Faculty of Forestry
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Investigating the use of Cellular Automata and Multi-Agent Systems for forest planning in Ontario.

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Introduction

Canadian Forest History (Apsey et al., 2000)

i. Pre historic: re-establishment of forests

ii. Liquidation: unregulated harvesting and land-use conversion

iii. Conservation: forest protection and sustainable production

iv. Sustained Yield: timber production based on regulated management

v. Present situation: sustainable forest management for multiple values

Sustainable Forest Management aims at maintaining and enhancing the long-term health of forest ecosystems, while providing economic, ecological, social, and cultural opportunities for the benefits of present and future generations (Canadian Council of Forest Ministers, 1992) .

Current Forest Management Context

- Increasing number of forest objectives (timber and non-timber)
- Conflicting timber and non-timber objectives (e.g. commercial extraction x forest protection)
- Increasing number of stakeholders (e.g. Aboriginals, government, industry, NGOs, general public)

Main Challenge

To deal with the multiple values system in a way to plan for sustainable, non-declining supply of timber and non-timber values at various temporal and spatial scales.

Forest Management Planning

To improve the probability that future developments are consistent with specified objectives.

Centralized Planning

- Lower level decisions should contribute to global objectives (e.g. bounds on harvest flows)
- "Top-down planning"
- Linear programming, heuristics methods (e.g. SA, Tabu Search)
- Challenges:
  - The need to simplify decision problem;
  - Formulation and solving (computational aspects);
  - Compromise local relationships;
  - Inclusion of dynamism and complexity.

Decentralized Planning

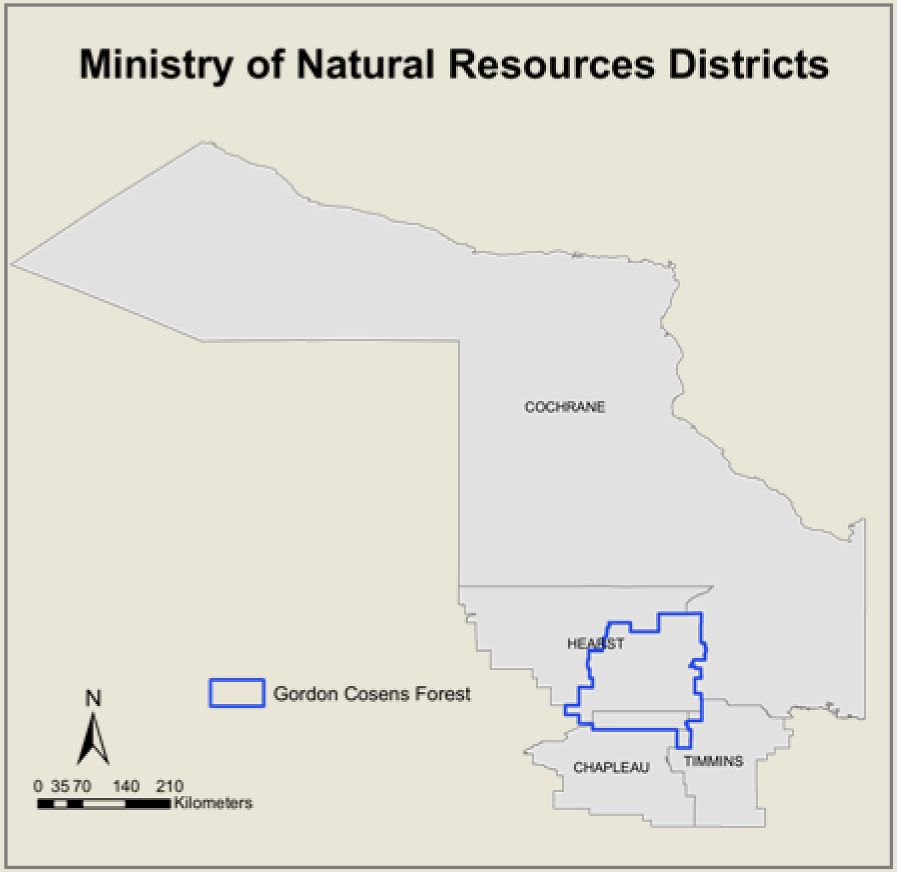
- Interactions and decisions at local stands lead to emergent properties at global level
- Interactions influenced by distance
- "Bottom-up planning"
- Cellular automata, Multi-Agent Systems
- Advantages:
  - Deals with dynamism and complexity;
  - Easy formulation (?);
  - Fast solving;
  - Intuitive way to conceptualize the world.

Current context in Ontario

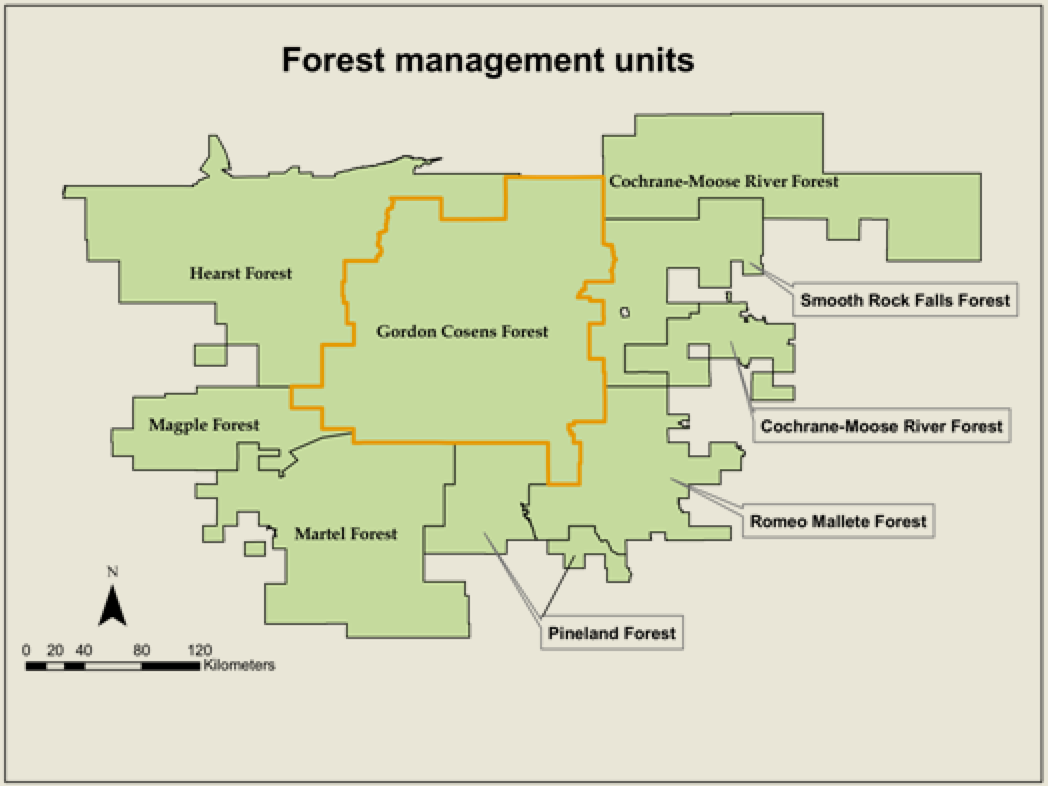
Study site: Gordon Cosens Forest

GORDON COSENS FOREST

- Crown land- SFL - Primary holder: Spruce Falls Inc.;
- 20 year period planning (2005 to 2025);
- North-eastern region of Ontario;
- 2 million ha; 1.5 million ha of managed forests;
- 1st and largest FSC certified forest;
- Stakeholders: forest industry, NGOs, Aboriginals, OMNR, tourist outfitters, trappers, local and regional clubs.



Study Site (contd.)



1. FOREST VALUES

- **Hydrological**
  - Major hydric system: Missinaibi, Kapuskasing, Opasatika….
  - Fur-trading route
  - Canoeing, fishing
- **Biological**
  - Habitat: moose, caribou, etc…
  - Plant sps: black spruce
  - Rare: red pine, white pine, black ash.
- **Economic**
  - Forestry industry: timber harvesting
  - Trapping: Aboriginals/Non-aboriginals
  - Tourism and Recreation: southern region; camping, canoeing, hunting, etc….
- **Social and Cultural**
  - Indigenous people: no community within the GCF; 12 First Nations (Smartwood) – Moose Cree and the Matagami; campsites, burial plots, traditional trading posts.
  - Protected area: Provincial Park (Missinaibi River and Rene Brunelle); other parks.

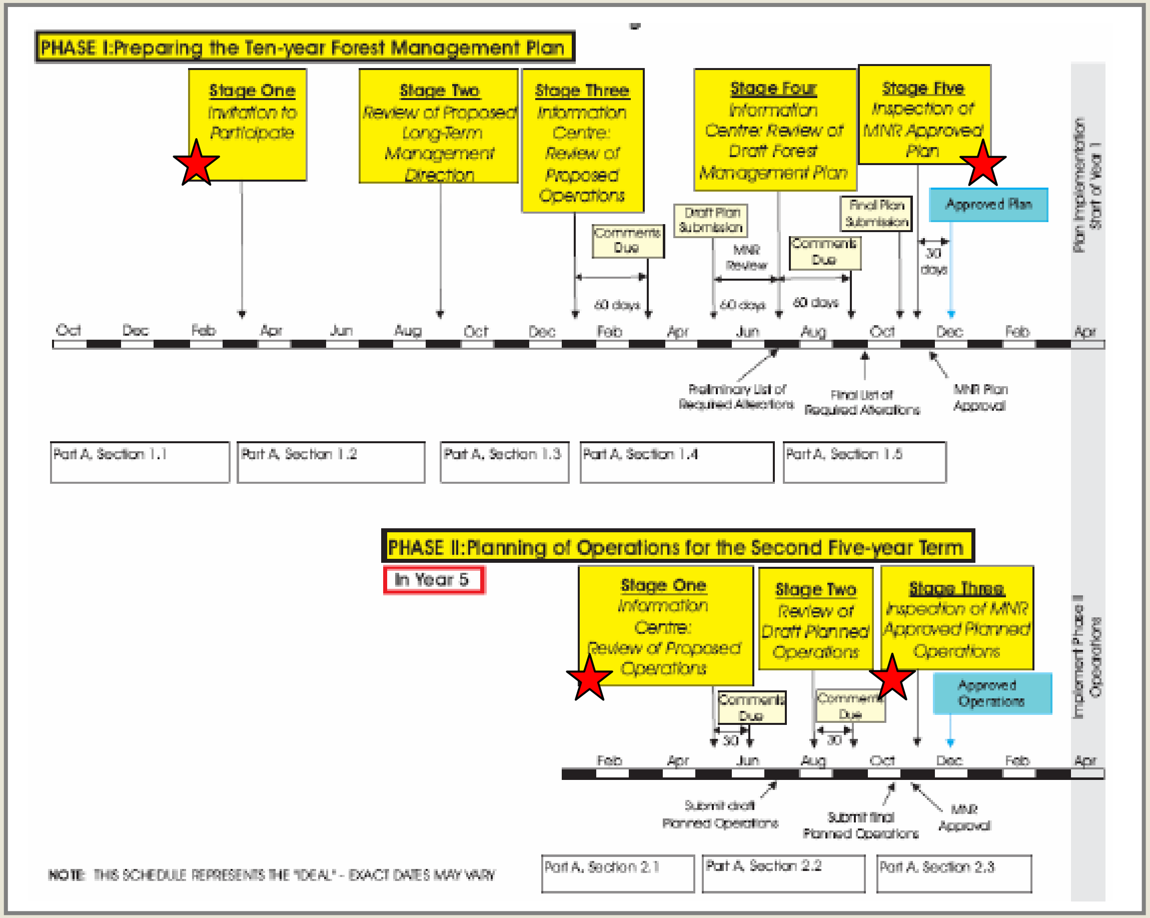
Study Site (contd.)

2. Shift towards a more participatory forest planning

- Multiple stakeholders
- Conflicting interests
- Increased pressure on non-timber values

★ Stages in which the public is involved:

✓ Local Citizens Committee



Study Site (contd.)

3. Main Issues

- On-going land claims with 3 First Nations with traditional territories overlapping portions of the GCF;
- Crown Legislation: Company MUST consider aboriginal interests in the land in their day to day operations to guarantee aboriginal rights;
- First Nations comments (FSC Report):
    1. Negative impact of forest operations on traplines (↓ of animals);
    2. Lack of formalized information process;
    3. Don't see sincere efforts to provide First Nations with benefits;
    4. Don't necessarily differentiate on SFL over another.
- NGOs (e.g. Earthroots) comments (FSC Report):
    1. Negative impact of forest operations on habitat suitability (woodland caribou);
    2. Concerns regarding cutblocks sizes and clearcuts over 260ha.
- Communities comments:
    1. Negative impact of forest operations on habitat suitability (woodland caribou);
    2. The concern about the potential reduction in wood supply;
    3. The conflict among users on road (development, use, harvesting);
    4. Missed opportunities to use secondary wood fibre (e.g. cedar and white birch).

Study Site (contd.)

4. Approach to Analysis - GCF

Planning Database
- FRI
- Forest units
- Silvicultural intensities
- Age-classes
- Forested areas for timber management:
  - ✓ Available
  - ✓ Unavailable

Scoping Analysis
- Wood production potential
- Current industrial demand
- Wood for sharing
- Meet management objectives
- Meet strategic targets

Base Model

INPUTS

Fire cycles

FRI

Natural forest succession rules

Post-fire succession rules

Yield Tables

Potential wildlife habitat

Strategic silvicultural options

↓

Strategic Forest Management Model

↓

Sensitivity Analysis
- SFMM
- Natural Benchmark

→ Loaded into Patchwork

Scoping analysis

Ontario Forestry Advisory Accord Board benchmarks

Maximum even-flow

→ Wood supply targets →

Management Strategy
- Testing and refining target levels for all management objectives

Study Site (contd.)

5. Analysis Tools – GCF

SFMM
- Non spatial linear program;
- Model:
  - ✓ Timber production
  - ✓ Wildlife habitat abundance
- Used to develop:
  - ✓ Base model
  - ✓ Natural Benchmark
  - ✓ Scoping Analysis

Heritage Assessment Tool (HAT)
- Predictive model;
- Evaluates:
  - ✓ DEM
  - ✓ Slopes
  - ✓ Drainage
- Determines Cultural Heritage Areas of Concern

Patchworks
- Spatial model;
- Used in conjunction with SFMM;
- Find balance of targets (spatial+non spatial) using weighting functionality;
- Used to refine 10 year harvest schedule.

Regional Community Constellation Impact Model (RCCIM)
- Measures spatial/industrial impacts of resource management in Ontario (Lake Abitibi Model Forest);
- Measure socio-economic impacts associated with the industrial forest.

Ontario Wildlife Habitat Assessment Model (OWHAM)
- Analyze habitat quality and supply;
- Run Habitat Suitability Indices (HIS);
- Spatial representation of wildlife habitat:
  - ✓ Core area scenarios
  - ✓ Core habitat statistics

Natural Disturbance Pattern Emulation Guide Tool (NDPEG Tool)
- GIS tool (Arc View based) that estimates: forest disturbance perimeter, planned clear cuts, sliding scale of goodness of fit.

Rationale

- Increase the participation of stakeholders during the modelling and planning stages.
- Demand for "artificial environments" to simulate models and scenarios to support participatory processes.
- Demand for decentralised models that better reflect humans' interests and actions in forest management and planning.

Research Questions

- How to promote the involvement of local stakeholders on the actual forest management and planning process in Ontario?
- How to incorporate stakeholders' different values, viewpoints, and objectives of the forest? How can this process leads to a common sharing of issues and facilitate management strategy formulation?
- How can decentralized models promote adaptive learning of stakeholders in a way to understand the consequences that may arise from actions and interactions?

Research objectives

i. To develop a decentralized spatial forest management model, extending the CA framework proposed by Mathey et al. (2005) including four stand values: timber, old-growth, Aboriginal, and forest diversity.

ii. To integrate landscape-level constraints within the stand-level optimization process in the previous model.

iii. To develop an integrated MAS and CA forest management model to simulate the perspectives and actions of four different agents in the decision making process: forest manager, forest industry, Aboriginals people, and environmental groups.

1. The evolution of CA applied to forest planning in Canada

◆ **In 2005, Mathey et al. developed a simple CA model specific to forest planning**:

- Forest stand = cellular automaton
- Cell state = one of the schedule of treatments
  1. no treatment for the planning horizon;
  2. harvesting at the beginning and end of planning horizon.
- Stand state evaluation = weighted average of two components

$$v(s(l), l) = w_h\, hv(s(l), l) + w_o\, ov(s(l), l)$$

- Non-spatial component: Harvest volume
- Location independent of the neighbouring

- Spatial component: Old-growth
- Location dependent of the neighbouring

- State transition function = selects next schedule that maximizes the OF - $v(s(l), l)$
- Stand updating: asynchronous

Random order for cell updating → State is not updated if value does not improves

Random order for cell updating → State updates if value improves → Allow other stands to react to it; then co-evolve

Iterative process stops when no update occurs in stands from the random list.

1. The evolution of CA applied to forest planning in Canada (contd.)

◆ **In 2007, Mathey et al. added global constraints to the first model**:

$$\mathrm{vol}^t_{\min} \le \mathrm{vol}_t(P) \le \mathrm{vol}^t_{\max} \quad \text{and} \quad \mathrm{lsa}_t(P) \ge \mathrm{lsa}^t_{\min}, \quad t = 1, 2, \ldots, T$$

Even-flow harvest volume

Minimum level of old growth

- Global constraints were incorporated by using penalties and incentives influencing cell level choices.

$$\alpha_t = \begin{cases} \dfrac{\mathrm{vol}^t_{\min}}{\mathrm{vol}_t(P)} & \text{if } \mathrm{vol}_t(P) \le \mathrm{vol}^t_{\min} \\ 0 & \text{otherwise} \end{cases},$$

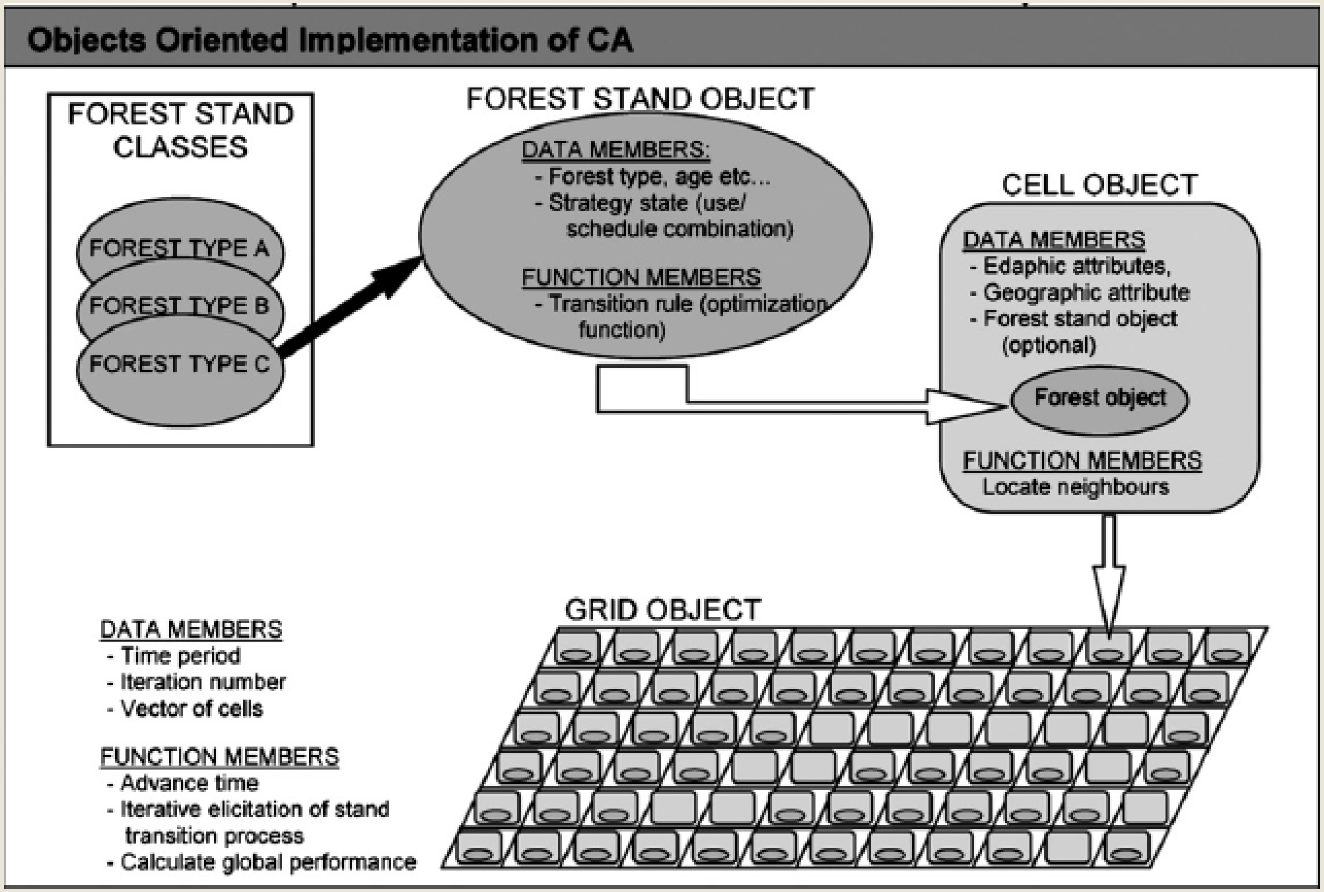
$$\beta_t = \begin{cases} \dfrac{\mathrm{vol}_t(P)}{\mathrm{vol}^t_{\max}} & \text{if } \mathrm{vol}_t(P) \ge \mathrm{vol}^t_{\max} \\ 0 & \text{otherwise} \end{cases},$$

$$\gamma_t = \begin{cases} \dfrac{\mathrm{lsa}^t_{\min}}{\mathrm{lsa}_t(P)} & \text{if } \mathrm{lsa}_t(P) \le \mathrm{lsa}^t_{\min} \\ 0 & \text{otherwise} \end{cases}$$

$$z(s(f)) = \sum_{t=1}^{T} \left[(\lambda_t + \alpha_t - \beta_t) \times \frac{\mathrm{HV}_t(s(f))}{\mathrm{HV}_f} + (1 - \lambda_t + \gamma_t) \times \frac{\mathrm{LS}_t(s(f)) + \rho \times \mathrm{LSN}_t(f)}{\mathrm{LS}_f} \right]$$

1. The evolution of CA applied to forest planning in Canada (contd.)

◆ **In 2008, Mathey et al. developed a decentralized spatial <u>decision support tool</u> for forest planning: Object-oriented implementation of the CA model**



1. The evolution of CA applied to forest planning in Canada (contd.)

- **The CA-OPP model was tested for:**
  - ✓ Harvest volume – **Economic value**
  - ✓ Old-growth areas – **Environmental value**

- **Conclusions of the CA models applied to forest planning:**

Advantages:

- Good representation of geophysical and ecological aspects;
- Allows combination of forest management problems involving inter-temporal trade-offs and both local and global (spatial/non-spatial) objectives and constraints;
- All elements of the system are, in time, influenced by all changes in the system;
- Reusability of both the code and information shared by similar objects.

1. The evolution of CA applied to forest planning in Canada (contd.)

◆ Conclusions of the CA models applied to forest planning:

Gaps for further research:

- Potential research on the incorporation of other stand values and constraints (local and global);
- Potential research on developing models and tools stimulating participatory processes in forest planning;
- Potential research regarding the distribution of the multiple users' activities on the forest land base;
- Potential research on developing models addressing the multiple stakeholders' perceptions, actions, and expectations during the decision making processes.

Can CA be used in all these cases? If not, what has been used in the literature to address these ???

2. The applications to MAS in Forestry

- **Applied to many areas in NRM**:
  - Irrigation and water management (Feuillette et al. (2003)-SINUSE; Becu et al. (2003)-CATCHSHAPE; Barreteau et al. (2001,2004)-SHADOC; Gurung et al. (2006))
  - Sylvopastoral systems management (Ettiene et al. (2003)-SYLVOPAST; Ettiene et al. (2003)-MEJAN)
- **Applied to forestry:**
  - Forest management
    1. Purnomo et al. (2005): Interactions of multiple stakeholders of a community-based forest, Indonesia.
    2. Campo et al. (2009): MAS+ RPG to improve participation of multiple stakeholders of a community-based forest, Philippines.
    3. Bone and Dragicevic (2009): Applied of reinforcement learning (heuristic) to test agents' learning, Canada.
  - Forest plantation
    1. Purnomo and Guizol (2006): MAS to simulate decision-making for a multiple stakeholders forest plantation, Malaysia.
  - Timber supply-chain management
    1. Frayert et al. (2007): Lumber supply chain (OP), Canada.
    2. Forget et al. (2008): Lumber supply chain (OP), Canada.

Methodology

1. Data Collection

SECONDARY DATA

- **Geospatial Data:**
  - Land Information Ontario (LIO)
  - Ontario Geospatial Data Exchange (OGDE)
  - MNR – Hearst District
  - Ontario Parks
  - Smartwood
- **Non-spatial Data:**
  - MNR – Hearst District: G&Y information, forest state
  - Smartwood
  - Ontario Parks

PRIMARY DATA

- **Non-timber values:**
  - Aboriginals
  - Forest Diversity (Caribou)
  - Questionnaires?, Games?, Meetings?

2. Decentralized CA model

GOAL: Adding two more forest values to Mathey et al.'s models – Aboriginal and forest diversity.

- **CA Grid definition:**
  - 2-dimensional grid
  - Forest stand = 9-16km^2 (???)/ Total = 1,602 stands
  - Moore Neighbourhood
- **State of cells:**
  - Timber – FRI + MNR
  - Old-growth – FRI + MNR
  - Aboriginal – Potentially Trapline Area (had no access to data yet)
  - Forest diversity – Concentration of biodiversity values:
    - Areas with high conservation values (had no access to data yet)
    - Caribou collection area (had no access to data yet)
    - Others: calving fawning site, Crown game preserves, habitat planning range, wild life corridor,….
- **Transition rules:**
  - Transition function: max the value for each stand; min differences among 4
  - Independent components: timber
  - Dependent components: Aboriginal, old-growth, diversity
  - Objective function: same weights to all components?? Information that can be collected from collective meetings.

3. Decentralized Integrated-CA model

GOAL: Integrate landscape-level constraints within the stand-level optimization to the previous model.

- **Determine min/max standards for each forest value:**
  - ✓ Stand and landscape level
  - ✓ Decision among stakeholders (representatives)
- **Use of incentive/penalty functions:**
  - ✓ Under-achievement
  - ✓ Over-achievement
- **Computational analysis:**
  - ✓ Computational efficiency: number of runs, objective value, average of iterations (to reach feasible solution, average computation time), etc…
  - ✓ Compare to other heuristic techniques: Patchwork analysis (??)

4. Decentralized MAS-CA model

GOAL: Test and simulates different type of negotiations (e.g. voting) of different stakeholders in allocating different forest management alternatives.

IF POSSIBLE!!

- **Specification of the environment (spatial organizations):**
  - ✓ CA-grid
  - ✓ BasicCell (forest stands): forest stand class, geographic location
  - ✓ AgentCell: allow agent to store/create information of their own description for each stand; perceptions; interests

- **Specification of agents and individual decision making:**
  - ✓ 4 stakeholders: forest manager (District Manager), Aboriginal, forest industry, environmentalists
  - ✓ Each has a set of preference functions
  - ✓ Each has methods to communicate/evaluate/decide/assign raking indicators to AC
  - ✓ CA-transition function: assign raking indicators

5. Decentralized MAS-CA model (contd.)

- **In case of a voting process: specification of synchronized decision making:**
  - ✓ Forest manager: collects list of AC from everyone;
  - ✓ Forest manager: identify forest stands with same/different forest management class;
  - ✓ Forest manager: request revision of forest stands with conflicting interests;
  - ✓ Forest manager: if consensus is not attained, conduct a voting process;
- **Simulation Scenarios:**
  - ✓ Scenario 1: Forest manager has higher decision power during voting process.
  - ✓ Scenario 2: Equal decision power to stakeholders during voting process.
- **Expectations:**
  - ✓ In terms of social analysis:

    Scenario 2 generates a higher social satisfaction than Scenario 1.
    (how to measure that!?)
  - ✓ In terms of forest value analysis:

    I don't know what to expect between both scenarios!!

Previous experiences

1. Primary data collection through questionnaires during Masters.

2. Primary data collection through economic games – Public good games

- Development of games using Ztree;
- Running sessions in a computer lab;
- Assistant during game sessions with Constance Lake First Nations Community;

3. First training course on a Collaborative and Participatory Process: COMMOD

- International training course on Companion Modelling for Integrated Renewable Resource Management;
- Thailand; May/2009
- Topics: Commod, UML, RpG, ABM, Designing and running RpG sessions, CORMAS

Expectations – Internship CIRAD/Green

- ❖ Better and deeper understanding of projects using Commod;
- ❖ Engage in learning CORMAS and develop models first prototypes;
- ❖ Enhance my knowledge in participatory processes and identify gaps and room for improvements in my own project.
- ❖ Be able to learn a little bit of French!!

Thanks for your attention!!

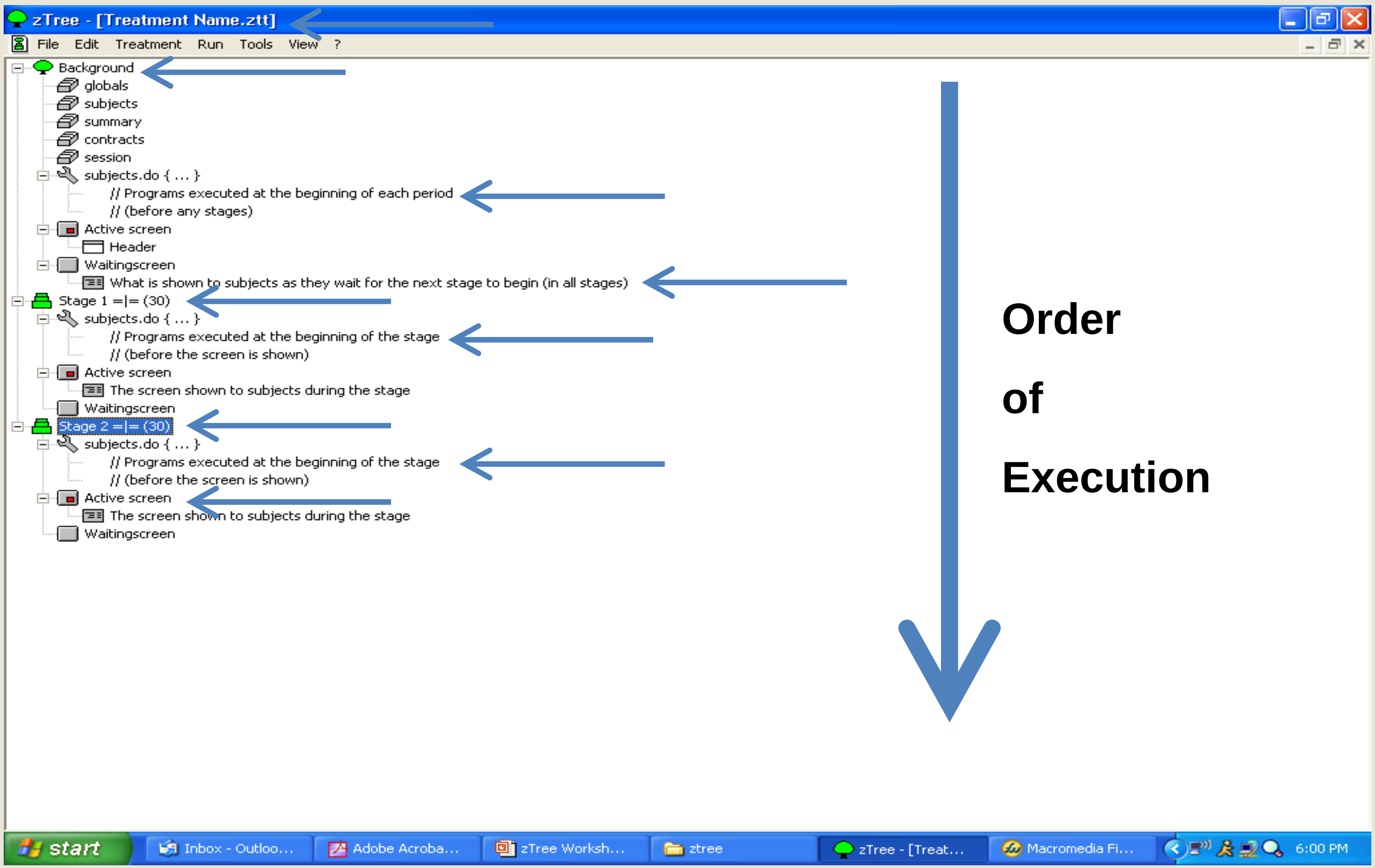
MERCI!!!

Suggestions, Comments, Questions??

ZTree

1. **Ztree- Zurich Toolbox for Readymade Economic Experiments (University of Zurich – Institute for Empirical Research in Economics)**

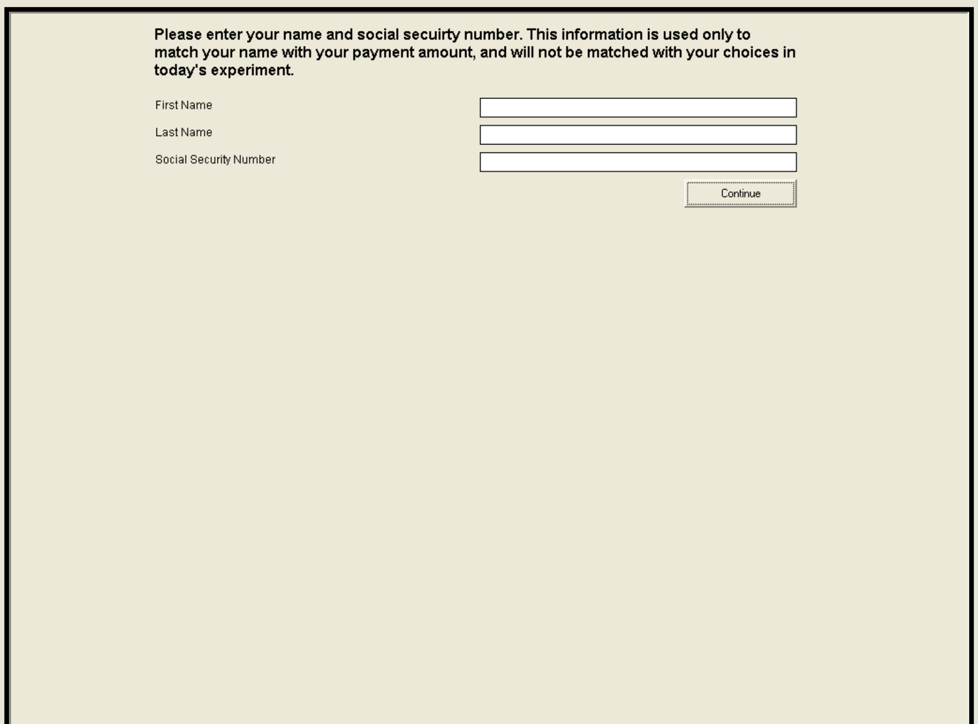
- Consists of 2 programs: zTree (the programming environment and experiment server) and zleaf (the client program for subjects – players)
- Designed primary for public goods games, structured bargaining experiments, posted-offer-markets, double auctions, and questionnaires and surveys.



ZTree (contd)

1. Ztree

- It can be applied in different languages (18) such as Deutch, English, French, Italian, Spanish, Russian, etc….
- It is quite easy to program!!! 
- You can define your parameters, use many mathematical functions, define group matching, define periods, and at the end will generate a payment file.



Please enter your name and social secuirty number. This information is used only to match your name with your payment amount, and will not be matched with your choices in today's experiment.

First Name

Last Name

Social Security Number

Continue

Scree shot of zLeaf

Public Good Games

1. **Local Public Good Games**

2. **Global Public Good Games – Climate change being global public good (bad)**

1. Local Public Good Games

- **Game 1:**
  - 3 rounds
  - 10 tokens
  - Private Account (PrA): 1 token = 4$
  - Public Account: 1token (PuA) = **6$**
  - Personal Returns = PrA+PuA/group

- **Game 2:**
  - 3 rounds
  - 10 tokens
  - Private Account (PrA): 1 token = 4$
  - Public Account: 1token (PuA) = **8$**
  - Personal Returns = PrA+PuA/group

2. Global Public Good Games

- **Game 3:**
  - 3 rounds
  - 10 tokens
  - Private Account (PrA): 1 token = 4$
  - Green Technology Account: 1token (PuA) = **6$**
  - Public Education Account: 1token (PuA) = **6$**
  - Personal Returns = PrA (returns from GT and PE may not be immediately available to the investors)

- **Game 4:**
  - 3 rounds
  - 10 tokens
  - Private Account (PrA): 1 token = 4$
  - Green Technology Account: 1token (PuA) = **8$**
  - Public Education Account: 1token (PuA) = 8$
  - Personal Returns = PrA

Data Collection

1. **Different First Nations Communities;**
2. **Undergraduate students from different backgrounds** (Economics, biological, etc.…)