Integrative Analyses of Human-Environment Systems

Pamela Matson
Stanford University

Integrative Analyses of Human-Environment Systems:

Intensive Agriculture, Environmental Change, and Sustainability in the Yaqui Valley, Mexico

Team members:

Pam Matson, Roz Naylor, Ivan Ortiz Monasterio
Wally Falcon, Amy Luers, David Lobell, Lee Adamms, Greg Asner, Karen Seto, Esther Cruz, Jose Luis Minjares, Steve Gorelick, John Harrison, Mike Beman, Bill Riley, Ellen McCullough, Jeanne Panek, Toby Ahrens, Steve Monismith, David Battisti, Peter Jewett, and many others

Roz's perspective (in 1990):
Food production and rural poverty

Ivan's perspective:
Yields and input efficiency in developing world agriculture

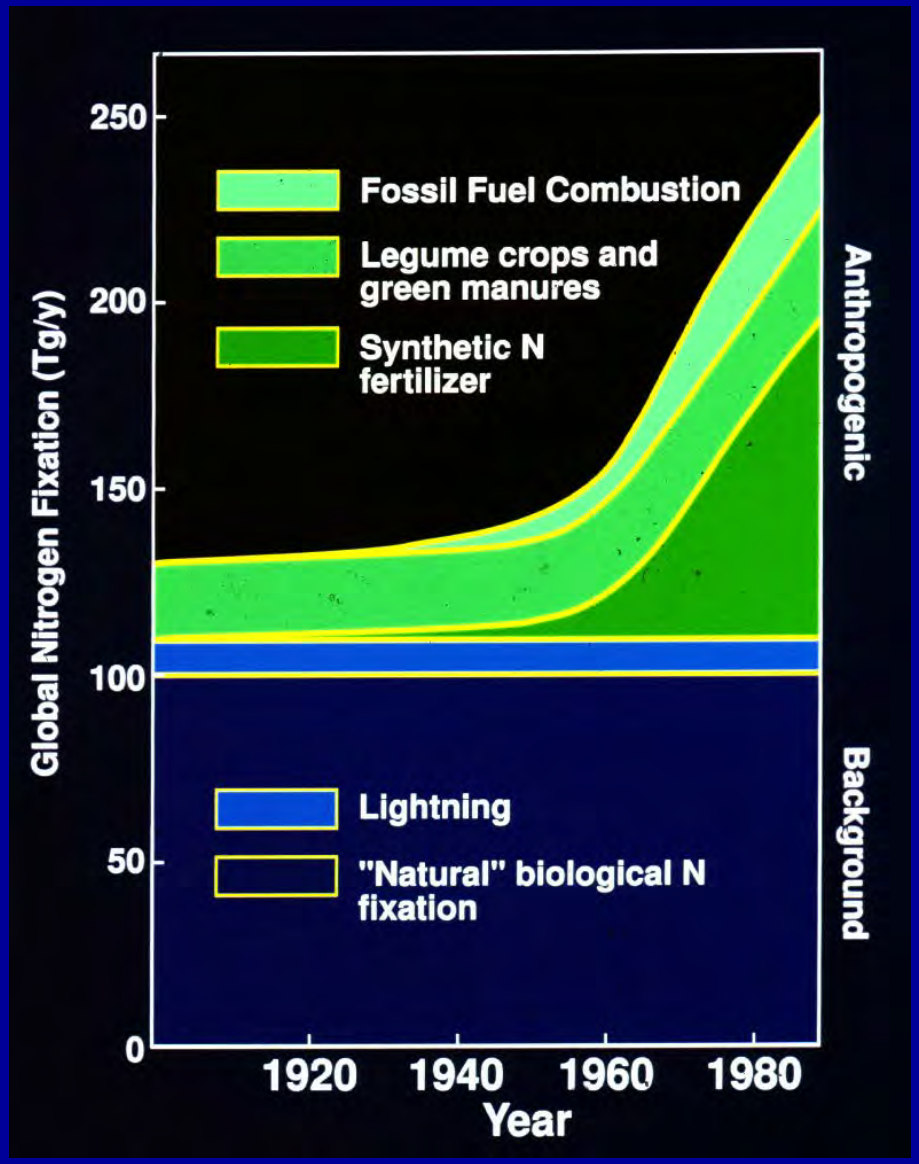
Pam's perspective:
Understanding global environmental change

Global Environmental Changes Resulting from Human Activities

- Atmospheric changes
- Climate change
- **Land cover and land use changes**
- Biodiversity loss
- Loss of ecosystem services
- Water resources limitations
- Soil degradation
- **Change in biogeochemical cycles**

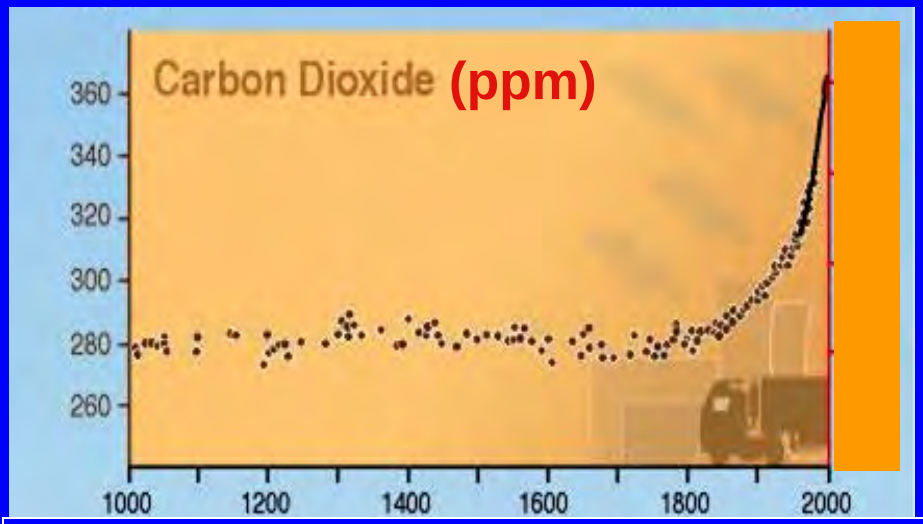
Consequences for nitrogen and carbon cycling??

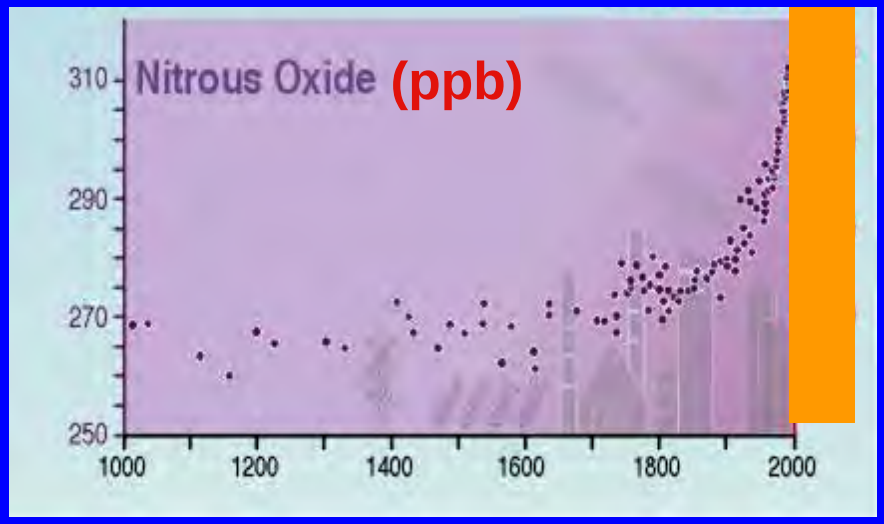
What about tropical agriculture and fertilizer use?

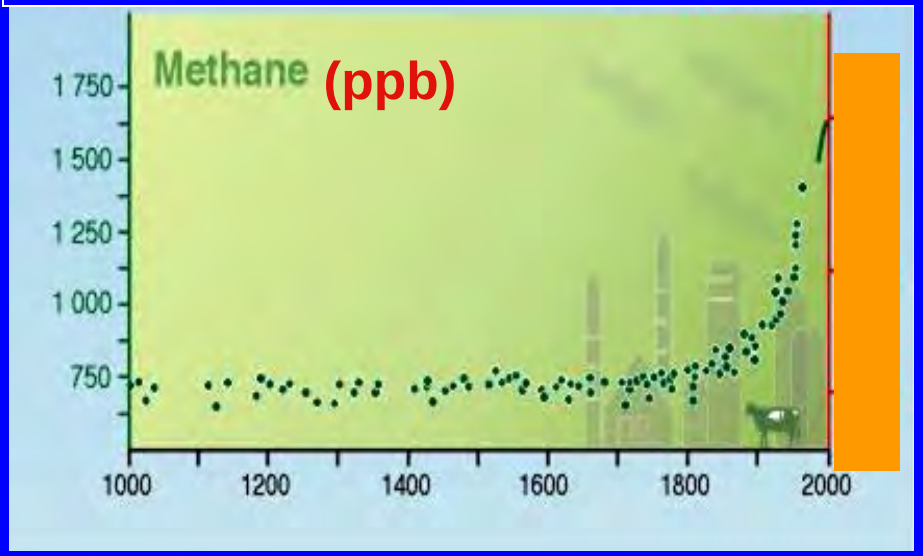


Vitousek and Matson 1993

Measured Changes in GHGs







IPCC (2001)

Roz's perspective (in 1990):
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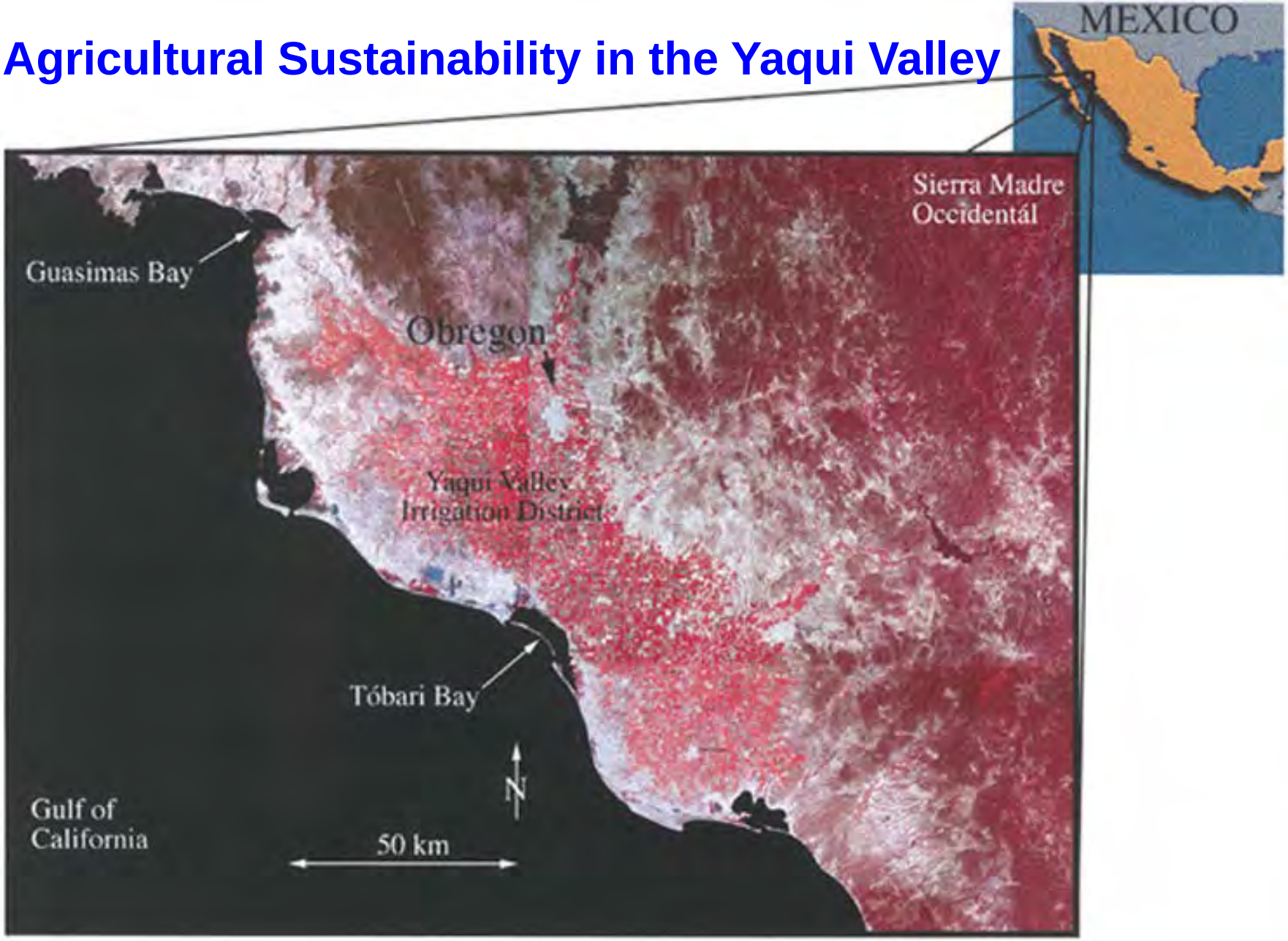
"Food, Conservation, and Environment: Is Compromise Possible?"

Aspen Global Change Institute 1992

ecologists, biogeochemists,
atm scientists, geographers,
economists, ag development,
agronomists, etc

Agricultural Sustainability in the Yaqui Valley



The Yaqui Valley -- "the home of the Green Revolution"

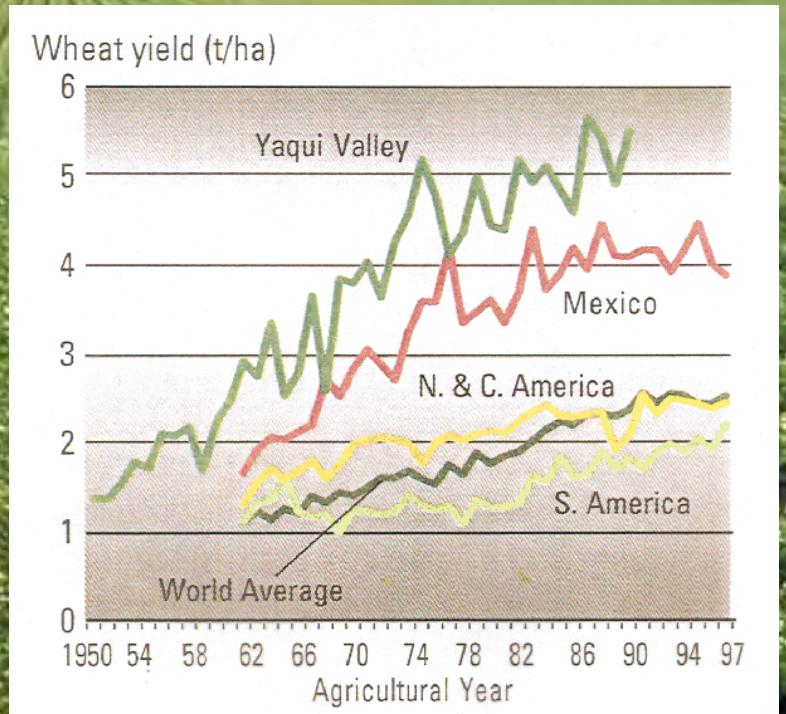
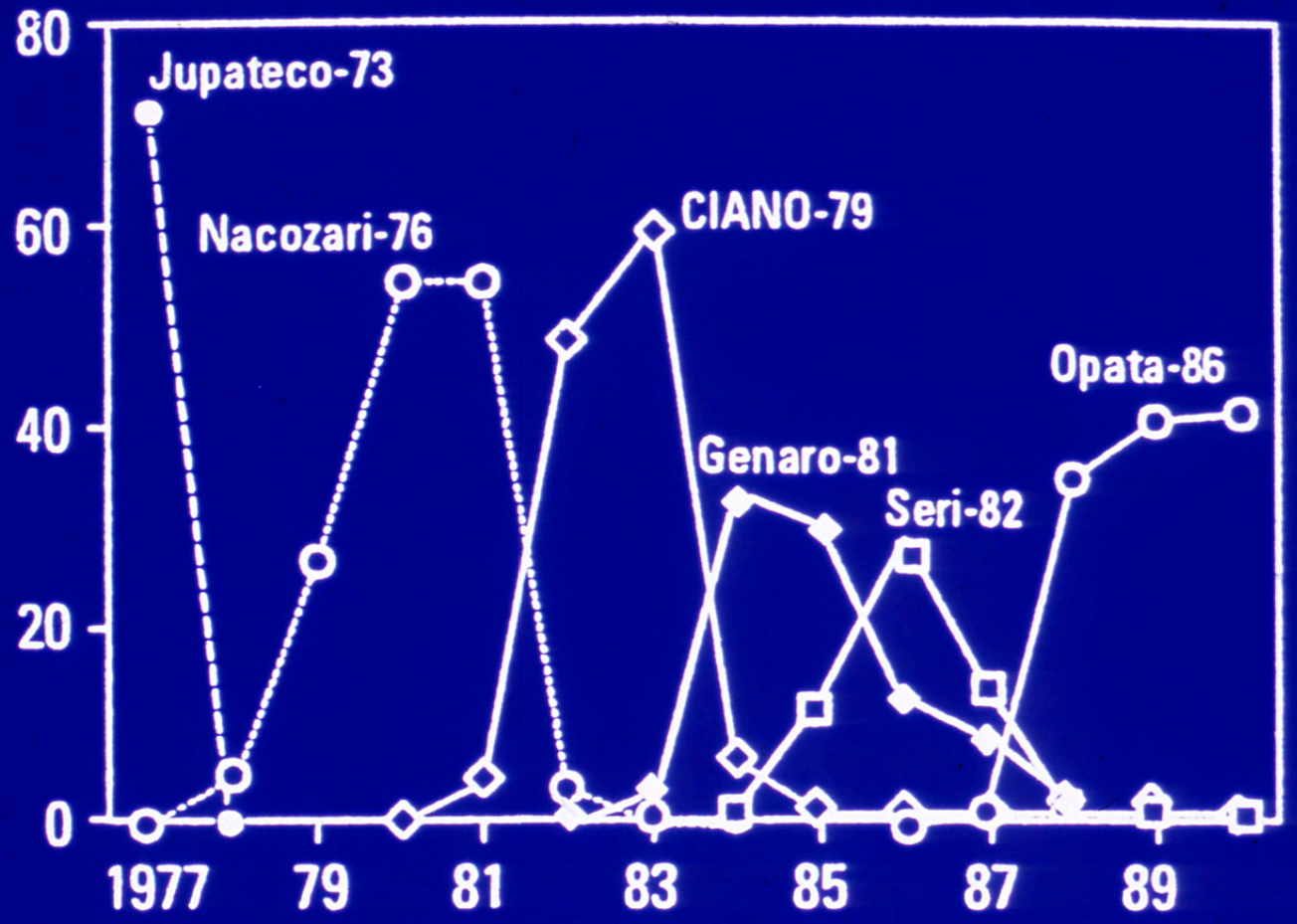


Figure 3. Comparison of world wheat yields to the Yaqui Valley.
Source: FAO Production Yearbook, CIMMYT.

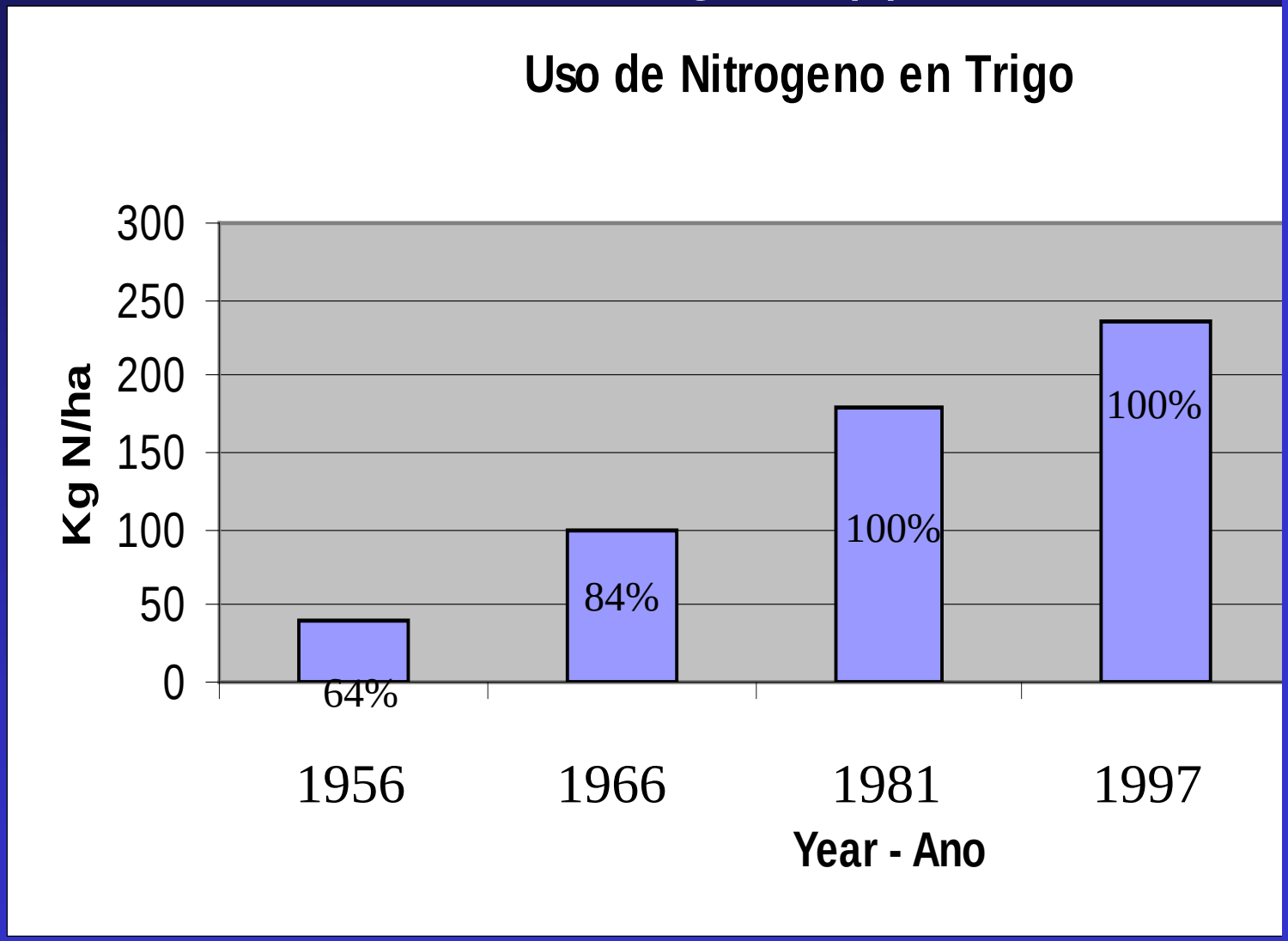
Area sown to variety[a] — Yaqui Valley, Mexico



[a] Bread wheat varieties only. Durum area was important in the late 1980s.


NH3

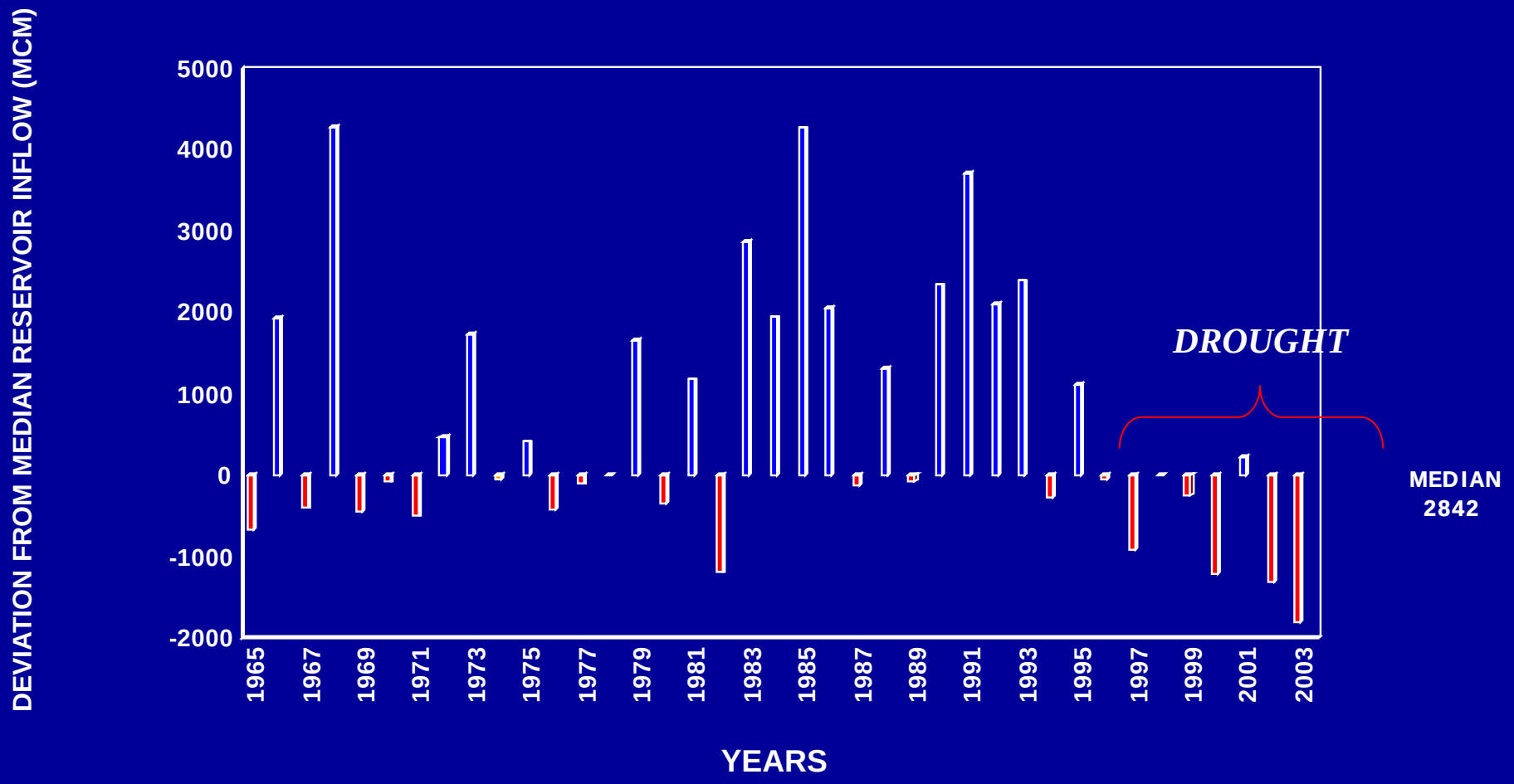
Rate of Nitrogen Application on Wheat



Percentage represents the proportion of the area that is fertilized

DEVIATION FROM MEDIAN RESERVOIR INFLOW (MCM)

(1965-2003)



1992

2003

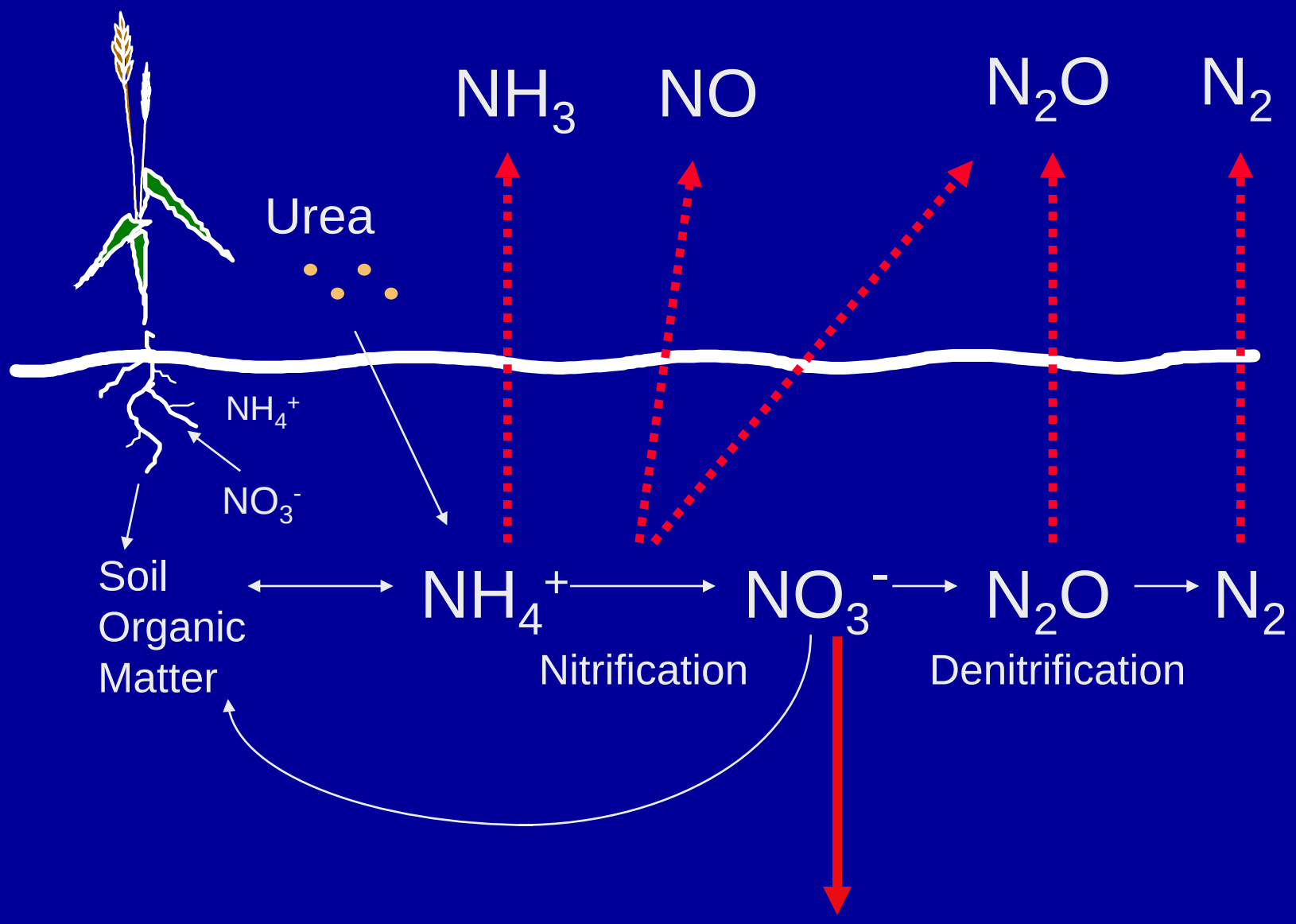
Our first question:
Can fertilizer be managed to maintain yields but reduce environmental degradation in the Yaqui Valley?

What are the biogeochemical consequences?

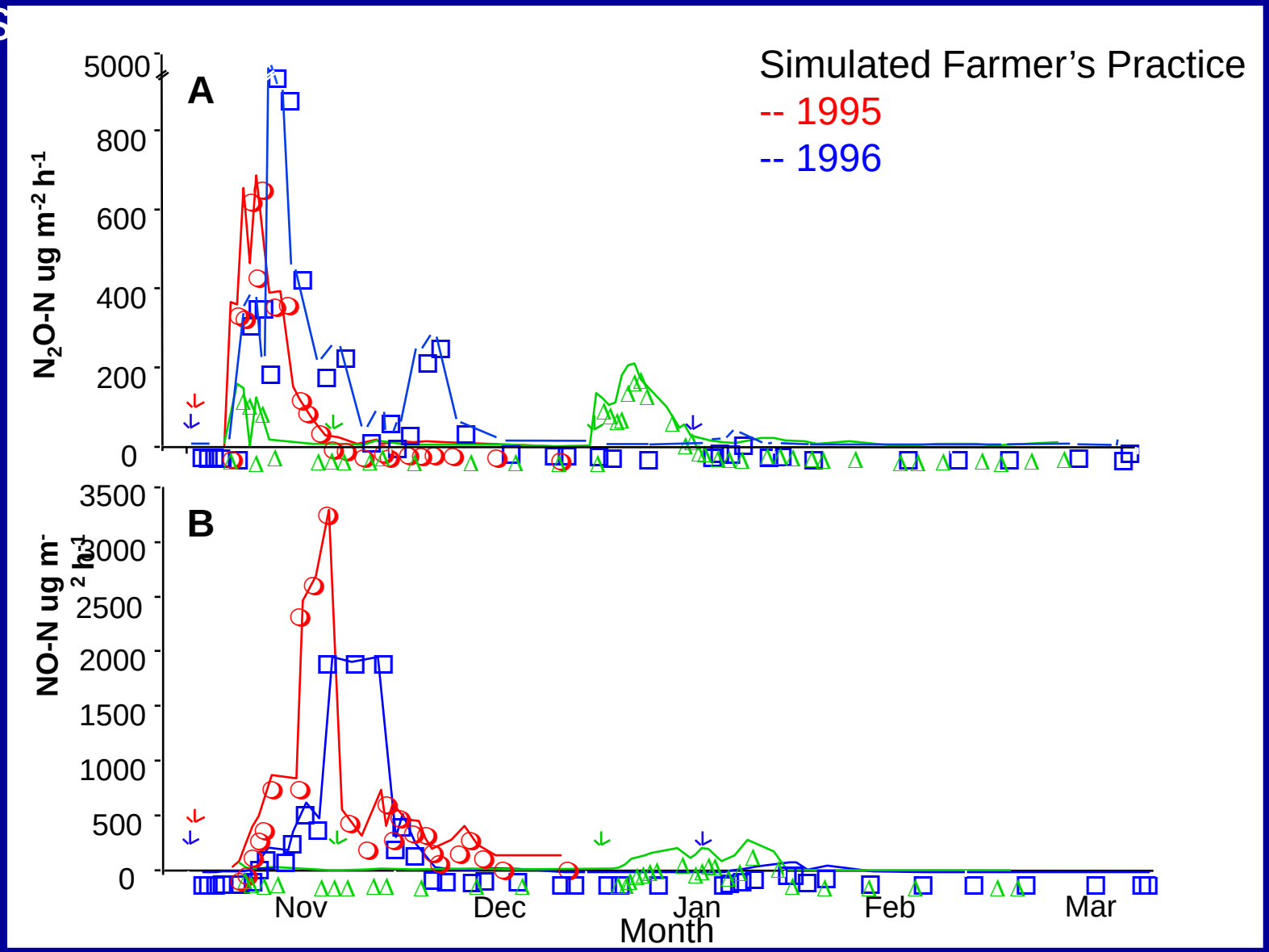
How and why do farmers fertilize as they do?

What alternatives are possible win-wins?

Fertilizer Use and Loss

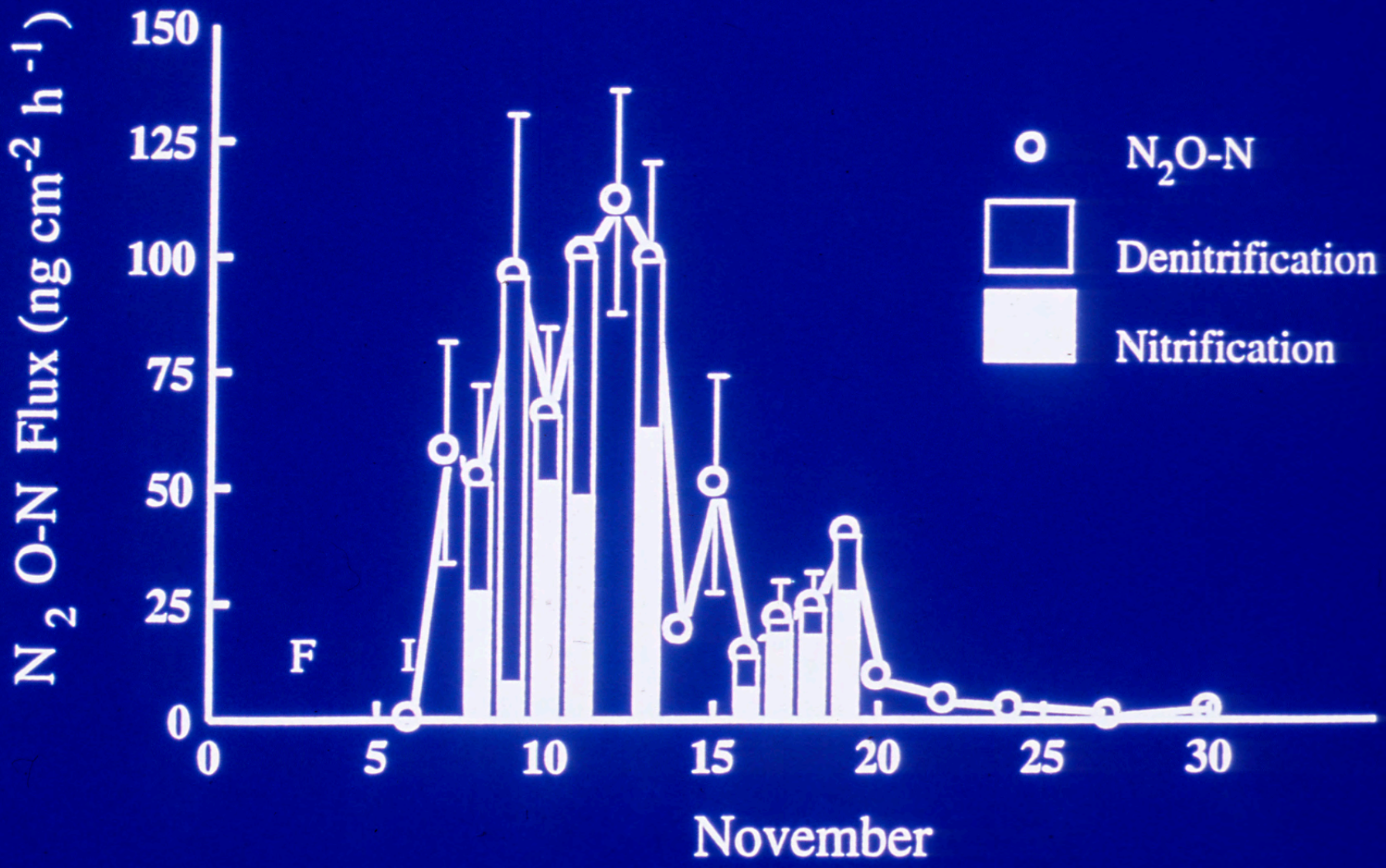


Nitrogen trace gas losses during the wheat s

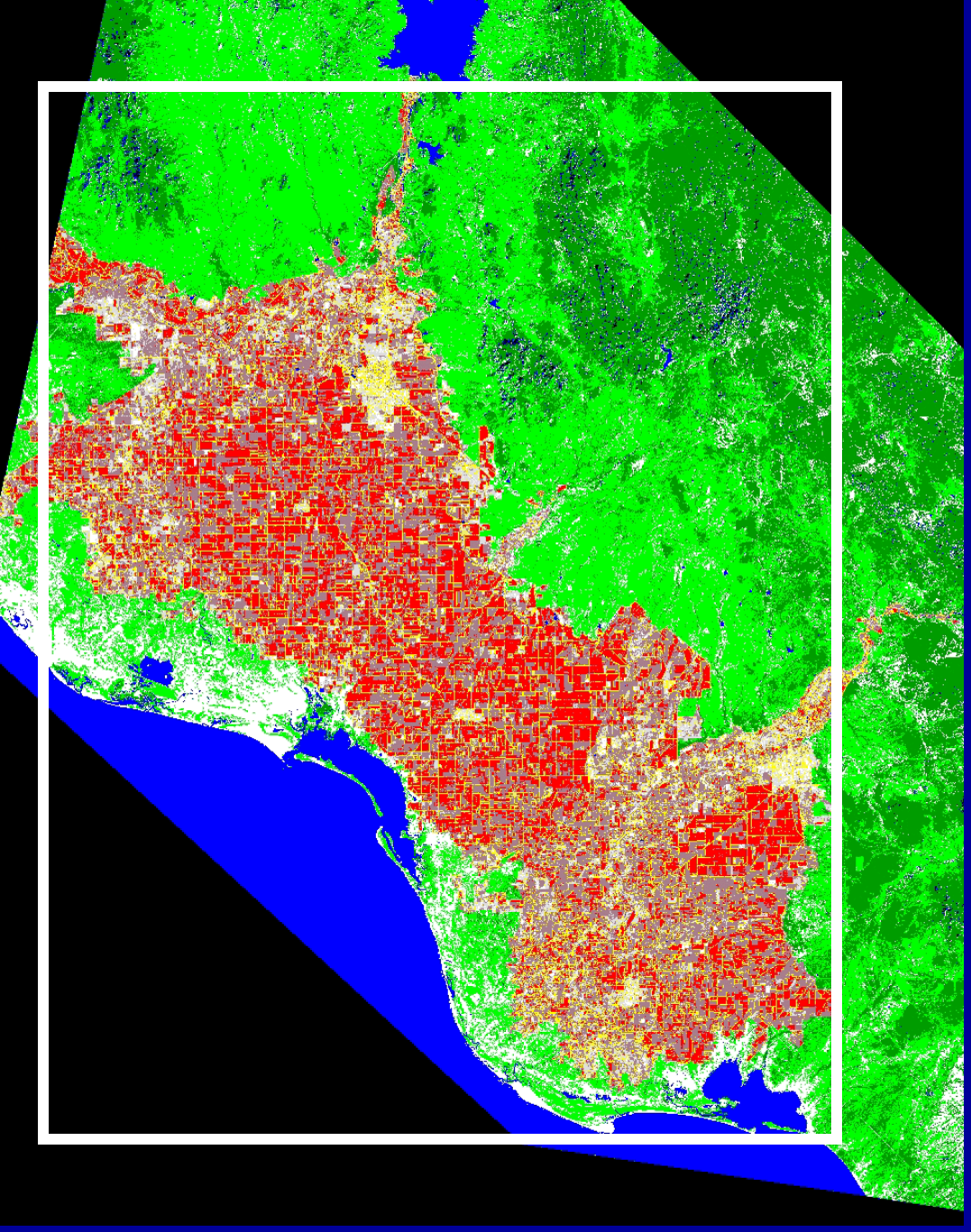


Matson et al 1998

Nitrification produces half of trace N flux

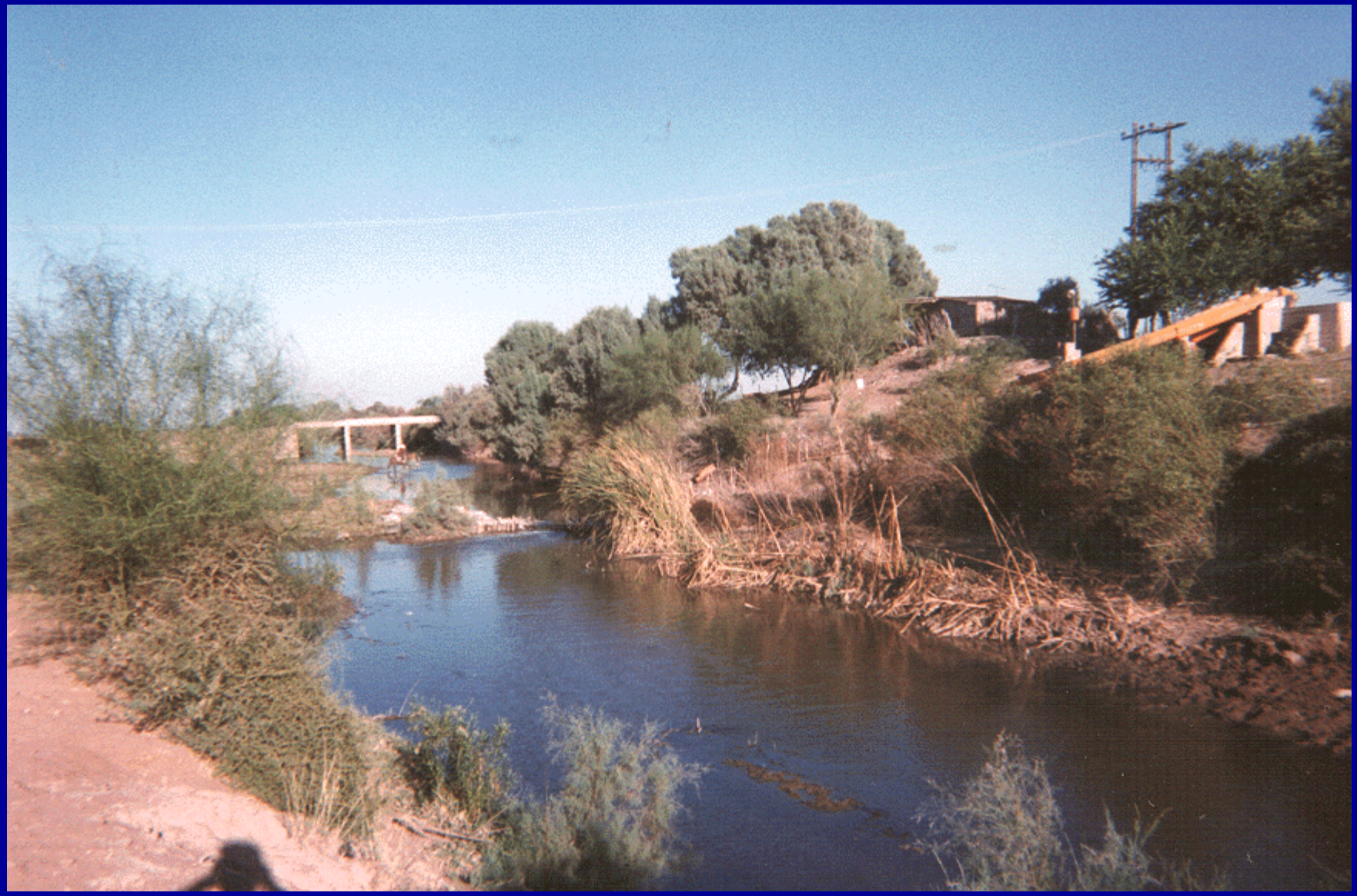


Panek et al 1999

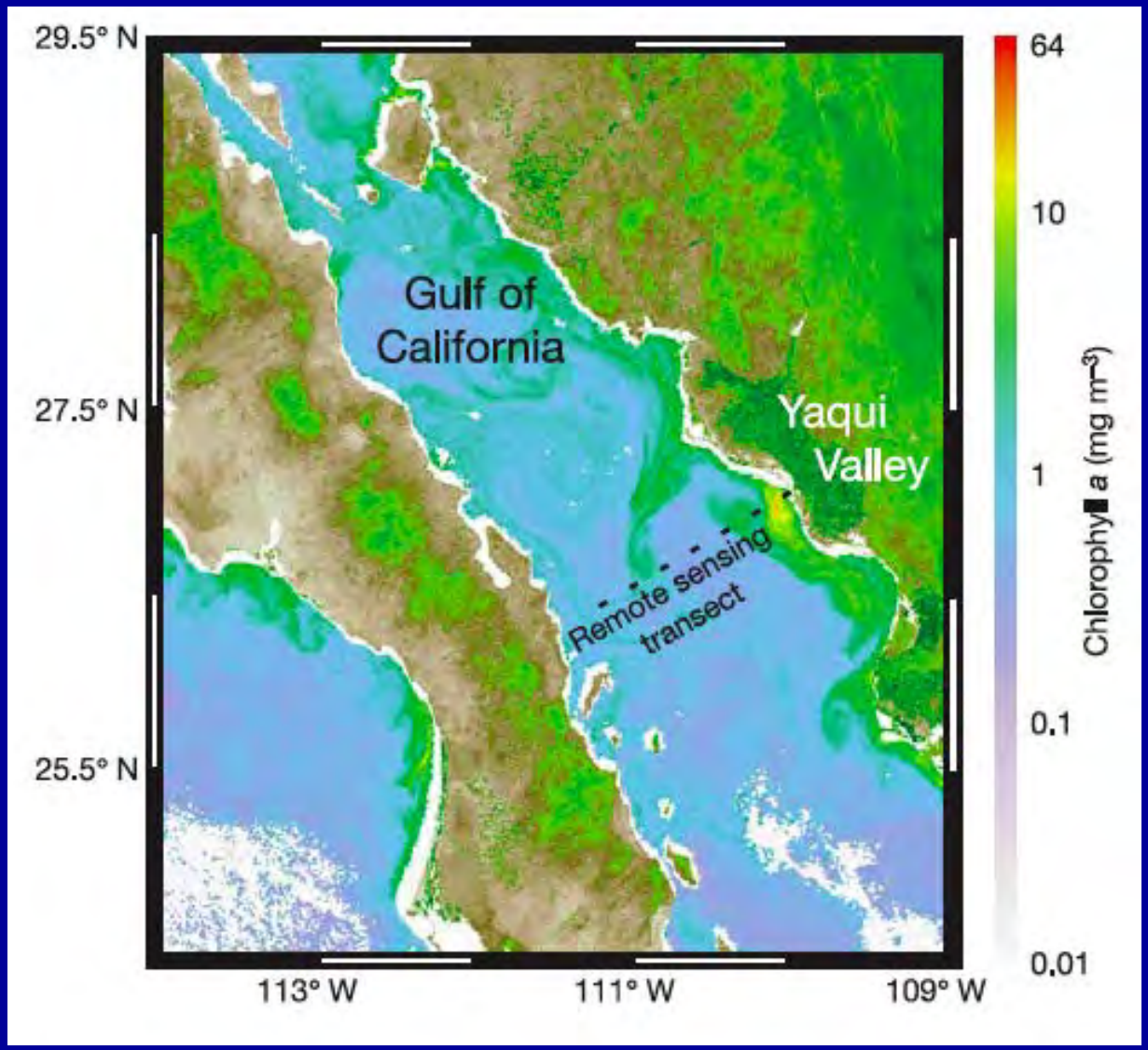


20-50 kg/ha/6 mo wheat cycle x area of wheat = N flux in solution

Riley et al 2001



Harrison et al 2004, 2005

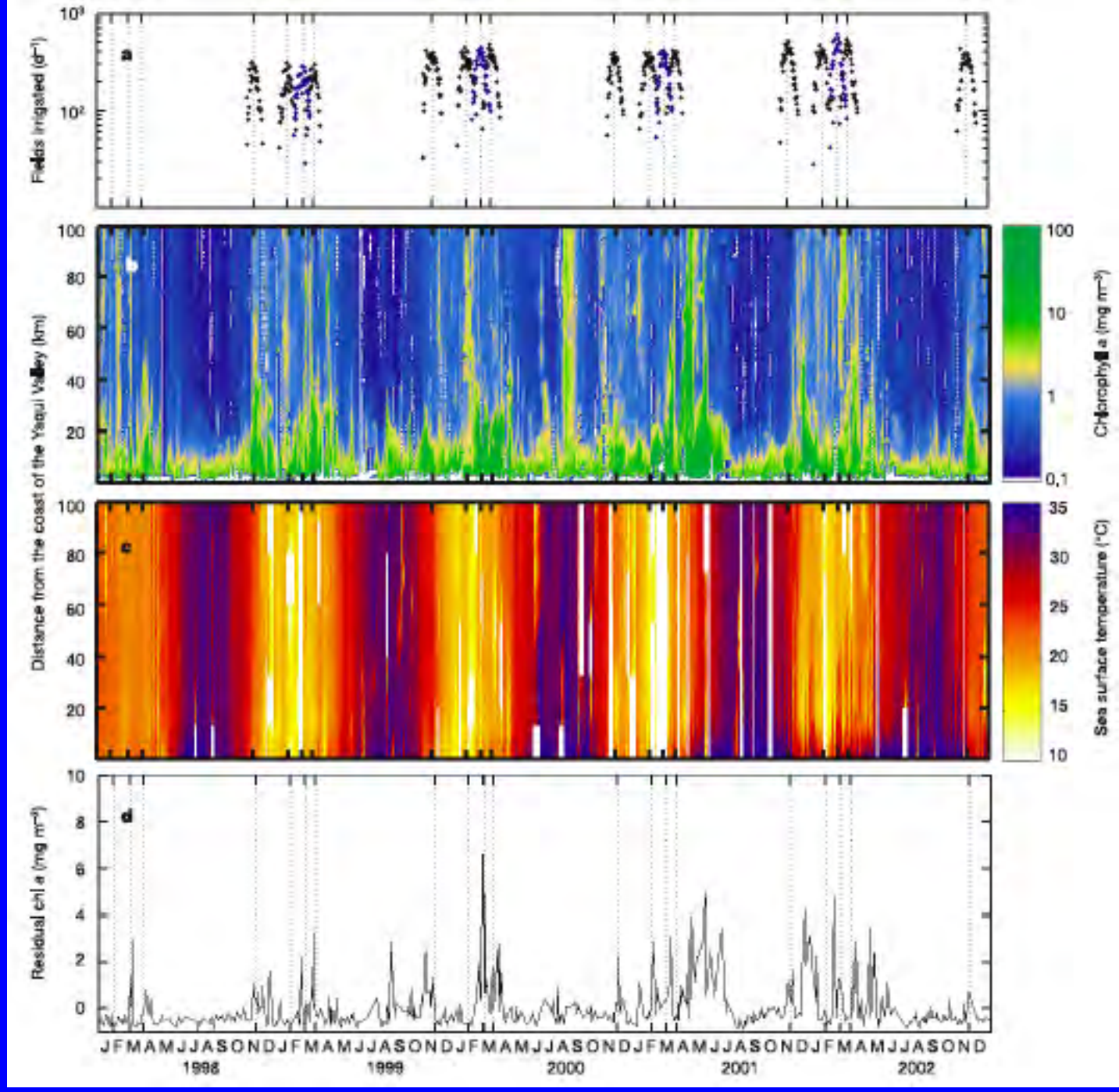

29.5° N
27.5° N
25.5° N
113° W
111° W
109° W
Gulf of California
Yaqui Valley
Remote sensing transect
64
10
1
0.1
0.01
Chlorophyll a (mg m-3)

Irrigation events

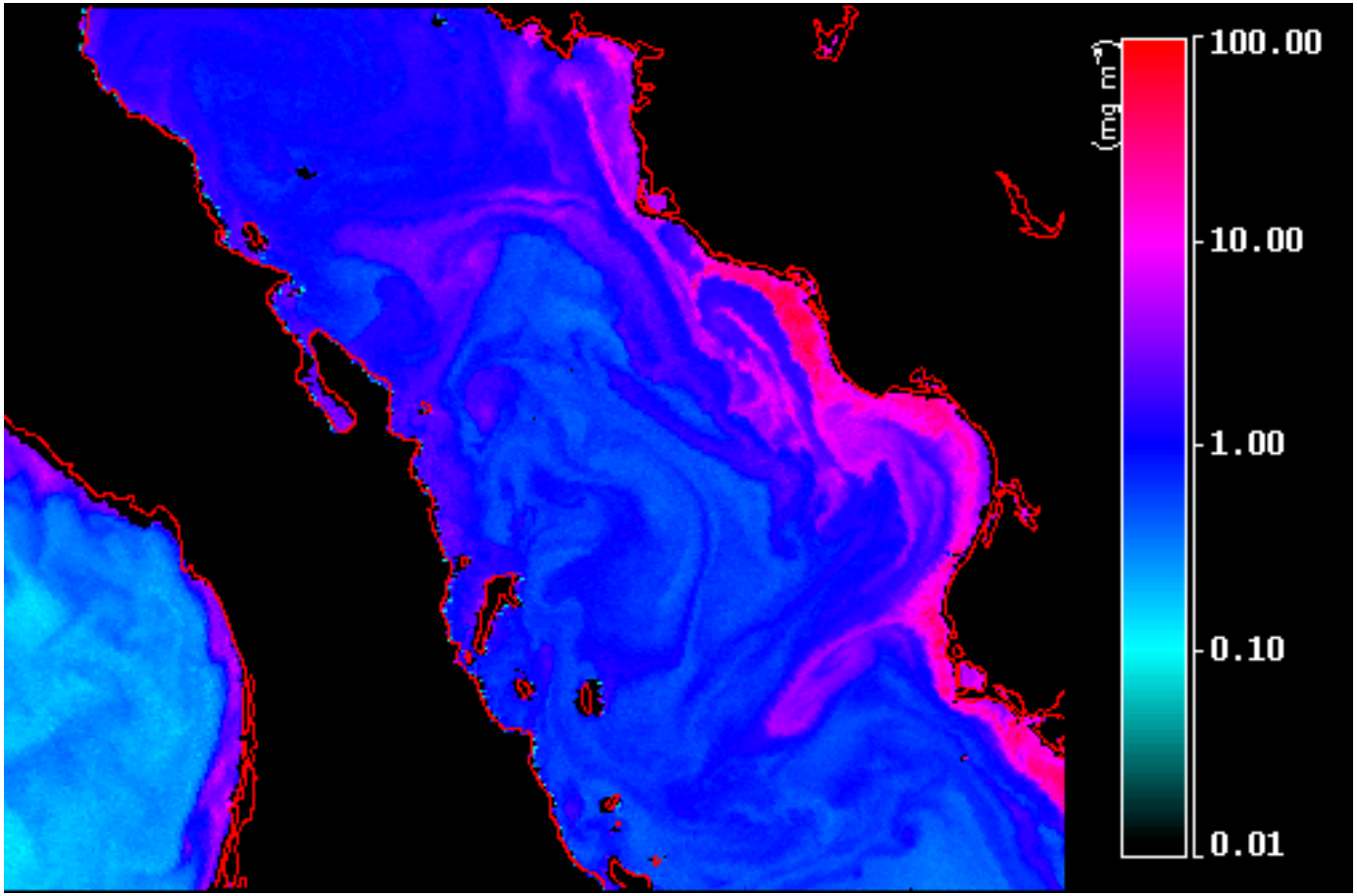
Chlorophyll

Sea Surface Temp

Residual Chlorophyll



Run-off of fertilizer nitrogen causes coastal over-enrichment and phytoplankton blooms



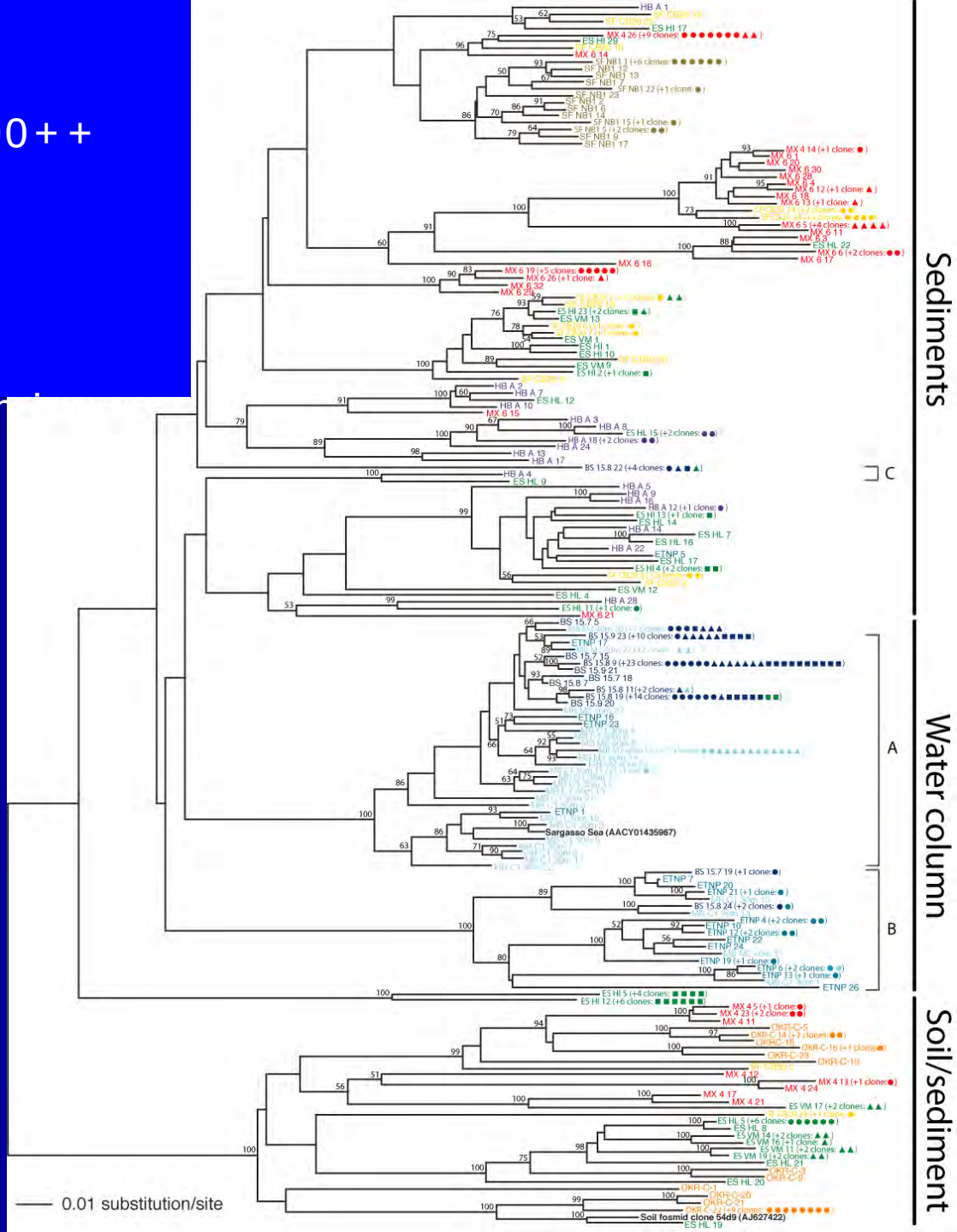
Beman, Arrigo and Matson 2005

Archaeal *amoA*

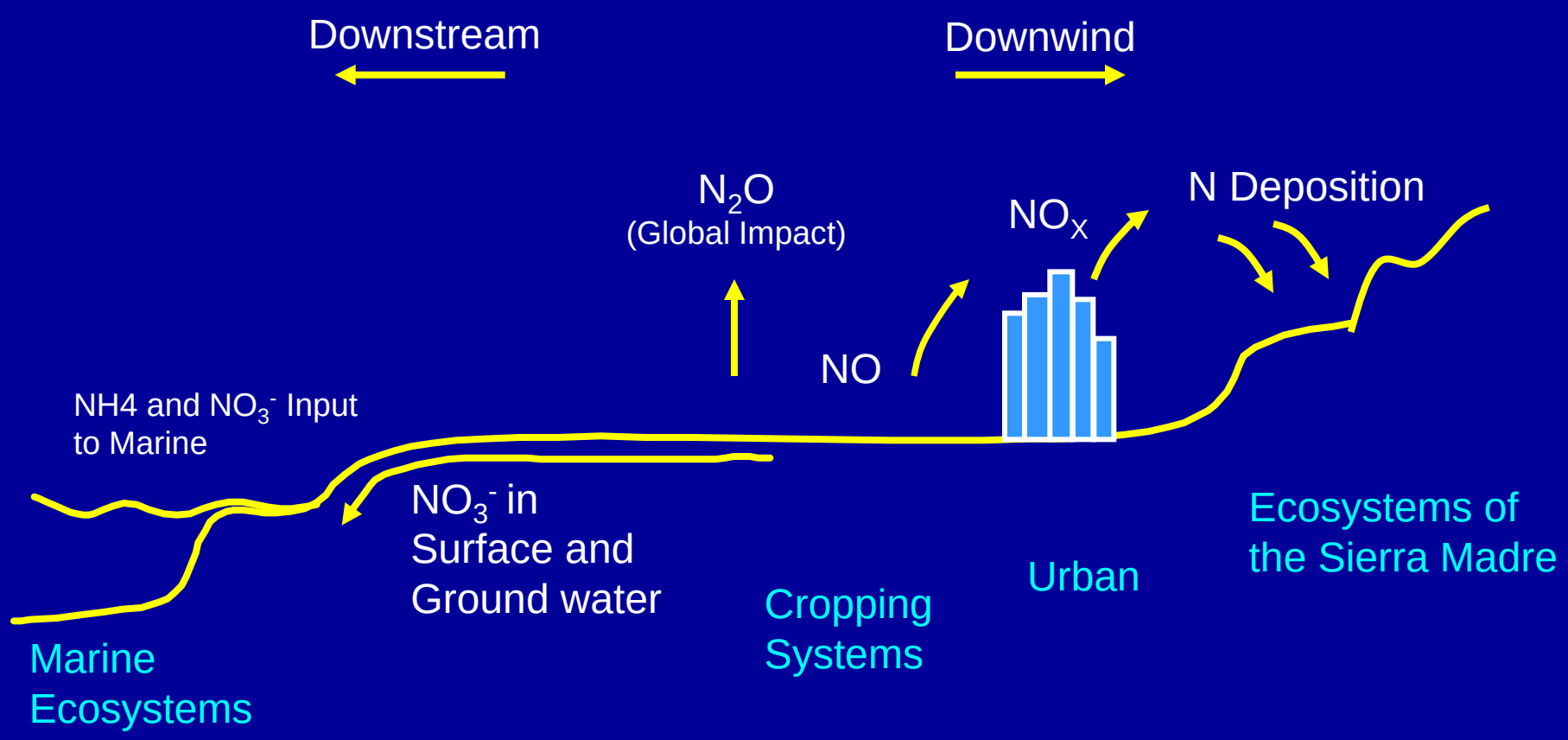
- From 2 sequences to 400++ and counting
- Ubiquitous in the ocean
- Diverse
- Found where nitrification is known to be important

- Elkhorn Slough (ES HI)
- Elkhorn Slough (ES HL)
- Elkhorn Slough (ES VM)
- North SF Bay (SF NB)
- Central SF Bay (SF CB)
- Oak Ridge Soil (OKR)
- Mexico (MX 4)
- Mexico (MX 6)
- Huntington Beach (HB)
- Monterey Bay (MB C1)
- Monterey Bay (MB M2)
- ETNP
- Black Sea (BS 15.7)
- Black Sea (BS 15.8)
- Black Sea (BS 15.9)

Francis et al 2005 PNAS



Nitrogen Interactions



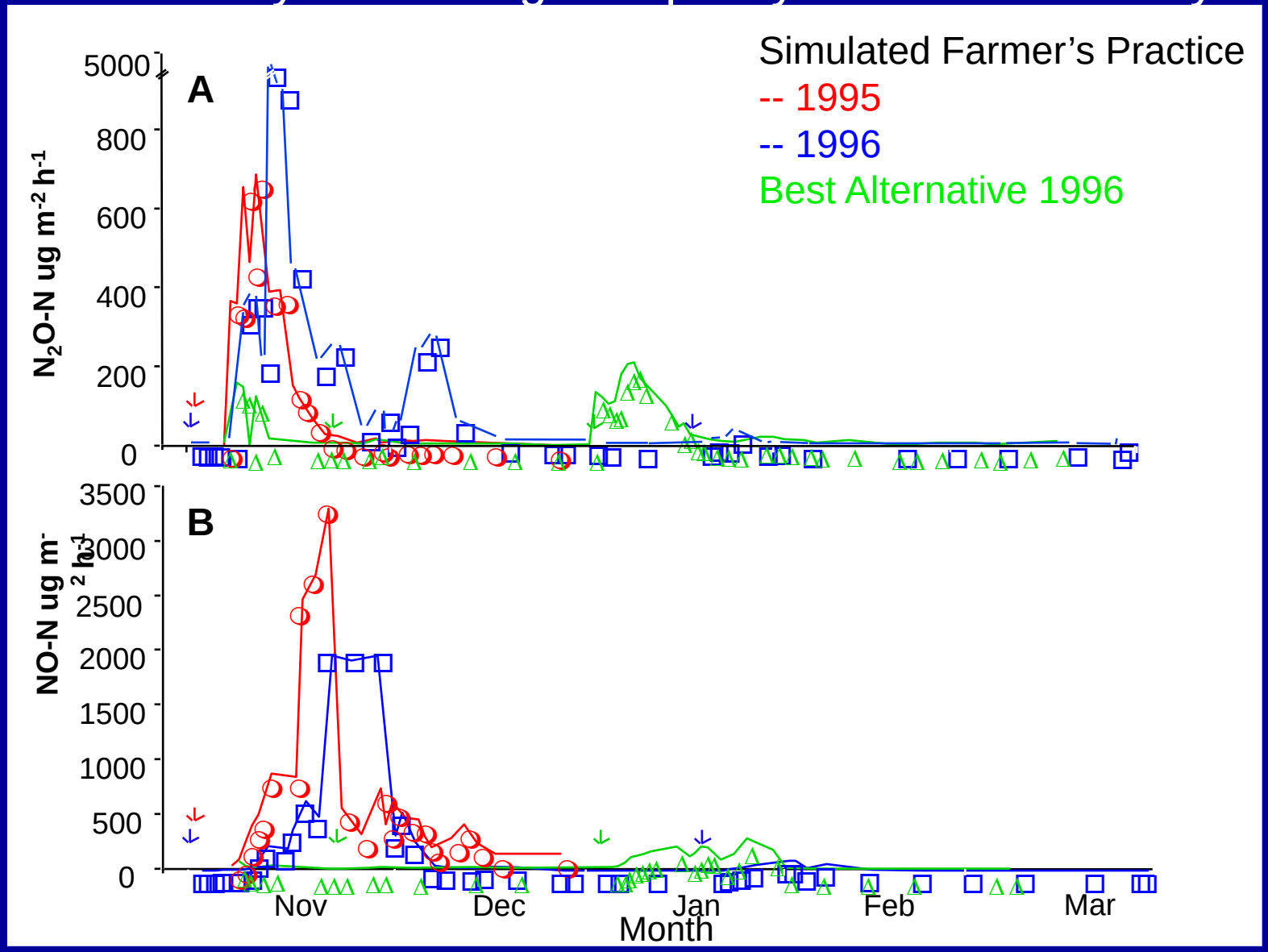
Why do farmers do what they do?

- *Changes in the policy environment*

- *Misperceptions about fertilizer timing*
- *Aversion to risk….*
- *Machinery constraints…*
- *Experience says it works…*

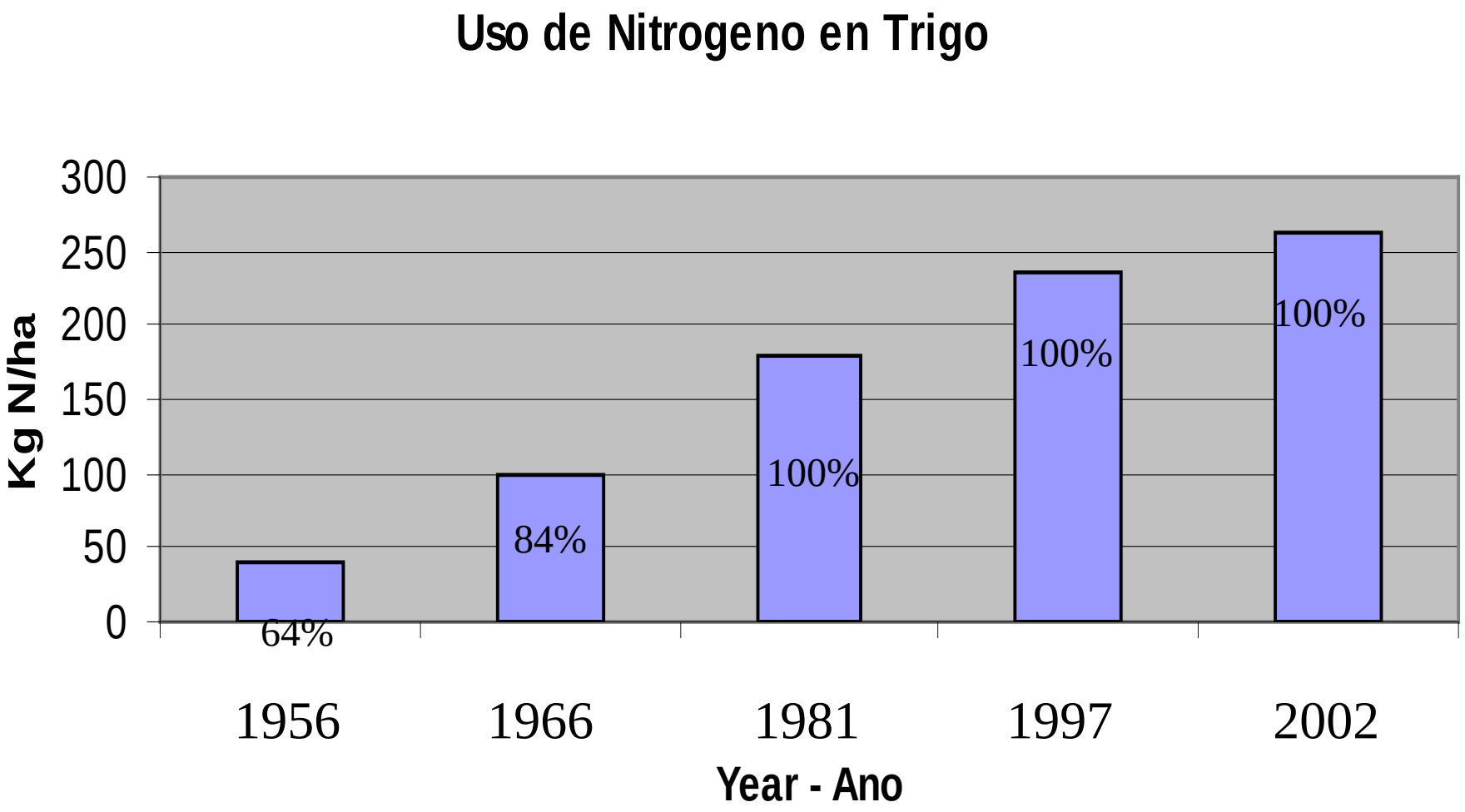
Are there win-win alternatives?

Best alternative reduces losses >10 fold, maintains yields and grain quality and saves money



Matson et al 1998

Rate of Nitrogen Application on Wheat

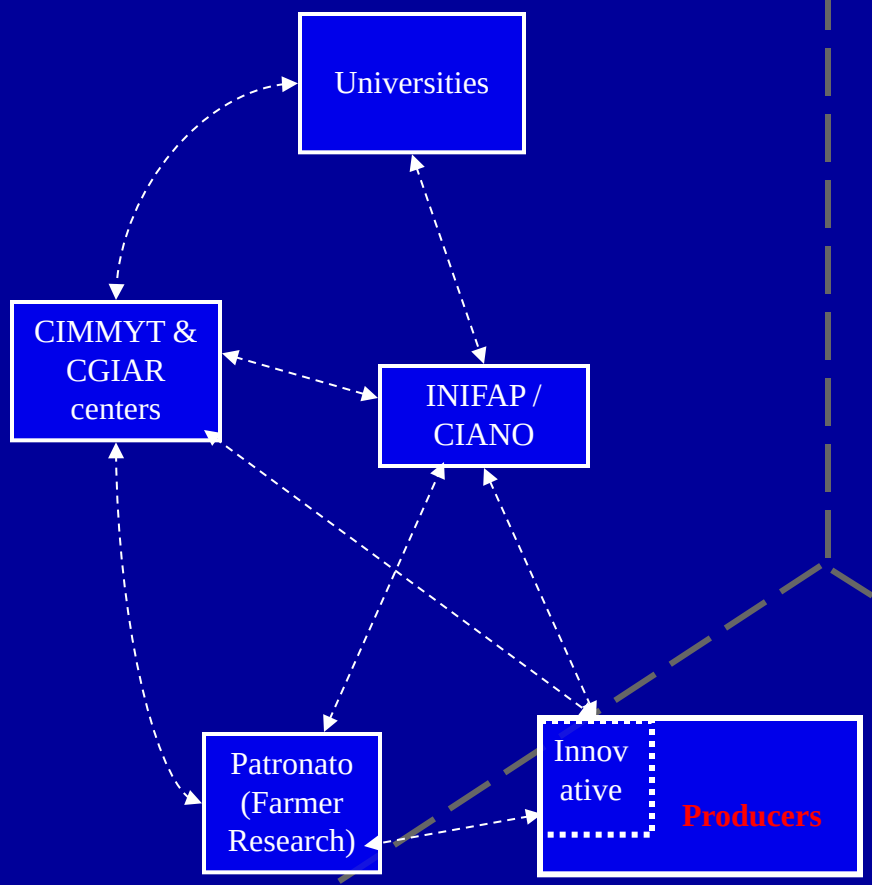


Percentage represents the proportion of the area that is fertilized

Research

Regulation/ Policy

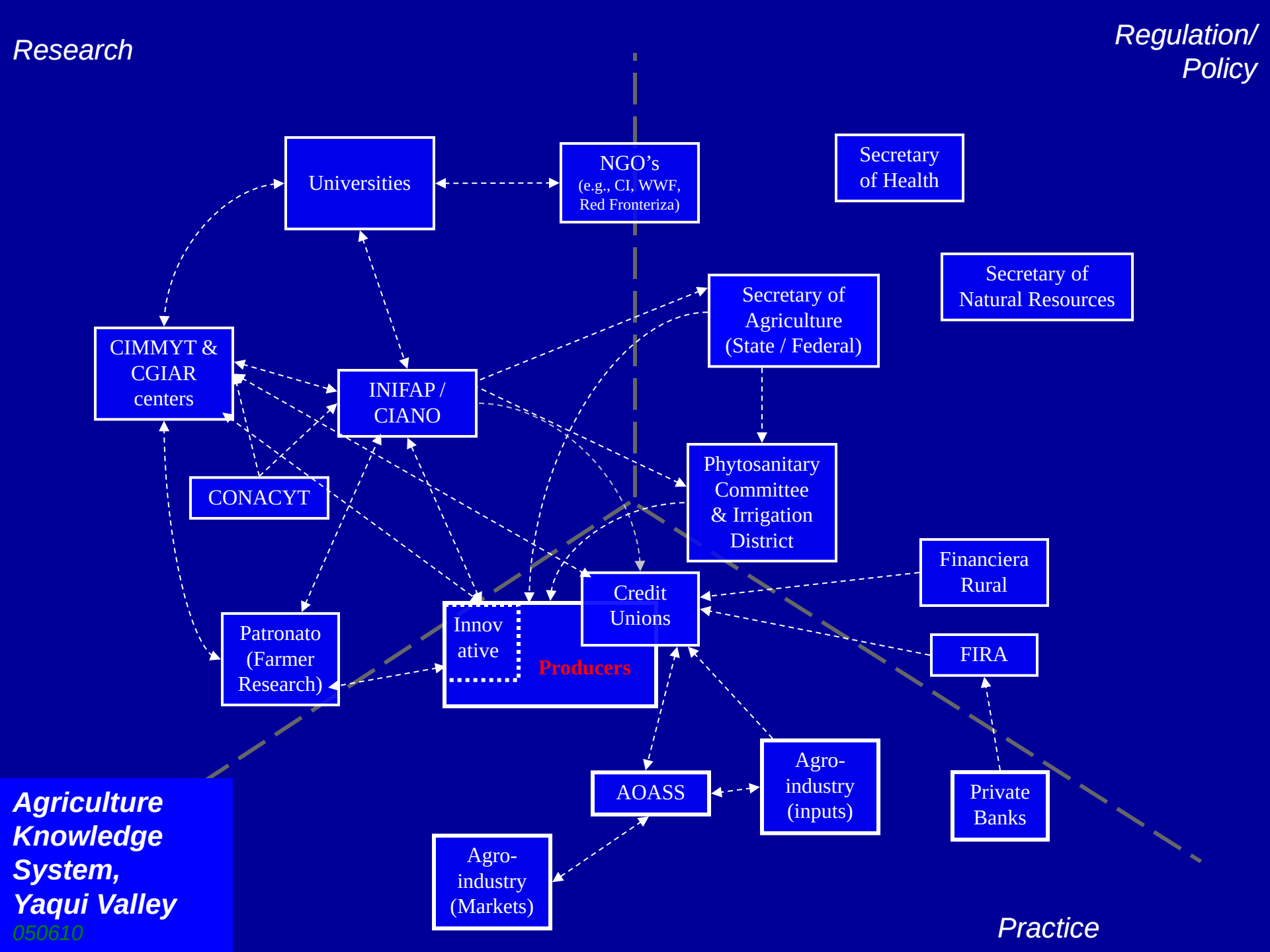
Knowledge --> action???



Agriculture Knowledge System, Yaqui Valley

050610

Practice



Agriculture Knowledge System, Yaqui Valley

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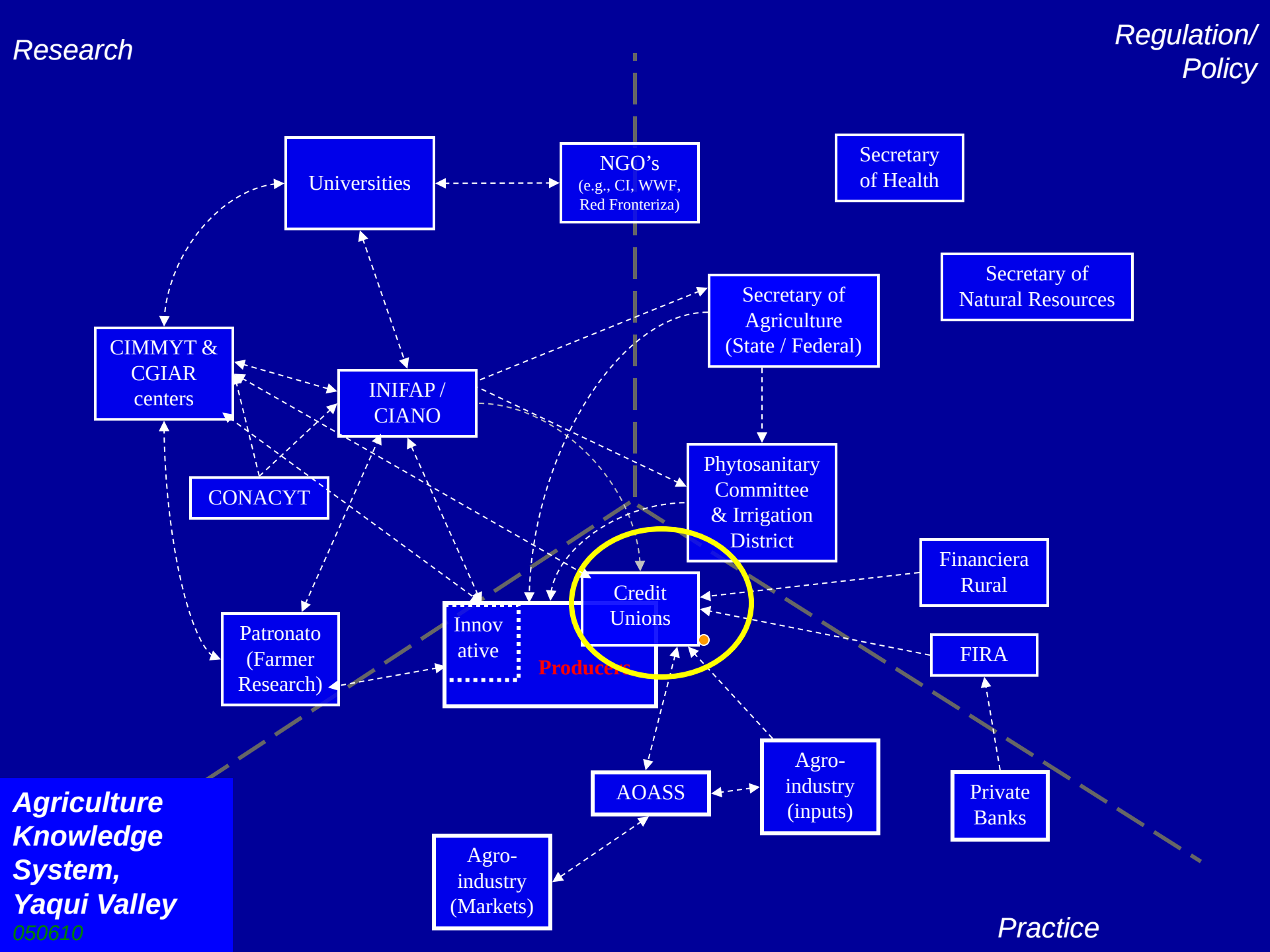
Research
Regulation/ Policy
Universities
NGO's (e.g., CI, WWF, Red Fronteriza)
Secretary of Health
Secretary of Natural Resources
Secretary of Agriculture (State / Federal)
CIMMYT & CGIAR centers
INIFAP / CIANO
CONACYT
Phytosanitary Committee & Irrigation District
Financiera Rural
Credit Unions
Innov ative
Producers
Patronato (Farmer Research)
FIRA
AOASS
Agro-industry (inputs)
Private Banks
Agro-industry (Markets)
Practice
Agriculture Knowledge System, Yaqui Valley
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What drives fertilizer management decisions?

credit union advice --

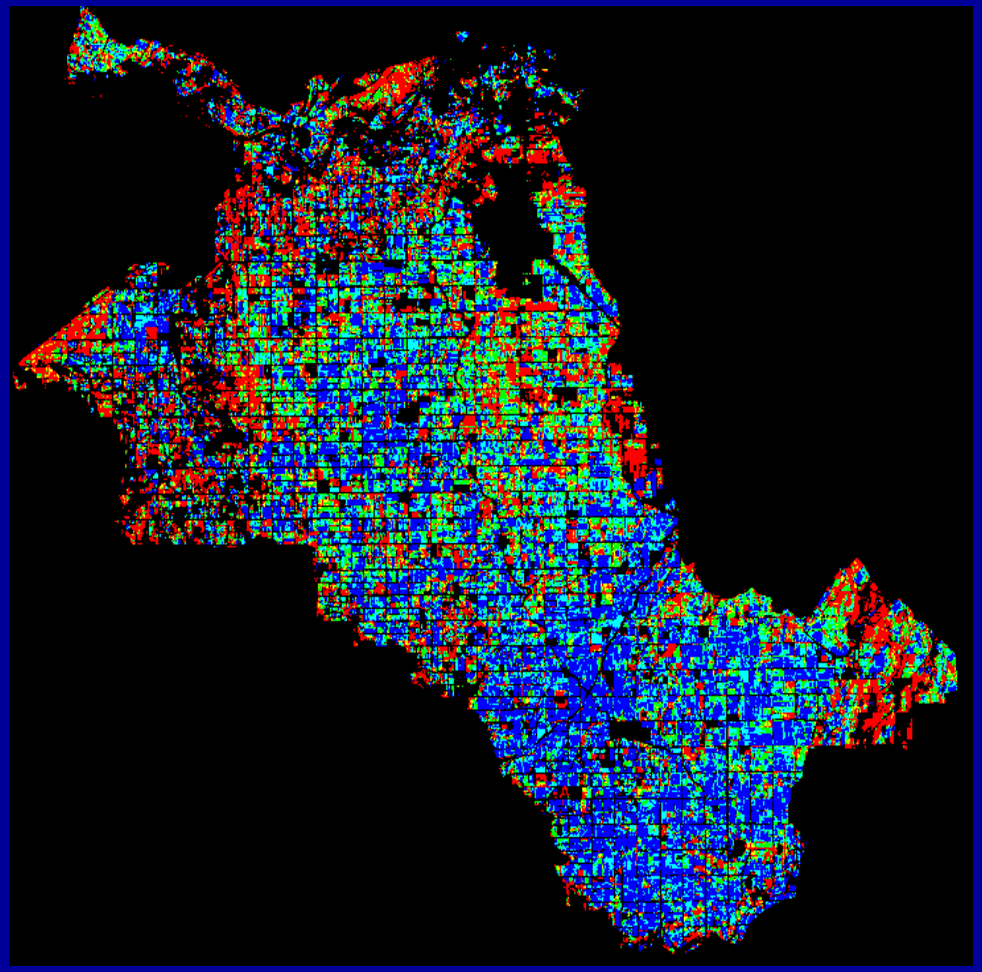
And risk aversion under uncertainty due to variability

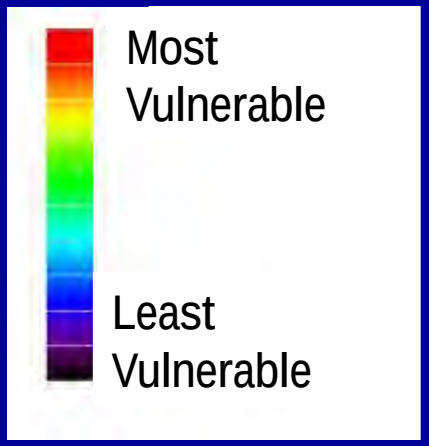
Reduce fertilizer use by reducing uncertainty… and work with farmers <u>and</u> credit union advisors to test and incorporate new approaches.

Real-time measurements of plant N relative to fertilized strips

Ortiz Monasterio et al.

Vulnerability of Wheat Yield to Temperature Variability and Change





$$V = \int \frac{|\delta Y/\delta t|}{|Y/Yo|} Pt\, dt$$

WHERE

Y = Yield

t = temperature

Pt = Probability of temperature

Luers, A.L., D. Lobel, L.S. Sklar, C.L. Addams , P.A. Matson. *Global Environmental Change*, 2003

Sustainability Challenges in the Yaqui Valley Human-Environment System

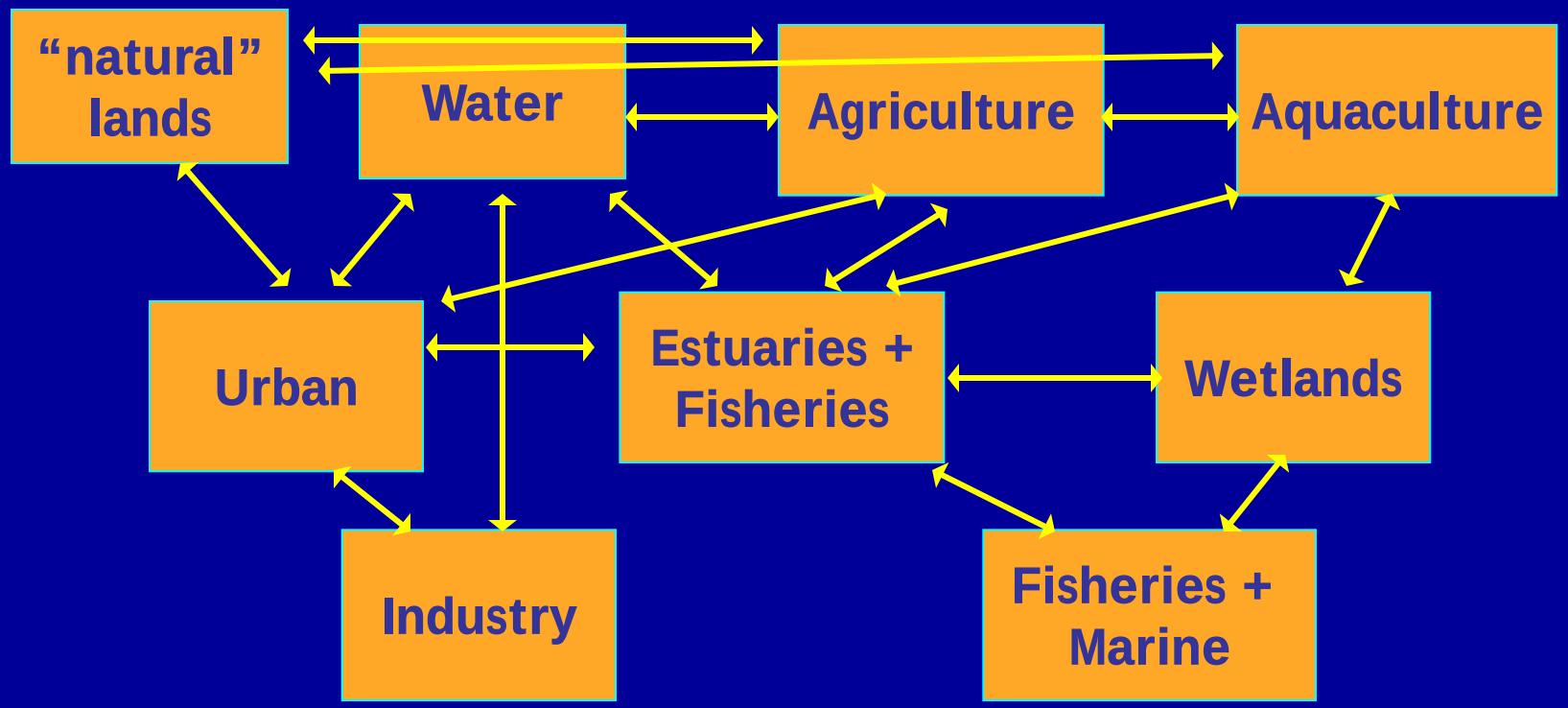
Trop ozone Δ
CO2 Δ

Climate Δ
(sea level, temp, precipitation)

Policies Δ

Technology & Markets Δ

Resources Δ



Note: institutions for each ▢, but no institutions for integrated system

1992

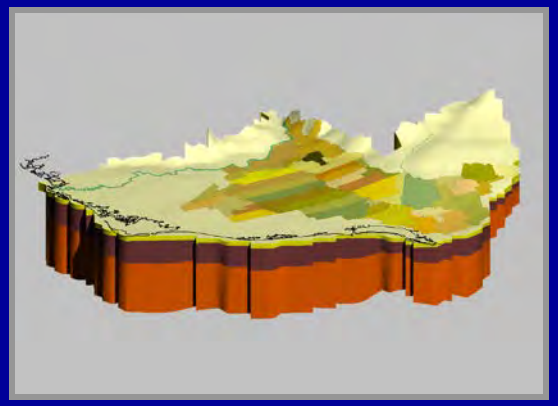
2003

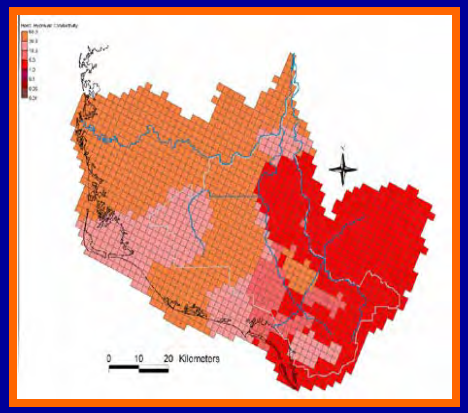
Water Resources in the Yaqui Valley

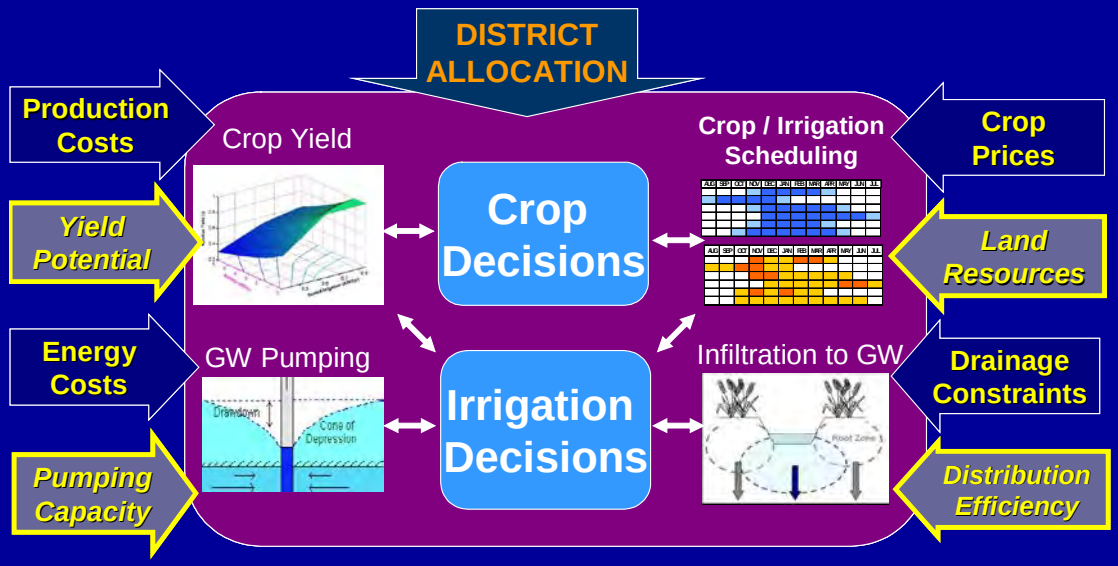
Aquifer vs reservoir use?
Climate history -- how frequent are droughts?
Sustainable management of water resources?

Jose Luis Minjares
Lee Adamms
Steve Gorelick
Wally Falcon
David Battiste

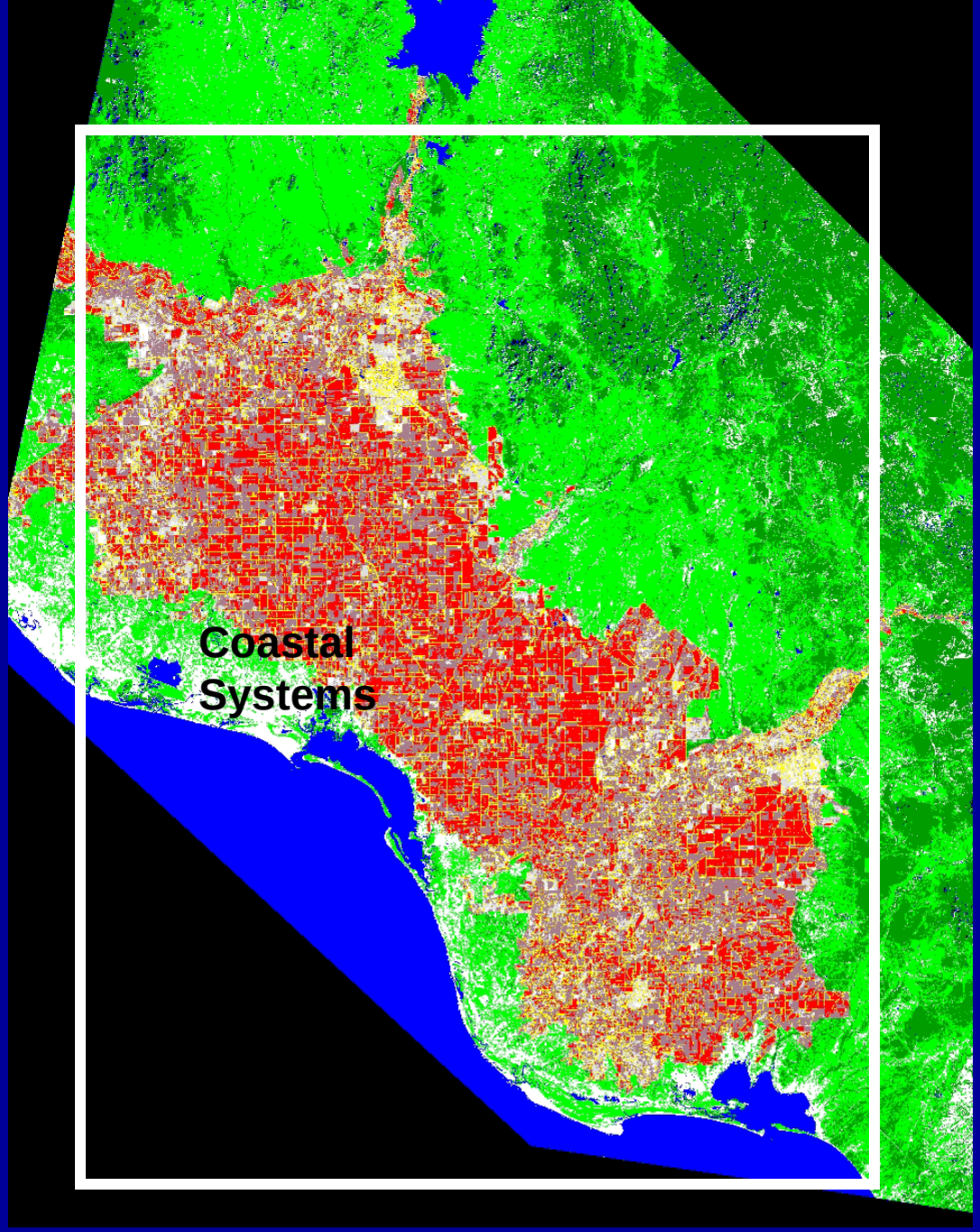
Reservoir and Aquifer Allocation Models for Sustainable Water Use



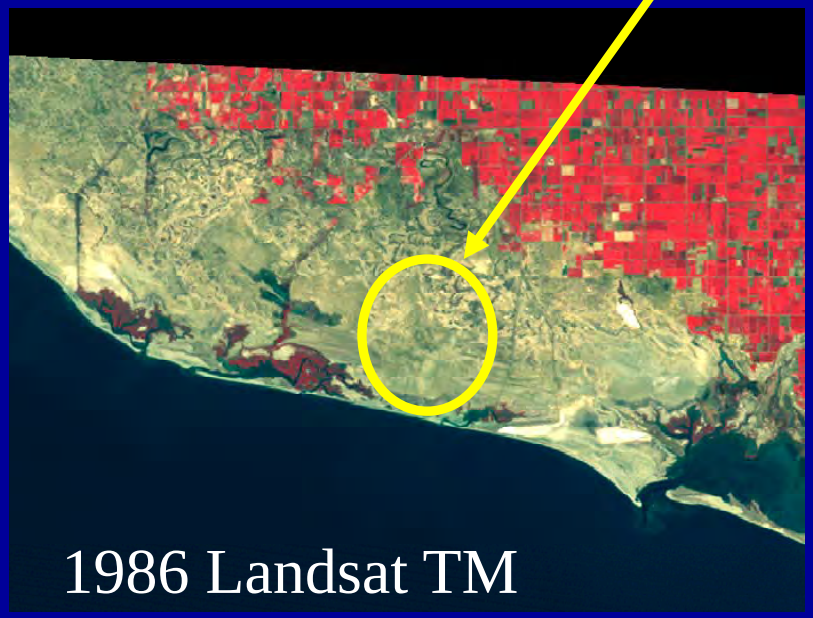




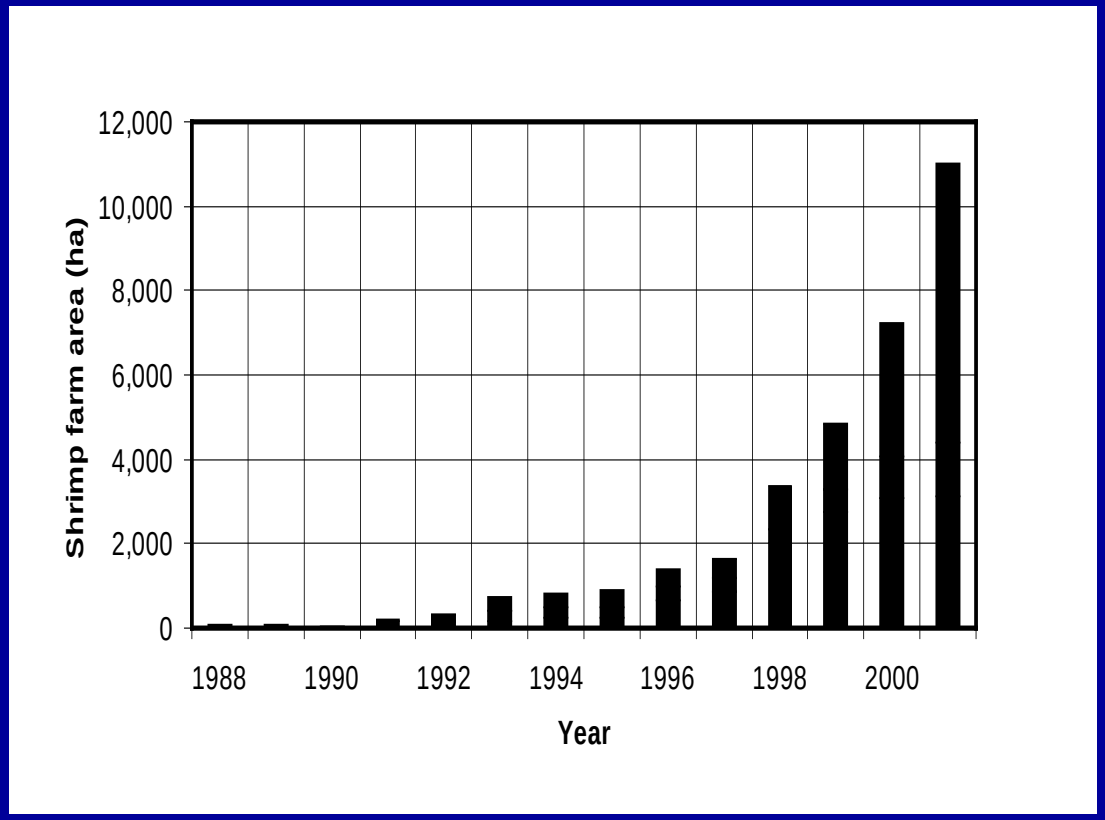
Lee Adamms Steve Gorelick, Wally Falcon (Stanford) and Jose Luis Minjares (CNA)


Coastal
Systems

Shrimp farm development



Shrimp Aquaculture in Southern Sonora



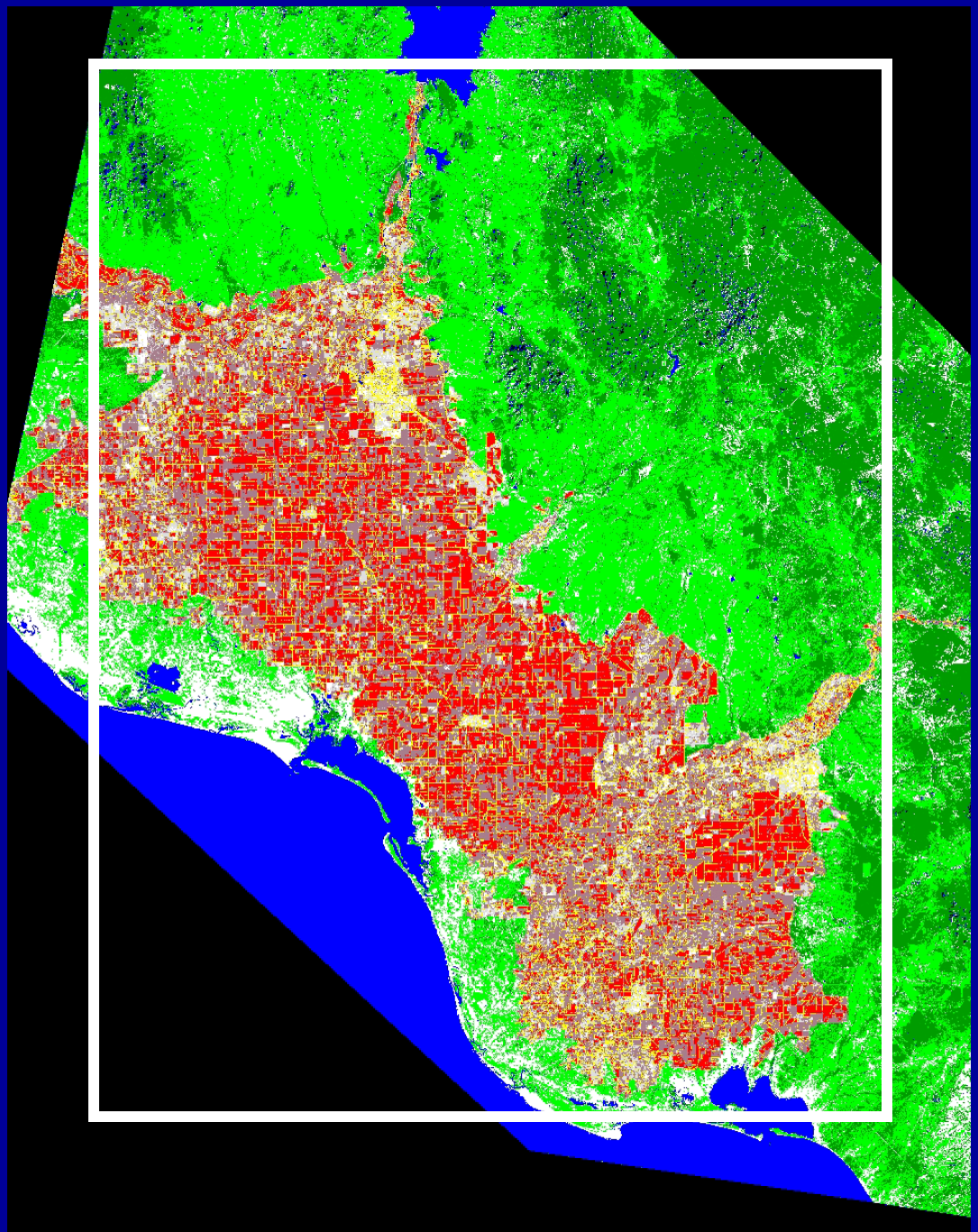
Government program

- 1988 PAIS

National policy

- 1986 Fishing Law
- 1992 Fishing Law
- 1992 Article 27 (Agrarian Reform)

Source: Luers et al. YEAR and field surveys 2001



Our integrated research perspective?

A sustainability perspective

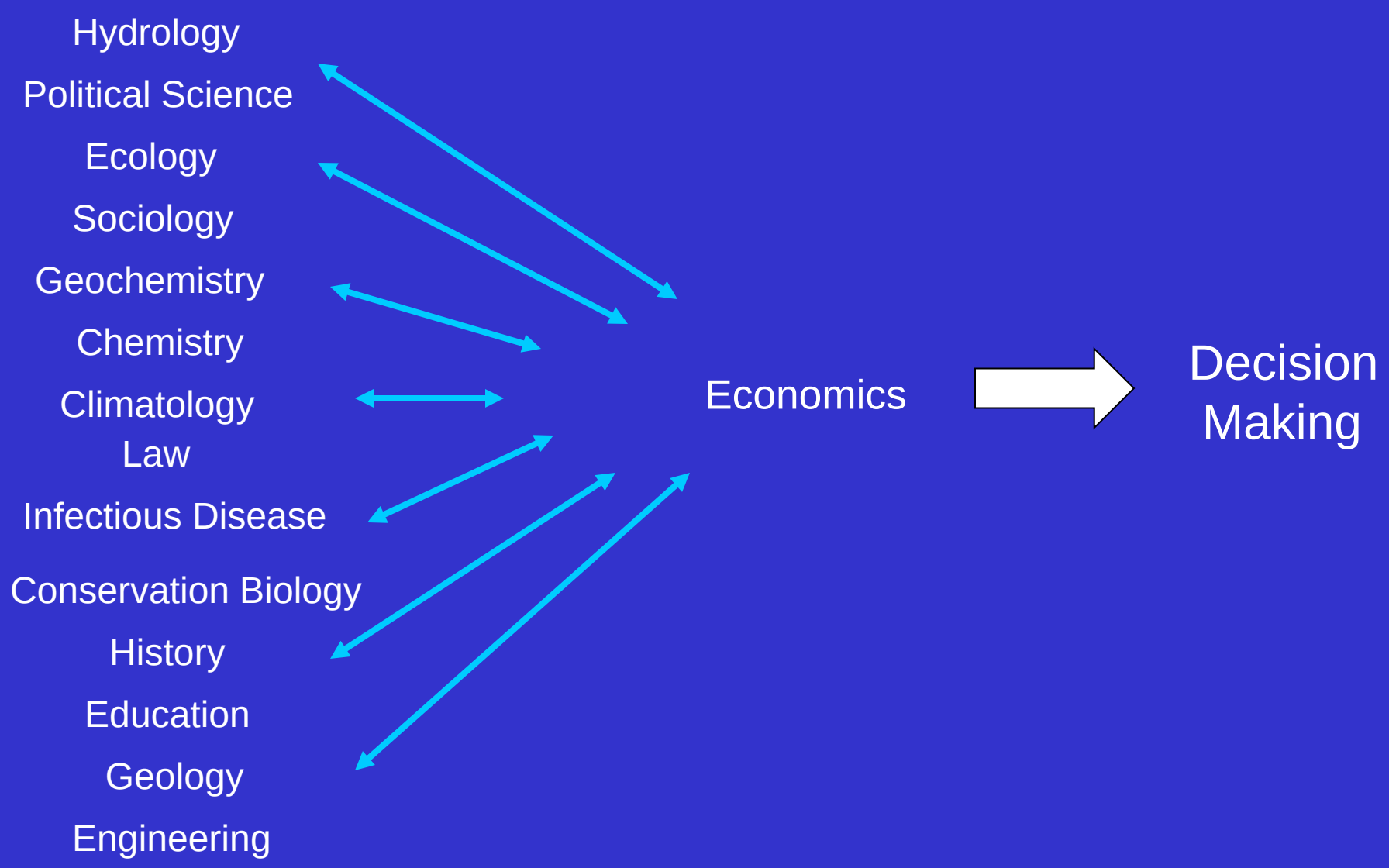
Meeting the needs of people

and

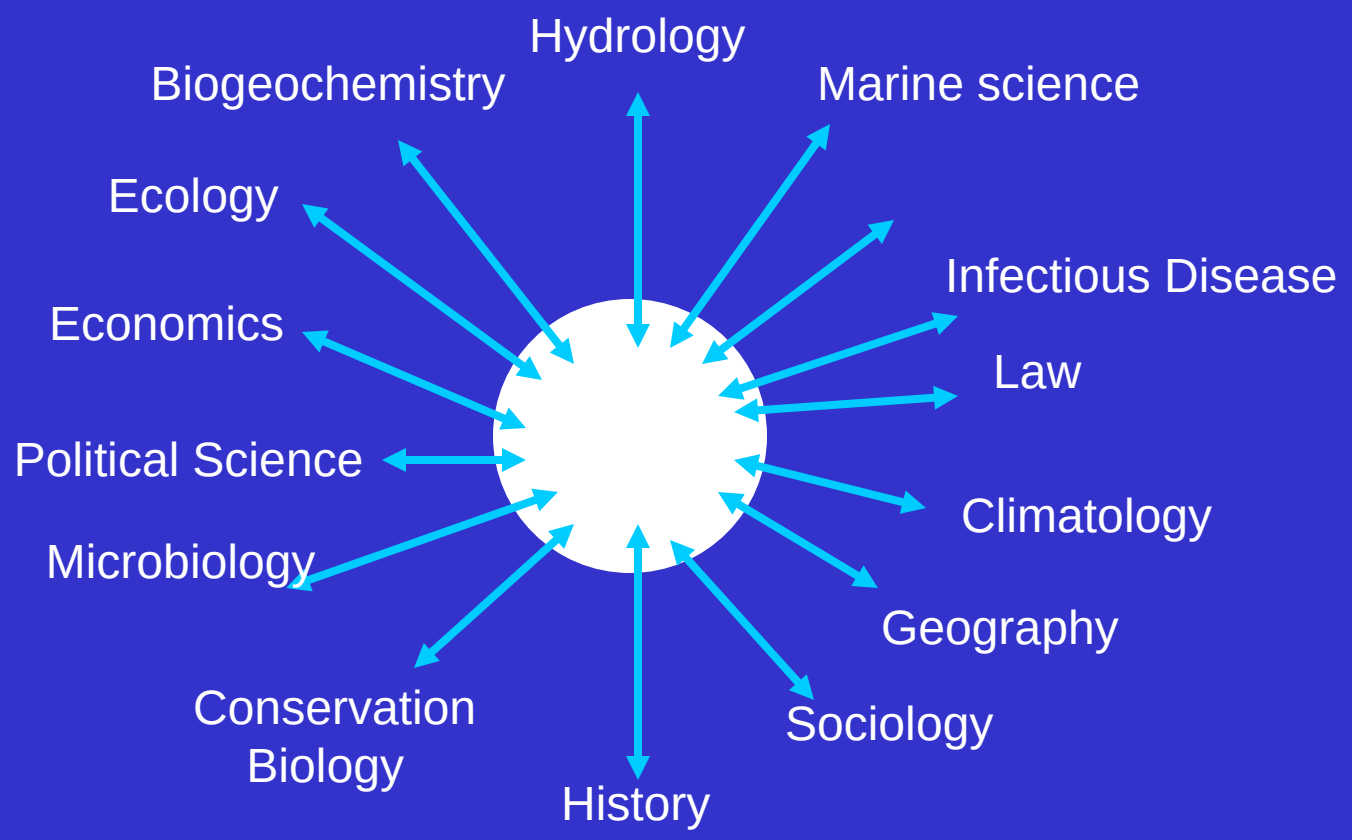
Sustaining atmosphere, water, climate and species and ecosystems

Lesson 1 -- Interdisciplinary research takes extra time and “matrix” money

Models for Interdisciplinary Research



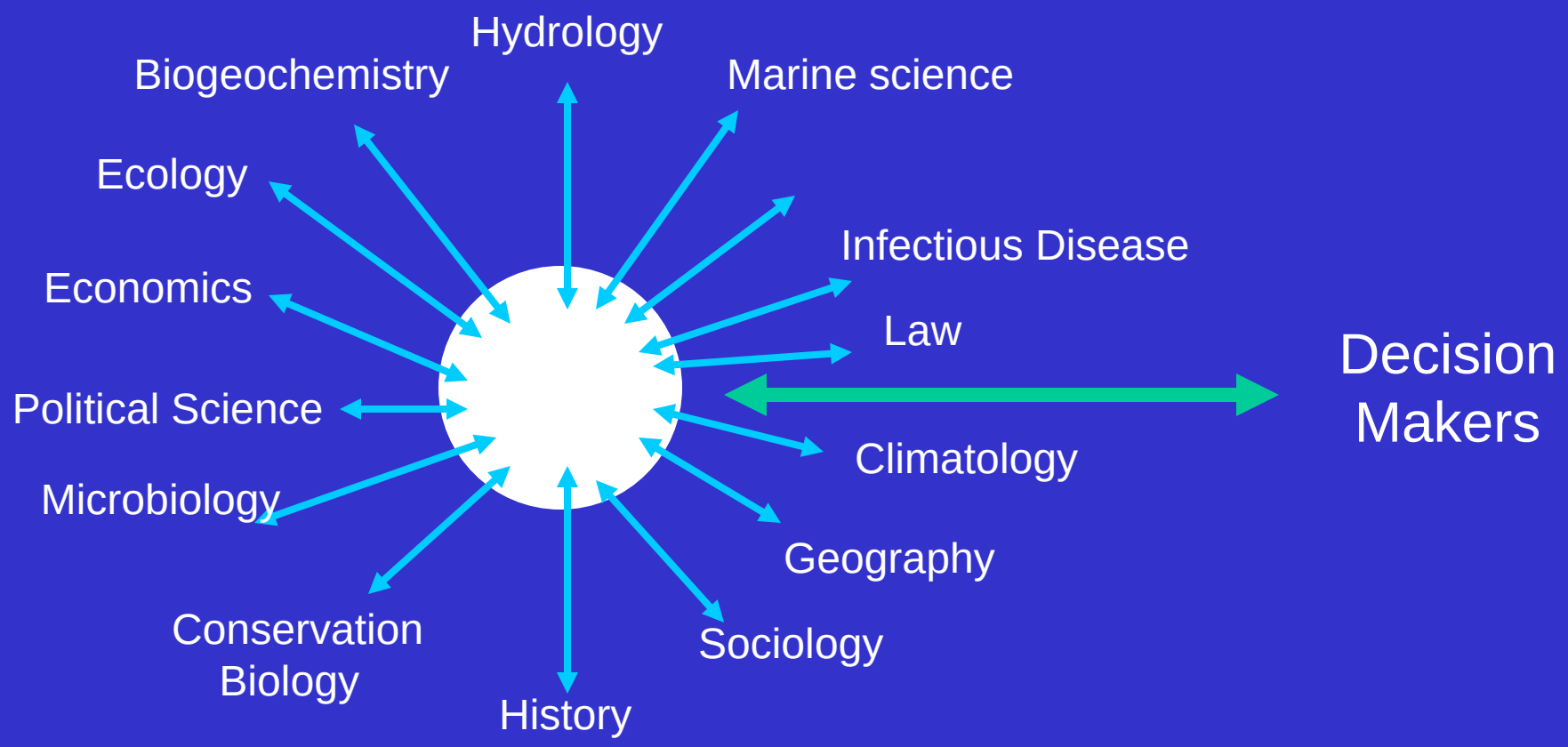
Yaqui Valley Project's Model



Decision Makers

Yaqui Valley Project's Model

for knowledge to action



Interdisciplinary research, focused on problems,
in dialog or partnership with decision makers and linking orgs

Lesson 2 -- a different kind of research

Decision makers

Improved
understanding

Existing
understanding

(modified from Stokes, 1997)

Decision Makers

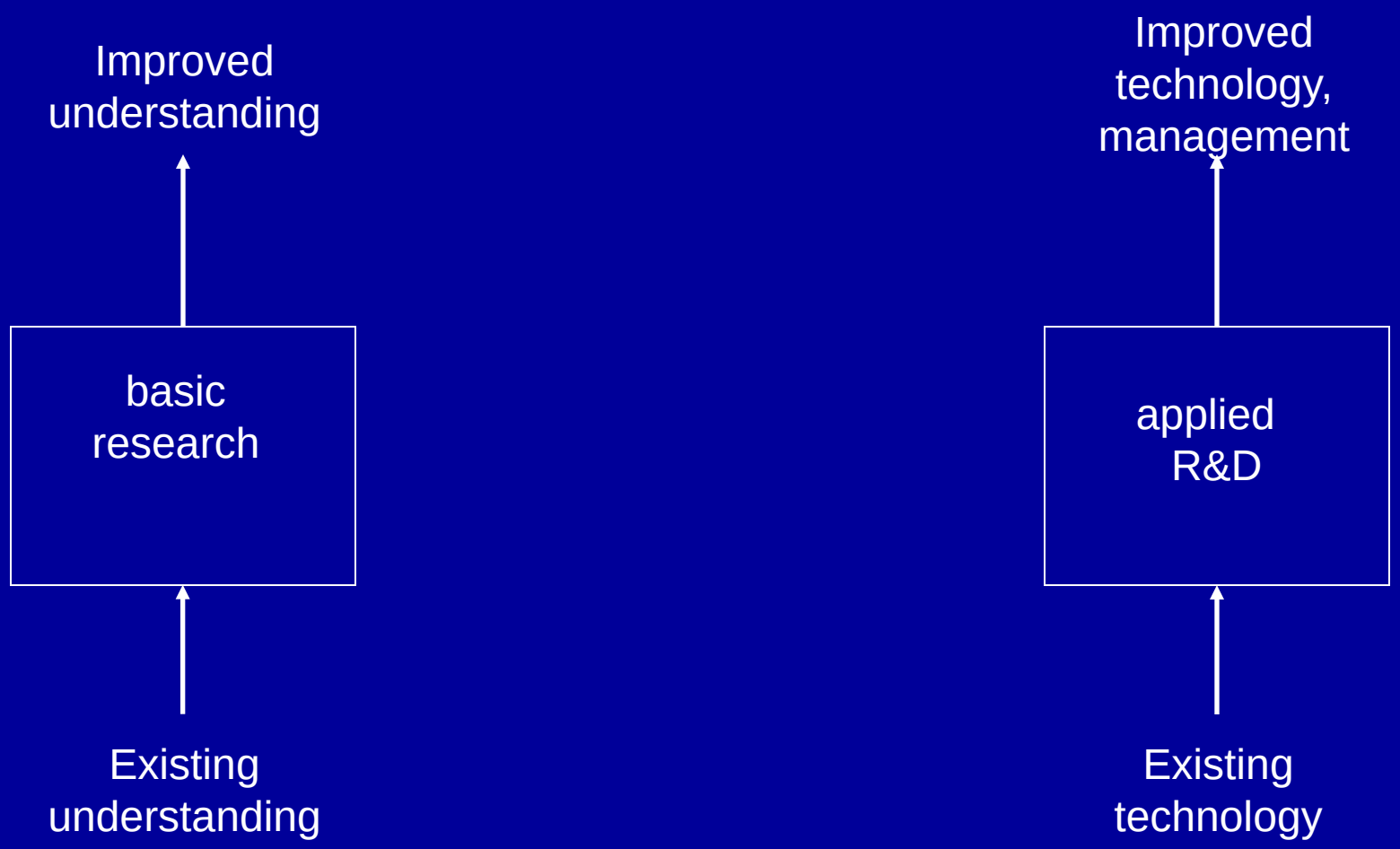
Improved
understanding

Improved
technology,
management

Existing
understanding

Existing
technology

(modified from Stokes, 1997)



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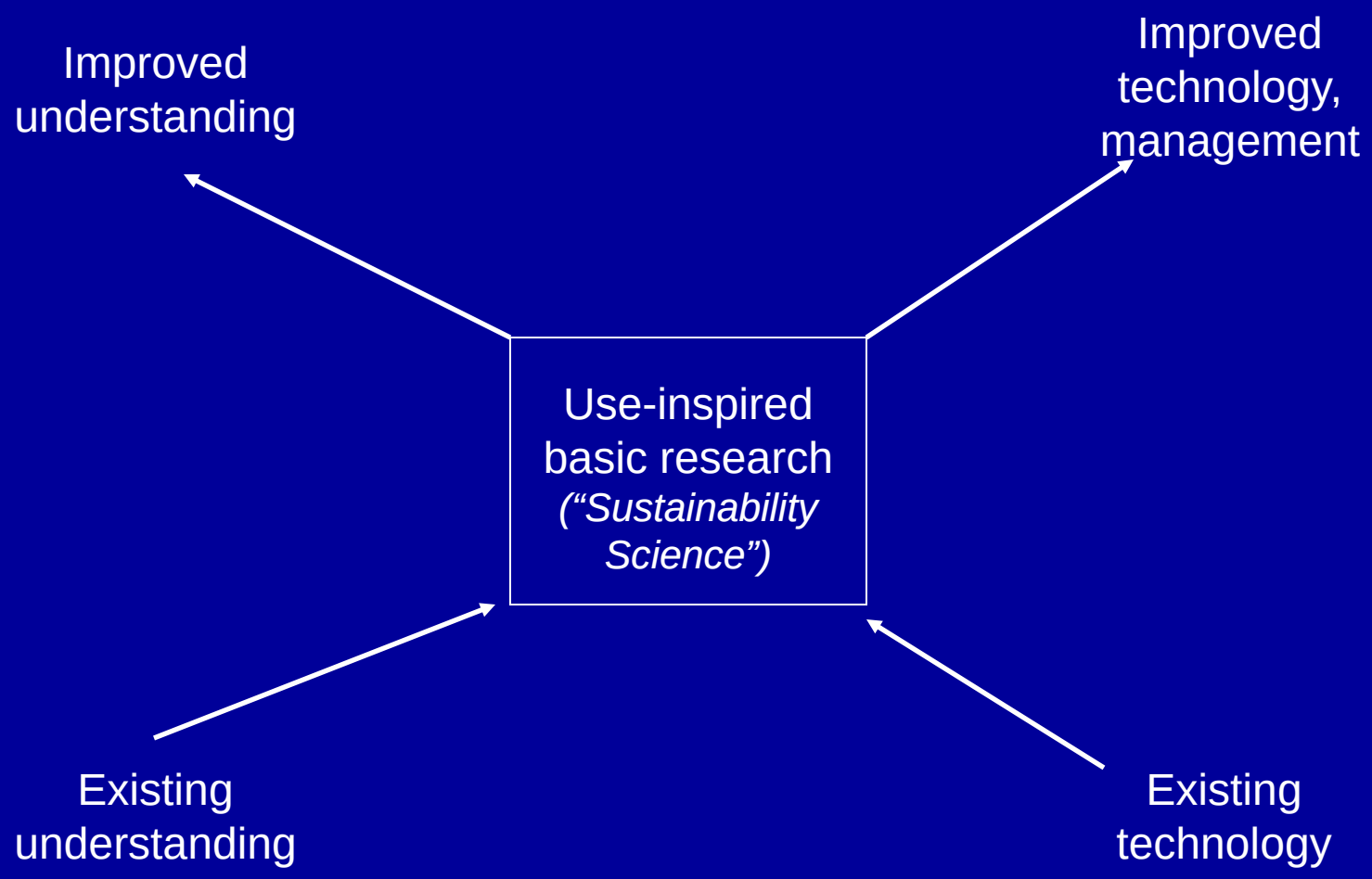

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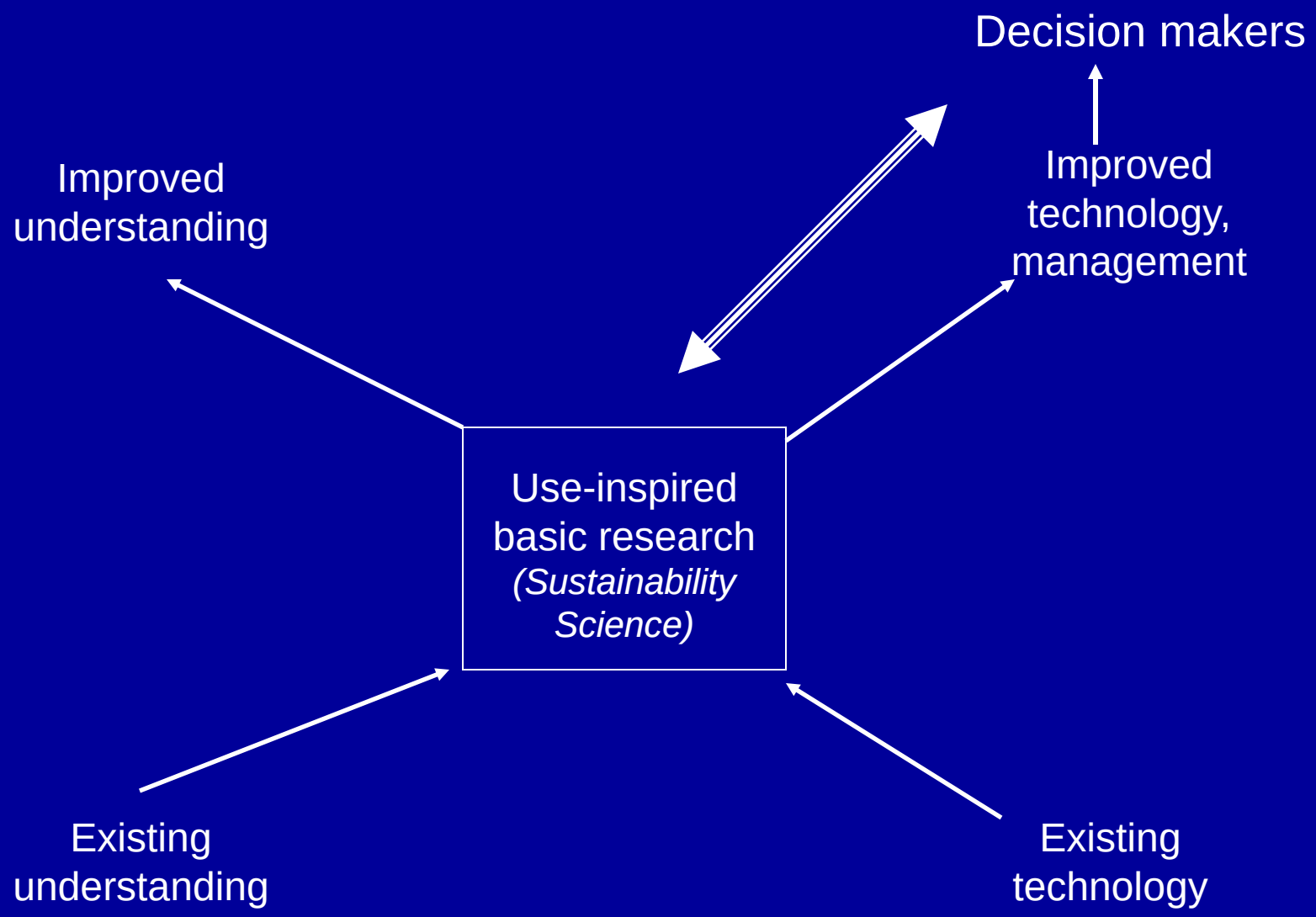
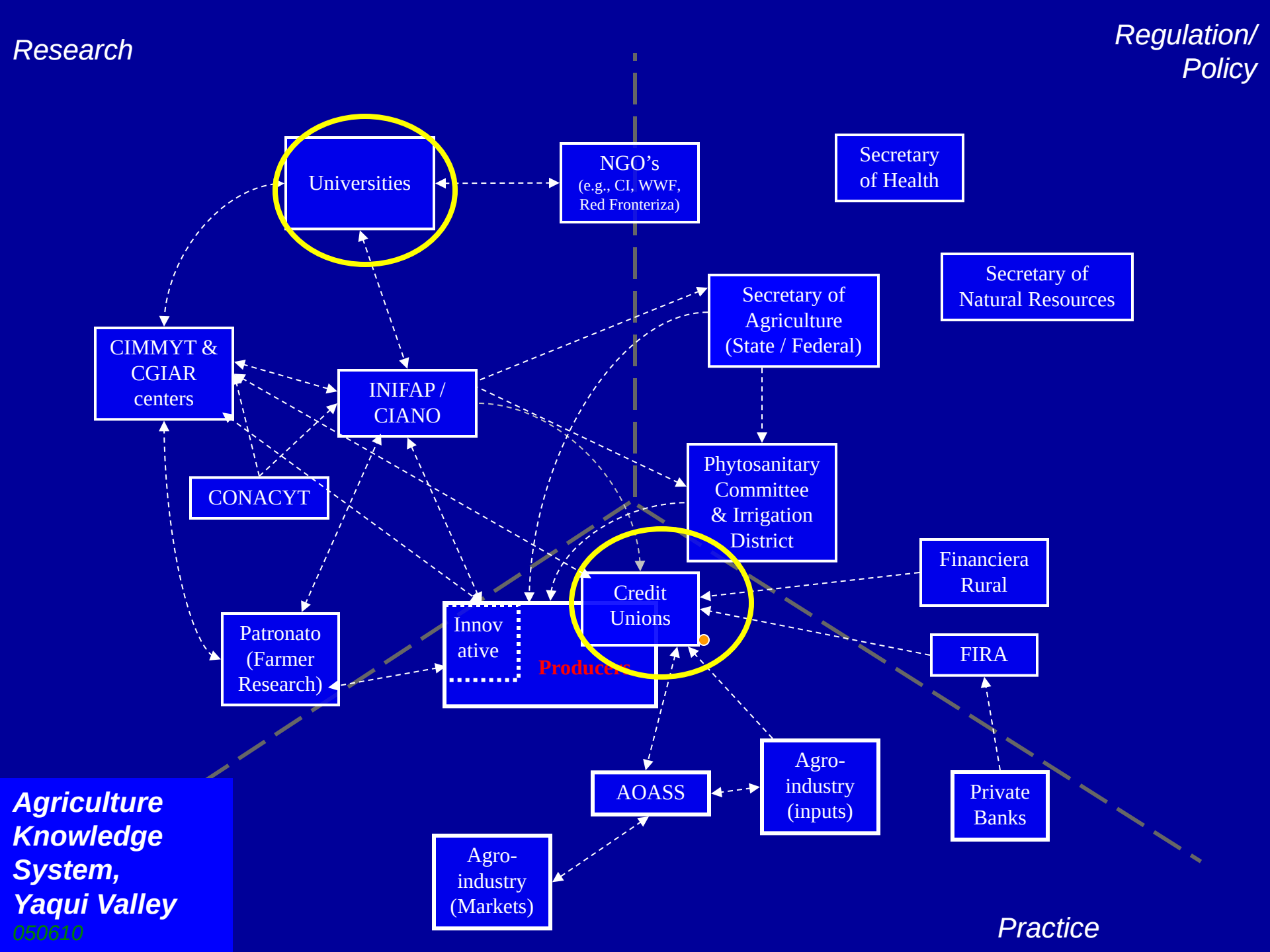


(modified from Stokes, 1997)

Lesson 3 -- Understanding the knowledge system is critical if we want to link knowledge to action


Research
Regulation/ Policy
Universities
NGO's (e.g., CI, WWF, Red Fronteriza)
Secretary of Health
Secretary of Natural Resources
Secretary of Agriculture (State / Federal)
CIMMYT & CGIAR centers
INIFAP / CIANO
CONACYT
Phytosanitary Committee & Irrigation District
Financiera Rural
Credit Unions
Innov ative
Producers
Patronato (Farmer Research)
FIRA
AOASS
Agro-industry (inputs)
Private Banks
Agro-industry (Markets)
Practice
Agriculture Knowledge System, Yaqui Valley
050610

Linking Knowledge to Action
("Knowledge Systems for Sustainability"):

1) Gap between what decision makers want from S&T and what S&T is offering ⇒

2) In effective knowledge systems, the problem to be solved is defined in a collaborative but ultimately user-driven manner ⇒ Need to foster institutions and procedures for initiating and sustaining such dialogues

…cont'd

Knowledge Systems - Common Themes

3) Need "supply chain" perspectives on the design of decision support systems

4) "Boundary organizations" that link the R&D community to decision making community are critical (must be trusted, credible, legitimate)

What will it take for a transition to sustainability?

- integrative knowledge, tools, approaches
- purposeful linking of knowledge to action

What will it take for a transition to sustainability?

- integrative knowledge, tools, approaches
- linking knowledge to action
- learning from experience
- public understanding
- new ethics
- hope, inspiration, and motivation
- the will to change
- leadership by corporations, citizens, governments, non-profits, universities…

Major Funding for the Yaqui Project

USDA - Ag fertilization and GHG
NASA - Drivers and consequences of Land Use Change
Packard Foundation - Integrated Land-Sea interactions
Packard Foundation - Sustainability in Yaqui
NSF - Vulnerability in human-environment systems
NOAA - Knowledge Systems for Sustainable Development
Ford Foundation - Ag Development in Latin America
Bechtel Foundation (Stanford) - Integrated Studies in Yaqui
Rockefeller, MacArthur and other Foundations
Graduate student fellowships (NSF, NASA, EPA, Switzer, Stanford Graduate Fellowships, etc)

How can universities encourage interdisciplinary research focused on problem solving as well as new understanding?

- Encouragement and valuing of collaborative, interdisciplinary research
- Innovation research funds
- Awards and rewards
- Lower barriers across disciplines or units
- Encourage “uncommon dialogues”
- Educational opportunities
- Research on how we learn and work interdisciplinarily
- For tenure evaluation, an interdisciplinary community
- Help create new publication venues

Quadrant Model of Scientific Research

Research inspired by...		Considerations of use? No	Considerations of use? Yes
Quest for fundamental understanding?	No		Pure applied research (Edison)
	Yes	Pure basic research (Bohr)	*Use-inspired basic research (Pasteur)*

(redrawn from Stokes, 1997)