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Will climate change drive temperate agroforestry systems towards increased competition or complementarity? A modelling approach

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UQÀM

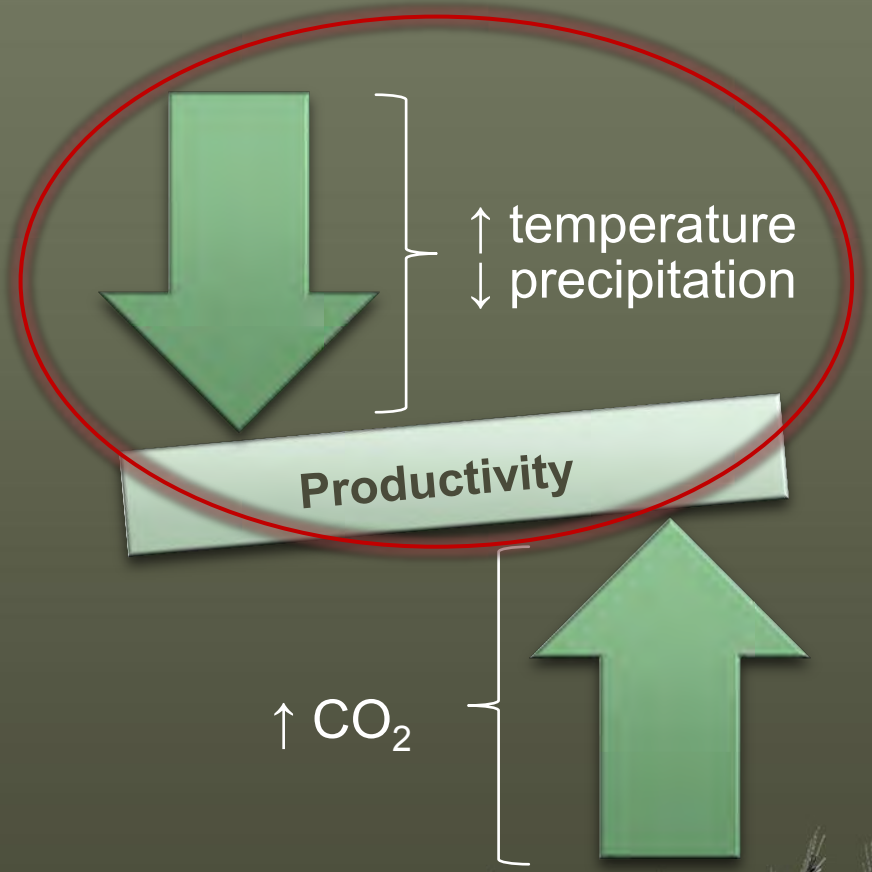
What is agroforestry?

Why adopt agroforestry?

1. Carbon sequestration
2. Biodiversity conservation
3. Soil enrichment
4. Improvement of water and air quality

… the impact of climate change on agroforestry systems?

Greenhouse gases will impact the growth and functioning of agroecosystems and forests



Objective

Evaluate the impact of climate change on the interaction processes that determine the productivity of agroforestry systems

Hypothesis: The complementarity between trees and crops in agroforestry systems will mitigate the effects of climate change on crop productivity

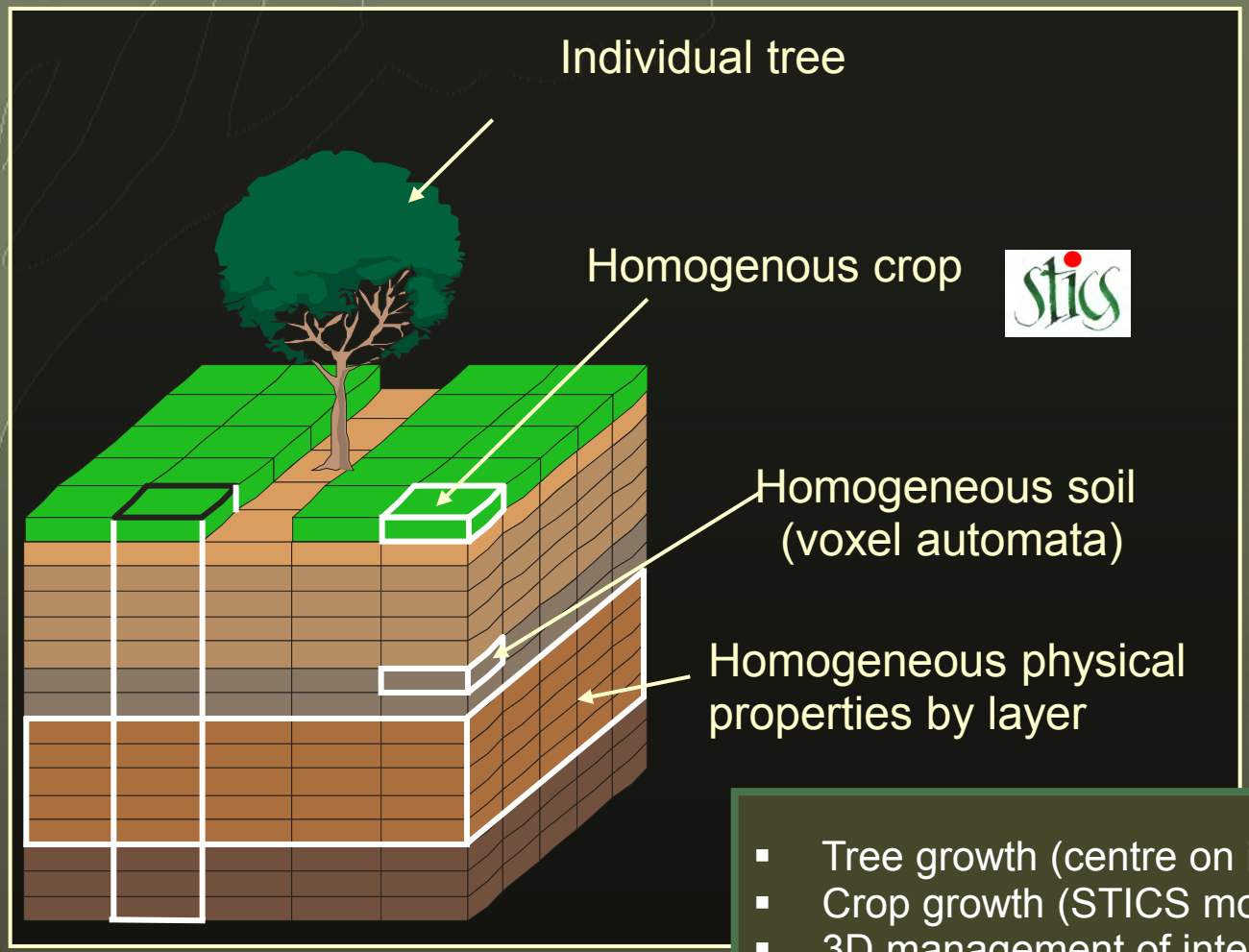
Why a modelling approach?

- Agroforestry systems: varying time and spatial scales, non-linear relationships, negative and positive feedback loops…in constant evolution
- Benefits of intercropping depend on the balance between the negative and positive interactions between the components
- Simulation modelling using process-oriented approaches is an effective way of studying complex biological systems

Hi-sAFe: 3-dimensional process-oriented simulation model

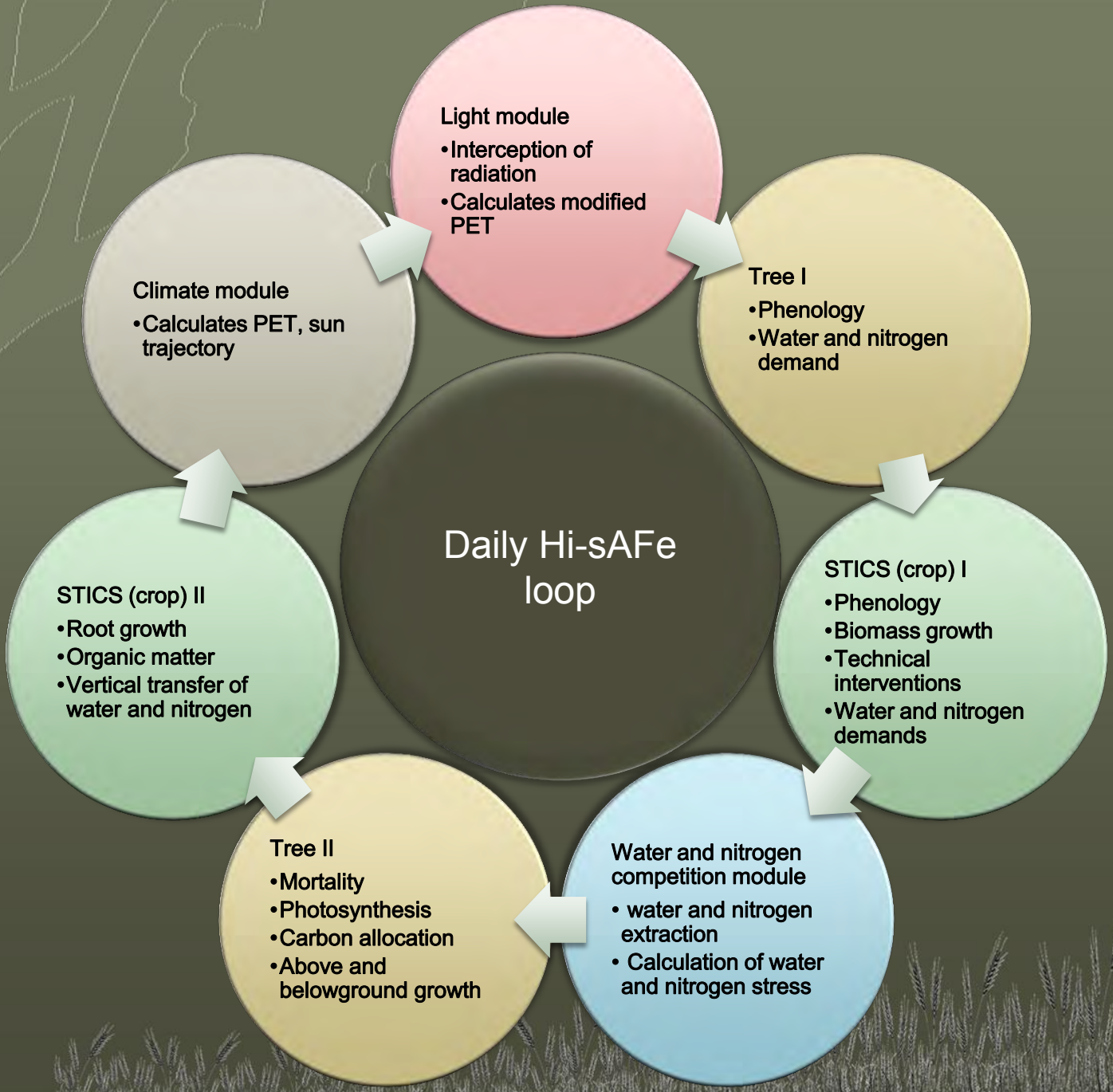
- Daily time step
- Tree model: centred on individual, photosynthesis, carbon allocation, geometry
- Crop model: STICS coupling
- Manages interaction processes for resource use: light, water, and nitrogen
- Integrates the processes over the full rotation

Hi-sAFe

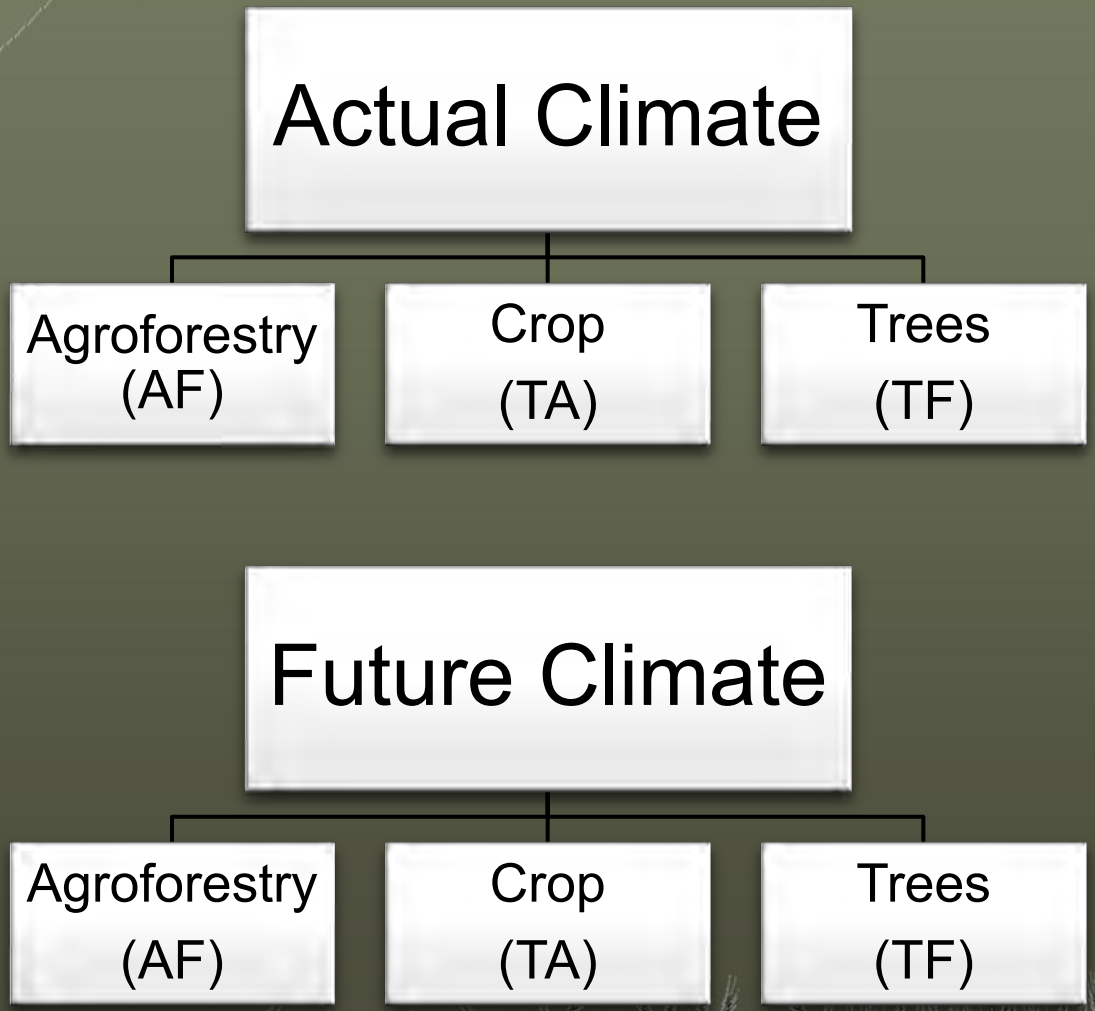


Adopted from Talbot (2010). dissertation presentation

- Tree growth (centre on individual)
- Crop growth (STICS model)
- 3D management of interactions:
  - light
  - water
  - nitrogen


Daily Hi-sAFe loop
Light module
•Interception of radiation
•Calculates modified PET
Tree I
•Phenology
•Water and nitrogen demand
STICS (crop) I
•Phenology
•Biomass growth
•Technical interventions
•Water and nitrogen demands
Water and nitrogen competition module
• water and nitrogen extraction
• Calculation of water and nitrogen stress
Tree II
•Mortality
•Photosynthesis
•Carbon allocation
•Above and belowground growth
STICS (crop) II
•Root growth
•Organic matter
•Vertical transfer of water and nitrogen
Climate module
•Calculates PET, sun trajectory

Virtual experimental plan



Virtual experiment

Tree species: poplar

Crop: winter wheat (STICS)

Climates files: current (1971-2000) and future (2041-2070)

Virtual scene: one tree, spacing of 9 meters between trees and 13 meters between the rows

Alignment: North-South

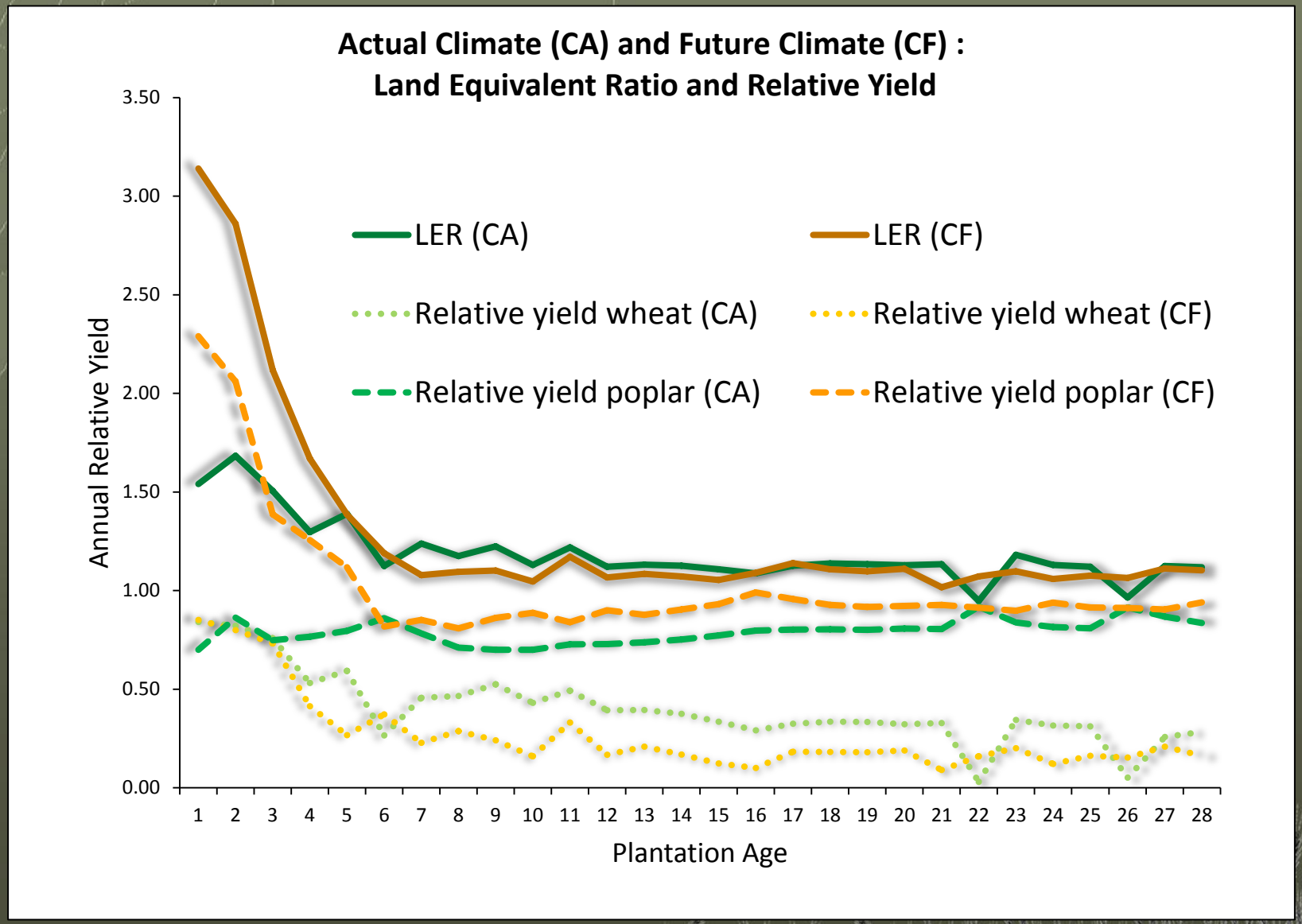
Selection of climate scenarios

- Climate data required: min/max temp (° C), global radiation (MJ.m-1), precip. (mm), min/max rel. humidity (%), wind speed (m.s-1)
- Consortium Ouranos: 102 simulations
- Cluster analysis based on the deltas: 5 simulations retained covering 74.5% of the variance
- 4 extreme climate simulations retained

The Land Equivalent Ratio (LER)

$$LER = AF_{crop}/TA_{crop} + AF_{tree}/TF_{tree}$$

- LER > 1 = yield of mixed system produces more than the same amount of land in a pure system
- Integrated LER (Dupraz et al. 1999): calculated from the cumulative yields over the span of a tree rotation


Actual Climate (CA) and Future Climate (CF) :
Land Equivalent Ratio and Relative Yield
Annual Relative Yield
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
LER (CA)
LER (CF)
Relative yield wheat (CA)
Relative yield wheat (CF)
Relative yield poplar (CA)
Relative yield poplar (CF)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Plantation Age

	Current Climate			Future Climate		
	RY Wheat	RY Poplar	LER	RY Wheat	RY Poplar	LER
20 years	0.464	0.767	1.231	0.309	1.075	1.383
25 years	0.424	0.781	1.205	0.276	1.043	1.319
30 years	0.400	0.791	1.190	0.265	1.030	1.295

Points to remember

- Intercropping systems using poplars and winter wheat are productive systems (LER>1);
- Poplar productivity increases while crop productivity decreases in time and this accentuated by CC;
- Crop yields (LER) are more stable in agroforestry systems with climate change (over a 30 year);
- Further validation using other crops and tree species required to fully understand complementarity and competition processes.

Acknowledgments

Modélisation de la Complexité de la Forêt

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