Measuring the Value of Changes in Ecosystem Services from Agriculture: Economic Contributions to Multidisciplinary Research

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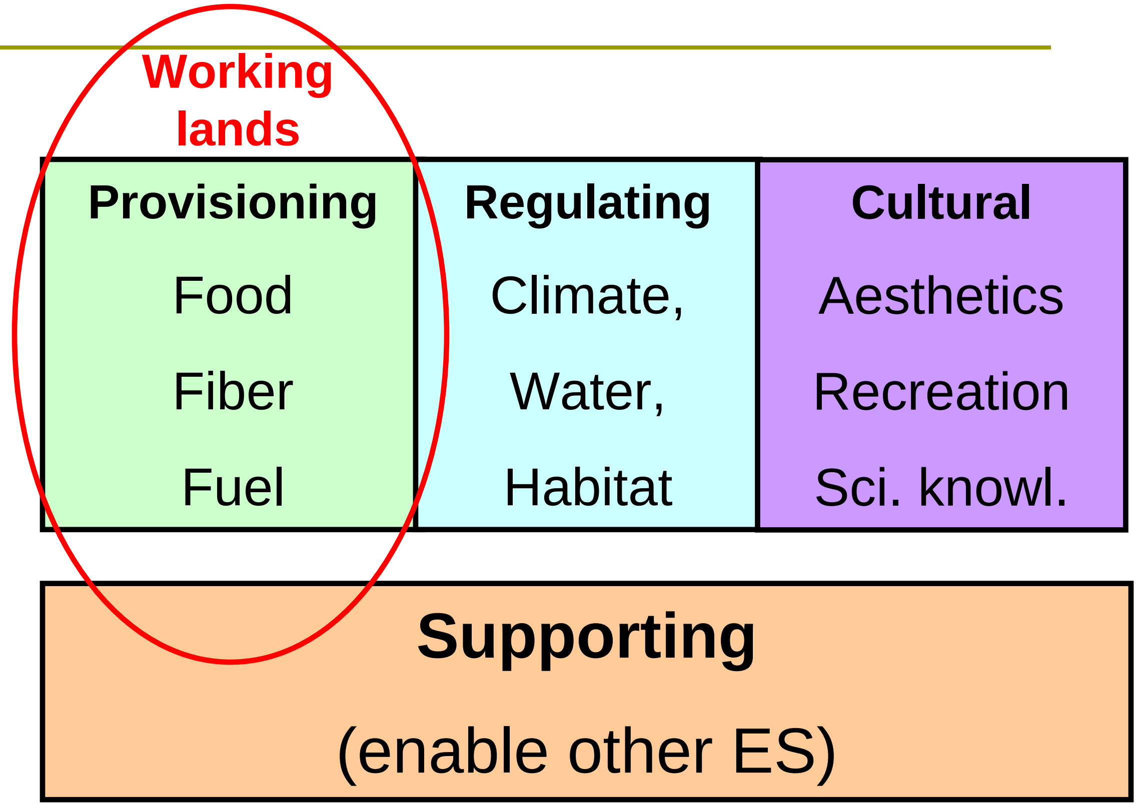
Where we're headed

- Ecosystem services that farming can offer.
- What biologist collaborators seek and what we think we offer.
- Measuring value: 3 stories with impacts.
- Multidisciplinary research team as a jazz ensemble.

Types of Ecosystem Services

- **“Ecosystem services** are the benefits that people obtain from ecosystems.”



Millennium Ecosystem Assessment, 2005

Agriculture is uniquely suited to provide more diverse ES

- World's oldest and largest managed ecosystem
- Strong research base
- History of government policy intervention
- Evidence of strong supply response ability

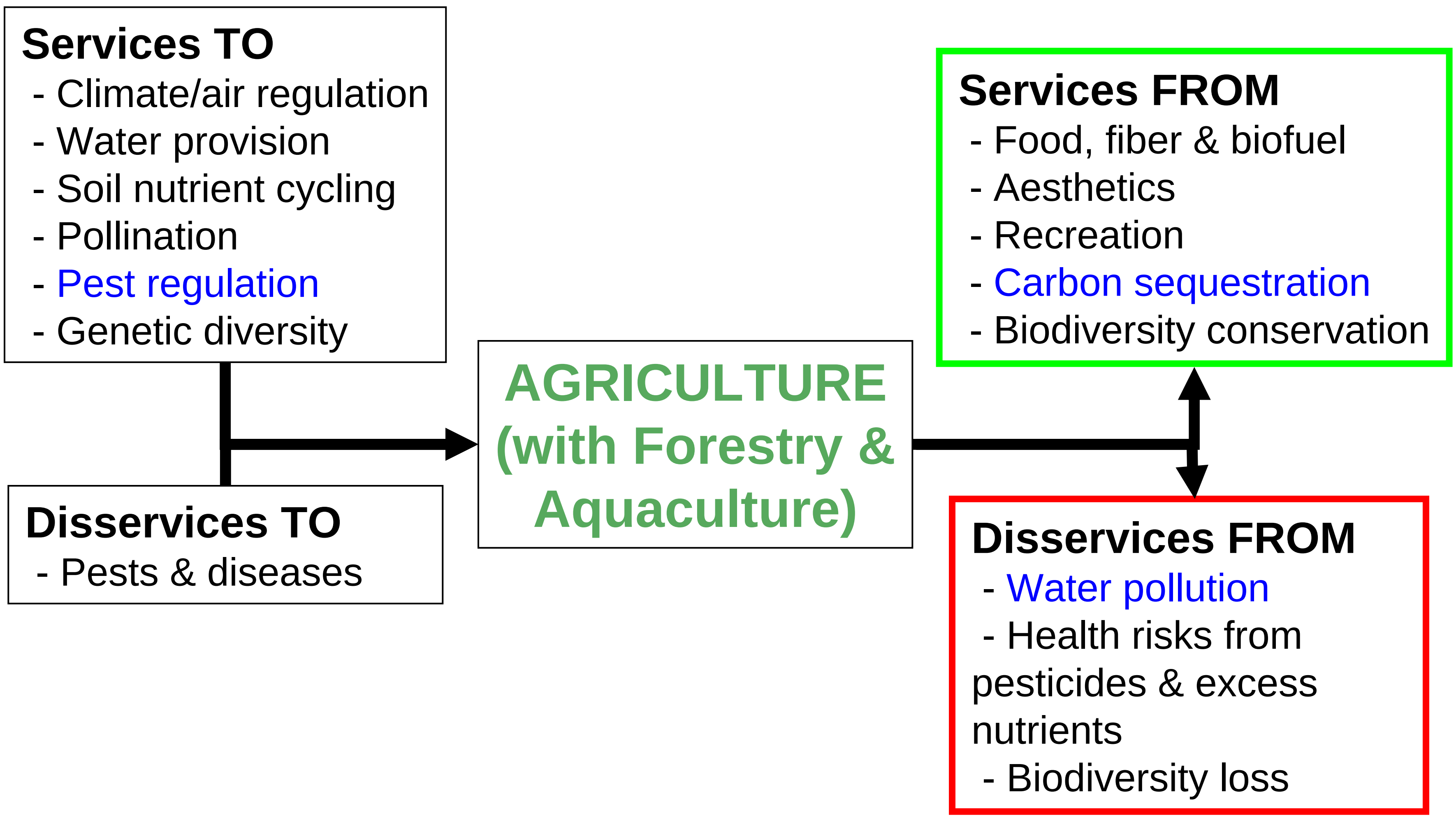
Public perception of agriculture: From Disservices to Services

- Harmful ecosystem disservices
  - Land conversion to agriculture (Marsh, 1864; Leopold 1949)
  - Soil exhaustion & erosion (1900-60)
  - Wildlife risks from pesticides (Carson, 1962)
  - Water quality (1970-2000)

- Beneficial ES (Daily 1997; MEA 2005) could be managed (Antle & Capalbo 2002; others)

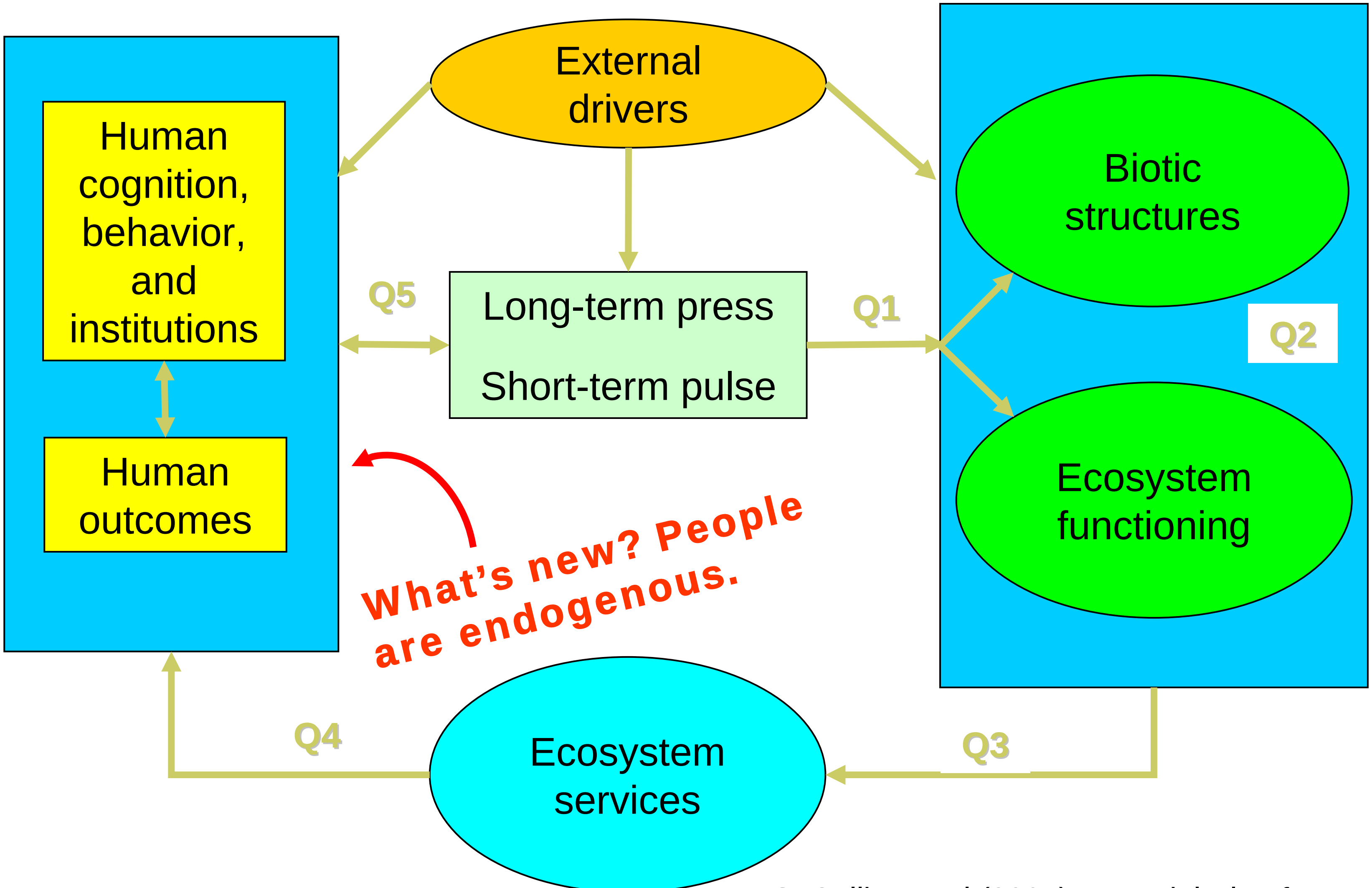
Swinton et al., *AJAE, 2006*

Agricultural ecosystems both receive and generate ecosystem services



Swinton et al., *Ecol Econ, 2007*

"Integrated Science for Society and Environment" - Framework for NSF social-ecological research



S. Collins et al (2007), Decadal Plan for LTER.

KBS-LTER: Long-term Ecological Research in agro-ecosystems since 1988

Key Questions

How do ecological processes ‘play out’ at different scales?

What is the role of ‘biodiversity’ in an agricultural ecosystem?

What ecosystem services are provided by (and to) agricultural systems?

What is value of these ecosystem services? How do managers decide to provide?

KBS LTER
Kellogg Biological Station
Long-term Ecological Research

What economists are perceived to offer

- Accounting services with public credibility
  - Big numbers can show that biological research deserves more funding.
  - Popular example: Costanza et al's value of the world's ecosystem services (*Nature*, 1997).
- Someone to "do the human side"
  - Many biophysical grants require incorporating people

What economists think we offer

- Problem framing
- Objective measures of economic value
  - Reflecting supply & demand
  - Dynamic feedbacks (esp. price)
- Policy design & analysis

- Avoiding buyer's remorse
  - They may seek a PR booster to justify major fixed investment in lab facilities and staff.
  - We want to be sober judges with creative insights.
  - Finding ways to do both.

Starting point: What is value?

- Intrinsic value:
  - True worth in philosophical sense.
- Economic value:
  - Market price reflects scarcity & production cost relative to demand).
    - Diamond-water paradox (G. Heal)
  - News to non-economists
    - Price is a function, not a constant
    - Economic surplus differs from gross revenue
    - An input's contribution to value depends on rest of production function (attribution problem)

Steps toward valuation of ES from agriculture

1. What is the ecosystem service?
   1. What economic role?
      1. System input vs output? Property rights?

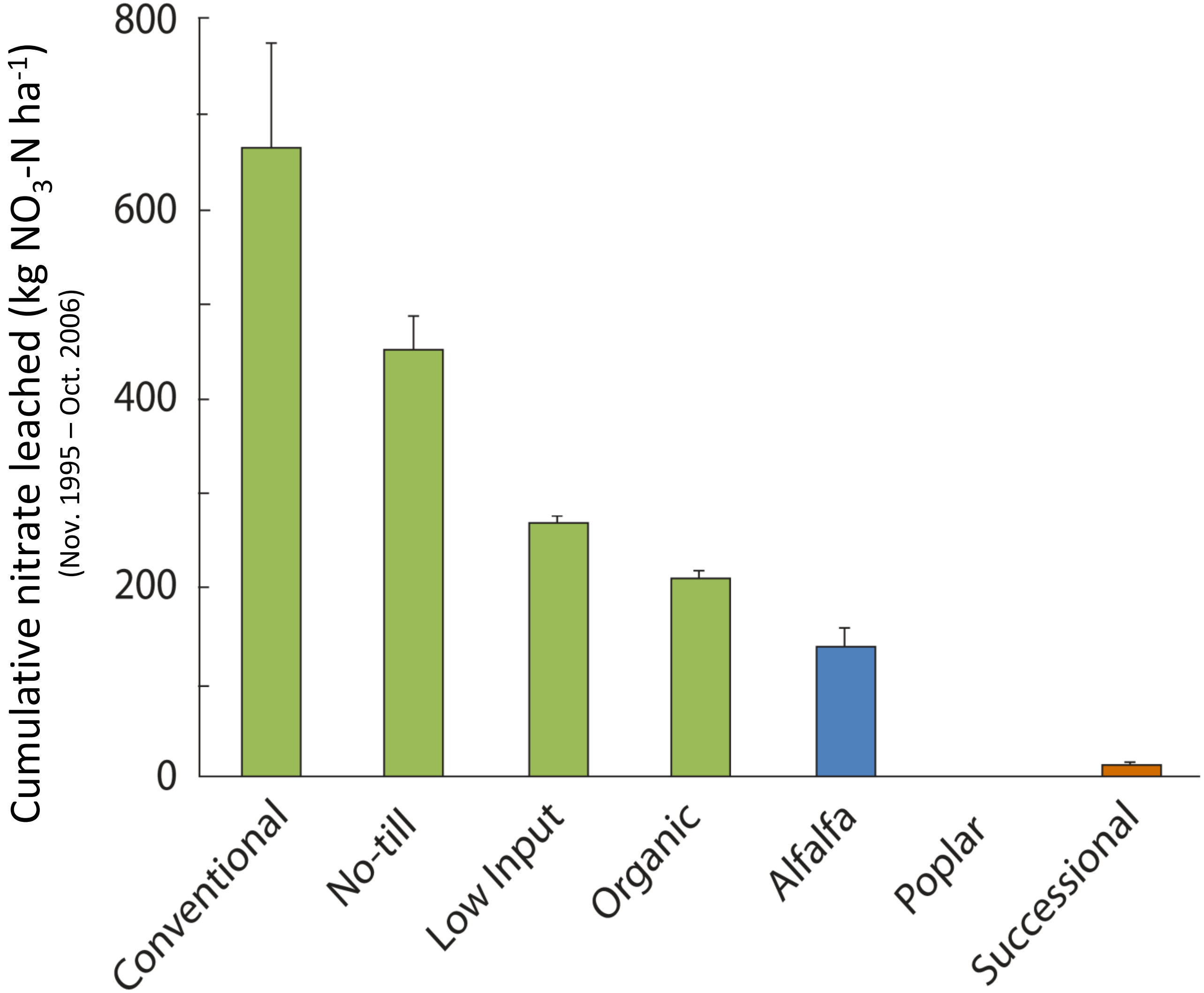
2. Is there experimental data?
   1. Budgeting experimental results can make for easy results, easily communicated
   2. Bioeconomic modeling can elucidate the system and human-natural “coupling”

3. Measuring people as managers & consumers
   1. Surveys & focus groups
   2. Captures human heterogeneity – not just land

Experiments at plot scale: KBS-LTER

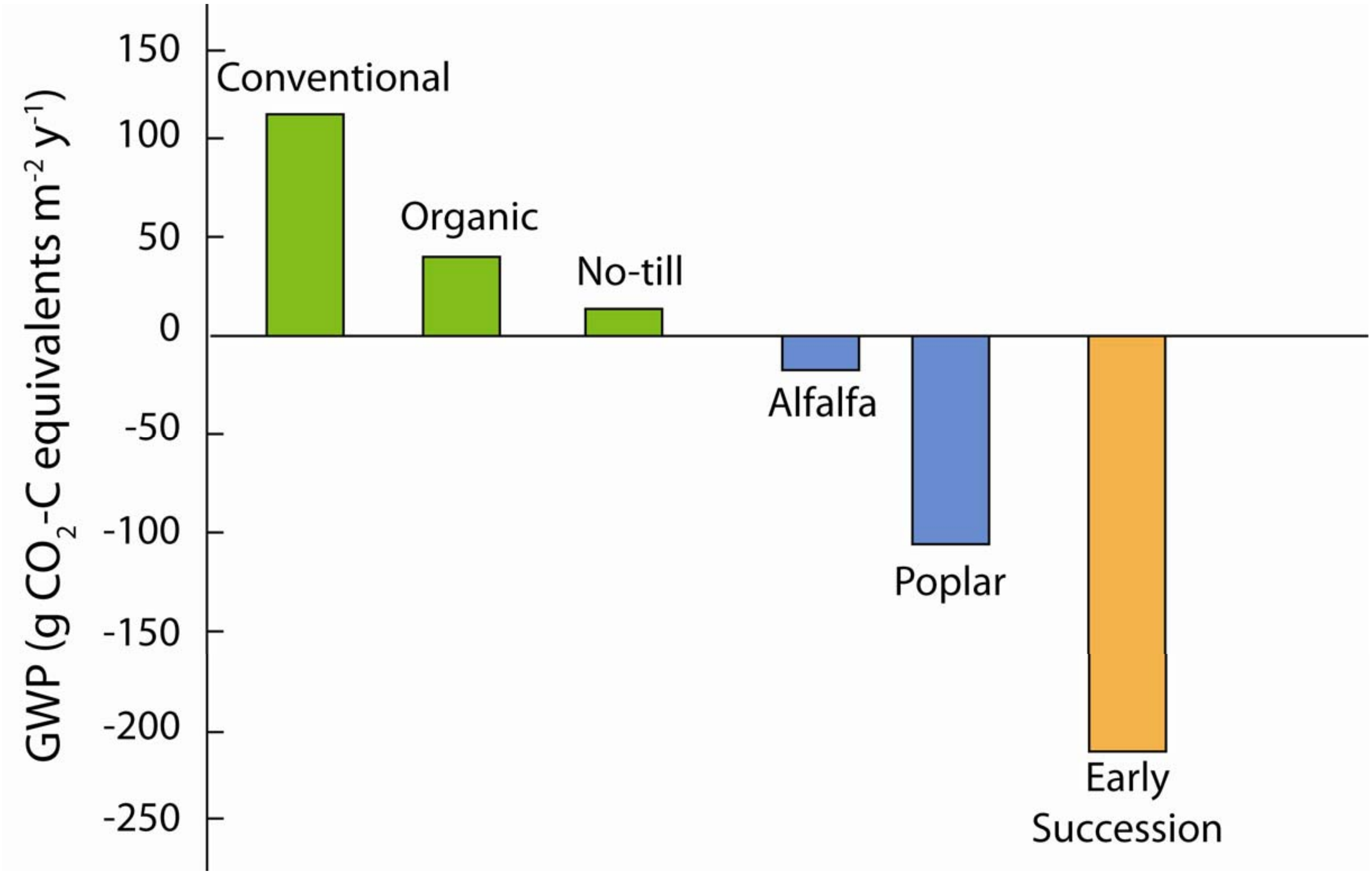
Land Management Type	**Management intensity**
Annual Grain Crops (Corn - Soybean - Wheat)	**HIGH**
•Conventional	↓
•No-till	
•Low-input with cover crops	
•Organic with cover crops	
Perennial Biomass Crops	
•Alfalfa	
•Poplar trees	
•Early successional old fields	**LOW**

Water quality: Nitrate leaching declines with management intensity



Syswerda 2009

Climate: Global warming potential declines with management intensity



Robertson et al., 2000, Science

What would it take to get farmers to provide more ecosystem services beyond food/fiber/fuel?

- “Representative farmer”
  - Can use experimental data
  - Adjust budgets for non-experimental conditions
  - Profit-ES trade-off analysis

- Bioeconomic optimization modeling
  - Captures potential value for “representative”

- Heterogeneous preferences & resources
  - Supply curve using stated preferences

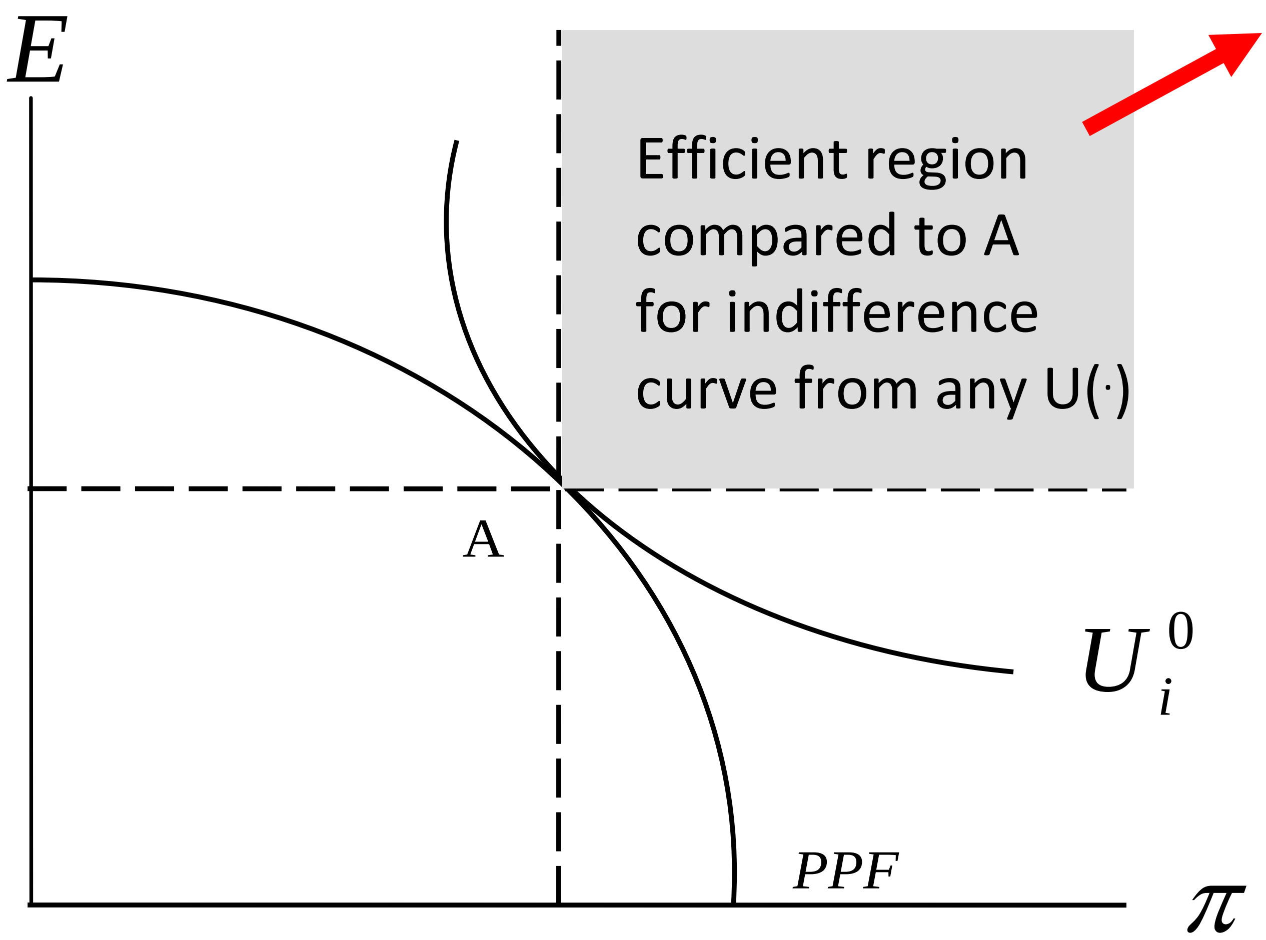
Simple approaches can frame usefully

- Enterprise budget based.

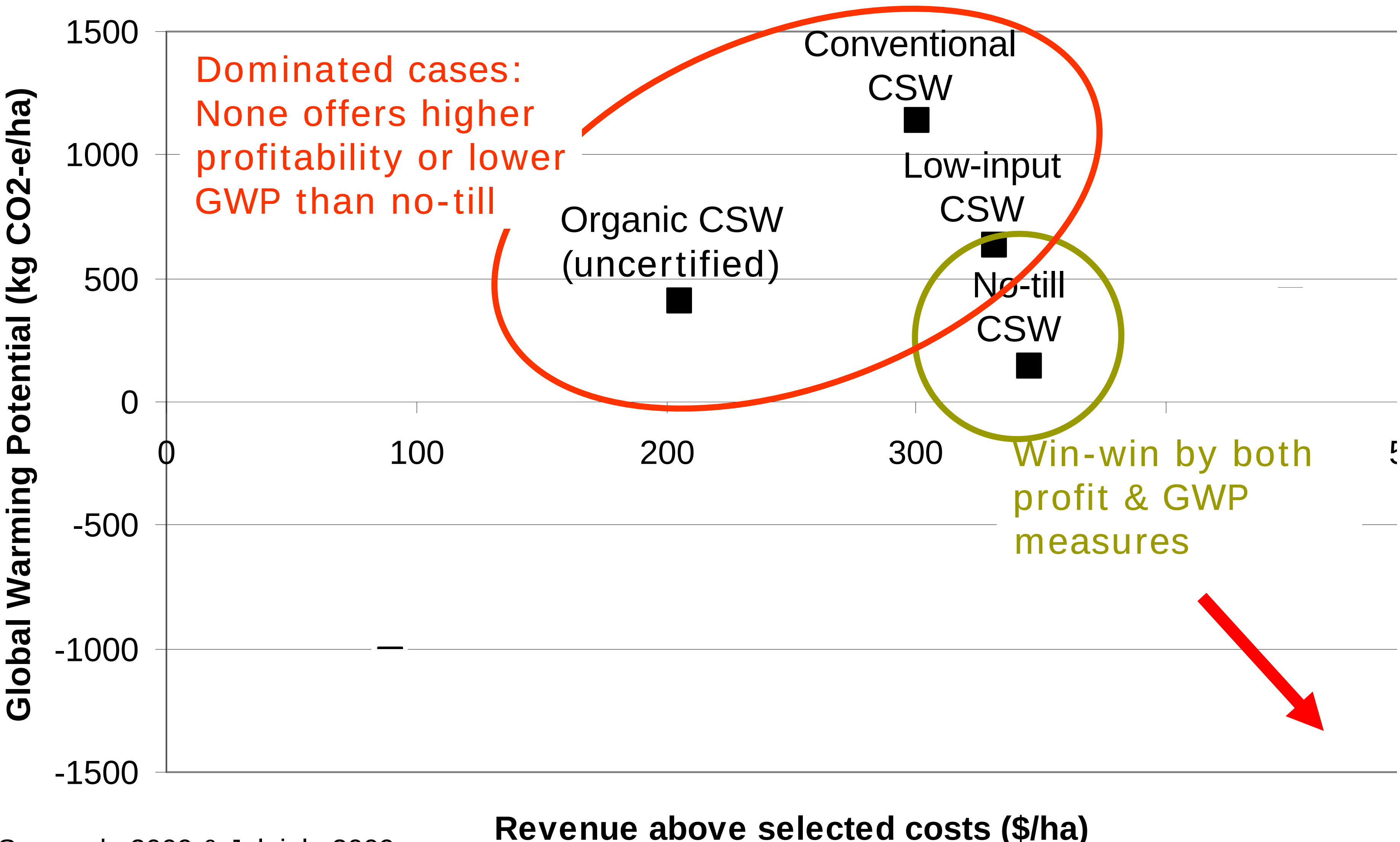
- Requires (and assumes) no:
  - Risk
  - Heterogeneity
  - Dynamics

- Ingredients
  - Experimental data
  - Secondary data on prices & custom rate costs

Efficiency & trade-off analysis in 2 attribute space (environment & profit)



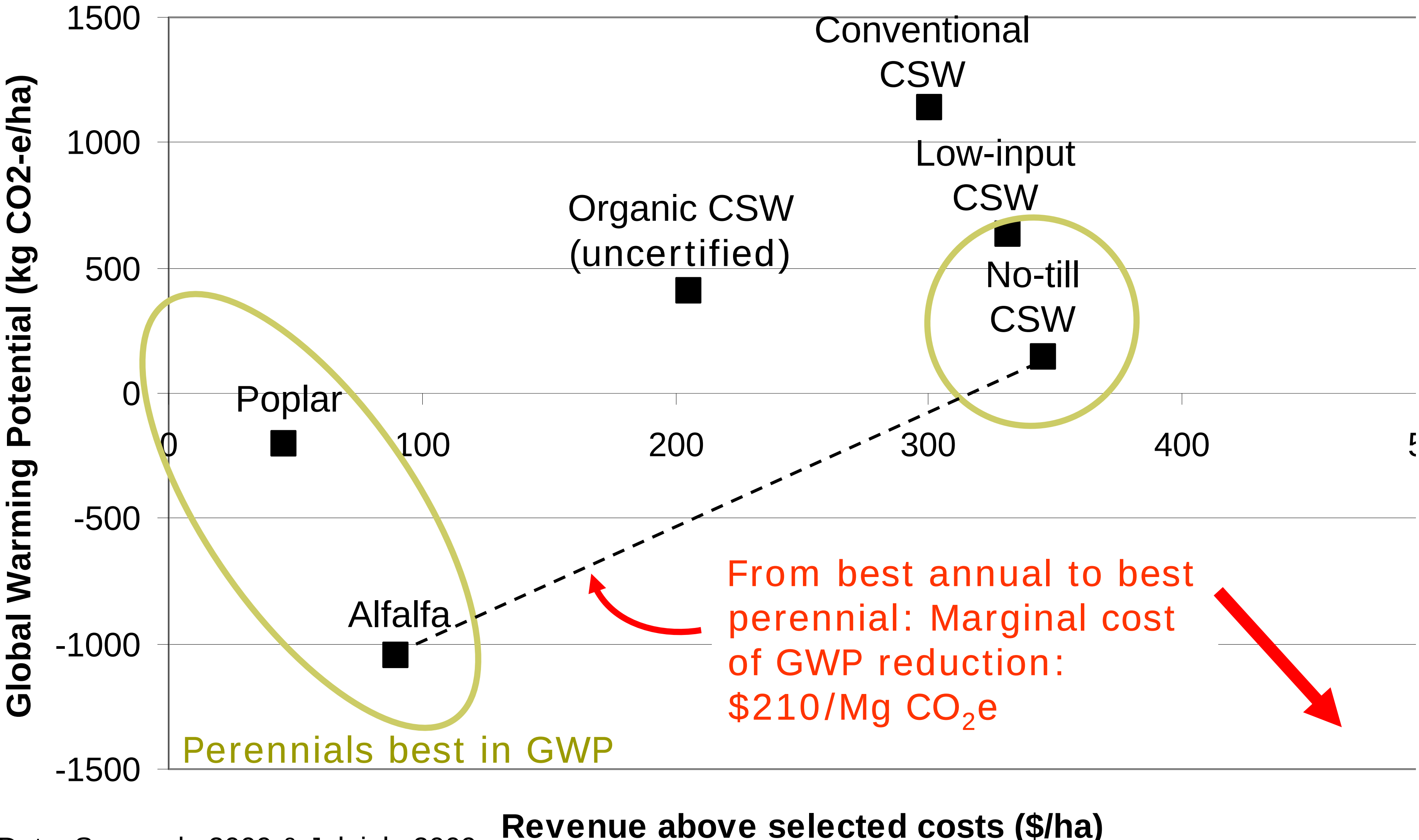
Dominance of no-till CSW among annual treatments in Profitability - Global Warming Potential space



Syswerda 2009 & Jolejole 2009.

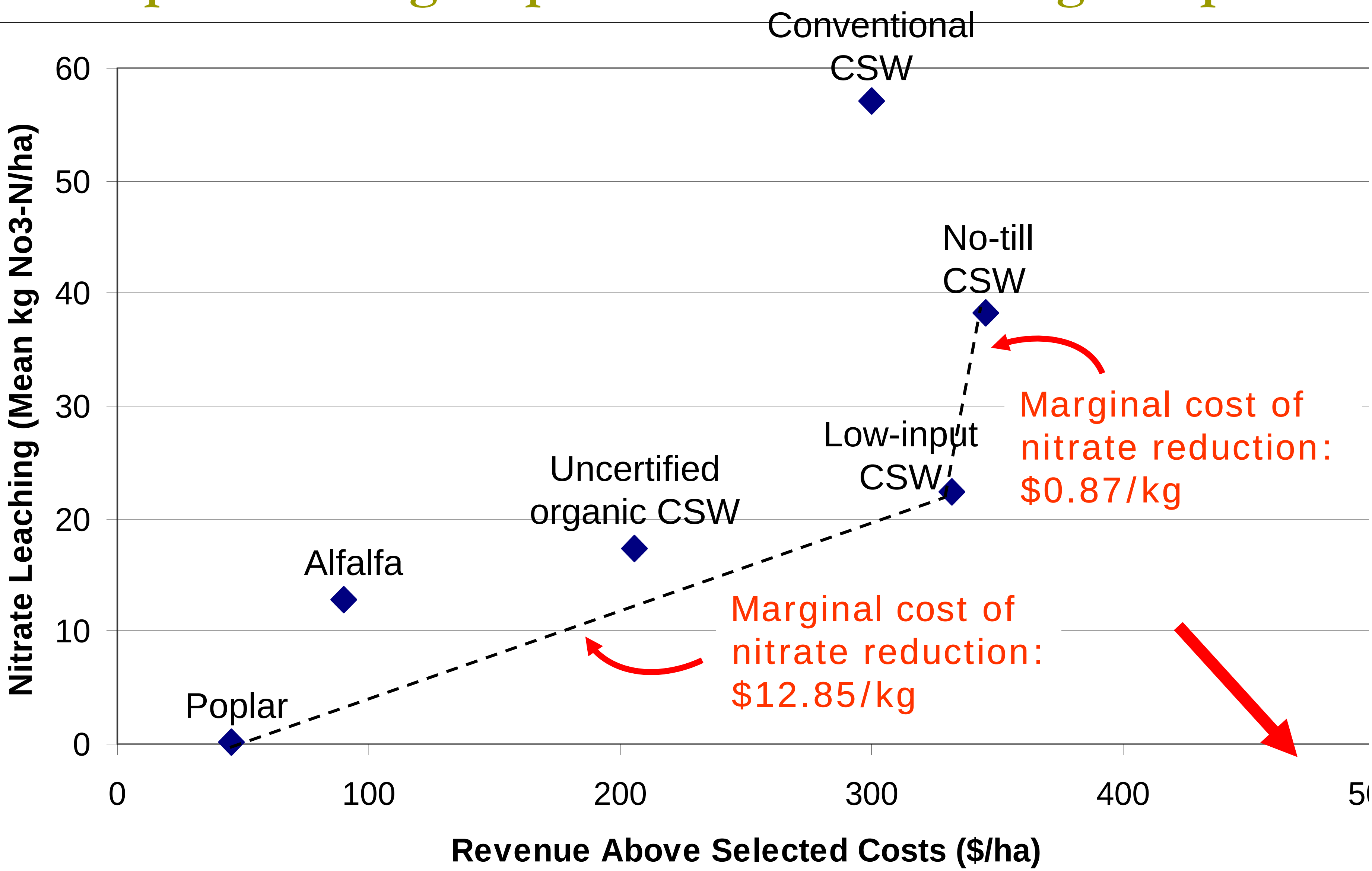
Cost of providing reduced Global Warming Potential

→ Implied cost of efficient GWP reduction @ KBS



Data: Syswerda 2009 & Jolejole 2009.

Now: Profitability – Nitrate Leaching space
Cheaper to change input levels than to change crops.

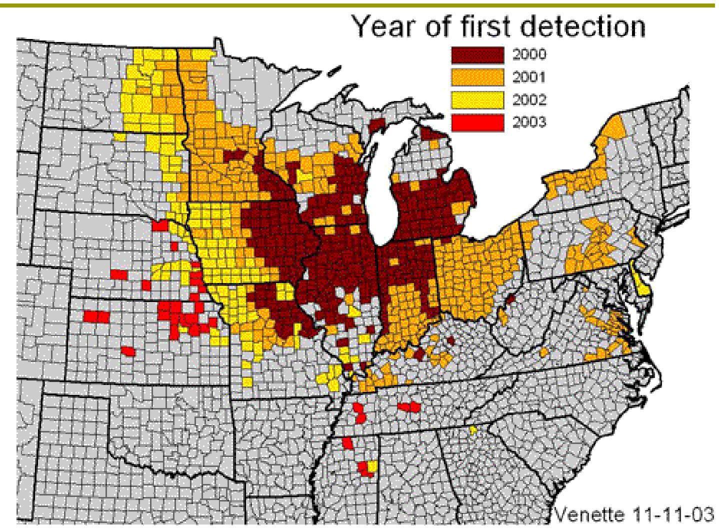


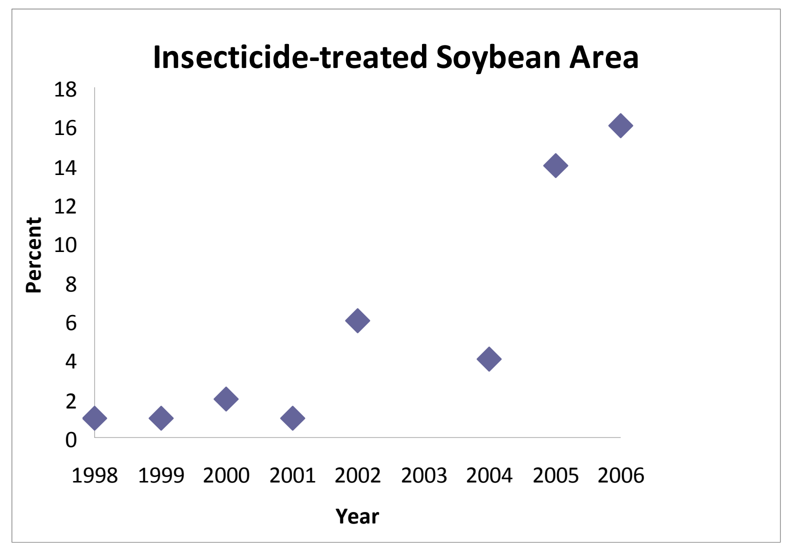
Case 2: Indirect market methods for predation of agricultural pest: Soy aphid

- Soybean aphid (*Aphis glycines*) detected in 2000 near Chicago

- Yield of infested soybeans reduced by 10 bu/ac (esp 2003)

- Insecticide use up from near 0 to >16% soy area.





Players in the drama

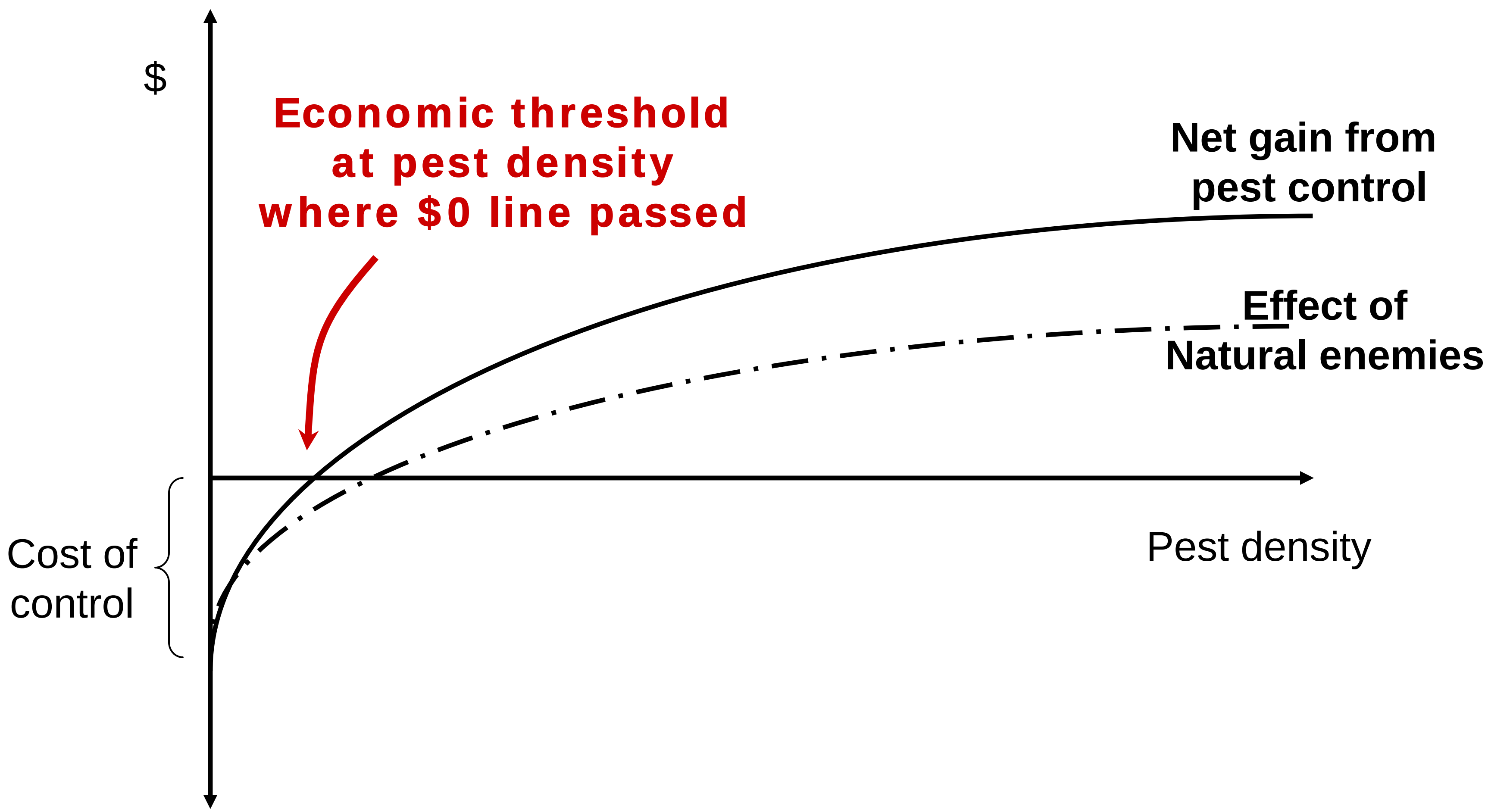
Soybean

Multicolored Asian ladybeetle

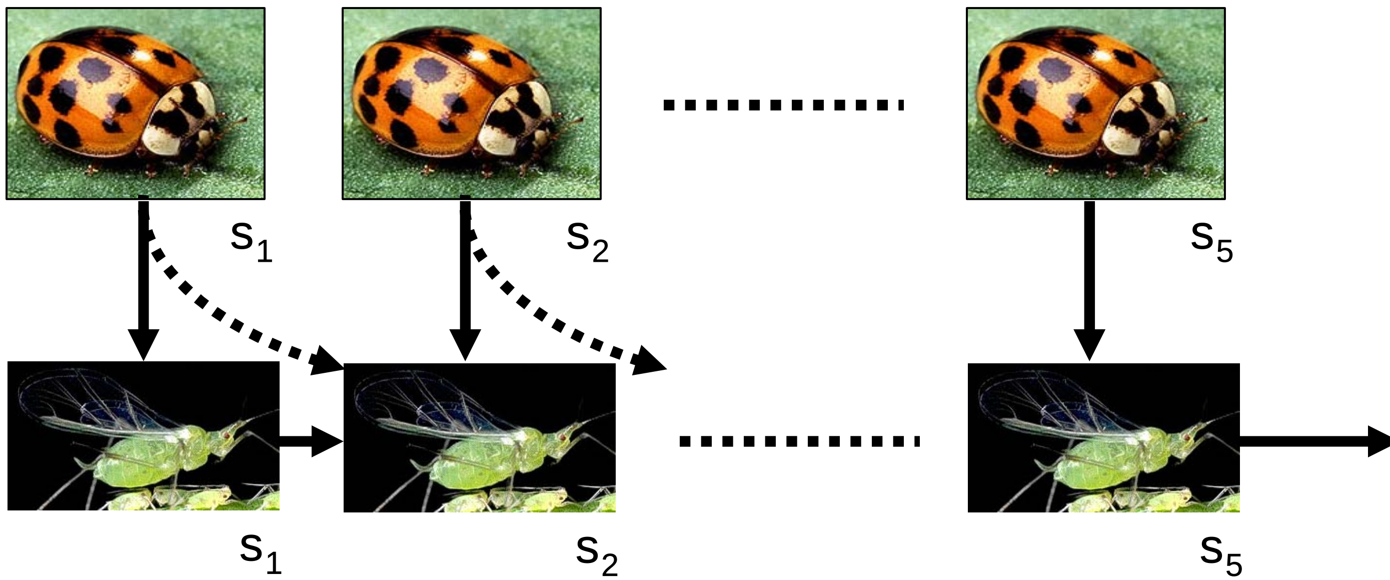
Soybean aphid

Buckthorn bush

Natural enemies reduce yield loss and pest control costs



Econ threshold modeled during soy reproductive growth stages (R1 to R5)



- Soy aphid damages soybean yield.
- Aphid and nat. enemy populations co-evolve. Insecticides kill both.

Bioeconomic dynamic optimization: Good research partnership, PhD effort

- Choose spray/not to Max Gross Margin over pest control cost

Subject to:

- Soy aphid (SBA) population dynamics

$$I_{t+1} = I_t * (Surv\_I_t) + Growth_t - Predation_t$$

- Natural enemy (NE) population dynamics (Lotka-Volterra form):

$$NE_{t+1} = (Surv\_NE_t) * [1 + d + b * (Surv\_I_t)]$$

  - *Surv* = survival proportion after insecticide
  - *d* = net decline rate in the absence of prey
  - *b* = reproduction rate of *NE* per prey eaten

- Yield response to SBA damage

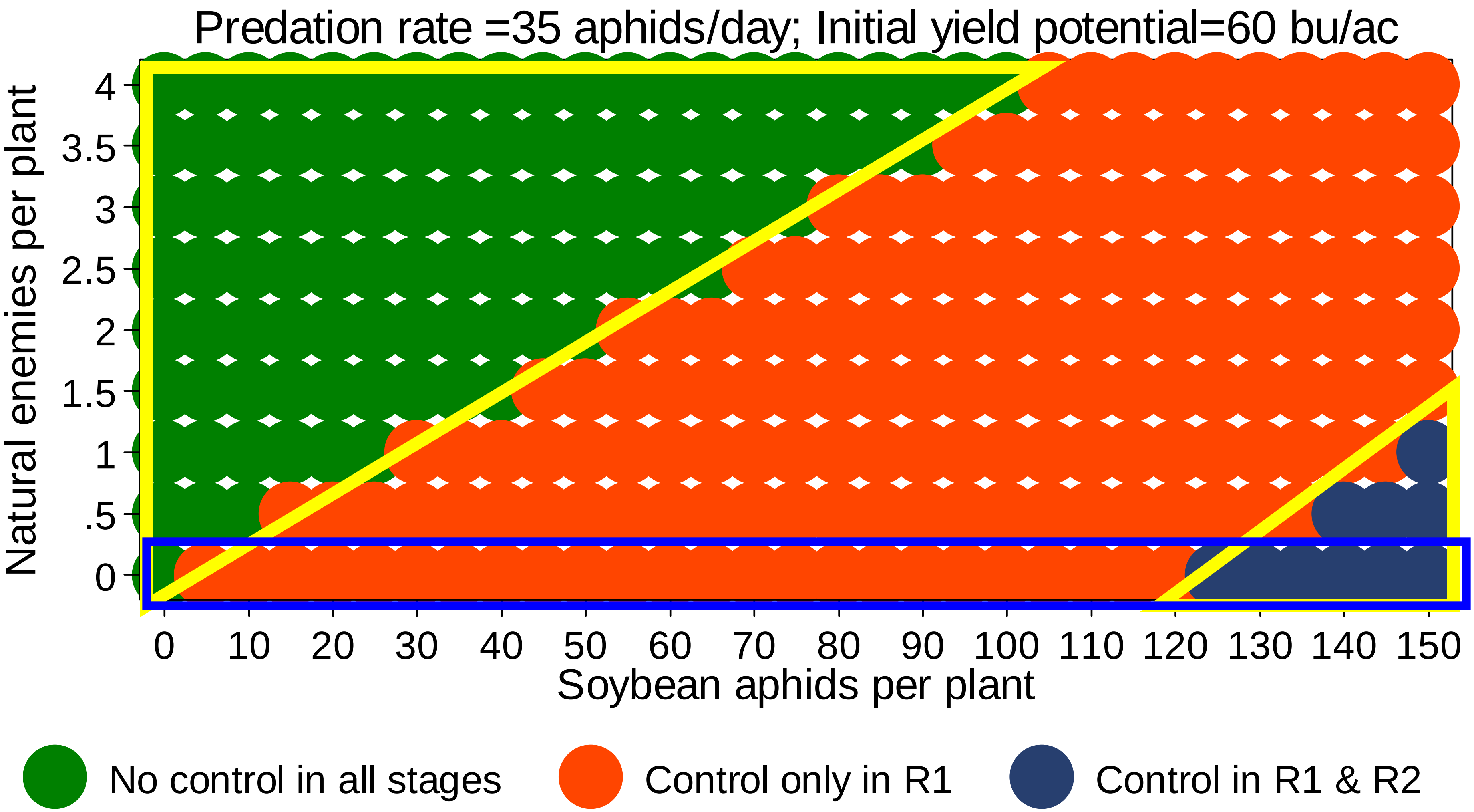
Hyperbolic yield decline = f(cumulative SBA days)

Zhang and Swinton, *Ecol Model* 2009.

Result: Natural enemies raise the threshold for pest control (less need to spray)

- Guide to graph on next slide: Each dot is an optimal control path based on initial NE & SBA population densities

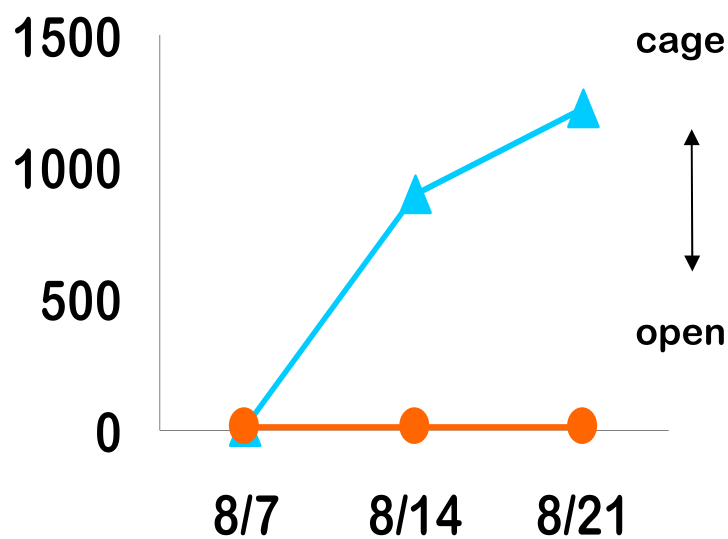
- Optimal control paths:
  - No control in all stages: “No spray”
  - Spray in stage R1 only: “Spray R1”
  - Control in both R1 and R2: “Spray R1+R2”



Zhang and Swinton, *Ecol Model* 2009.

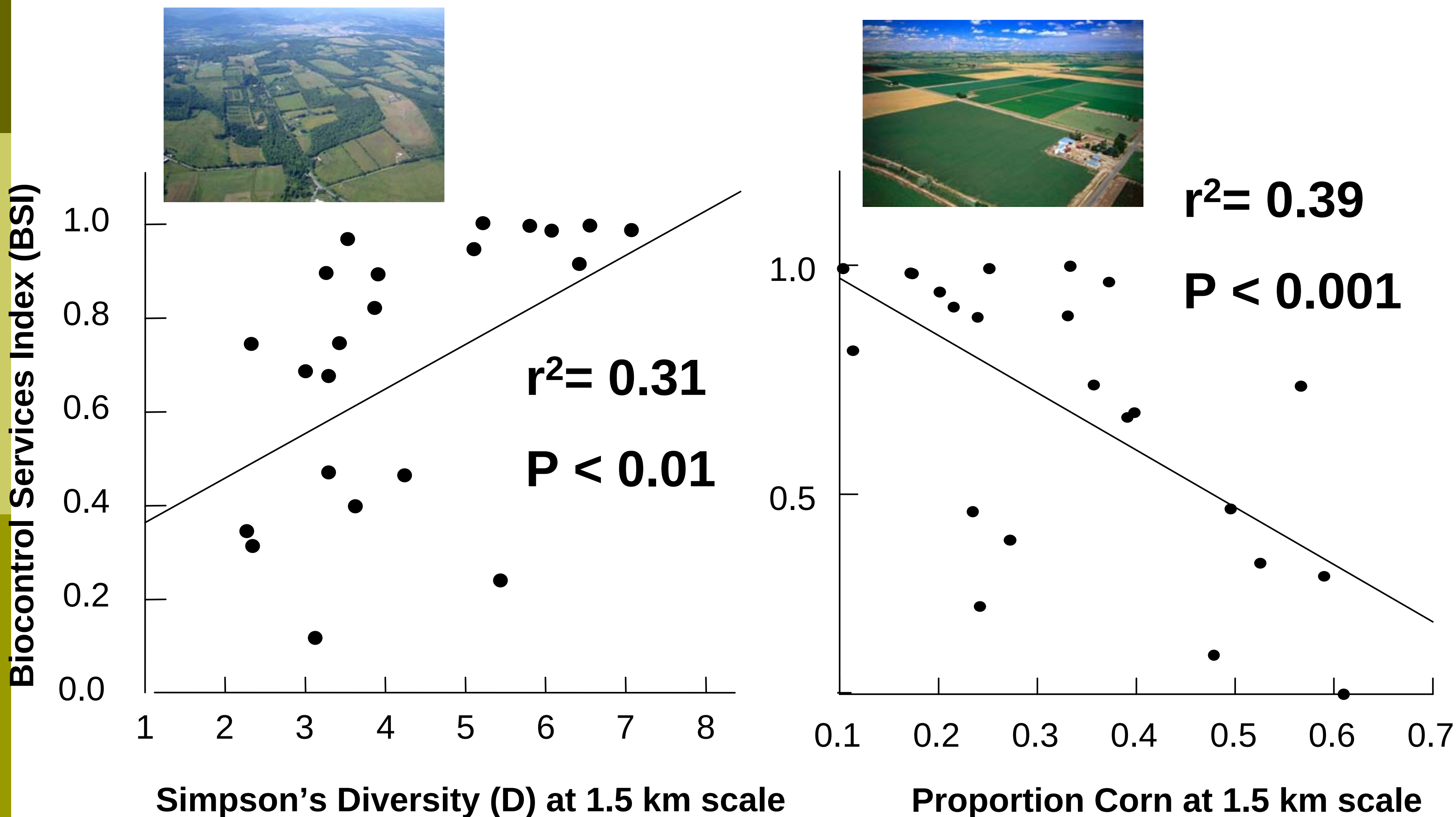
Model gives conditional value of natural enemies; landscape studies give mean cases

Surrounding landscape affects predation of soybean aphid



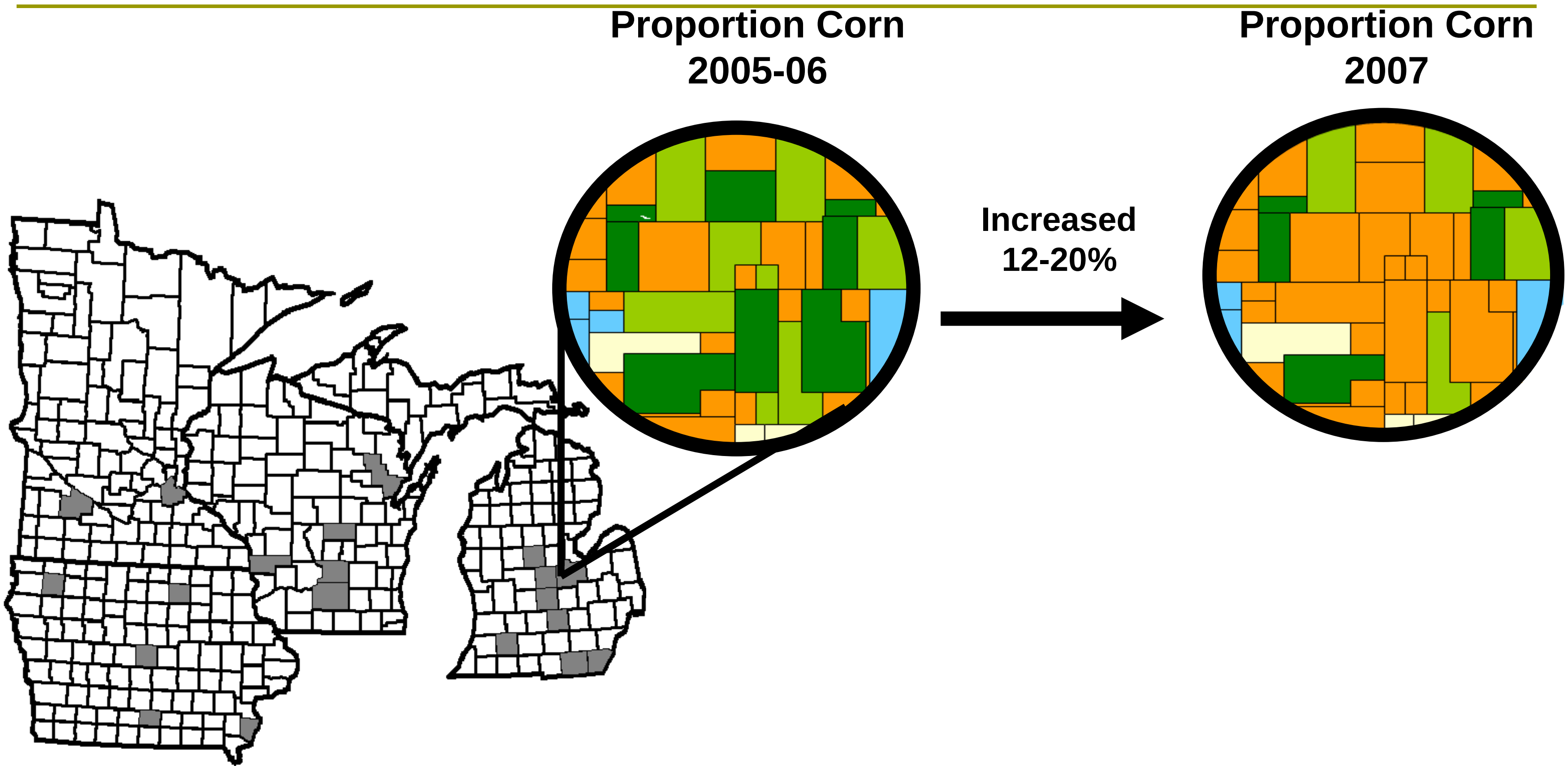
Soybean aphids per plant rise in cages that exclude predators

Biocontrol rises with diverse land cover; falls with corn area



Gardiner *et al*. Ecol. Appl. 2009

Implications for expanded U.S. corn acreage



Due to increased demand for ethanol, corn acreage increased 19% nationally from 2006-2007.

Simple value-added contribution to place value on biocontrol services

- **$23 $ha^{-1}y^{-1}$ in 2005-06**
  - **- Averted yield loss**
  - **- Insecticide savings**
  - **= $239 M y^{-1} Michigan, Wisconsin, Minnesota and Iowa alone**

- **Loss of $58 M y^{-1} ($9 ha^{-1}) in biocontrol services due to 2007 increase in corn acreage**
- **Impact: PNAS article w/ press coverage**

Landis, Gardiner, van der Werf, Swinton. *PNAS* 2008

Capturing heterogeneity in valuation of ecosystem services: Supply & Demand

- For farmer suppliers to provide more ES:
  - Direct cost (including equipment)
  - Opportunity cost (foregone earnings)
  - Environmental preferences
  - Verify information set

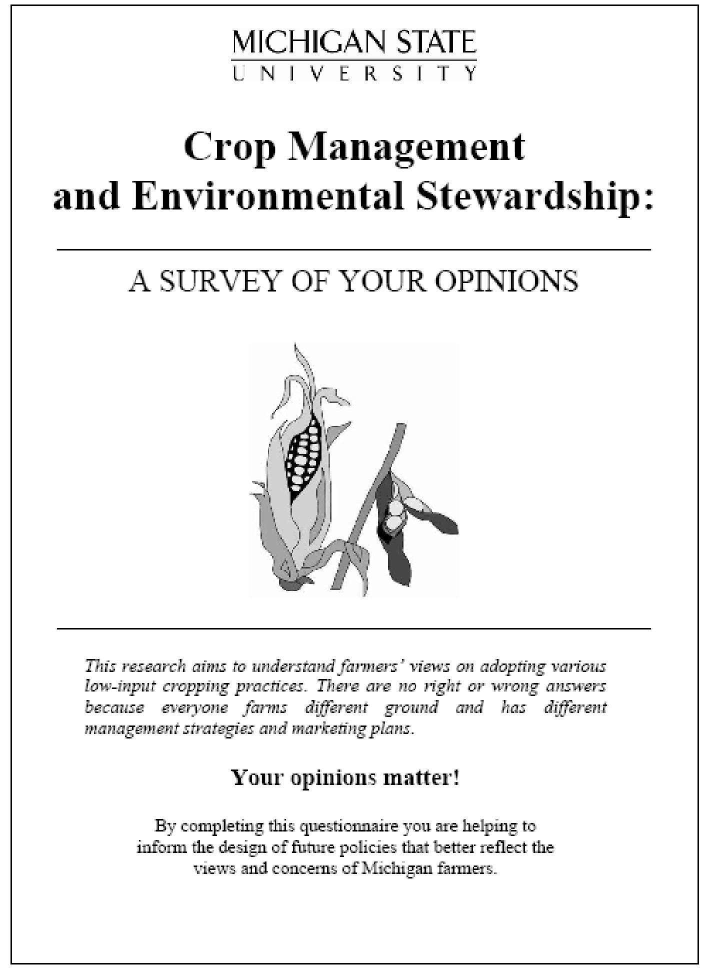
- For consumer demanders of more ES:
  - Willingness to pay
  - Information set

Multidisciplinary survey planning

- Ensures scientific rigor and applicability
- **Focus groups** of practitioners may be informative to scientists

Real farms and farmers are more heterogeneous than any experiment

- Survey of 1800 farms
- Environmental stewardship based on KBS-LTER crop systems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Crop Management and Environmental Stewardship:

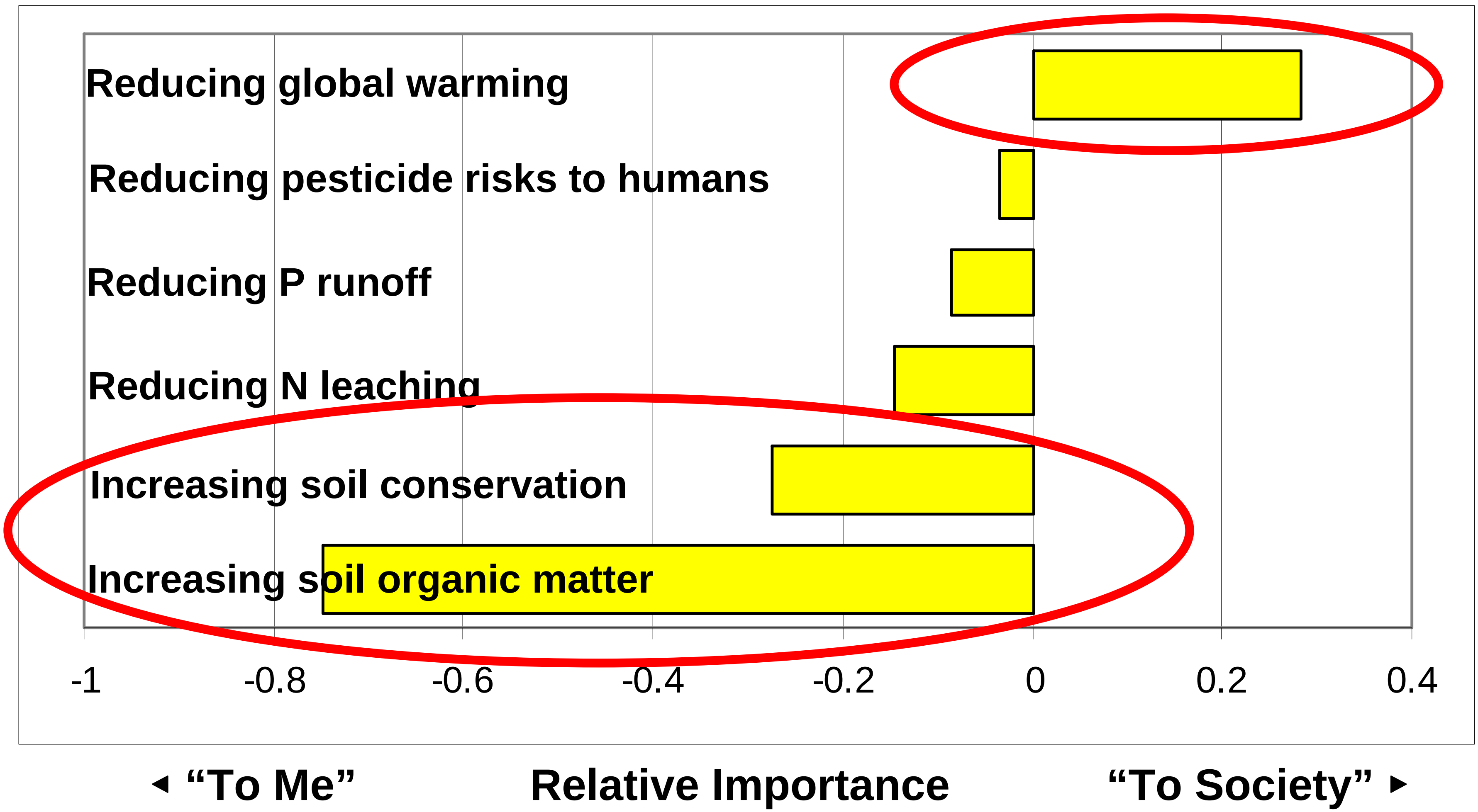
A SURVEY OF YOUR OPINIONS

This research aims to understand farmers' views on adopting various low-input cropping practices. There are no right or wrong answers because everyone farms different ground and has different management strategies and marketing plans.

Your opinions matter!

By completing this questionnaire you are helping to inform the design of future policies that better reflect the views and concerns of Michigan farmers.

Attitudes: Some ES have more private value, others more public



N=1800 Michigan corn-soy farms. Unpublished data 2008.

Efficacy: Doubts about effect of cropping practices on global warming

- Skepticism about global warming benefit claimed for these practices

- Reluctance to no-till for 4 years in a row

Incentives: How willing are farmers to supply ES from lower input systems?

- **A**: Corn-soybean
- Reduced tillage
- Nitrogen fertilizer just-in-time based on tests

- **D**: Corn-soybean-wheat
- Reduced tillage
- Nitrogen fertilizer just-in-time based on tests
- Winter cover crop
- 1/3 cut in fertilizers by applying only over row

Added costs of System D compared to corn-soybean rotation (A)

System D	Added Costs
Corn-soy-wheat	Wheat→lower revenue than corn or soybean (recent quality problems)
Reduced tillage	OK
Just-in-time pre-sidedress nitrate test	Soil test delays fertilization (field time risk)
Cover crop in winter	Costs of seed & planting labor
1/3 reduction in fertilizer, applied over the row	Band applicator for fertilizer (equipment)

- If a program run by a (non-governmental organization or government) would pay you $X per acre each year for 5 years for using this cropping system, would you enroll in this program? (Yes) (No)

- If Yes, how many acres would you enroll in this program? __________ ACRES

Hurdle model of acreage enrollment

- Participation decision (probit)

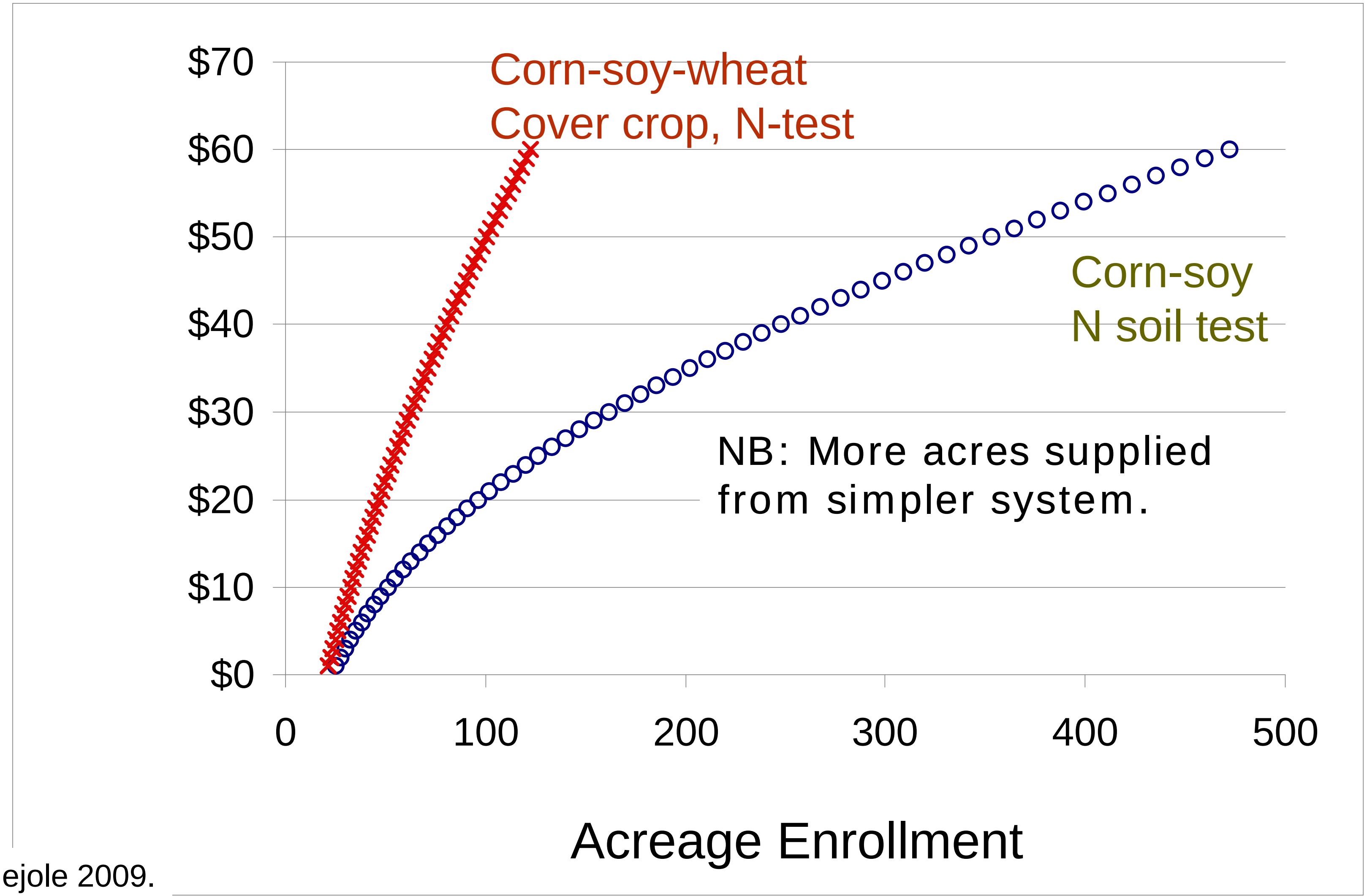
$$P(\alpha_i > 0 | x) = \Phi\left(\frac{\beta'_\rho x_i}{\sigma}\right)$$

- Acreage enrollment - conditional on participation (truncated regression)

$$\alpha_i = \alpha_i * | \alpha_i * > 0 \sim \text{Truncated Normal}$$

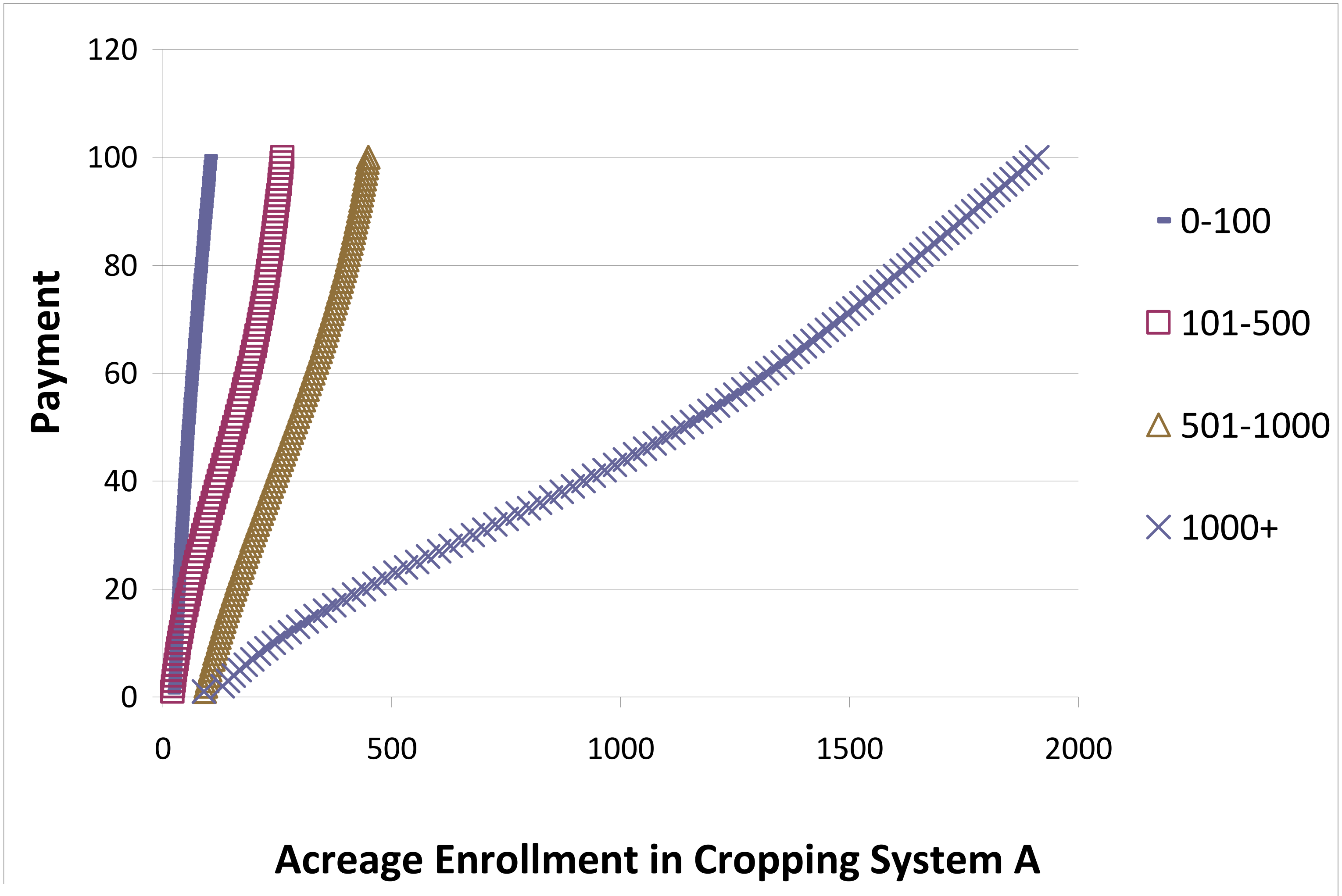
$$PREDICTACRES = \Pr(\alpha_i > 0 | x) * E(\alpha_i | \alpha_i > 0)$$

Supply-side value as function of costs, farmer preferences & site conditions



Jolejole 2009.

Large farms are the low-cost suppliers of ecosystem services for payment

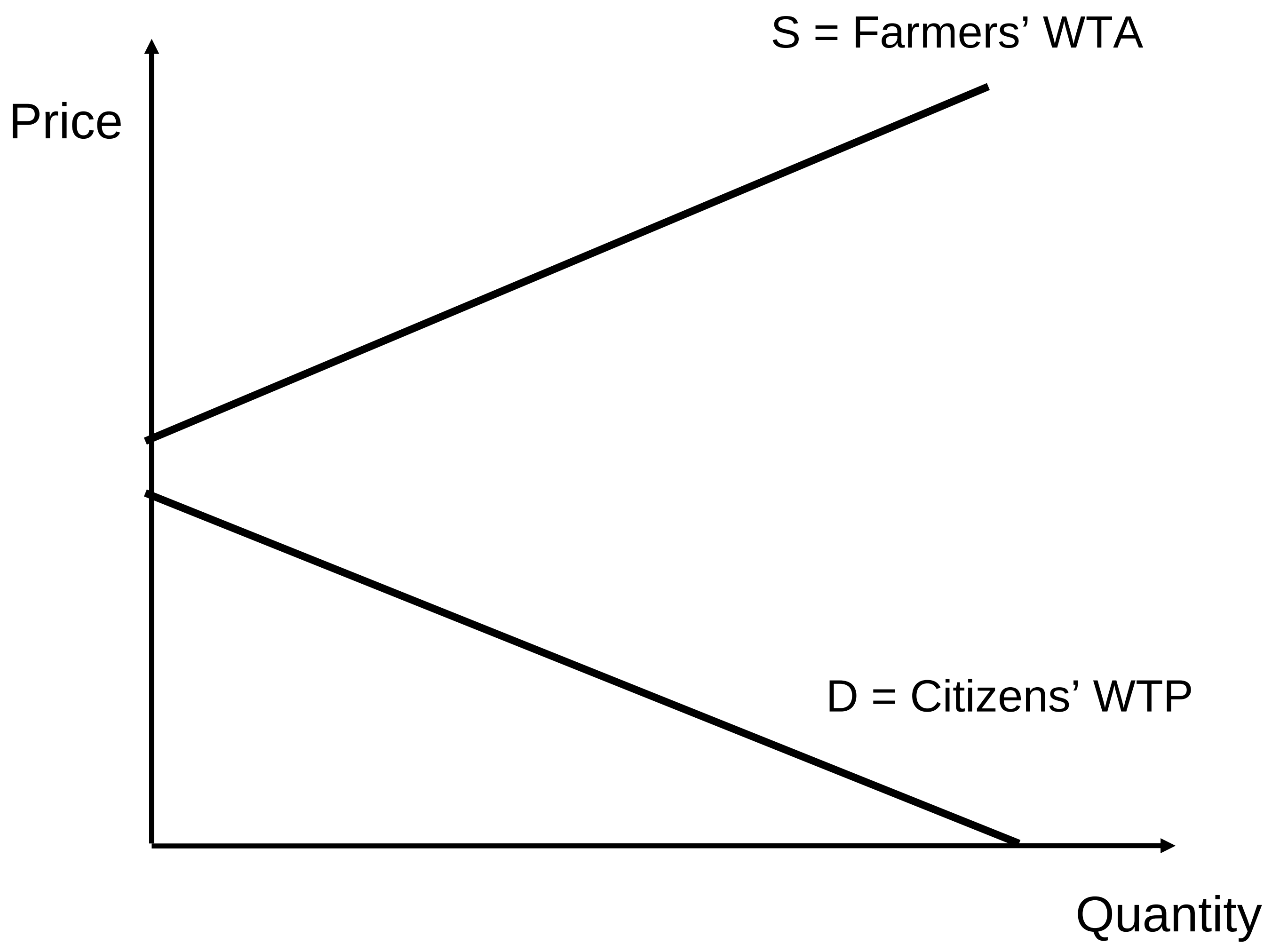


Jolejole 2009.

From Supply-side to Demand-side valuation of ecosystem services

- ES are produced in bundles (joint products)
  - So cost of changed crop practices expressed per unit of land
- But ES consumed individually
  - So demand distinct for improvements in
    - Recreational water quality
    - Drinking water quality
    - Climate
  - Consumer survey just completed on WTP for fewer eutrophic lakes and more greenhouse gas mitigation

Putting Supply & Demand together in same units: How will it look?



Multidisciplinary research as a jazz ensemble

- When another skilled musician plays the melody, play a good harmony.

- Everyone gets to solo, showing their disciplinary strengths.

Summing up: Valuation research with multidisciplinary teams

- Budget-based trade-off analysis offers quick bang-for-the-buck
  - Easy to communicate, can be timely
  - Timeliness matters for science news journals
- Bioeconomic modeling can build close ties, especially to other modelers
- Serious nonmarket valuation studies
  - More robust & time-consuming
  - Minimal involvement by non-economists; communication *ex post* may be harder

Final thoughts

- Demand is strong for economic contributions on ecosystem services
  - valuation
  - policy design
- Achieving impact calls for creativing, not necessarily complexity
- Jazz band – my ideal

Thanks to

- Mary Gardiner, Doug Landis, Frank Lupi, Christine Jolejole, Sara Syswerda, Wopke van der Werf, Wei Zhang and other colleagues in multi-disciplinary research, especially KBS-LTER.

- Funding partners who have magnified impacts.