



# WELCOME TO THE TRA 6 LECTURE SERIES INNOVATION PATHWAYS TO SUSTAINABILITY

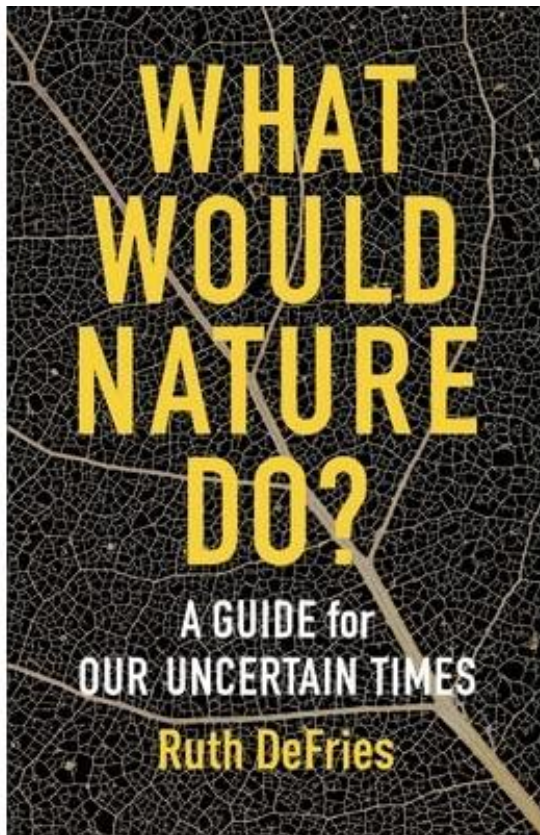
NATURE'S SECRETS FOR NAVIGATING UNCERTAIN  
TIMES

RUTH DE FRIES, PROFESSOR OF ECOLOGY AND SUSTAINABLE  
DEVELOPMENT, COLUMBIA UNIVERSITY

MODERATORS:

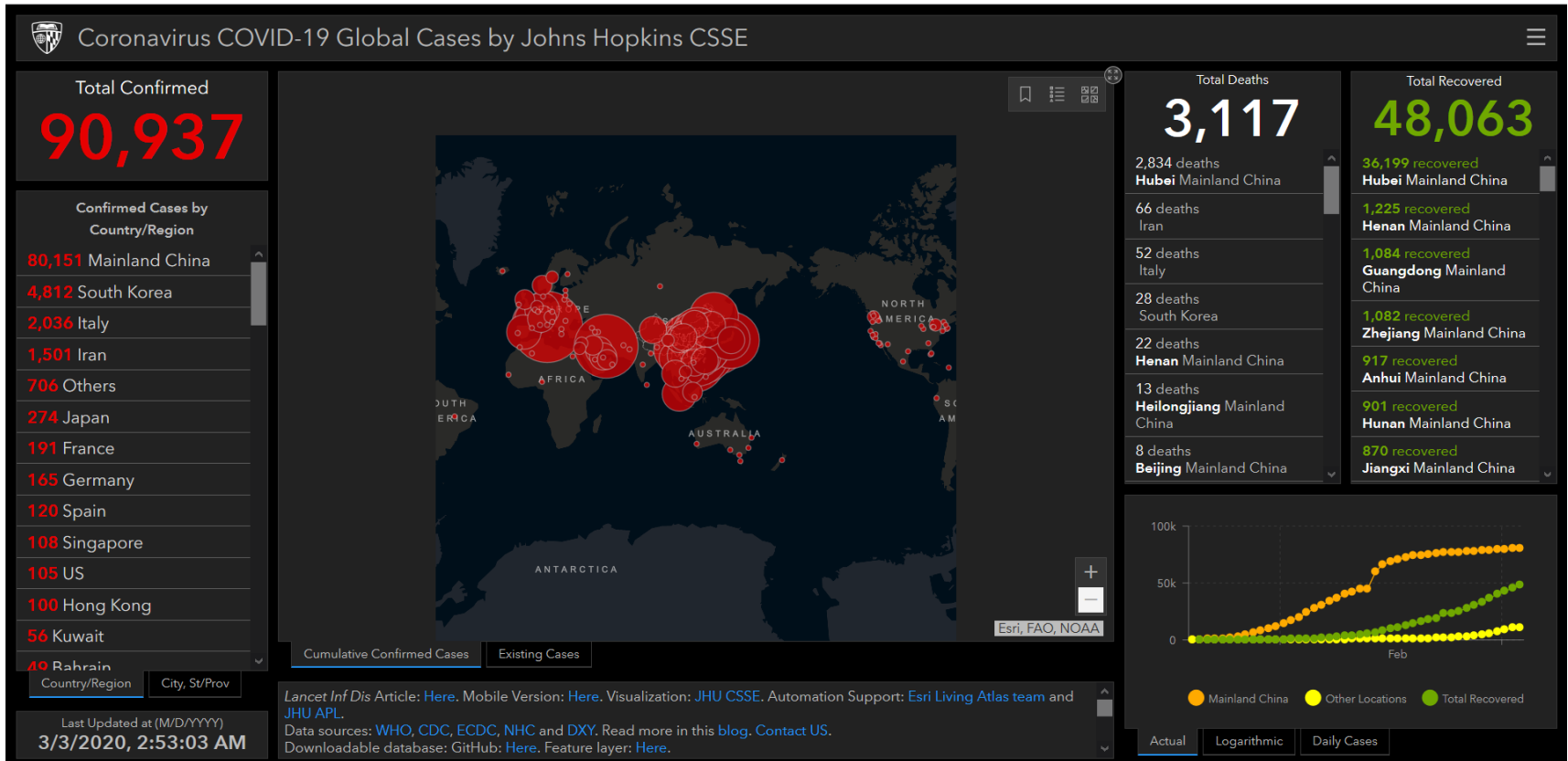
JAN BÖRNER, JOACHIM VON BRAUN, TRA 6-SPEAKERS,  
UNIVERSITY OF BONN

# NATURE'S SECRETS FOR NAVIGATING UNCERTAIN TIMES

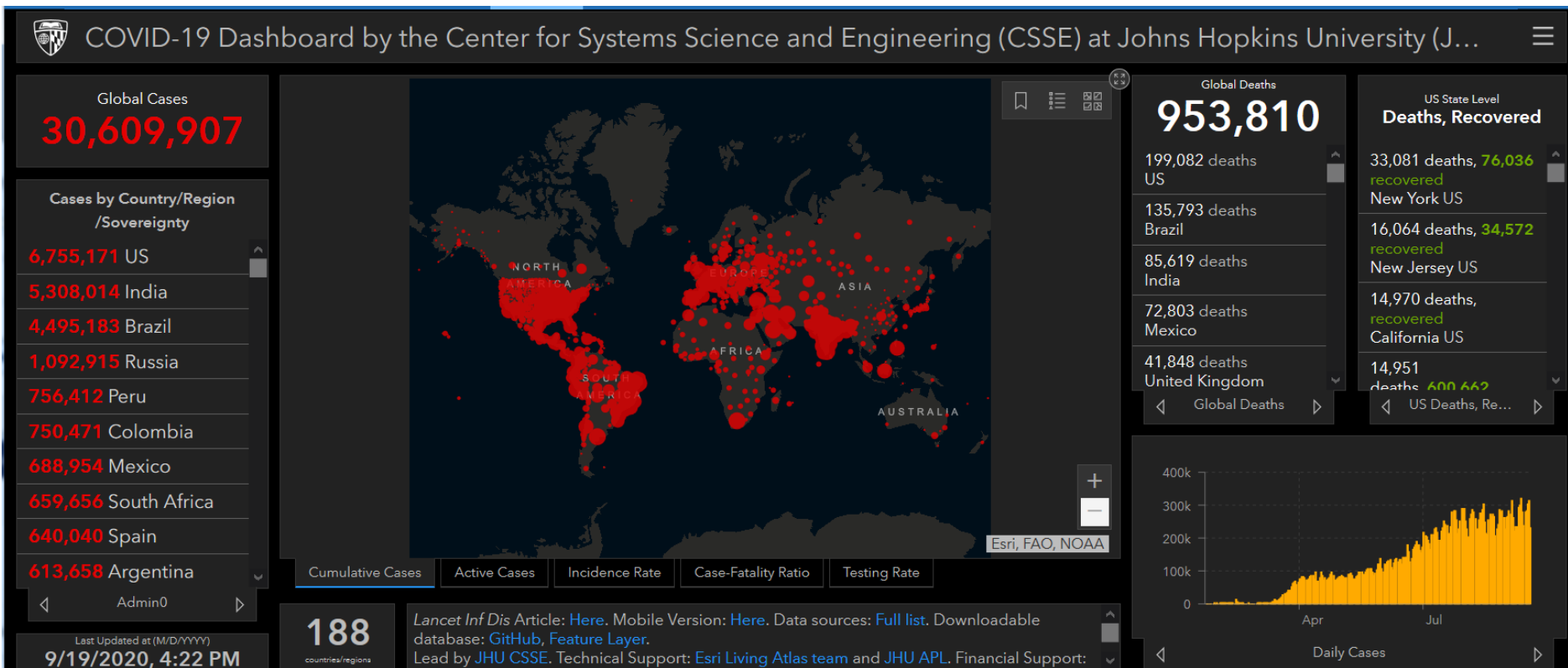


R. DeFries, Columbia University  
Univ of Bonn  
Innovation Pathways to Sustainability Series  
Jan. 26, 2021

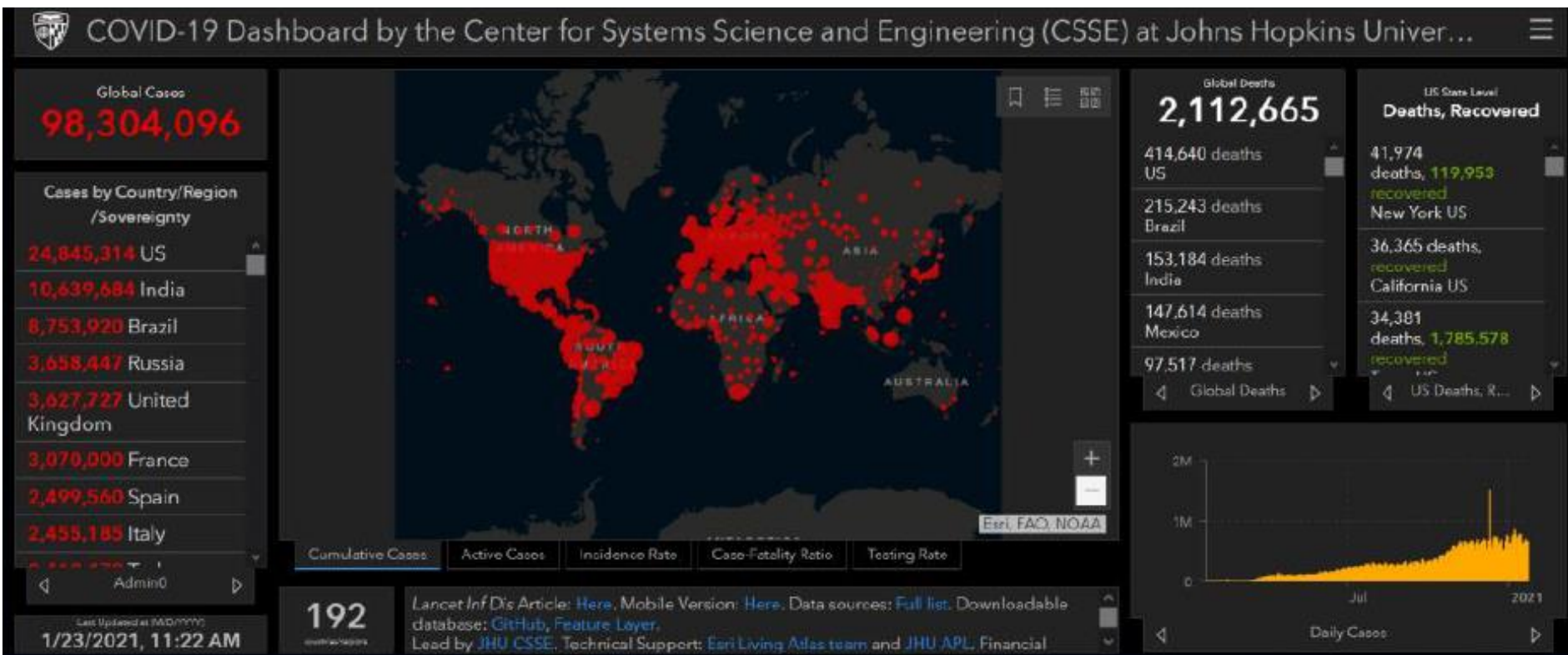
# March, 2020



# September, 2020



# Now



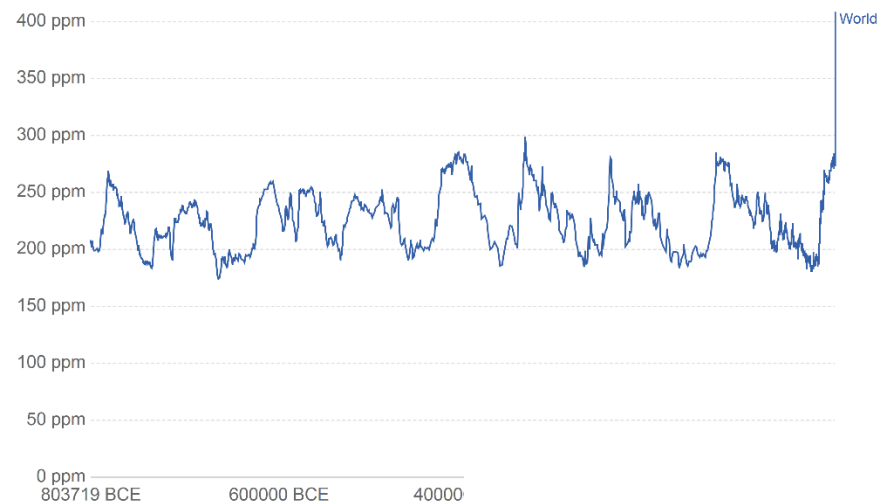




## Atmospheric CO<sub>2</sub> concentration

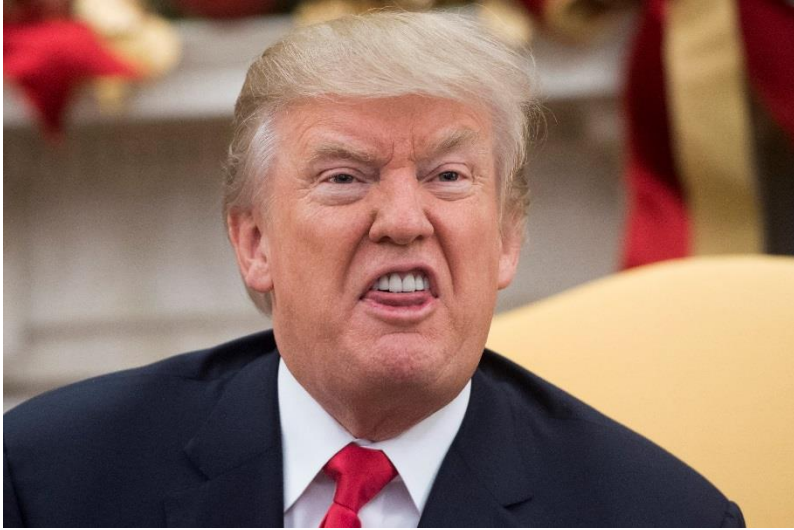
Global average long-term atmospheric concentration of carbon dioxide (CO<sub>2</sub>), measured in parts per million (ppm). Long-term trends in CO<sub>2</sub> concentrations can be measured at high-resolution using preserved air samples from ice cores.

Our World  
in Data



Source: EPICA Dome C CO<sub>2</sub> record (2015) & NOAA (2018)

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY







# An urban, interconnected, complex world



roads shipping airline

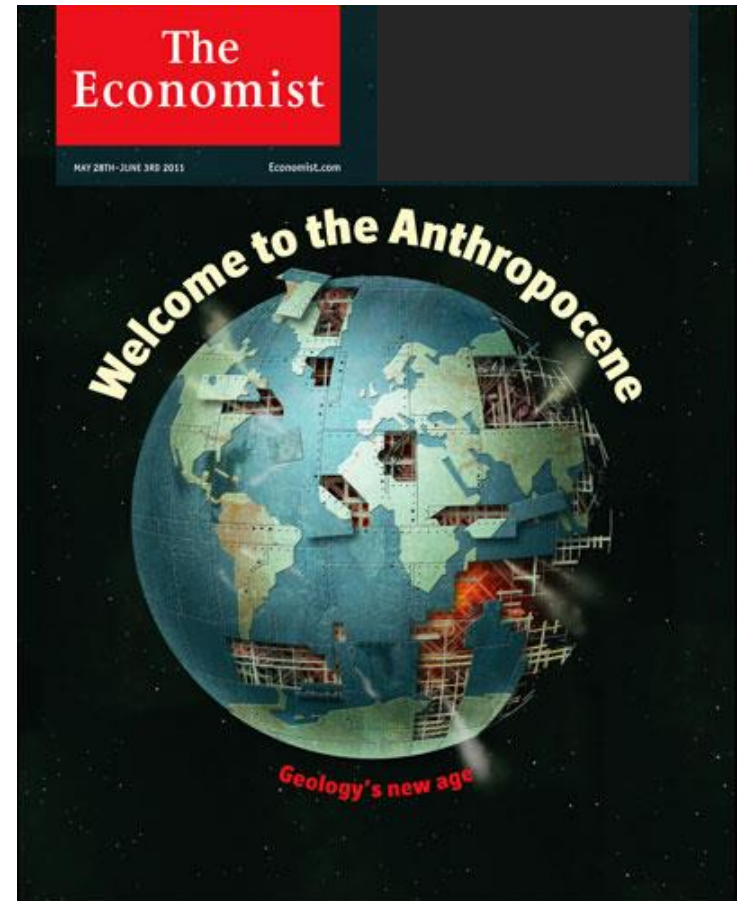
# COMPLEX SYSTEMS ARE INHERENTLY UNPREDICTABLE

	<b>SIMPLE SYSTEM</b>	<b>COMPLEX SYSTEM</b>
Focus is on.....	individual parts	interactions among parts
Understandable through.....	reductionist approach	holistic, integrated approach
Relationship between parts are.....	linear	non-linear
Behavior is.....	predictable	not obvious from individual parts
Examples.....	stereo accelerator	human body termite mounds cells predator-prey relationships <b>economy</b> <b>climate system</b> <b>political institutions</b> <b>trade</b>

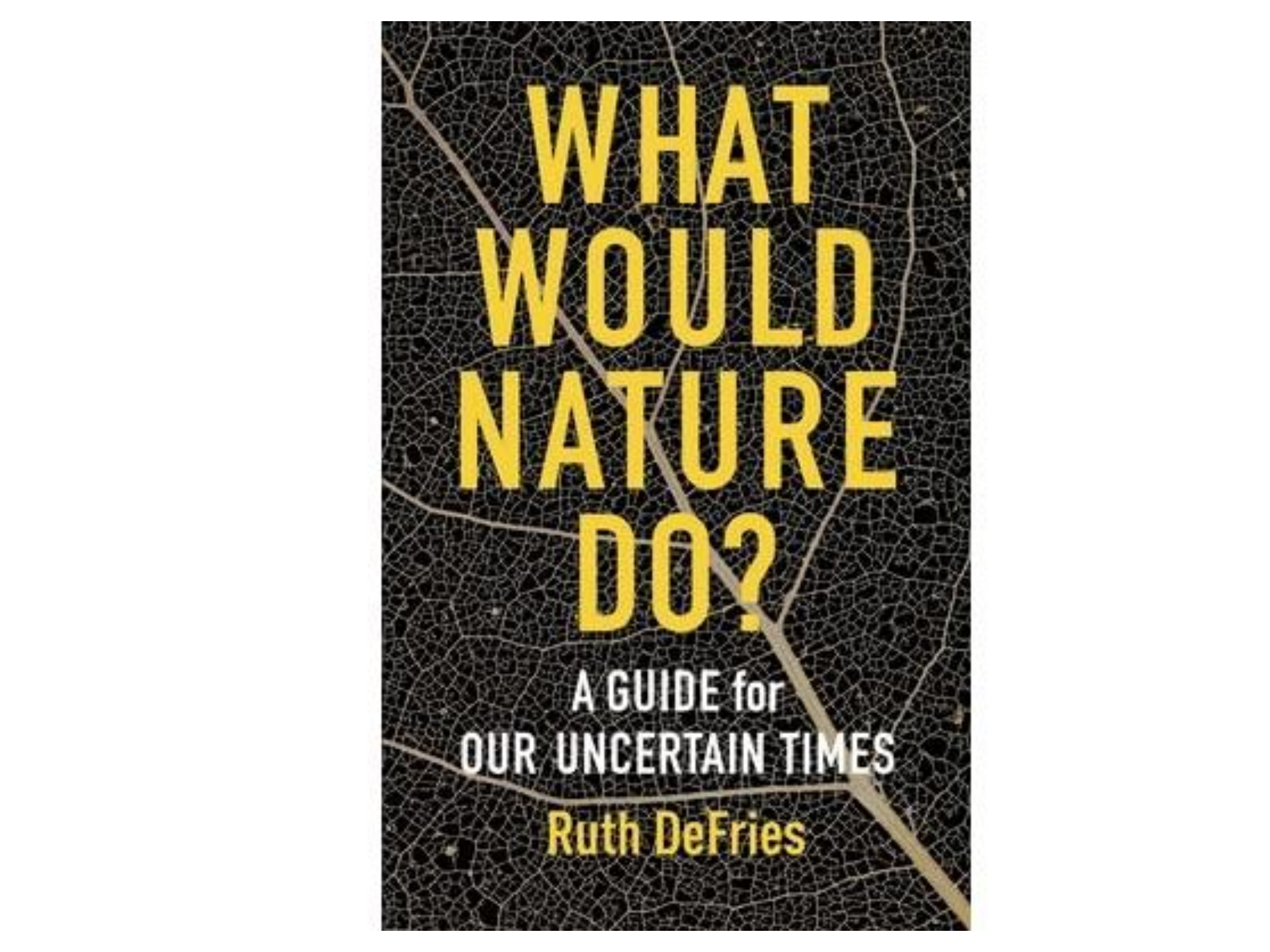
**COMPLEXITY IS EVERYWHERE IN MODERN CIVILIZATION**

# OUR REALITY IN THE COMPLEX SYSTEM OF THE ANTHROPOCENE

- Unpredictable feedbacks
- Uncertain perturbations
- No prior experience or roadmap
- Risk of cascading and uncontrollable failures







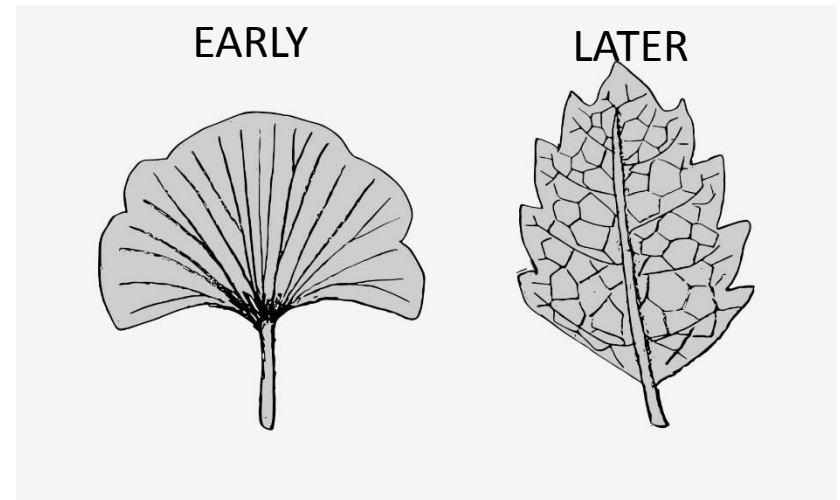
# WHAT WOULD NATURE DO?

A GUIDE for  
OUR UNCERTAIN TIMES

Ruth DeFries



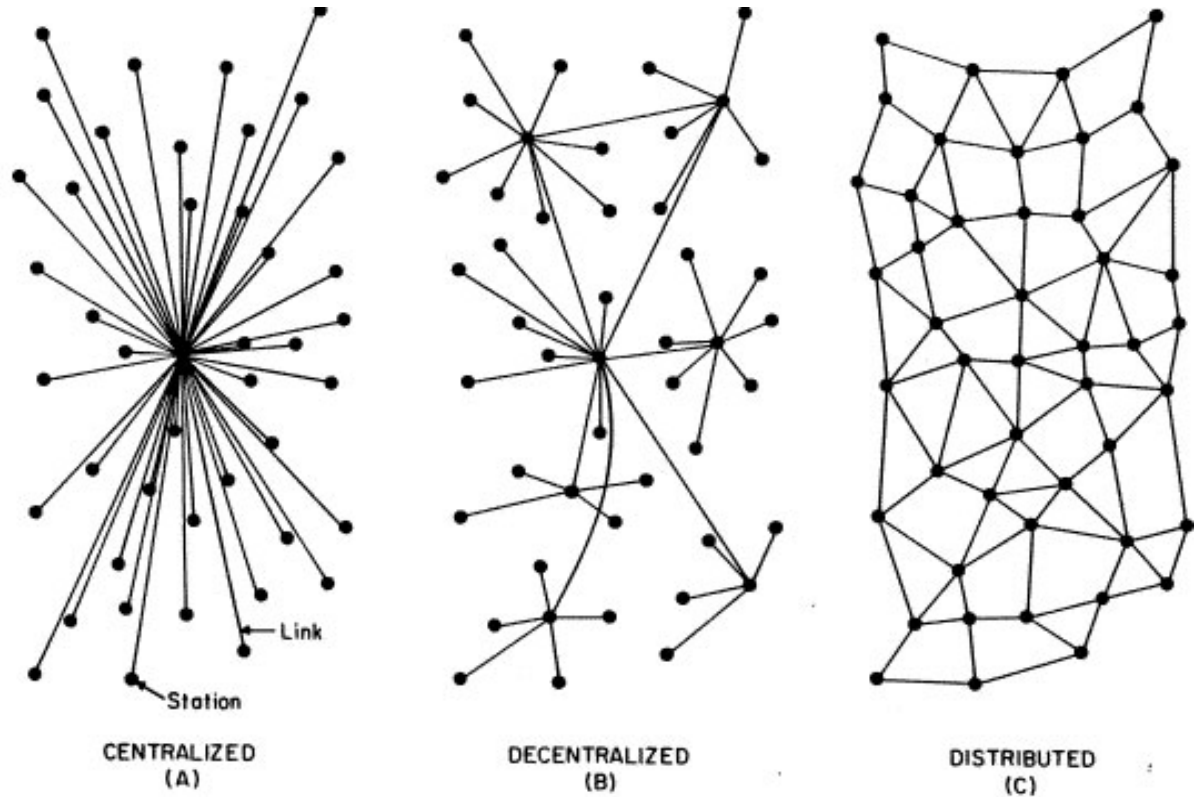
# *Strategy #1: Life persists through redundancy in networks*



# Redundancy in the internet



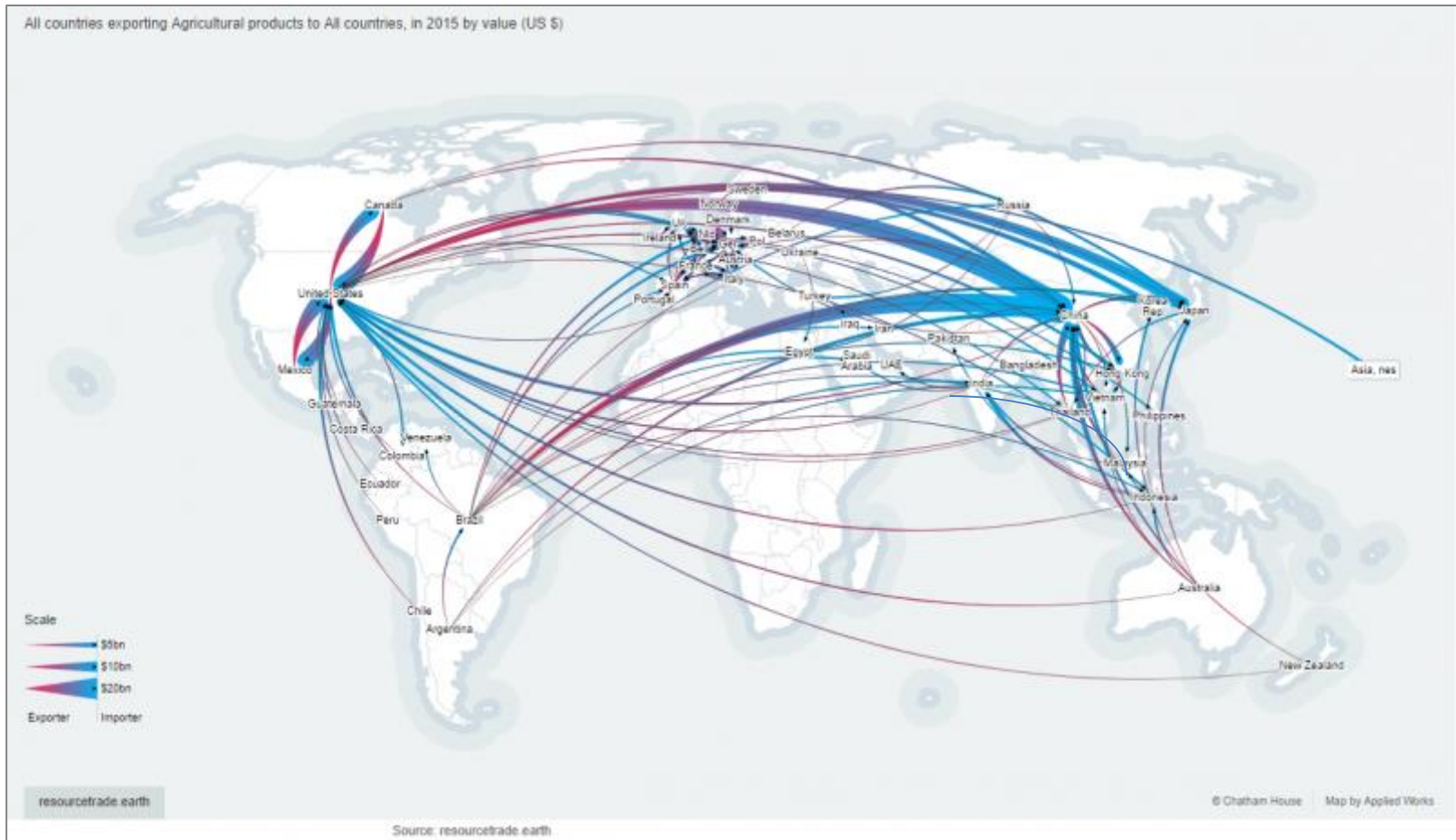
Paul Barron (1926-2011)  
Internet Hall of Fame



# Redundancy in engineering

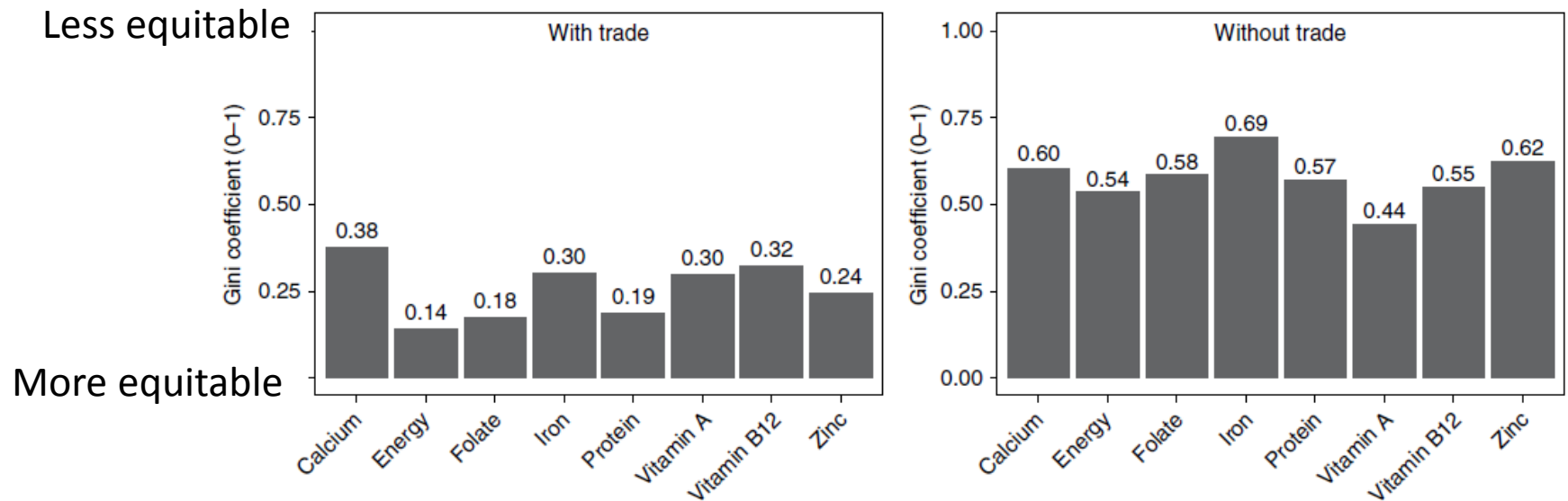


# THE GLOBAL FOOD TRADE IS HIGHLY CONCENTRATED





# .... GOOD FOR DISTRIBUTING NUTRIENTS

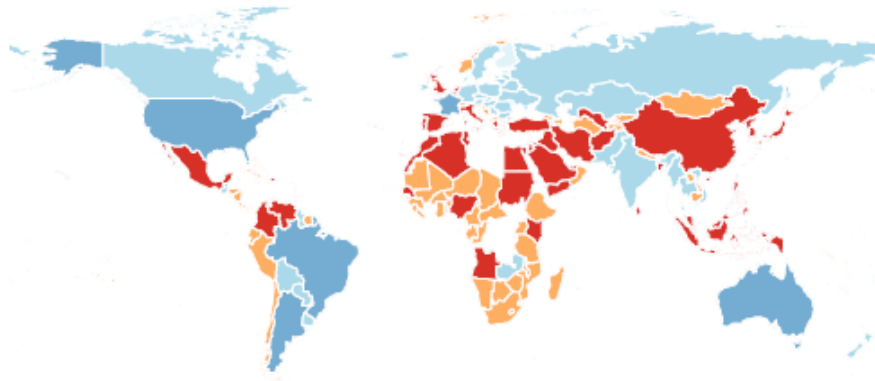


## Trade and the equitability of global food nutrient distribution

Stephen A. Wood<sup>1,2\*</sup>, Matthew R. Smith<sup>3</sup>, Jessica Fanzo<sup>4</sup>, Roseline Remans<sup>5,6</sup> and Ruth S. DeFries<sup>7</sup>

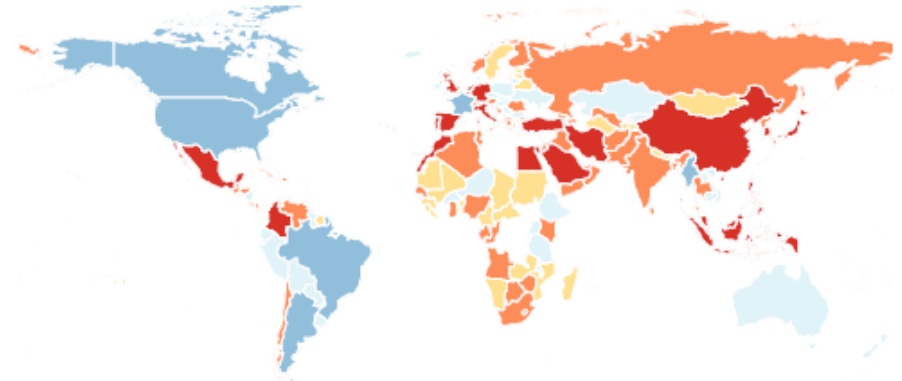
# Many countries depend on a few for dietary nutrients

ENERGY



Energy ■ (-228, -6) ■ (-6, 0) ■ (0, 0.3)  
■ (0.3, 68) ■ (68, 480)

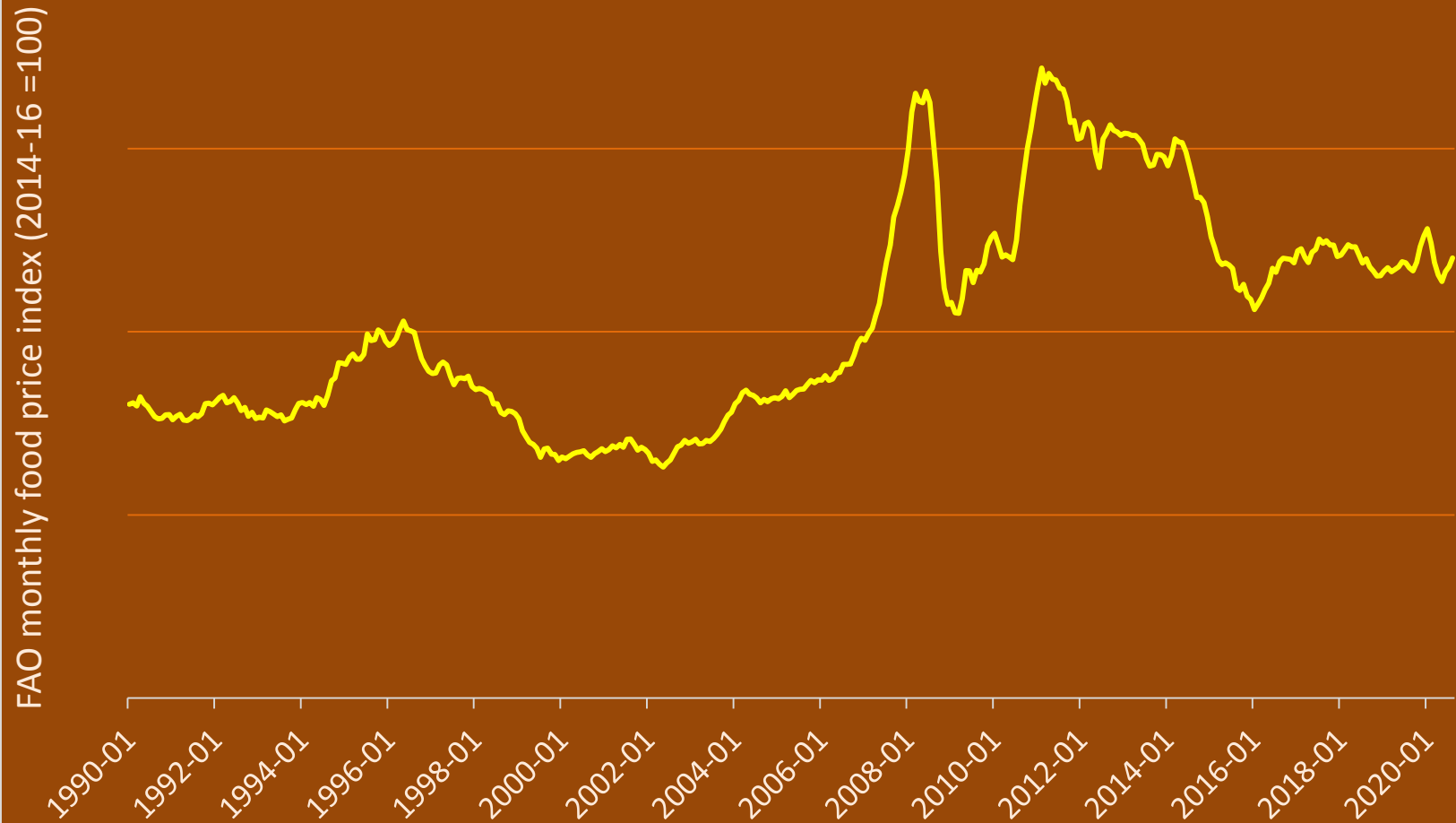
IRON



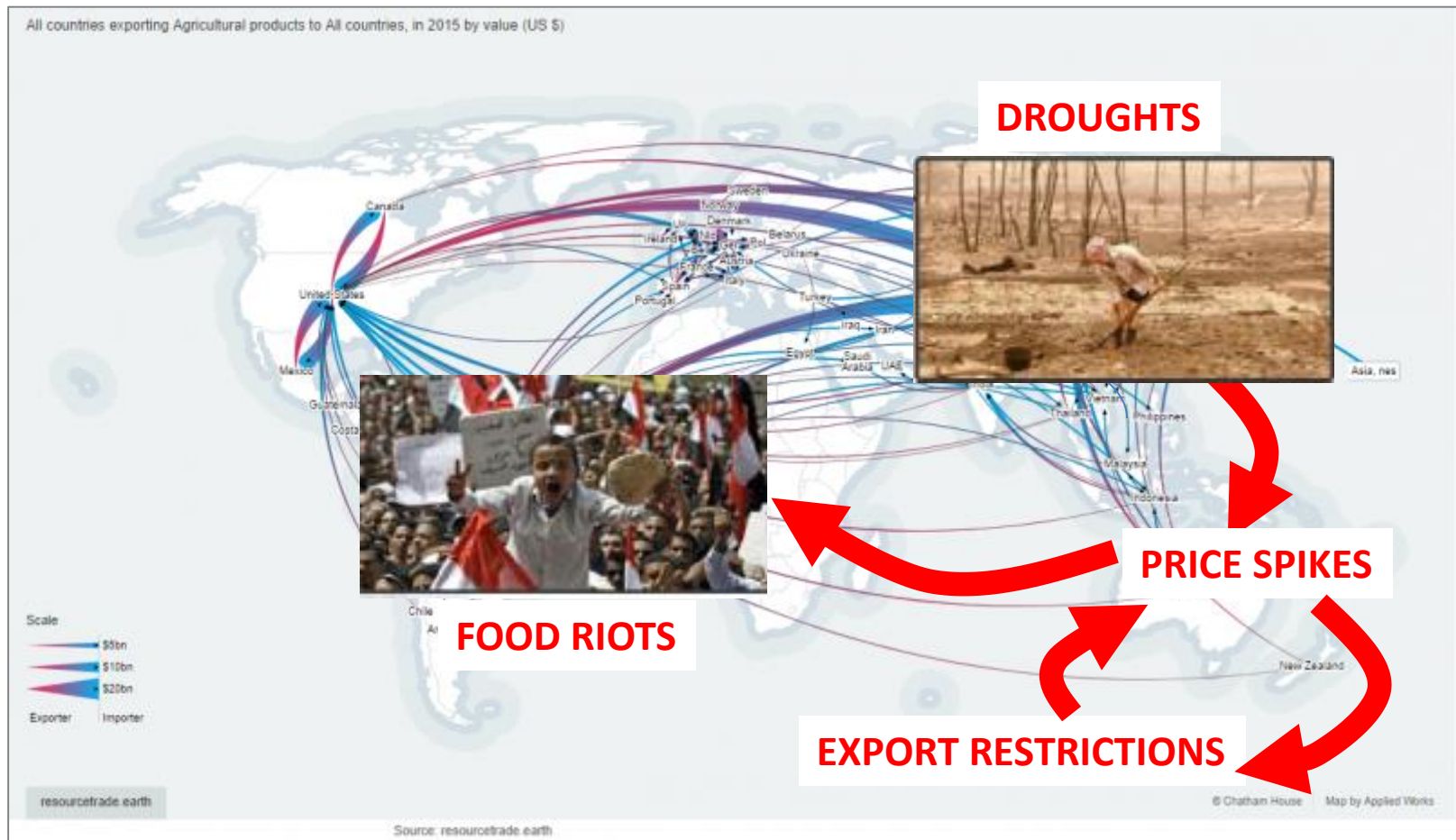
Iron ■ (-847, -24) ■ (-24, -1) ■ (-1, 0)  
■ (0, 101) ■ (101,  $1.7 \times 10^3$ )

Change in number of people who could be nourished without trade.

## Volatility in Food Price Index

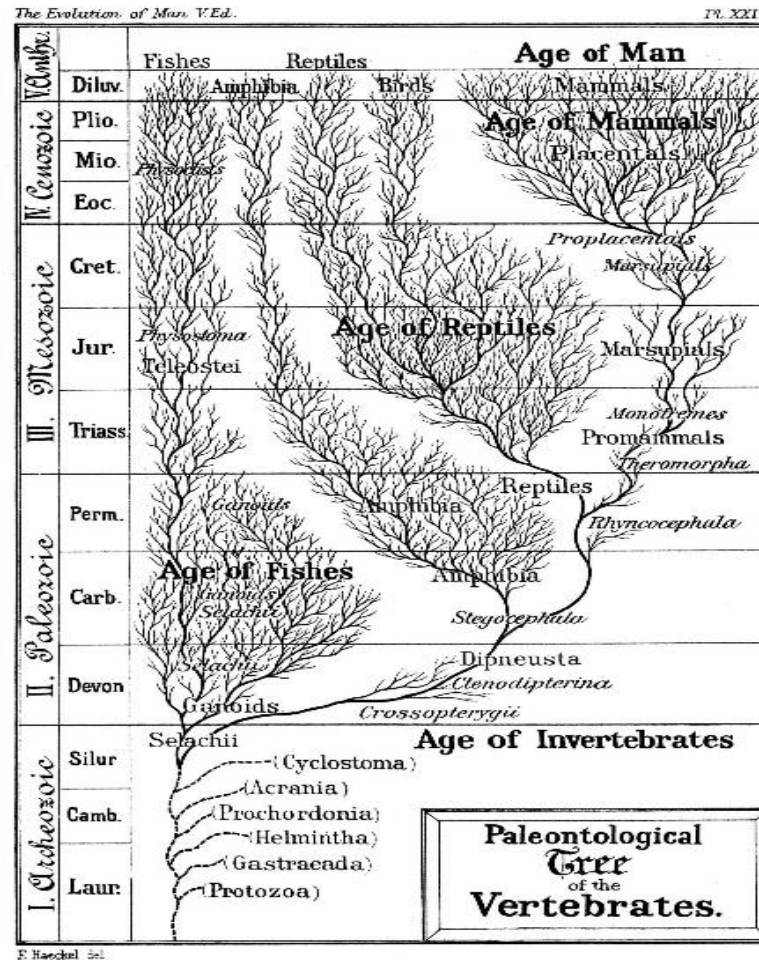


# .... FRAGILE WHEN NETWORK DISRUPTED: CASCADING PRICES SPIKES





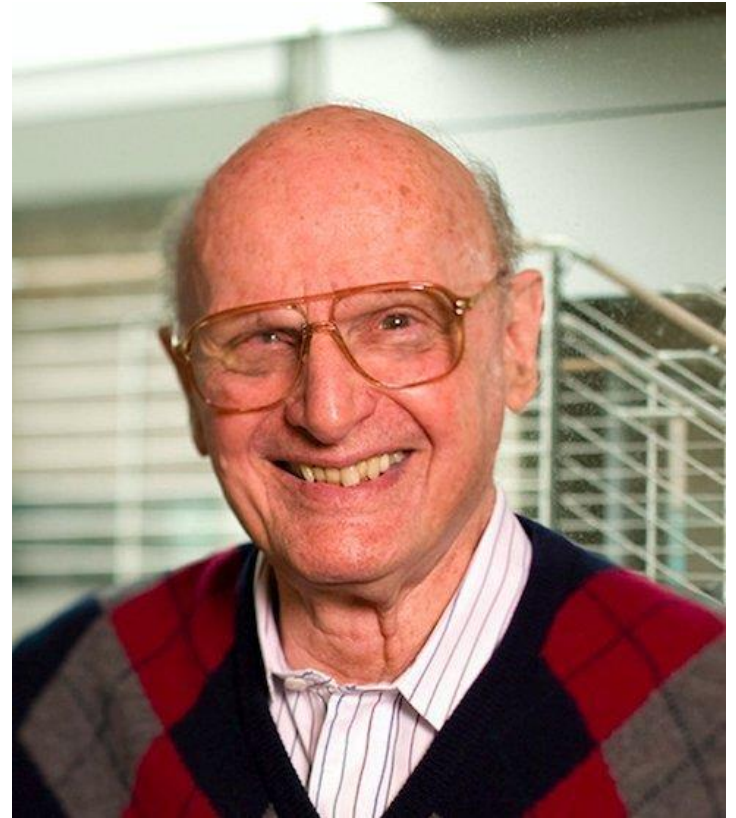
# Strategy #2: Nature invests in diversity to keep options alive



*Tree of Vertebrates from Ernst Haeckel's The Evolution of Man, 1910*

# Diversified bet-hedging

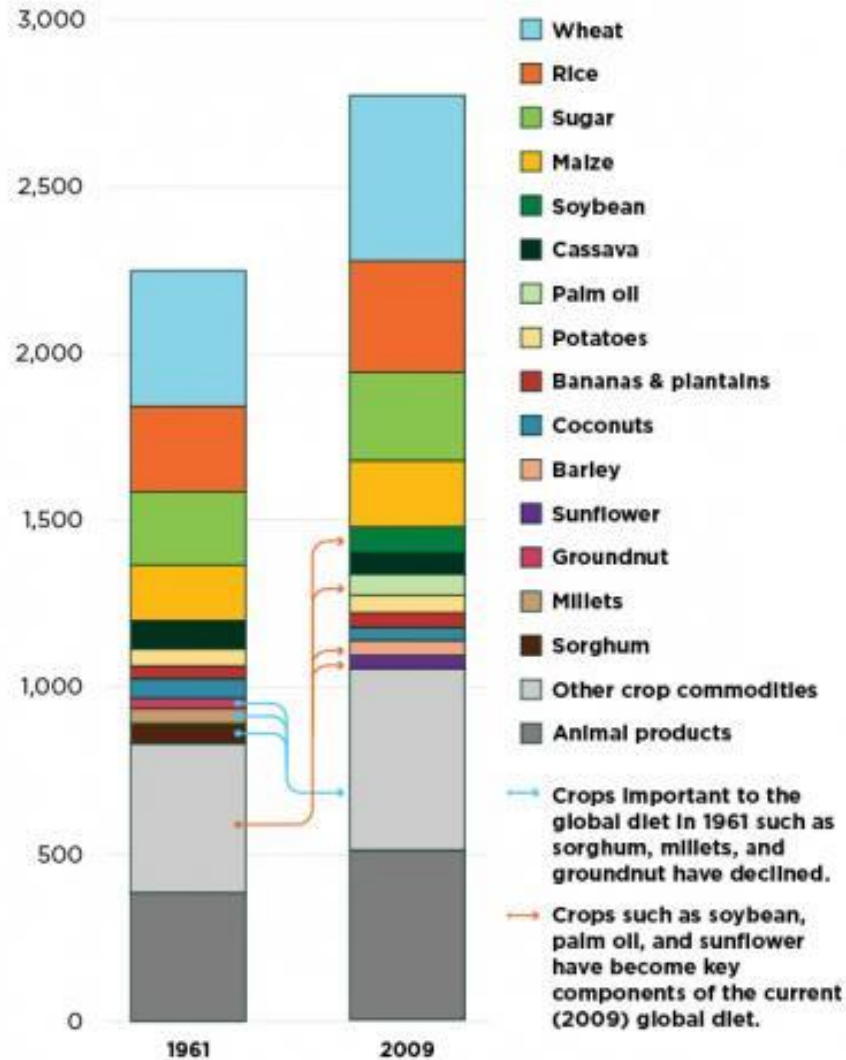
**“A portfolio with sixty different railway securities, for example, would not be as well diversified as the same size portfolio with some railroad, some public utility, mining, various sorts of manufacturing etc.”**



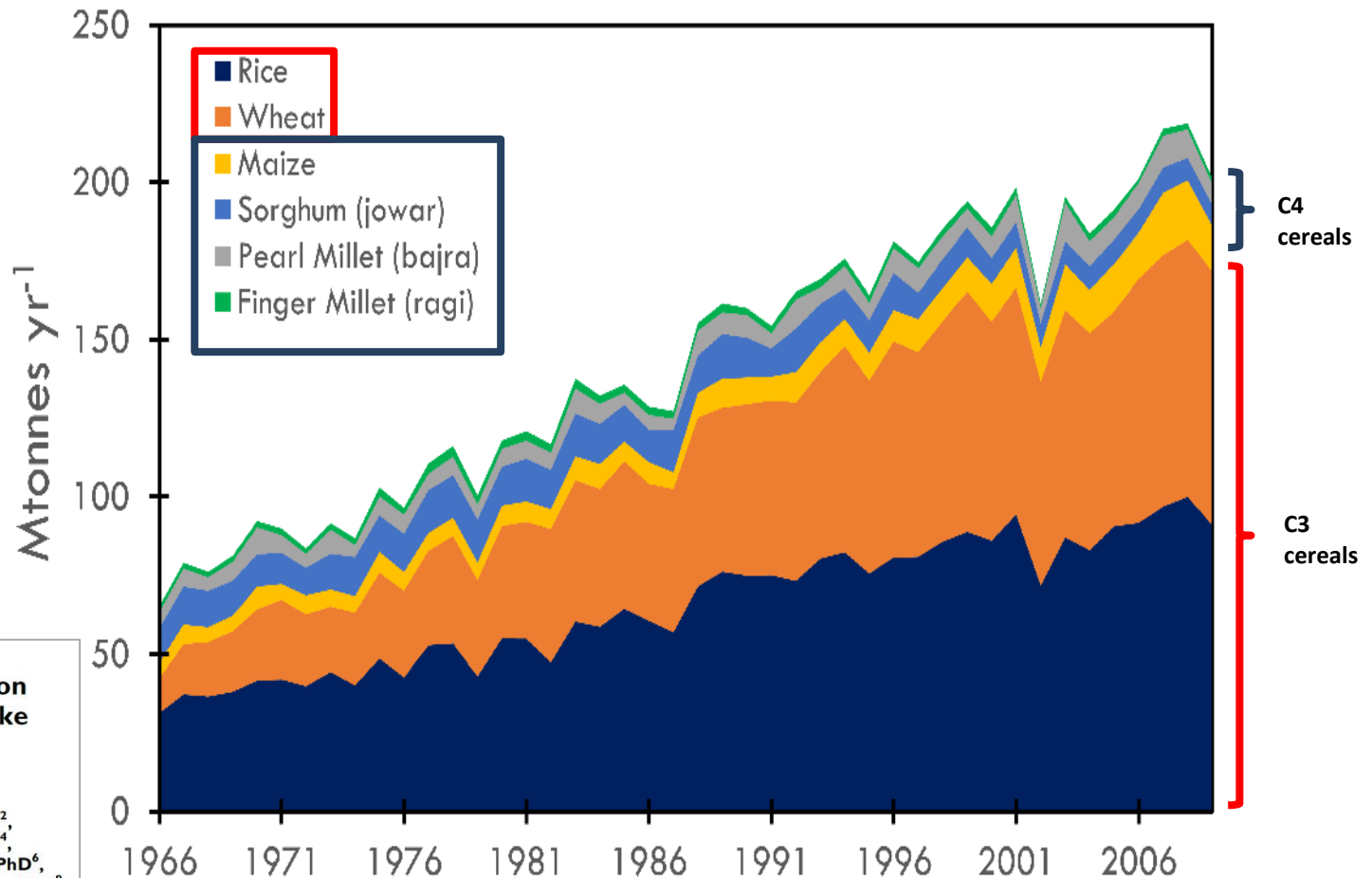
Harry Markowitz (1927- )  
Nobel Prize in Economic Sciences in 1990

## Diets worldwide are increasingly comprised of major globalized crops.

Relative contribution of major crops to the average food supply composition for calories (kcal/capita/day) worldwide, 1961 and 2009



# The good and the bad of the loss of cereal diversity from India's Green Revolution



**Impact of Historical Changes in Coarse Cereals Consumption in India on Micronutrient Intake and Anemia Prevalence**

Ruth DeFries, PhD<sup>1</sup>, Ashwini Chhatre, PhD<sup>2</sup>, Kyle Frankel Davis, PhD<sup>1,3</sup>, Arnab Dutta, MS<sup>4</sup>, Jessica Fanzo, PhD<sup>5</sup>, Suparna Ghosh-Jerath, PhD<sup>6</sup>, Samuel Myers, MD, MPH<sup>7</sup>, Narasimha D. Rao, PhD<sup>8</sup>, and Matthew R. Smith, PhD<sup>7</sup>



## **C3 CEREALS**



**wheat**



**rice**

## **C4 CEREALS**



**maize**



**pearl millet**

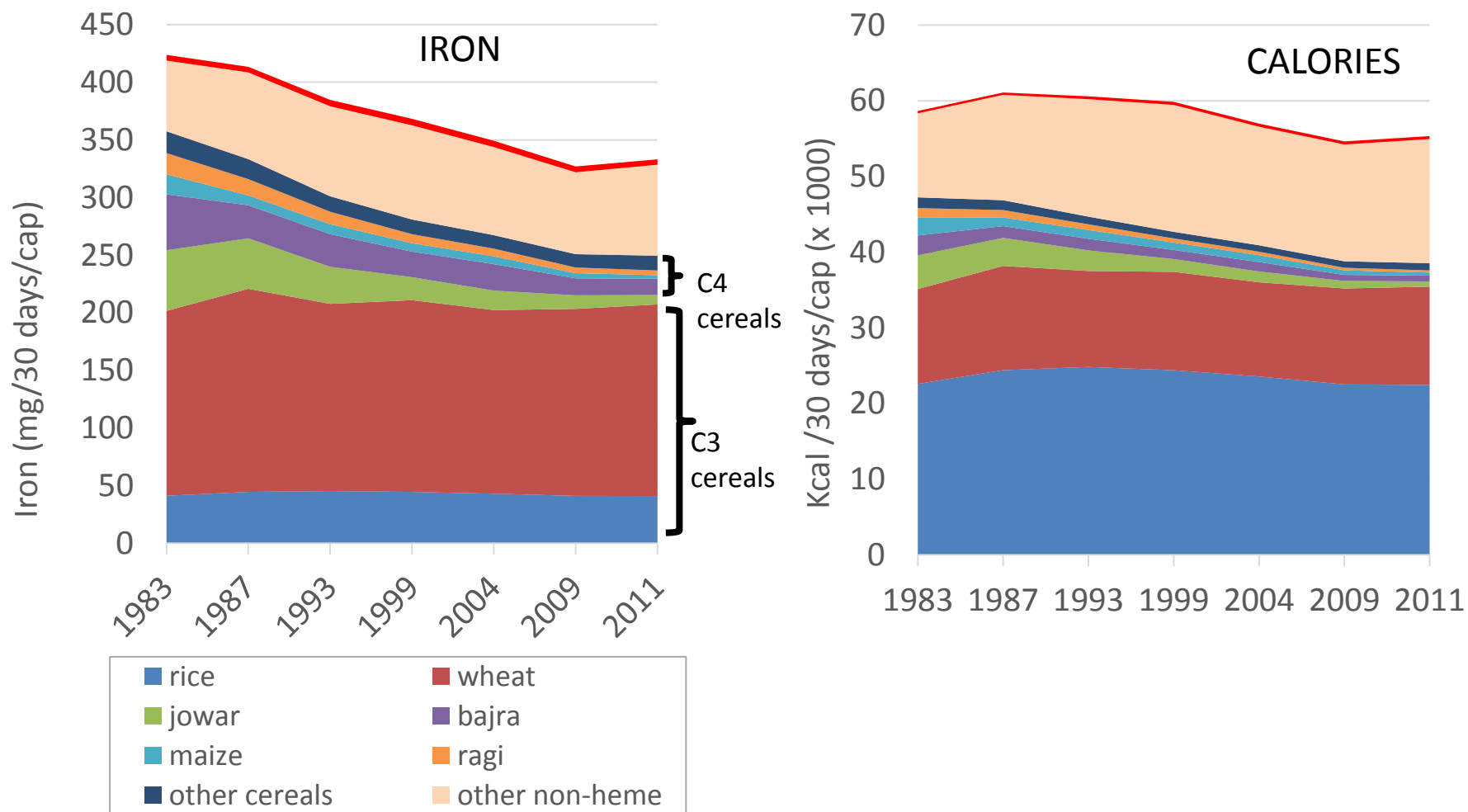


**finger millet**



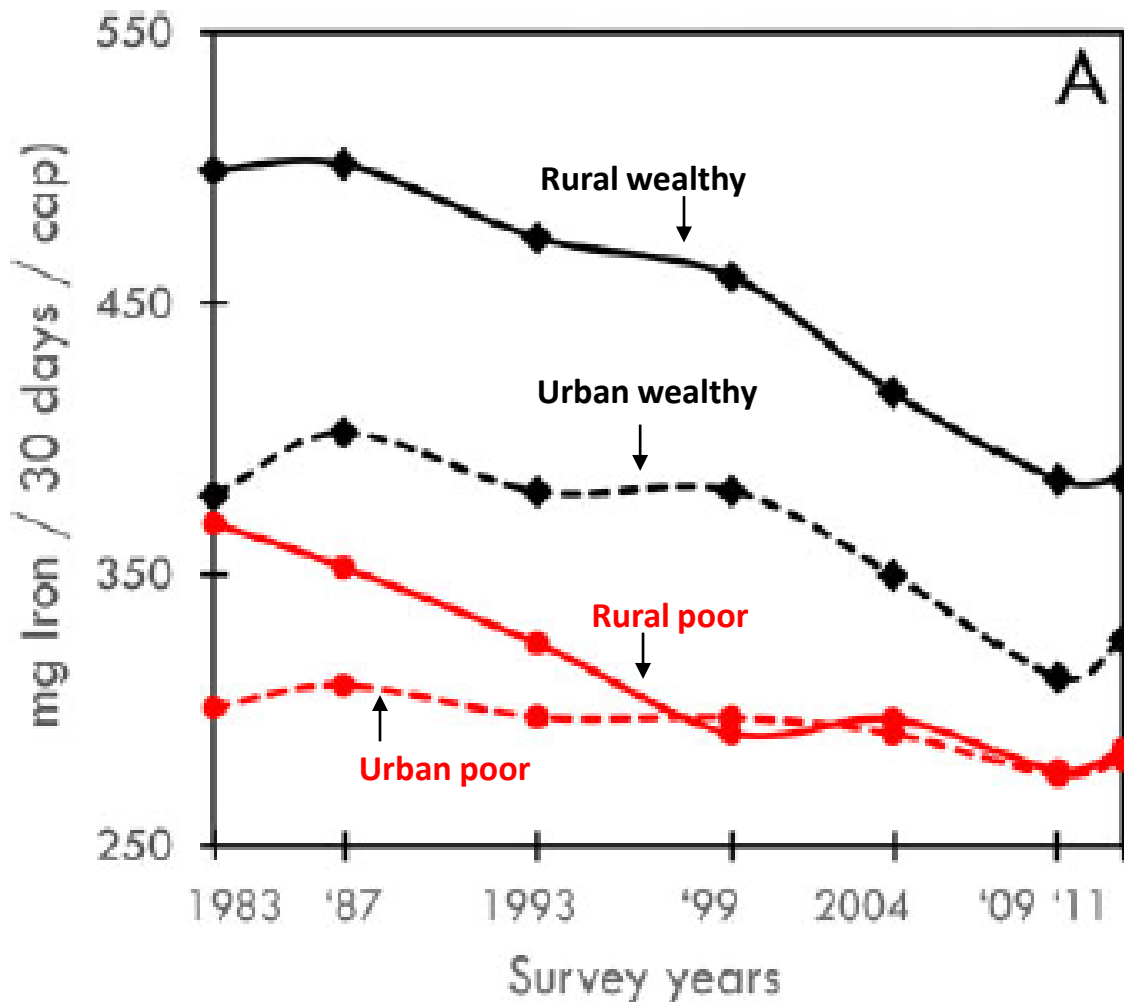
**sorghum**

# LOSS OF IRON FROM DECLINE IN CONSUMPTION OF C4 CEREALS HAS NOT BEEN COMPENSATED BY OTHER FOOD GROUPS



(DeFries et al., 2018)

# STEEP DECLINE IN IRON CONSUMPTION FOR RURAL POOR



Recommended intake  
~ 580 mg/iron/30 days/cap

(DeFries et al., 2018)

# THE MILLET TEAM



**Ashwini Chhatre**, Indian School of Business, Hyderabad



**Suparna Ghosh-Jerath**, Public Health Institute of India, New Delhi



**Ruth DeFries**, Columbia University, New York



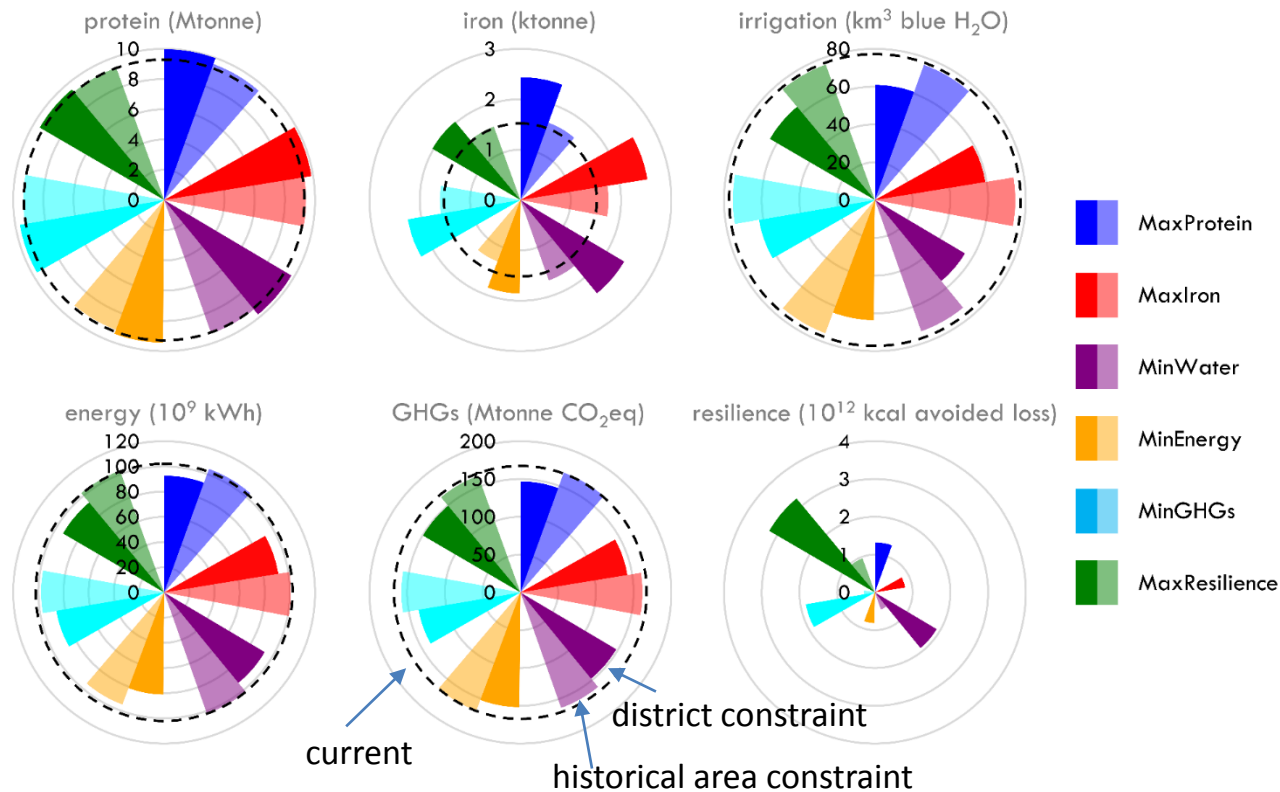
**Kyle Davis**, Columbia University, New York/ Univ. of Delaware



**Narasimha Rao**, IIASA (Austria)/Yale University (New Haven CN)



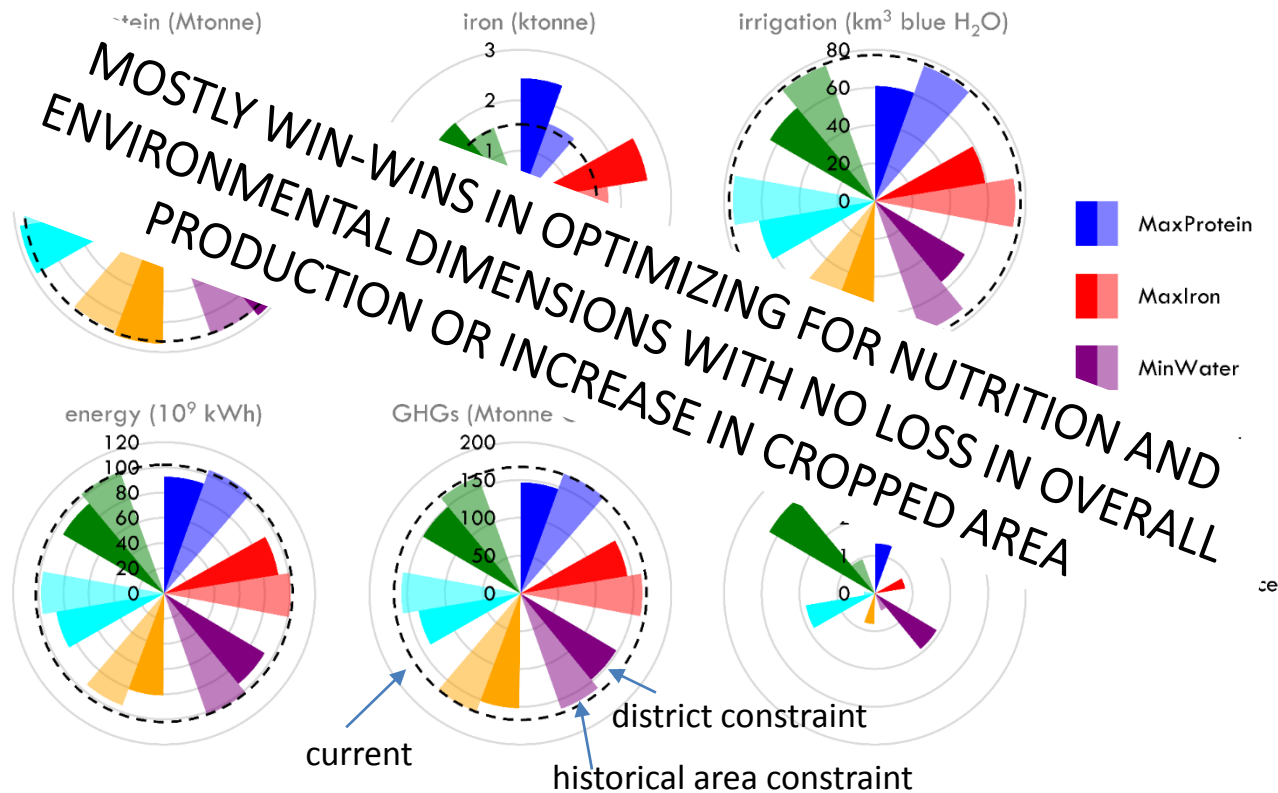
# WITH TOTAL PRODUCTION AND CROPPED AREA CONSTANT, DIVERSIFICATION WITH C4 CEREALS BENEFITS ALL DIMENSIONS



## Assessing the sustainability of post-Green Revolution cereals in India

Kyle Frankel Davis<sup>a,b,c,1</sup>, Ashwini Chhatre<sup>d,e</sup>, Narasimha D. Rao<sup>f,g</sup>, Deepti Singh<sup>h</sup>, Suparna Ghosh-Jerath<sup>i</sup>, Anvi Mridul<sup>j</sup>, Miguel Poblete-Cazenave<sup>g</sup>, Nabin Pradhan<sup>d,e</sup>, and Ruth DeFries<sup>k,1</sup>

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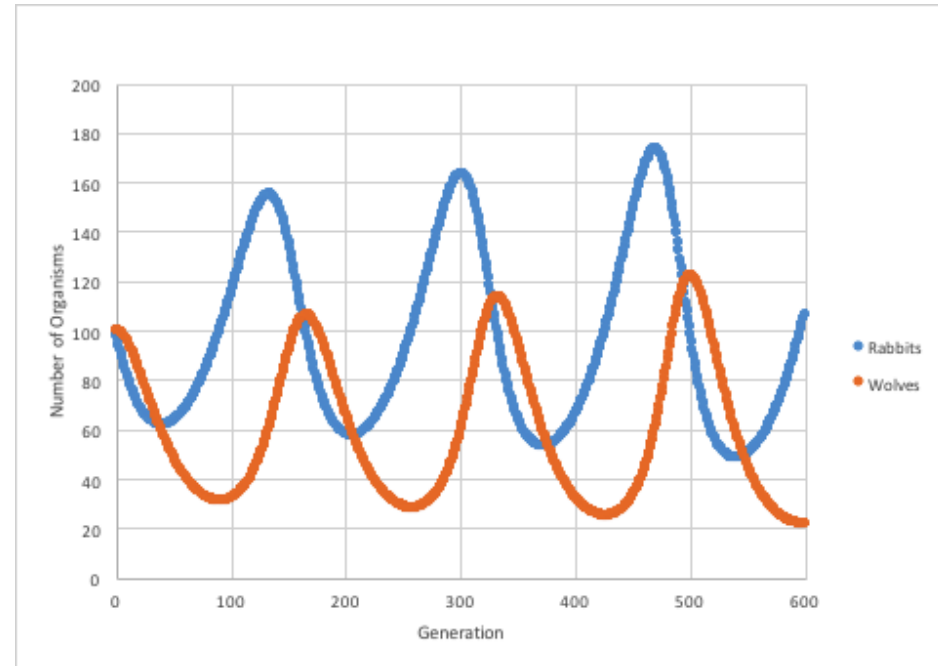
## BRINGING BACK DIVERSITY IN CEREALS: FAD OR SOLUTION TO CLIMATE RESILIENCE, NUTRITION AND ENVIRONMENTAL PROBLEMS IN INDIA'S FOOD SYSTEM?



# *Strategy #3: Nature can self-correct*



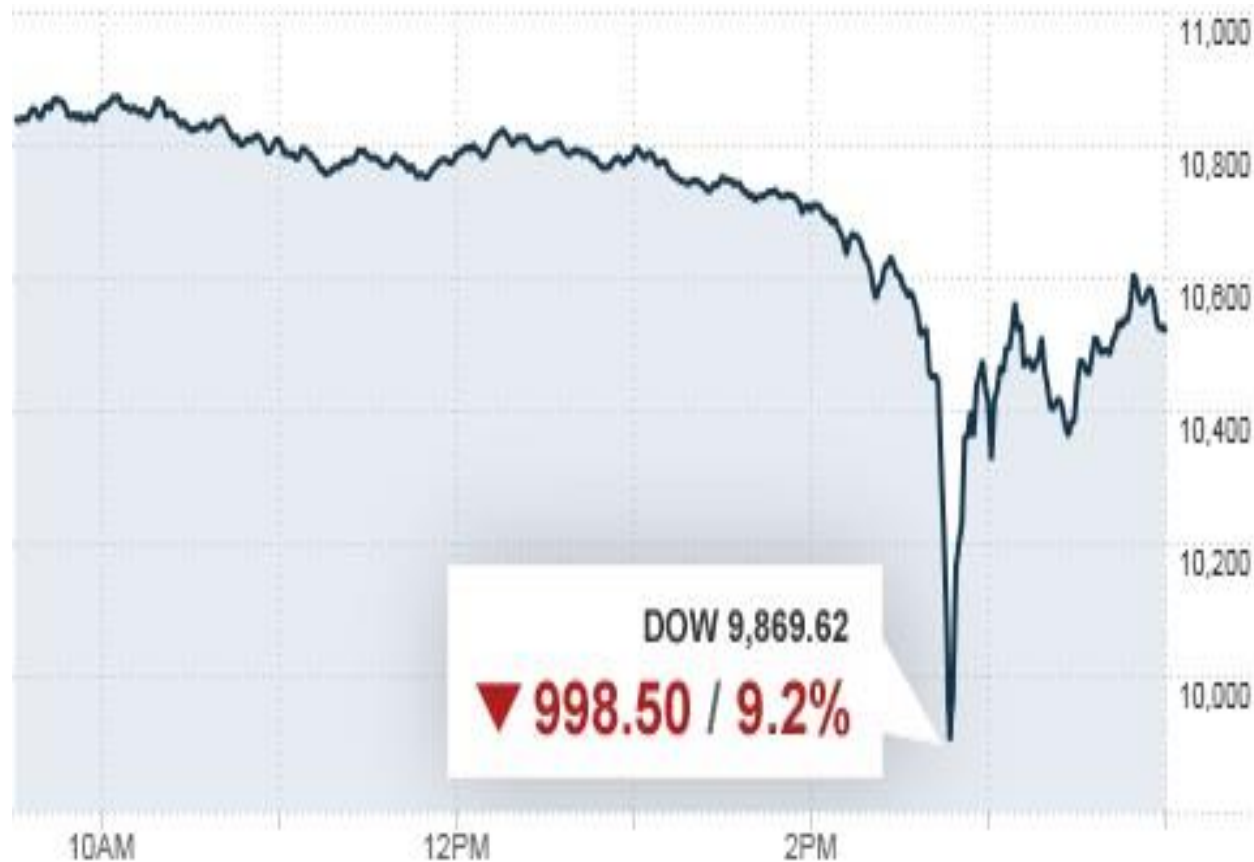
**THE LONG-TERM CYCLING OF  
CARBON REGULATES THE  
PLANETARY LIFE-SUPPORT SYSTEM**



**PREDATOR-PREY DYNAMICS**



# SELF-REGULATION IN THE STOCK MARKET



Flash crash on May 6, 2010

# SMOKEY BEAR IGNORED SELF-REGULATING FEEDBACKS



# *Strategy #4: Decisions from the bottom up*



**Elinor Ostrom (1933-2012) –  
Nobel Memorial Prize in  
Economics in 2009**



*The Tragedy of the Commons*

**GARRETT HARDIN**

# Success from bottom-up decisions based on local information

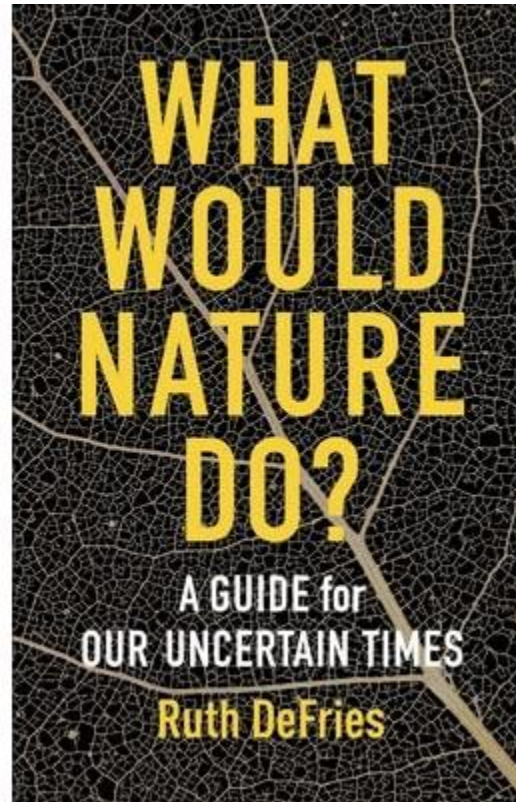




# Nature's secrets for navigating uncertain times

- **Architecture of networks**
- **Diversity**
- **Self-regulating feedbacks**
- **Bottom up solutions**
- **.....**

**“You cannot solve a problem with the same sort of thinking that created the problem” - *Albert Einstein***



**“If you do not change direction, you may end up where you are headed” - *Lao Tzu***