Integrated Modeling of Crops, Pests, Economics: What Purposes and Approaches?

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AgMIP Pest and Disease Modeling Workshop, University of Florida Feb 23 2015

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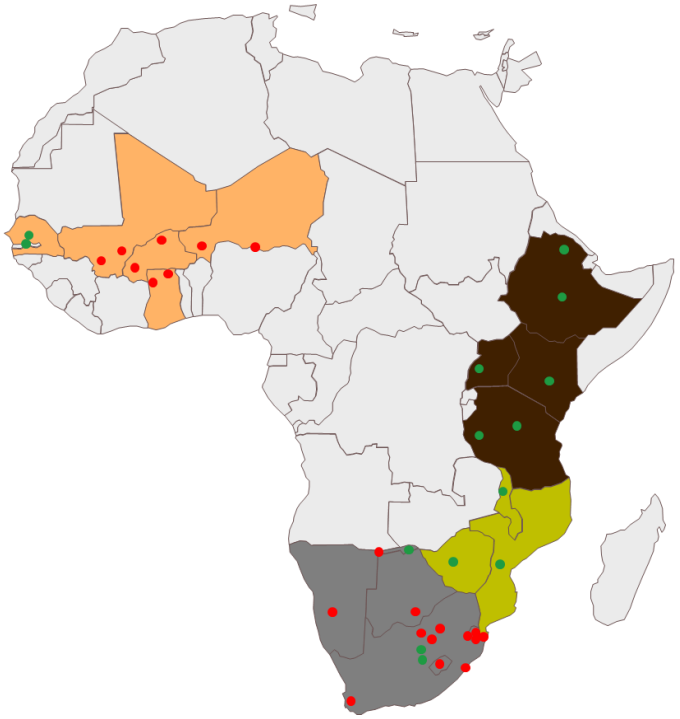
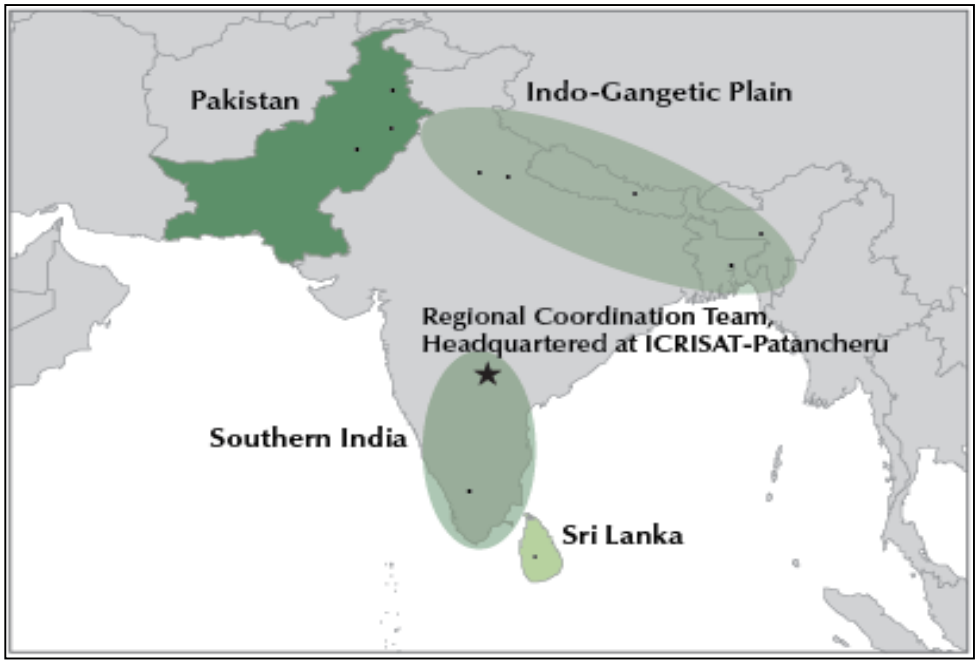
Oregon State University OSU

REACCH Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

AgMIP Regional Assessment Teams

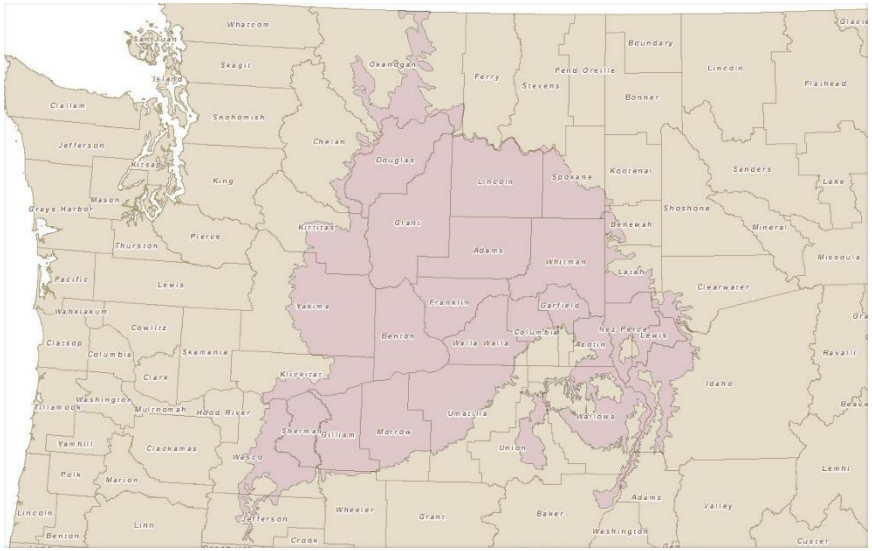


5-year project, DFID funded
8 regional teams, 18 countries, ≈ 200 scientists
Data, models, scenarios designed & implemented by multi-disciplinary teams & stakeholders



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

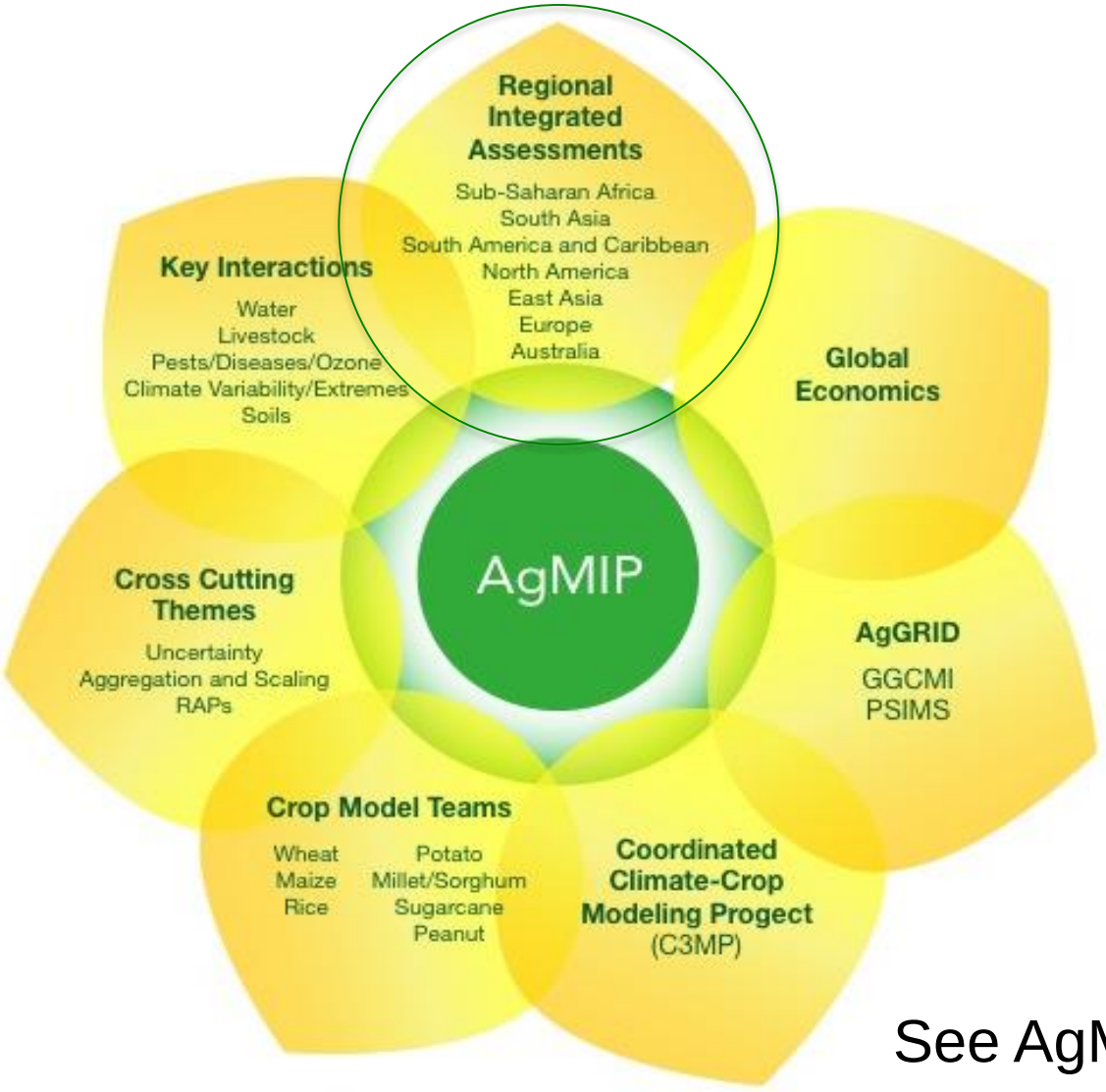
REACCH - Regional Approaches to Climate Change in Pacific Northwest Agriculture

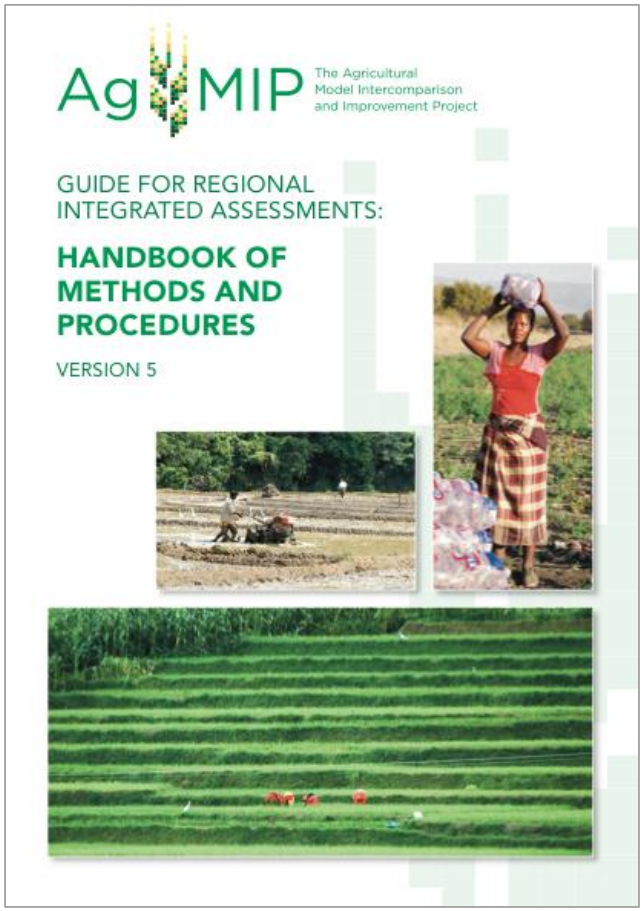


5-year project funded by USDA-NIFA
University of Idaho
Oregon State University
Washington State University
USDA-ARS
+ 100 scientists & students

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

AgMIP Initiatives: how to improve the scientific quality and usefulness of integrated assessment of ag systems from farm to regional to global scales? Many challenges!





See AgMIP.org

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Themes

- The AgMIP approach to Regional Integrated Assessment
- Pest management as risk management
- Role of crop & livestock models in the RIA framework
- Implications for pest & disease modeling
- Some steps forward

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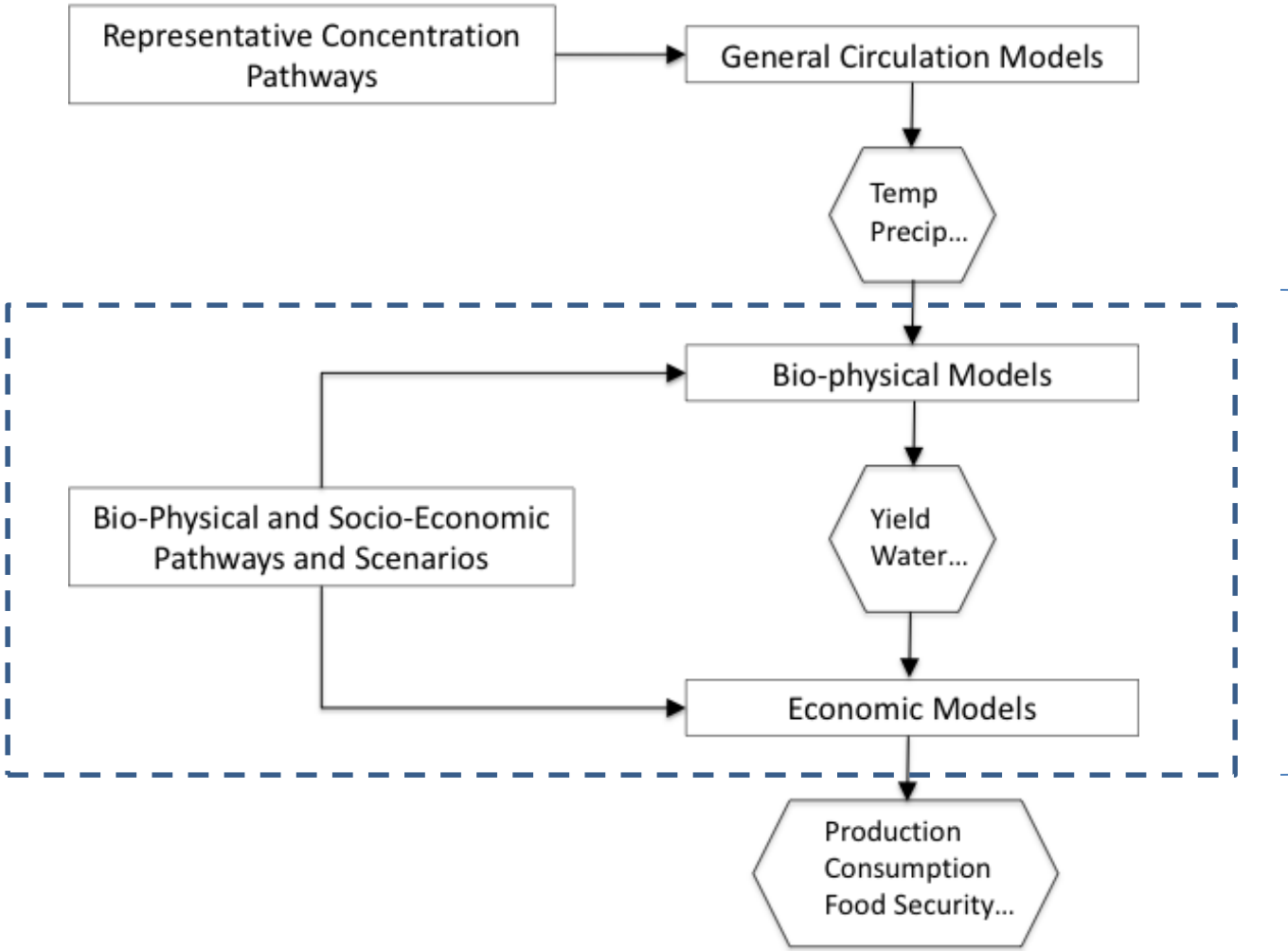
Ag, Food and Climate Change

- The Goal: sustainable food & nutritional security under future bio-physical and socio-economic conditions
  - Scales: national, local and household relevance
  - Beyond commodity production, to the food system
  - Assessment not yet feasible: major data and methodological challenges remain
- Vulnerability: who is at risk of loss, and who can gain?
  - Urban consumers: primarily price effects?
  - Rural ag households: production and price changes affect income, availability, stability
- Mitigation and adaptation: what can we do, sustainably?
  - R&D for adaptation
  - Economic, environmental, social (health) impacts

Integrated Assessment Paradigm



Many processes at different scales

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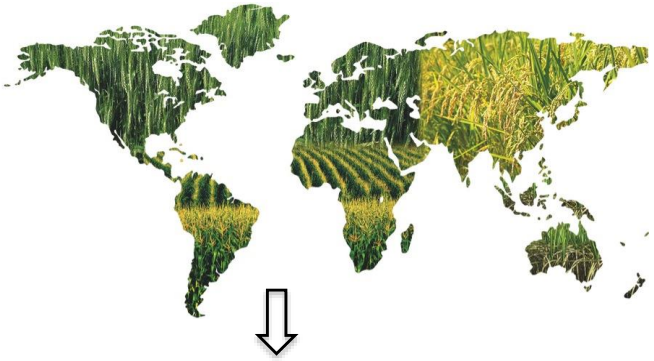
Key components of Regional IA Methods

- RIA based on simulation experiment design
- Many experiments possible: see AgMIP RIA "questions"
- Key components
  - Climate: RCPs and GCMs
  - Climate policy: for mitigation, adaptation
  - Non-climate state of the world
    - Shared socio-economic pathways (SSPs)
      - Demographics, productivity & technology, non-climate policy
    - Global processes: ag & other markets, prices & production, consumption, institutions, policies, …
    - Representative Ag Pathways (RAPs)
      - Bio-physical conditions, ag-specific productivity & technology, institutions & policies, prices
  - Technology: farm household system

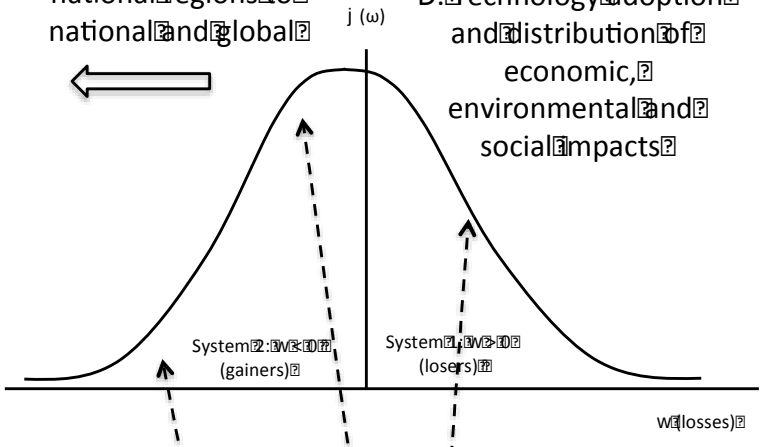
AgMIP's RIA Approach: Scales



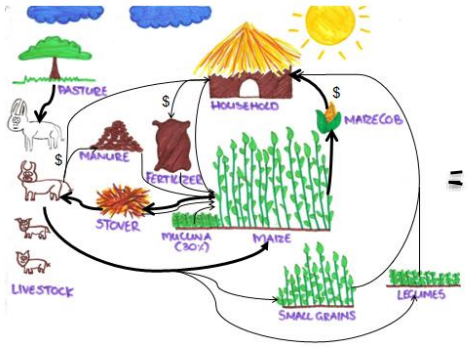
A. Global & national prices, productivity and representative ag pathways and scenarios (RAPS)

E. Linkages from sub-national regions to national and global

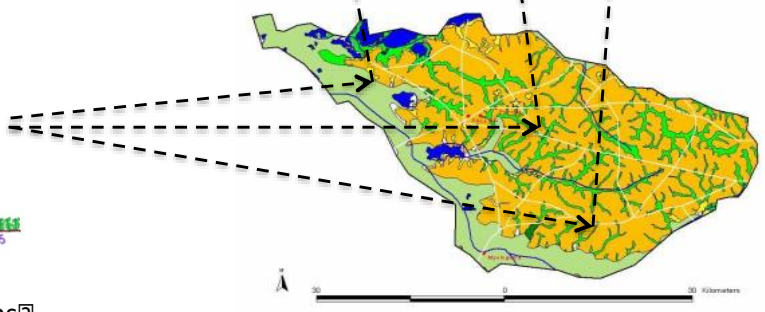
D. Technology adoption and distribution of economic, environmental and social impacts



Adaptation Packages



B. Complex farm household systems



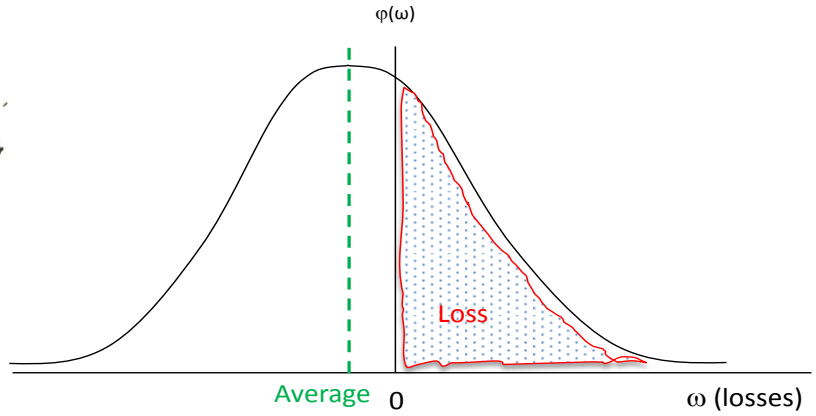
C. Heterogeneous regions

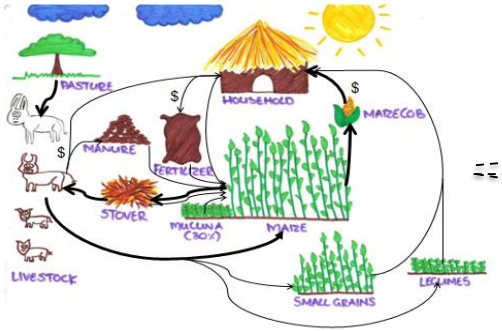
Antle, J.M. et al. 2014, *Handbook of CC and Agroecosystems*

AgMIP's RIA Approach: Vulnerability

A. Global & national prices, productivity and representative ag pathways and scenarios (RAPS)

TOA-MD model simulates gains and losses
tradeoffs.oregonstate.edu





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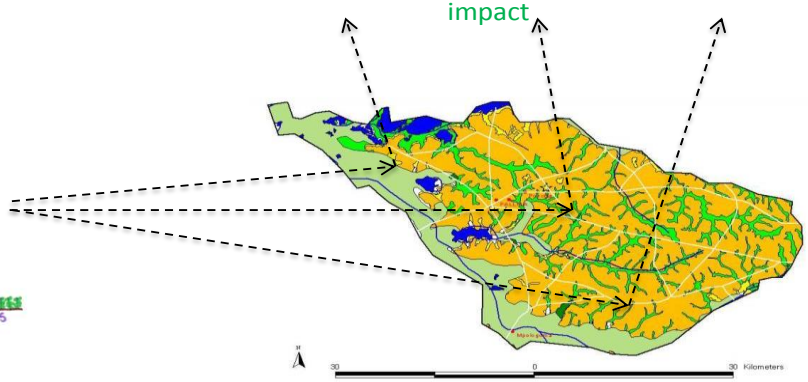

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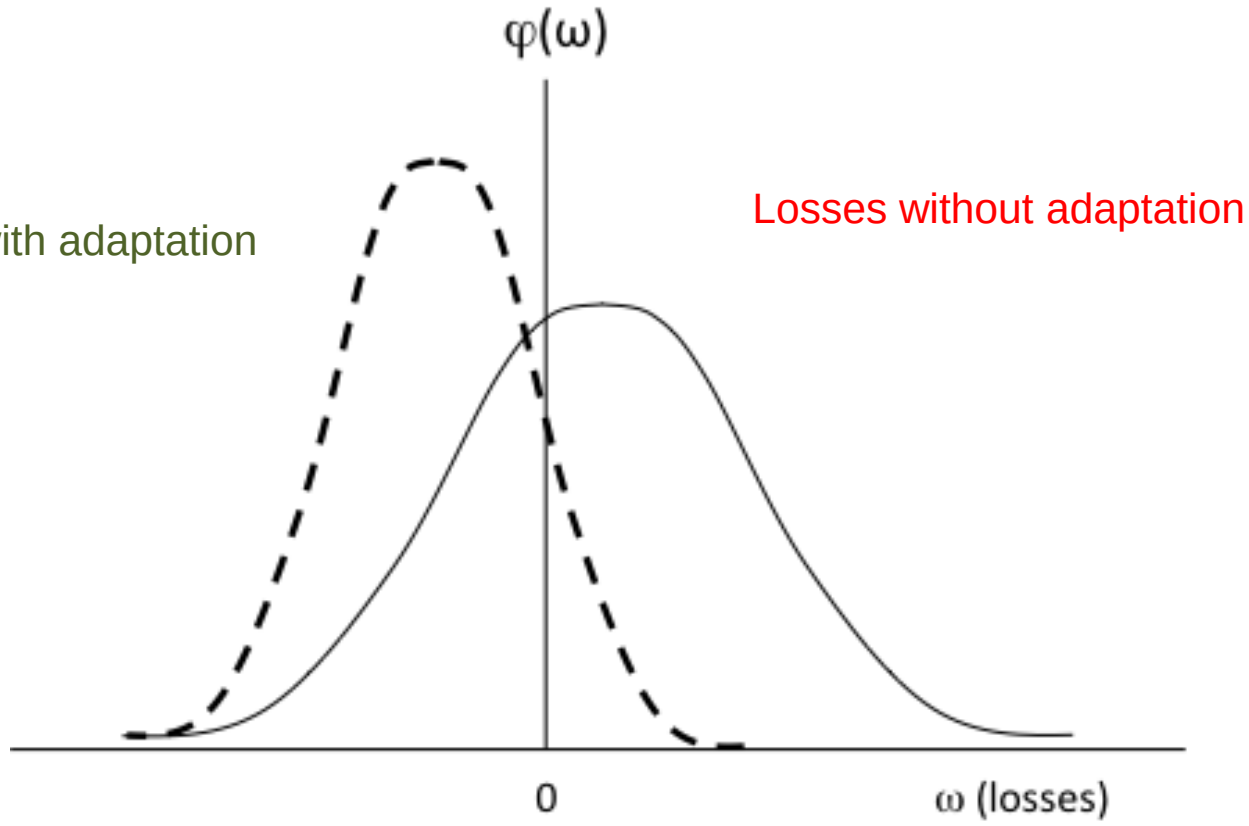
Vulnerability without and with adaptation



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From farm populations to individual farms and fields

- The preceding discussion showed outcomes (gains and losses) for a **population of farms**.
- Now we consider what happens on an **individual farm**.
  - How can we represent the effects of management, pests & diseases, weather and climate?
  - How can we use that information to carry out the RIA analysis just described (i.e., go back from individual crops and farms to populations of farms)?

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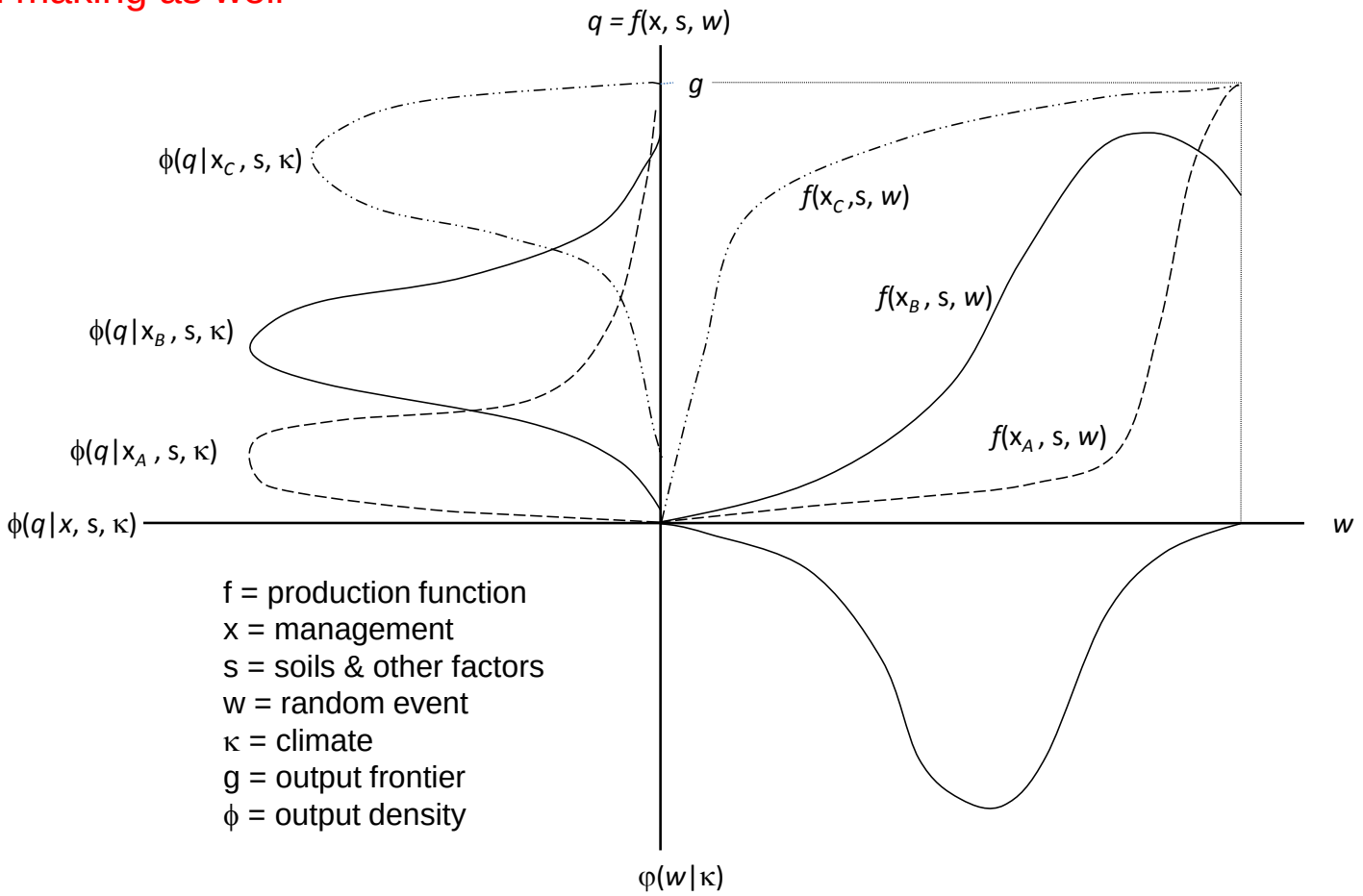
Crop management, pests and risk

- Crop management models
  - Production or value function: output & quality, value = function of sequence of management decisions and random events (weather, bugs, breakdowns, prices, etc…)
  - Decisions: *ex ante*, based on anticipated (expected) outcomes; made sequentially conditional on available information to meet objectives
    - Intra-seasonal, inter-seasonal
  - Outcomes or realizations after decisions made; information updated for next decision period
- Management objectives
  - Economic: max expected (anticipated) economic value conditional on available info
  - Role of Risk: process nonlinearities, risk attitudes
  - Many other objectives may exist along with economic!
- Role of pests and diseases
  - Contribute to *ex ante* risk: properties of output distribution conditional on management decisions, climate, soils and other factors.
  - Pest management: affects properties of output distribution
    - Shifts location (mean)
    - Changes other properties (higher moments)

Output distribution model

Need to understand f(x,s,w) to model decision making as well as outcomes

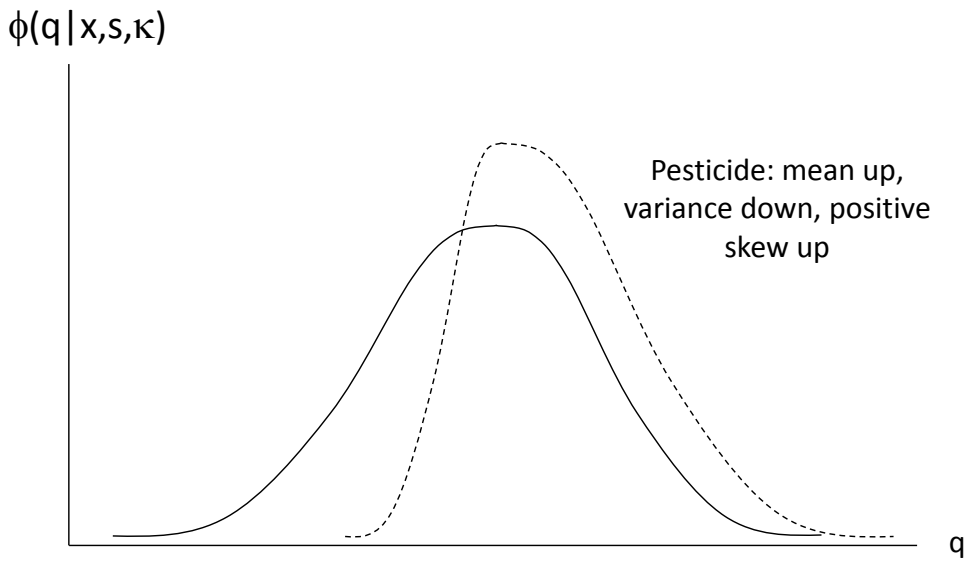


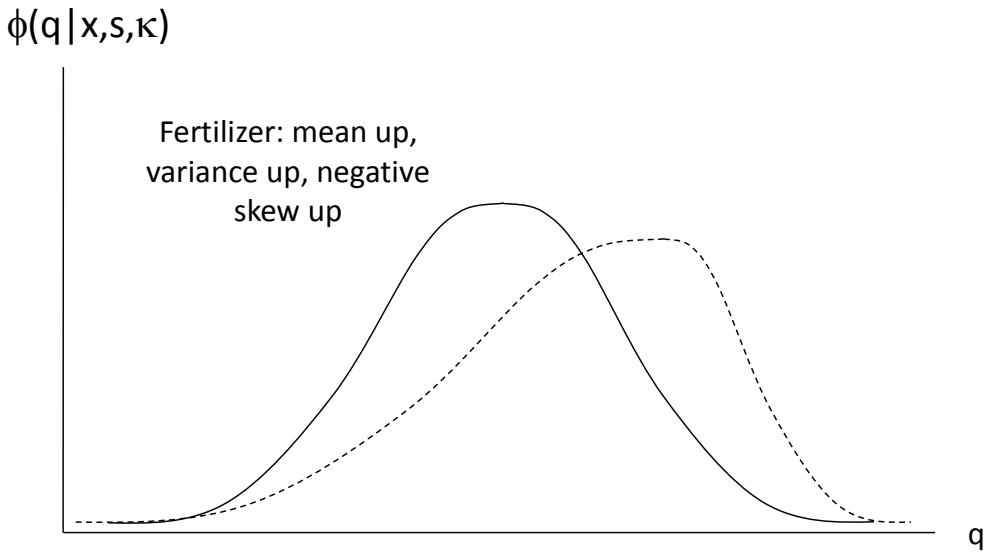
Source: Antle, "Asymmetry, Partial Moments and Production Risk." *Am J Ag Econ* 2010.

Effects of management on output distributions

Pesticides: risk reducing
Fertilizer: risk increasing

Linkages to "potential, actual, attainable" yield and pest epidemic concepts





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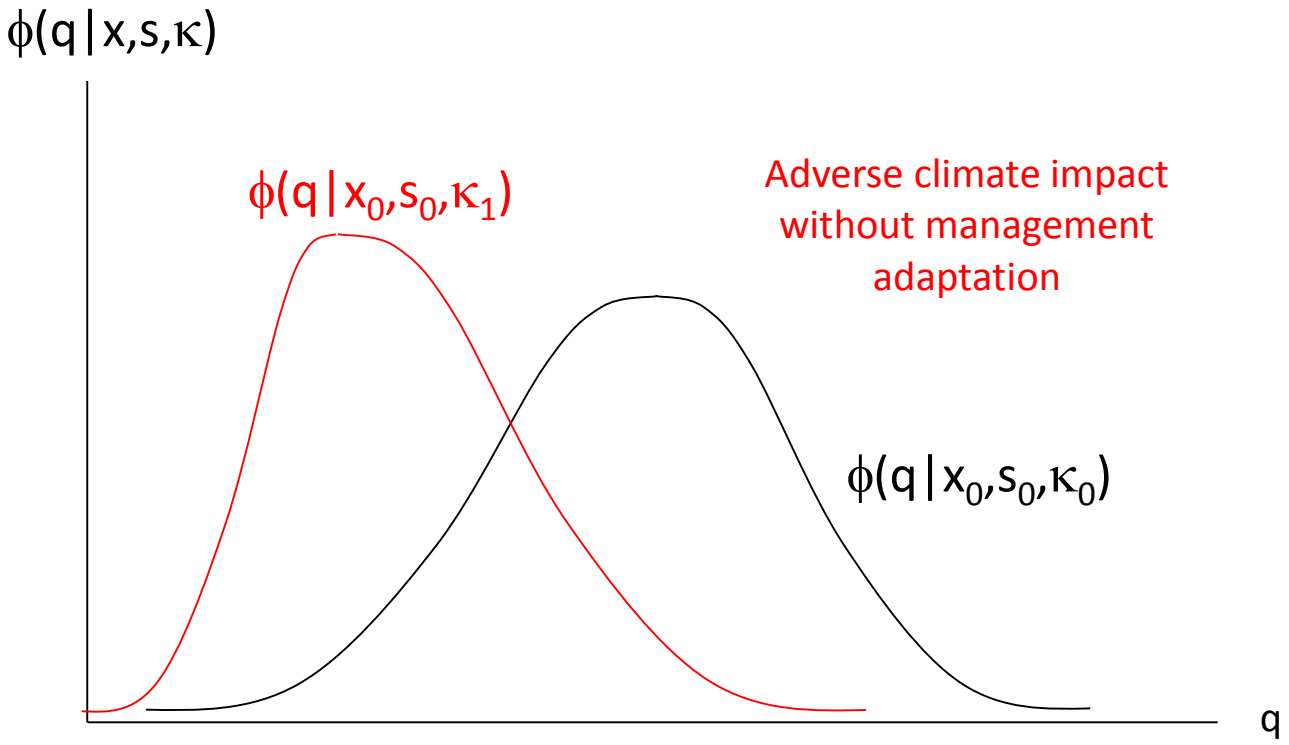
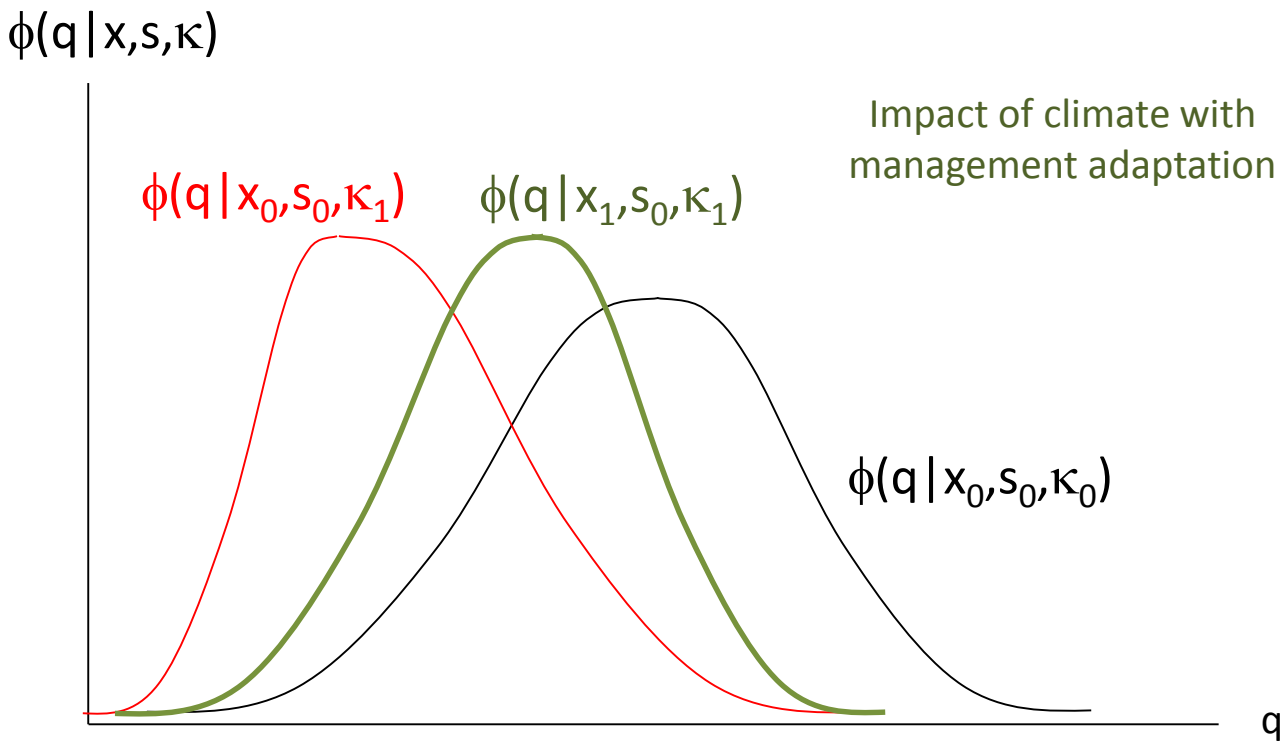
Climate impact



Climate adaptation



Linking Crop and Economic Models

- Now consider mean outcomes (yields, economic returns); can generalize to higher moments
- Assume expected yield is "strongly separable" in "climate factor" that can reflect pests, diseases etc
- Expected yield at a site s is:

$m(x,s,\kappa) = a(x,s,\kappa) \cdot b(x,s,\kappa)$

$a(x,s,\kappa)$ = expected yield without adverse event (pest infestation)

$b(x,s,\kappa)$ = 1 – expected proportional pest damage

= average relative yield from crop model

Various models can estimate $b(x,s,\kappa)$, e.g., statistical (econometric damage models), process-based pest and crop models

$b(x,s,\kappa)$ = relative yield = $E[y(x,s,w)|\kappa=\text{future}]/E[y(x,s,w)|\kappa=\text{present}] \leq 1$

$y(x,s,w)$ = simulated yield

Linking Crop and Economic Models: Heterogeneity

- Now let $d(x,s,\kappa)$ and $a(x,s,\kappa)$ vary across sites, i.e., be random variables in a population of sites (fields or farms):

$$a(x,s,\kappa) \sim (\mu_a, \sigma_a) \text{ and } b(x,s,\kappa) \sim (\mu_b, \sigma_b)$$

Simulating a crop model for a representative sample of sites gives estimates of μ_b, σ_b.

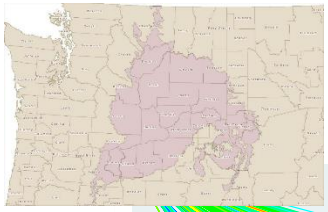
Observational data is used to estimate μ_a, σ_a.

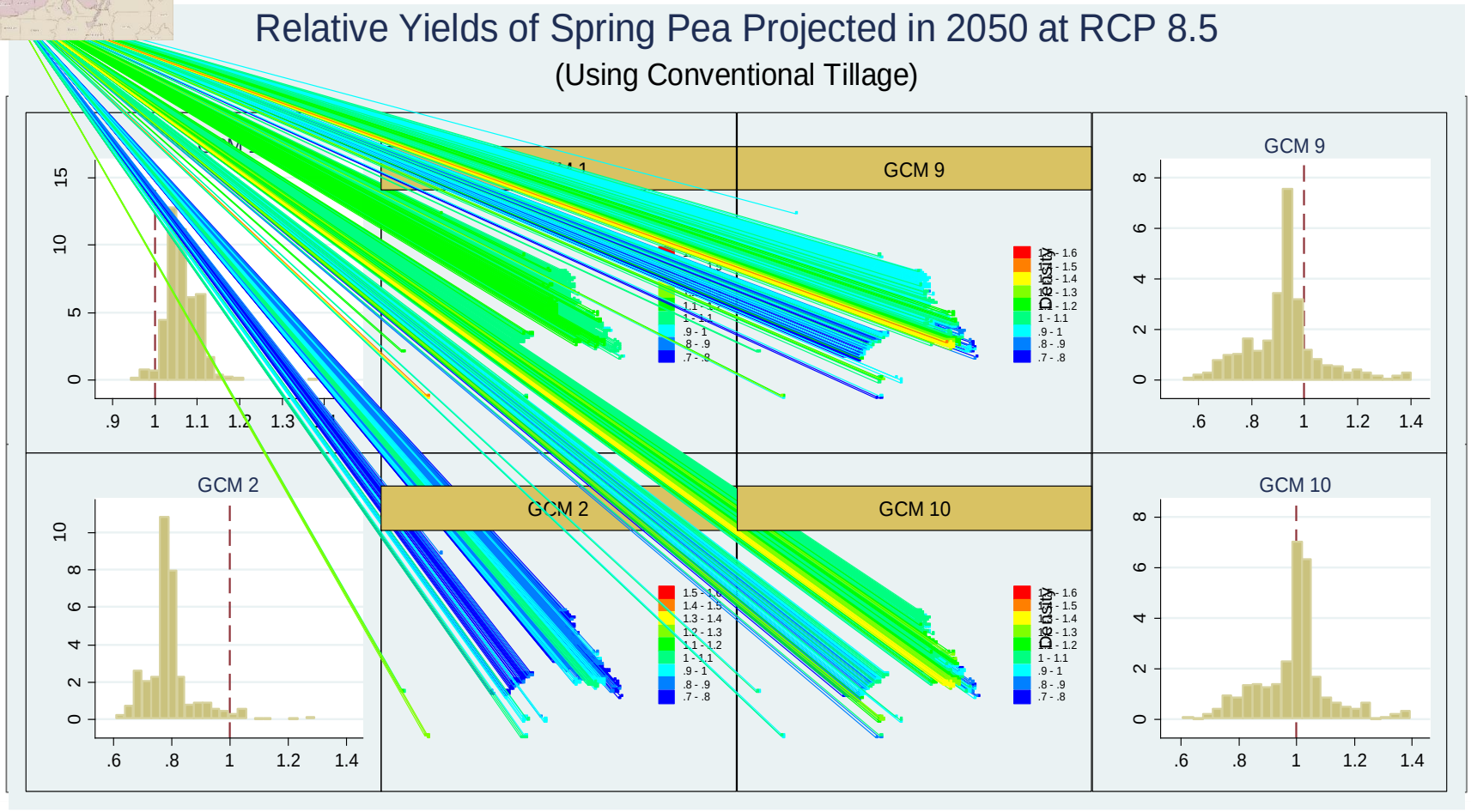
Combining them we can construct the spatial distribution for $m(x,s,\kappa) = a(x,s,\kappa) \cdot b(x,s,\kappa) \cdot$ in the population of farms.

E.g., if a and b are independently distributed, then can show that mean and variance of $m(x,s,\kappa)$ are functions of μ_a, σ_a, μ_b, σ_b.

This distribution will be defined for the regional climate and other factors defining management decisions (soils, prices, farm size distribution, etc.)

Example: Relative wheat and spring pea yield distributions (US PNW, CropSyst)

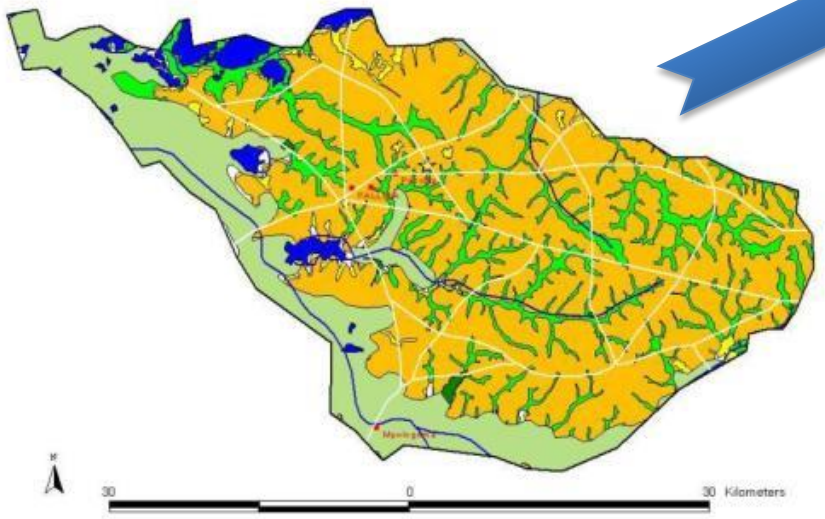


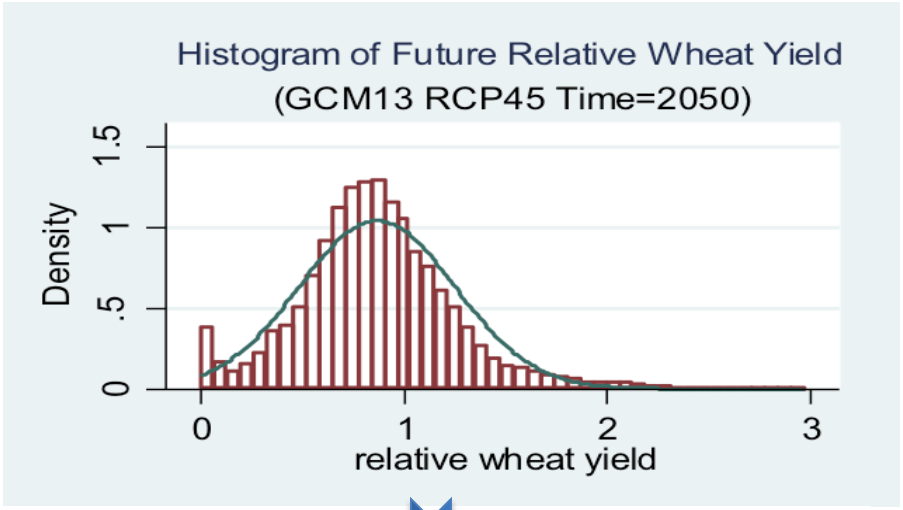


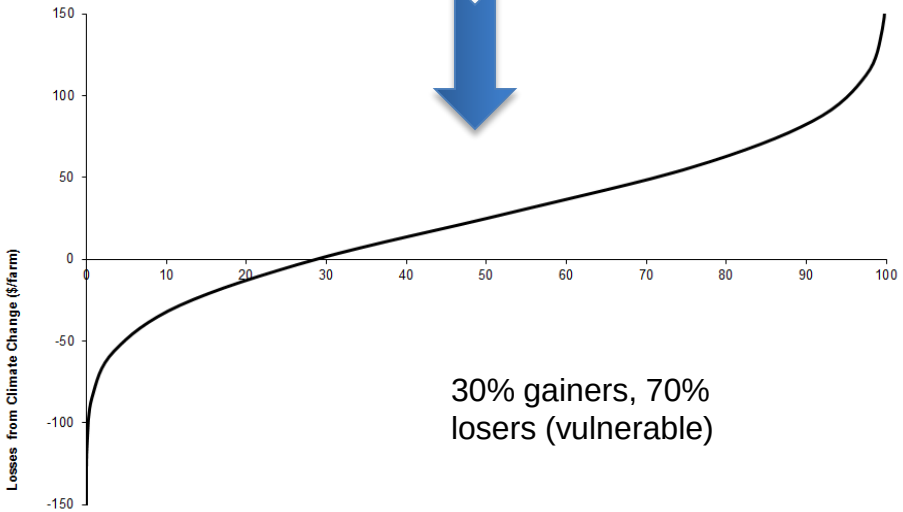
Source: Author and collaborators, REACCH-PNA Project

Example: Relative wheat yield distribution and gains and losses from CC

Heterogeneous region



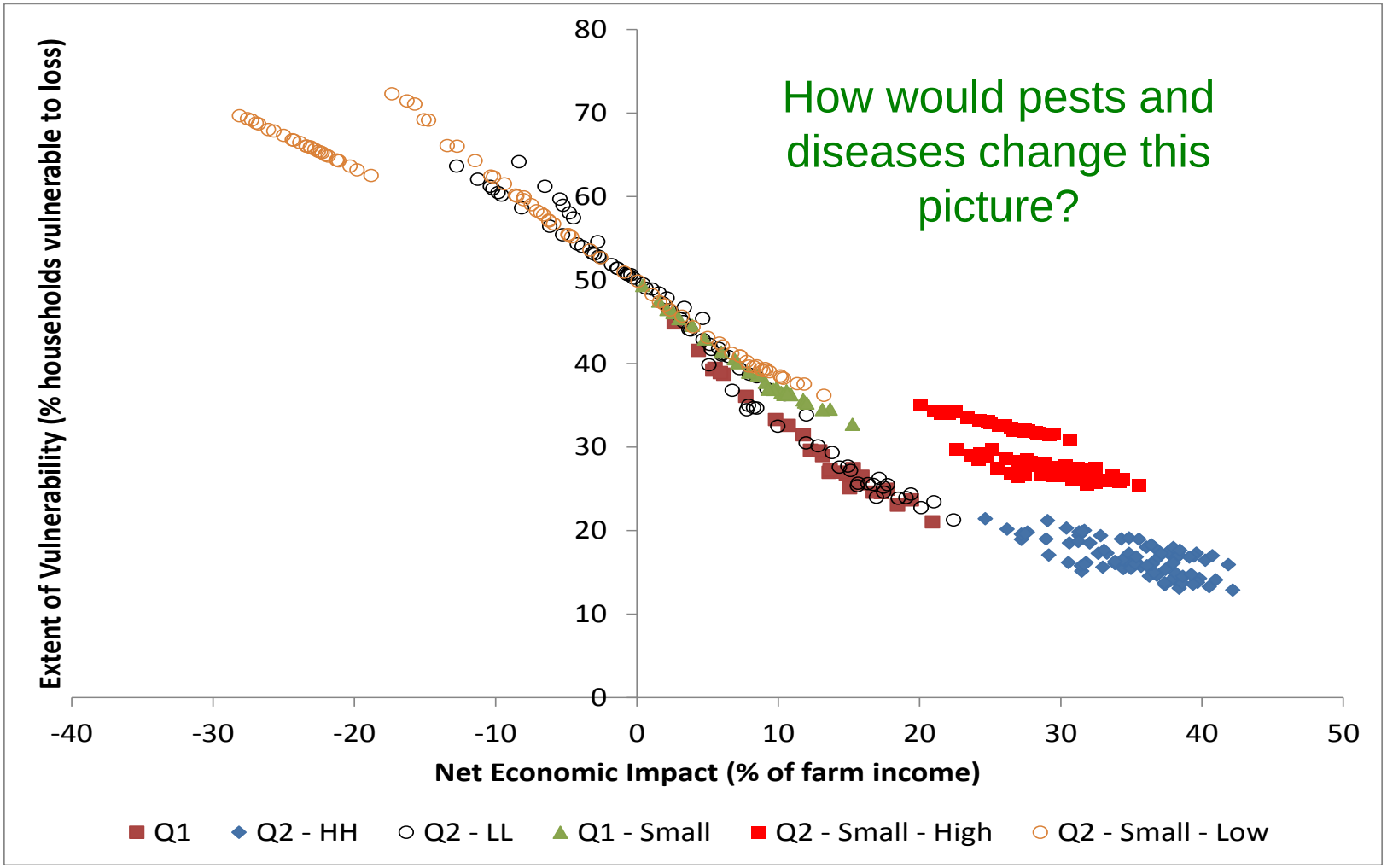




30% gainers, 70% losers (vulnerable)

TOA-MD model simulated gains and losses

Vulnerability without adaptation: PNW winter-wheat fallow, low/high wheat prices, small/large farms



Source: Author and collaborators, REACCH-PNA Project

Implications: An Economist's Perspective

How to model pests and diseases for assessment of impact, adaptation, vulnerability?

- Modeling approaches: site-specific vs population/regional vs global
  - Economic concept of "structural" vs "reduced-form" may be useful
  - Can simpler models meaningfully project effects of CC? E.g., capture as-yet unobserved thresholds or non-linearities?
- Scenario approaches: better "plausible futures" instead of models?
  - What are key pathways for major changes, impacts?
  - "crop health scenarios"?
- Better data – better ways to observe? Apps & crowd-sourcing
- Linkages across scales - bugs to farms to regional to global?

A way forward?

Select test sites for multiple teams to test new, alternative modeling approaches (NextGen!) …

Don’t forget the wine!