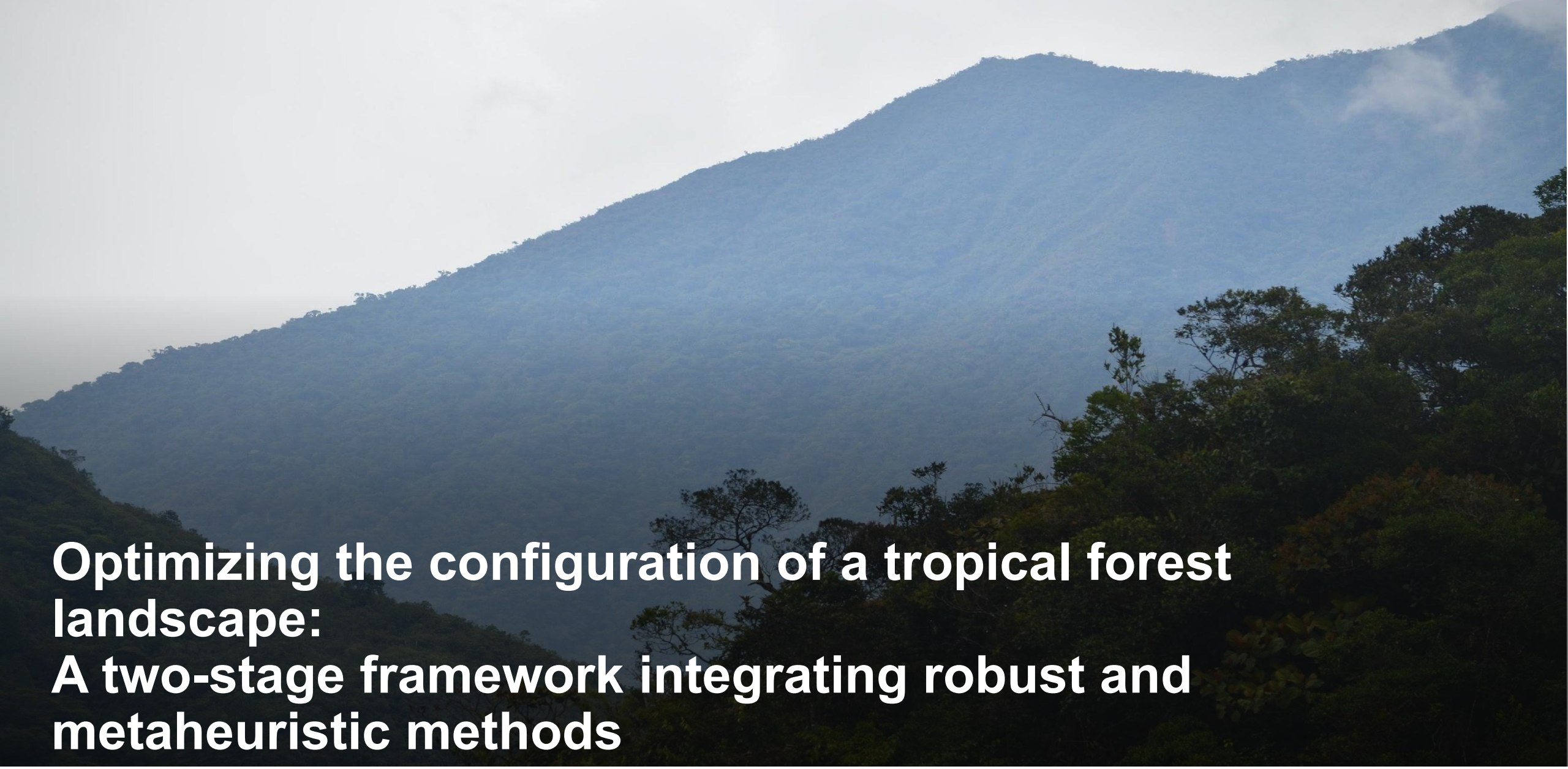

Optimizing the configuration of a tropical forest landscape: A two-stage framework integrating robust and metaheuristic methods

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RESPECT

Technische Universität München

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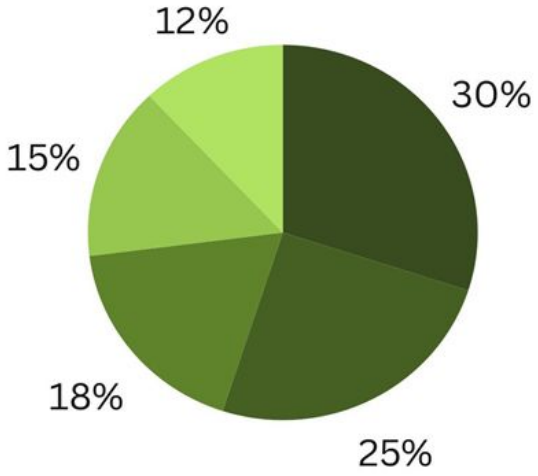
Symposium on Ecosystem Services, Forest Management and Decision Making

Introduction

Moving towards multifunctional landscapes might enhance ES provision, reduce biodiversity loss, and mitigate socio-economic impacts

Introduction

Landscape multifunctionality is influenced by both landscape composition and landscape configuration[1]



Landscape composition

Landscape configuration

[1]Boesing et al. 2024 Global Change Biology. *DOI: 10.1016/j.ecoser.2024.101630*

Study Area

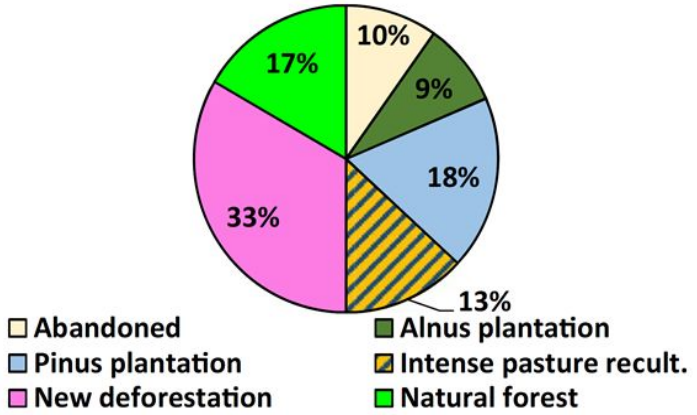
Important biodiversity hotspot, harboring unique levels of species diversity and endemism

Study Area
Highway
Primary River
Elevation (m)
Value
3416
887

Dominated by natural forests and pastureland

Methodological Approach

Robust optimization approach that integrated multiple decision criteria to inform land-use allocation[2]



Indicators:

9 socio-economic, 14 ecosystem services and 2 biodiversity

Scenarios:

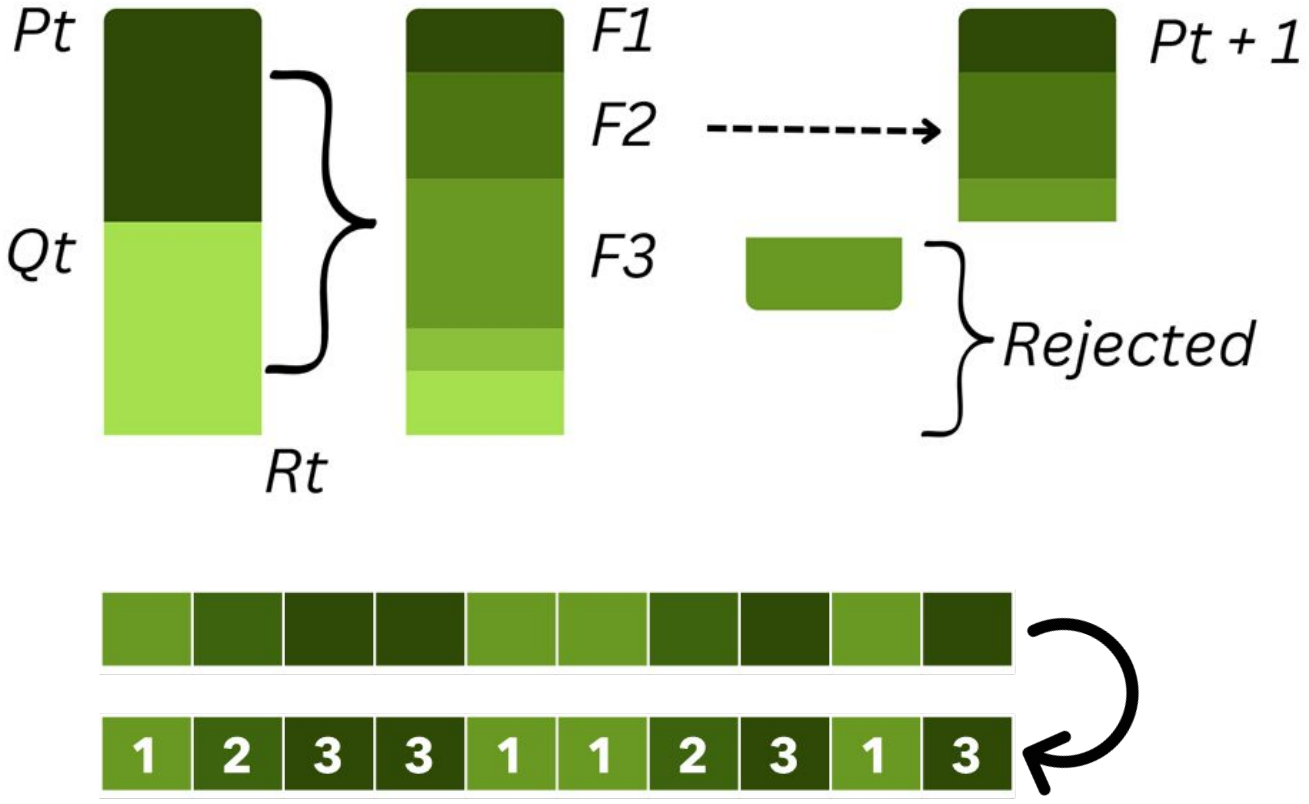
3 *groups* of hypothetical decision-makers

Potential for adressing spatial challenges

[2] Knoke et al. 2020 Global Change Biology. *DOI: 10.1111/gcb.15003*

Methodological Approach

NSGA II: Non-dominated Sorting Genetic Algorithm[4]



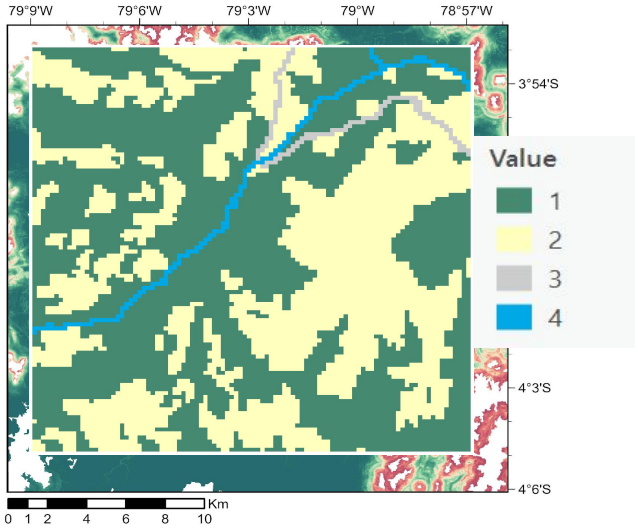
Couple robust optimization with a metaheuristic optimization algorithm:

"Constrained Multi-objective Optimization of Land use Allocation – CoMOLA"[3]

[3]Strauch et al. 2019 Environmental Modelling Software. *DOI:* 10.1016/j.envsoft.2019.05.003
[4]Deb et al. 2002 IEE Transactions on Evolutionary Computation

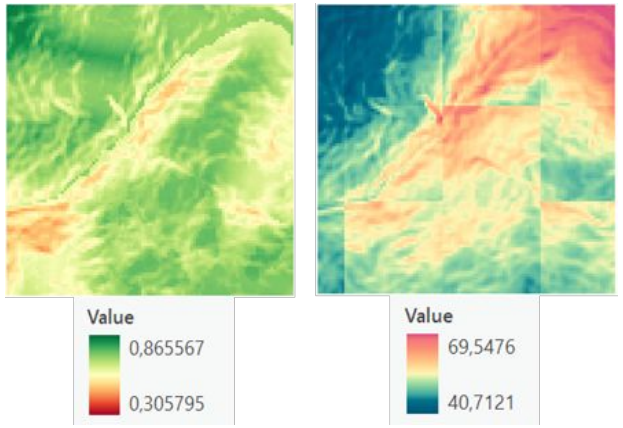
Methodological Approach

1. LULC map[5]



2. Objective Functions

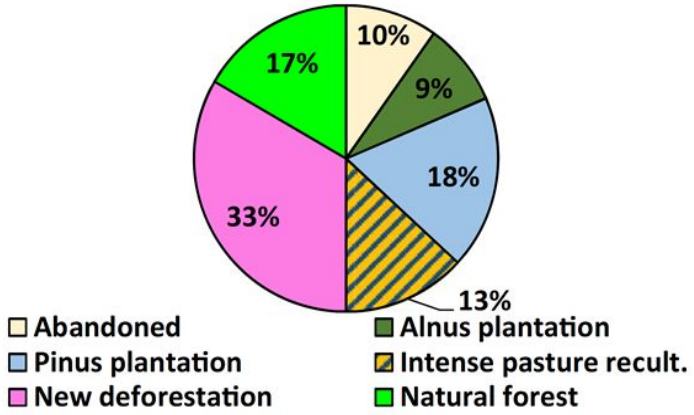
- Pasture Productivity
- Ecological Connectivity



3. Spatial transition rules

	1	2	3	4
1	1	1	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

4. Constraints



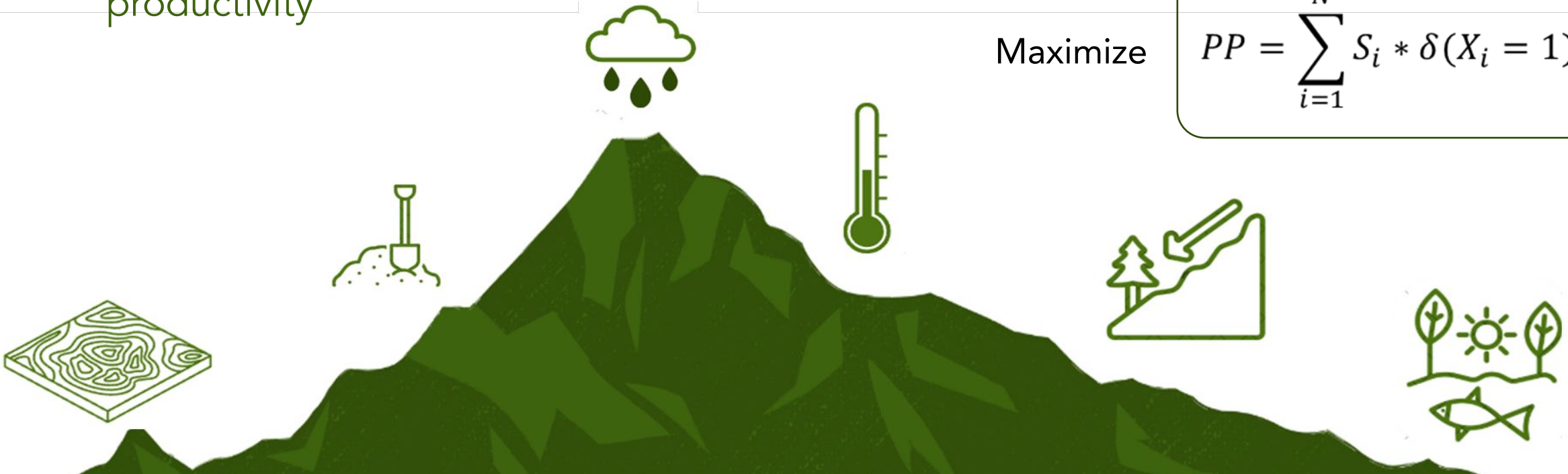
[3]Strauch et al. 2019 Environmental Modelling Software. *DOI:* 10.1016/j.envsoft.2019.05.003
[5]Pintado & Knoke 2025. Journal of Environmental Management. DOI: 10.1016/j.jenvman.2025.125956

Methodological Approach

Objective functions: Max. Pasture Productivity

12 Key variables relevant to pasture productivity → Fuzzy Logic approach with an AHP integration → Pasture Suitability Model (*Si*)

Maximize $$PP = \sum_{i=1}^{N} S_i * \delta(X_i = 1)$$



Methodological Approach

Objective functions: Ecological Connectivity

8 Key species from different functional groups and their movement drivers

→

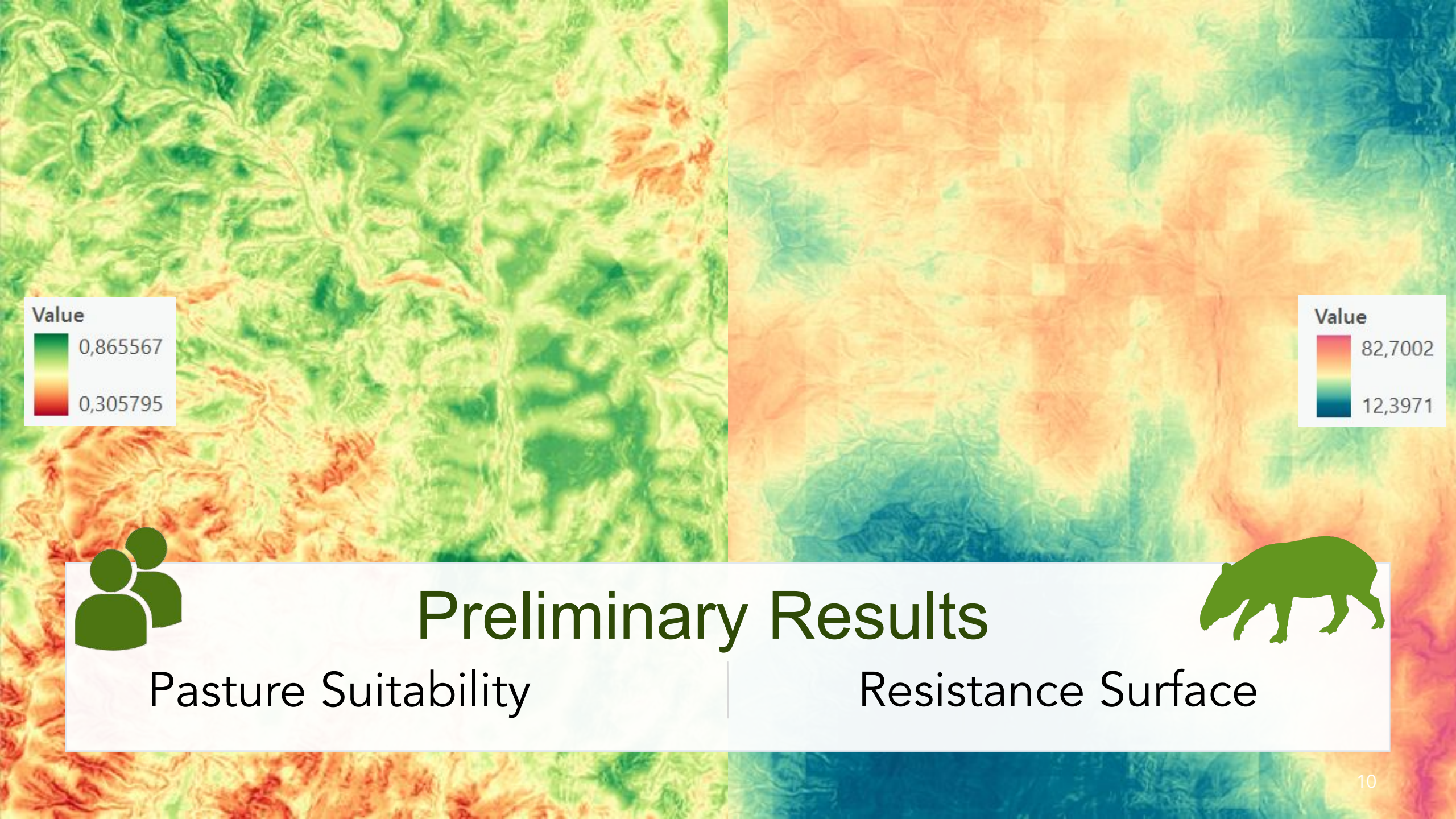
Multi-taxa Resistance Kernel approach

→

Connectivity resistance model (*Ri*)

Maximize

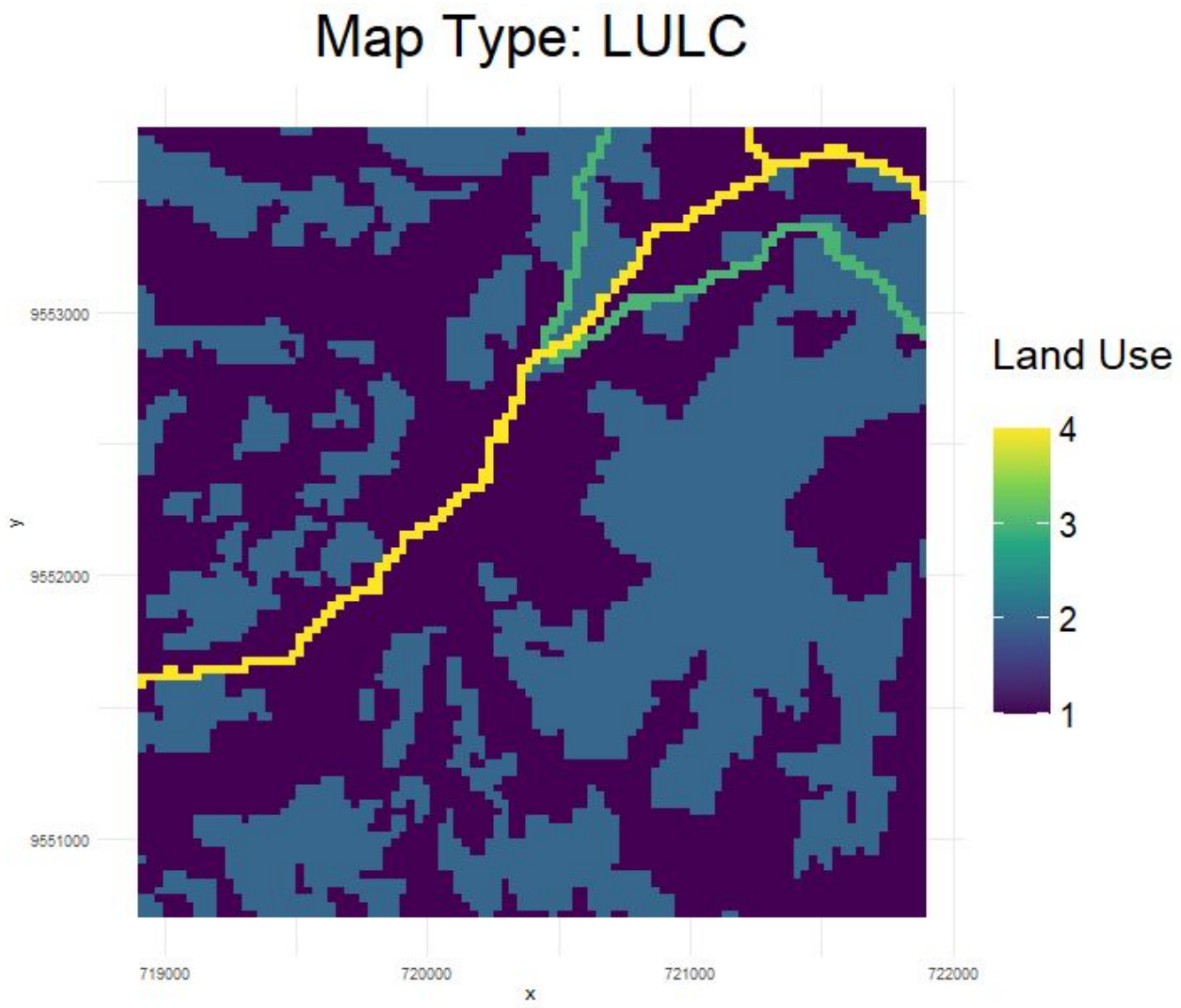
$$EC = \sum_{i=1}^{N} (1 - R_i) * \rho_{x_i}$$



Preliminary Results

Pasture Suitability

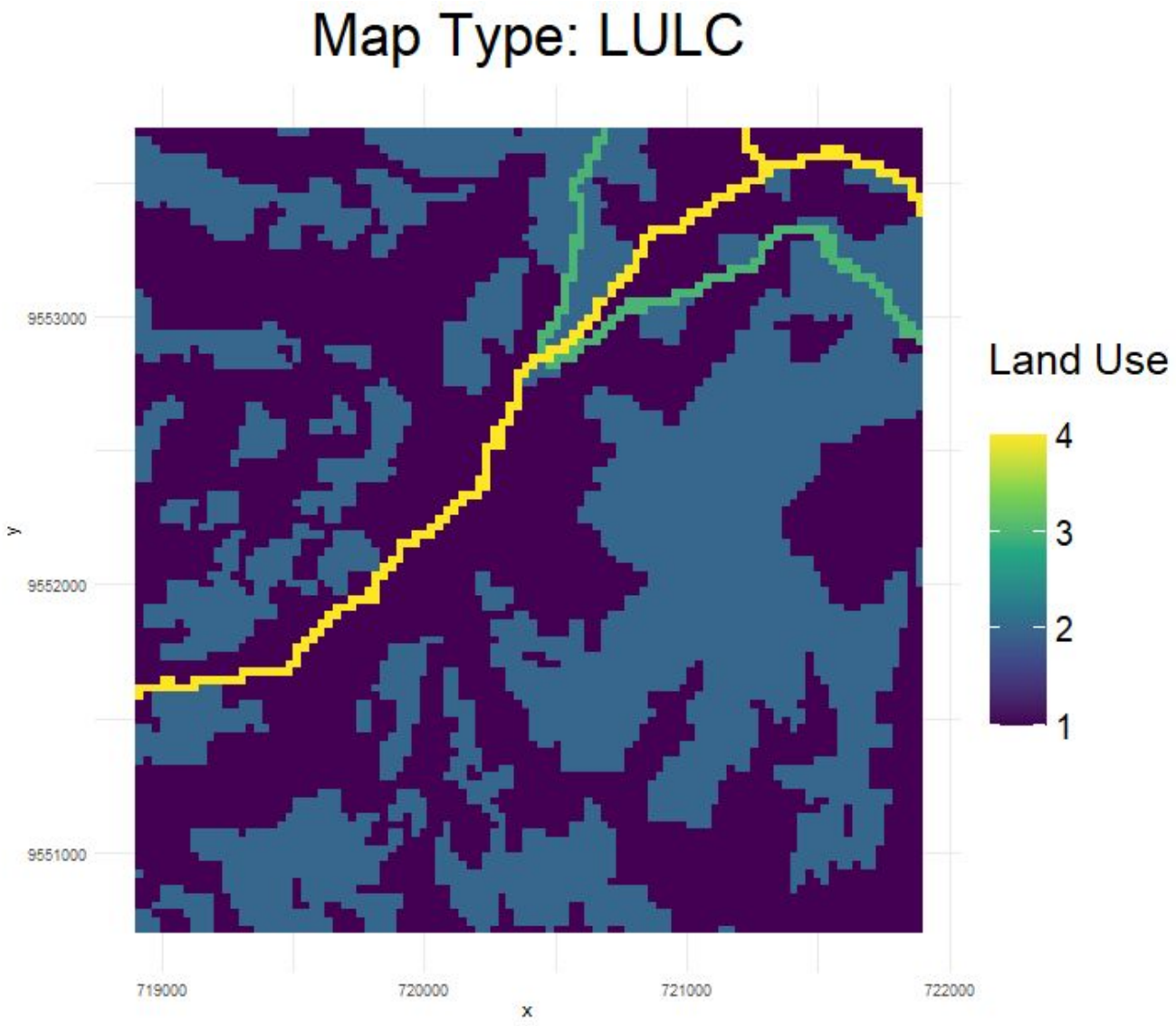
Resistance Surface



Preliminary Results

Population Size = 5
Generations = 5
Mutation Rate = 0.01
Crossover Rate = 0.9

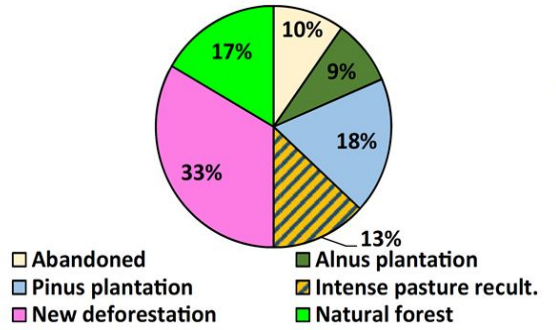
Unconstrained



Preliminary Results

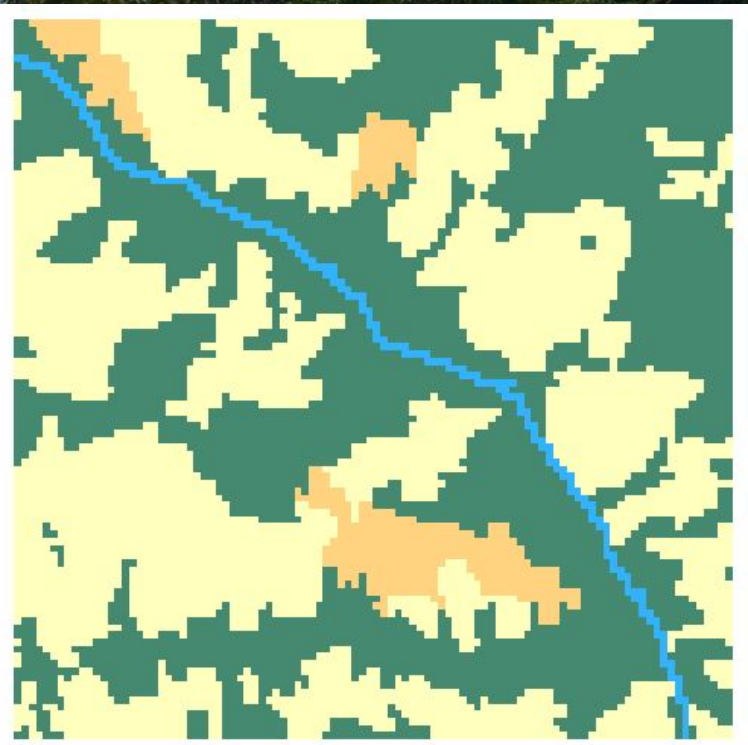
Population Size = 5
Generations = 5
Mutation Rate = 0.01
Crossover Rate = 0.9

Constrained



Next Steps

- Fine tuning our CoMOLA algorithm
- Include Abandoned land in the analysis
- Evaluate results – Pareto frontier



Advantages

- Consideration of inherent biophysical constraints and spatial interactions
- Provides decision-makers with reliable, site-specific data to better navigate the uncertainties of forest management

Thanks!
Obrigado!

Do you have any comments or questions?

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