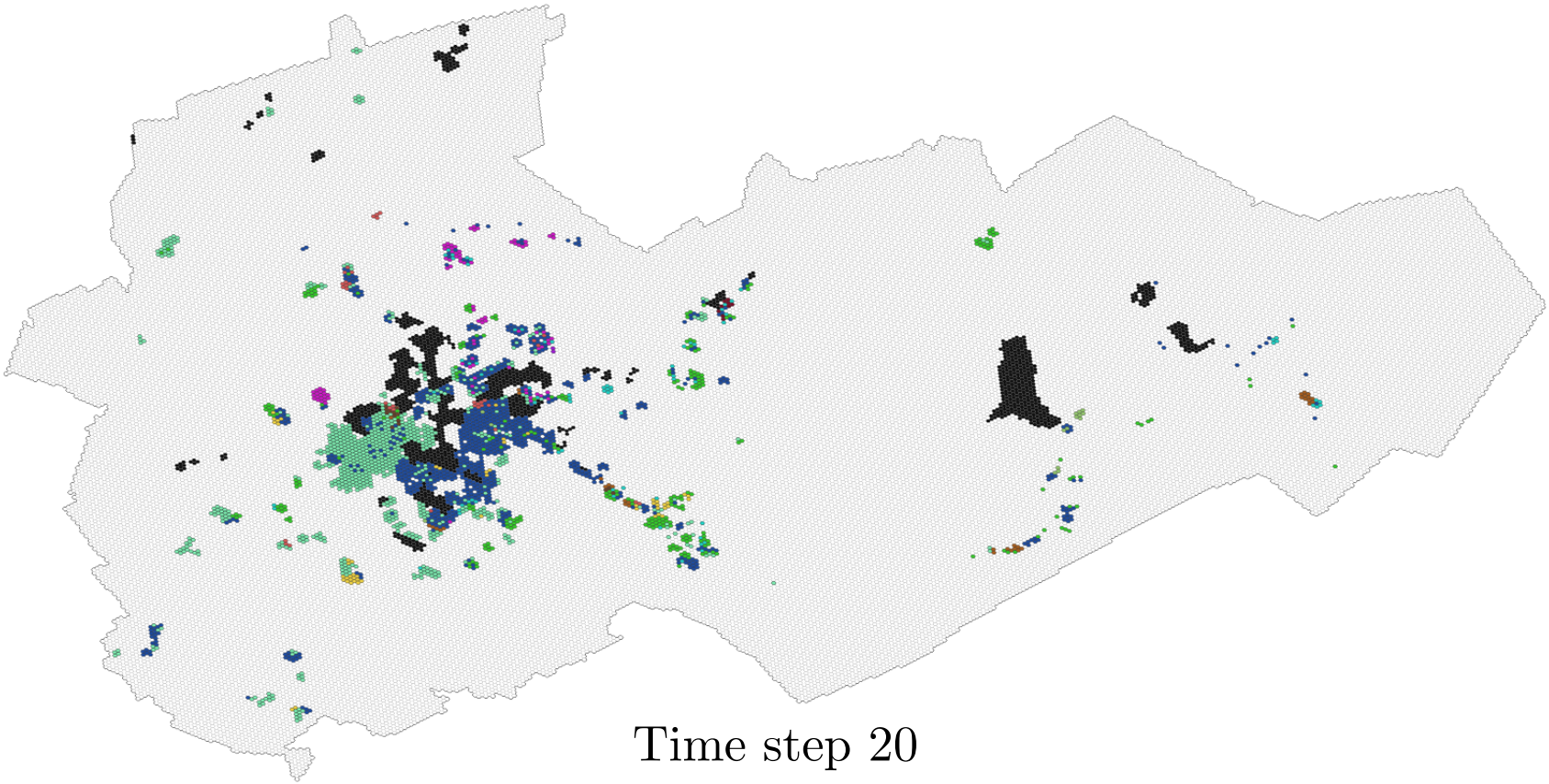
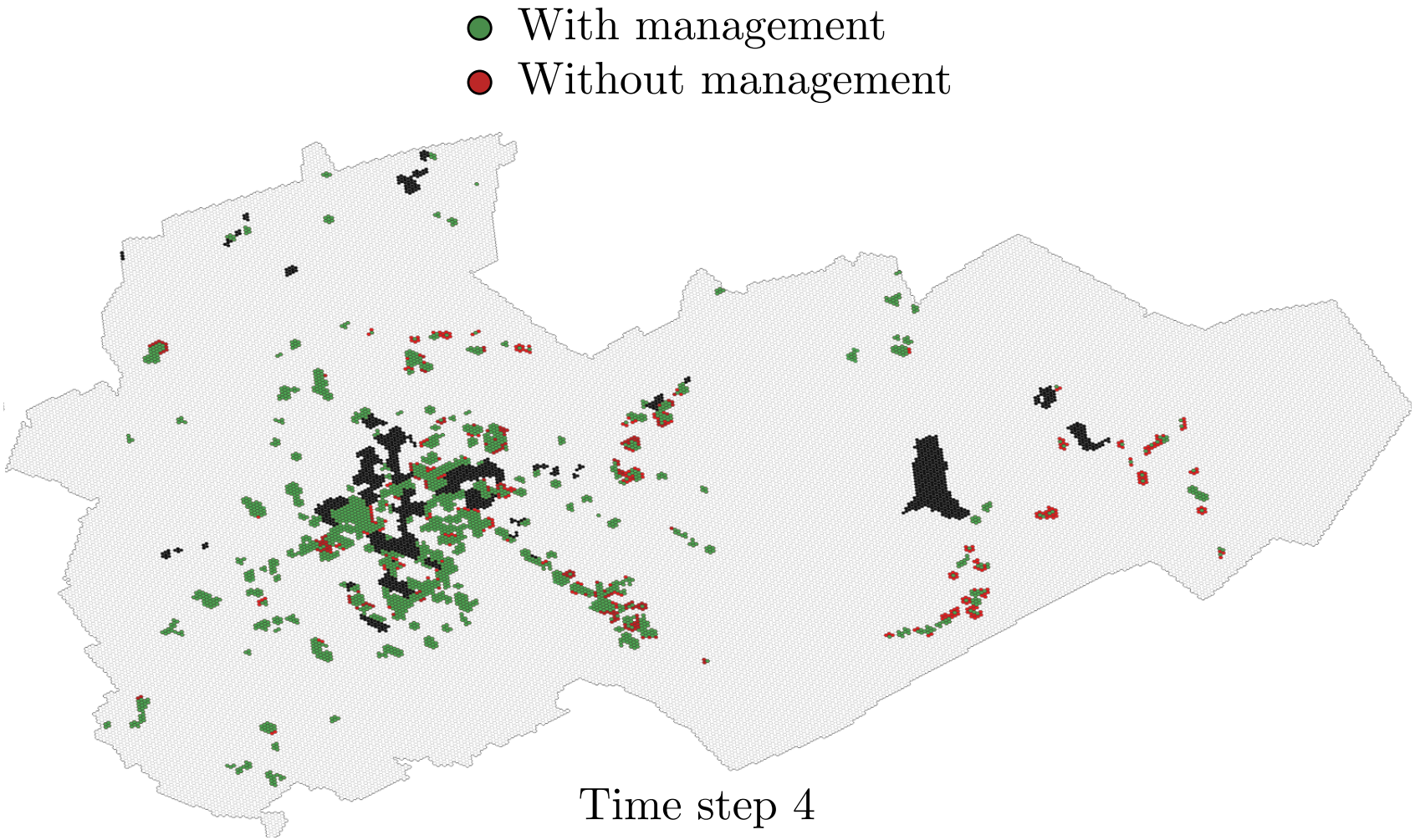
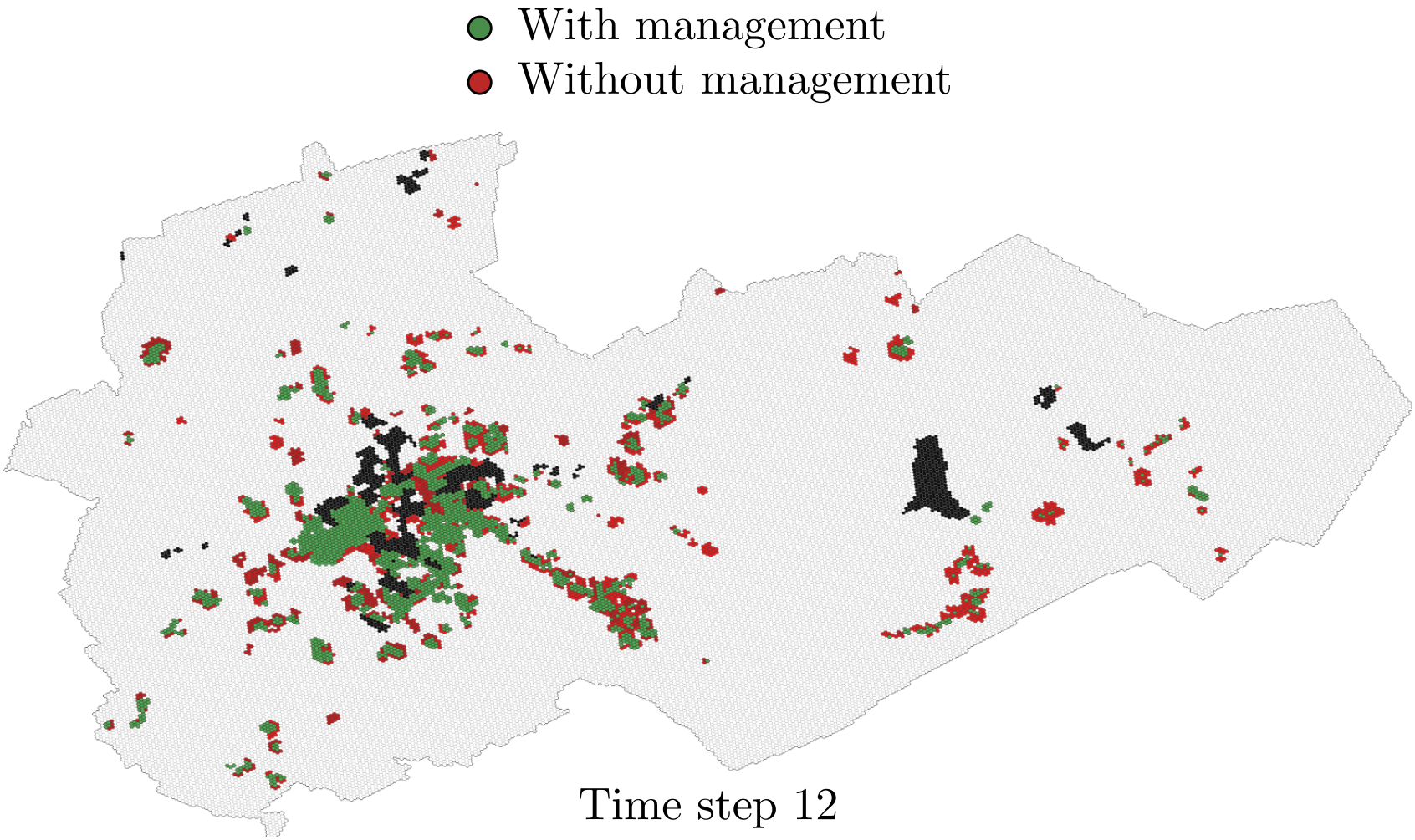


Time step 20

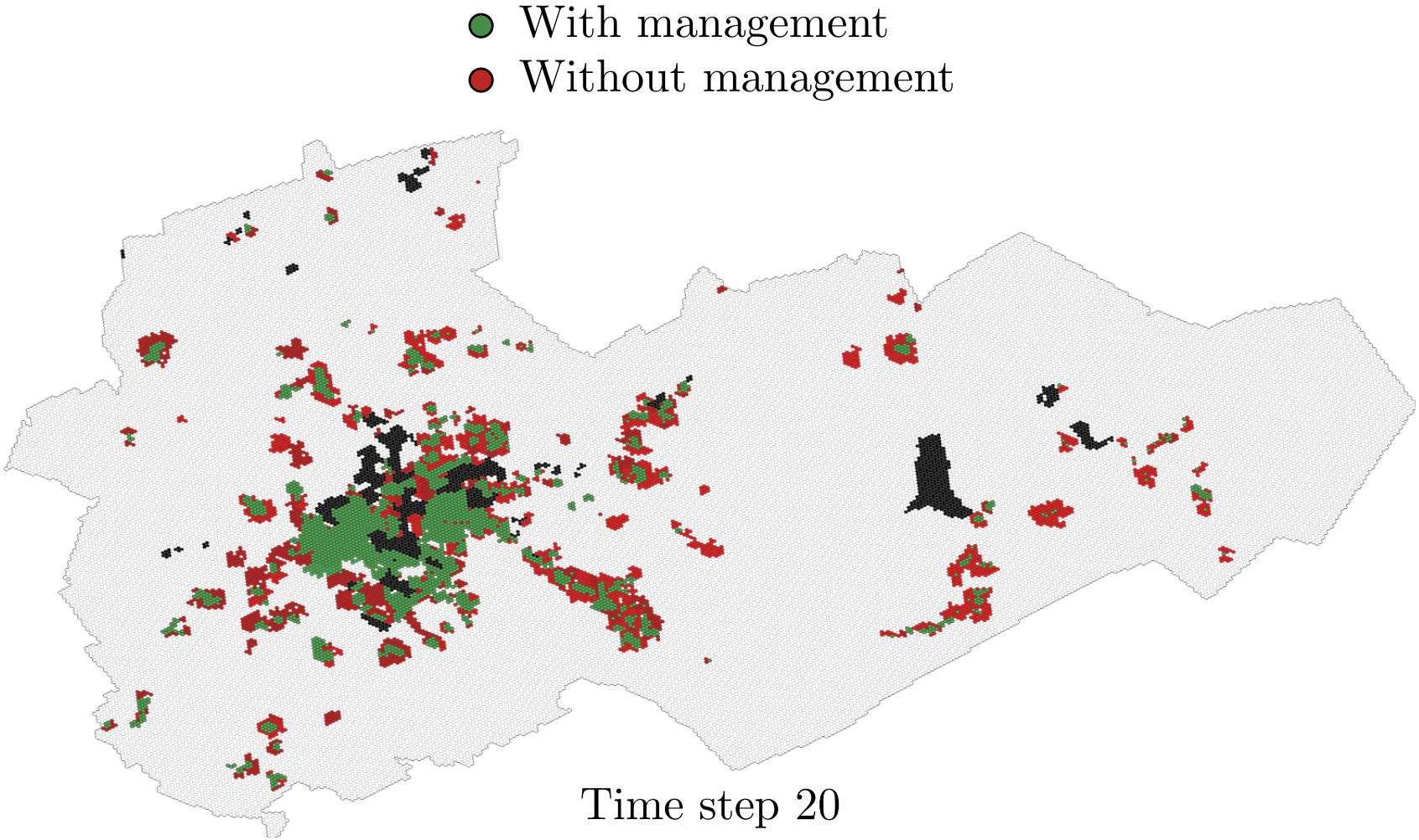
The potential effect of management



The potential effect of management



The potential effect of management



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Pyšek P, Richardson DM, Rejmánek M, Webster GL, Williamson M & Kirschner J, 2004, *Alien plants in checklists and floras: towards better communication between taxonomists and ecologists*, Taxon, **53(1)**, pp. 131–143.

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