



# Trade Network Modeling

## *May 21, 2019*

Michael J. Puma and colleagues  
Next-Generation Food Shock Modeling  
May 20-24, 2019



POTSDAM INSTITUTE FOR  
CLIMATE IMPACT RESEARCH

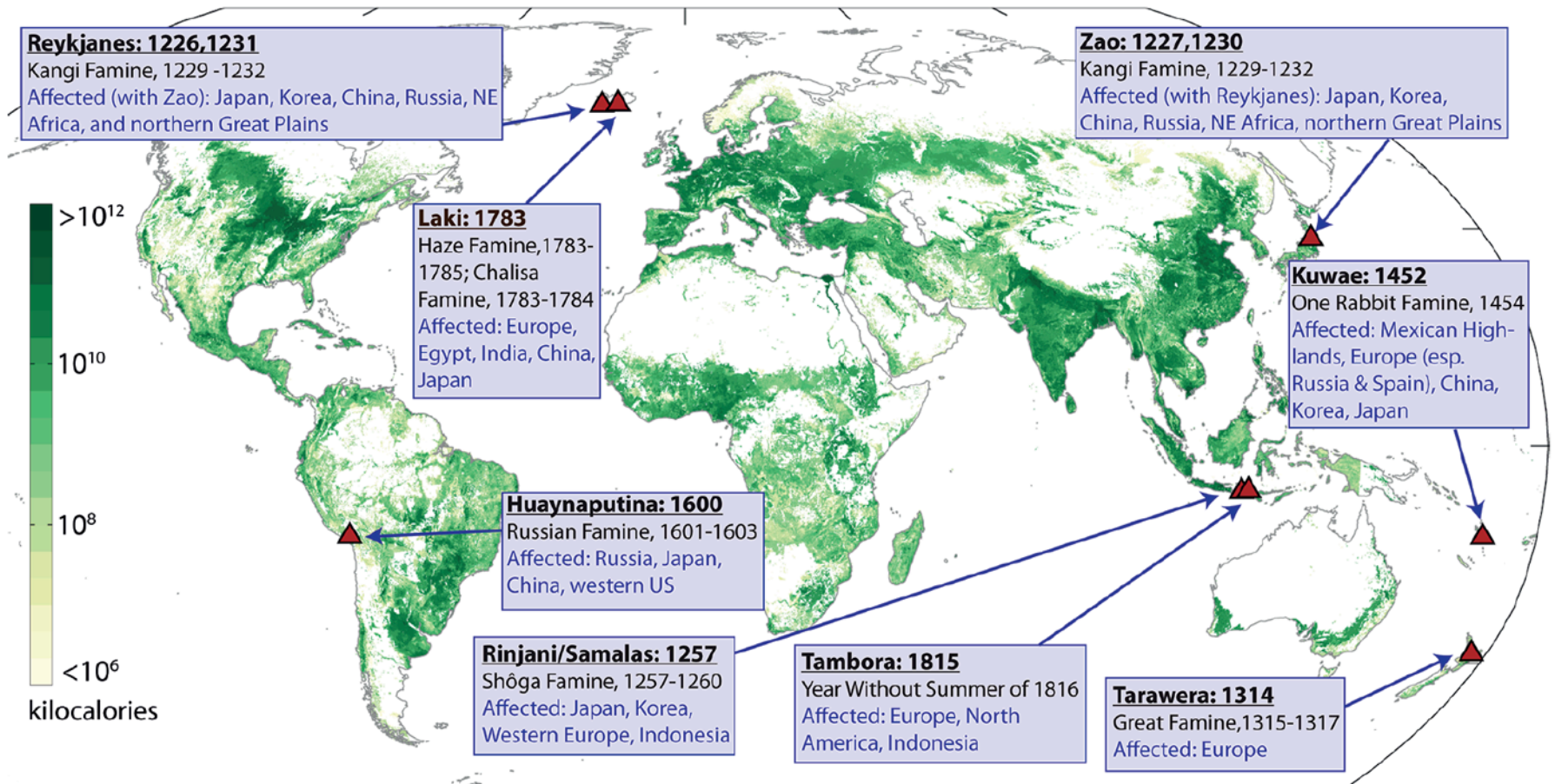


THE EARTH INSTITUTE  
COLUMBIA UNIVERSITY



Special thanks to C. Otto, B. Schauburger, A. Heslin, K. Davis, A. Moore, A. Higgins

# Multi-bread basket failure... *Volcanoes*



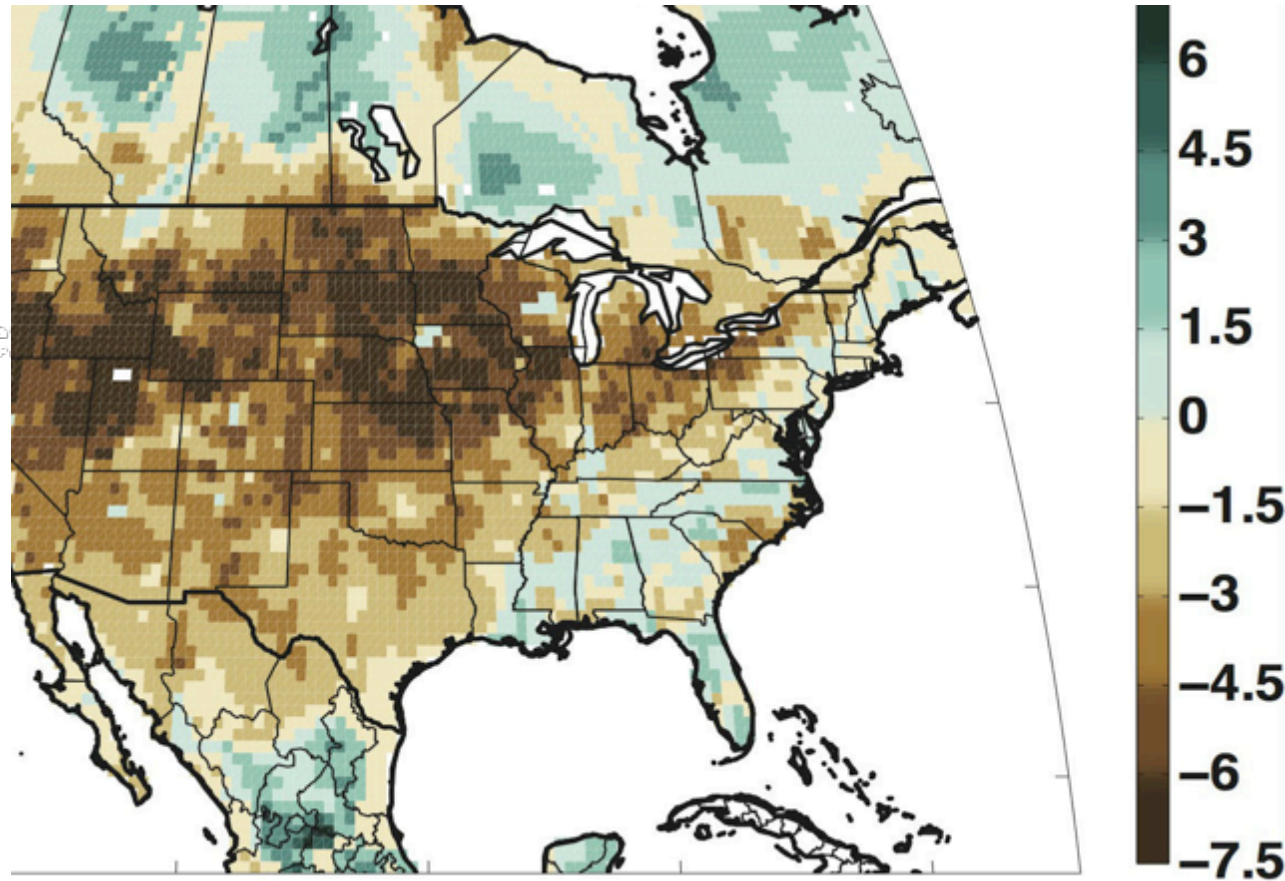
“Hazards such as dormant volcanoes may operate as limiting factors so rarely that they can be ignored by human populations. Such hazards can be, and regrettably are, ‘coped’ with by the ability of human fertility to compensate for occasional catastrophic mortality” (Halstead & O’Shea, 1989)

# Single breadbasket failure... *US Dust Bowl*

## Palmer Drought Severity Index



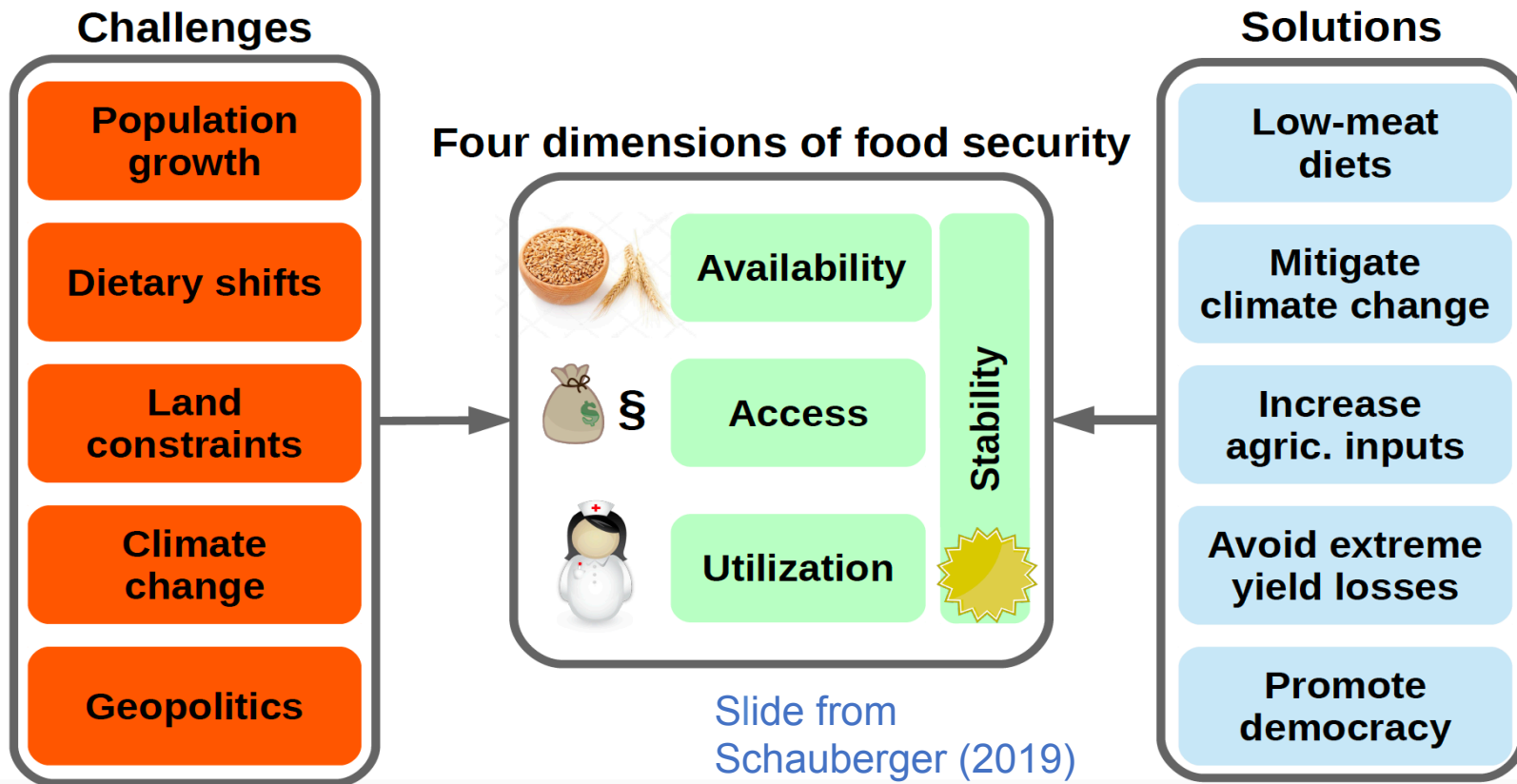
1934 Had Worst  
Drought of Last  
Thousand Yrs



# We're interested in metrics of food security

Food security is defined along four dimensions – and all are challenged

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. (FAO definition)



Slide from  
Schauberger (2019)  
presentation



# Multi-level analyses required

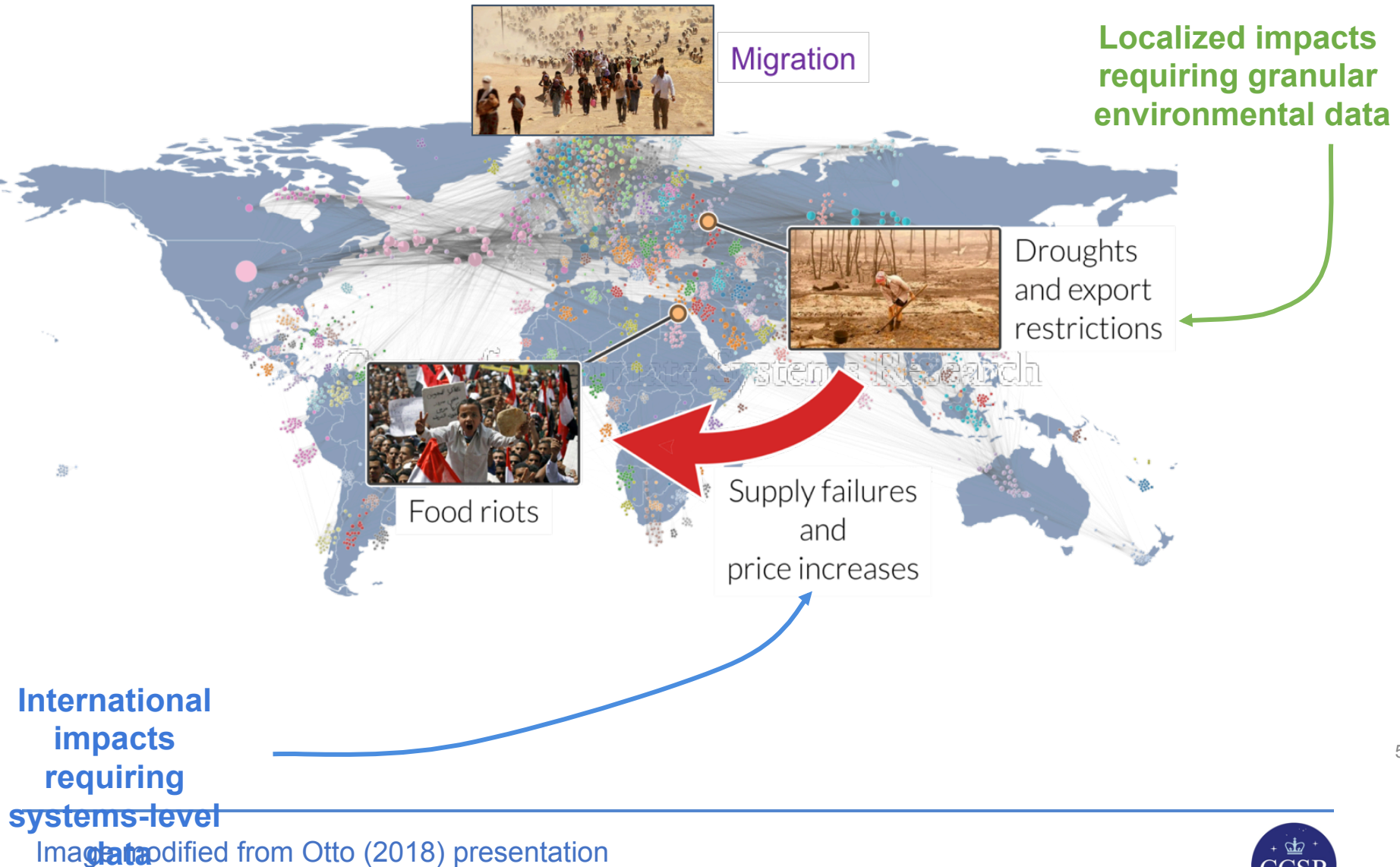
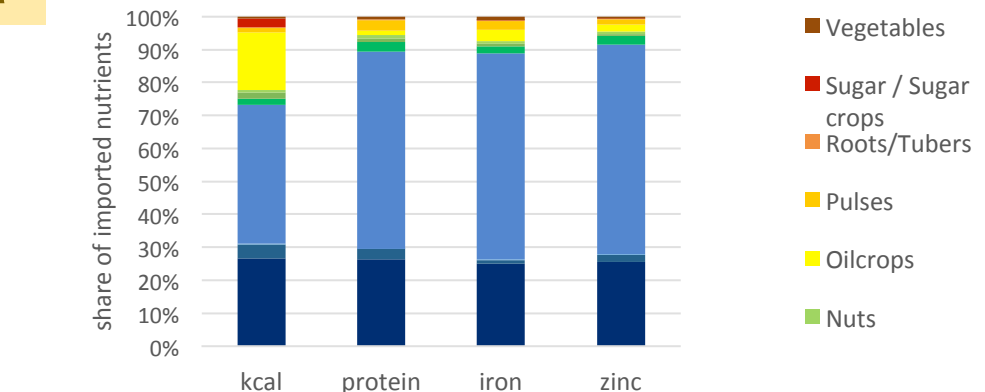
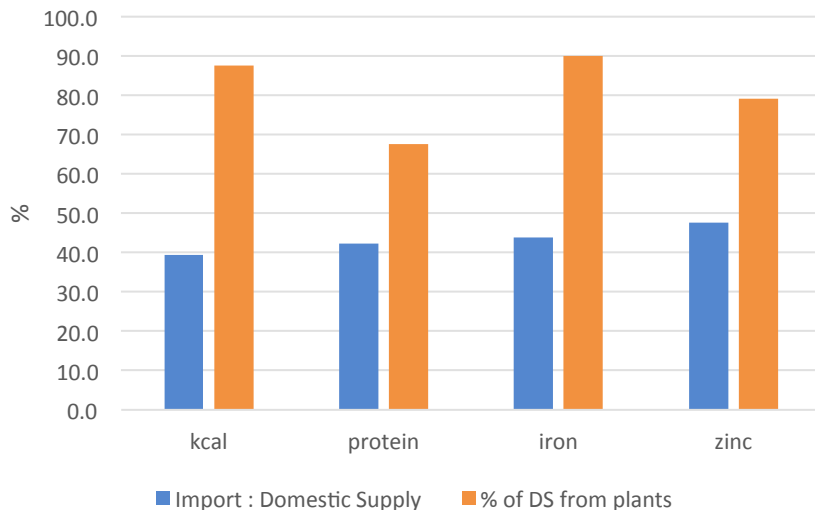


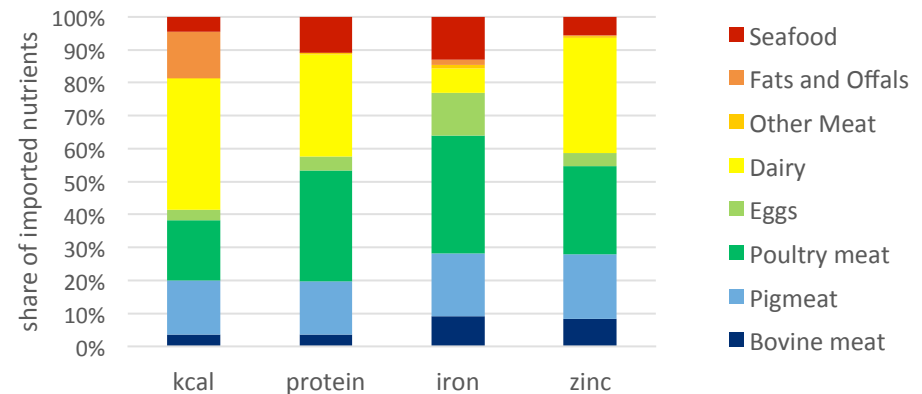
Image modified from Otto (2018) presentation

# Start with national food data

## Trade and nutrition... *Guatemala*



But systems research



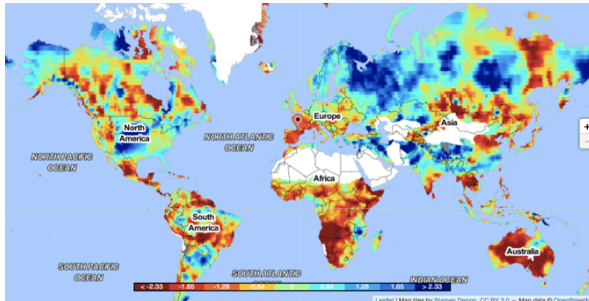
### Next...Shannon index import score

- Diversity of trade partners
- Diversity of commodities from individual trade partners
- Diversity of commodities from all trade partners

# Global env. variables

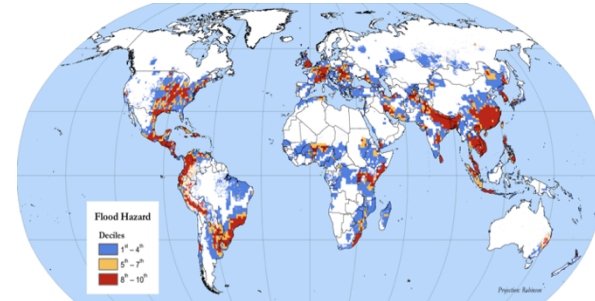
e.g. SERVIR and the Composite Drought Index from yesterday

Drought



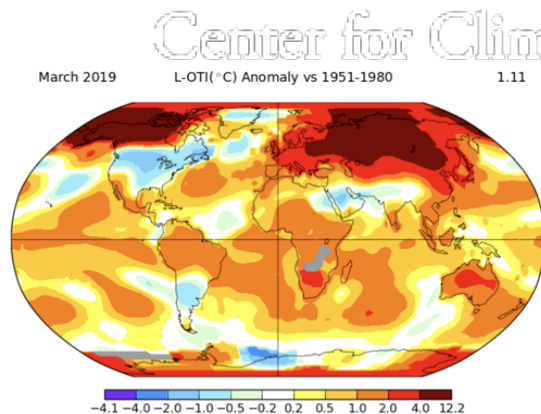
Source: SPEI, Spanish National Research Council

Flood

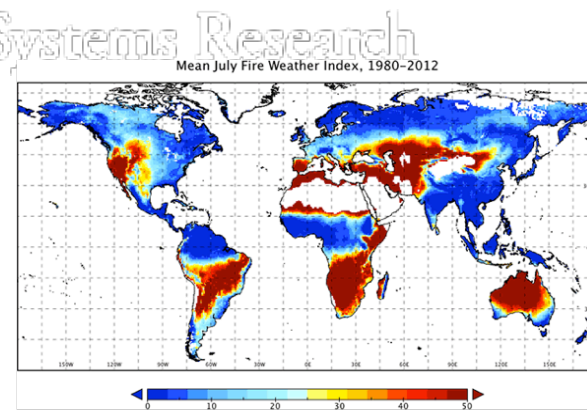


Source: World Bank and Columbia University

Temperature



Source: NASA GISS



Source: NASA GISS

Fire

*Link to suite of models*

A Heslin & M. Puma for MURI migration

# Simulating global prices and transmission to national level



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Christian Otto and Theresa Falkendal (PIK)

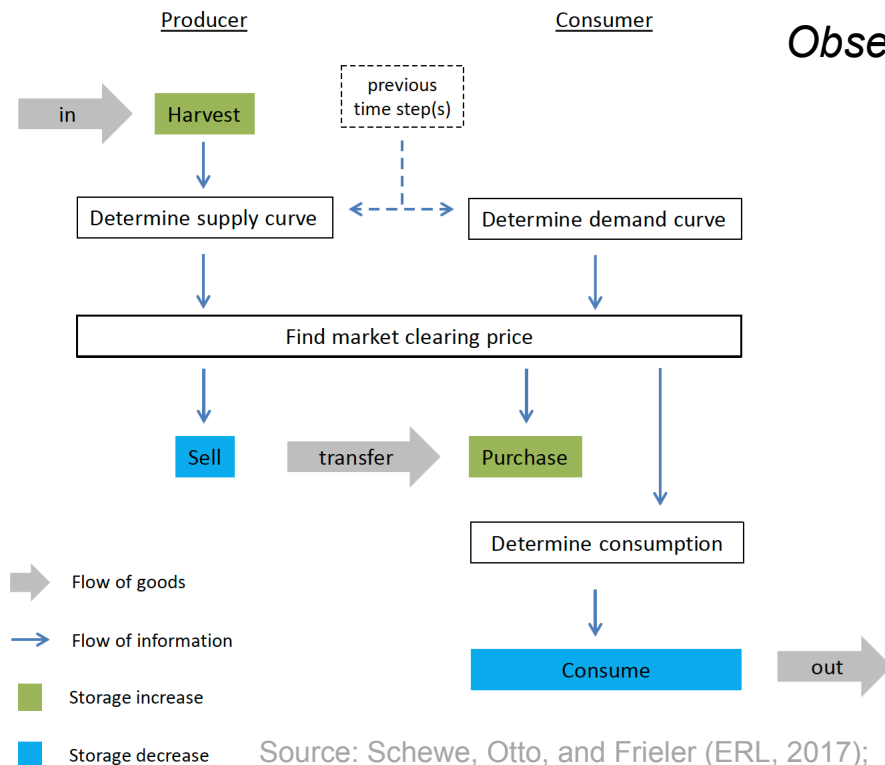
Storylines  
→  
Scenarios

Crop Models: LPJmL,  
APSIM, DSSAT

Production  
→

Trade With  
Storage (TWIST)  
model

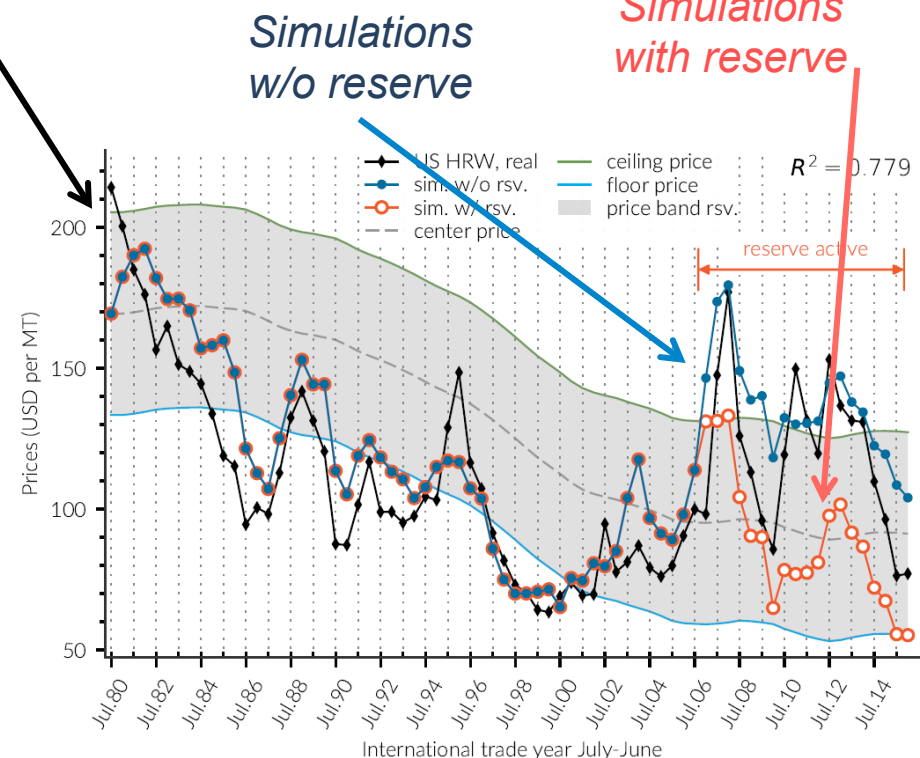
## TWIST model



Source: Schewe, Otto, and Frieler (ERL, 2017);  
Otto, Schewe, Puma, and Frieler (to be  
resubmitted)

Assess regional and international  
food security policies (e.g., food  
reserves)

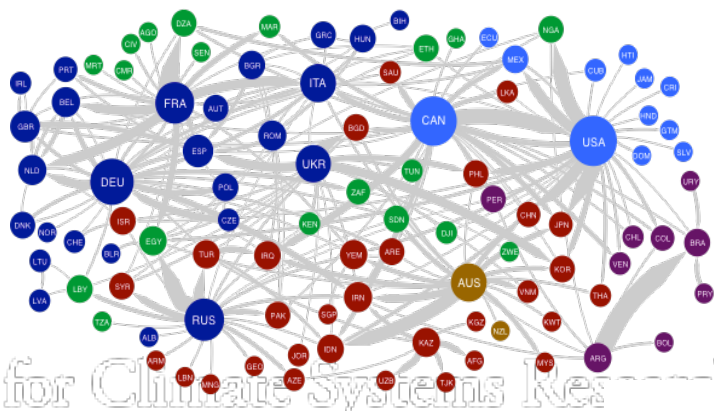
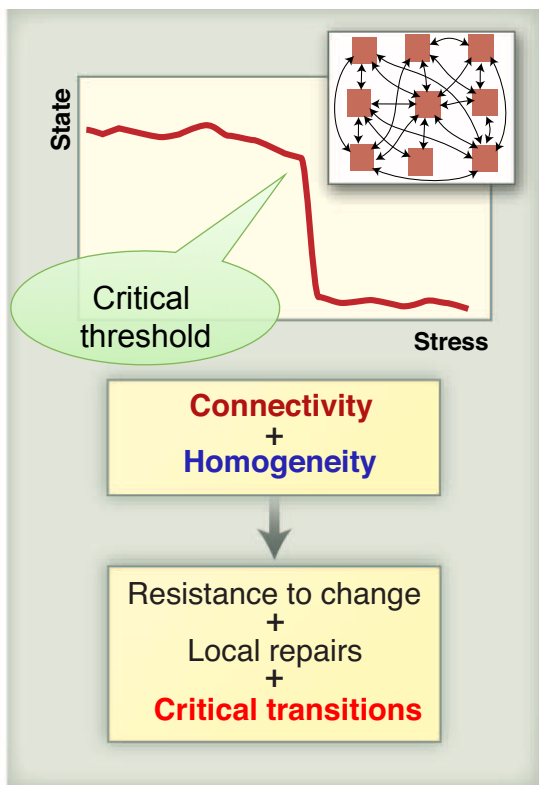
Observations



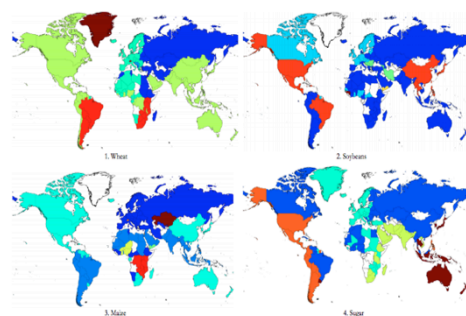


# Class of “large” events... *inventory-dominated dynamics*

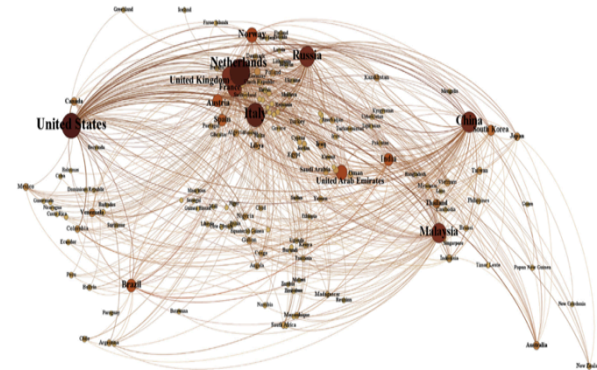
Moderated by...



Connectivity  
(wheat network)



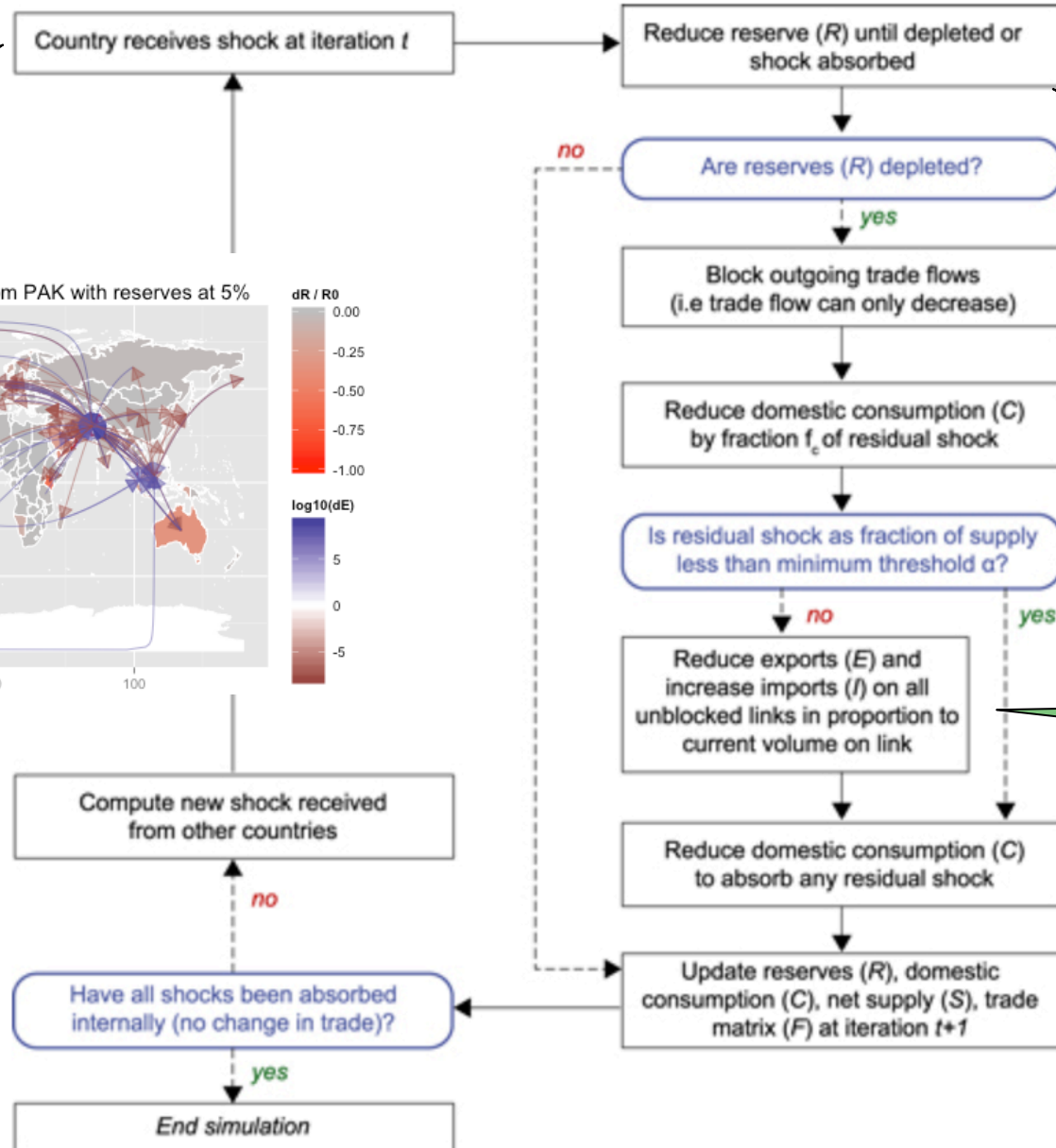
Community structure/  
geopolitics  
(different commodities)



Interdependencies  
(energy network)

# When global markets fail... *e.g. trade restriction, panic buying, hoarding*

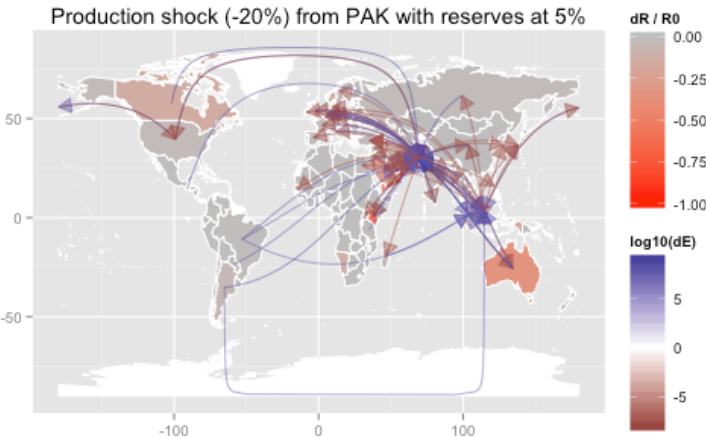
Shock to food production



Use reserves

Reduce consumption

Modify trade



Source:  
Marchand et al  
(2016)

# Ensemble of shocks

## Ensemble run

### Network

Initialized with historical data from one of the time periods.

### Simulations

Afghanistan

Albania

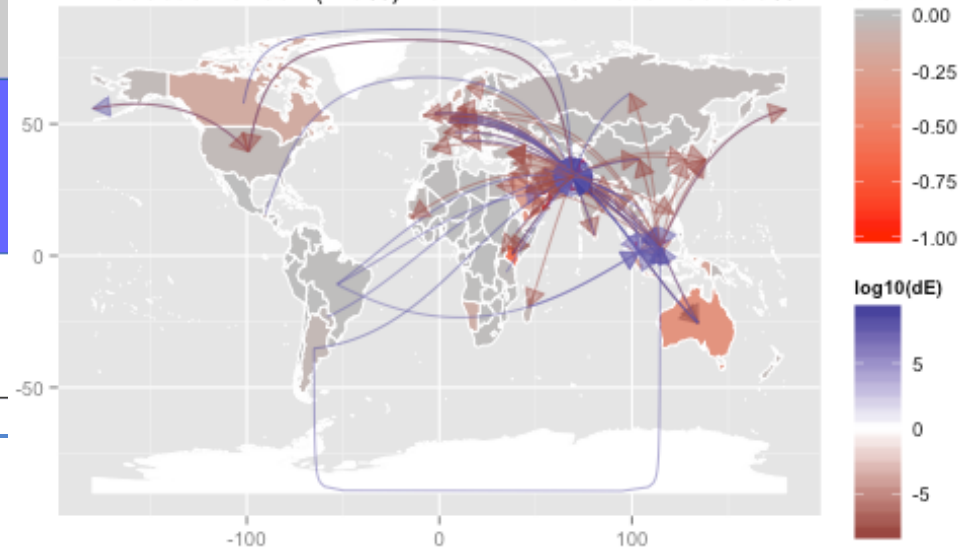
Algeria

## Example parameters

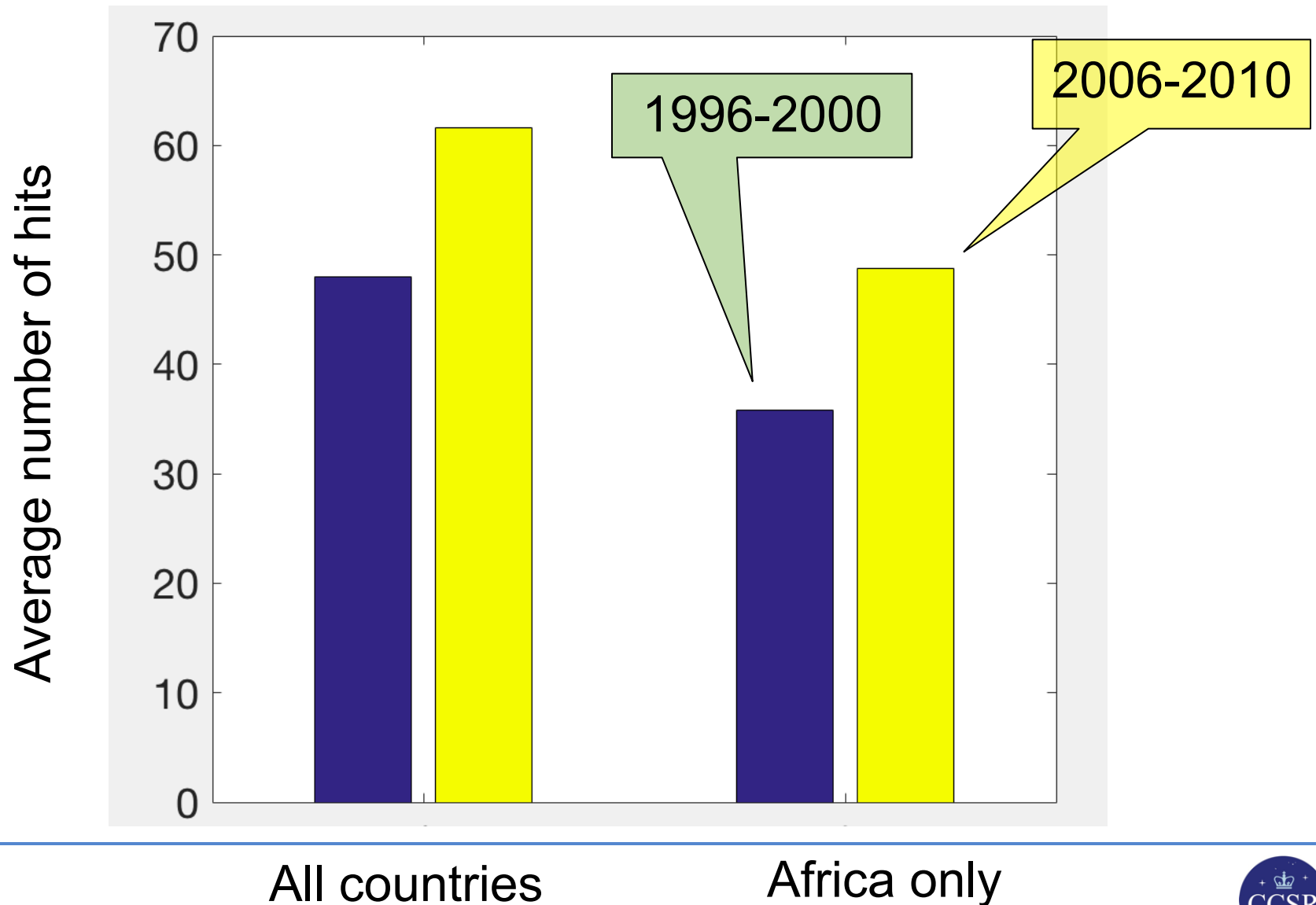
- 20% shock to production
- 50% of reserves available for use
- Use can be reduced by up to 1%

research

Production shock (-20%) from PAK with reserves at 5%



## Ensemble statistics... *# of supply hits*



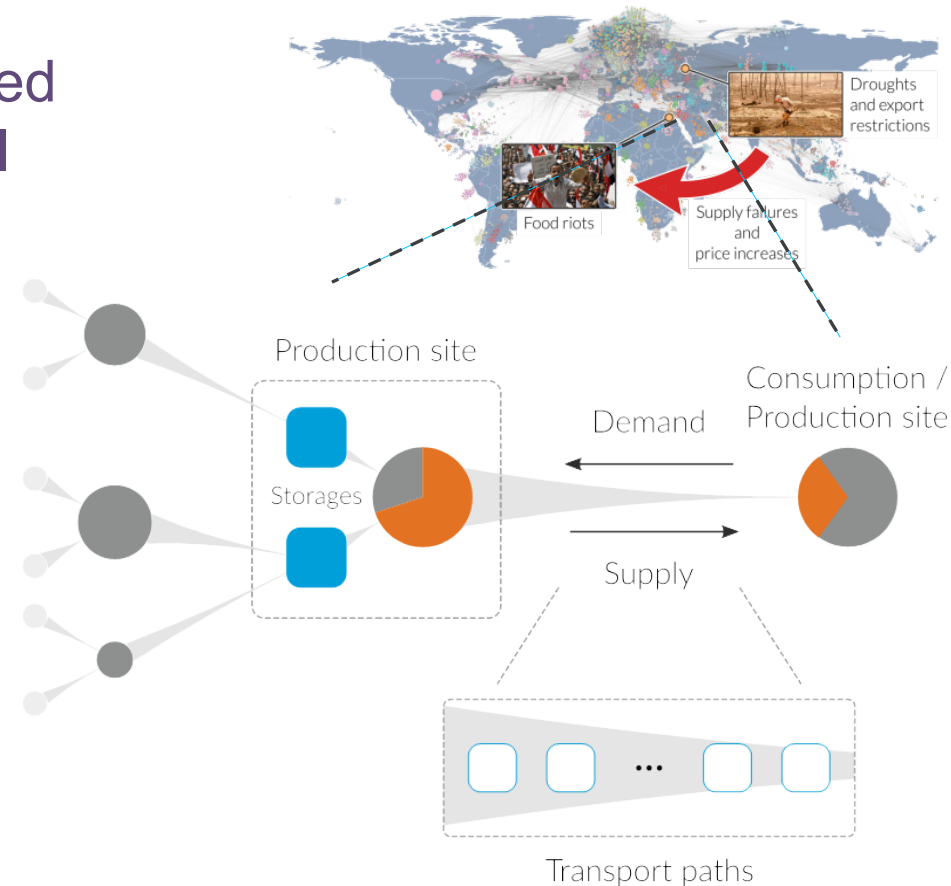
# Modeling global supply chains



## Acclimate: a global agent-based dynamic supply-chain model

### Main features

- Micro-economic foundation
- High sectoral + regional detail
- Daily temporal resolution
- Storages and transport delays
- Dynamically resolves
  - Cascading supply-failures
  - Price effects
  - Abrupt regime changes



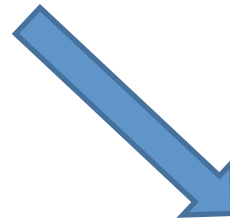
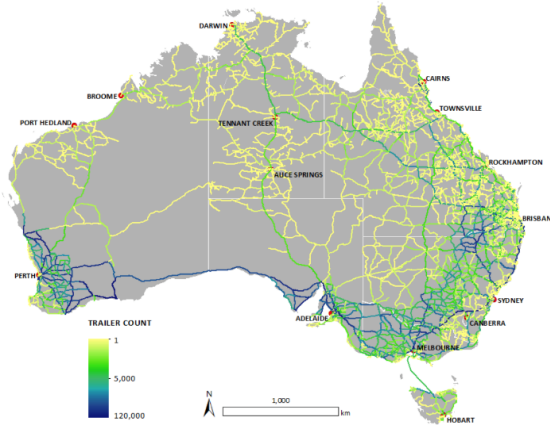


# TraNSIT: Model road, rail and sea transportation networks



by Andrew Higgins (CSIRO)

CSIRO TraNSIT tool analyses transport and logistics options for agriculture to identify potential cost savings.



INPUT: Transport network and related attributes, vehicle characteristics, production locations and yields, storage and processing locations and throughputs, domestic demand and export points/demand

OUTPUT: freight volumes and people movements across the transport network by time

CODE: Python, Fortran

RUNTIME: minutes per country

RESOLUTION: transport segment and monthly time step

## Railway mania

Freight transported by rail, 2014  
Tonne-kilometre, trn



## Railways (selected)

Existing/proposed

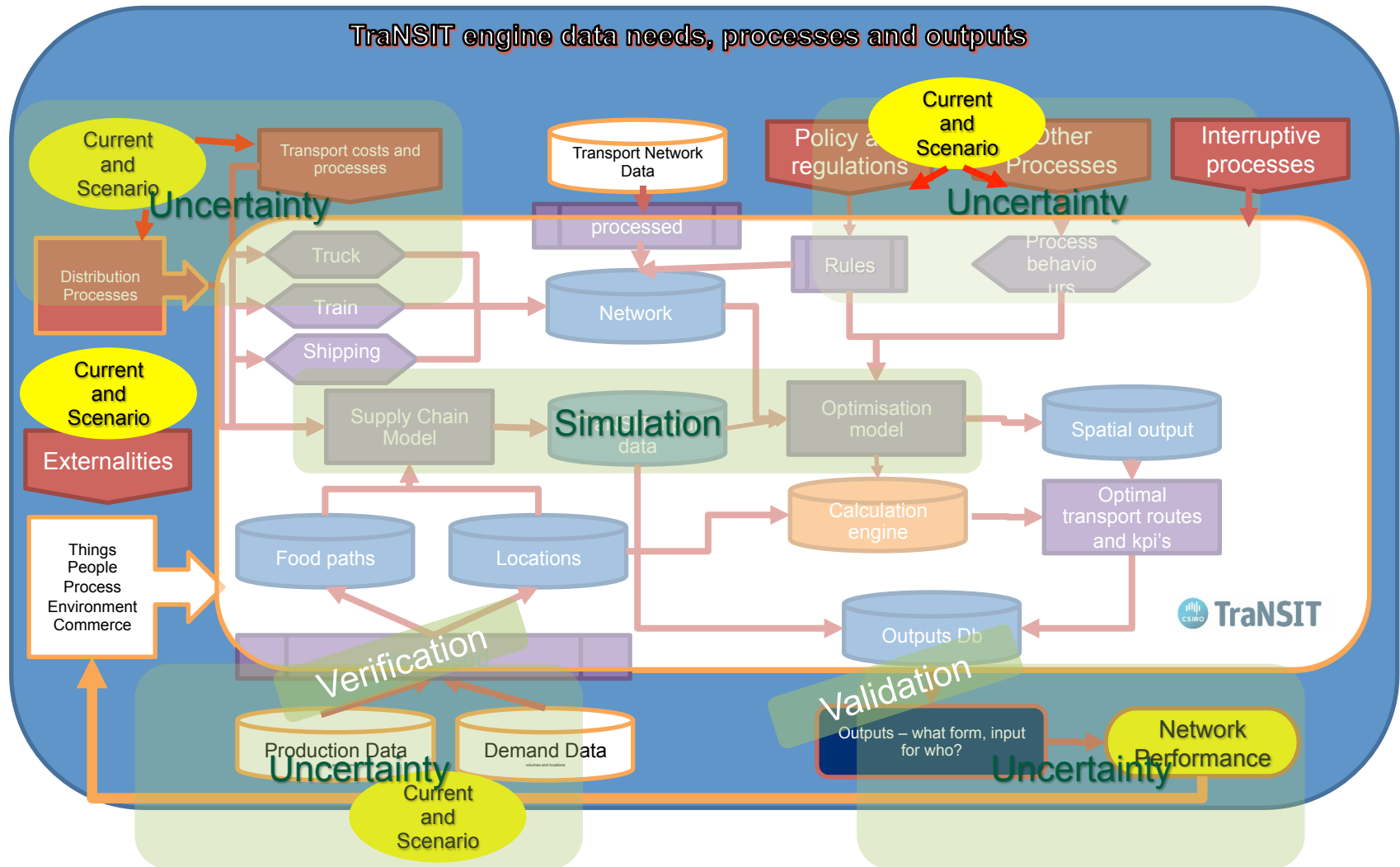
Planned standard-gauge project



Economist.com

# TraNSIT.global – Conceptual Design

by Andrew Higgins & Stephen McFallan



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# Thanks!

Center for Climate Systems Research

## Thanks to Funders

- Columbia University Center for Climate and Life
- Columbia World Projects
- DARPA World Modelers
- Multi-University Research Initiative (Army Research Office)