

# A MODEL AND SIMULATION FRAMEWORK FOR EXPLORING POTENTIAL IMPACTS OF LAND USE POLICIES: THE BRAZILIAN CERRADO CASE

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# AGENDA

The Problem

Methodology

MASE System

Case Study – Federal District Cerrado

Results

Conclusion & Future Work

# THE PROBLEM

Land Use/Cover Change (LUCC) research aims to support insightful management of land resources in order to avoid irreversible damage.

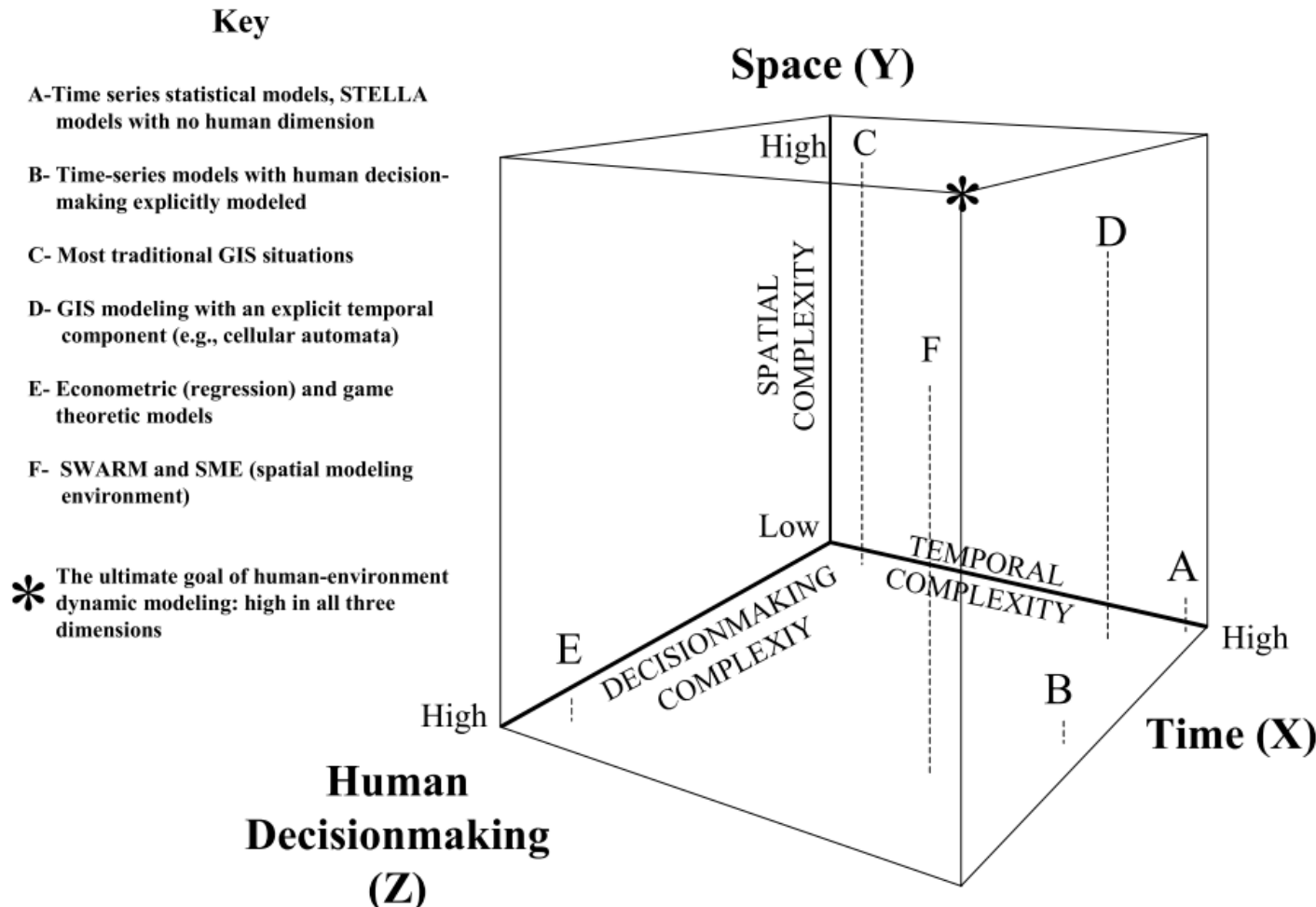
Increasing demand for agricultural production worldwide vs  
Preserve ecosystem structure & function

The patterns of change in time & space are produced by the interaction of biophysical and socioeconomic processes:

How to represent such interaction through computational models?



# Three dimensional framework for reviewing and assessing land-use change models (Agarwal et al., 2001).



## Levels of human decision-making complexity

Level	Description
1	No human decision-making (HDM) — only biophysical variables in the model
2	HDM assumed to be related determinately to population size, change, density
3	HDM as a probability function depending on socioeconomic and/or biophysical variables beyond population variables without feedback from the environment to the choice function
4	HDM as a probability function depending on socioeconomic and/or biophysical variables beyond population variables with feedback from the environment to the choice function
5	One type of agent whose decisions are modeled overtly in regard to choices made about variables that affect other processes and outcomes
6	<b>Multiple types of agents</b> whose decisions are modeled overtly in regard to choices made about variables that affect other processes and outcomes; the model might also be able to handle changes in the shape of domains as time steps are processed or <b>interaction between decision-making agents at multiple human decision-making scales</b>

# THE PROBLEM

## Agent-Based Modeling (ABM)

- natural metaphor to represent patterns of human interaction
- theories of interactivity in societies (model complex problems)

## Multi-agent systems

- adequate to implement agent-based models (autonomous entities, reasoning skills)

## Multi-agent simulation (MAS)

- experimental technique for hypothesis testing and scenario analysis
- better understanding of real systems (social, economical, environmental aspects)

*Software that integrates environmental modeling, stakeholder knowledge and decision making investigation is currently lacking (Gray et al., 2013).*

# MASE SYSTEM

MASE is a freeware multi-agent model and simulation system which aims to assist analyzing LUCC dynamics for exploring potential impacts of land use policies.

- Configurable user model
- Hybrid modelling structures: top-down and bottom-up.
- Cooperative and competitive interactions
- Implement complex human-decision making through cognitive agents
- To explore different scenarios useful for planning, developing sustainable LUCC strategies

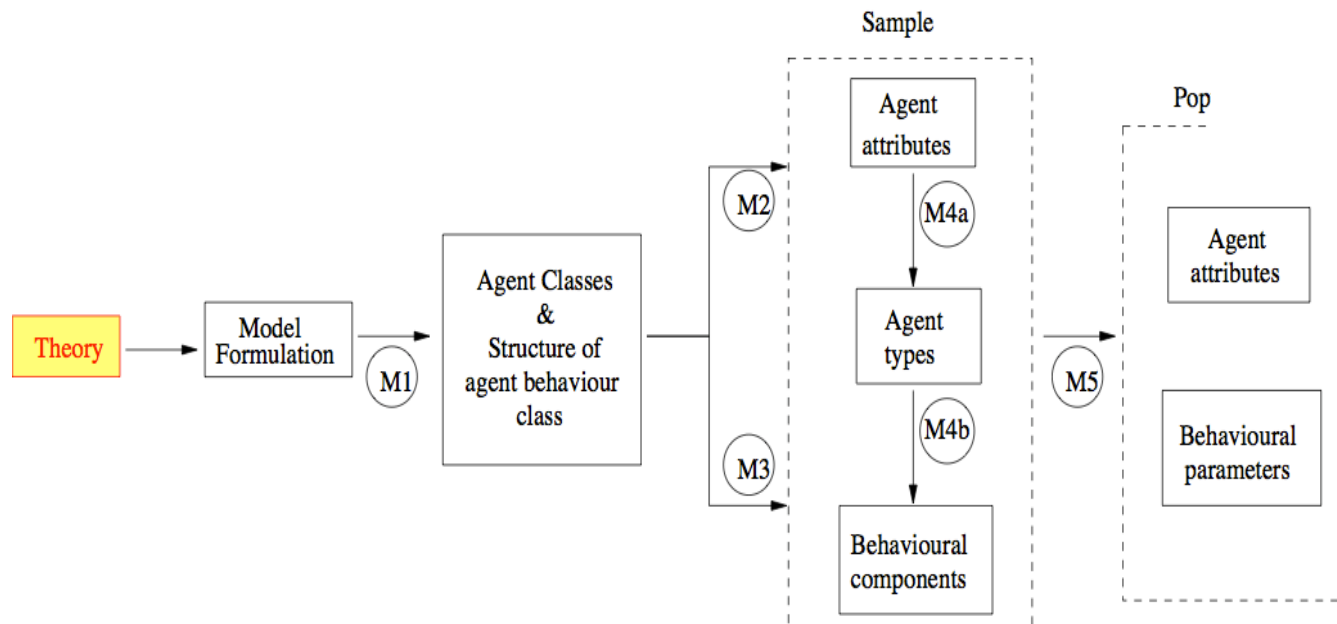
The logo for MASE, featuring the word "mase" in a lowercase, rounded, orange font. The letters are slightly shadowed, giving them a 3D appearance as if they are floating above a dark teal surface.

multiagent system for environmental simulation

# METHODOLOGY

In order to adopt a replicable parameterization process:

1. Systematic & structured empirical characterization of the model (Smaijl et al., 2011)
  - ABM requires systematic representation of 3 main phenomena: agents, their social networks & agent environment



Set most commonly used empirical methods for the challenge of parameterize behavioral responses of humans:

- expert knowledge
- participant observation
- social surveys
- Interviews
- census data
- field or lab experiments
- role-playing games
- cluster analysis
- dasymetric mapping
- Monte Carlo method

# METHODOLOGY

2. Conceptual structure definition according to the agent-based model documentation protocol - Overview, Design concepts and Details - ODD (Grimm et al., 2010)

Overview	Purpose
	Entities, state variables and scales
	Process overview and scheduling
Design Concepts	Design concepts
Details	Inicialization
	Input data
	Submodels

Normal critics on documentation of ABM:

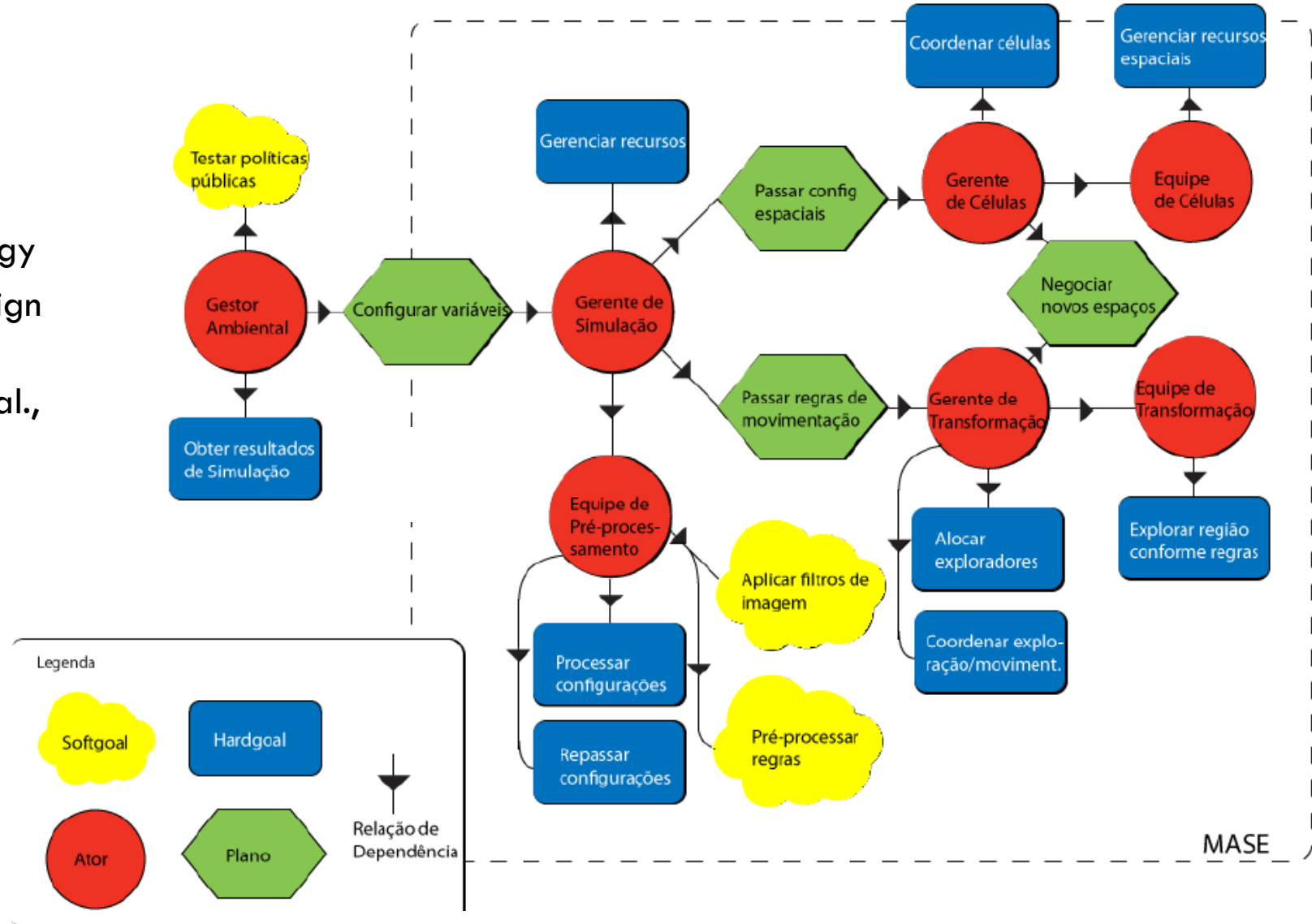
- lacks in consistency in text description of such models
- not enough information to replicate results
- difficult to read
- not presented logical order

(Lorek & Sonnenschein, 1999)

# METHODOLOGY

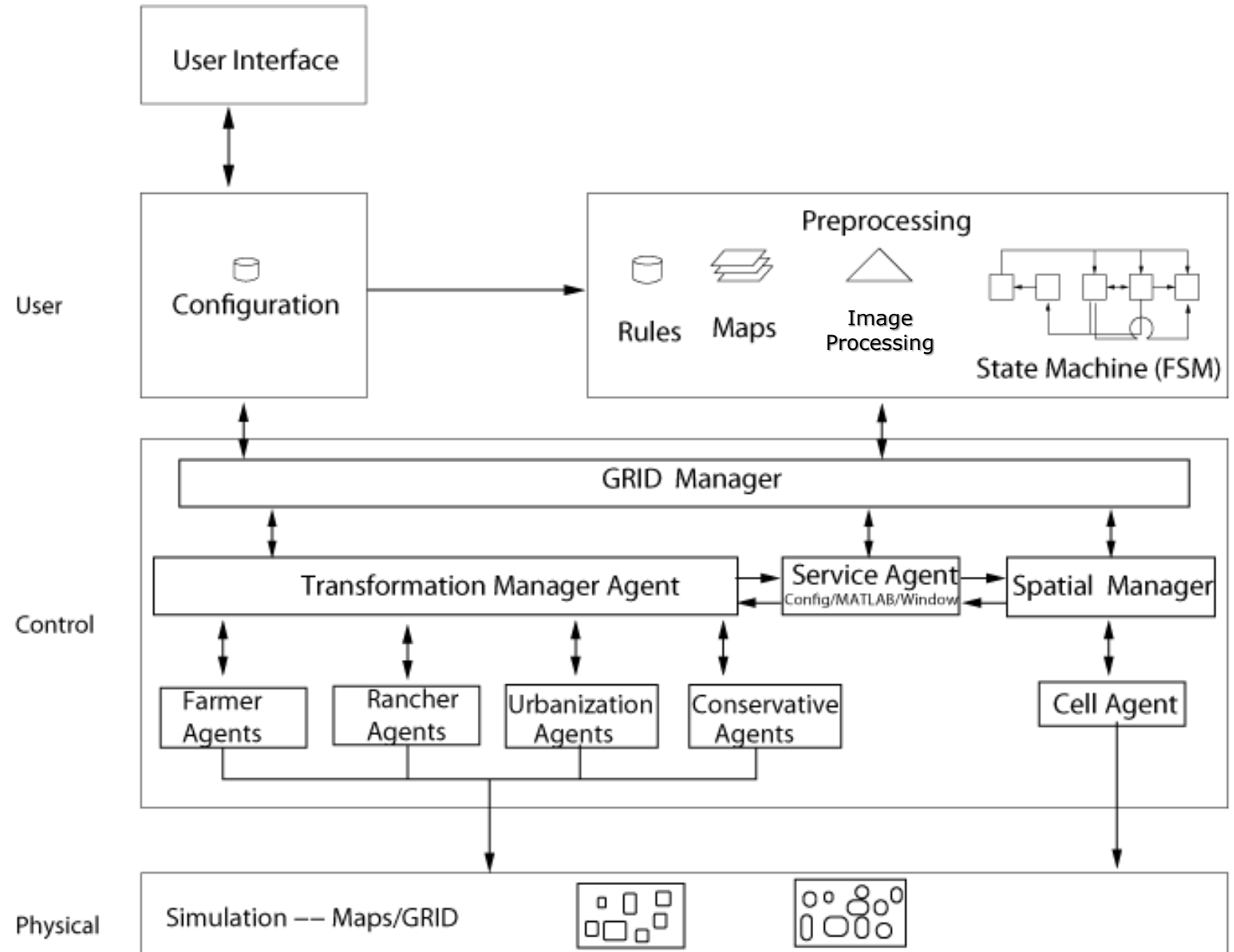
## 3. TROPOS – an agent-oriented software development methodology

- Improving the Architectural Design of a multi-agent system
- Focus requirements (Giorgini et al., 2004)



# ARCHITECTURE

- Three structural layers
- Hierarchy within classes and subclasses of agents



# AGENTS

Agent Class	Type of Agent	N° of Instances	Function
GRID Manager (GGRID)	Goal-based	1	Promote interface parameterizations defined by the user Manage start, pause and end of agents Receive agents state for the visualization Promote agents state visualization for the user
Spatial Manager (SM)	Goal-based	1	Set the cell instances for the simulation Get orders from GRIDM and replicates to cells Receive the states of cells and replicates to GRIDM
Transformation Manager (TM)	Goal-based	1	Set the instances of TA for simulation Get orders from GRIDM and replicates for TA Receive TA states and replicates to GRIDM
Cell Agent (CA)	Reflexive agent with internal state	Set by the user	Receive tasks from SM Inform state to SM agent Begin land/vegetation recovering or stop it Signal whether or not TA occupies land
Transformation Agent (TA)	Reflexive agent with internal state	Set by the user	Receive tasks from TM Inform state to TM agent Request position change to TM agent Move and explore the cell Identify if cell has exhausted its ability to be exploited
Conservative Agent (CoA)	Reflexive agent with internal state	Set by the user	Perceive the state of a cell Receive tasks from TM Receive messages Wait on exploration Recover the vegetation of a cell Identify if a cell must be preserved

# ENVIRONMENT

## Real

## Implemented

Partially observable

Partially Observable

Stochastic

Deterministic

Sequential

Episodic (steps)

Dynamic

Static

Continuous

Discrete (Finite-State Machine)

Multi-agent

Multi-agent

Competitive

Competitive

# IMPLEMENTATION

JADE (Java Agent Development Framework): middleware for developing and executing applications based on agents

- version 4.0, release date 04/20/10
- Foundation for Intelligent Physical Agents (FIPA) compliant
- Agent Communication Language (ACL) defined by FIPA

Library ImageJ to process image files

Available in Sourceforge

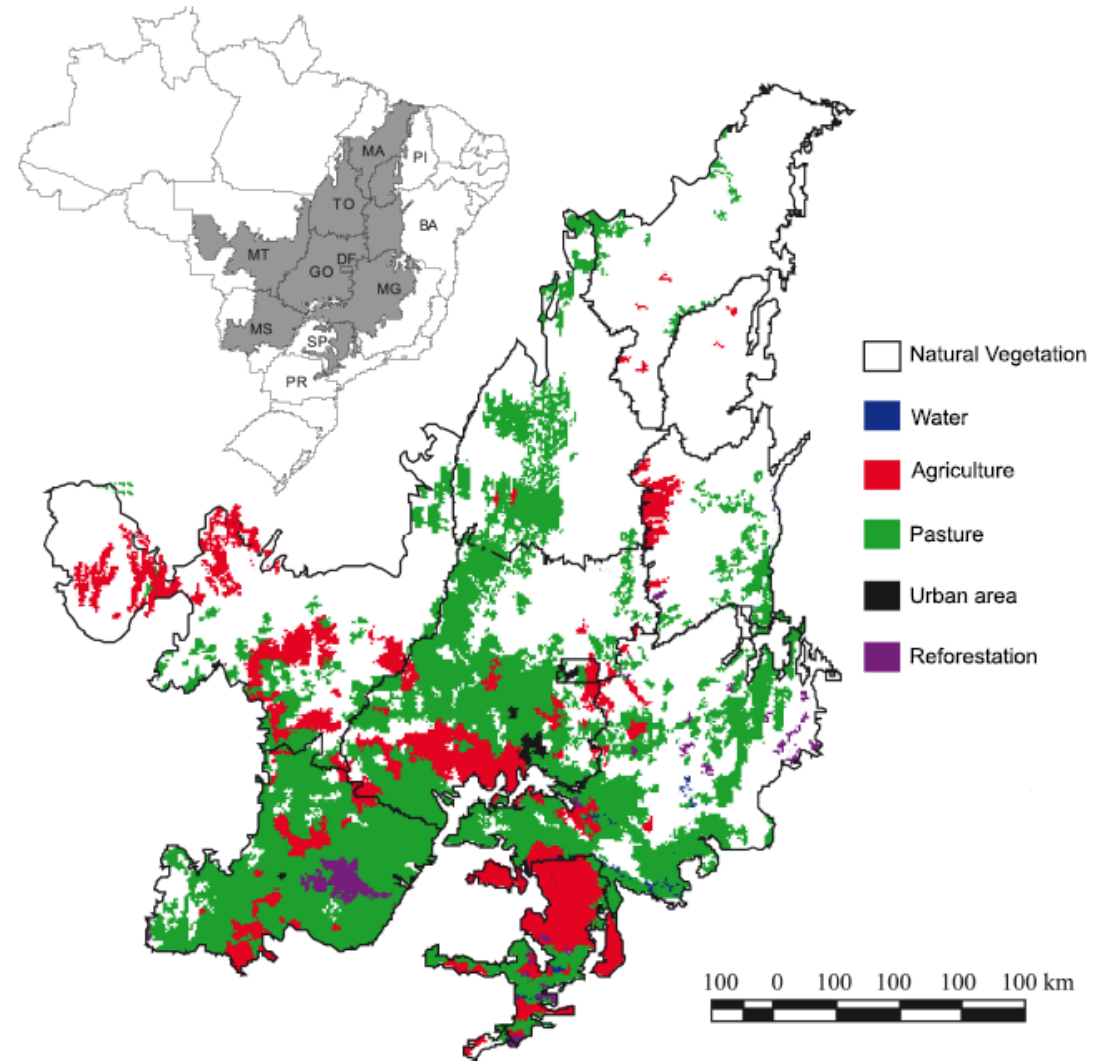
# STUDY CASE

Cerrado: major Brazilian savanna-like ecosystem, the second largest biome in South America

- Undergoing rapid transformation to cattle ranching and to soybean production
- Biodiversity hotspot
- 20% of legal reserve in rural properties
- To assess the impact of recent alterations in the Brazilian Forest Code

## Partnership:

- Ecology Department – University of Brasilia
- Brazilian Institute of Environment and Renewable Resources - IBAMA



# MODEL INPUT

## Area: Federal District

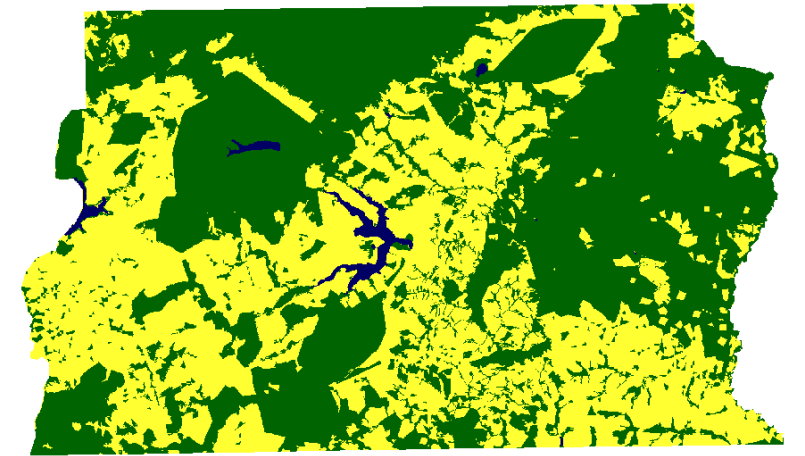
- 68,11% of 5,789km<sup>2</sup> of native vegetation cleared even when 90% of its area is protected by law

Simulations were carried out involving period 2002-2008 (365 time-steps or 7 years)

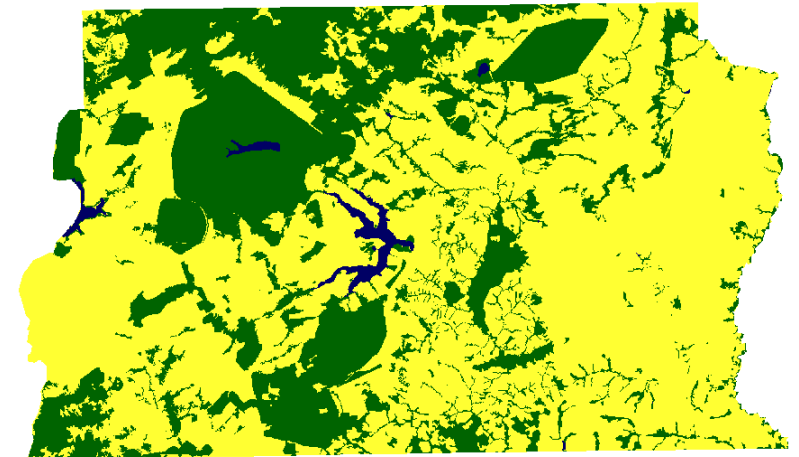
Initial landscape model – images raster-GIS obtained by satellite monitoring (LANDSAT ETM) and classified by PROBIO

Transformation agents set by user (# of farmers, ranchers, conservative agents)

Agents location - greater likelihood of exploitation

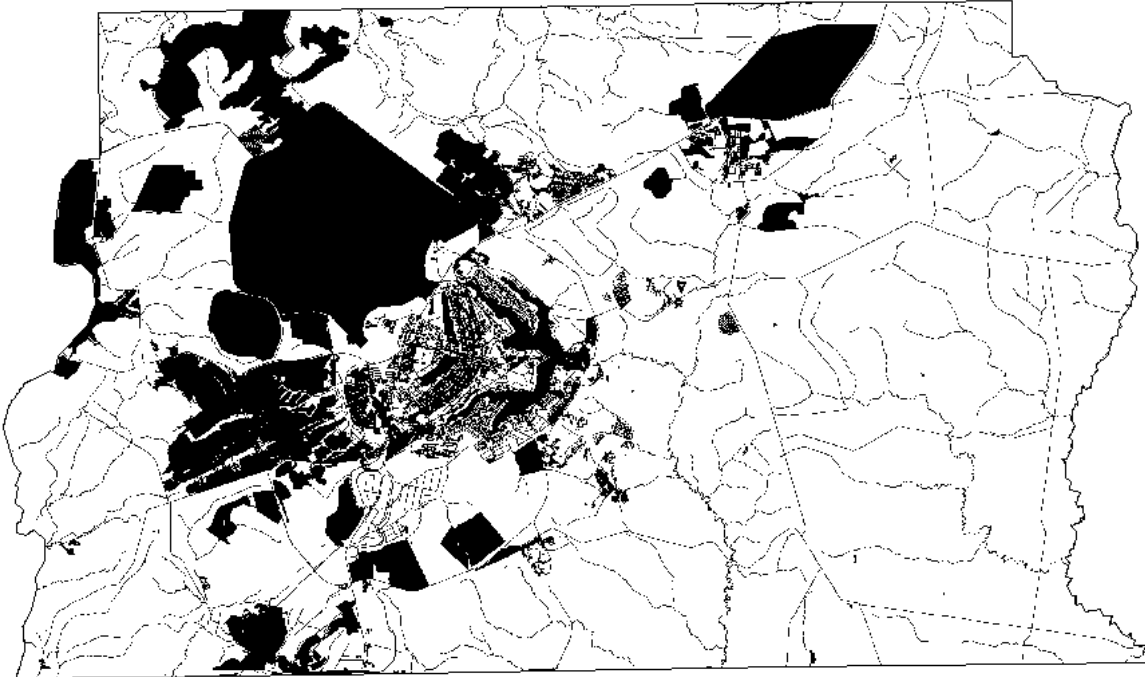


**2002**



**2008**

# MODEL INPUT

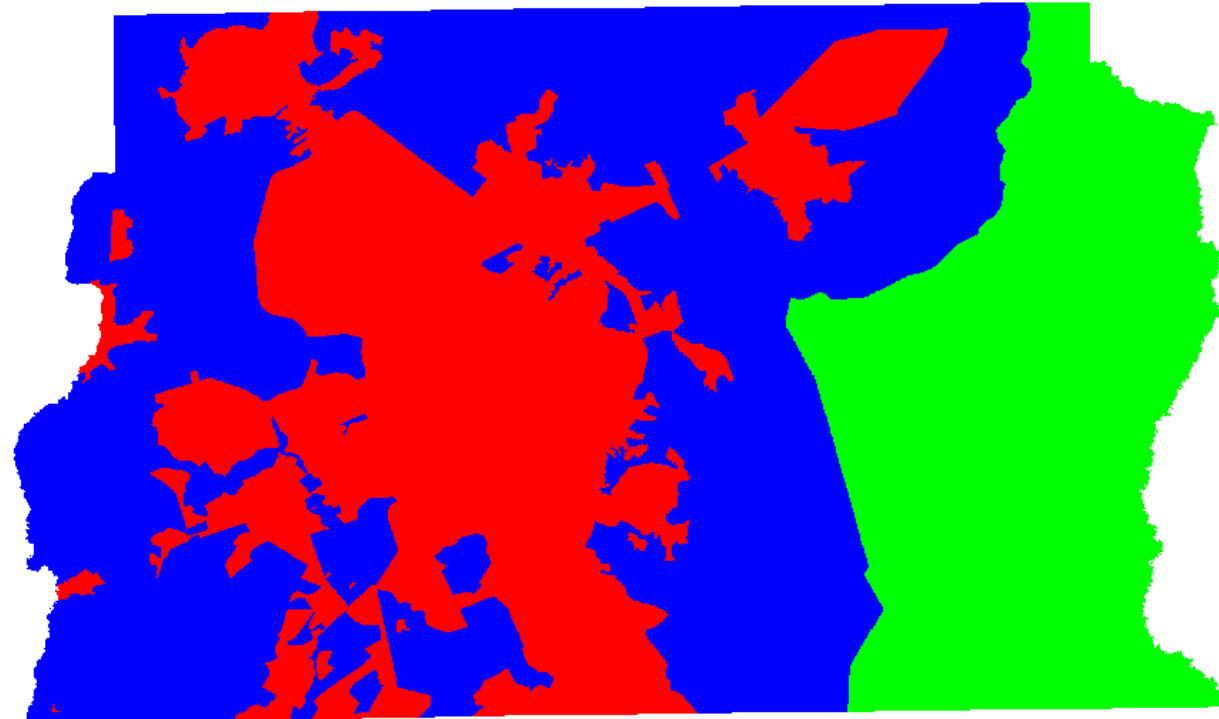


Physical environment is represented by a set of GIS derived images (proximal variables): (a) railways, (b) highways, (c) rivers, (d) lakes, (e) streets, (f) buildings

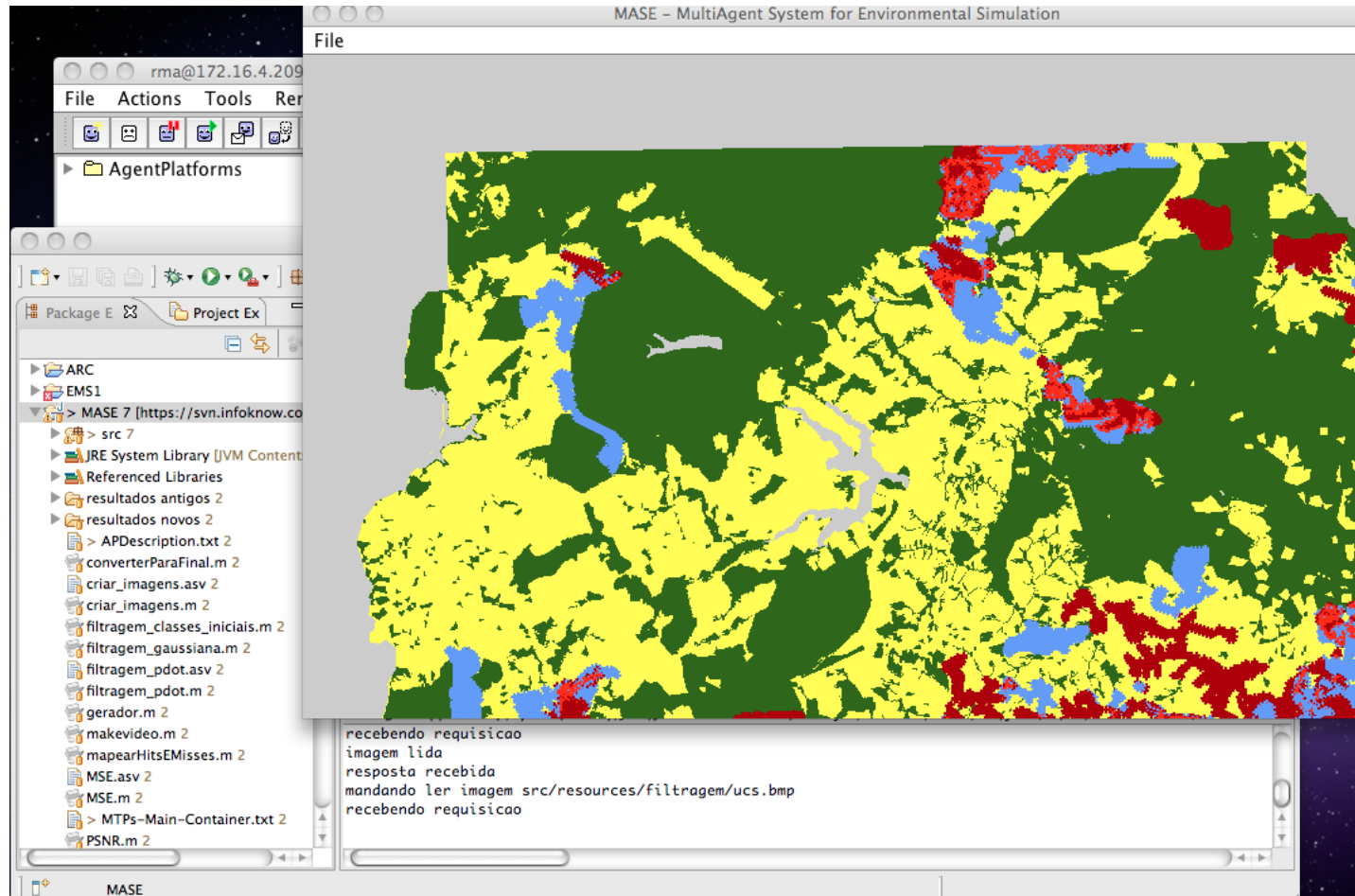
Local LUCC Policies as a variable in the simulation:

PDOT – Federal District Spatial Plane (2002-2008) was translated into an influence matrix for the agents who will change the land use and land cover.

- Urban and Protected Areas
- Controlled Use Area
- Diversified Use Area



# SIMULATION



Set of simulation  
changing the  
characteristics and  
number of transformation  
agents.

In Detail:

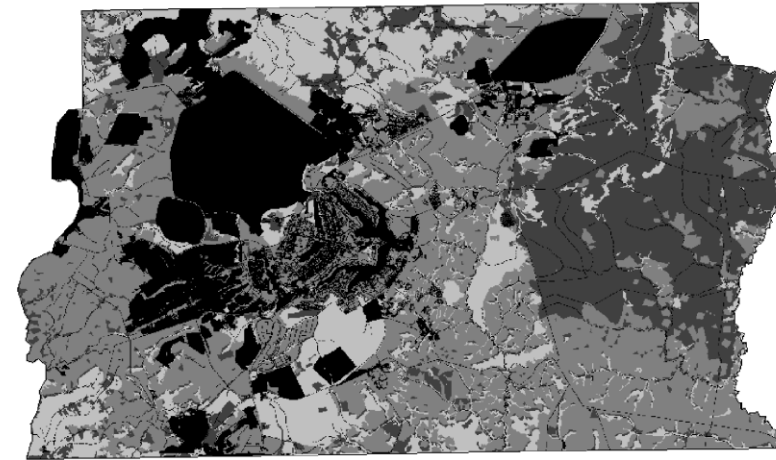
- Blue: farmers
- Red: ranchers
- Sim X: number of agents of each TA type

# RESULTS

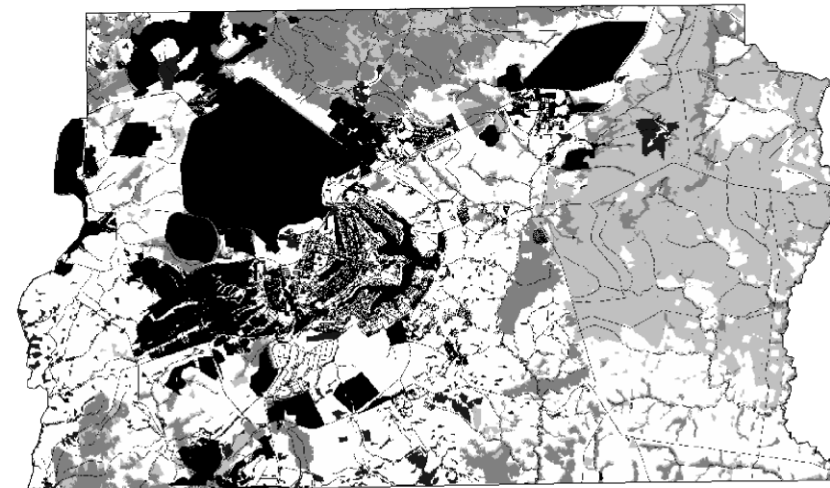
Three map comparison: (i) a reference map of initial time (2002); (ii) a reference map of subsequent time (2008); (iii) a prediction map of the subsequent time (2008) – (Pontius et al., 2008).

User analysis:

Not even the 20% of legal reserve in rural properties in the Cerrado are being preserved.



a Observed



b Predicted

Legend for a and b

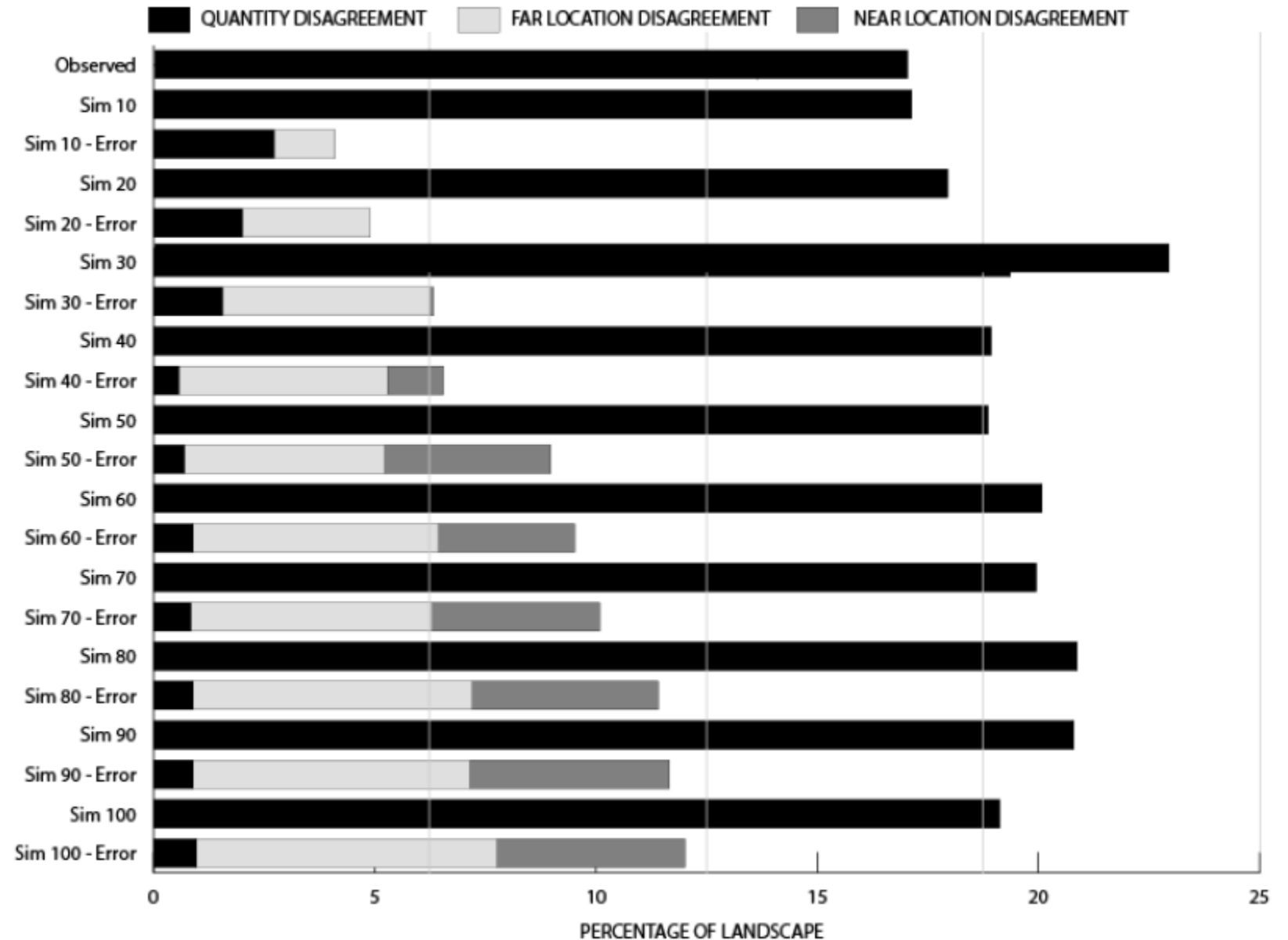
- Layers
- Anthropic gain
- Anthropic persistence
- Native vegetation persistence
- Anthropic loss

# RESULTS

The observed bar is the error of a null model that predicts pure persistence, i.e., no change between time 1 and time 2; so if the observed bar is smaller than the error bar, then the null model is more accurate than the LUC model.

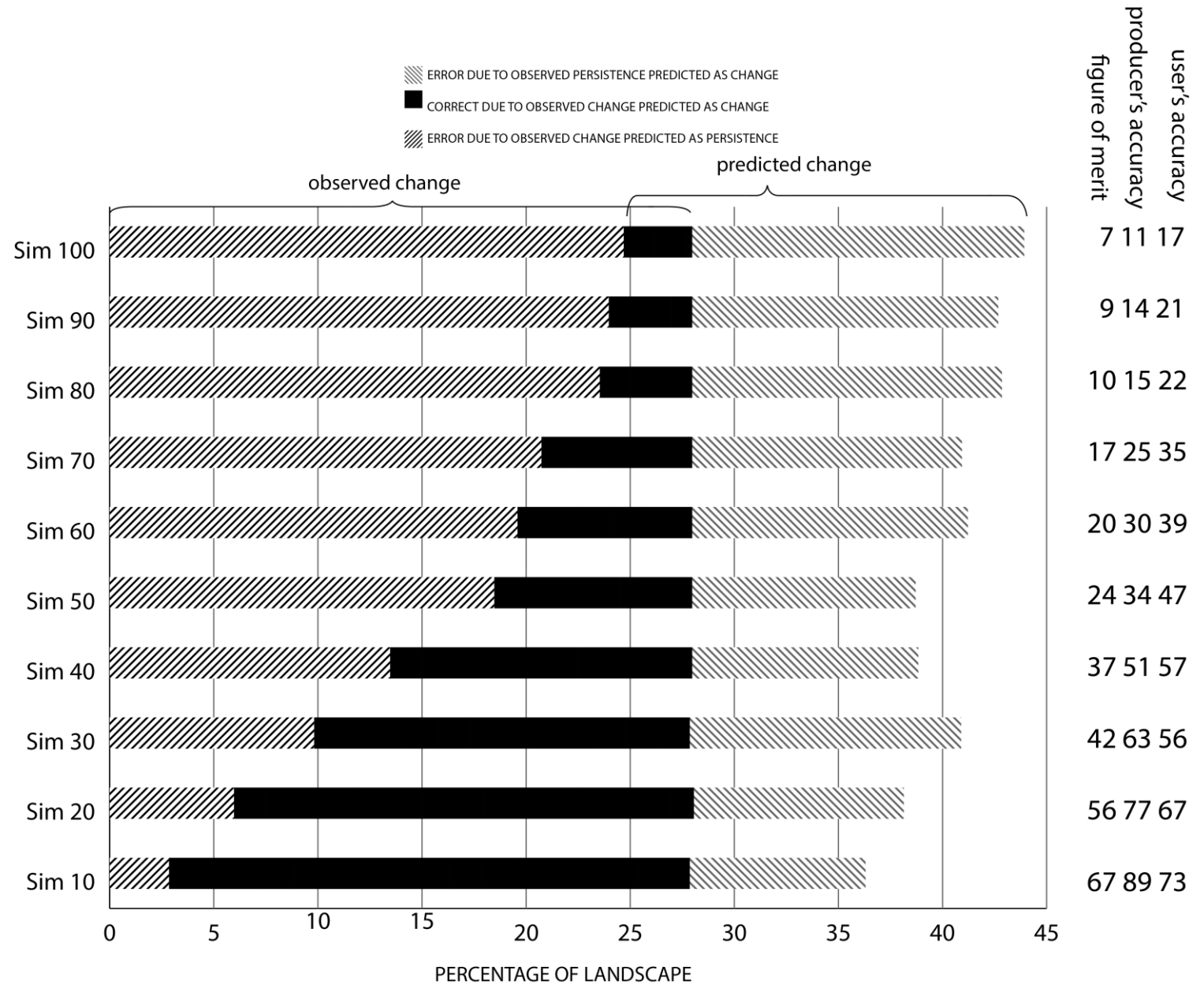
## Components of error:

- Quantity disagreement
- Far location disagreement
- Near location disagreement



# RESULTS

Figure of merit  $> 50\%$   
 amount of correctly  
 predicted change is  
 larger than the sum of  
 any type of error!



# CONCLUSION

MAS + ABM is a valid approach to represent and simulate LUCC decision support

Investigate the consequences of environmental policies to raise awareness for environmental sustainability

Where are we going?

- Improve agents rationality (most challenging part!)
- MASEX - using Belief-Desire-Intention Model, theory of human practical reasoning (Bratman, 1999)
- Apply qualitative expressivity to make easy to ecologists to model
- Represent space using topology to automatic reason about geographical aspects (spatial-temporal reasoning)

# mase

multiagent system for environmental simulation

<http://mase.cic.unb.br/>

## THANK YOU!

## QUESTIONS?



**UnB**

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