AACREA
CRED, Columbia University, Elke Weber
Proyecto CLIMA

Behavioral Decision Theory:

How Judgments and Decisions are Made Under Uncertainty

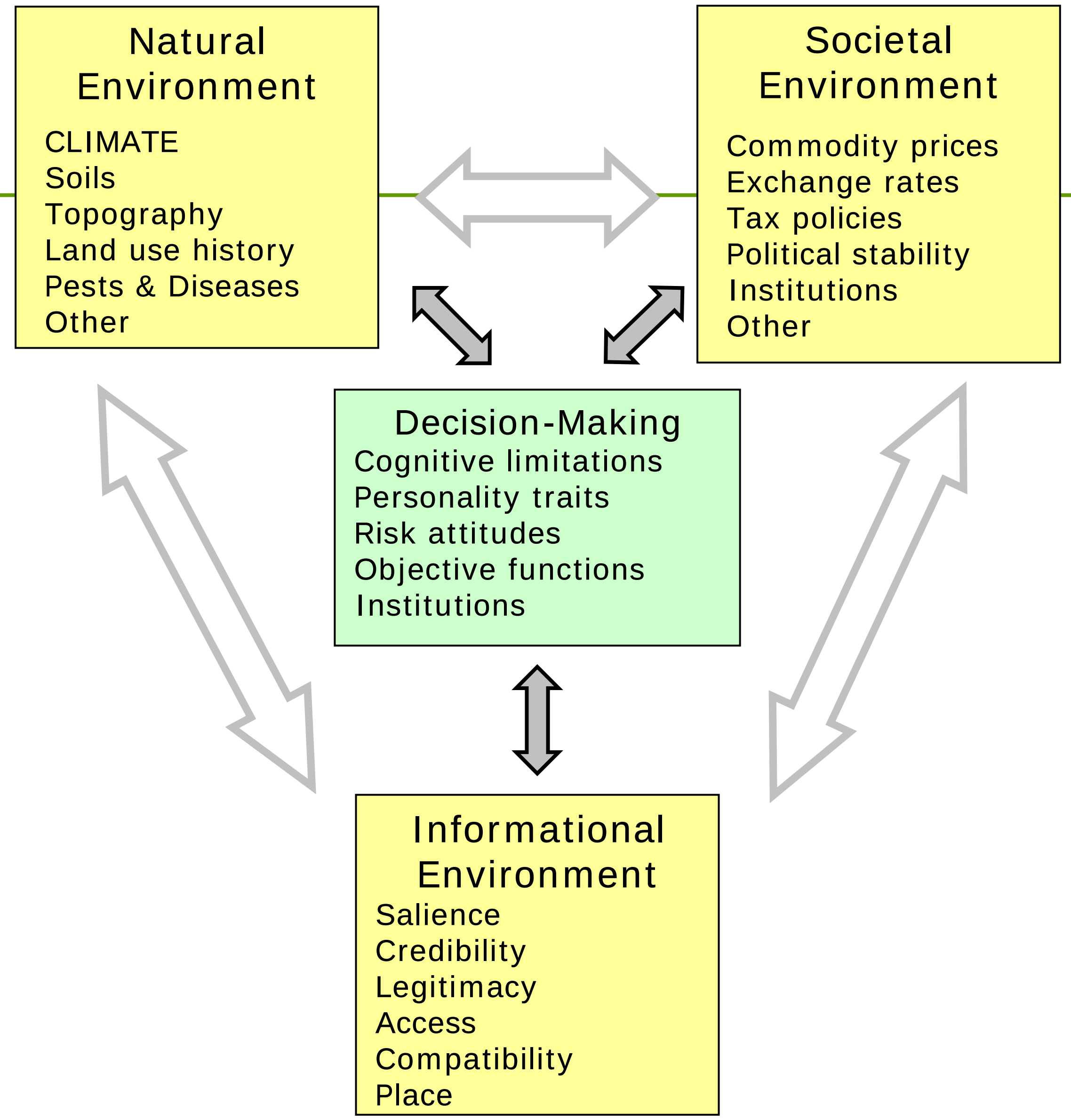
Lesson 7

Expected Utility, Regret-Adjusted Expected Utility, and Prospect Theory

AACREA/CRED/Proyecto CLIMA Interaction

- Societal problem/question addressed
  - Adaptive and sustainable agricultural production management in an uncertain and complex physical and social environment

- Answers to important societal questions require
  - multi- and ideally inter-disciplinary investigation
  - consideration/modeling of multiple components
  - combination of component models
    - often across different levels of analysis

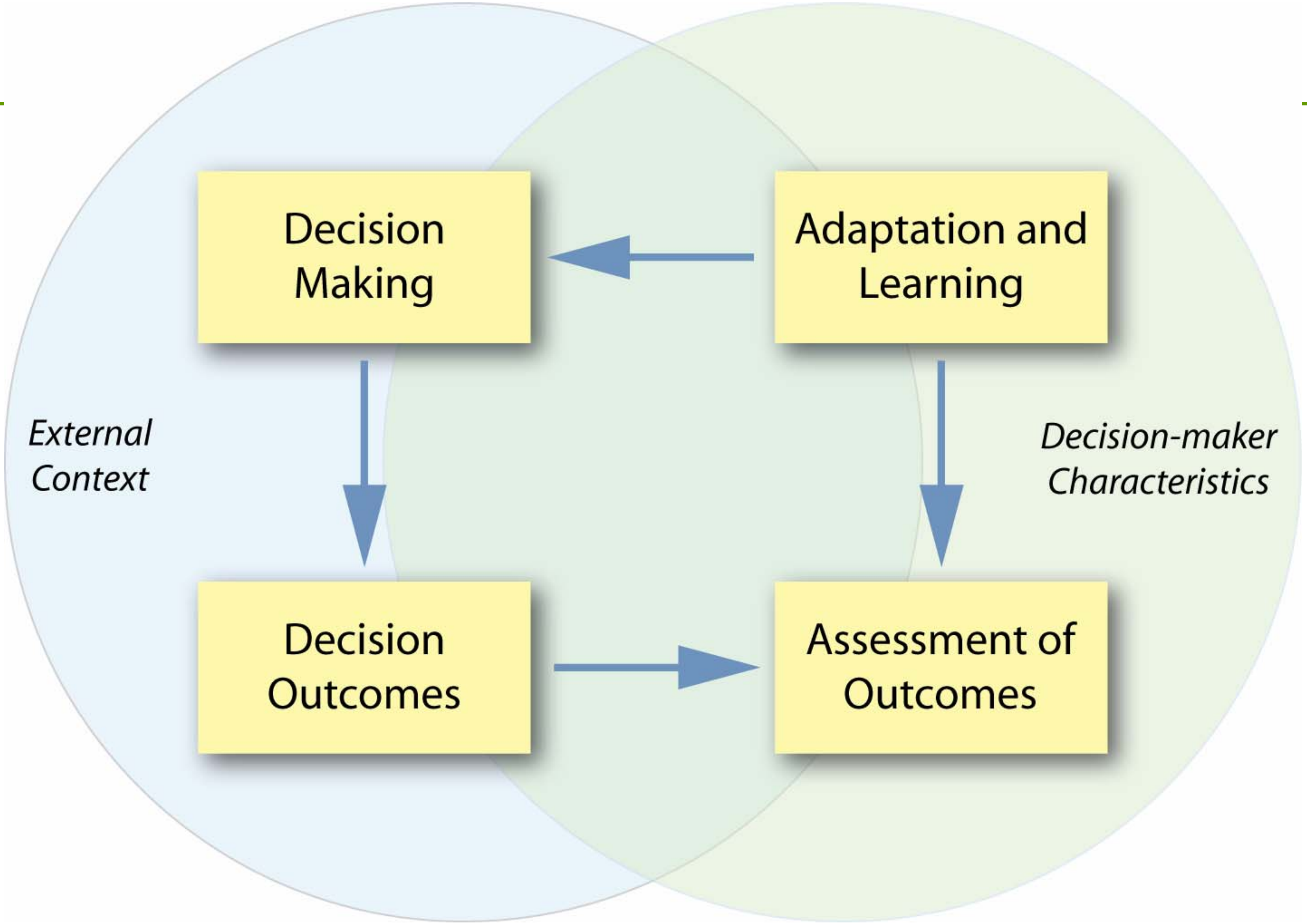

Natural Environment
CLIMATE
Soils
Topography
Land use history
Pests & Diseases
Other
Societal Environment
Commodity prices
Exchange rates
Tax policies
Political stability
Institutions
Other
Decision-Making
Cognitive limitations
Personality traits
Risk attitudes
Objective functions
Institutions
Informational Environment
Salience
Credibility
Legitimacy
Access
Compatibility
Place

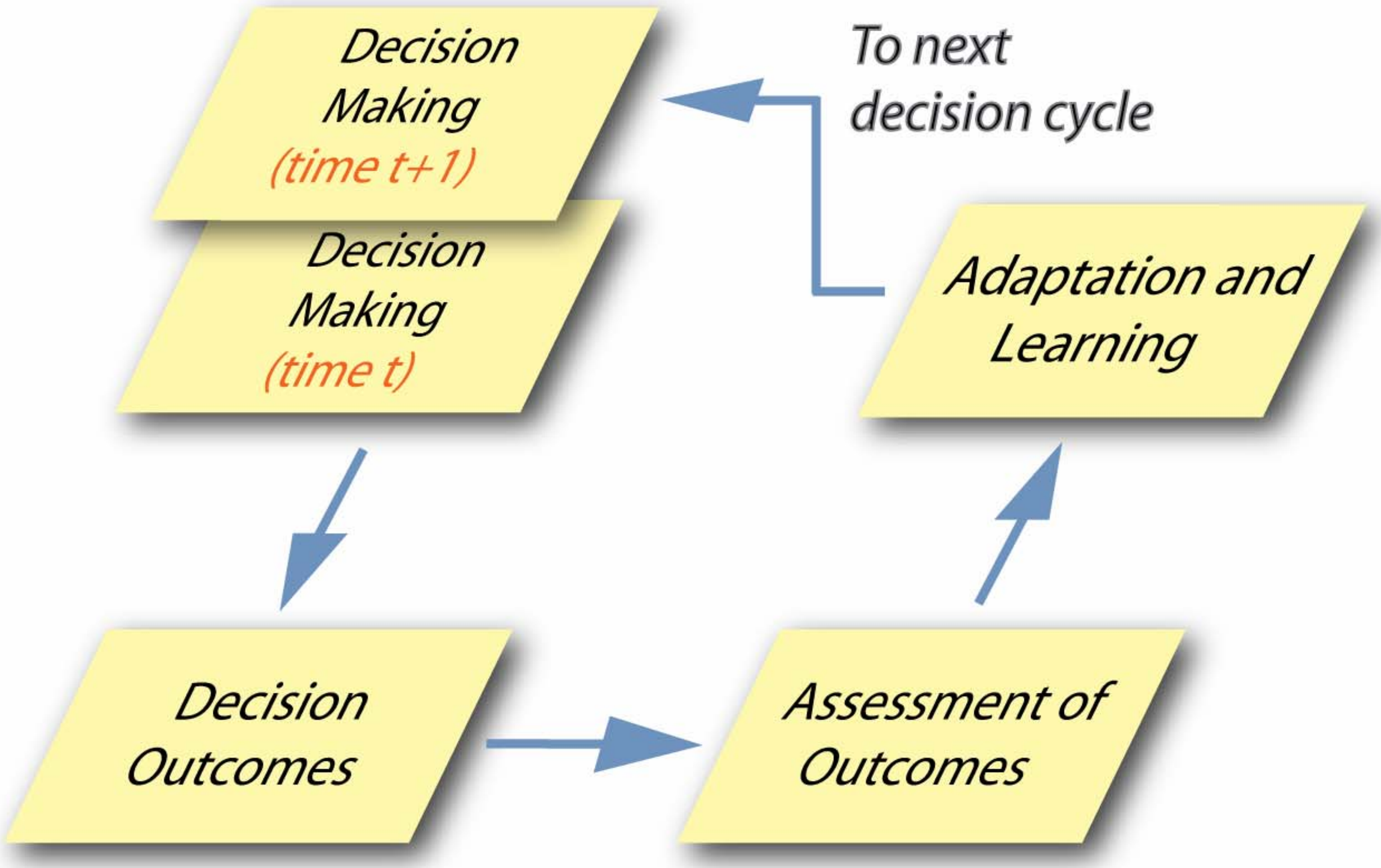
Center for Research on Environmental Decisions

- **Mission**
  - Investigate decision processes underlying adaptation to uncertainty and change, in particular uncertainty and change related to climate change and climate variability
- **Coordinates and integrates 20+ projects conducted by an interdisciplinary set of 24 researchers**
  - Headquartered at Columbia University in New York City
  - Project sites in the US, Brazil, Argentina, Europe, Uganda, Greater Horn of Africa, South Africa, Middle East
- **Combines lab research with field research using decision makers in their natural environment**
  - e.g., farmers, water resource managers, policy makers

Specific Questions Posed

- How to conceptualize/model “adaptation” to an uncertain and possibly non-stationary environment?
  - At the individual level, iterative learning from feedback
    - psychological models of learning and decision making under uncertainty


Decision Making
Adaptation and Learning
External Context
Decision-maker Characteristics
Decision Outcomes
Assessment of Outcomes


Decision Making (time t+1)
To next decision cycle
Decision Making (time t)
Adaptation and Learning
Decision Outcomes
Assessment of Outcomes

Specific Questions Posed

- At the individual level, iterative learning from feedback
  - psychological models of learning and decision making under uncertainty
    - What are the goals, aspirations, and objectives of farmers' decisions ("objective functions")?
    - Are there individual differences in objective functions?
    - Do these differences dictate different adaptive behavior?
    - Do they result in different reactions to technological innovations?
- At a more aggregate level (social groups, communities), other forms of learning and communication come into play
  - social networks

Candidate "objective functions"

- Expected Utility (EU) maximization
  - Allows for individual differences in
    - wealth, risk aversion

- Regret-adjusted expected utility maximization
  - Comparison of obtained outcome to outcomes that other actions would have produced
    - often a social comparison ("what did my neighbor get?")
    - requires information about outcomes of alternative actions
  - Allows for individual differences in
    - risk aversion, wealth
    - susceptibility to regret

- Prospect-theory value maximization
  - Allows for individual differences in
    - reference point
    - risk aversion
    - and loss aversion

EU Maximization

Risky prospect $q = (p_1, w_1; \ldots; p_n, w_n)$

EU maximization $EU(q) = \sum_i p_i u(w_i)$

real-valued utility function *u(w)* given by Pratt (1964) as

$$u(w) \propto \begin{cases} \dfrac{w^{1-r}}{1-r} & if \;\; r \neq 1 \\ \ln w & f \;\; r = 1 \end{cases}$$

where *r* is the coefficient of constant relative risk aversion (CRRA).

Regret-adjusted EU Maximization

Regret-Theoretical Expected Utility (RTEU) (Braun &Muermann, 2004)

modified for discrete states of the world corresponding to different cropping cycles
RTEU for risky prospect *q:*

$$RTEU(q) = \sum_{i=1}^{n} p_i \left\{ u\,(w_i) - k\; g(\Delta u_i) \right\}$$

contains an additively separable regret function, increasing in the difference between the utilities of the realized and unrealized outcomes:

$$\Delta u_i = u(w^{\max}) - u(w_i)$$

where w^{max} is the maximum outcome achievable under state of the world *i*, corresponding to a counterfactual action

parameter *k*, initially introduced by Loomes and Sugden (1982) weights the effect of regret

$$g(\Delta u) = 1 - \beta^{\Delta u}$$

Laciana et al. (2005) proposed the following explicit form for function *g*:

parameter β (0≤β≤1)describes the decision maker's sensitivity to the magnitude of Δu

Prospect-Theory Value Maximization

Prospect theory (Kahneman Tversky 1979) defines the subjective value of prospect *q* as:

$$V(q) = \sum_i \Omega(p_i)\, v(\Delta w_i)$$

where represents the difference between outcome and a reference point , a free parameter, that separates perceived gains from perceived losses.

the value of this difference is defined by: $v(\Delta w) = h(\Delta w) \left| \Delta w \right|^{\alpha}$

the step function $h(\Delta w) = \begin{cases} 1 & if \quad \Delta w \geq 0 \\ -\lambda & if \quad \Delta w < 0 \end{cases}$

parameter λ reflects degree of loss aversion

parameter α (0 ≤ α ≤ 1) reflects degree of risk aversion (concavity) in the gain region and risk seeking (convexity) in the loss region

64 different Cropping Enterprises

Enterprise ID	Enterprise management						Economic returns for owners ($ ha^{-1})		Economic returns for tenants ($ ha^{-1})	
	Genotype	Planting date	Fertilizer added (kg N ha^{-1})	Row spacing (m)	Available soil water at planting (%)	Available soil N at planting (kg N ha^{-1})	Mean	S.D.	Mean	S.D.
Maize										
Ma21	DK752	Sep 15	100	0.70	100	70	113.2	106.8	6.8	157.7
Ma23		Oct 15	75				116.5	84.1	5.8	128.6
Ma24		Oct 15	100				116.3	90.1	9.8	135.8
Full-cycle soybean										
Soy14	DM4800	Oct 25	0	0.52	100	50	188.1	60.7	69.4	89.0
Wheat-Soybean										
SW19	Scorpion[a] & DM4800[b]	Jun 10	40	0.19[a] 0.52[b]	90	60	162.1	83.4	62.3	121.7
SW20		Jun 10	60				167.3	84.7	72.3	122.5
SW21		Jun 10	80				168.8	85.0	77.6	122.0

- *Simulation of yields: agronomic models*
  - yields for each enterprise simulated using the crop models in Decision Support System for Agrotechnology Transfer package (Jones et al. 1998)
    - Generic-CERES (Ritchie et al. 1998) for maize and wheat
    - CROPGRO (Boote et al. 1998) for soybean
  - for each enterprise, 70 simulated yields were obtained, one for each cropping cycle in the 1931-2001 historical record

- *Simulation of economic outcomes*
  - for a hypothetical 600-hectare farm, median size of AACREA farms in the Pergamino region

  - net economic returns per hectare for year and enterprise as the difference between income and costs: $\pi_{ij} = Y_{ij} P_j - (F_j + V_{ij} + S_i + T_i)$
    - gross income per hectare is the product of simulated yield for a year and enterprise and output price for each crop
    - four types of cost: (i) fixed costs for enterprise are independent of yield; (ii) variable costs are a function of yield on year *i* for enterprise *j*; (iii) structural costs that only apply to owners; and (iv) income tax

Optimization Procedure

- choice variable is vector $\vec{x} = (x_1, ..., x_{64})$
  - indicates the number of hectares on a 600-hectare hypothetical farm allocated to each of the 64 alternative cropping enterprises
  - optimized land allocations to the 64 enterprises for the of each of three objective functions
  - optimization performed using algorithm MINO5 in the GAMS software package (Gill et al., 2000)

Constraints

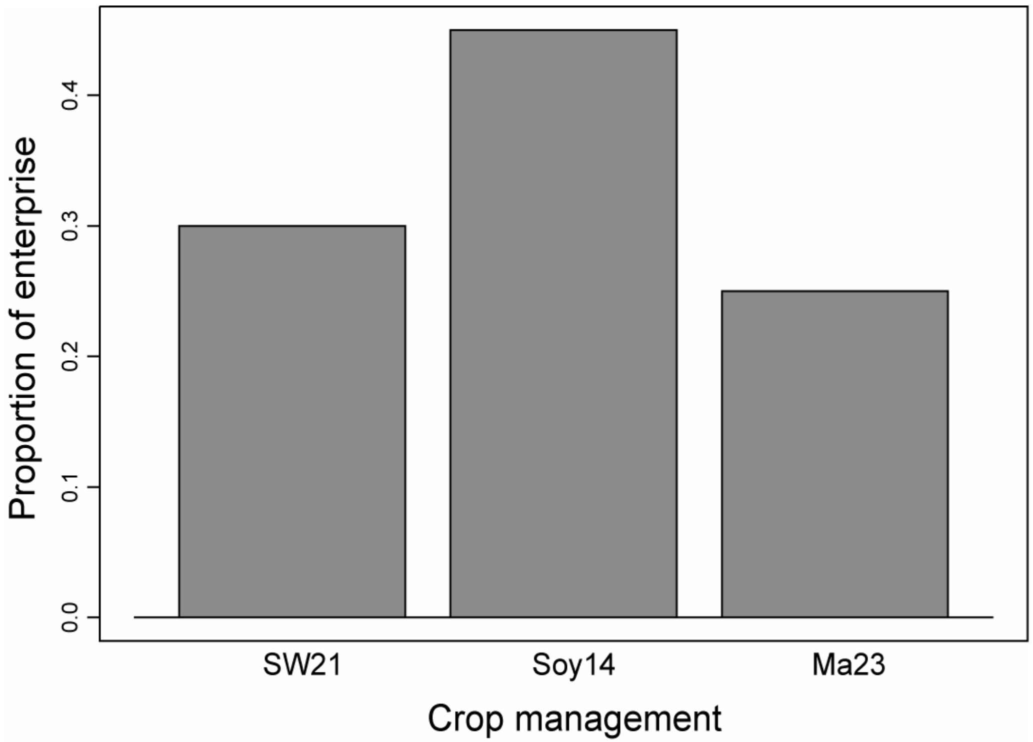
- For Owners
  - AACREA advocates allocating 1/3 of the land to each of three main cropping systems (maize, soybean, and a wheat-soybean double crop) and to rotate those from year to year
  - to allow owners some flexibility in land allocation, we introduced two constraints
    - land assigned to a crop could be no less than 25%, and no more than 45% of the farm area.

- For Tenants (1 yr land leases are typical)
  - no constraints

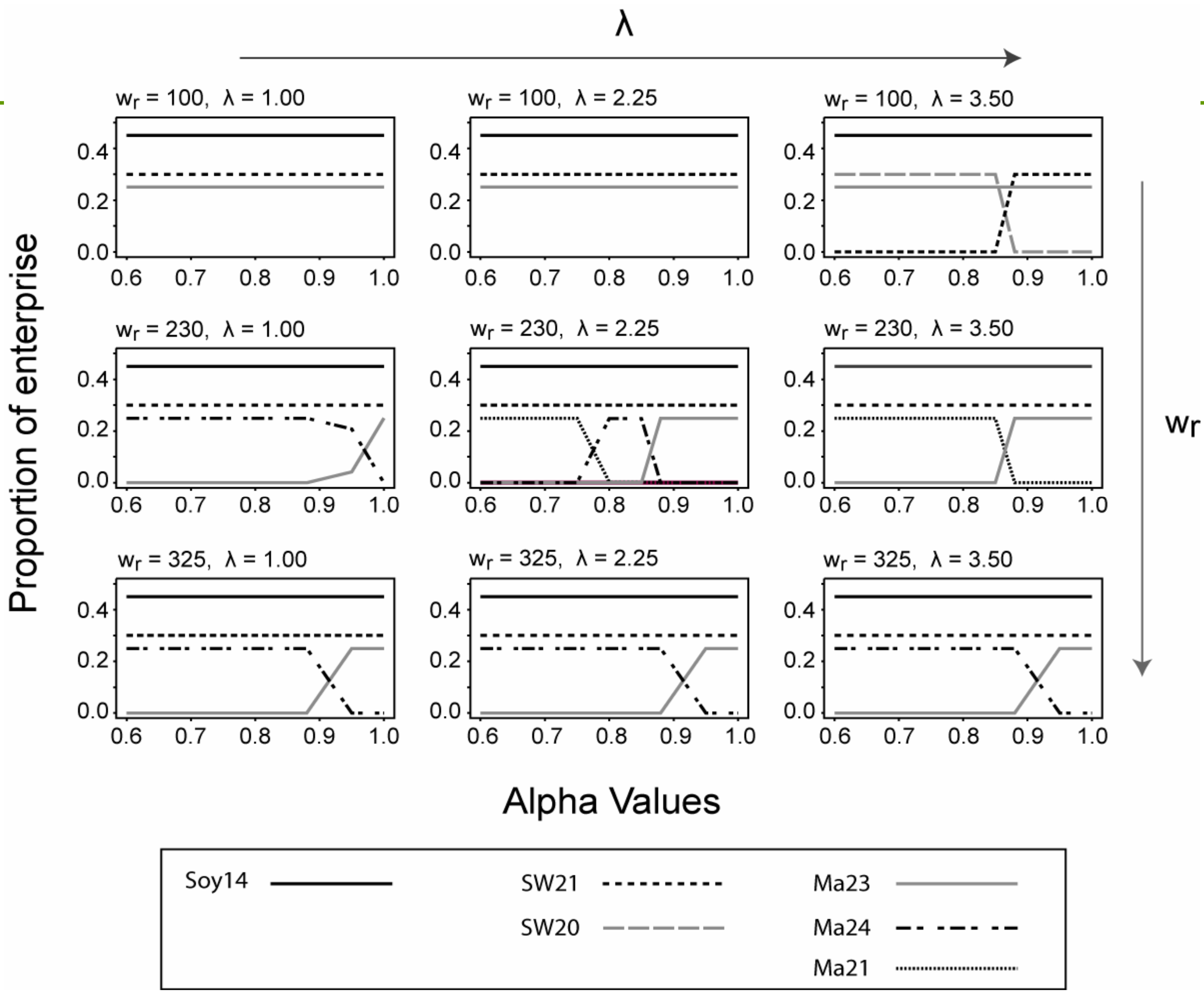
Results

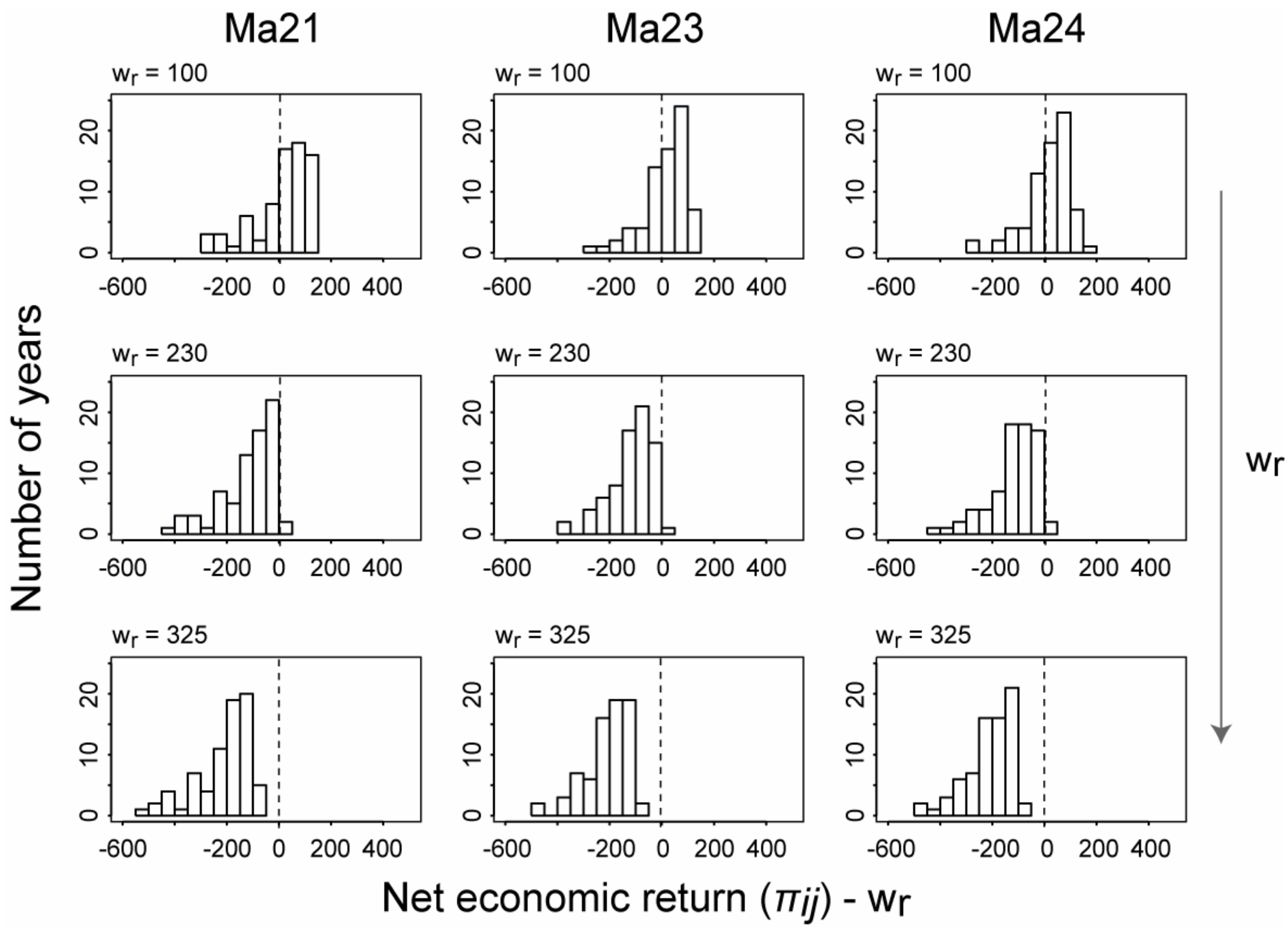
- Constraints matter!
  - Major differences in optimal crop enterprise allocation for owners and tenants
- No effect of anticipated regret minimization
  - for both owners and tenants, regret does not change optimal behavior under EU maximization under typical assumptions of degree of risk aversion
- Major effects of reference point and degree of loss aversion
  - Interaction between ref point and alpha (risk aversion for gains, but risk seeking for losses)

Land Allocation/Owners/EU and RTEU



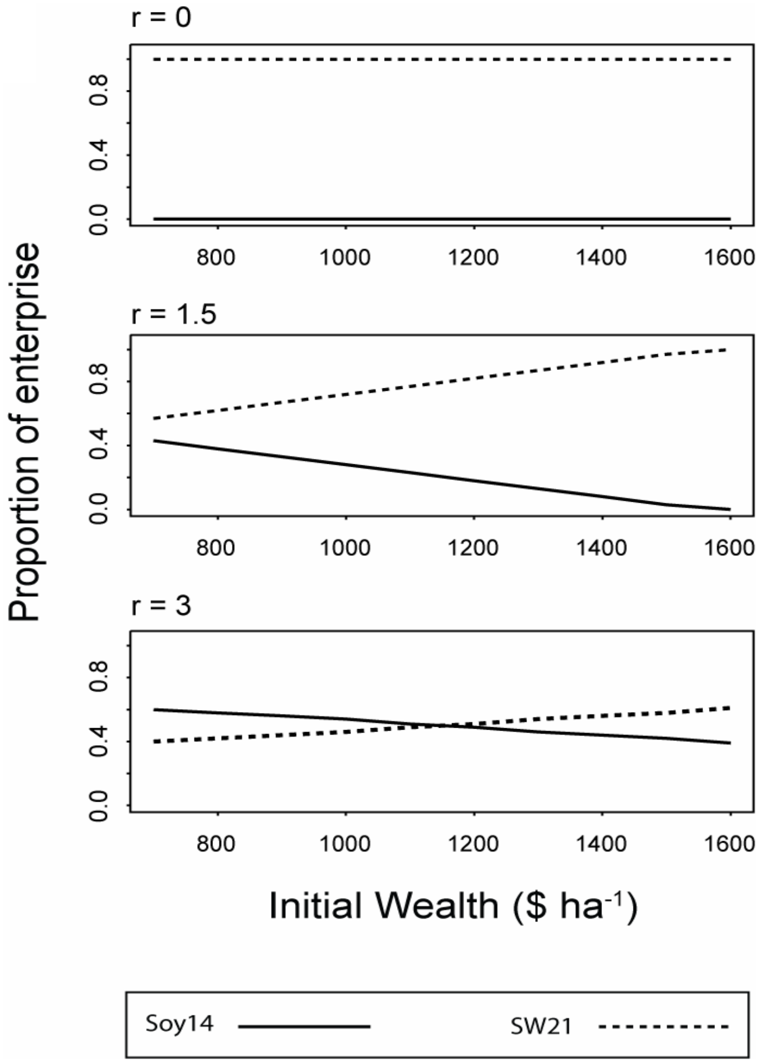
Land Allocation/Owners/PT



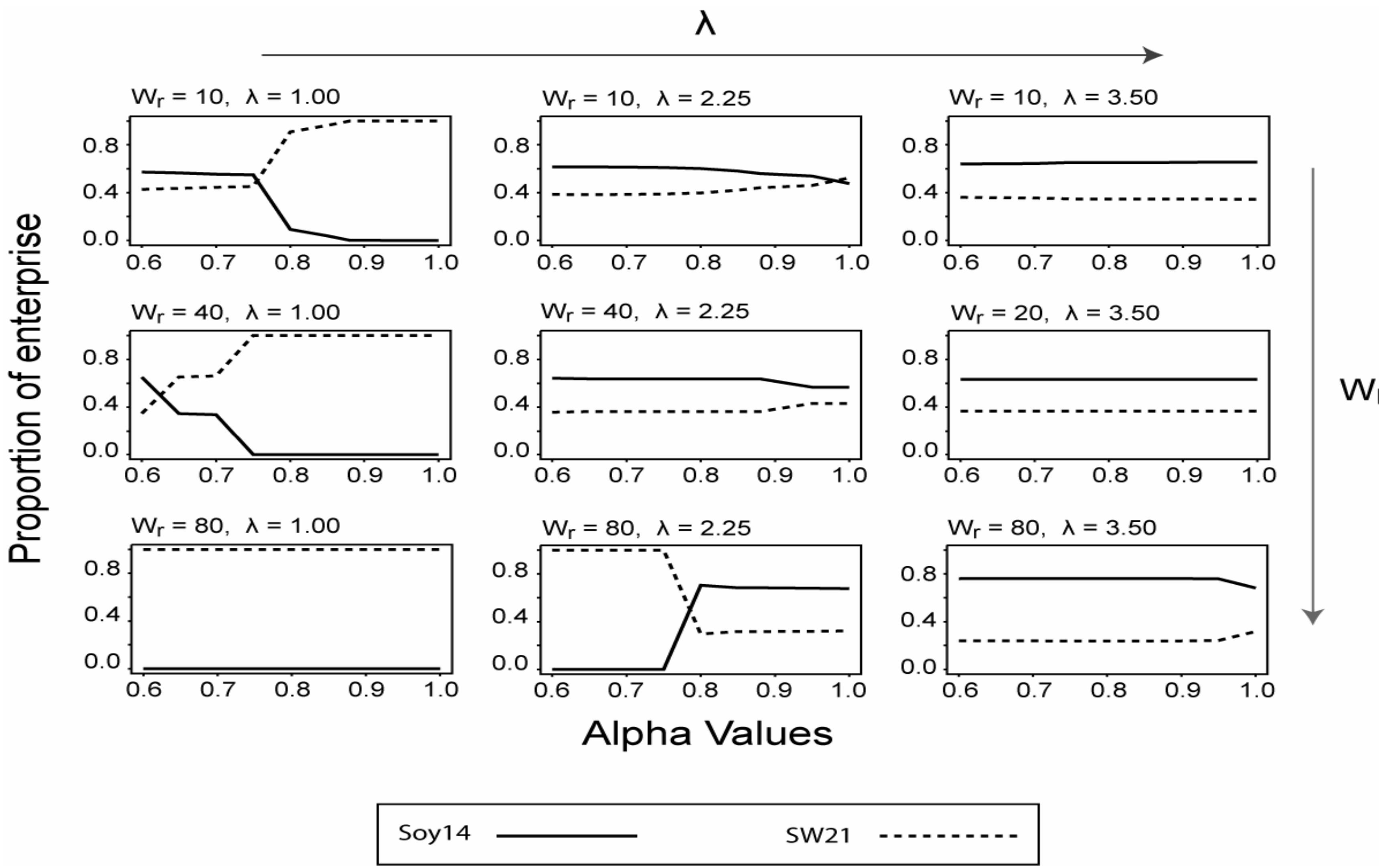


Ma21
Ma23
Ma24
wr = 100
wr = 230
wr = 325
wr
Number of years
Net economic return (πij) - wr

Land Allocation/Tenant/EU and RTEU



Land Allocation/Tenant/PT



Results and beyond

- Different predicted patterns of land allocation for 3 objective functions (OF) and their parameter space
  - use data on actual land allocation over previous years (from AACREA) to find best-fitting OF and parameter values
  - estimate OF and parameter values from realistic decision experiment and from set of money lottery choices
    - How many different “types” of farmers are there?
    - Does identified OF and parameter estimates agree for analysis of farm decisions and analysis of gambling decisions?

Aggregation

- Use output of OF segmentation of farmers as input into agent-based models
  - For each agent, make assumptions about
    - Evaluation of achieved outcomes (reference levels, decreasing marginal utility, loss aversion)
    - Mechanisms of learning
      - own experience
      - experience of others
      - which “others” (how many, how geographically close)?
      - etc.
- Can run model to see effect of
  - relative frequency of different types of agents
  - introductions of different policies or institutions
  - introduction of new technologies

Effect of Introduction of New Technologies

- Value of information (VOI) of seasonal climate forecasts
- Drought-resistant seed corn

- For VOI of seasonal climate forecasts
  - Examine effect of different objective functions (and their parameter space)
    - Go beyond EU maximization
    - Regret a much stronger possibility here

  - Effect of different skill levels of forecast
    - Go beyond assumption of perfect forecasts

  - Effects may be on
    - VOI itself
      - Difference between farm profitability with and without climate forecast
    - best practice recommendations
      - Combination of production decisions that achieve objective function optimization

Preliminary Results on VOI

- Objective functions and parameter values do not change value of climate information, but instead change recommended best practice
  - with skill levels like those in the Argentine Pampas, forecasts allow for in increase in productivity of 5-7%
  - Forecasts with low(er) skill levels can result in negative VOI

Heterogeneity in decision makers

- Traditionally on
  - Demographic variables (e.g., age, education)
  - Economic variables (e.g., income, farm size)
- Psychologically on
  - Goals/Objectives
  - Personality traits (e.g., degree of risk aversion and loss aversion)