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Multiple-Agent Modeling Applied to Agro-Ecological Development

Overview of Research Activities at ZEF - Bonn University

Agent-based Spatial Model Class

Balmann's Farm Cellular Automata

\+ Behavioral heterogeneity

\+ Interaction, communication

\+ Integration of natural resources

\+ Empirical parameterization and validation

= Agent-based spatial model class

→ **Diffusion of innovations**

→ **Resource use changes**

→ **Dynamic policy analysis**

Outline

1. Combination of MAS and CA
2. Empirical parameterization
3. Validation of model outcomes
4. Wrapping up
5. Multiple Agent Modeling at ZEF

Dynamic Spatial Modeling of LUC

Statements:

- Spatial patterns of land use change can be modeled in terms of individuals' economic decisions
- Data requirements can be met by applying a "common sampling frame"
- *Ex ante* impact assessment of technological alternatives and policy options provides useful insights for policy makers

Steps for Model Building

(1) Define the basic entities or agents of an agricultural region (e.g. farm-households, landscape units, hydrologic units)

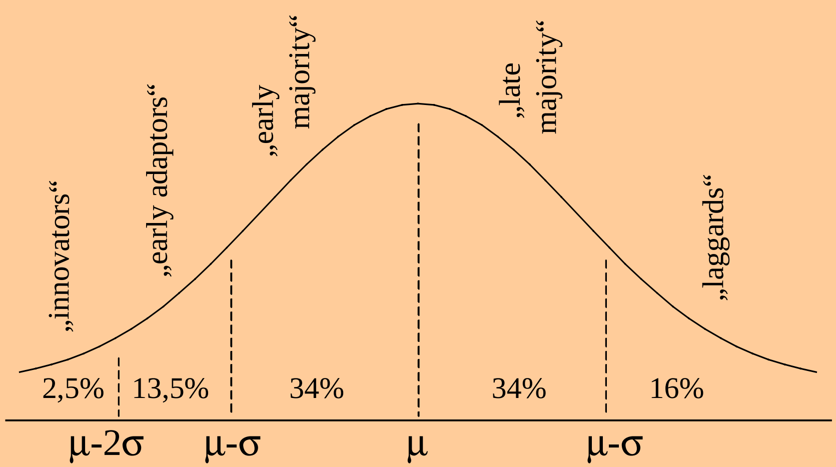
(2) Establish the rules for their dynamics and interactions

(3) Set up the starting situation and calibrate the spatial MAS on micro and macro level

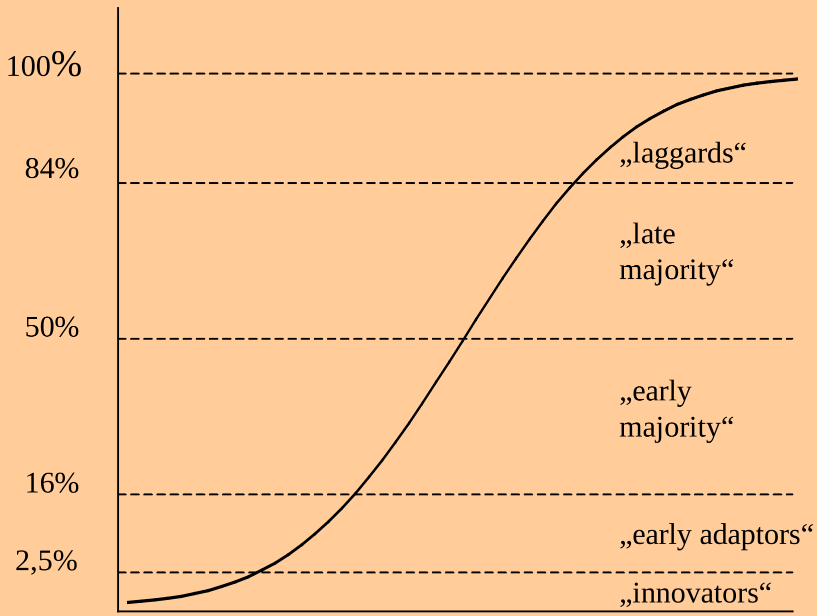
(4) Run the simulation model and observe "self-organizing" processes at aggregate level

Bandwagon Process

Adopter categories



Network thresholds



S-shaped diffusion curve

Adoption Decision Rule

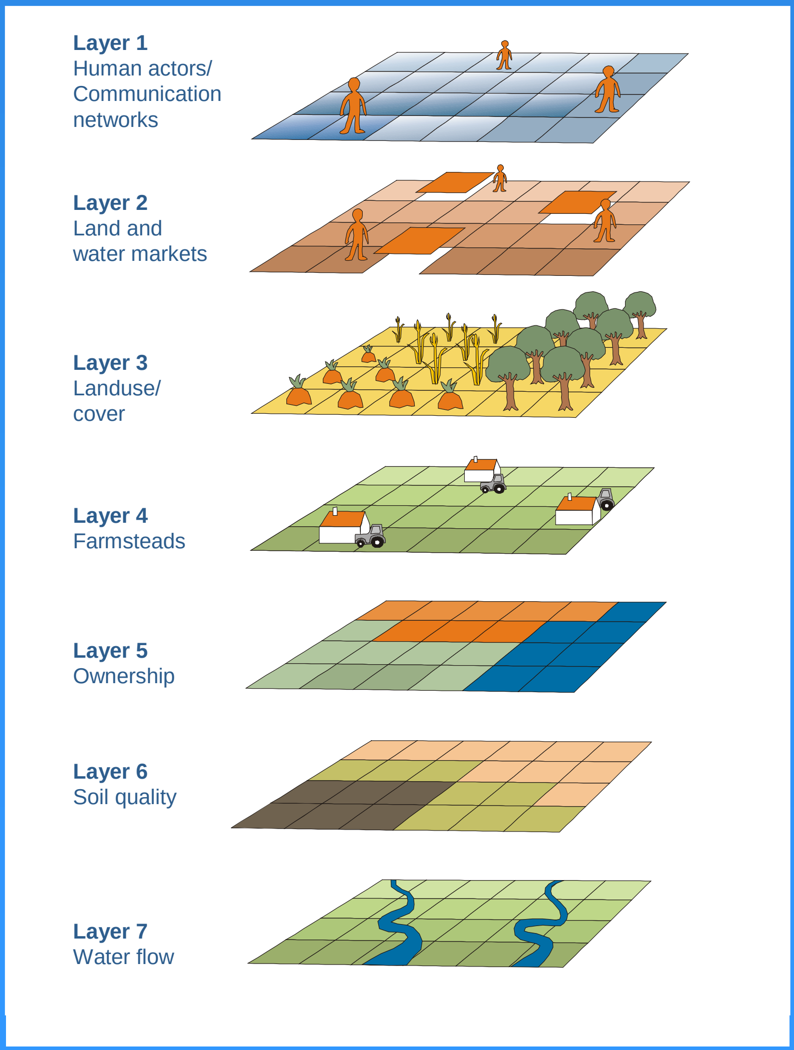
(1) Monitor the present adoption level and compare it with the individual threshold

(2) If threshold is reached, calculate the farm's net benefits from adoption

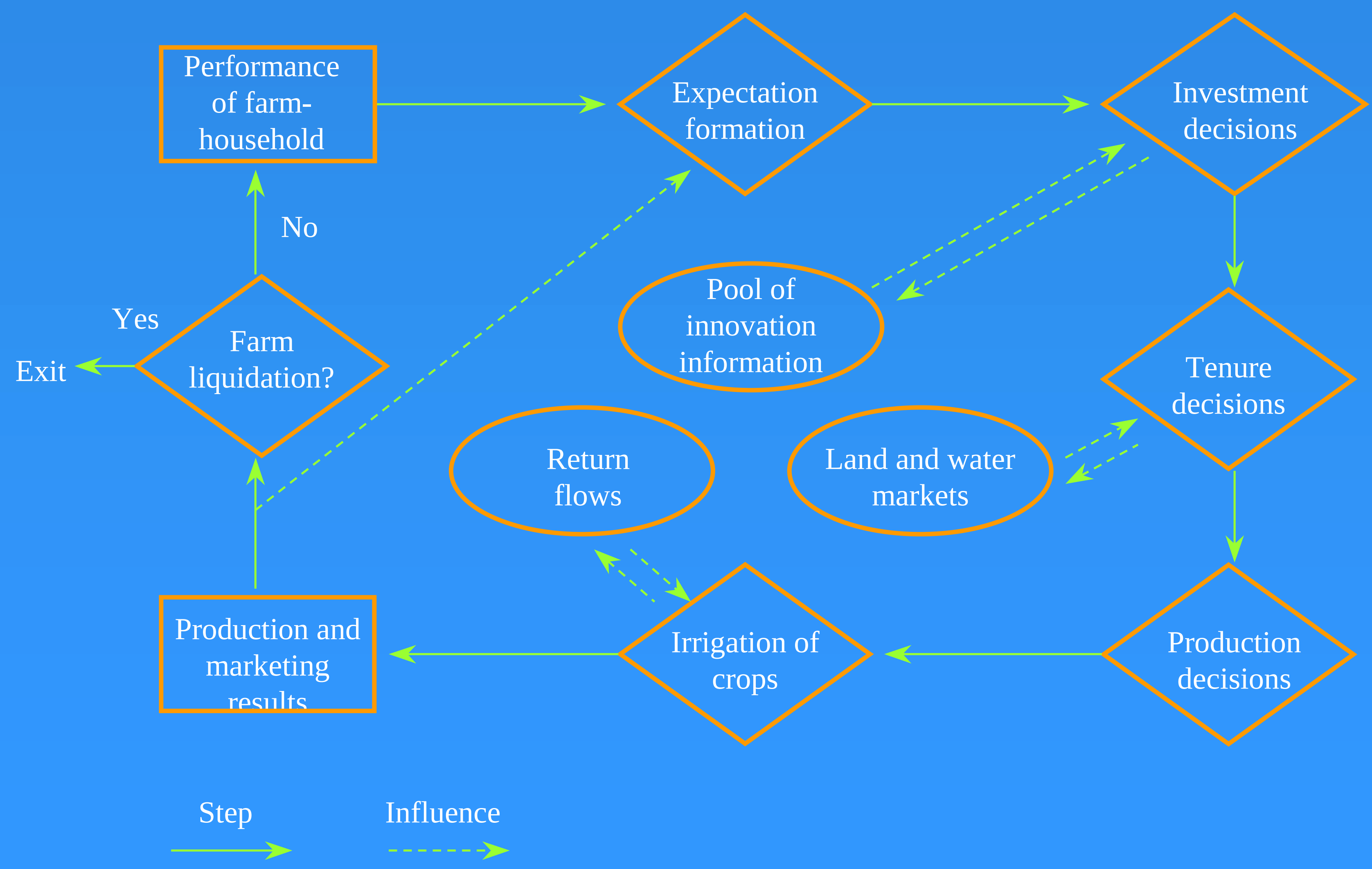
(3) If the net benefits are positive, adopt the technology

Adding a few more assumptions allows predicting the time path of adoption for several technologies simultaneously

Spatial Data Representation



Flow Chart



Performance of farm-household
Expectation formation
Investment decisions
No
Yes
Farm liquidation?
Exit
Pool of innovation information
Tenure decisions
Return flows
Land and water markets
Production and marketing results
Irrigation of crops
Production decisions
Step
Influence

Variables and Parameters

Exogenously Determined Variables	*Endogenous Variables*	*Parameters*
market prices for "tradeables"	prices for "non-tradeables"	input-output coefficients
interest rates	acreages of crops	depreciation rates
wages	yields	sunk costs for fixed assets
taxes and contributions	investment levels	unit transport cost
minimum consumption level	working capital expenditures	adoption constraints
supply of land	borrowing and saving levels	expectation coefficients
supply of freshwater	labor utilization	
supply of innovations	return flows in irrigation	
initial location of farms	ownership of plots/water	

Estimation of Model Parameters

(1) Farm-Household Survey (round 1)

(2) Identification of household groups

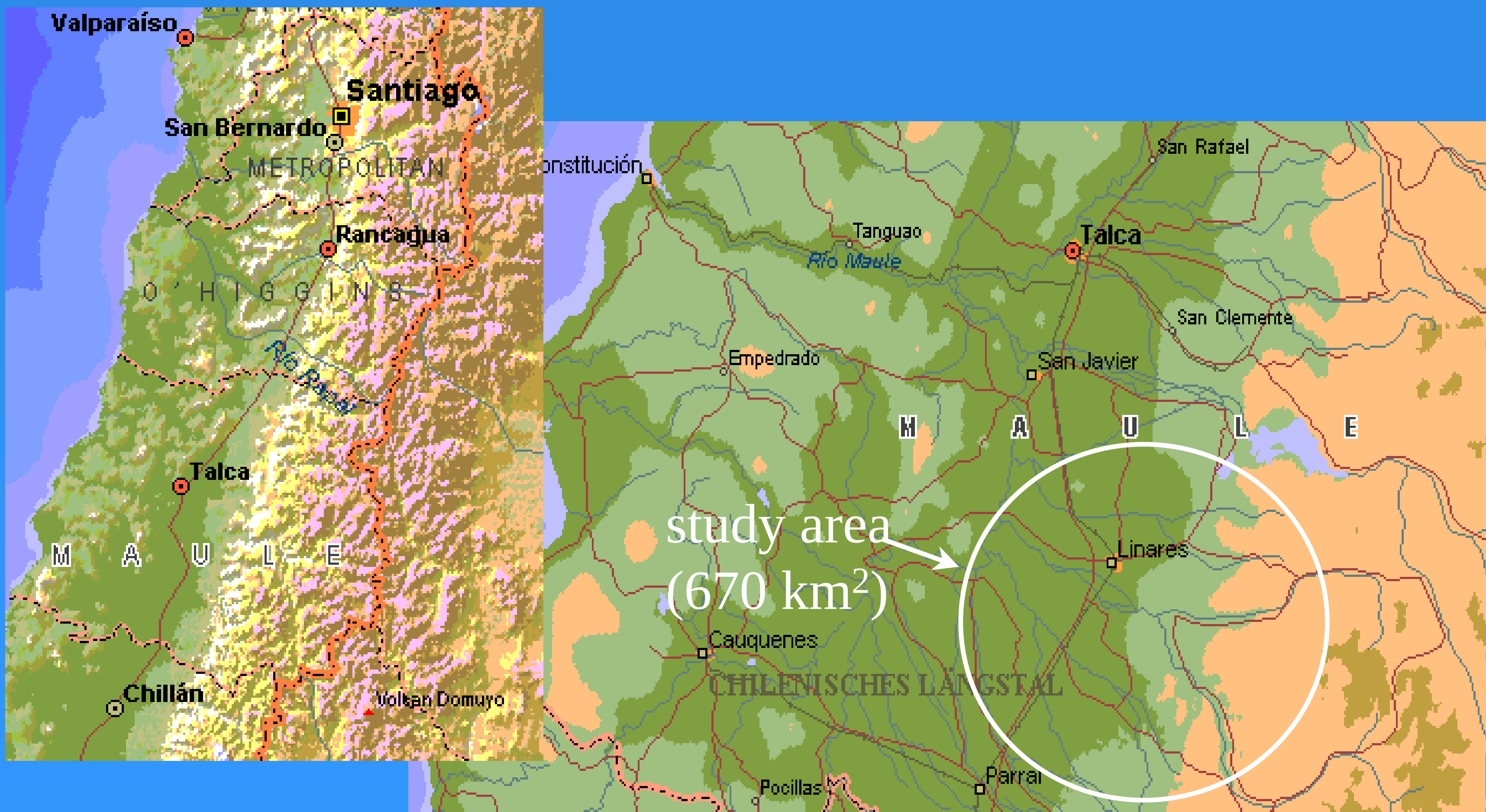
(3) Selection of representative households

(4) Farm-Household Survey (round 2)

(5) Estimation of parameters for LP-Matrix

(6) Generation of a complete household data set (random-generated "synthetic" data)

Study Area (Chile)



Policy-related Research Questions

(1) Can we expect substantial changes in the use of land and water as a result of water-saving irrigation methods?

(2) Will these innovations create sufficient incomes and reach the traditional farmers?

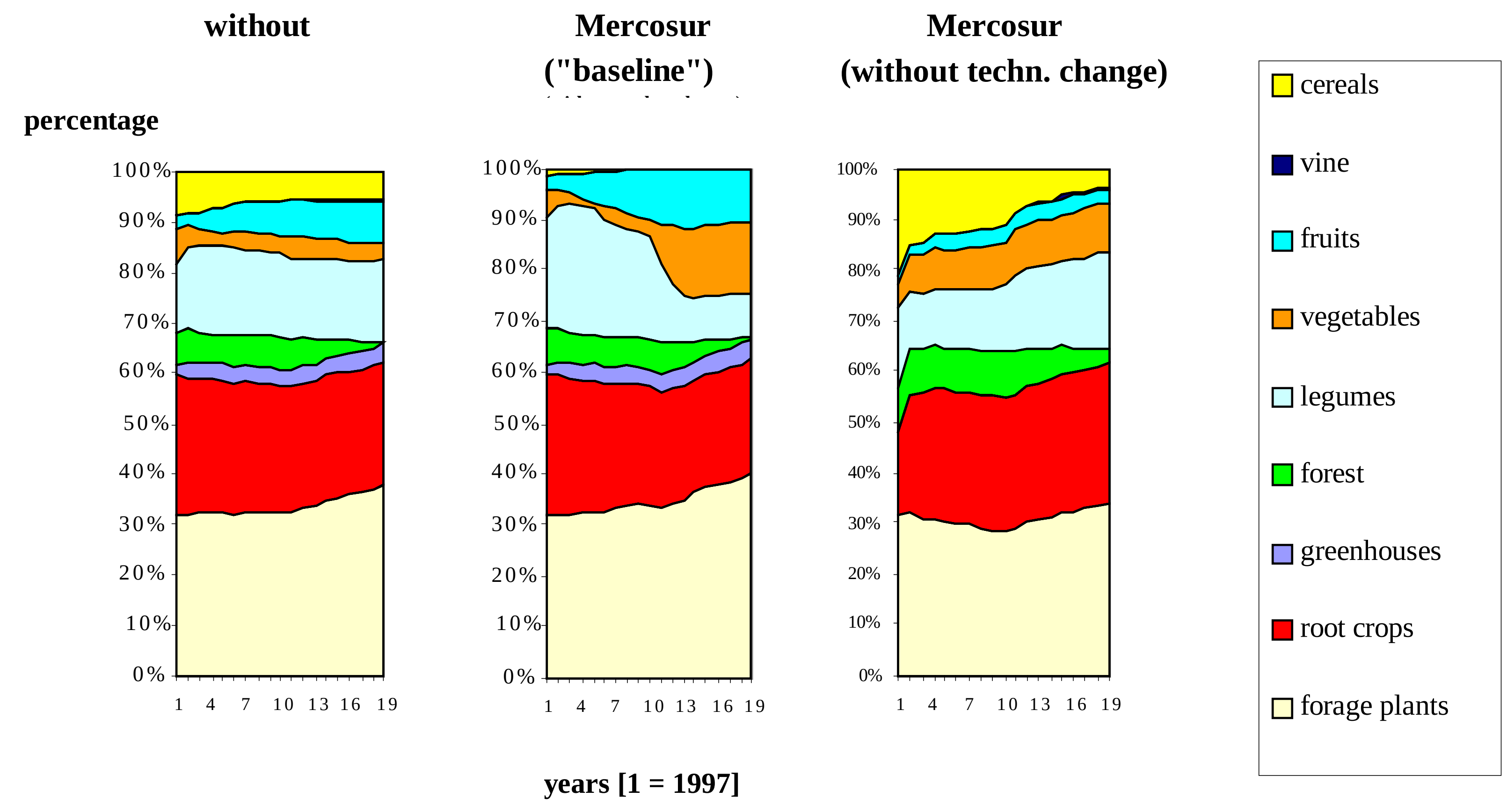
(3) Will out-migration increase or decrease?

(4) What will be the structural effects of a "treadmill" innovation process?

Model Validation

- "Goodness of fit" at micro and macro-level
  0.977 (standard error = 0.01, R^2 = 0.991)
  0.704 (standard error = 0.107, R^2 = 0.657)
- Robustness experiments and supportive statistical tests
  identical and changing starting conditions
  (average income; on-farm labor allocation)
- Expert opinion and "peer" review

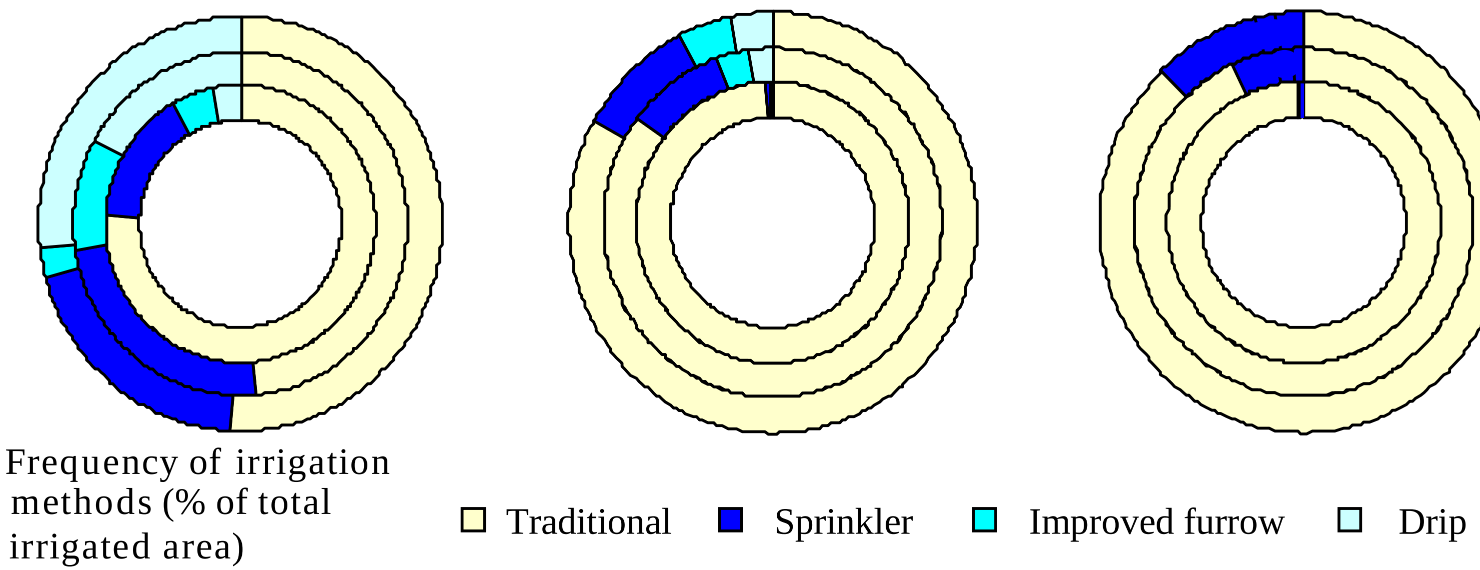
Simulation Results: Land Use



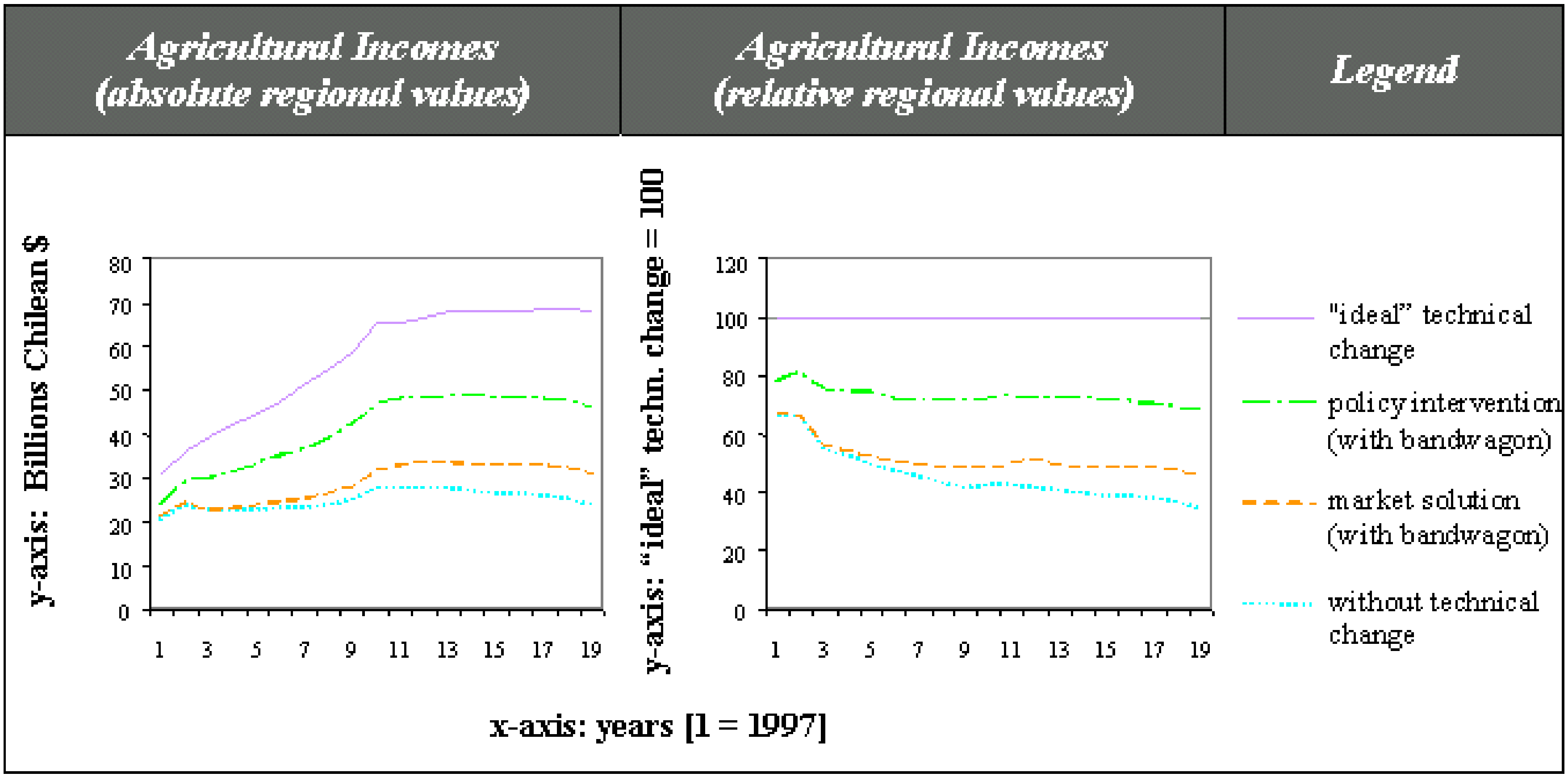
Simulation Results: Irrigation

"ideal" technical change	*market solution*	*without technical change*

inner ring =year 1; ring in between =year 10; outer ring =year 19

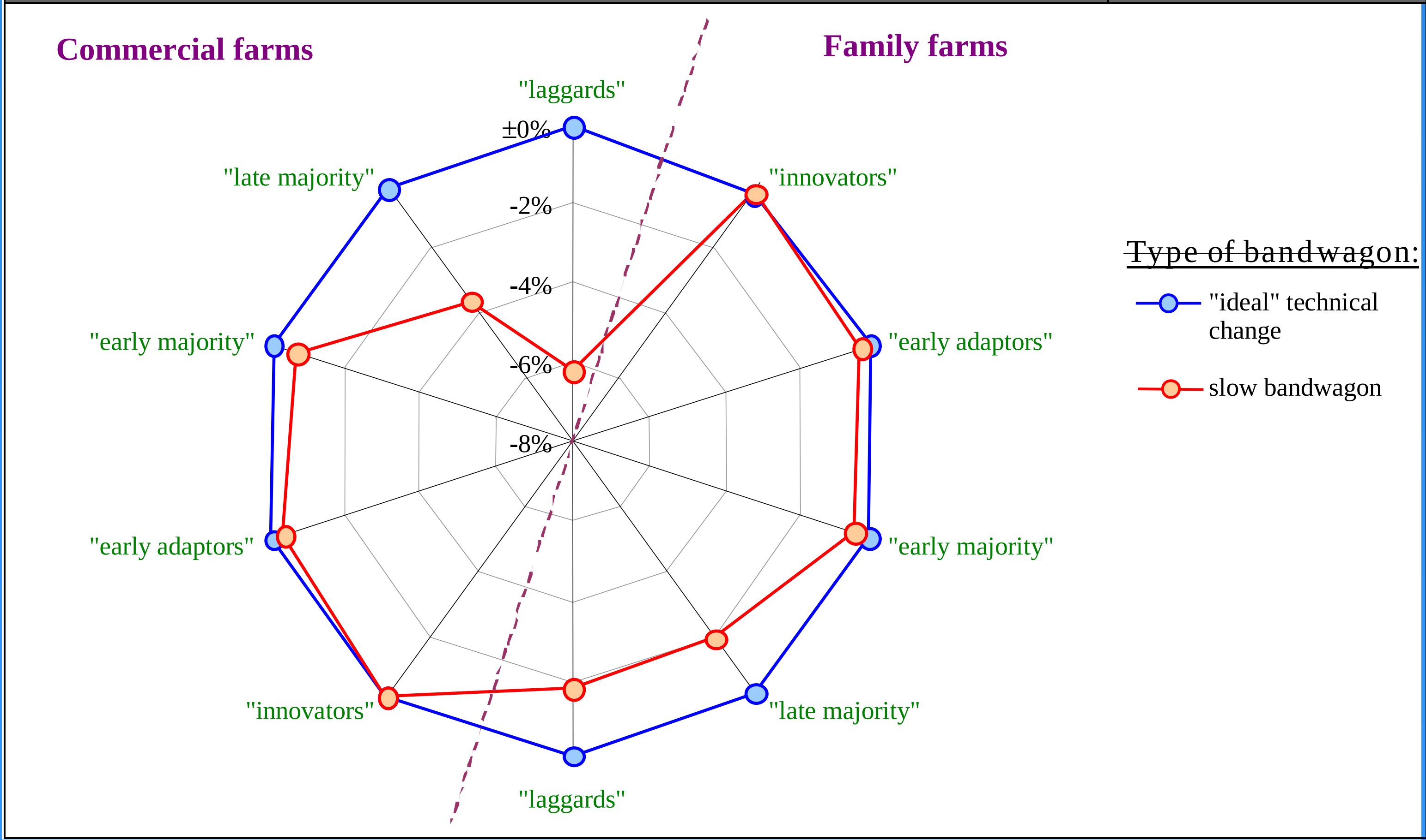


Simulation Results: Incomes



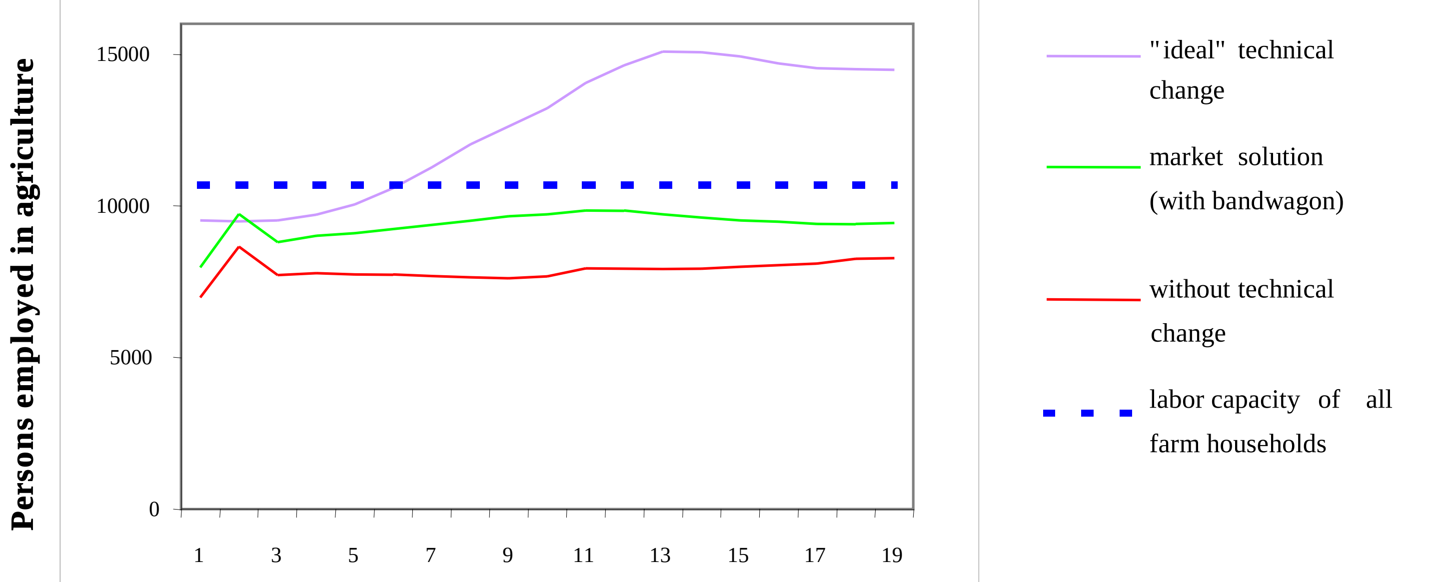
Simulation Results: Farm Exits

Rate of Anual Change in Farm Number	*Legend*



Simulation Results: On-Farm Labor

On-farm labor allocation | ***Legend***



Years [1 = 1997]

Conclusions

- Heterogeneous economic behavior and policy responses from the farm-households' viewpoint
- Introduction of improved land use practices and migration as a farm investment decision
- Inclusion of inter-household linkages permits modeling of "bottom-up" phenomena
- Further integration of biophysical and socioeconomic processes at multiple spatial scales is called for

ZEF's Research Portfolio

Project 1

Technical and structural change in agriculture - Chile (completed in 1999)

- Diffusion of water-saving irrigation methods in a watershed
- Structural effects of a 'treadmill' innovation process in agriculture

Project 2

Policies for improved land management - Uganda (with IFPRI)

- Introduction of sustainable land-use practices as a farm investment decision
- Identification of suitable policy incentives to enhance the adoption of such practices

Project 3

Interrelated water and land use changes in the context of global change – Volta Basin (LUCC endorsed)

- Spatially explicit representation of decision-making processes
- Human responses to policy and environmental changes

Project 4

Community-based management of natural resources - Ghana (Robert-Bosch-Foundation)

- Collective action and environmental externalities
- Dynamic evolution of property rights institutions