Managing pests and diseases under climate change: What do we need to learn?

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Outline

- Inputs needed for a system of adaptation
- ‘Simple’ estimates of climate change effects on disease/pest risk
- Identifying system components for inclusion in climate change scenario analyses
- Impacts of system variance and the color of weather time series

Yield loss (Oerke 2006)

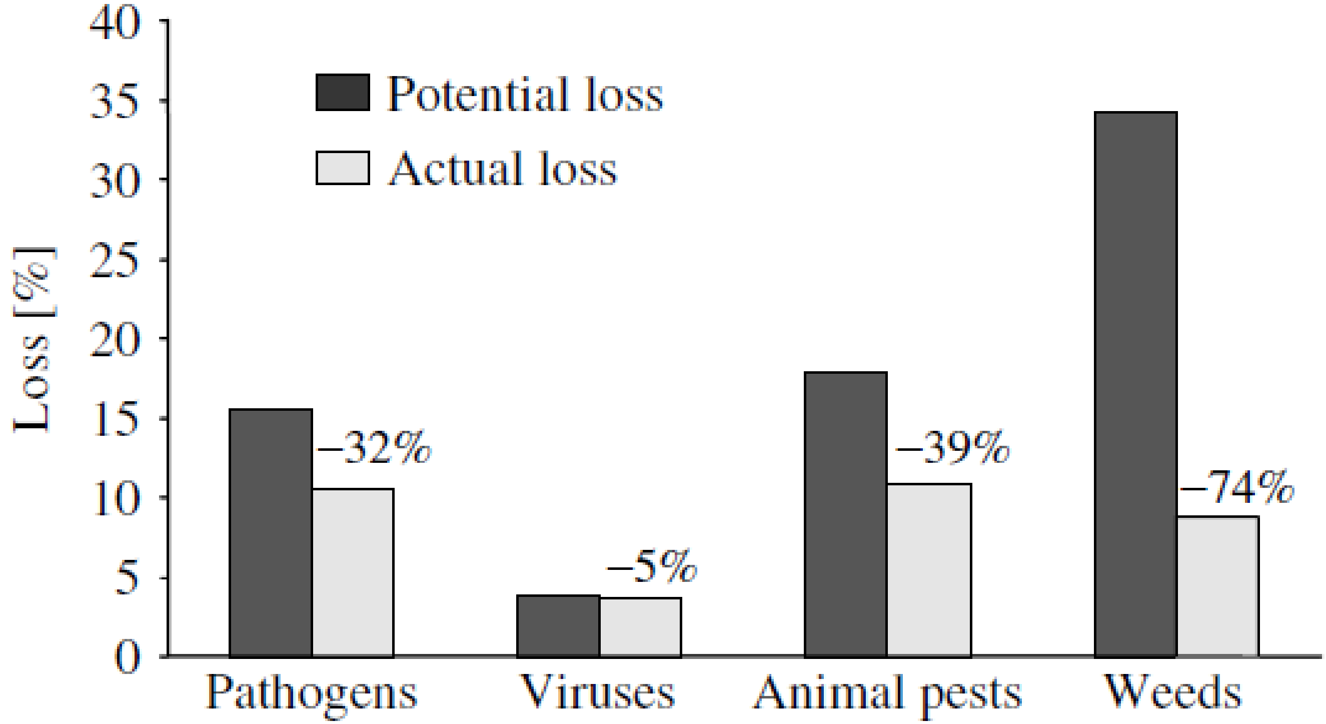


Fig. 7. Average efficacy of pest control practices worldwide in reducing loss potential of pathogens, viruses, animal pests, and weeds, respectively (reduction rates calculated from estimates of monetary production losses in barley, cottonseed, maize, oilseed rape, potatoes, rice, soybean, cotton, sugar beet, tomatoes and wheat, in 2001–03).

Scoping study for pests/diseases

CGIAR

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY

- **Priorities to address pests and diseases in agricultural adaptation to climate variability and change: East Africa, West Africa, and the Indo-Gangetic Plains**
- K. Garrett, Andy Dobson (Oxford), Juergen Kroschel (CIP), Simone Orlandini (U Florence), M. Sporleder (CIP), Henri Tonnang (CIP), Corinne Valdivia (U Missouri)
- We are selecting crop and livestock systems to emphasize based on their importance and likely response to climate change, and welcome your input

1. Weather and climate data as input information

Hourly/daily/weekly weather

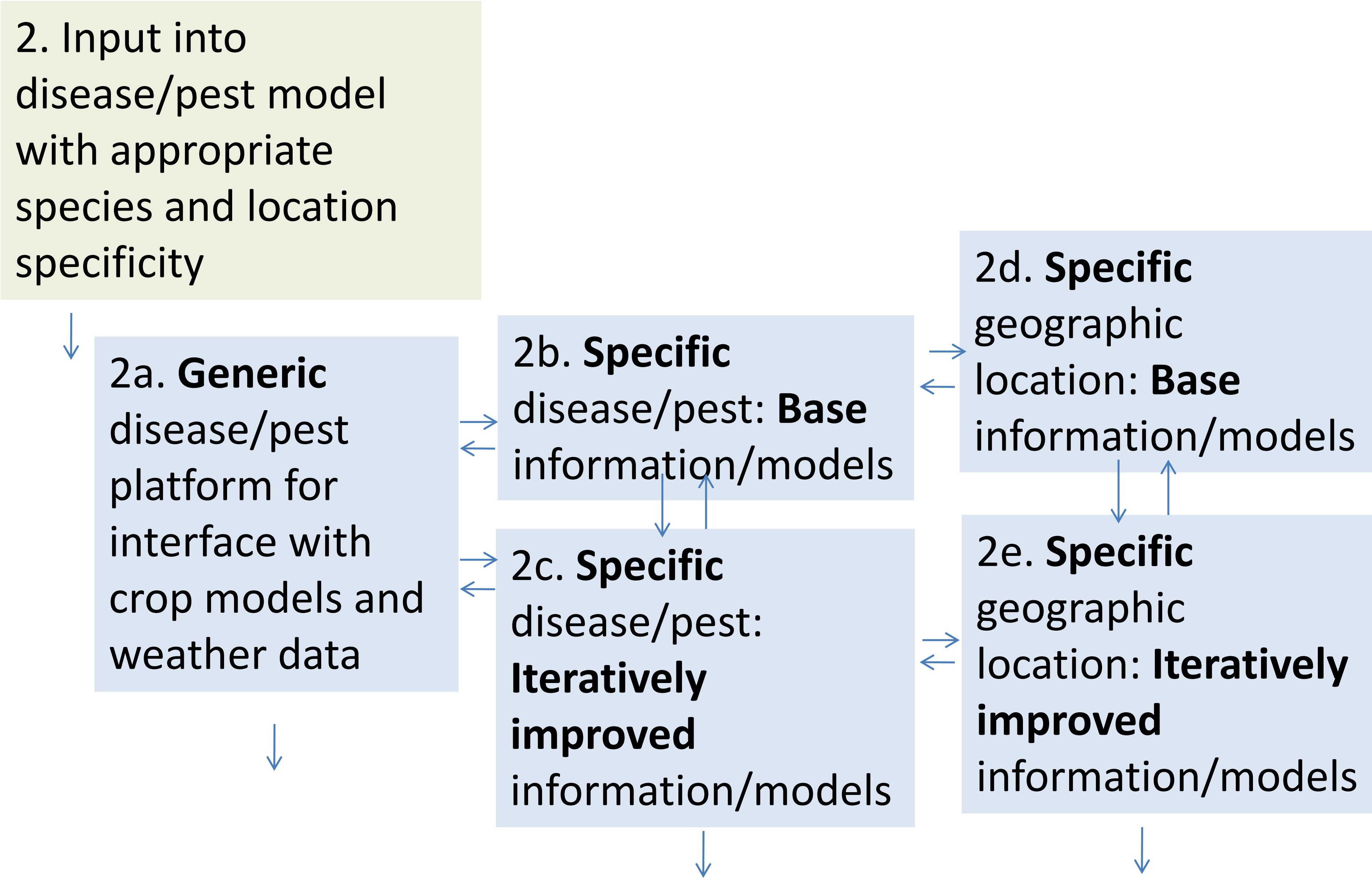
↓

Seasonal/annual weather

↓

Decadal climate

↓


2. Input into disease/pest model with appropriate species and location specificity
2a. Generic disease/pest platform for interface with crop models and weather data
2b. Specific disease/pest: Base information/models
2c. Specific disease/pest: Iteratively improved information/models
2d. Specific geographic location: Base information/models
2e. Specific geographic location: Iteratively improved information/models

3. Disease/pest analysis to inform decision-makers

3a. Farmers' chemical, cultural, and biological decisions

3b. Farmers' species and variety/breed decisions

3c. Insurance rate and payout decisions

3d. Donors'/scientists' / and policy makers' prioritization decisions

4. Better management to improve system outcomes

Improved food security, livelihood, and environment

Analysis of 'simple' temperature and relative humidity effects may provide a 'first order approximation' to the future level of risk

We used models of potato late blight risk developed by Fry et al. and Grunwald et al., rescaling them for use with coarser temporal resolution data at larger spatial extent

esa

ECOSPHERE

A metamodeling framework for extending the application domain of process-based ecological models

2011

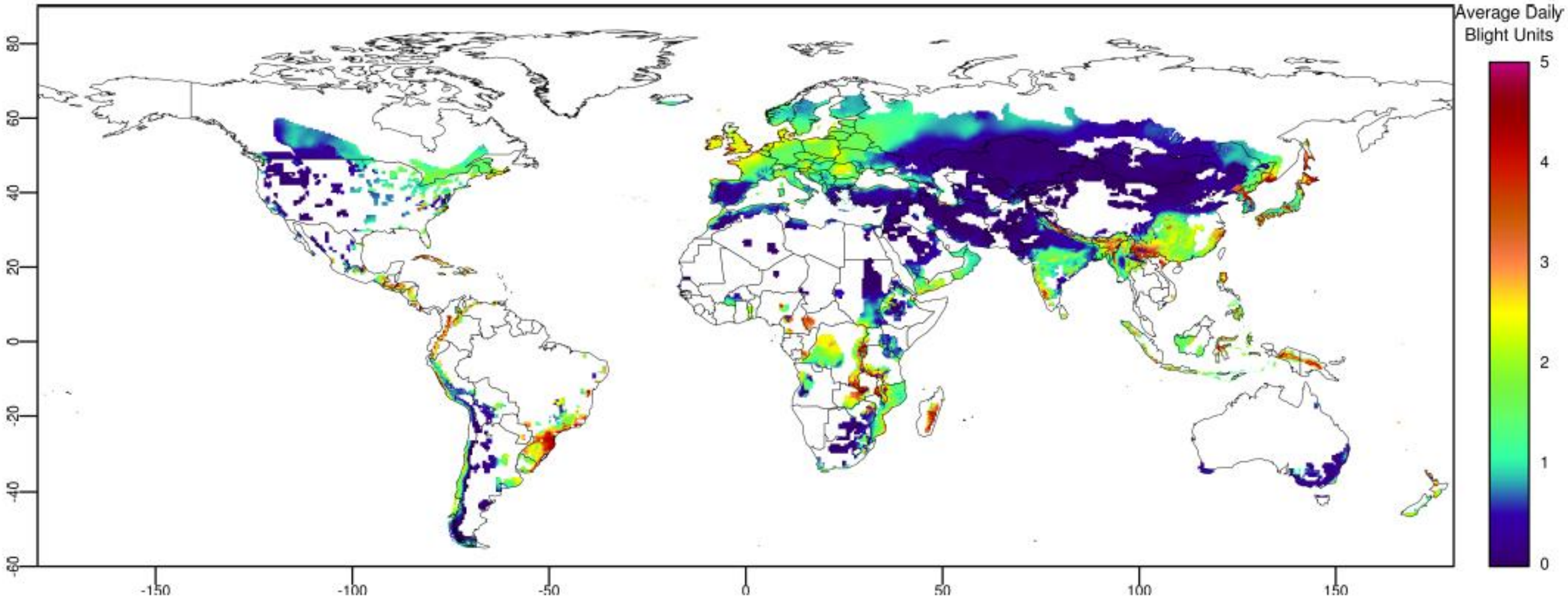
A. H. Sparks,[1,4] G. A. Forbes,[2] R. J. Hijmans,[3] and K. A. Garrett[1,†]

Estimated Potato Late Blight Risk

For current potato production regions

Adam Sparks, R. Hijmans, G. Forbes, K. Garrett

1961-1990

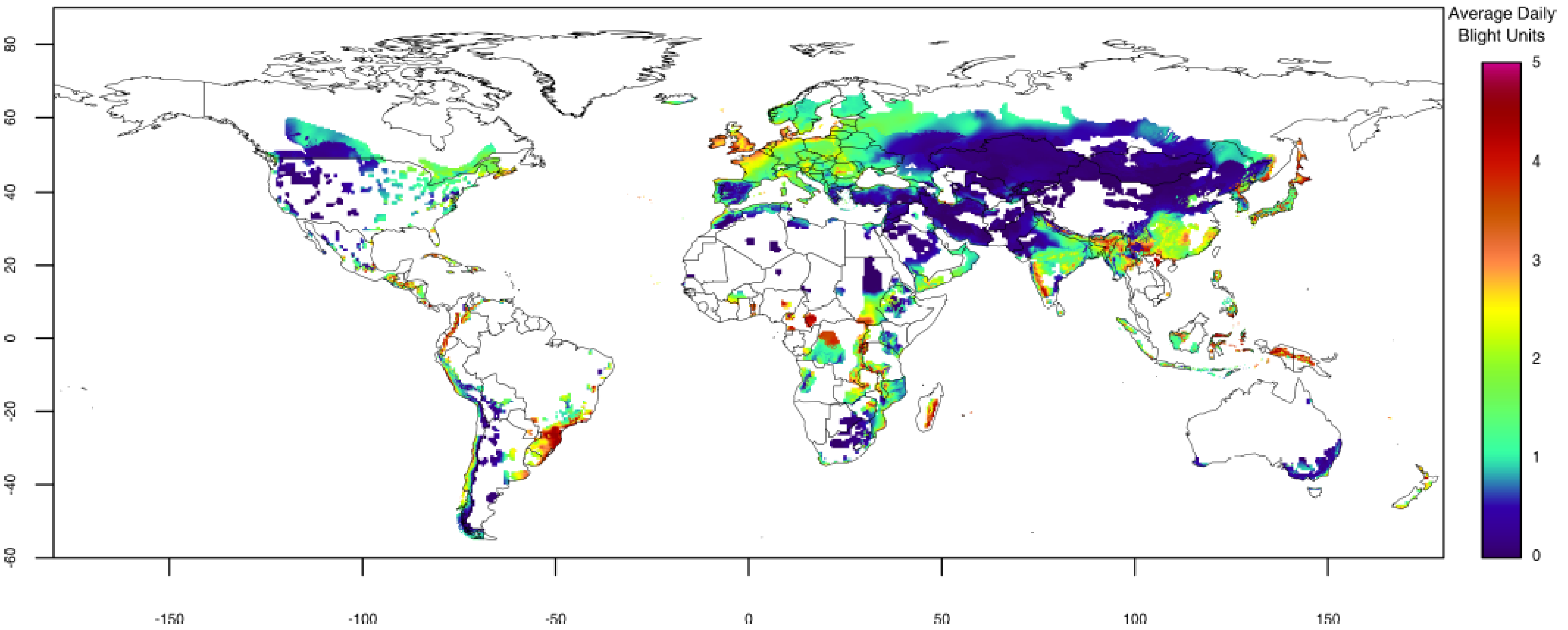


Estimated Potato Late Blight Risk

For current potato production regions

Adam Sparks, R. Hijmans, G. Forbes, K. Garrett

2040-2060



Plant Pathology (2011) **60**, 15–30 Doi: 10.1111/j.1365-3059.2010.02409.x

Complexity in climate-change impacts: an analytical framework for effects mediated by plant disease

K. A. Garrett[a], G. A. Forbes[b], S. Savary[c], P. Skelsey[a], A. H. Sparks[a], C. Valdivia[d], A. H. C. van Bruggen[e], L. Willocquet[c], A. Djurle[f], E. Duveiller[g], H. Eckersten[f], S. Pande[h], C. Vera Cruz[c] and J. Yuen[f]

Complexity in terms of the amount of information needed to adequately predict outcomes

	Lower complexity	Higher complexity
1. Are multiple biological interactions important?	A single pathogen species 'acting alone' causes disease in a single plant species	Microbial communities, vector communities, and/or complex landscapes influence disease outcomes

	Fusarium head blight	Potato late blight
	++ Multiple host species Multiple pathogen species	+ Multiple host species

	Lower complexity	Higher complexity
2. Are there environmental thresholds for population responses?	Pathogen population responses to climate variables are constant throughout the relevant range	Pathogen population responses change suddenly at particular thresholds

	Fusarium head blight	Potato late blight
	0 Little evidence for this	0 Little evidence for this

Allee effects

- Disproportionate reduction in reproductive success at low population densities
- Mechanisms
  - Difficulty finding a mate -> Karnal bunt of wheat
  - Lack of predator saturation
  - Impaired group dynamics
  - Environmental conditioning

An Allee Effect Reduces the Invasive Potential of *Tilletia indica*

K. A. Garrett and R. L. Bowden 2002

PHYTOPATHOLOGY

	Lower complexity	Higher complexity
3. Are there indirect effects of global change factors on disease development?	The relationship between climate variables and disease risk is unrelated to other factors	Global change factors (land use, water, transportation, markets) influence the relationship

	Fusarium head blight	Potato late blight
	+ Land use change: maize and wheat co-occurrence, and reduced tillage systems	+ Enhanced transport networks: greater exchange of seed and pathogen populations

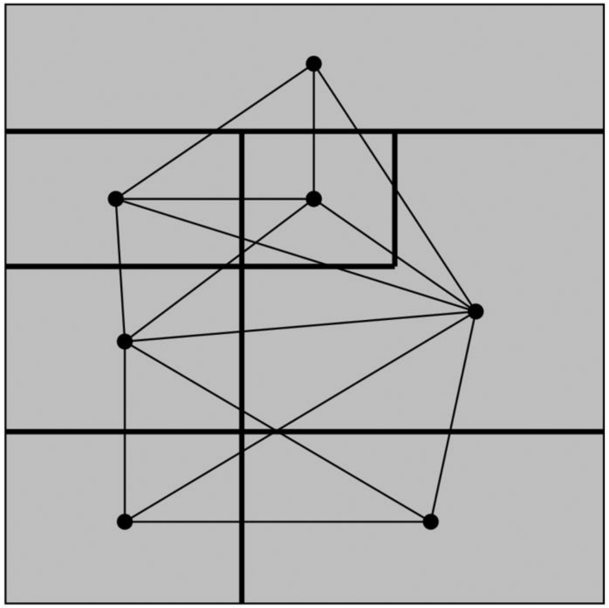
	Lower complexity	Higher complexity
4. Are spatial components of epidemic processes affected by climate?	Disease risk at a given location is not influenced by disease risk at other locations	Climate may influence the likelihood of disease spreading among locations

	Fusarium head blight	Potato late blight
	+ Temporal/ phenological requirements for infection	+ Aerobiology/ dispersal may be modifed

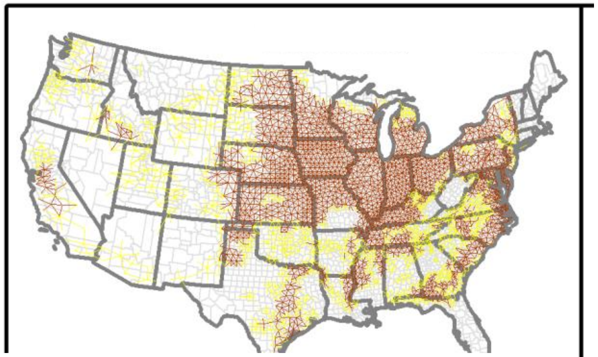
Connectivity of the American Agricultural Landscape: Assessing the National Risk of Crop Pest and Disease Spread

MARGARET L. MARGOSIAN, KAREN A. GARRETT, J. M. SHAWN HUTCHINSON, AND KIMBERLY A. WITH

February 2009 / Vol. 59 No. 2 • BioScience 141



Maize



Red = connected areas for pathogens that require **at least low** maize density to spread

Red = connected areas for pathogens that require **high** maize density to spread

	Lower complexity	Higher complexity
5. Are there feedback loops for management?	Management tools have the same level of efficacy despite changes in other system components	Management efficacy changes greatly with changes in the system

	Fusarium head blight	Potato late blight
	++ Buildup of inoculum from multiple host species makes management more difficult	+ Worldwide, as sanitation and other techniques may become less useful ++ Highland tropics, as colder highlands disappear

A benefit of high temperature: increased effectiveness of a rice bacterial blight disease resistance gene

K. M. Webb[1,2], I. Oña[2], J. Bai[1], K. A. Garrett[1], T. Mew[2], C. M. Vera Cruz[2] and J. E. Leach[3]

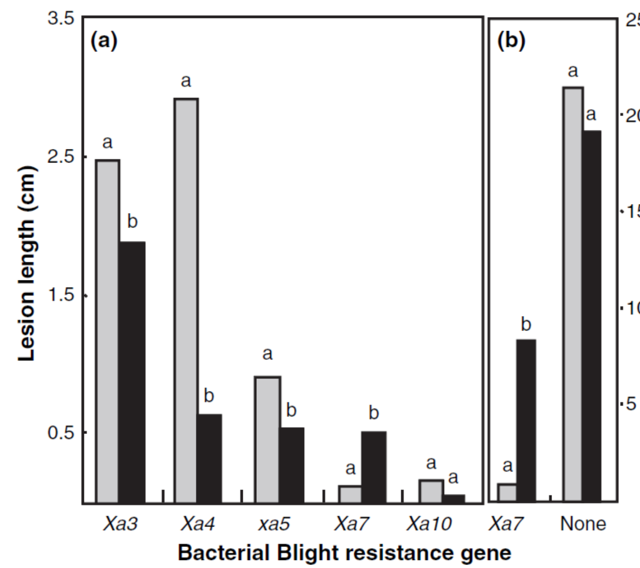


Fig. 4 *Xa7* is more effective in higher (gray bars) than in lower (black bars) temperature regimes. (a) Leaves of rice near-isogenic lines with *R* genes *Xa3*, *Xa4*, *xa5*, *Xa7*, and *Xa10* were inoculated with strains of *Xanthomonas oryzae* pv. *oryzae* that result in resistant interactions using a pin-prick method and grown in high- (35 : 27°C, day : night) and low-temperature regimes (29 : 21°C, day : night). (b) Leaves of rice near-isogenic lines containing the *Xa7* gene (IRBB7) and no *R* gene (cultivar IR24) were inoculated using a leaf clip method grown in high- (35 : 29°C, day : night) and low-temperature (29 : 21°C, day : night) regimes. Lower-case letters indicate significant differences between temperature regimes within a single *R* gene interaction ($P = 0.05$).

Ecological Applications, 19(7), 2009, pp. 1868–1883

Intraspecific functional diversity in hosts and its effect on disease risk across a climatic gradient

K. A. Garrett,[1,2,3,7] L. N. Zúñiga,[4] E. Roncal,[5] G. A. Forbes,[2] C. C. Mundt,[3] Z. Su,[1,8] and R. J. Nelson[2,6]

The benefits of potato mixtures for late blight management were lower in areas with longer growing seasons (Cajamarca-Peru, Quito-Ecuador) compared to areas with shorter growing seasons (Huancayo-Peru, Corvallis-USA)

Where season length increases under climate change, methods such as resistance deployment in mixtures (and sanitation, certain resistance genes) may become less useful

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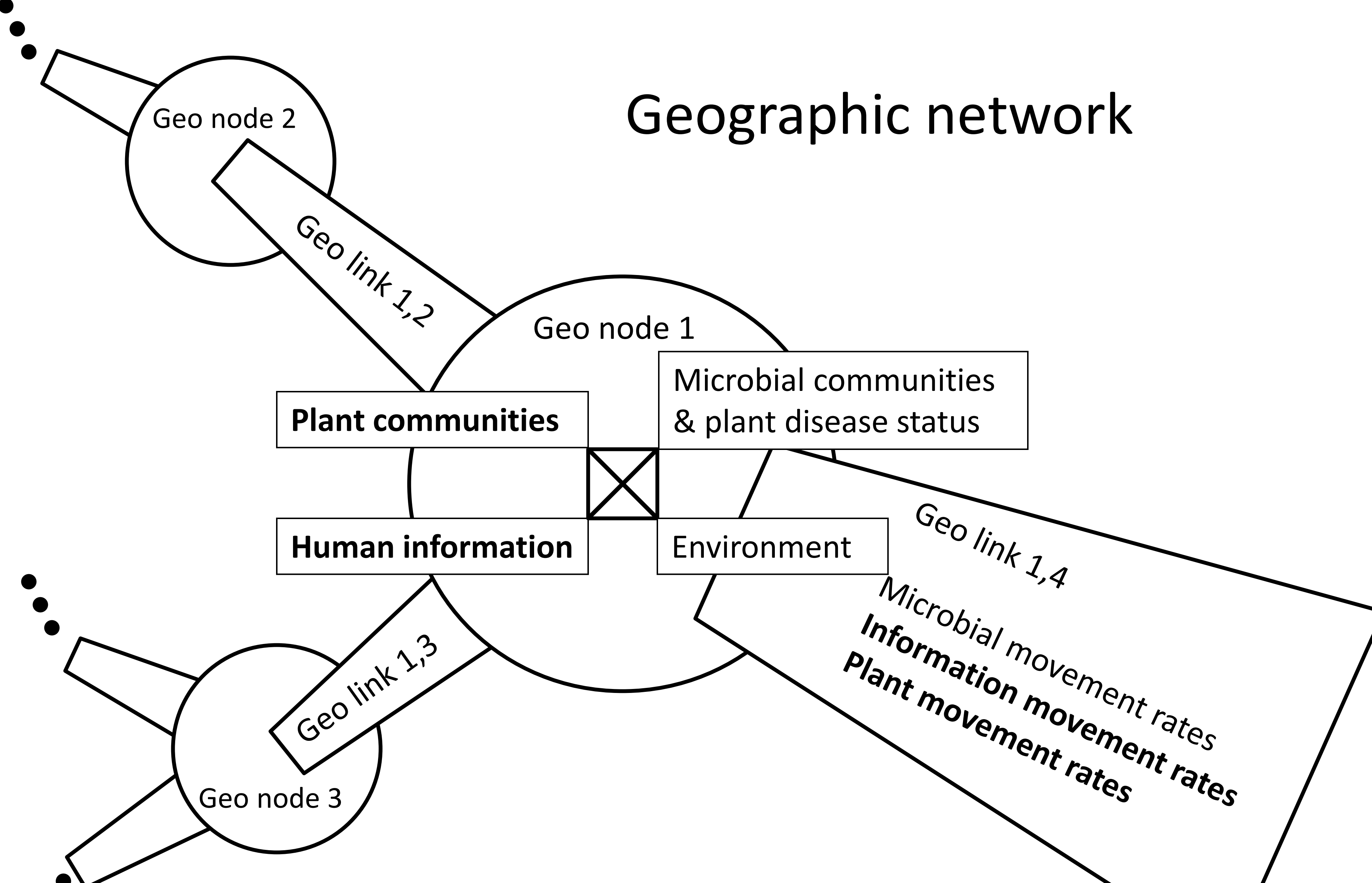
FROM THE AMERICAN PEOPLE
NSF

	Lower complexity	Higher complexity
6. Are networks for intervention technologies slower than epidemic networks?	Disease is already present in relevant areas, or is well understood and easily managed	Disease moves to new areas where farmers do not have tools and knowledge; no knowledge networks
	Fusarium head blight	**Potato late blight**
	+ Online risk evaluations available for some regions	++ Reliance on pesticides, with high knowledge requirements; Slower vegetative propagation of resistant varieties

Geographic network



Information networks for disease: commonalities in human management networks and within-host signalling networks

K. A. Garrett Eur J Plant Pathol (2012) 133:75–88

	Lower complexity	Higher complexity
7. Are there effects of plant disease on multiple ecosystem services?	Disease has impacts only on yield of a single host plant species	Disease may impact other plant species and/or health of humans, other animals, and soils

	Fusarium head blight	Potato late blight
	+++ Management may increase erosion and reduce support for wildlife; mycotoxins create health risks	+ Increased LB results in increased pesticide exposure for humans and environment

Beyond Yield: Plant Disease in the Context of Ecosystem Services

M. R. Cheatham, M. N. Rouse, P. D. Esker, S. Ignacio, W. Pradel, R. Raymundo,
A. H. Sparks, G. A. Forbes, T. R. Gordon, and K. A. Garrett

NCEAS

Policy

Biological impacts from beyond target region

Resistance genes
Invasive species

Ecosystem services

Provisioning services
e.g., Food
Supporting services
e.g., Nutrient cycling
Regulating services
e.g., Climate regulation
Cultural services
e.g., Recreation

System diversity

Pests/disease

& their management

2009 Phytopathology 99:1228-1236.

	Lower complexity	Higher complexity
8. Are there feedback loops from plant disease to climate change?	Disease is affected by climate change, but has no impact on climate change	Epidemics affect climate change factors such as soil erosion and/or photosynthetic capacity

	Fusarium head blight	Potato late blight
	+ Increased 'carbon cost' of wheat production; Tillage may reduce carbon sequestration	+ Increased 'carbon cost' of potato production

The effects of climate variability and the color of weather time series on agricultural diseases and pests, and on decisions for their management

CGIAR

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY

- K. Garrett, Andy Dobson (Oxford), Juergen Kroschel (CIP), Bala Natarajan (KSU), Simone Orlandini (U Florence), Henri Tonnang (CIP), Corinne Valdivia (U Missouri)
- Agricultural and Forest Meteorology, in revision

- In this theoretical model, yield loss grows following a logistic curve, with the rate of yield loss determined by the time series of weather conduciveness to yield loss
- The first results shown are in the absence of management

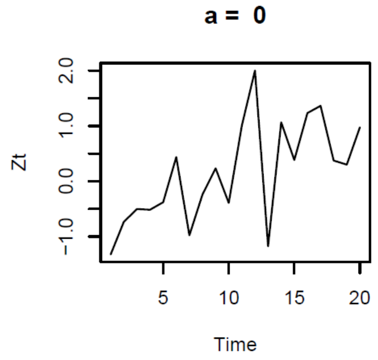
Color of disease/pest loss conduciveness time series

Disease/pest loss conduciveness time series

Yield loss rate time series

Cumulative yield loss time series

White:
no autocorrelation



Light pink:
Moderate autocorrelation

Darker pink:
High autocorrelation

Color of disease/pest loss conduciveness time series

Disease/pest loss conduciveness time series

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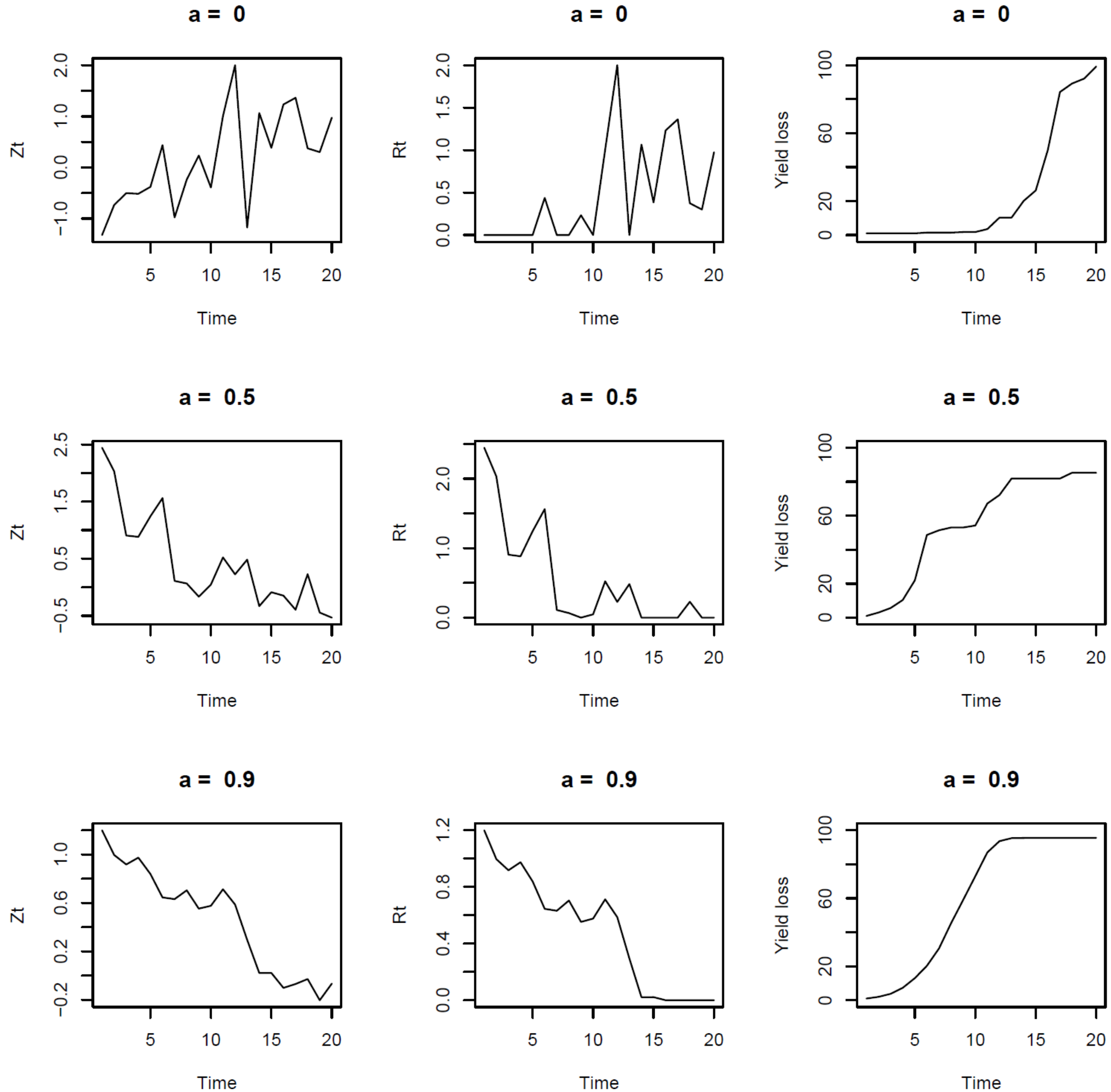


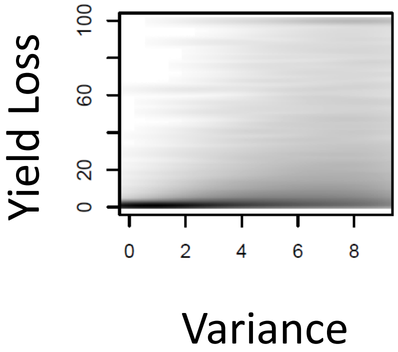
Color of disease/pest loss conduciveness time series

Low mean conduciveness to loss

Intermediate mean conduciveness to loss

High mean conduciveness to loss

White:
no autocorrelation



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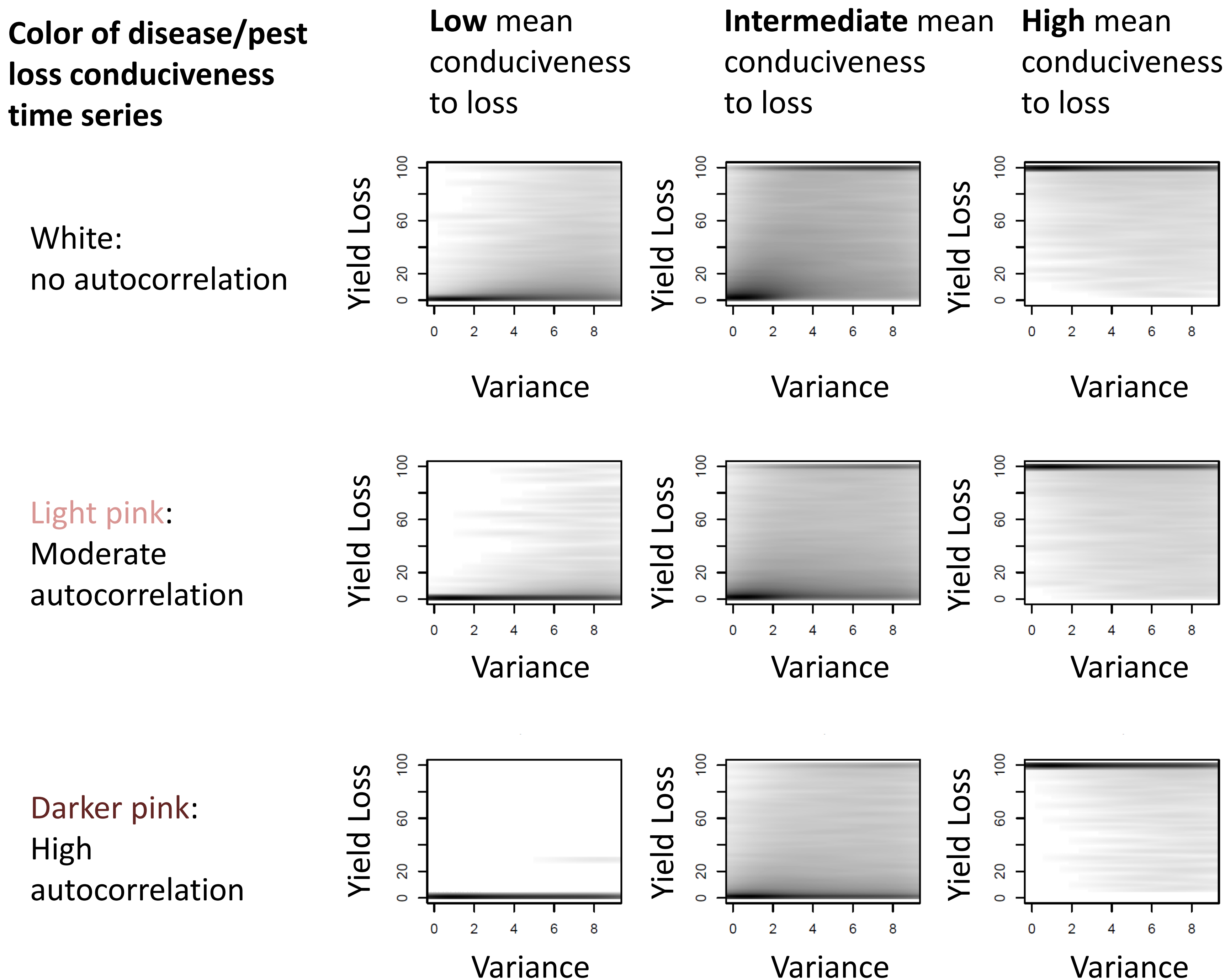
Color of disease/pest loss conduciveness time series
Low mean conduciveness to loss
Intermediate mean conduciveness to loss
High mean conduciveness to loss
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Yield Loss
0
20
60
100
Variance
0
2
4
6
8

Resulting hypotheses

In the absence of management:

- Under less conducive mean conditions, increasing variance increases yield loss
- Under more conducive mean conditions, increasing variance decreases yield loss

What information will farmers use for decision-making?

- Past years
  - In our simulation: If yield loss exceeds the cost of management in 2 out of 3 years, use management this year
- Current year
  - In our simulation: If yield loss has begun by mid-season (>5%) and is not too high (< 100% minus cost of management), use management this year

Resulting hypotheses for success of decision-making

- False positive: decision to manage when it reduces profit
- False negative: decision not to manage when it would have increased profit

- Low or intermediate mean conduciveness to pest/disease loss:
  - Increasing variance increases false positives and false negatives
  - Higher temporal autocorrelation decreases false positives and false negatives
- High mean conduciveness to pest/disease loss: increasing variance decreases false positive rates

Outline

- Inputs needed for a system of adaptation
- ‘Simple’ estimates of climate change effects on disease/pest risk
- Identifying system components for inclusion in climate change scenario analyses
- Impacts of system variance and the color of weather time series

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Thanks for your attention!

Thanks to all the collaborators on these projects

Support provided by US NSF, US DOE, USDA, USAID, CGIAR

Photo: Pete Garfinkel

END OF MAIN PRESENTATION

- Additional slides are supplements that might be useful during the discussion

What do we need to understand to adapt to climate change?

- For growers
  - How to adapt early warning systems for within-season tactical decision making
  - How to construct longer-term (season or longer) support for decision making
- For plant breeders
  - What diseases to prioritize where
- For policy makers / donors
  - What the important disease problems are for investment in the future
  - How financial tools can buffer farmers from increased variability
- In natural systems
  - A lot… including the distribution of resistance genes

Crop arthropod pests

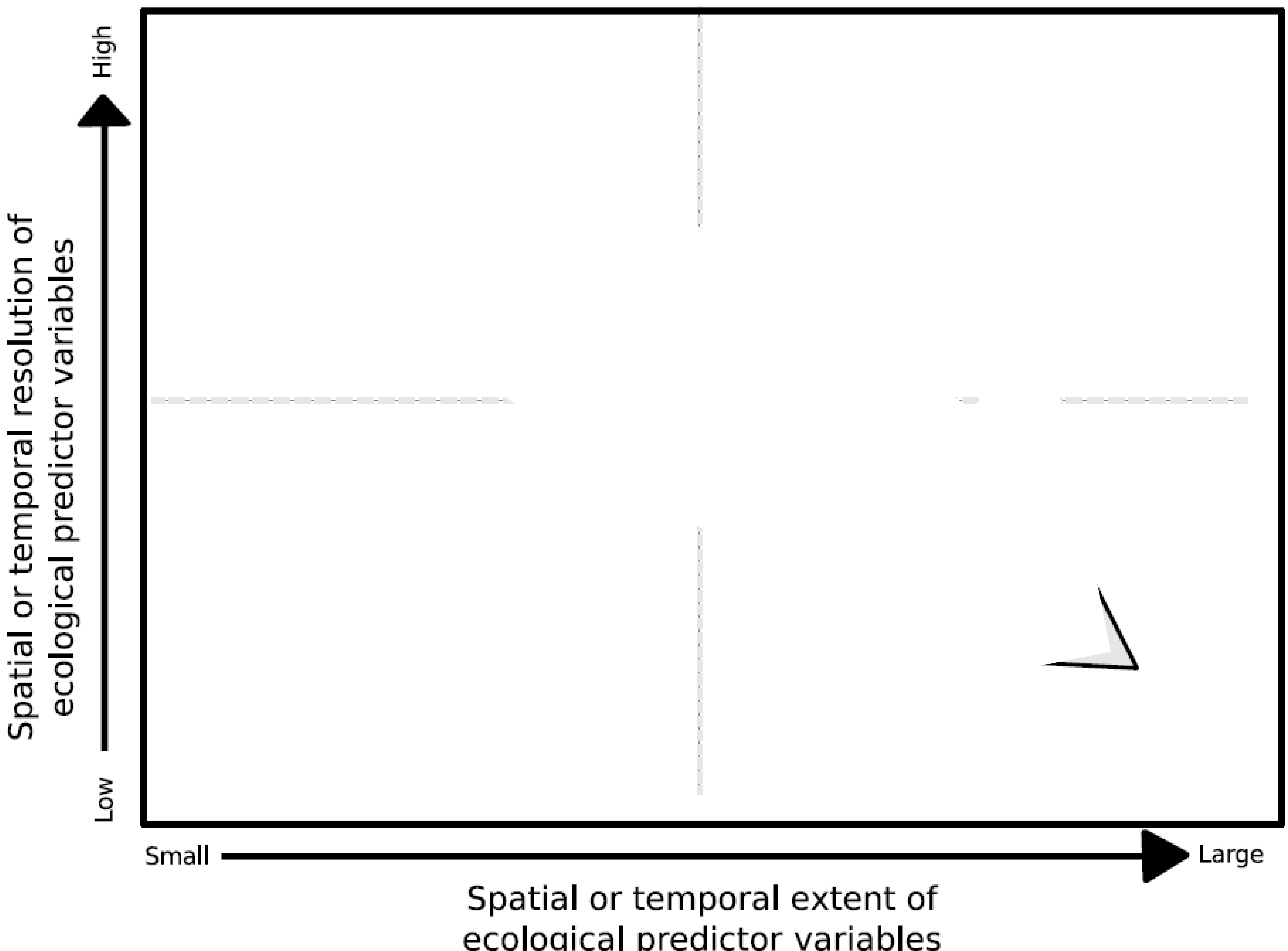
- Potato tuber moths: *Phthorimaea operculella, Tecia solanivora, Symmetrischema tangolias*
- Potato leafminers: *Liriomyza huidobrensis, L. trifolii, L. sativae*
- Cruciferae: *Plutella xylostella*
- Maize: *Plutella xylostella*
- Sweetpotato weevils: *Cylas puncticollis* and *C. brunneus*
- Sweetpotato butterfly: *Acraea acerata*
- Potato whitefly: *Bemisia tabaci Type A and B. afer, Trialeurodes vaporarium*
- Maize stem borers: *Chilo partellus, C. orichalcociliellus* and *Busseola fusca; Sesamia calamistis*
- Cassava mealy bug: *Phenacoccus manihoti*
- Cassava green mite: *Mononychellus tanajoa*
- Mango, Sri Lanka fly: *Bactrocera invadens*

Crop diseases

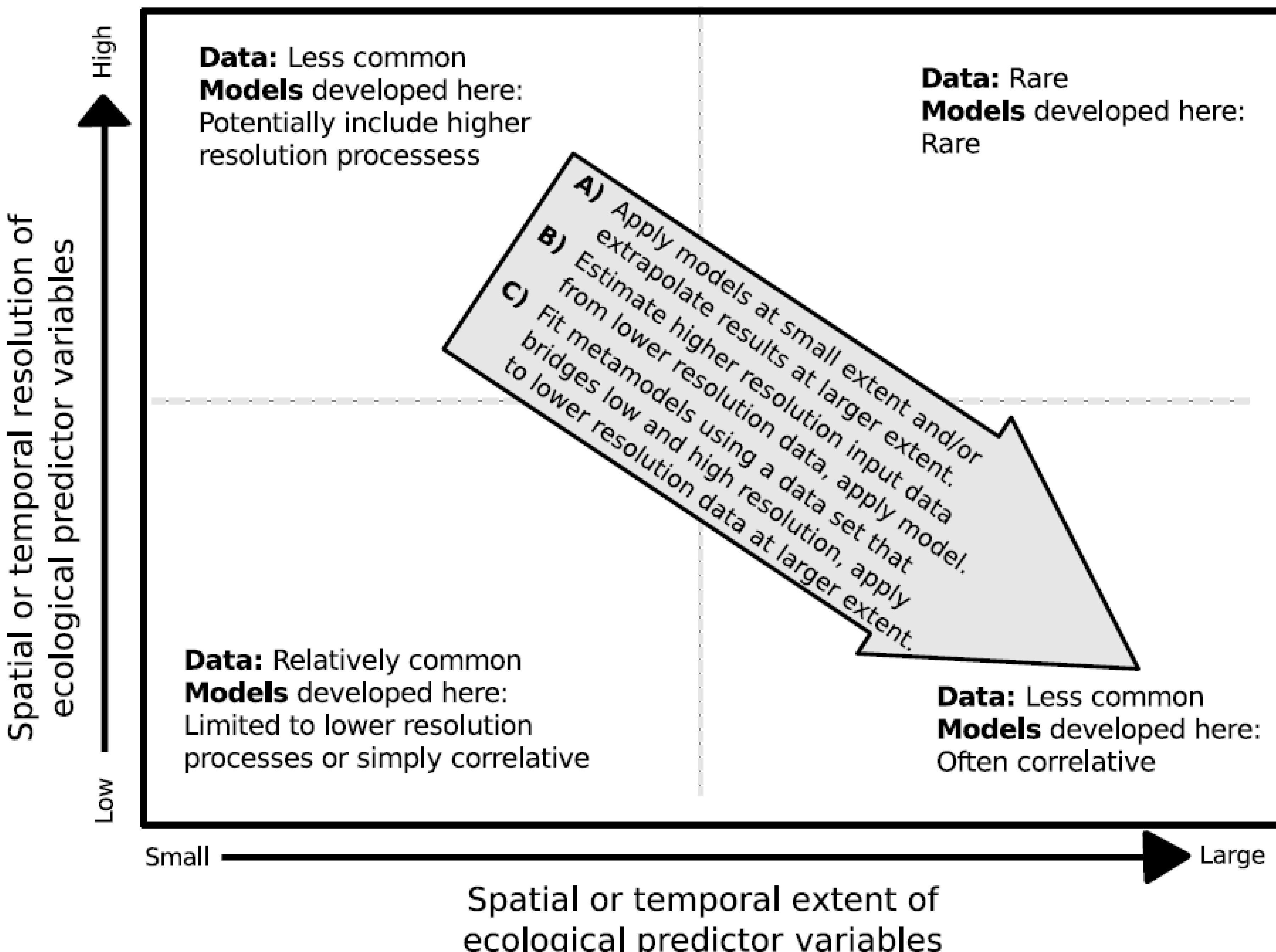
- Maize streak virus
- Rice blast, brown spot, grain rot, and bacterial blight
- Pigeonpea Phytophthora blight
- Wheat rusts
- Potato late blight
- Virus complexes of cassava, sweetpotato, and potato
- Chickpea dry rot (*Rhizoctonia bataticola*)
- Banana bunchy top virus, *Xanthomonas* wilt, and Panama disease
- Mycotoxin-producing pathogens

Livestock pests and diseases

- Fascioliasis: wide host range, incl. humans
- African Horse Sickness: Horses, mules, donkeys
- Rift Valley Fever: Livestock and humans
- Peste de Petites Ruminants (PPR): goats and sheep

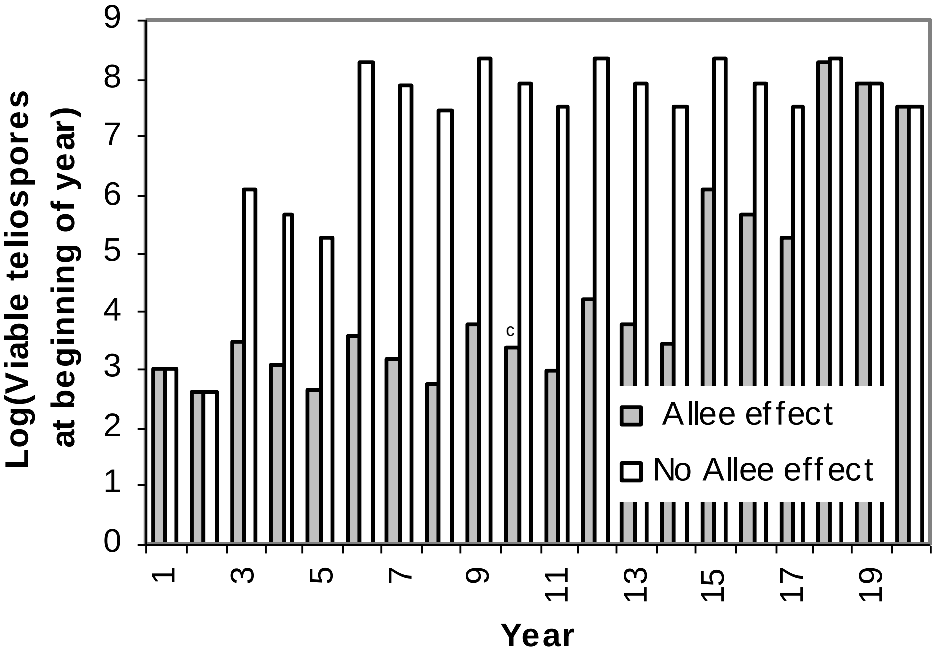


Sparks, Forbes, Hijmans, Garrett, 2011



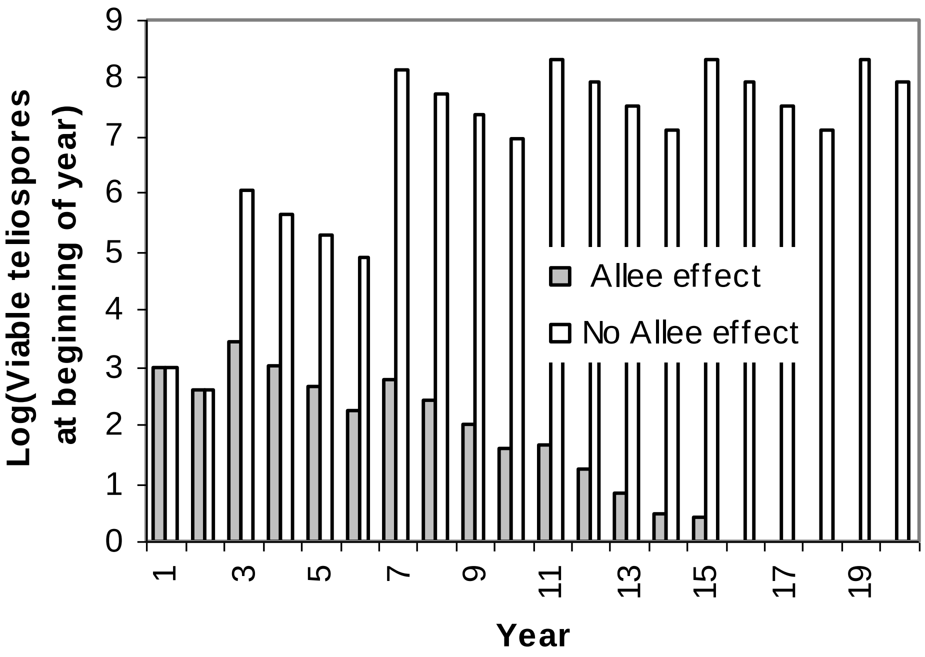
Sparks, Forbes, Hijmans, Garrett, 2011

Conducive year every 3 years



Garrett and Bowden 2002 Phytopathology

Conducive year every 4 years



Garrett and Bowden 2002 Phytopathology

Color of disease/pest loss conduciveness time series	**Low** mean conduciveness to loss	**Intermediate** mean conduciveness to loss	**High** mean conduciveness to loss
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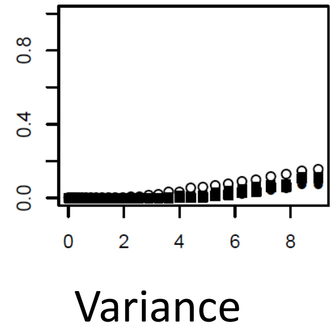

Proportion Incorrect Decisions

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