Risks and Resilience Global Food Systems: An invitation for mathematicians

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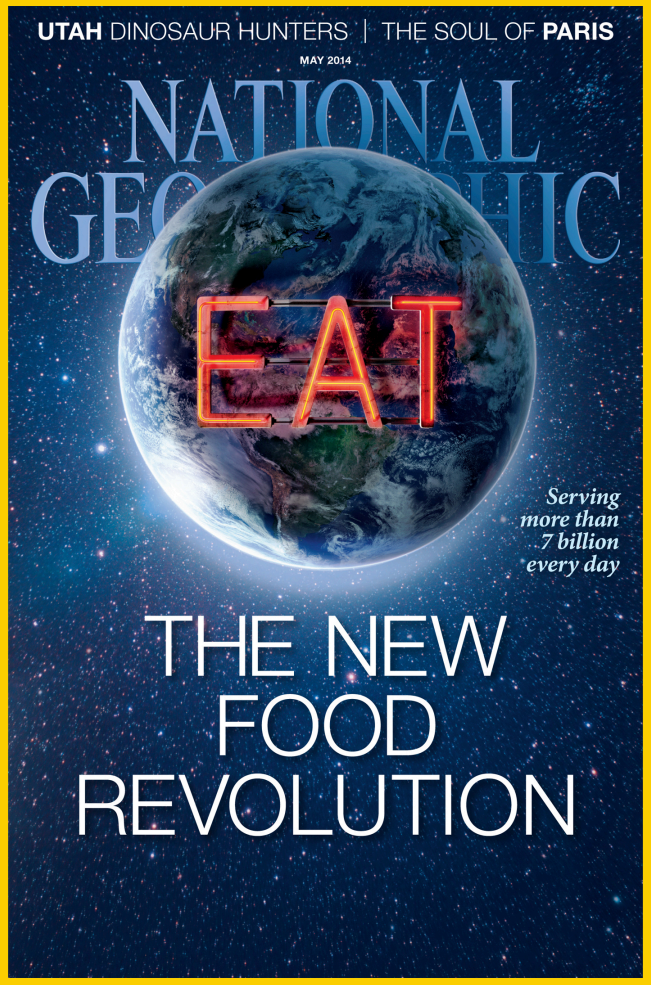
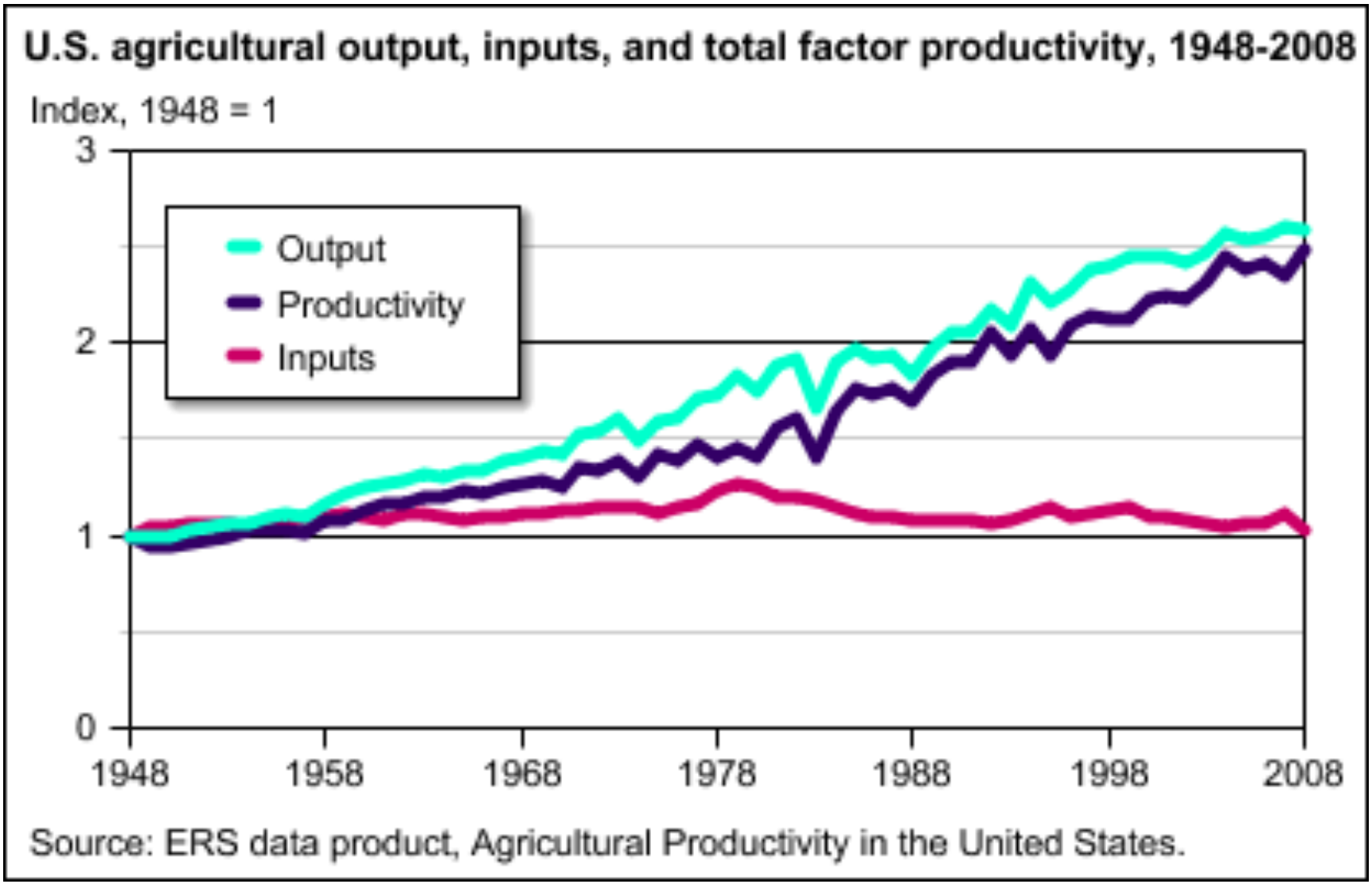
Photo:Edward Burtynsky

Special thanks to Oliver Bettis, Walt Beyeler, Peter Brooks, Virginia Dale

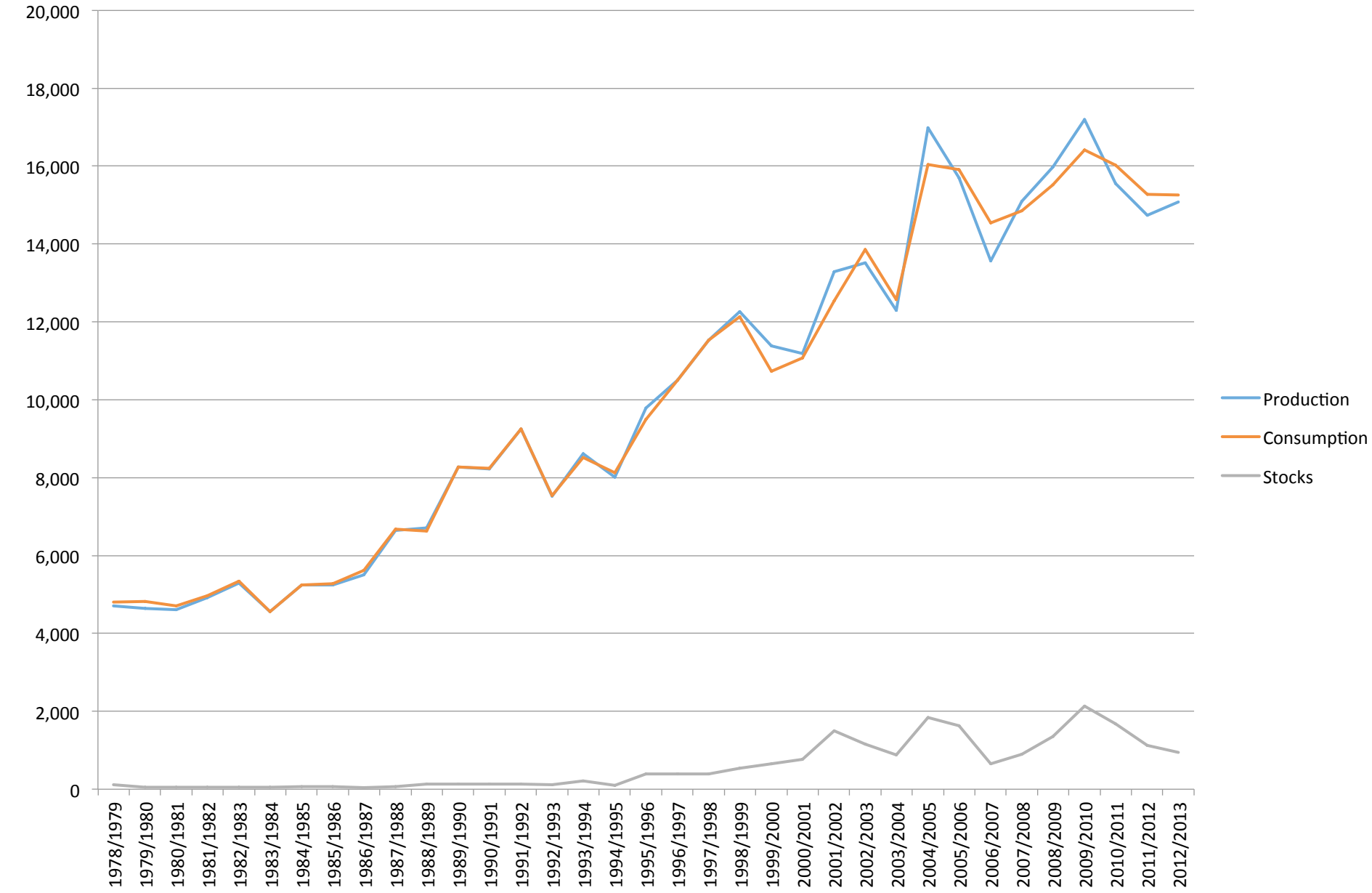

UTAH DINOSAUR HUNTERS | THE SOUL OF PARIS
MAY 2014
NATIONAL
EAT
Serving more than 7 billion every day
THE NEW FOOD REVOLUTION

We've been stunningly successful in driving at agricultural productivity and efficiency…..



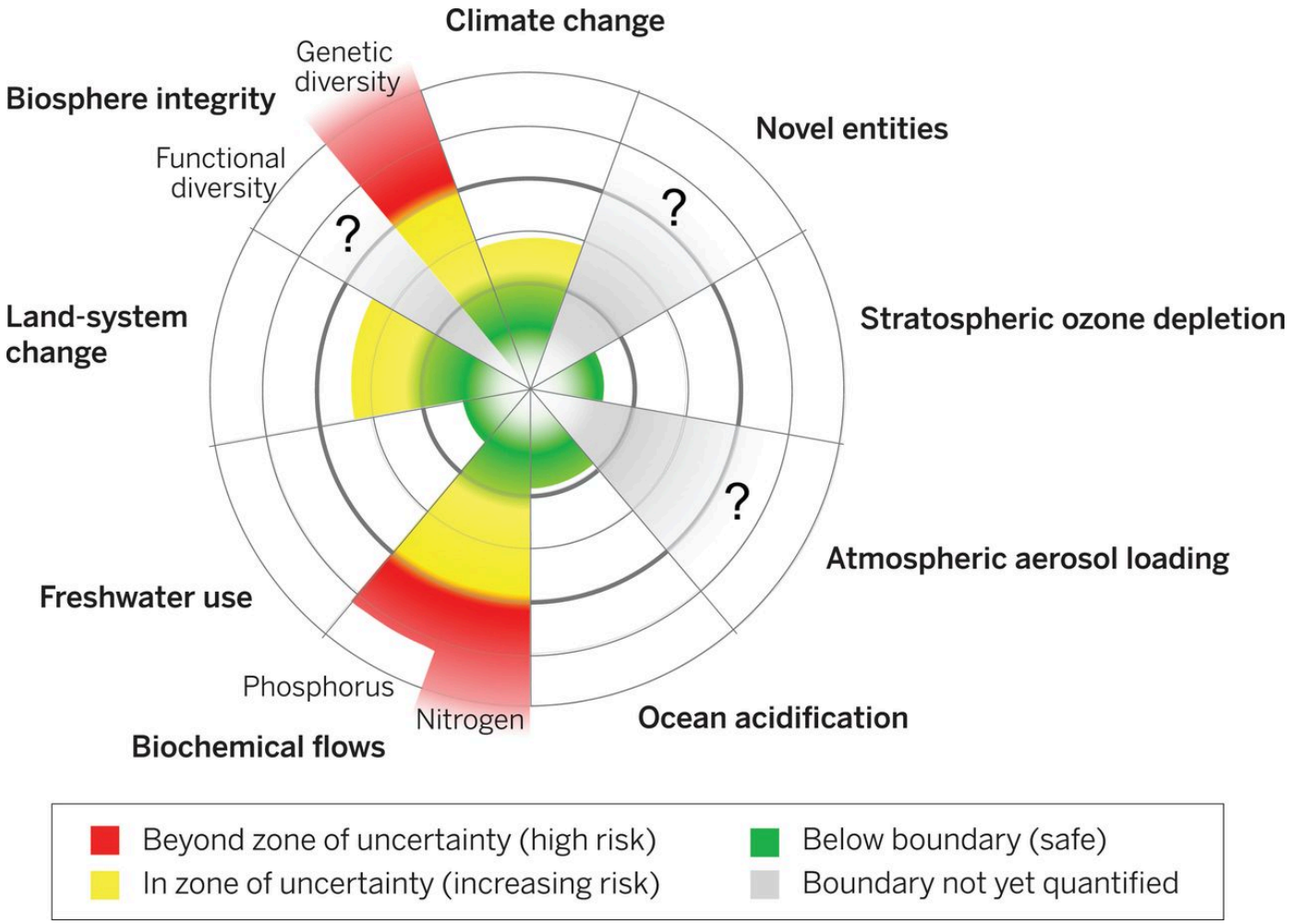
Our current theory is
"More, more, more will make it better, better, better"—
This blinds us to systems properties

“More, more, more.” Even in good years we eat almost all we produce



Marc Sadler

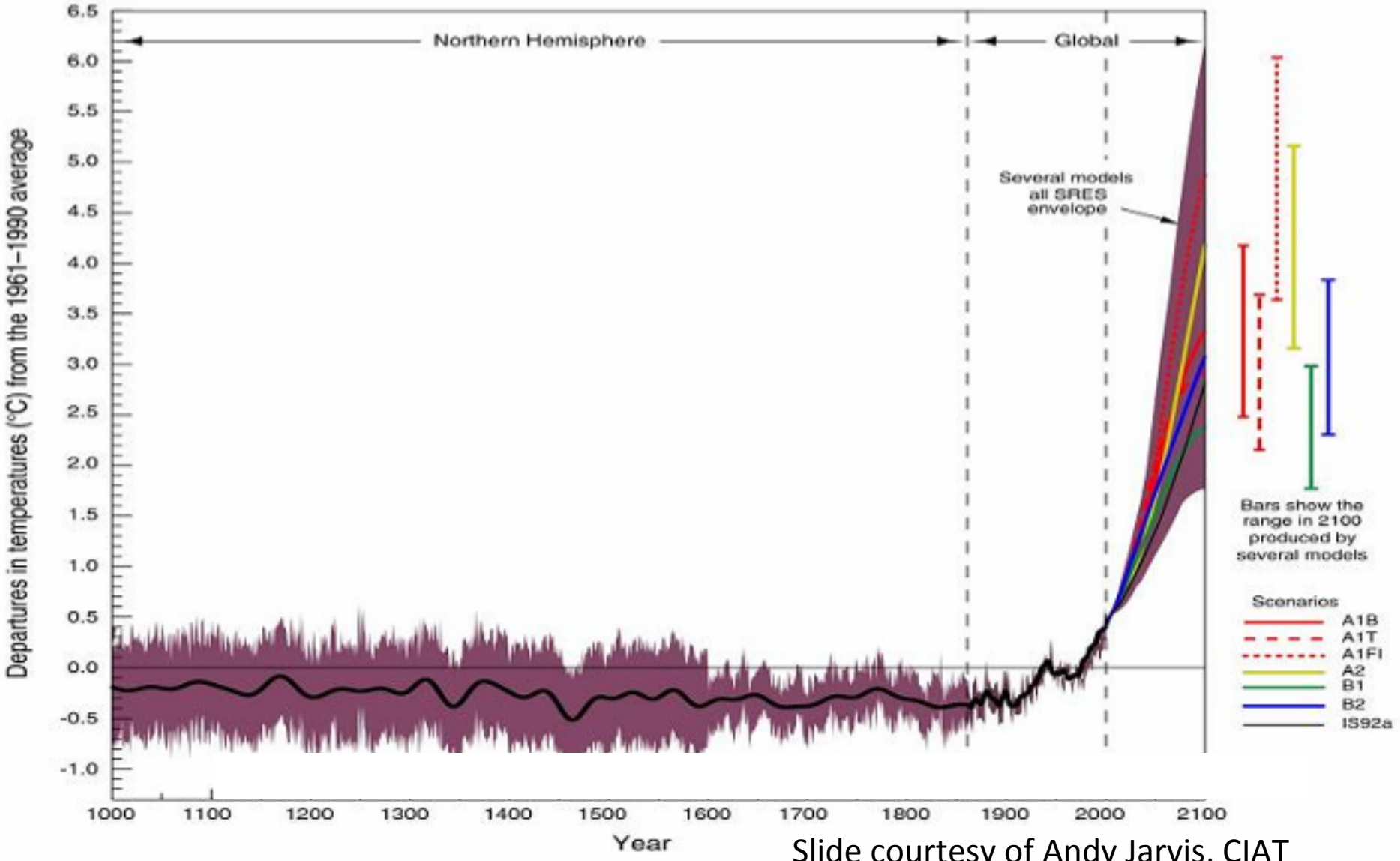
While we run our planet onto the rocks♪



Steffen et al. 2015


Not so Smart
WeirdNutDaily.com

Baseline conditions are changing



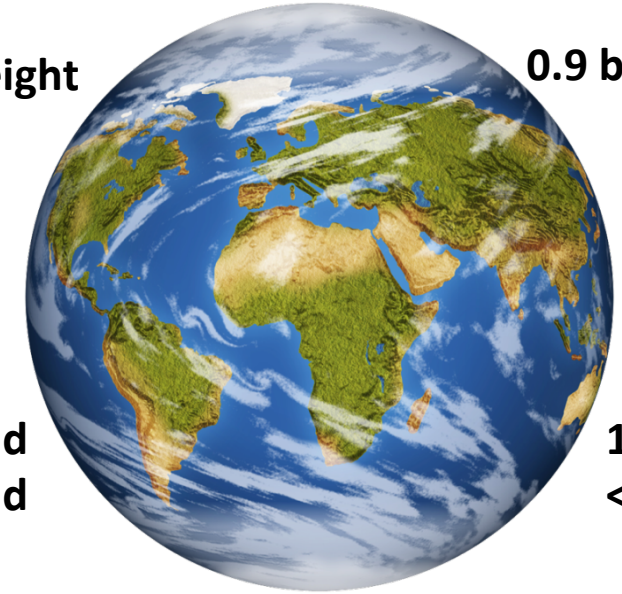
Slide courtesy of Andy Jarvis, CIAT

And our systems do not perform well enough today

7.4 billion people in the world

1.5 billion overweight

0.9 billion undernourished



1.3 billion tonnes of food wasted each year

200+ million more hungry after 2007/8 price spikes

1.5 billion depend on degrading land

1.4 billion live on <USD1.25 / day

12 million ha of agricultural land degraded each year

7.5 billion USD lost to extreme weather in 2010

Commission on Sustainable Agriculture and Climate Change



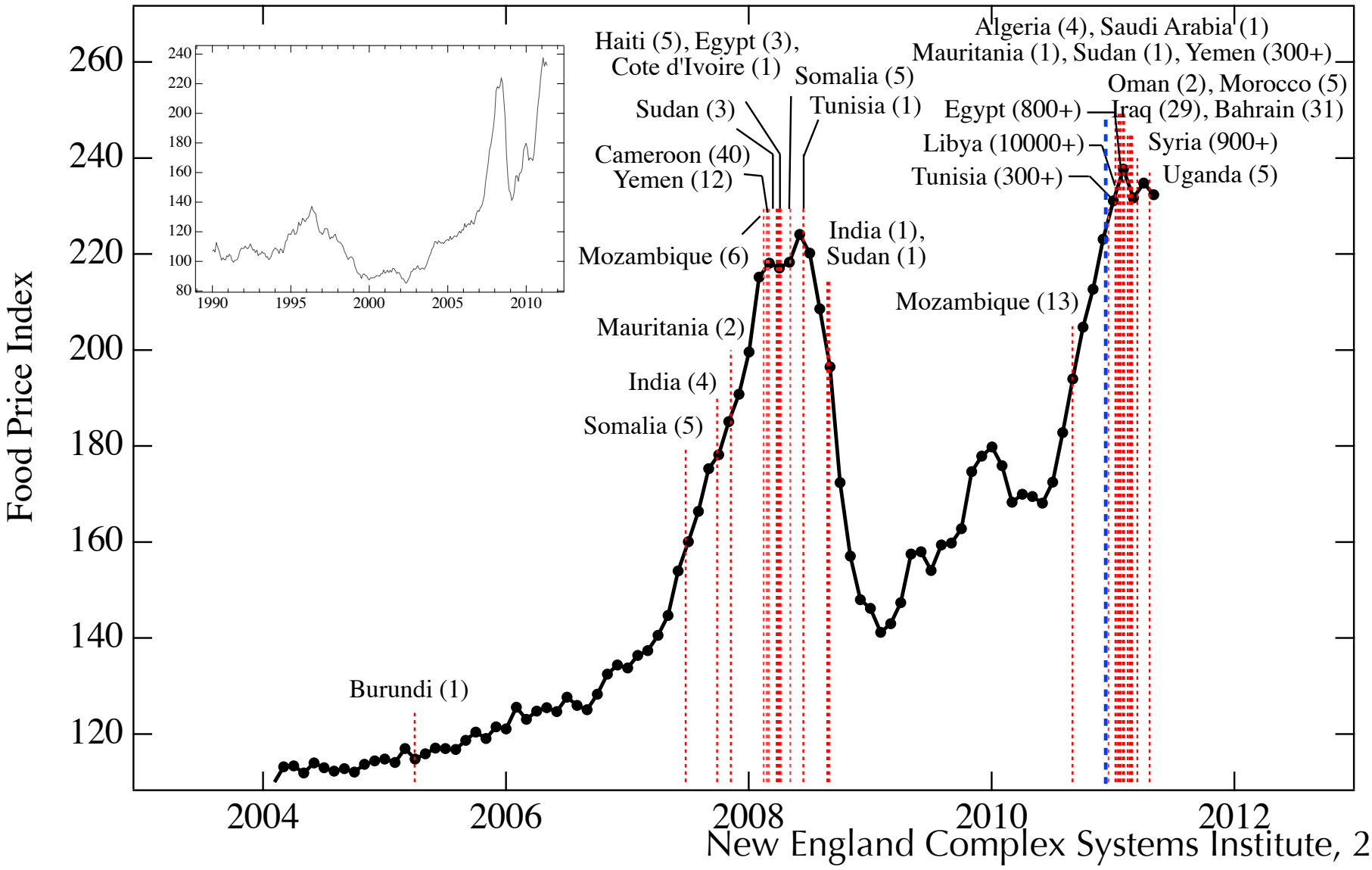
1950s — focus on insufficient production, population increase
1970s — focus on economic failures, interest in
purchasing power, markets
1980s — focus on political failures, equity, agency, access
1990s — focus on food as a human right,
rights-based development
2000s — focus on food insecurity as structural injustice
2010s — focus on food systems as facet of
global human security and human culture

after Elina Andersson


WELCOME
TO THE Fabulous
ANTHROPOCENE
ERA

Patterns of civil instability overlaid with the food price index

Requires better event definition, fine-grained analysis, automated approaches to disparate data



New England Complex Systems Institute, 2012

Civil Unrest/Terrorism

Climate change and
Extreme weather

Land Degradation

Diet-related health

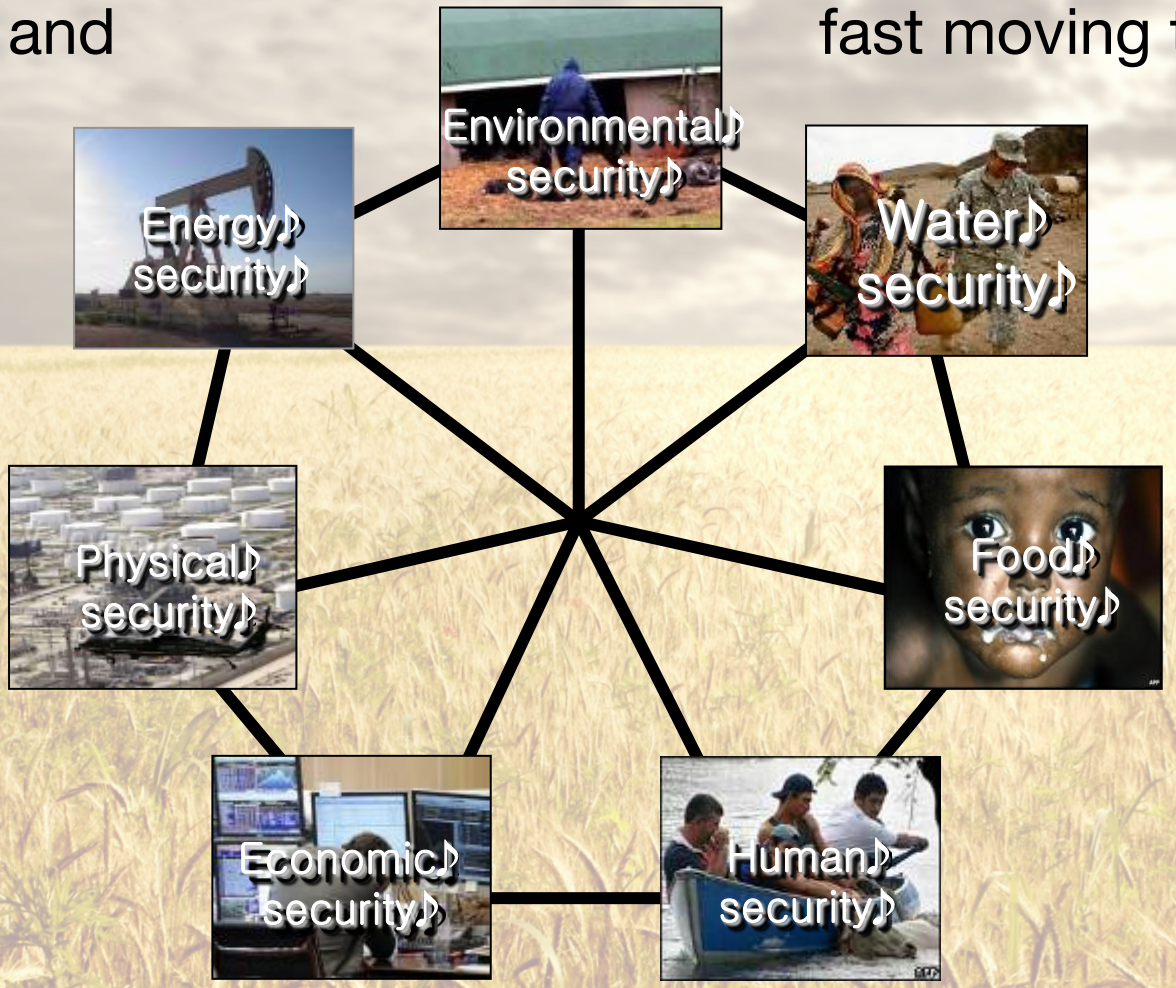
Poverty

Food security is fundamentally connected to everything else

New intelligence paradigms focused on better

anticipatory insights, better multi-scale tools, better insights

slow and fast moving trends



The “Circle of Securities” –many opportunities for mathematicians

Slide adapted from David Robson, image from miriadna.com♪

A call to action for SIAM's Mathematics of Planet Earth?

We're none too early to set our sights on securing a "safe operating space" for our food systems and our planet

Food systems include agriculture, energy, water, logistics and human health and wellbeing in balance with resources

Introducing the

International Commission on Sustainable Agriculture and Climate Change

CLIMATE CHANGE
AGRICULTURE AND FOOD SECURITY

CGIAR

Earth System Science Partnership

Global Donor Platform for Rural Development

Commission on Sustainable Agriculture and Climate Change

Recommendation 1: Integrate food security and sustainable agriculture into global and national policies

Recommendation 2: Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade

Recommendation 3: Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture

Recommendation 4: Target populations and sectors that are most vulnerable to climate change and food insecurity

Recommendation 5: Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating habits worldwide

Recommendation 6: Reduce loss and waste in food systems, particularly from infrastructure, farming practices, processing, distribution and household habits

Recommendation 7:* Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions of agricultural and food systems

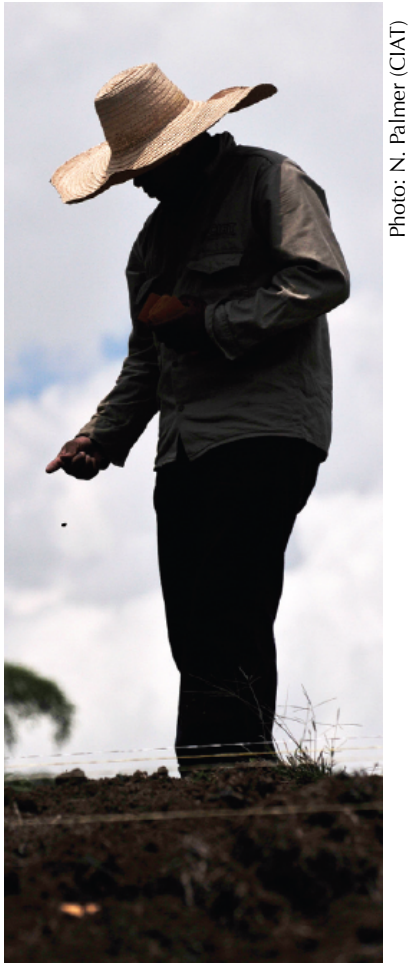
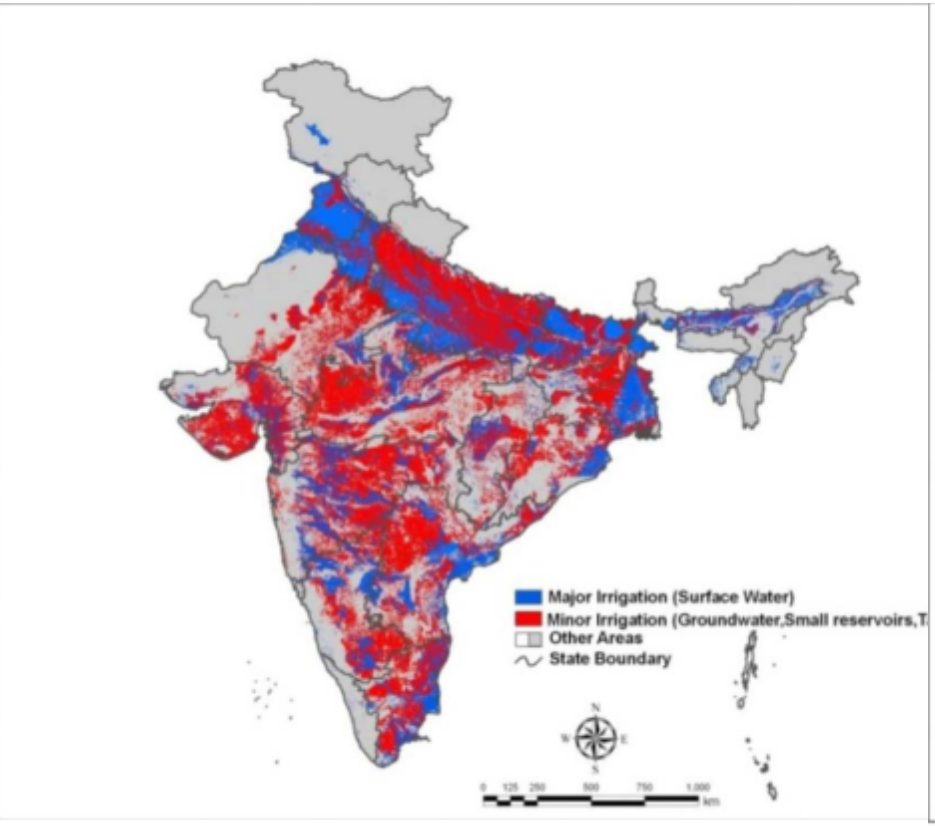


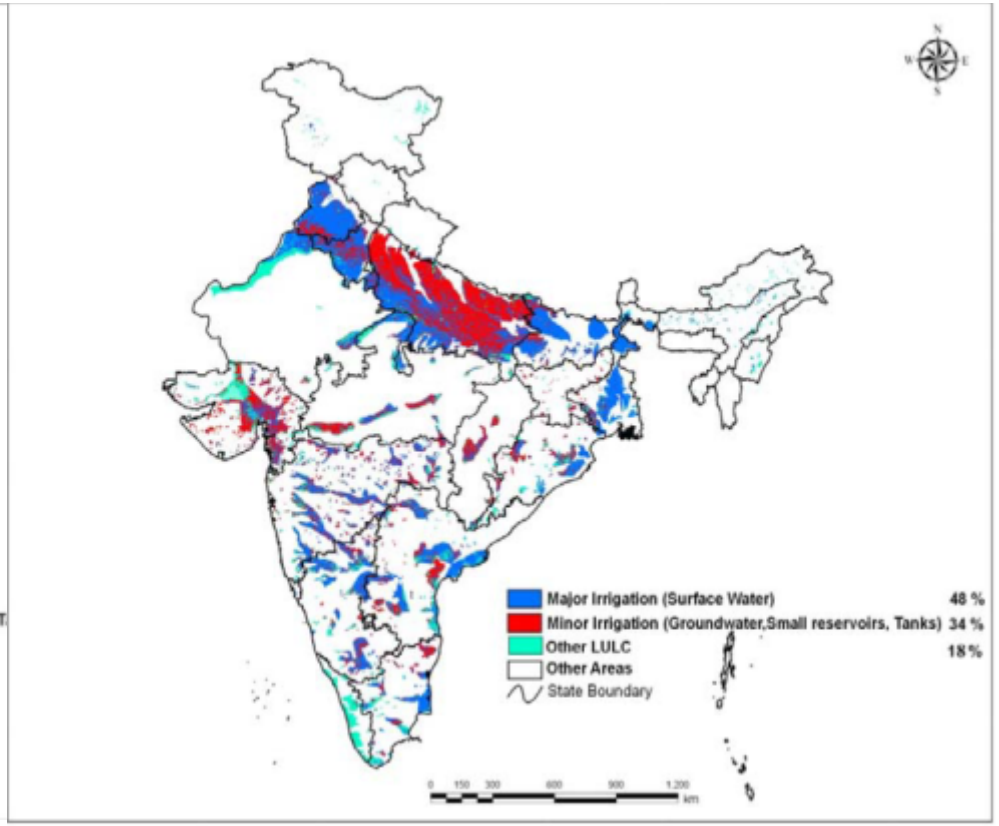
Photo: N. Palmer (CIAT)

Why is "Recommendation No. 7" so important?
How much irrigated area in India?

Intl. Water Management Inst.
113 M ha (net)



Government of India
57-62 M ha



Source: Slide courtesy of T. Hertel and G.C. Nelson

Madame Under Secretary,

Are you telling me that the scientific community doesn't have clear consistent, trusted, ways to share dynamic information about our food systems and the potential implications for national security?
-2010

Unnamed Senior Federal official

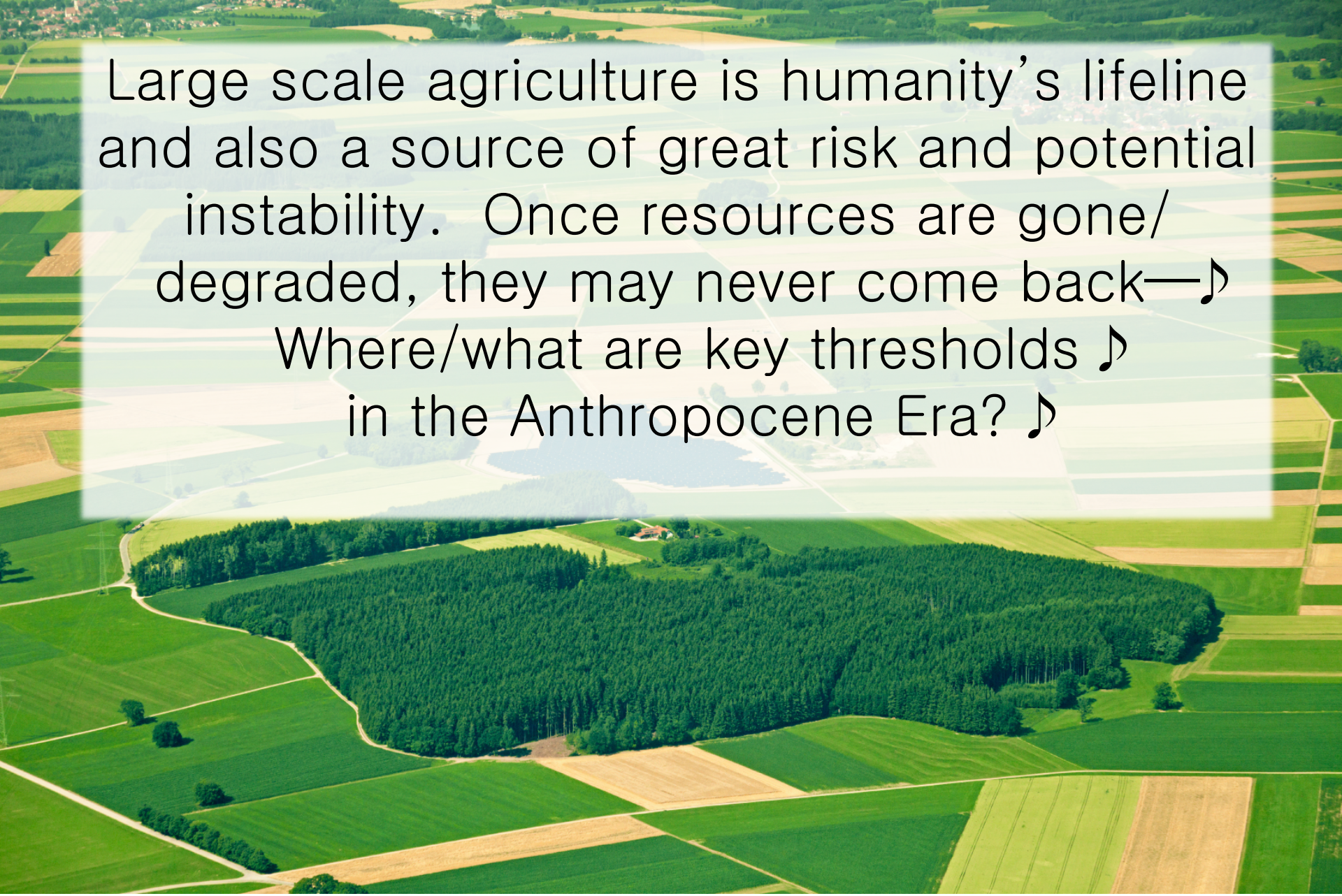
No, Sir.
We don't track our food systems that way….
We have lots of yield estimates, we track critial infrastructures but I do see your point, sir.....

But we'll get right on that, sir.

9 Billion People / 1 Planet ♪

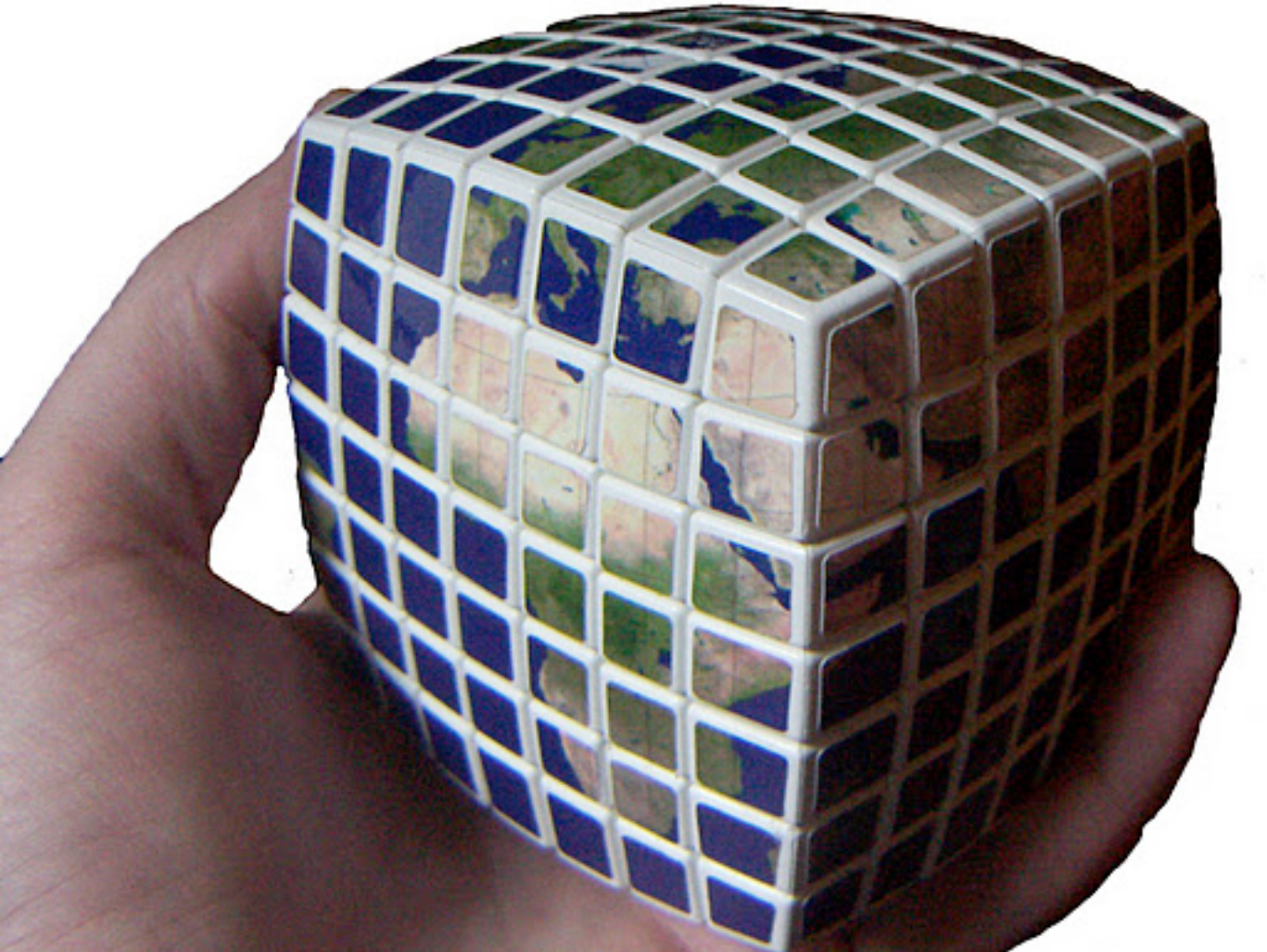
Do we have a plan?♪

Food, Water, Clean Air, Energy, Materials for our kind♪
on a habitable beautiful planet♪

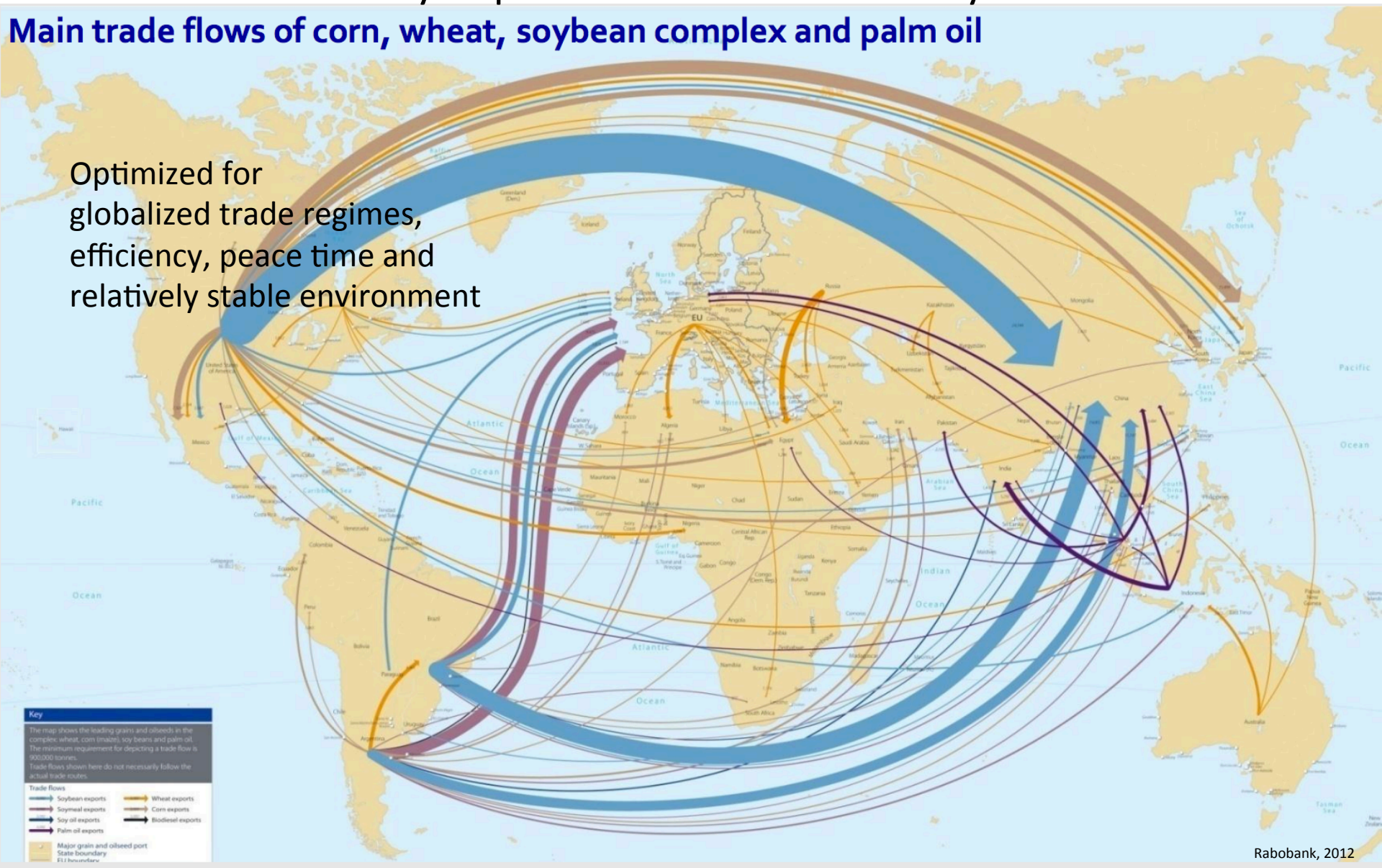


Can we move at scale from extractive to regenerative practices with full accounting for inputs, outputs, and outcomes in multiple dimensions?♪

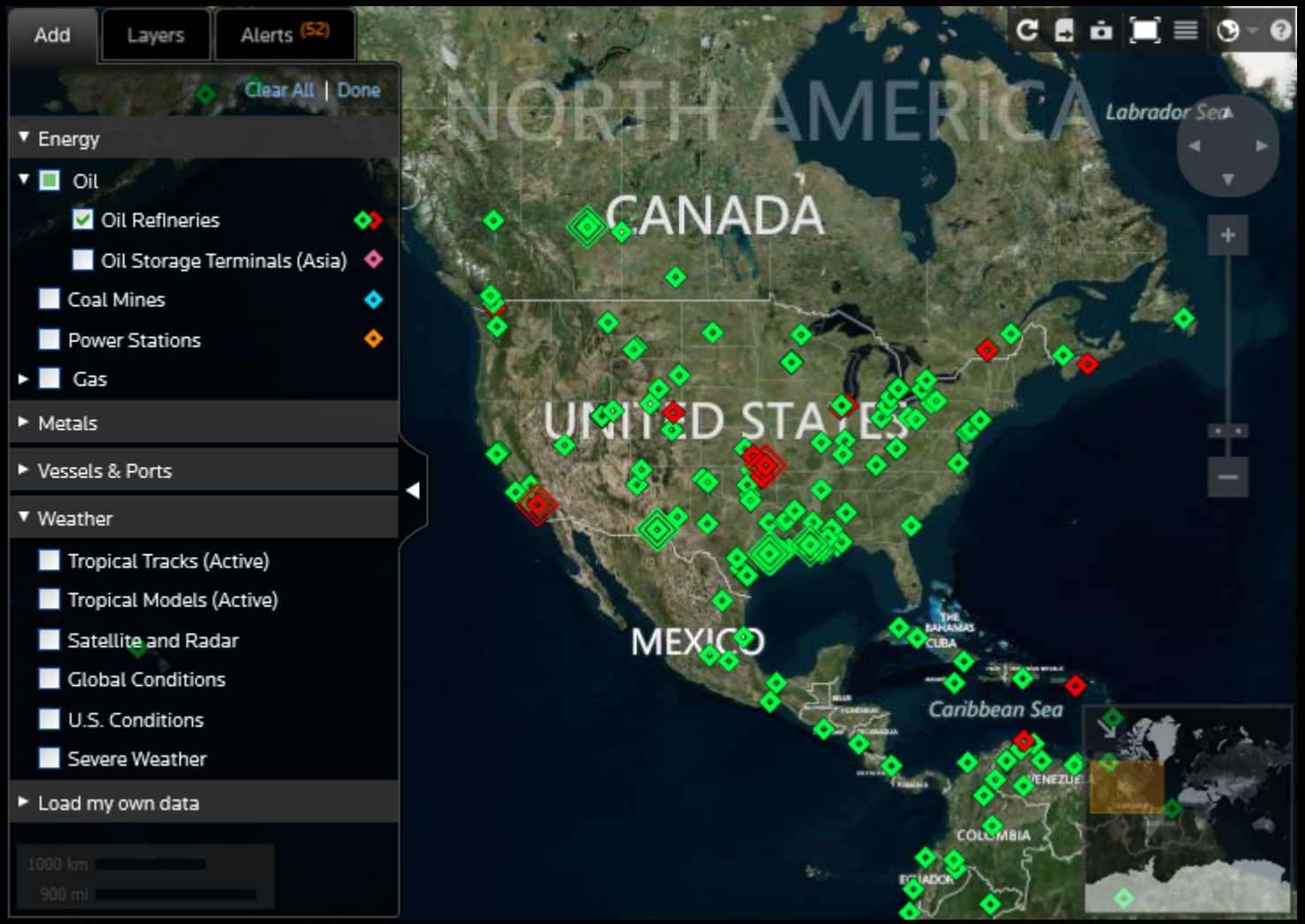
Some Challenges from my world to Mathematicians for Decision-Relevant Insights about Food Security and Food Systems



Modern food systems are a significant part of our species' massive energy and fossil water binge-- dynamic, complex and fundamentally important to human security and survival

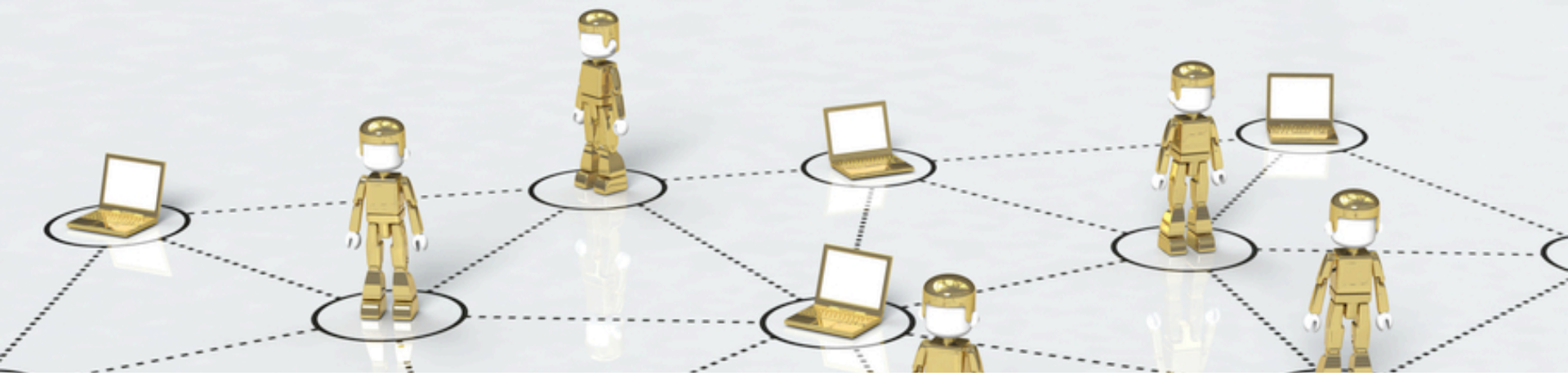


Risks in the food system? tracking vessels, weather conditions, infrastructure-- NRT interactive maps♪



- This is a vast network of networks that changes itself through time
- We have wildly disparate data about these flows, many types of data, data gaps, humans are key—sentiment analysis increasingly emphasized
- Ultimately it is the flow of energy in various forms around the planet including the energy in human beings but we can't "see" this properly
- What will the role of modeling be and data/model fusion to make a weather map like depiction of global food systems and its dynamics?
- We have extremely fragmented insight about the demand side of food systems, the results of the way our food systems work and therefore human outcomes
- And we have an extremely incomplete understanding of…….

From productivity to risk analysis♪
Focus is moving from global to local ♪
From maximized local yield to improved overall system performance including humans and the planet, and resilience♪



Food Security and Food Systems
Data, analytics and theoretical gaps abound
No sector can go it alone

Increasingly unconventional partnerships working to create transparency, trusted information sharing environments in public/ pre-competitive space for collective benefit

An unconventional collaboration:
Oak Ridge Nat Lab and an International Ag Research Center with a global research network GEOGLAM

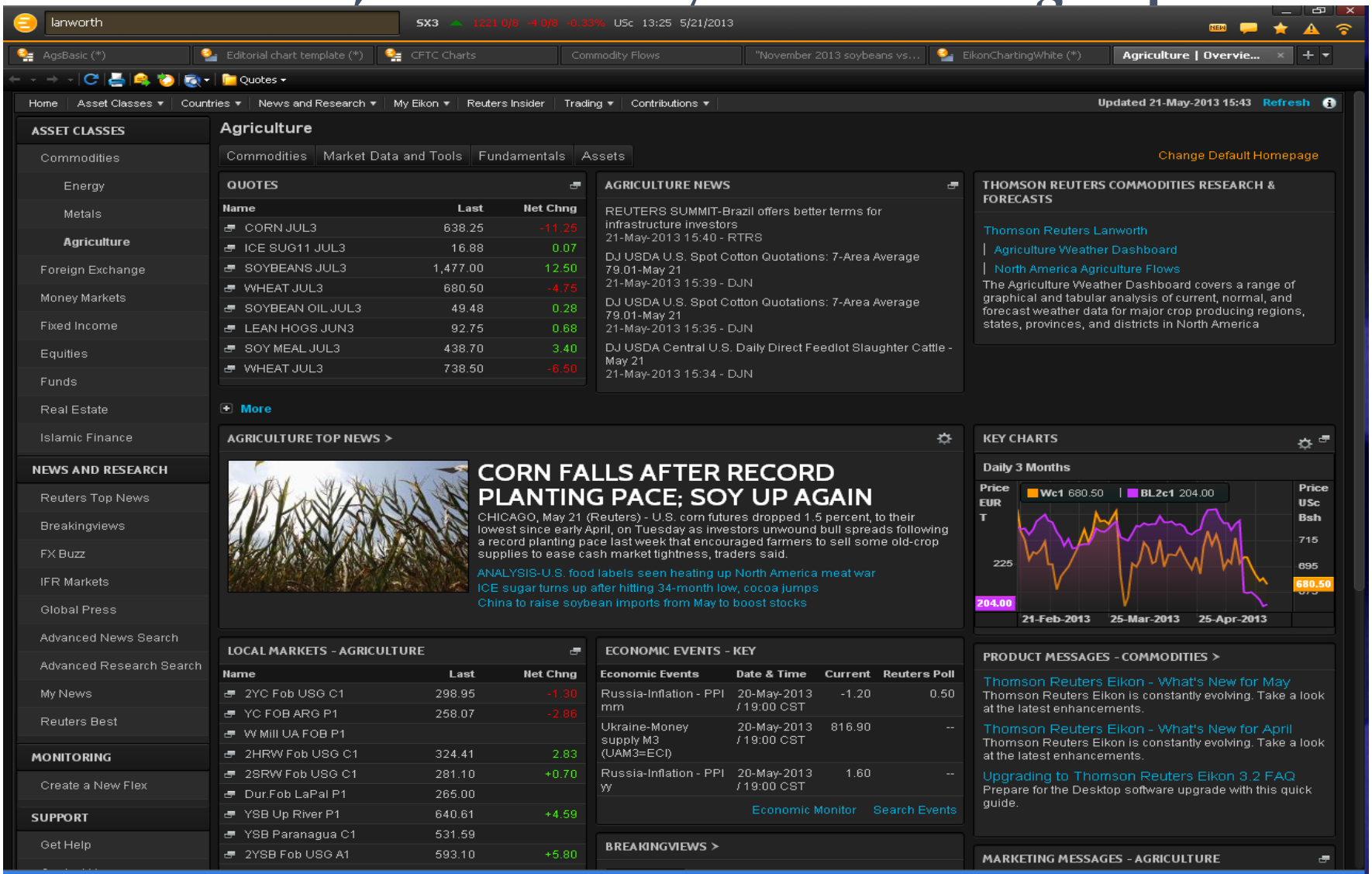
Landscape Scale Crop Assessment tool (LCAT)

Objective	• Compile and build a comprehensive **data inventory** needed for landscape crop assessment
Partnership Capabilities	• Extend existing **data mining algorithms** to build an assessment capability for croplands • Provide a comprehensive analysis summary that provides data, **visualizations, and analysis techniques**
Significance	• Cropland identification • Crop type classification • Crop Phenology • Crop Condition/Status • Yield forecasting

Principal Investigators:
Suresh Vannan(santhanavans@ornl.gov),
Budhendra Bhaduri

Public/Private Research Platforms
Thomson Reuters Eikon

Powerful tools, news & analytics at our fingertips



ASD NII / DOD CIO | USD(I) RFO | USA TRADOC

Multi Agency Collaboration Environment

Where do we take this information? ♪ ♪ To rule makers in the financial community to inform risk to capital♪

Image from www.biometricupdate.com

Risks, Actuaries and Systems Change

Institute
and Faculty
of Actuaries

Canadian
Institute of
Actuaries

Institut
canadien
des actuaires

SOCIETY OF
ACTUARIES

Actuaries
Institute

LLOYD'S

Food insecurity a significant risk to "global society"

Insurance can play a large role in risk mitigation/management as well as innovation/investment

Active collaborations with the actuarial profession in the UK and North America

FEAST OR FAMINE

BUSINESS AND INSURANCE IMPLICATIONS OF FOOD SAFETY AND SECURITY

Food insecurity will be one of the largest risks to global society over the next 10 years.

"The world's resources are under huge stress and the issue of food security is receiving growing attention. Food security is a situation where 'all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life'. The average person needs 2,300 calories per day to live a healthy and active life. On average, in wealthy nations there is enough for each person to eat an additional 1,100 calories, while in low-income countries, national food supplies fall 100 calories short."

Climate change is one of the most important supply side drivers of food insecurity with the potential to substantially change global food markets

"There is general consensus that the impact of climate change on food production will be largely negative and any modest increases in crop yields in high-latitude regions will be more than cancelled out by losses in the tropics and sub-tropics. Although there is great uncertainty about the location and magnitude of temperature changes, rainfall and extreme events, they all pose a significant threat to agricultural systems and therefore food supply. In many places, but particularly in poorer countries, climate change will act as a multiplier of existing threats to food security by 2050."

The issues surrounding food safety and security create a number of direct and indirect risks, as well as opportunities for businesses

"Risks can be categorised as physical, operational, financial, reputational, geopolitical, regulatory, and societal"

The community now focused on "food security" once primarily anchored in "agriculture" is now very large, complex

and widening with each shock

The exposures of food and drinks companies, in particular, have increased with the growth in global supply chains.

"The more complex and extensive a company's food supply chain, the greater its supply chain risk. Contamination or disruption to one part can affect a number of downstream companies."

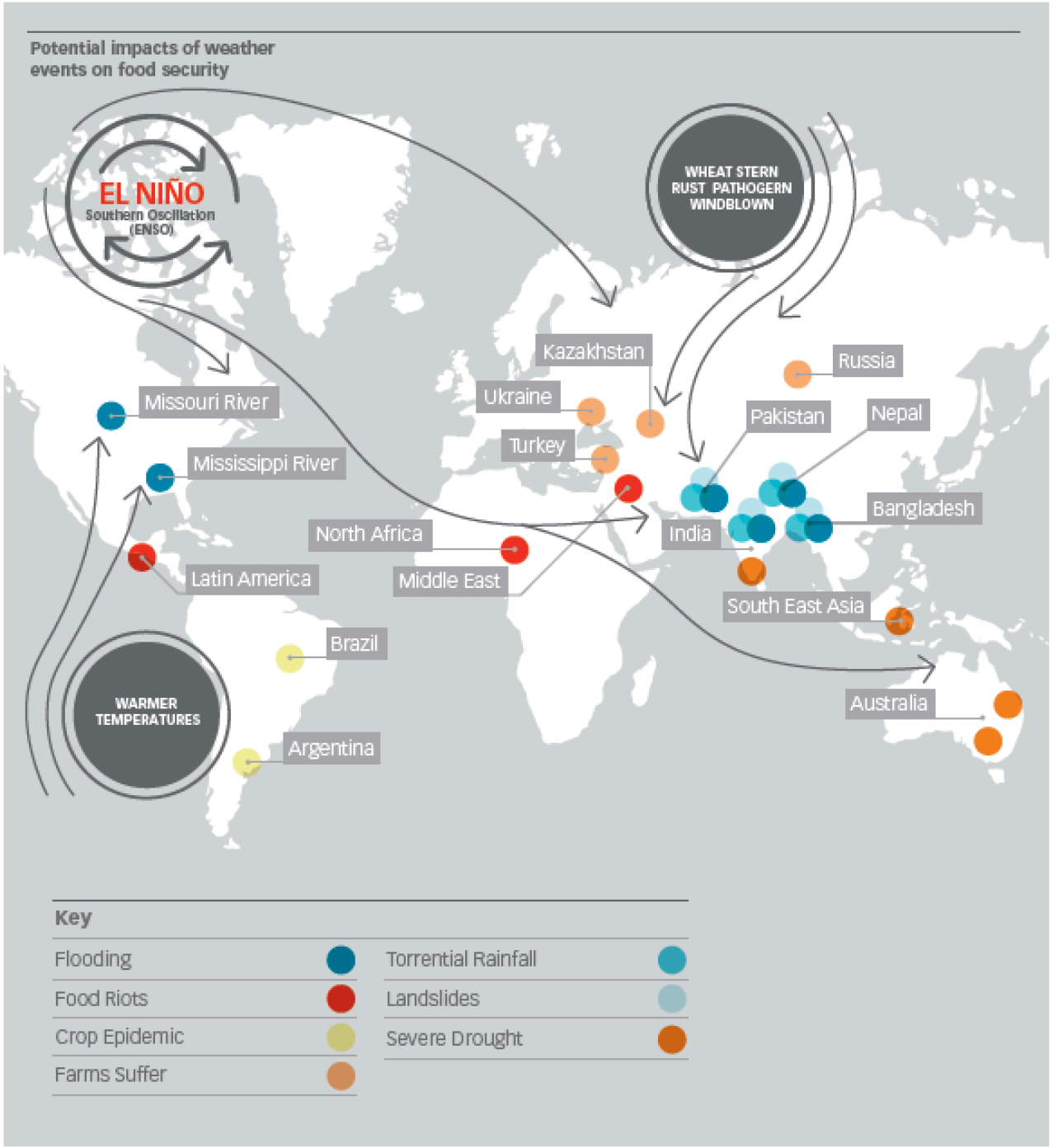
In 2015: The “Lloyd”s food shock scenario

“Extreme”
“Plausible”
Food system shock scenario

- *Maize: 10% production shock*
- *Soy: 11% production shock*
- *Wheat: 7% production shock*
- *Rice: 7% production shock*

From left to right: Sophie Abraham (Willis), Lucy Stanbrough (Lloyd’s), Dr John Alarcon (Willis), Oliver Bettis (Munich Re), Nigel Ralph (Lloyd’s), Tom Hoad (Tokio Marine Kiln), Trevor Maynard (Lloyd’s), Mike Maran (Catlin), Will Steeds (Catlin), Kenneth Donaldson (Munich Re), Dr Aled Jones (Anglia Ruskin University), Prof Molly Jahn (University of Wisconsin-Madison)

Attendees not pictured: Nick Beecroft (Lloyd’s), Andrew Hitchcox (Tokio Marine Kiln), Falk Niehörster (RMS)



Possible Responses:

Nigerian civil war and terrorism in India

Greek Euro exit

Unrest in Middle East and North Africa

NATO/Russian tensions

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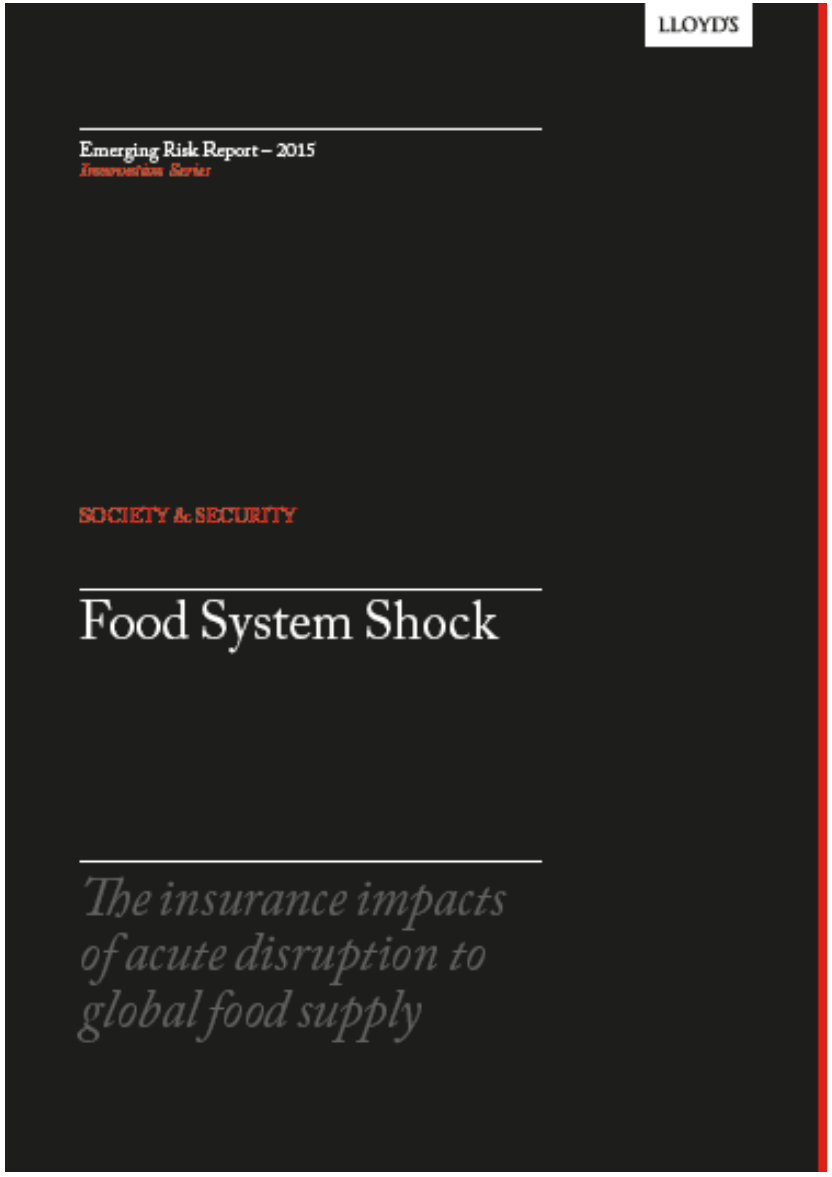
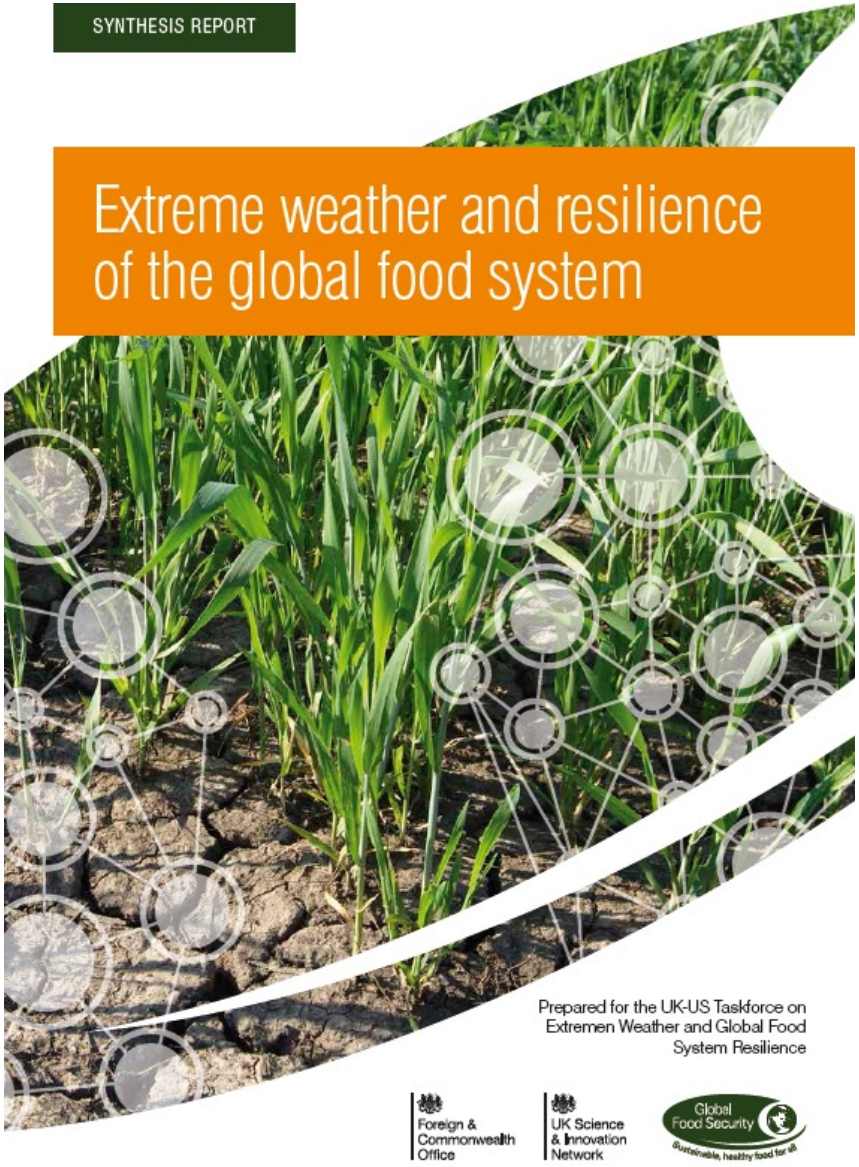
Climate Change Will Likely Test The Resilience Of Corporates' Creditworthiness To Natural Catastrophes

Miroslav Petkov, S&P

More of our 2015 work……. Science + Capital + Policy





Overall global economic impact♪

US stocks lose 5% of value

EU stocks lose 10% of value

Global rice production falls by 7%

Global maize production falls by 10%

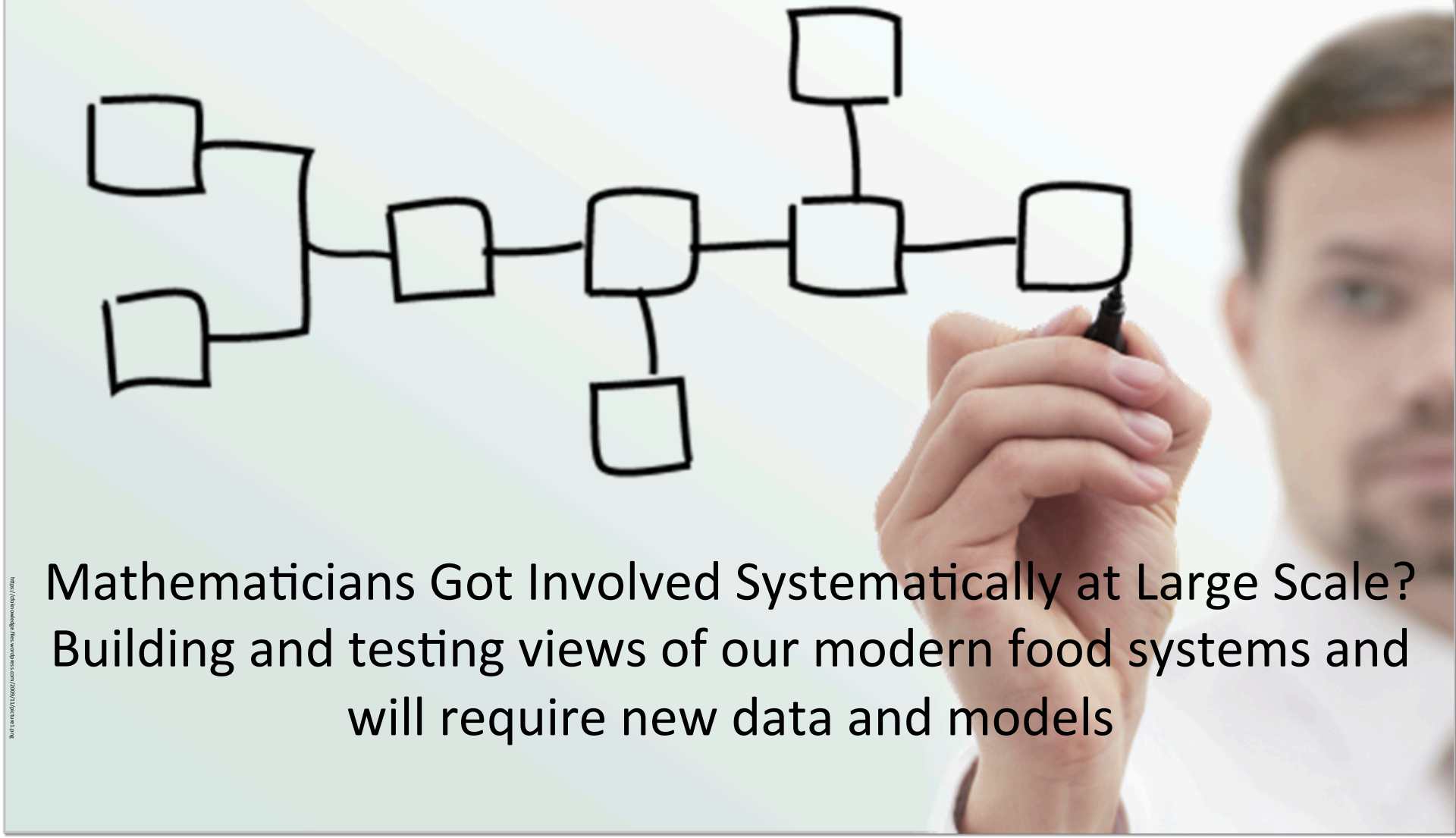
Global soybean production falls by 11%

Rice prices increase by 500%

FOOD
CHAIN
REACTION
A Global Food Security Game

9-10 November 2015

WHAT IF?



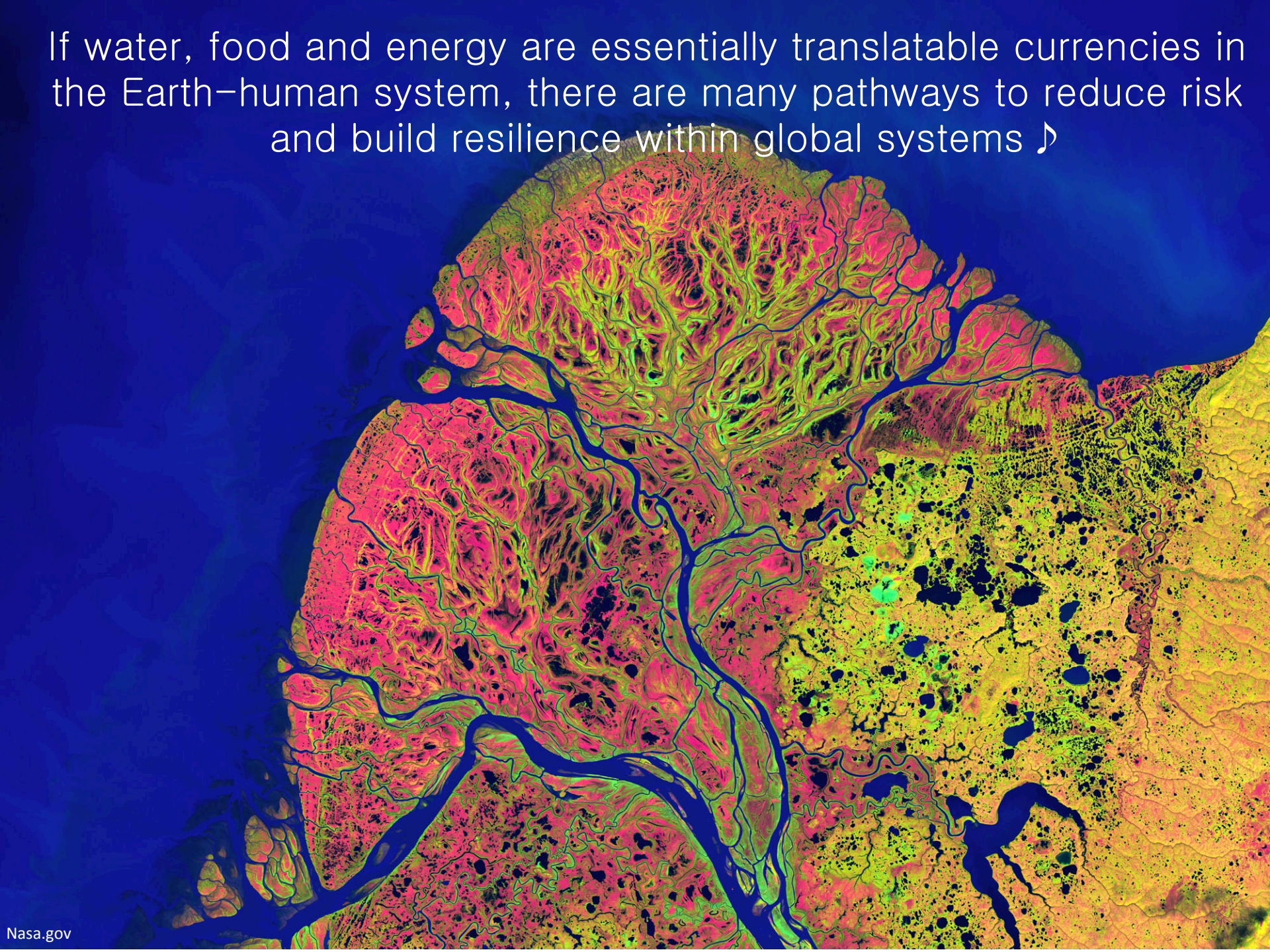
Mathematicians Got Involved Systematically at Large Scale?
Building and testing views of our modern food systems and will require new data and models

Toward something more like personalized medicine for managing the planet♪

- In a globalized economy, where ♪should we be doing what?♪
- Proactive responses focused on ♪risk mitigation, ♪stability/health ♪
- Toward productive, **resilient** ♪systems with sufficiency in ♪human dimensions♪
- Requires high resolution, geo-♪located data, new tools, ♪new governance ♪structures♪
- Partnerships across many ♪different kinds of ♪boundaries will be key♪


Robert Muir-Wood
Chief Research Officer
Risk Management Solutions, Inc.
A focus on food systems in catastrophe modeling is long overdue.
Applications of hybrid approaches, like catastrophe modeling shows great promise
This will create new demands for data & analytics
ex·ceed·ance
RMSCONFERENCE2014

If water, food and energy are essentially translatable currencies in the Earth–human system, there are many pathways to reduce risk and build resilience within global systems ♪



Nasa.gov

Global Assessment Report on Disaster Risk Reduction

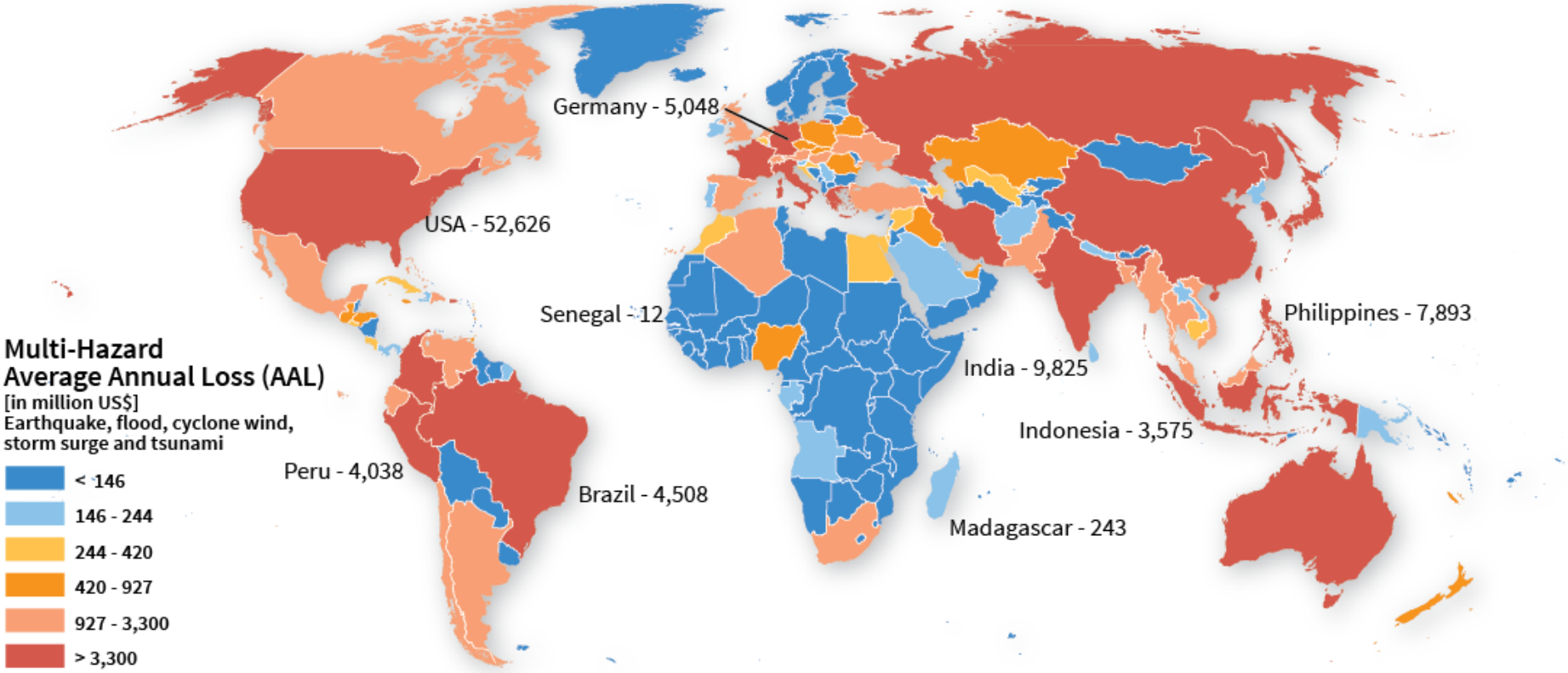
2015

Making development sustainable: the future of disaster risk management

UNISDR
The United Nations Office for Disaster Risk Reduction

GAR

We need mathematicians to help with probabilistic multihazard risk modeling for agriculture

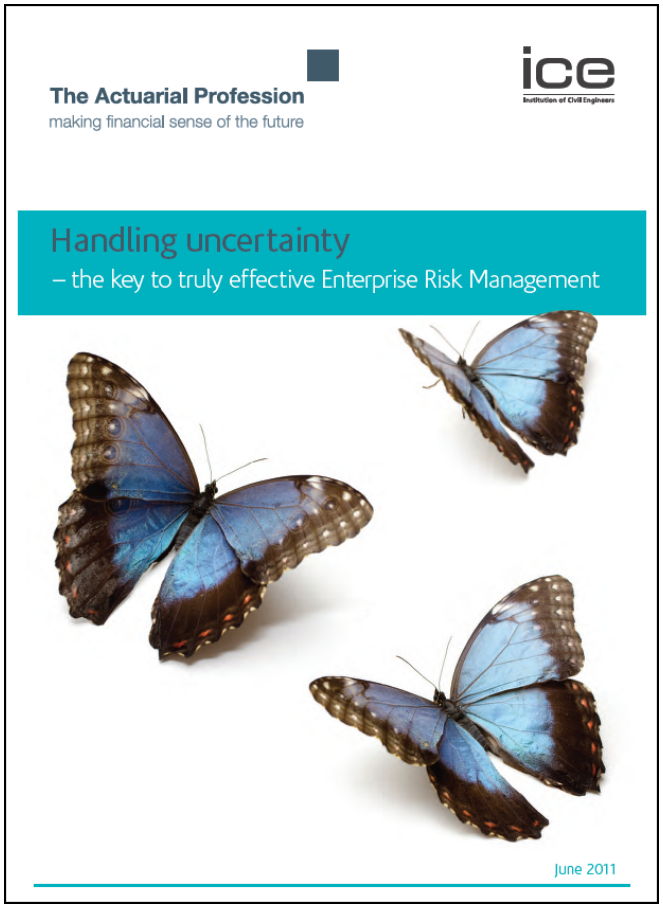


Expected future disaster losses annualized over the long term

UNISDR
The United Nations Office for Disaster Risk Reduction

GAR

We need better integration of rigorous approaches to uncertainty



Institute and Faculty of Actuaries

Joint paper on handling uncertainty with systems thinking, by the Institute and Faculty of Actuaries and the Institution of Civil Engineers. https://www.actuaries.org.uk/documents/handling-uncertainty-key-truly-effective-enterprise-risk-management-0

Report in from the Actuary/Scientist Front
We need better foundations in economic theory

PS I feel slightly strange talking in this way but need to explain my thinking. Did you ever see that war film "A Bridge Too Far" (some critics unkindly called it "An hour too long", but I liked it). It was about the parachute attack in Arnhem in 1944, trying to finish the war early. But it was too ambitious and ended in disaster. That's kind of my feeling about trying to link together those like you in the primary economy and like me in the tertiary economy. Until we have better economics, it's a very risky strategy. Finance professionals have no sound authority to talk about the internal workings of finance in normal times. How could they have reasonable grounds to figure out the impact on the finance sector of extreme events that occur in the primary economy?

Theoretical Inadequacies have major practical consequences

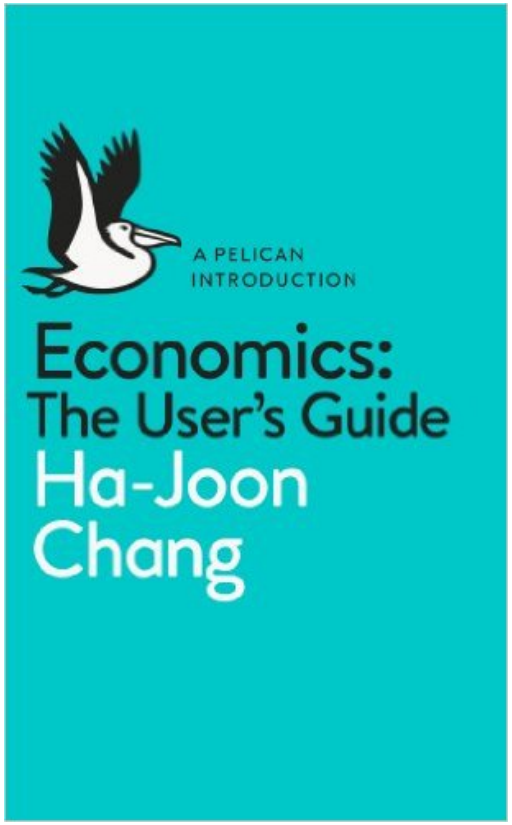
I see neoclassical economics as like a vast ancient, rotten, malevolent tree that's throwing its shade over the seeds and saplings underneath, blocking out the light and stopping them growing, with every grant proposal turned down and paper rejected. Cut down that tree and the seeds and saplings will grow and bloom. Those of us in the finance sector can attack in a certain way, while those in the primary economy have a different and complementary set of possibilities for attack (for example, most actuaries are mathematics graduates and don't know about thermodynamics)

More pluralism needed in economics

- All models are wrong, some models are useful
- Different models are needed for different purposes

Cambridge University economist Ha-Joon Chang's book "**Economics: The user's guide**" has introduction to other schools of economic thought

Also suggests that the old name "political economy" was better



Institute and Faculty of Actuaries

'Economics: The User's Guide', by Ha-Joon Chang, Pelican 2014

SAND2014-3148P

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Sandia National Laboratories

Food and Agriculture Attack Modeling and Simulation

We need models in which network growth dynamics interacts with network flow dynamics

Mathematics that are useful for considering tradeoffs in sustainability

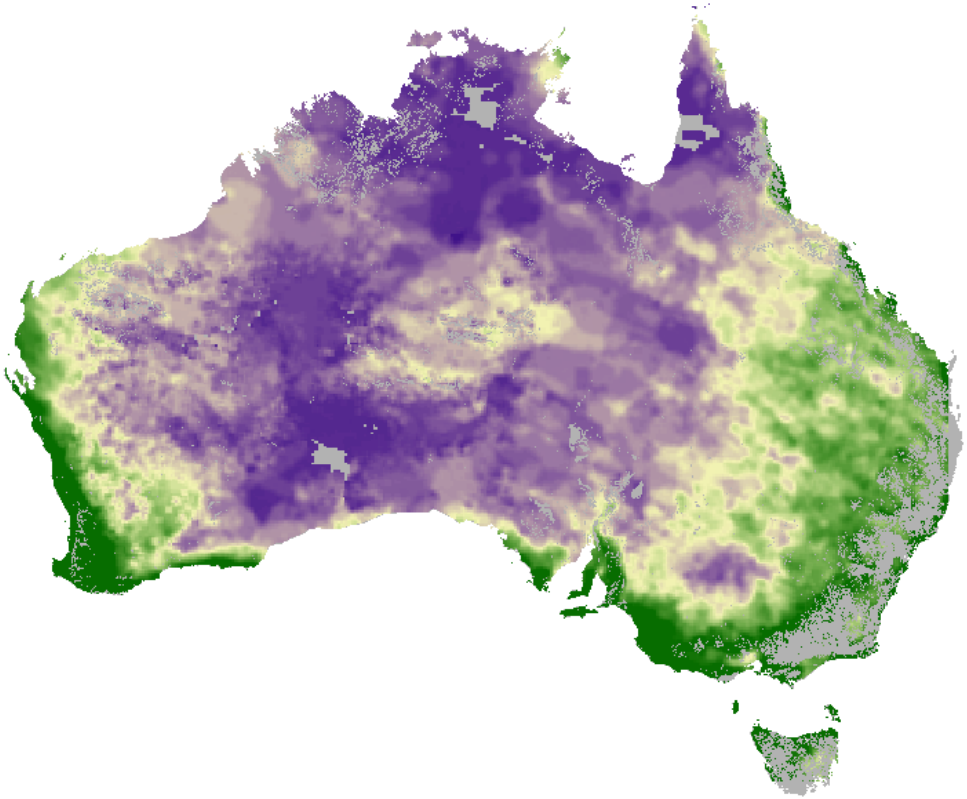
- Systematic treatment of relationships
- Optimization
  - Spatially explicit
  - Multimetric
- Aggregation theory
  - Normalization
  - Weighing
  - Distance to target approach
- Gaming

Potential Applications

Spatial crop modelling

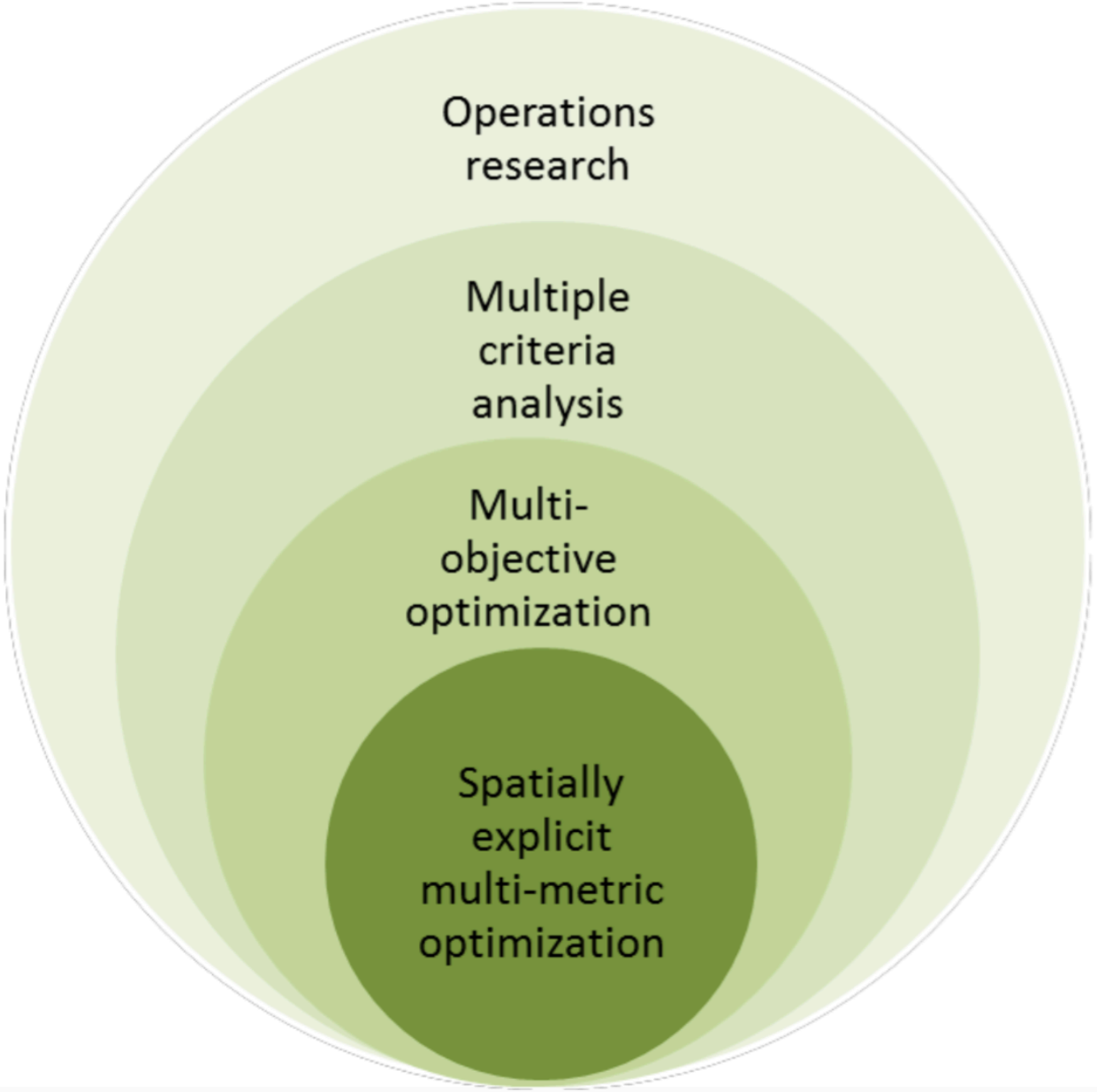
- **Yield forecasting**
- **Crop insurance**
- **Futures markets trading**
- **Food security – future scenarios**
- **At the paddock, farm, region or nation**

Water Limited Wheat Yield Potential



Connect modeling to real time streams of data – can we have soil moisture, soil carbon, soil nitrogen levels as we need them?

Optimization as a way to identify options



ENVIRONMENTAL Science & Technology

Article

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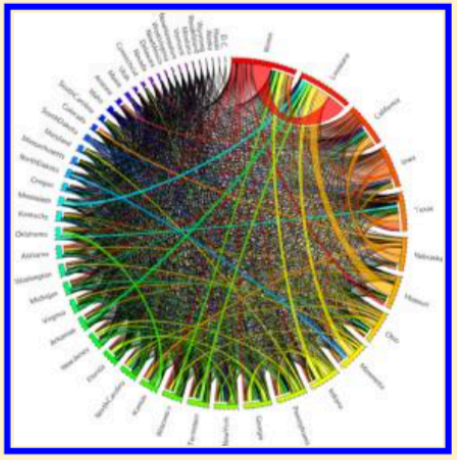
A Network Analysis of Food Flows within the United States of America

Xiaowen Lin,[†] Qian Dang,[†] and Megan Konar*[,†]

[†]Department of Civil and Environmental Engineering, University of Illinois at Urbana−Champaign, Urbana, Illinois 61801, United States

Supporting Information

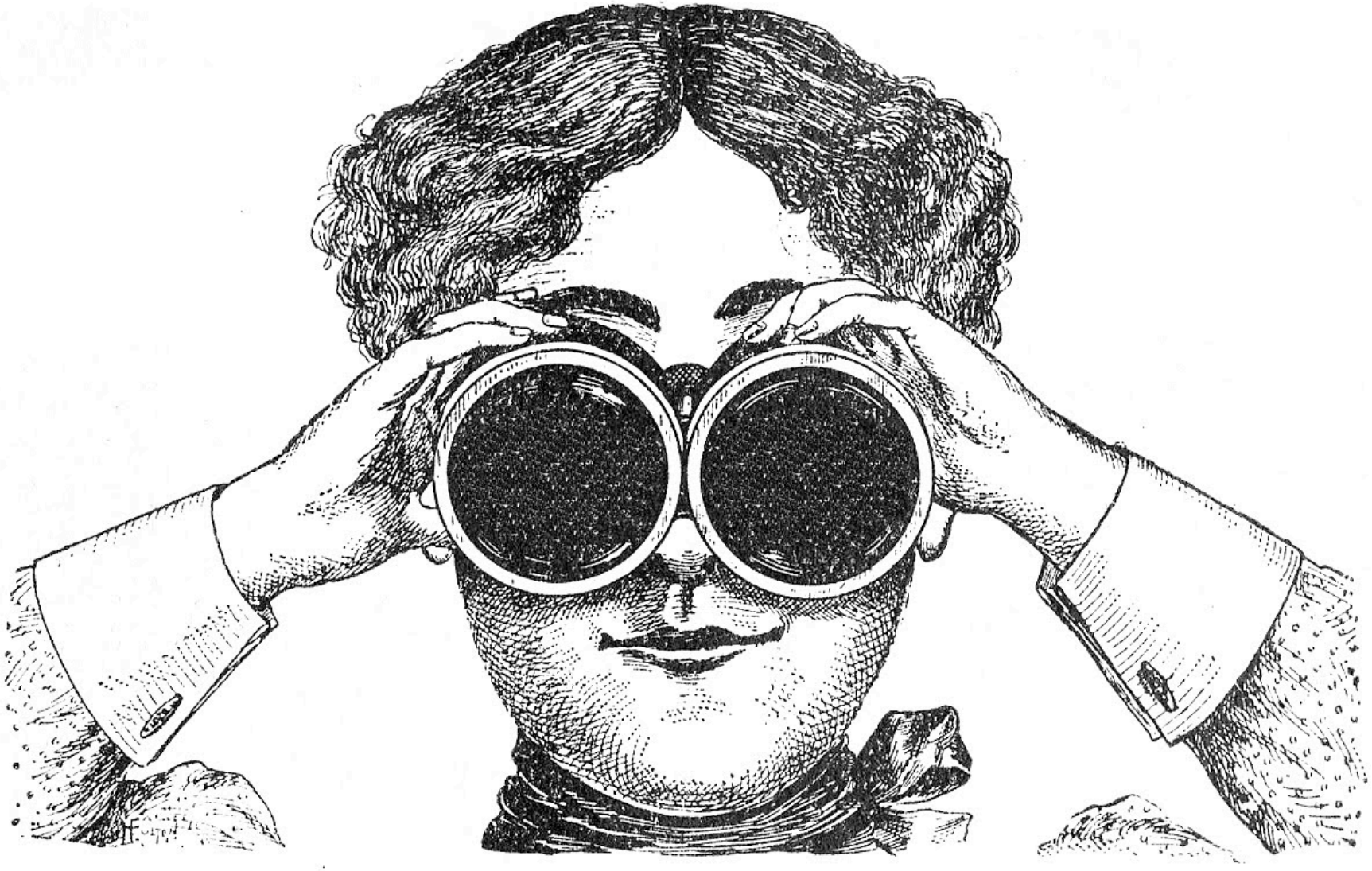
ABSTRACT: The world food system is globalized and interconnected, in which trade plays an increasingly important role in facilitating food availability. We present a novel application of network analysis to domestic food flows within the USA, a country with global importance as a major agricultural producer and trade power. We find normal node degree distributions and Weibull node strength and betweenness centrality distributions. An unassortative network structure with high clustering coefficients exists. These network properties indicate that the USA food flow network is highly social and well-mixed. However, a power law relationship between node betweenness centrality and node degree indicates potential network vulnerability to the disturbance of key nodes. We perform an equality analysis which serves as a benchmark for global food trade, where the Gini coefficient = 0.579, Lorenz asymmetry coefficient = 0.966, and Hoover index = 0.442. These findings shed insight into trade network scaling and proxy free trade and equitable network architectures.



The risks of failing vulnerable people locally creates material systemic risks to capital

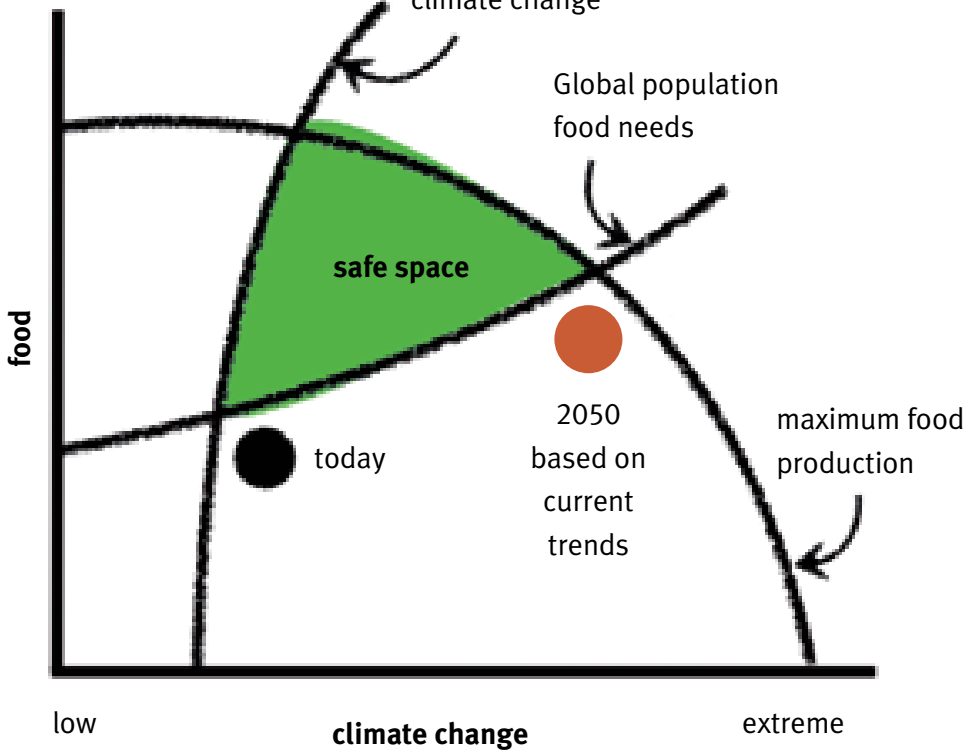
Therefore, the risks of failing vulnerable people are material systemic risks to all

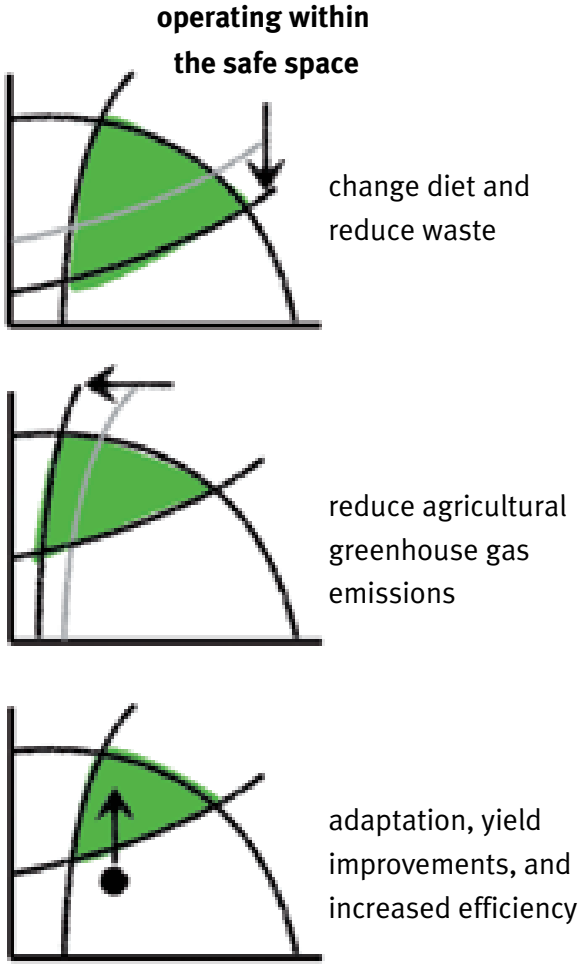
We can and should learn to better objectively reflect these risks in actionable formats



What do we see looking forward, recognizing links between global and local scales, food and health, environment and security?—These are new frontiers

Can we drive our systems into safer space?





Developed in collaboration with University of Minnesota, Global Landscapes Initiative


Nimble systems to scan integrated information assets for patterns that allow earlier detection and intervention--build new research capabilities focused on safer space

Design of adaptive actions in
“operations” mode.
Building experiments to design and test
timely preparedness for extreme events
while protecting human and civil rights

Sustainable Development Goals
spurring ambition for high-quality decision-relevant NRT information that -
recognizes food/water/energy nexus, -
is relevant at smallest scales, and
- advances humanitarian commitments

http://mariadouglass.files.wordpress.com/2014/06/lightbulb-plant-water-nexus-istock_000020312449medium1-e1402754075877.jpg

Tracking Human equity as a component of agricultural and food systems

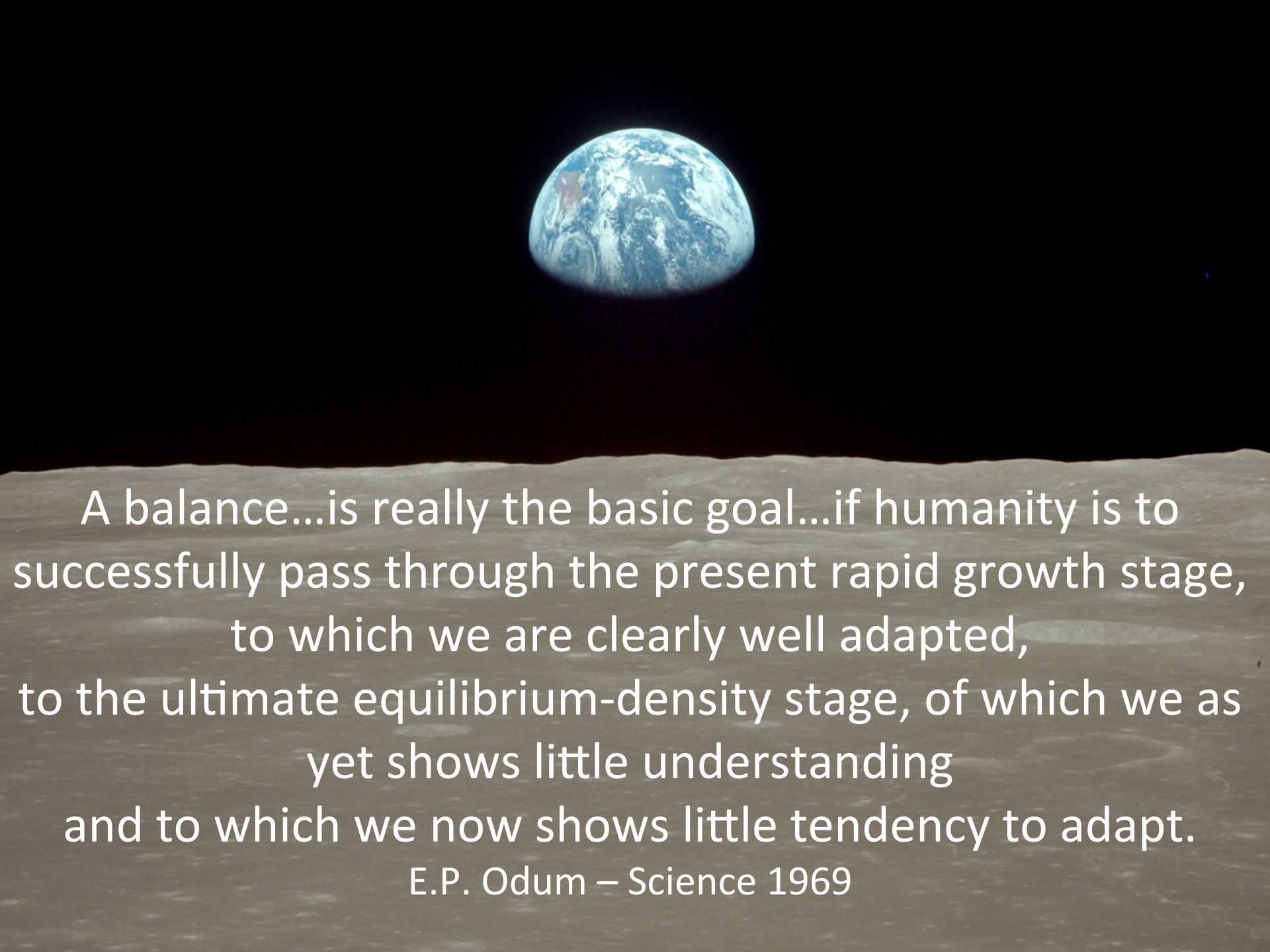
http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/images/216.jpg

When we include humans in the picture there are♪

♪surprises….♪

What do wigs have to do with food security?♪

http://online.wsj.com/media/020312pod03_J.jpg



A balance…is really the basic goal…if humanity is to successfully pass through the present rapid growth stage, to which we are clearly well adapted, to the ultimate equilibrium-density stage, of which we as yet shows little understanding and to which we now shows little tendency to adapt.

E.P. Odum – Science 1969