Transitioning Cereal Systems to Adapt to Climate Change

November 13-14, 2015

Funded through Award #2011-68002-30191 from USDA National Institute of Food and Agriculture

Assessing How Agronomic and Economic Adaptations Affect Vulnerability to Climate Change

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REACCH Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

AgMIP The Agricultural Model Intercomparison and Improvement Project

Oregon State UNIVERSITY OSU

Acknowledgements

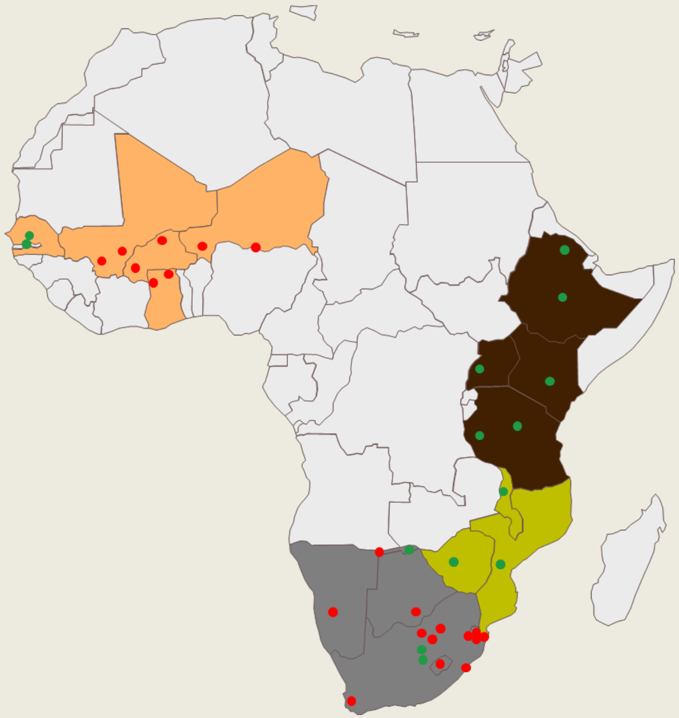
- REACCH project & collaborators, USDA-NIFA
- AgMIP project & collaborators
- UKAID (DFID)

Themes

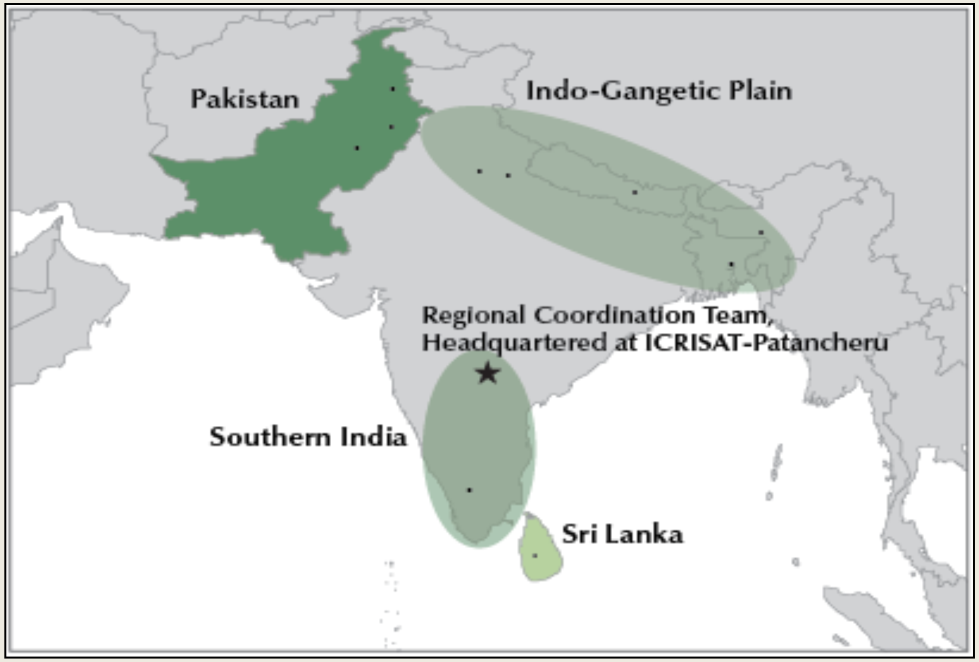
- AgMIP & REACCH projects
- The AgMIP RIA Method
- Adaptation: methodological challenges
- Linking agronomic & economic models for adaptation analysis
- The way forward: CGRA

AgMIP Regional Climate Change Impact Assessment Teams

5-year project, DFID funded
8 regional teams, 18 countries, ≈ 200 scientists
Data, models, scenarios designed & implemented by multi-disciplinary teams & stakeholders

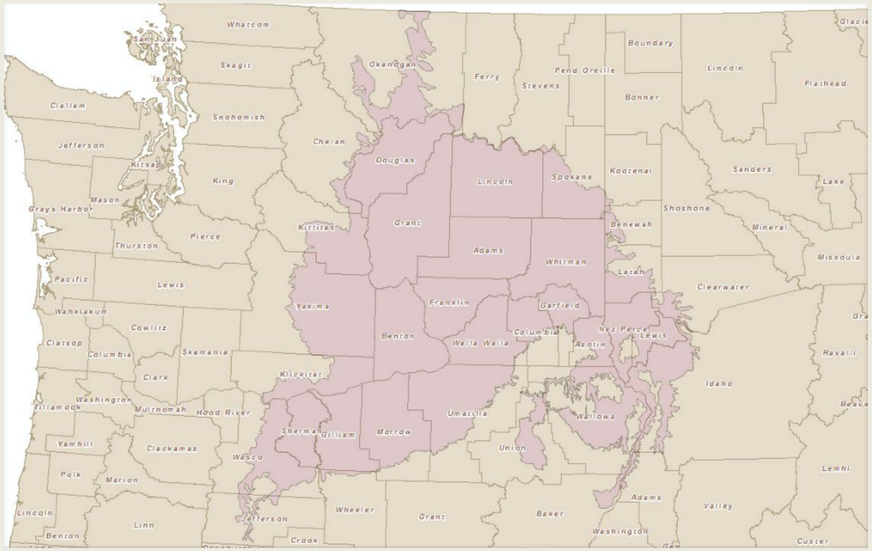


Small-scale, mixed crop and crop-livestock systems; principal crops vary by region (maize, millet/peanut, rice, wheat) typical of “semi-subsistence agriculture”



For the AgMIP story (agmip.org):

REACCH - Regional Approaches to Climate Change in Pacific Northwest Agriculture



5-year project funded by USDA-NIFA
University of Idaho
Oregon State University
Washington State University
USDA-ARS
+ 100 scientists & students

Large-scale wheat-fallow and annual cropped systems typical of "industrial commodity agriculture"

Stakeholders: the climate is changing, what to do?

What will African, US ag be in 2030, 2050?

How can they be improved in the face of climate, technological & many other changes?

Eastern Uganda

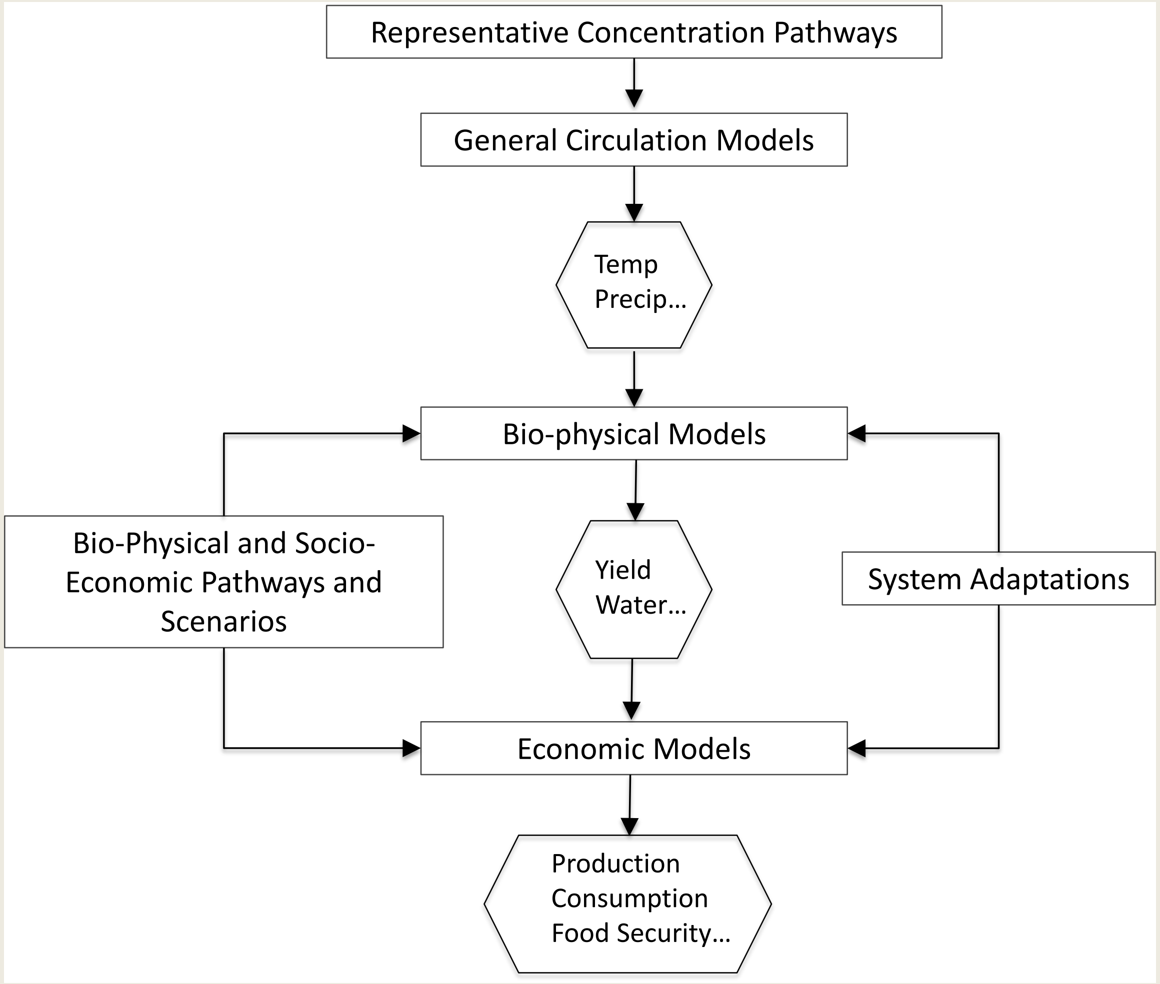
Northwest USA

Adaptation Concepts and Challenges

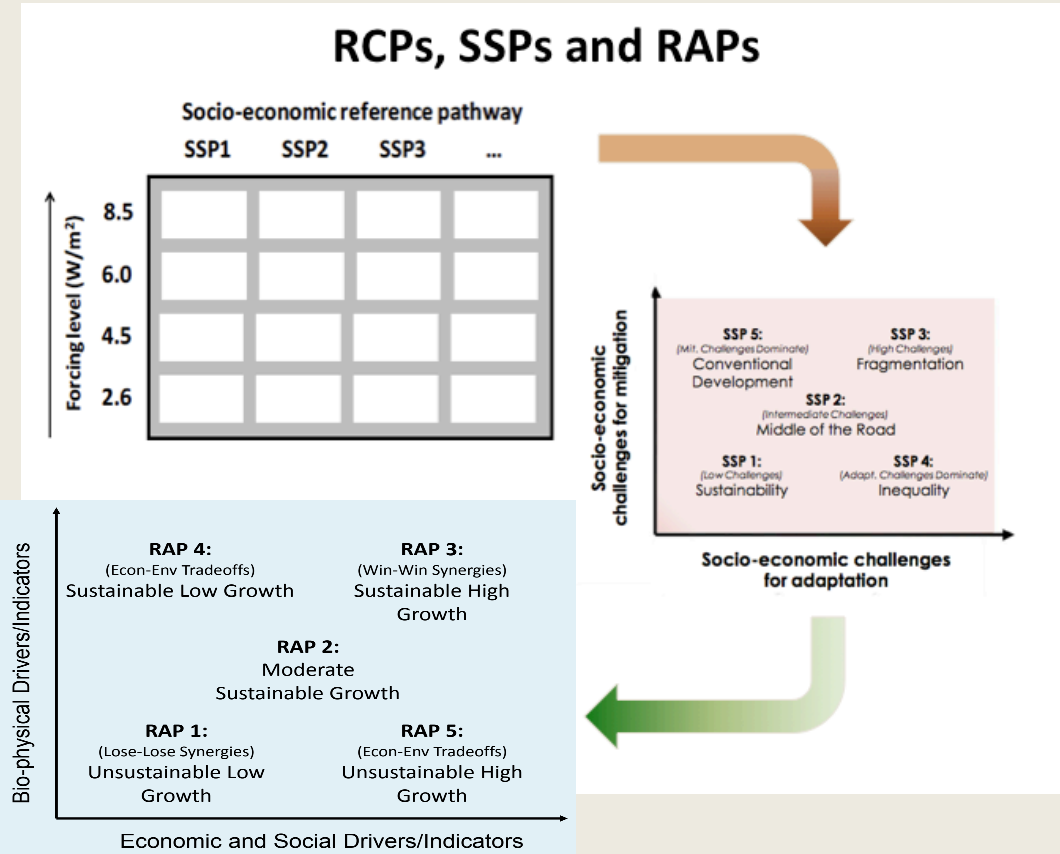
- Natural, autonomous, planned
- Agronomic
- Behavioral
- Economic & Social
- Institutional
- Within-system (short-run)
- Between system (long-run)

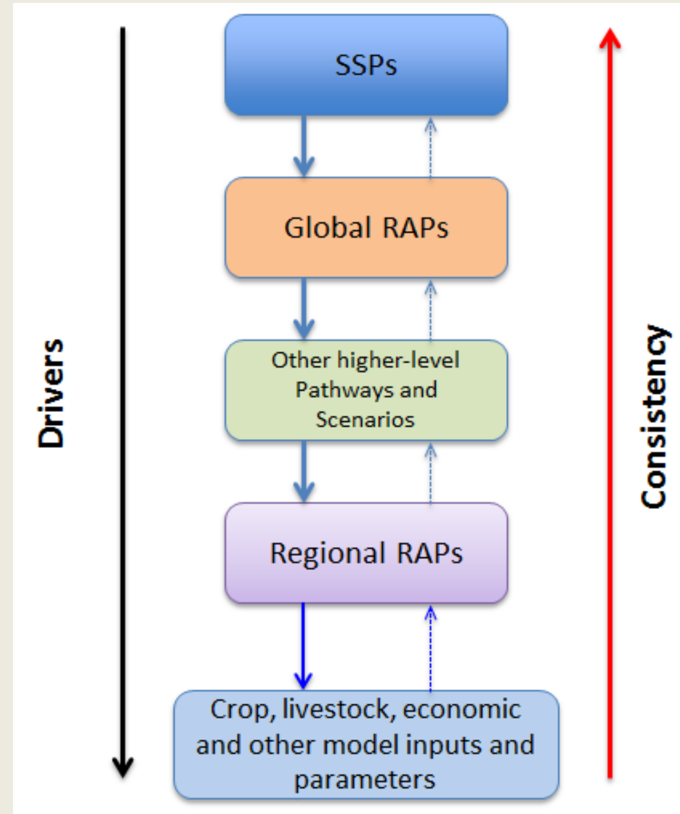
⇒ Need an analytical framework to evaluate **benefits of adaptation distinct from climate impact**

Integrated Assessment Framework: system adaptations evaluated in context of climate and other system changes



Looking Forward: Pathways and Scenarios

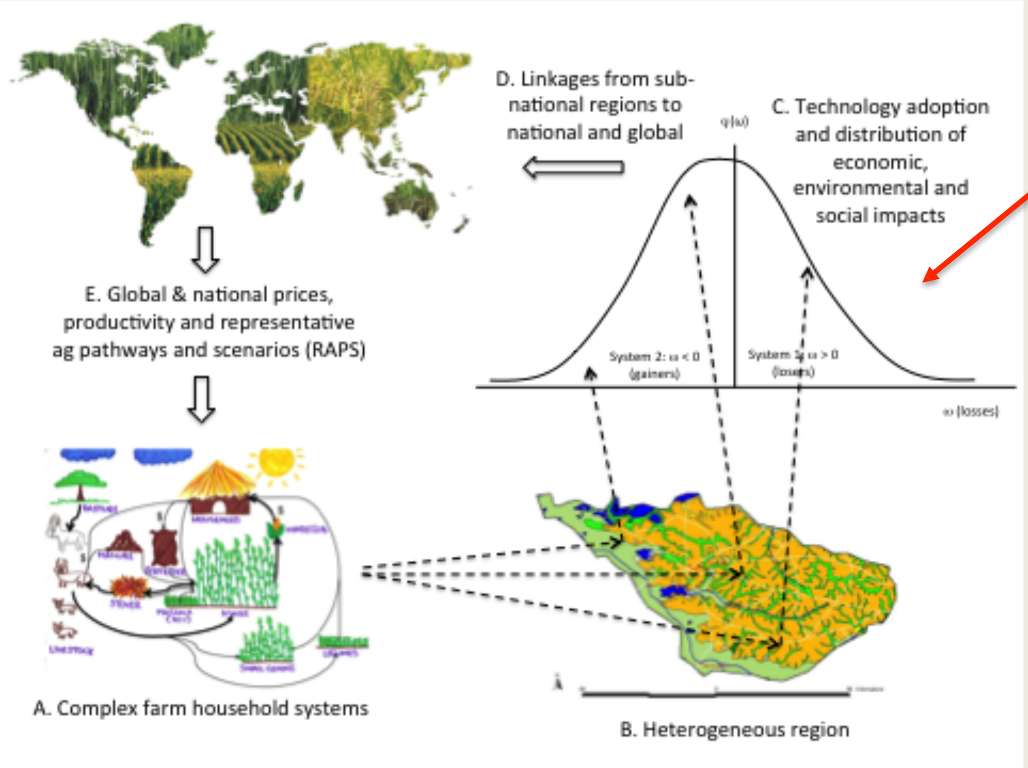




Valdivia, R.O., J.M. Antle, C. Rosenzweig, A.C. Ruane, J. Vervoort, M. Ashfaq, I. Hathie, S. Homann-Kee Tui, R. Mulwa, C. Nhemachena, P. Ponnusamy, H. Rasnayaka and H. Singh. (2015). Representative Agricultural Pathways and Scenarios for Regional Integrated Assessment of Climate Change Impact, Vulnerability and Adaptation. C. Rosenzweig and D. Hillel, eds. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments, Part 1.* London: Imperial College Press.

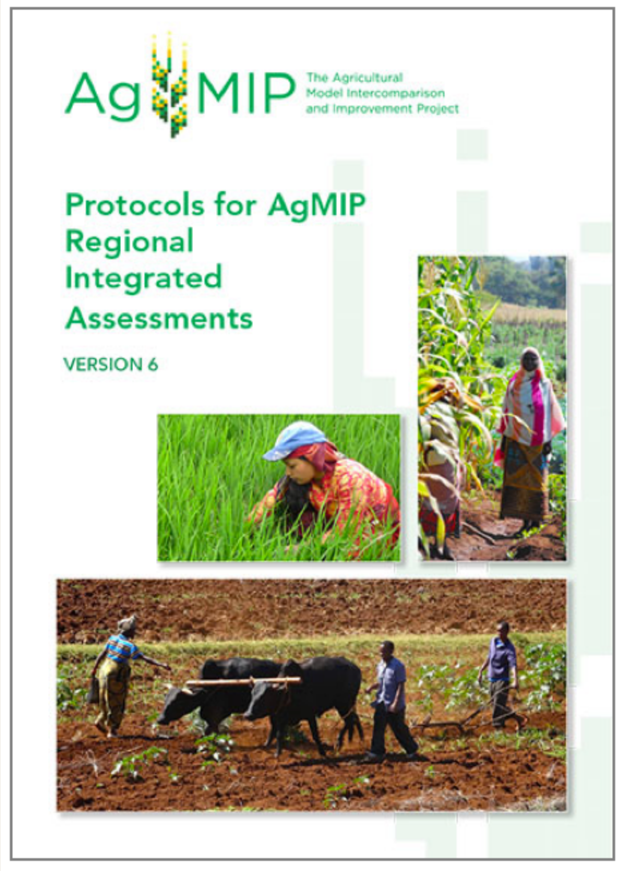
Impact, Adaptation & Vulnerability of Ag Systems:

AgMIP Regional IA Methods (http://www.agmip.org/regional-integrated-assessments-handbook/#)

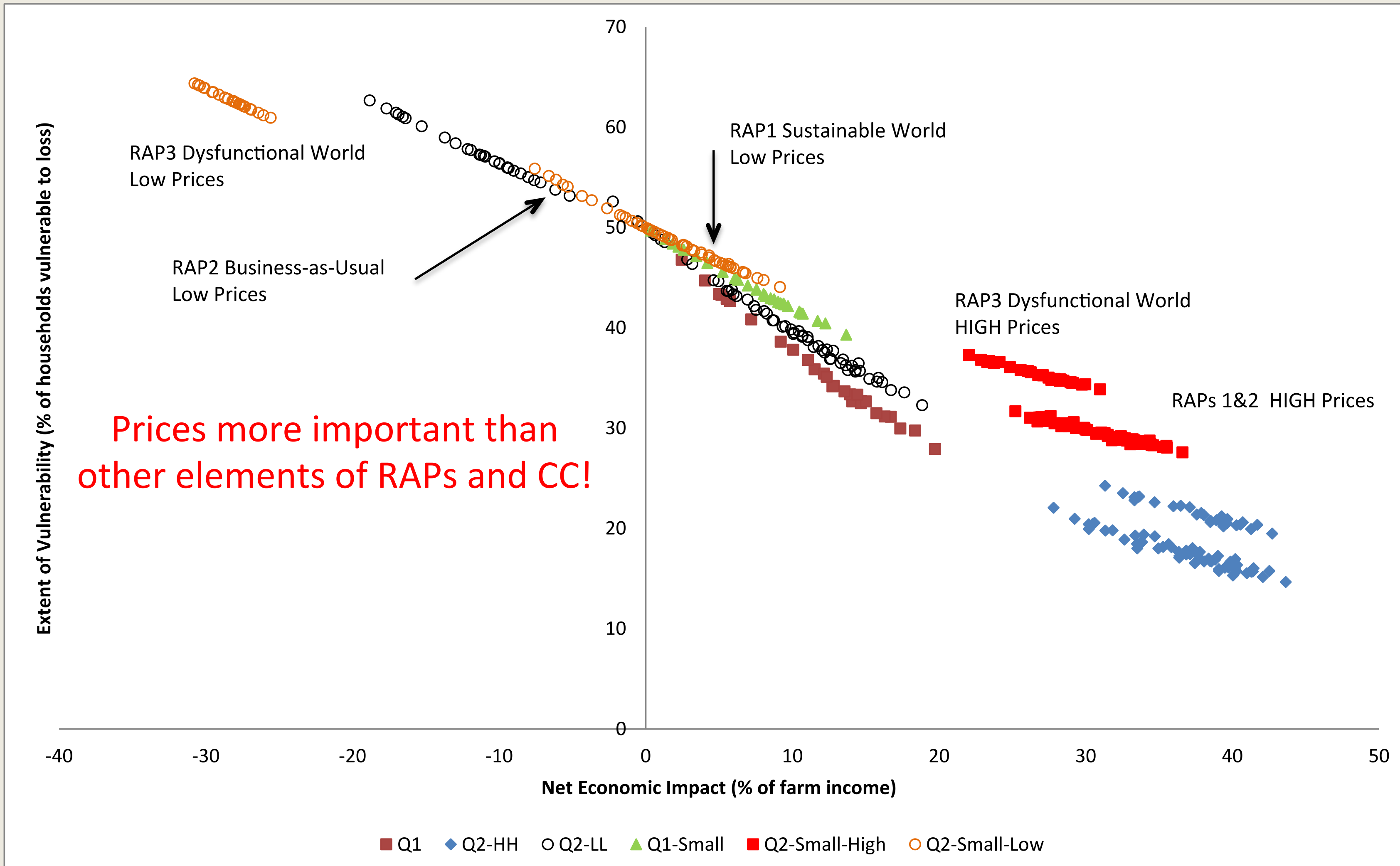


Vulnerability = risk of loss

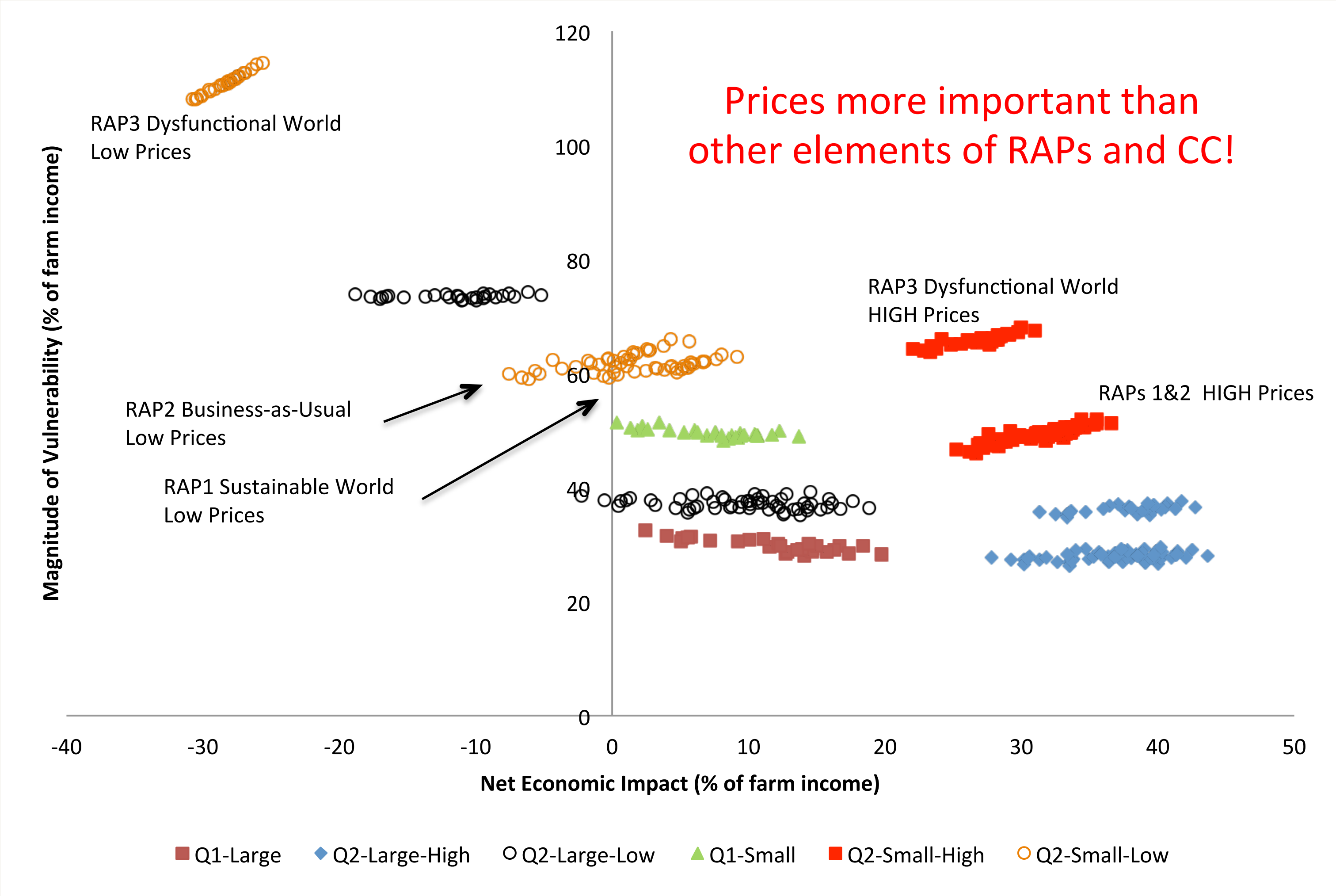
Antle, J. M., R.O. Valdivia, K.J. Boote, S. Janssen, J.W. Jones, C.H. Porter, C. Rosenzweig, A.C. Ruane, and P.J. Thorburn. (2015). AgMIP's Trans-disciplinary Agricultural Systems Approach to Regional Integrated Assessment of Climate Impact, Vulnerability and Adaptation. C. Rosenzweig and D. Hillel, eds. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments, Part 1.* London: Imperial College Press.



REACCH Project: Extent of vulnerability (loss) without adaptation



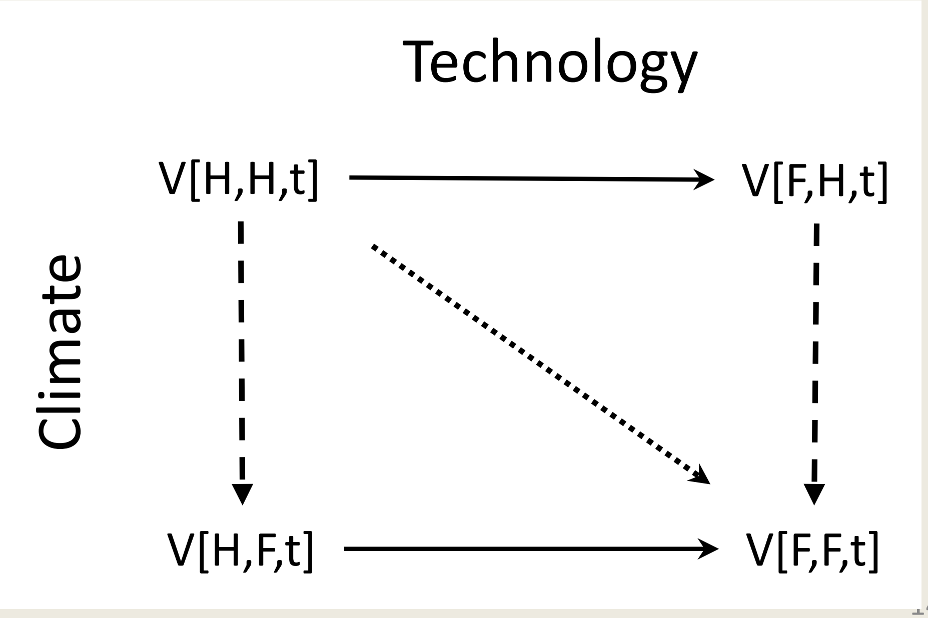
REACCH Project: Magnitude of vulnerability (loss) without adaptation



Experimental design: impact vs adaptation

- Must quantify well-defined **treatment effects** to distinguish environmental change, policy, and other drivers of change
  - Impact indicator: V[technology, climate, state of world]
  - H = historical or current conditions, F = future conditions

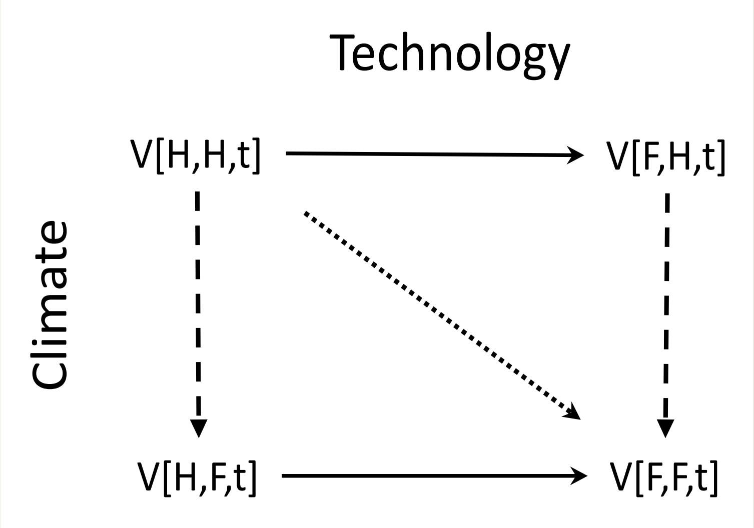
Antle, J.M. and C.O. Stöckle. 2015. Perspectives on climate impacts on crops from agronomic-economic analysis. Paper prepared for the symposium on impacts of climate change on agriculture in the *Review of Environmental Economics and Policy (in review)*



Treatment effects relevant to science & policy stakeholders

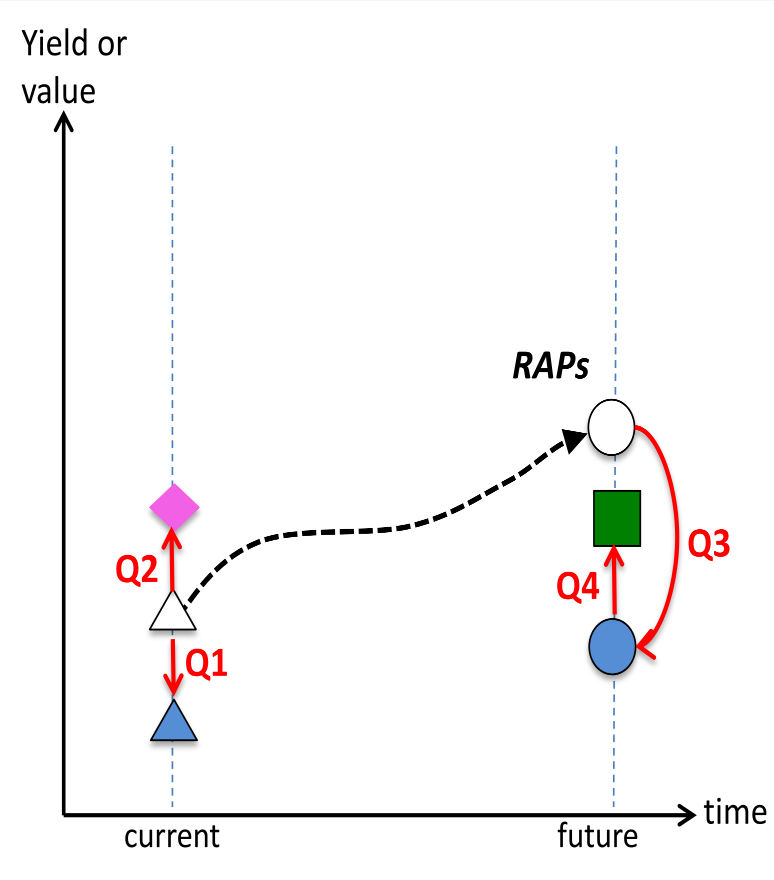
- Reduced-form statistical/econometric models only represent climate impact + adaptation in current (historical) world
- "Hybrid (semi-)structural models" that satisfy "Marshak's Maxim" can estimate all relevant treatment effects

Antle, J.M. and C.O. Stöckle. 2015. Perspectives on climate impacts on crops from agronomic-economic analysis. Paper prepared for the symposium on impacts of climate change on agriculture in the *Review of Environmental Economics and Policy (in review)*

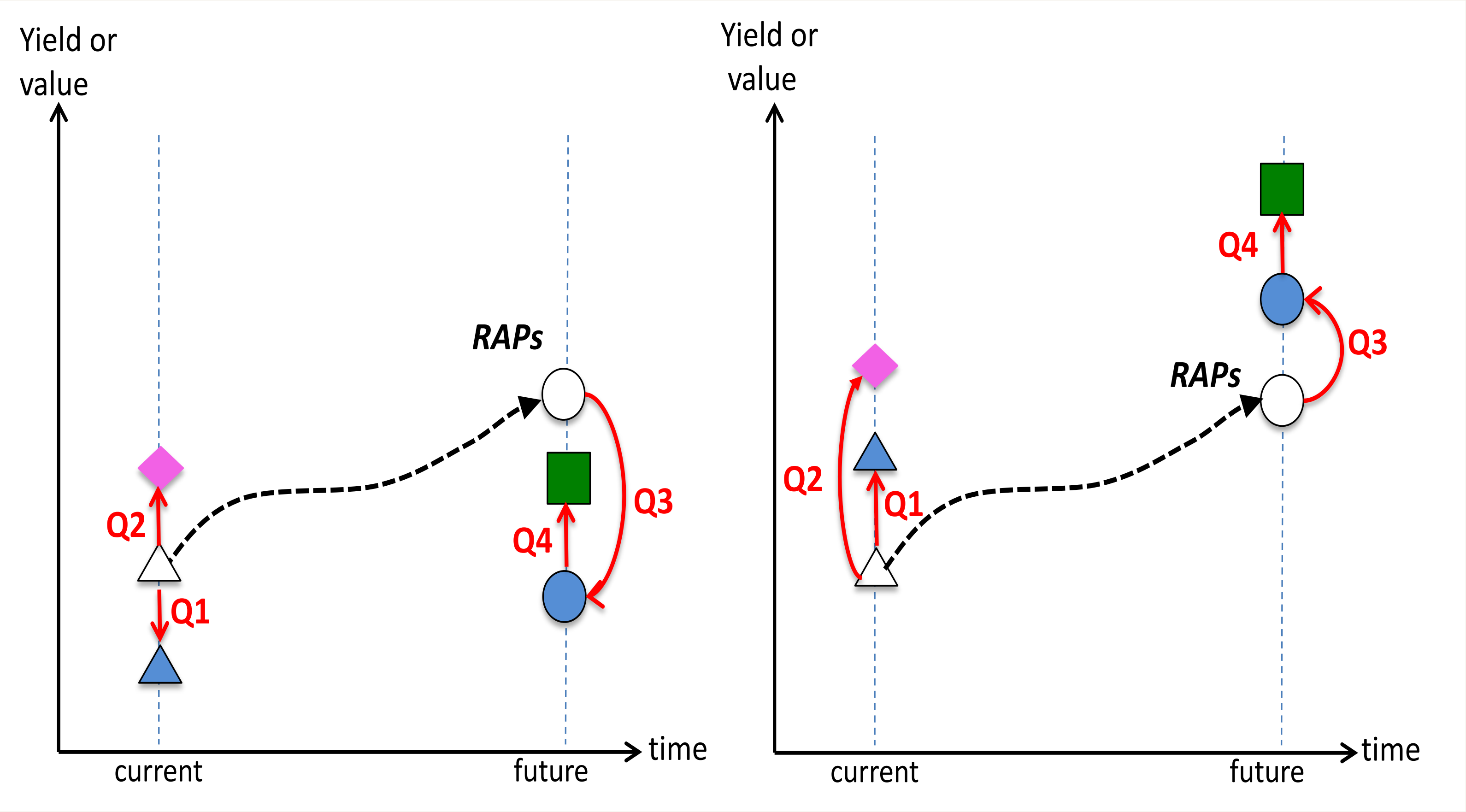


AgMIP "Core Questions" for IAV Assessments

1. What is the sensitivity of current agricultural production systems to climate change?
2. What are the benefits of adaptation in current agricultural systems?
3. What is the impact of climate change on future agricultural production systems?
4. What are the benefits of climate change adaptations?



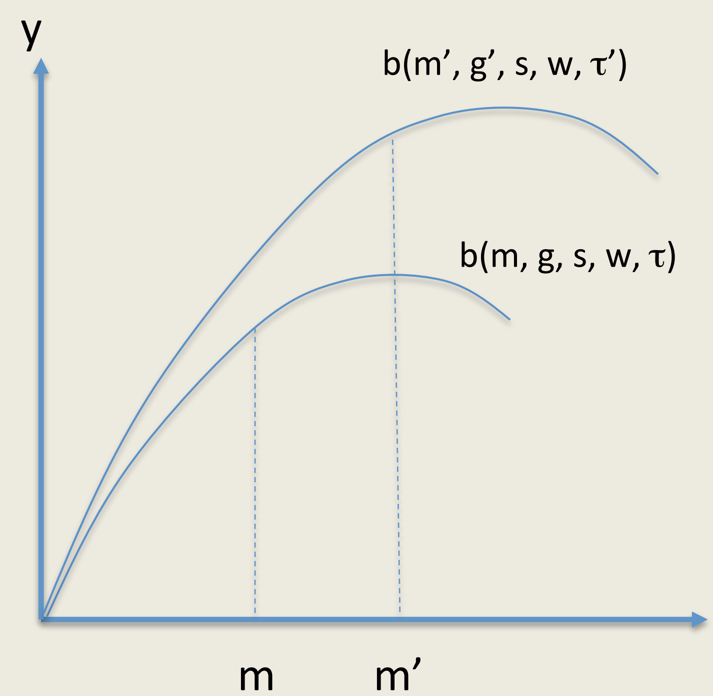
Need to adapt to positive climate changes too …



Linking Crop Models to Economic Models: Relative Yields

Agronomic and economic concepts of production function

$y = b(m, g, s, w, \tau)$



y = yield (kg/ha)
m = management variables (unit/ha)
g = genetic characteristics of the crop
s = soil variables
w = weather variables
τ = parameters

Technological change = shift in production function
= change in m, g and τ

(note: can add other biotic factors: pests & diseases)

Climate adaptation

- All technologies are designed to perform in relation to a particular climate (distribution of weather = γ)

- Without climate change, technological change (m, g and τ) improves performance of system at compound rate Γ

  - Γ estimated independently using SSPs, RAPs (independent of crop or livestock models)

  - Future (expected) yield without climate change: $y_F = \Gamma y_H$

- Climate adaptations = changes in m, g and τ *distinct from those included in a no-climate scenario*

  - Example: PNW cropping system: crops & rotations

Linking Crop Models to Economic Models: Relative Yields

- We use crop or livestock simulation models to estimate the effects of climate or technology adaptation on productivity, *holding all else constant.*

- Crop or livestock models are used to isolate the effects of climate change, or the effects of a change in technology, consistent with the experimental design described above.

- Climate γ = distribution of weather w

- $b(m_t, g_t, s_t, \gamma_t, \tau_t)$ = average simulated yield (note γ replaces w in prod fn)

- Define a relative yield due to climate change:

$$r(m_t, g_t, s_t, \gamma_F, \gamma_H, \tau_t) \equiv b(m_t, g_t, s_t, \gamma_F, \tau_t) / b(m_t, g_t, s_t, \gamma_H, \tau_t)$$

Or $r(T_t, \gamma_F, \gamma_H) \equiv b(T_t, \gamma_F) / b(T_t, \gamma_H)$, $T_t = (m_t, g_t, \tau_t)$

Core Question 1: Climate Sensitivity in Current System

- Definition of relative yield

$$r(T_t, \gamma_F, \gamma_H) \equiv b\,(T_t, \gamma_F)/\,b\,(T_t, \gamma_H)$$

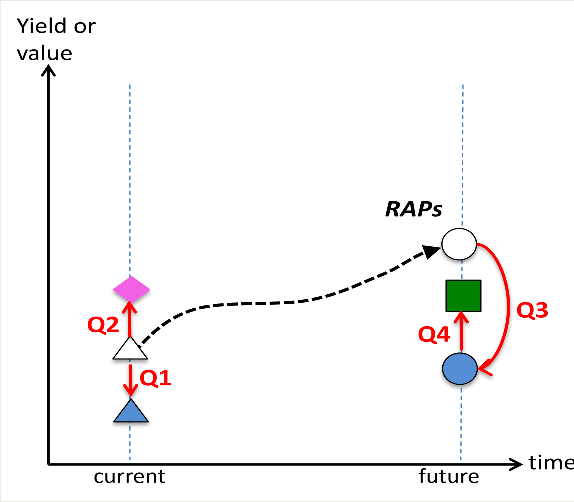
Implies (H = current, F = future):

$$b\,(T_H, \gamma_F) = r(T_H, \gamma_F, \gamma_H)\; b\,(T_H, \gamma_H)$$

Replace $b\,(T_H, \gamma_H)$ with observed yield y_H

- Then projected yield μ with changed climate is:

$$\mu_H(y_H, T_H, \gamma_F, \gamma_H) = r(T_H, \gamma_F, \gamma_H)\; y_H$$



Core Question 2: Adaptation in Current Climate & World

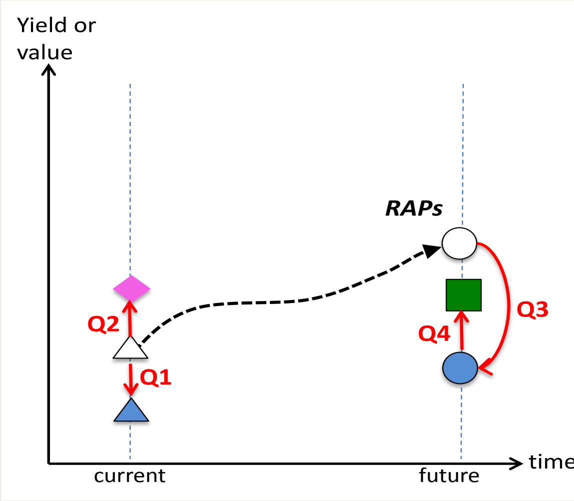
- Definition of relative yield for adaptation analysis:

$$r(T_H^a, T_H, \gamma_H) = b(T_H^a, \gamma_H) / b(T_H, \gamma_H).$$

Note: here we assess management and technology change for a given climate.

Projected yield with adaptation in current climate:

$$\mu_H(y_H, T_H^a, T_H^a, \gamma_H) = r(T_H^a, T_H, \gamma_H)\, y_H$$



Core Question 3: Climate Impact in Future Climate & World

- Recall definition:

$$r(T_t, \gamma_F, \gamma_H) \equiv b\,(T_t, \gamma_F)/\,b\,(T_t, \gamma_H)$$

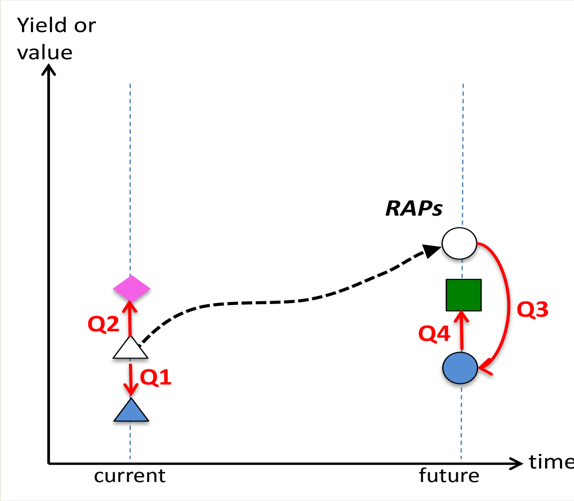
In future world, this implies:

$$\mu_F(y_F, T_F, \gamma_F, \gamma_H) = r(T_F, \gamma_F, \gamma_H)\, y_F$$

Also recall $y_F = \Gamma\, y_H$ so:

$$\mu_F(\Gamma, y_H, T_F, \gamma_F, \gamma_H) = r(T_F, \gamma_F, \gamma_H)\, \Gamma\, y_H$$

Note: no "double-counting" of technological change Γ and effect of climate change (γ_F, γ_H)



Core Question 4: Climate Adaptation in Future World

Recall from Question 2:

$$\mu_H(y_H, T_H^a, T_H, \gamma_H) = r(T_H^a, T_H, \gamma_H)\, y_H$$

In future world this becomes:

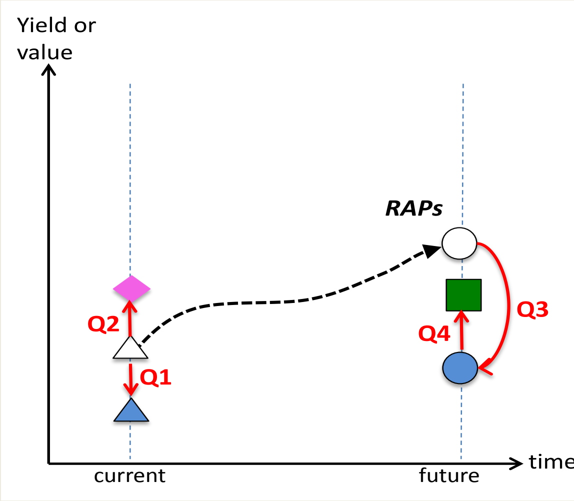
$$\mu_F(y_F, T_F^a, T_F, \gamma_F) = r(T_F^a, T_F, \gamma_F)\, y_F$$

Thus

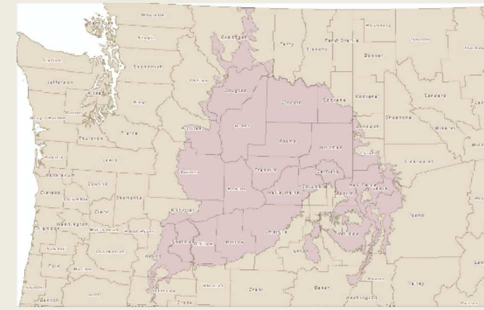
$$\mu_F(\Gamma, y_H, T_F^a, T_F, \gamma_F) = r(T_F^a, T_F, \gamma_F)\, \Gamma\, y_H$$

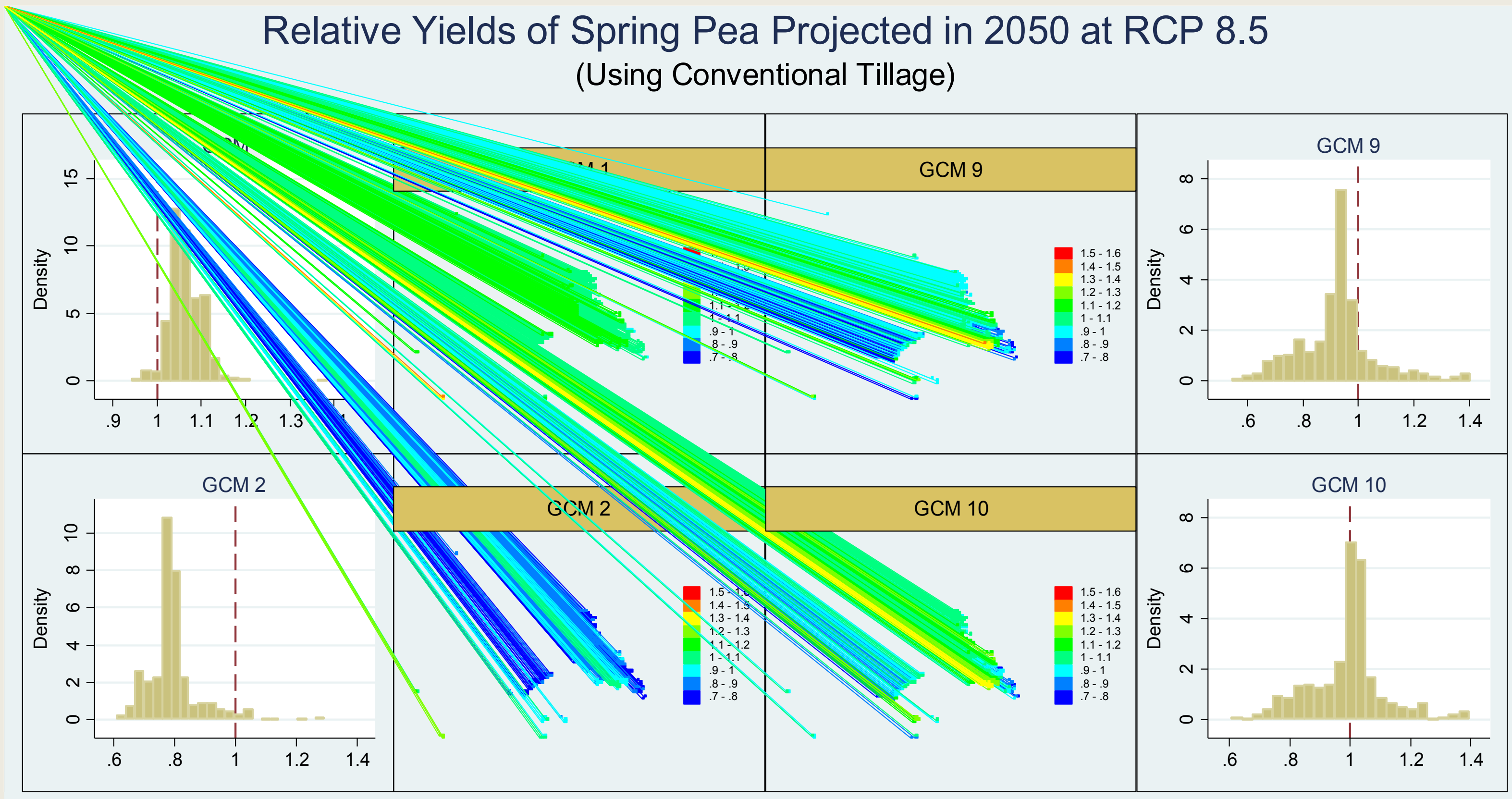
Note: distinct effects of tech change (Γ), effect of climate (γ_F) and climate adaptation (T_f^a and T_F)

Note:
relative yield with CC + adaption
= (relative yield with CC) x (relative yield with adaptation)



Relative yield distributions in dryland wheat region of PNW

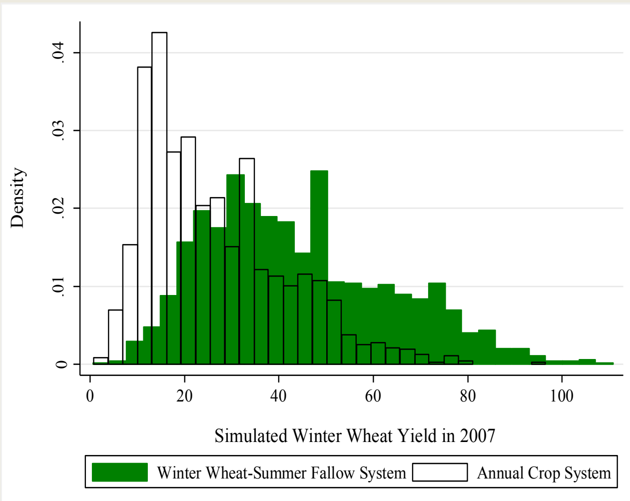


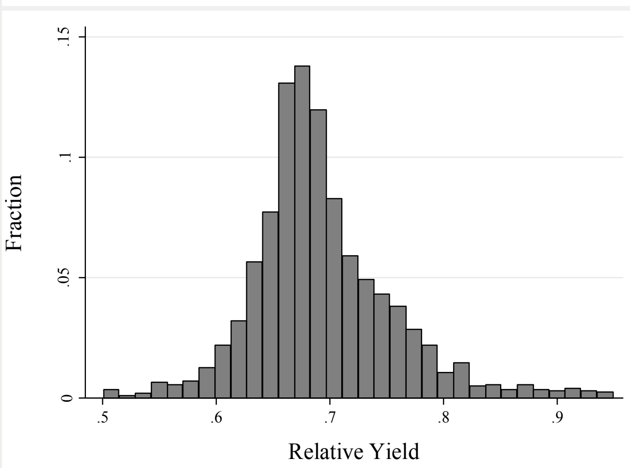


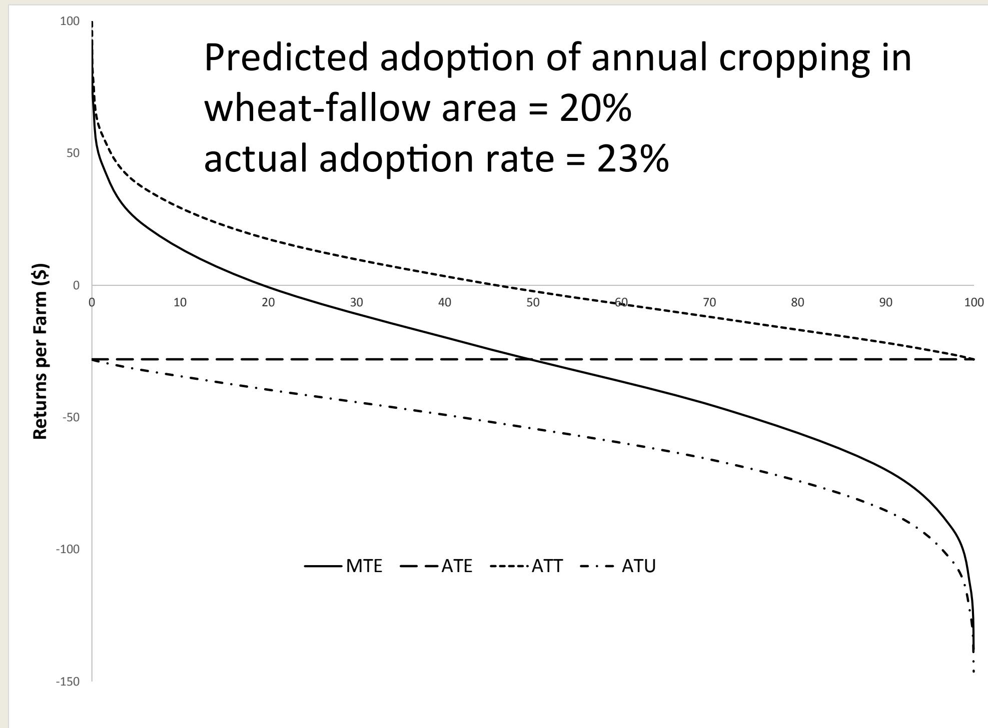
Source: Author and collaborators, REACCH-PNA Project

Application: system choice in PNW low-rainfall zone using CropSyst and TOA-MD models

Economic model: expected net returns = f(prices, cost, relative yield)



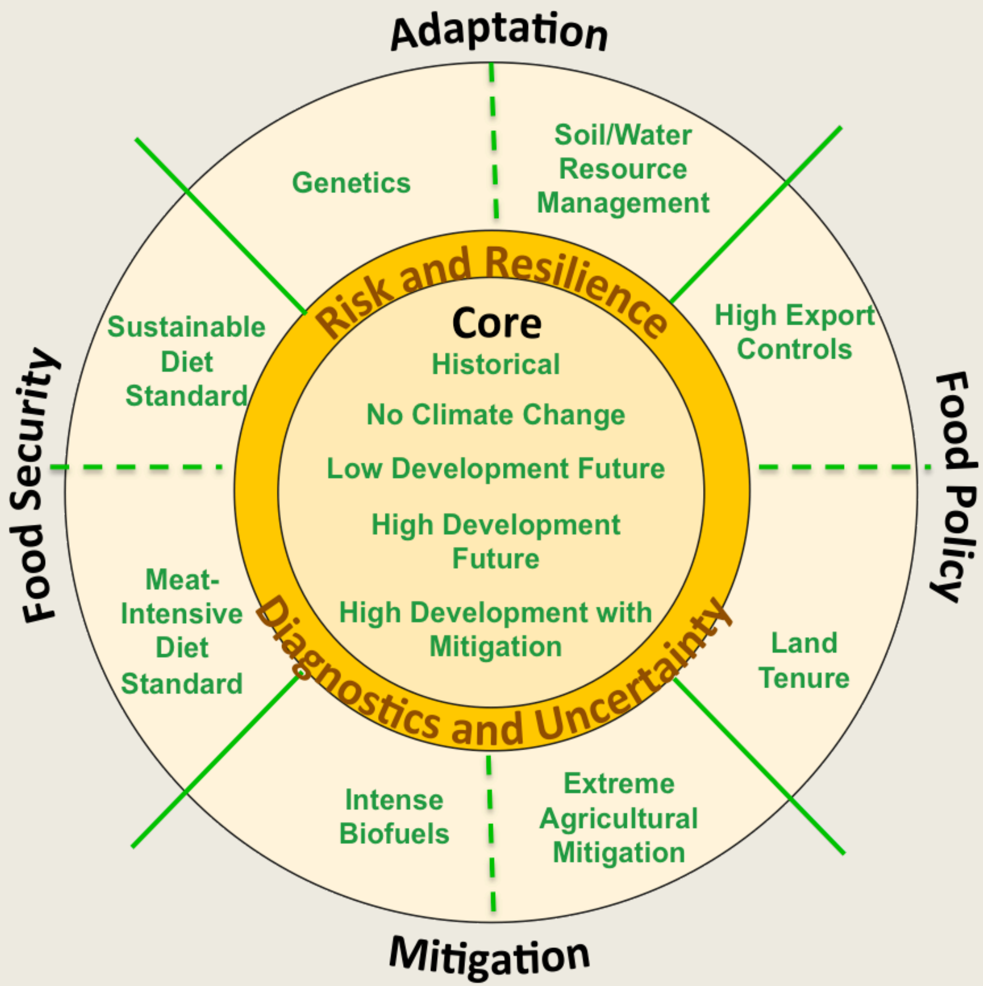




Antle and Stöckle, 2015 *REEP* (in review)

The way forward: AgMIP Coordinated Global and Regional Assessments (CGRA)

- Goal: results ready for AR6
- Key features:
  - New food security and nutrition indicators
  - Focus on risk and resilience to extremes, and long-term CC impact and adaptation
- Core project for global scenario design and model simulations
- Regional/national assessments with common protocols
- 1st year:
  - pilot projects for protocol development
  - Food security and nutrition indicator development



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Regional Approaches to Climate Change –
PACIFIC NORTHWEST AGRICULTURE

Thank you!

University of Idaho

Washington State University

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Oregon State University OSU

CHS

Pacific Northwest
Farmers Cooperative

Monsanto