Assessing the impact of global regulation on oil palm development with an agent-based model: the Palm-LAB model

[1]INRA, SAD-ASTER, F-88500 Mirecourt, France
[2]CIRAD, UPR Systèmes de pérennes, F-34398 Montpellier, France
[3]SMART Research Institute, ID-28112 Pekanbaru, Indonesia

* contact: julie.wohlfahrt@mirecourt.inra.fr

Moulin M[1], Bessou, C[2], Caliman, JP[3], Wohlfahrt J[1]*

Sustainable Palm Oil Production **SPOP**

Introduction - Rationale

Palm oil production results from **different oil palm cultivation systems** (e.g.: smallholders, industrial companies, large and small scale plantations)[1]. Assessing the **global sustainability** of oil palm implies assessing the combination of these different systems, their biophysical characteristics and their global resultant. Sustainability must be hence assessed at larger scale than the plantation, being **the landscape scale**[2]. Regarding the **complexity** of oil palm landscapes, understanding their dynamics and anticipating their potential futures is not straightforward[3].

In this study we developed an **agent based model (ABM) of oil palm cultivation dynamics at the landscape scale**, the Palm-LAB model. This model, based on a virtual landscape, allows for exploring the impact of different socio-political contexts (scenarios) on oil palm development and oil palm fertilizer management taking into account the diversity of oil palm systems and their spatial distribution. Simulation results will highlights the main levers toward a greater global sustainability of oil palm landscapes. We specifically investigated the impact of certifying selected systems in a landscape, assuming indirect effects on the other oil palm systems within the landscape.

*Definition : **Oil palm landscape***

The oil palm landscape is composed of different oil palm management systems and is mainly structured by oil palm production

The oil palm landscape is the result of interactions between human actions and environmental processes, it is considered as a complex adaptative system[4]

Specificities of the oil palm landscape:
- Variety of stakeholders operating at different levels
- Specific environmental and societal issues
    - peat soil, primary forests, biodiversity
    - food production, development
- Specific targets in term of sustainability, linked to international pressure
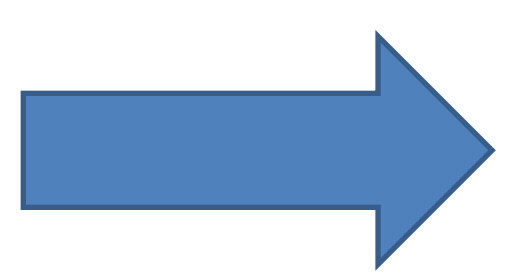
Exploring the impact of different socio-political contexts on oil palm develoment and oil palm fertilizer management spatial distribution

Increasing knowledge on complex interactions between landscapes' stakeholders and their environment

Producing supports information to assess sustainability taking into account spatial and temporal dimensions

Material and Method

What is an Agent-Based Model (ABM)?

An ABM simulates processes based on the specificities of involved agents and their environnements, which are transleted into rules (if…then)

- **Adapted to model complex systems** (emerging properties, surprises, non-linearity)
- **Complementary approach to detailed surveys** – possibility of up-scaling
- Harnessing information from expert knowledge and prospective scenarios
- Providing a virtual platform to experiment rules and control levers
- Flexibility in terms of data used: expert knowledge, spatial data, sub-models…
- Iterativity: starting from a simple model and **increasing its complexity in an iterative process**

What is inside Palm-LAB ? (figure 1)

- **3 types of agents**: Industrial growers, Villagers, Investors + State
- Actions are controlled by **agents strategies** and characteristics (richness, knowledge) and plots characteristics (soil type, plot cover, distance to the road)
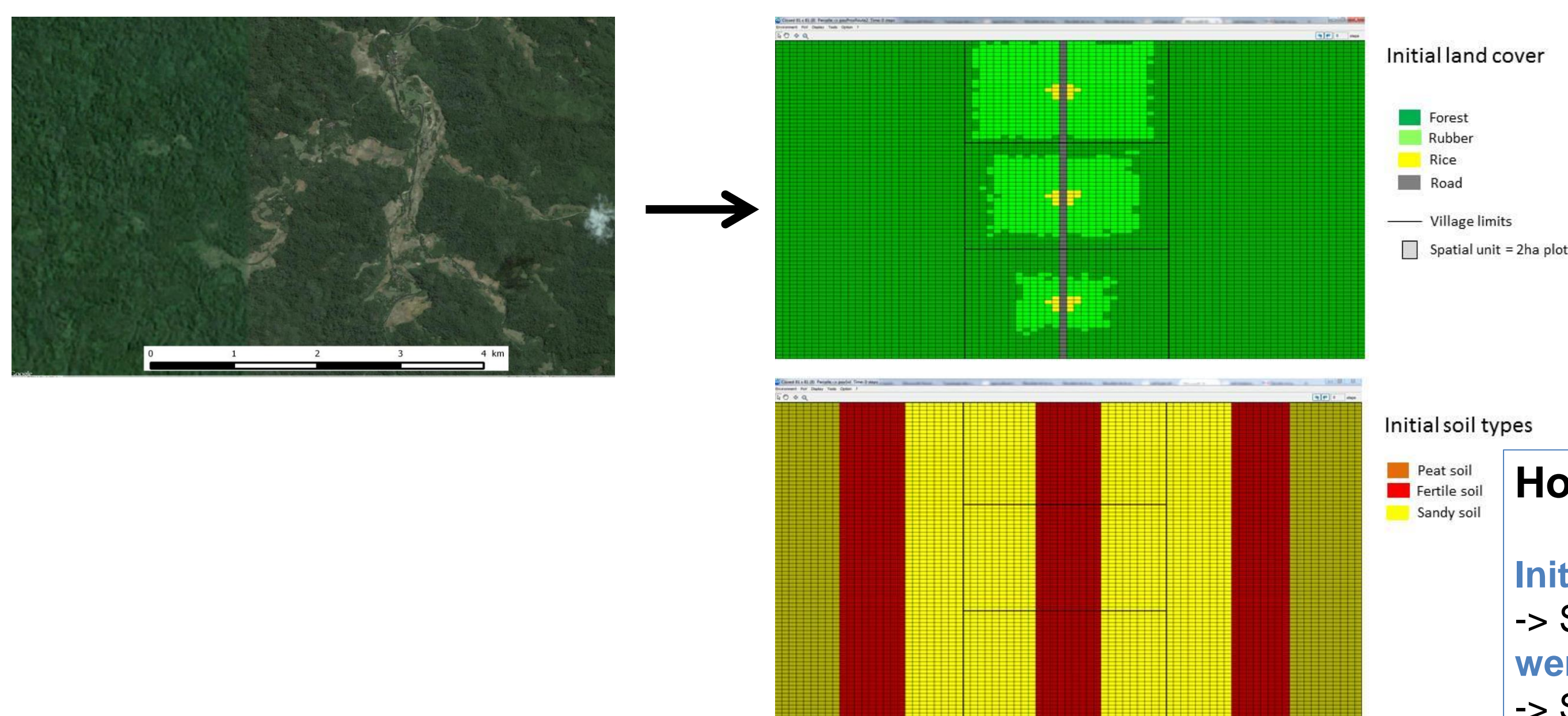- **Virtual realistic landscape** where 1 spatial unit (cell) = 2ha plot (see figure 2)

Figure 1: Representation of the Palm-LAB model

State controlling *Conserve chosen areas*

State controlling *Select Industrial growers*

Individual processes *richness, knowldege increase*

Oil palm growers interacting *Exchange land*

Oil palm growers acting on landscape *Implant oil palm / Fertilize oil palm / Build roads*

Oil palm Landscapes' features *Ownership, land cover and biophysical properties / Constrained co-locations*

Initial land cover
- Forest
- Rubber
- Rice
- Road
- Village limits
- Spatial unit =2ha plot

Initial soil types
- Peat soil
- Fertile soil
- Sandy soil

Figure 2: From real to realistic initial land covers and soil types distributions

How did we use Palm-LAB ?

Initializing the model (scenarios) :
-> State and industrial growers **strategies** regarding area conservation, oil palm plantation and N fertilizer management **were combined**
-> Smallholders' strategies and characteristics were **distributed equiprobably** among the agents

Running the model (simulations) :
-> Running the model for a **50-year simulation cycle** (time step = 1 year)
-> Step 1: Introduction of oil palm in a landscape composed of forest, rubber and rice soil covers (see figure 2)
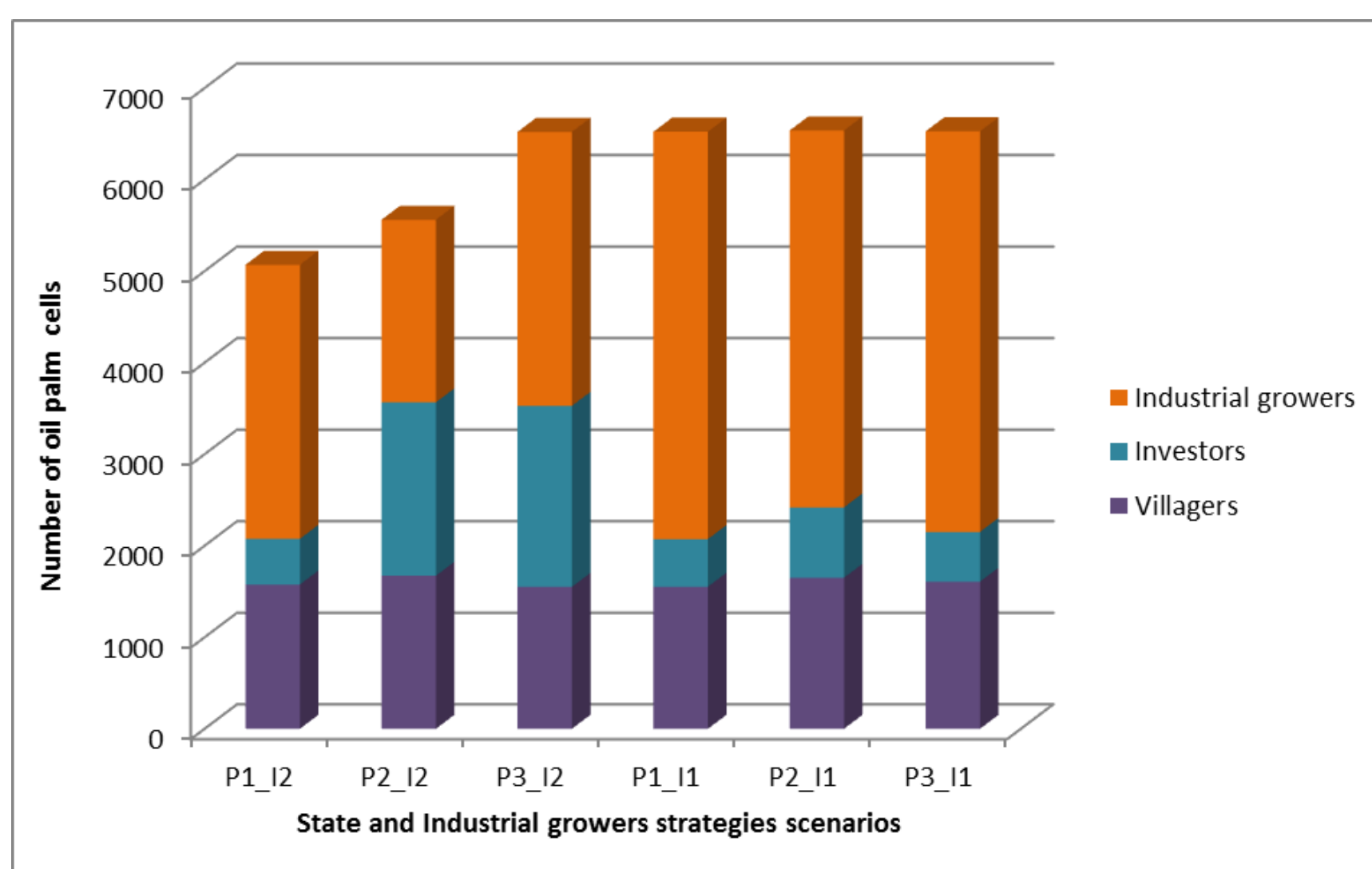-> ~1000 simulations to test various scenarios

Results

Figure 3: Oil palm distribution between growers (after 50 years of simulation)

Legend: Industrial growers, Investors, Villagers

P1= State does not conserve / P2=State conserves random areas / P3= State conserves peat soils
I1= Industrial growers consider only economic aspects to implant OP / I2=Industrial growers consider biophysical and environmental issues to implant OP
ICS1= Industrial growers strategy is to maximize OP yields / ICS2= Industrial growers strategy is to maximize their revenu / ICS3= Industrial growers strategy is to take into account environmental impacts
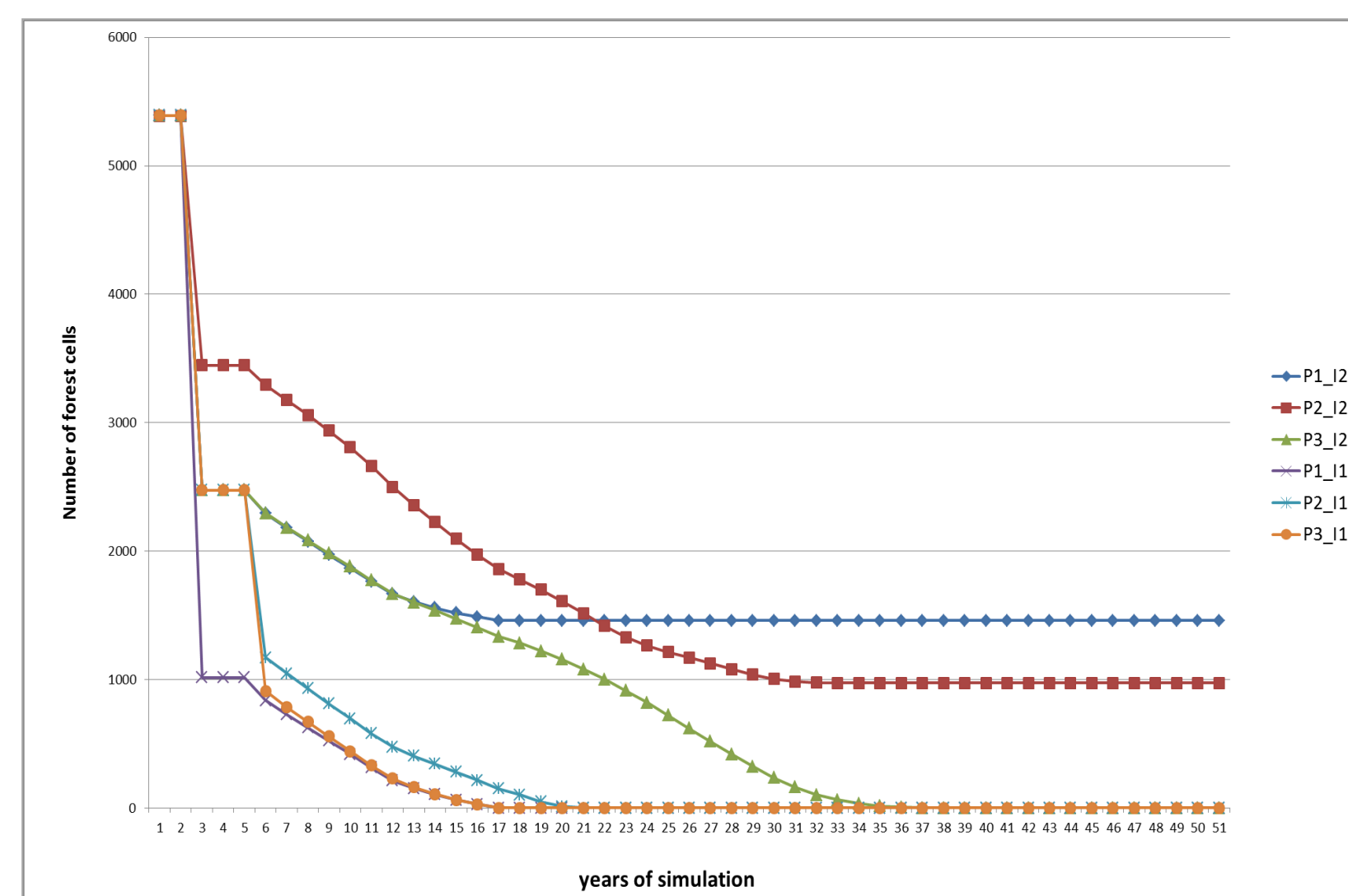

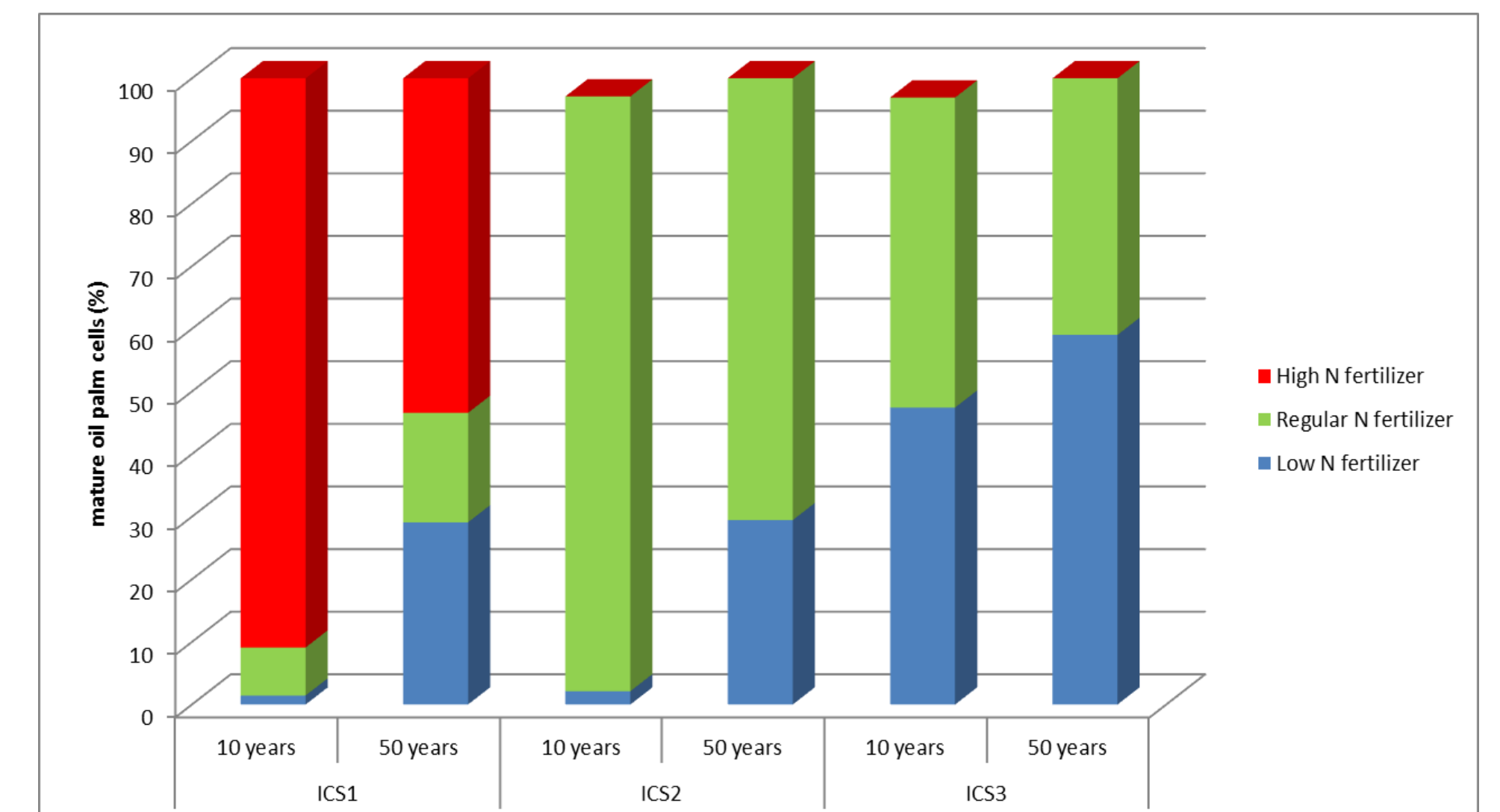Figure 4: Forest cells dynamics for a 50-year simulation

Figure 5: Oil palm N fertilization distribution at 10 and 50 years of simulation considering three conduct strategies and two time periods (P2_I2 scenario)

Legend: High N fertilizer, Regular N fertilizer, Low N fertilizer

Figures 3 to 5 present examples of results that can be obtain with Palm-LAB. At the end of the simulation cylce, the total number of oil palm cells (i.e. the importance of oil palm development) and their distribution per grower type vary between scenarios (fig. 3). When industrial growers consider environmental and biophysical issues to develop oil palm (I2 scenarios), areas are automatically spared without state intervention (see figure 3, differences in the total number of OPC). When the state conserves areas (P2 and P3 scenarios), smallholders tend to develop oil palm in protected areas (P2_I2 and P3_I2 scenarios). Forest cover decreases along the simulations after the introduction of oil palm. Depending on the scenarios, the final landscape may not consist of both oil palm and forest areas (fig.4). Finally, the model allows for distinguishing nitrogen (N) fertilization patterns at the landscape scale depending on oil palm management strategies, which can evolve according to changes in knowledge and richness among growers (fig.5)

> Oil palm development and its influence on the landscape depend on the interactions of the various involved stakeholders. The palm-LAB model allows for simulating landscapes evolutions based on prospective scenarios taking into account stakeholders' assets and strategies

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