GLOBAL PHOSPHORUS SECURITY

THE TRUE COST OF PHOSPHORUS FROM MINE TO THE DINNER TABLE

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NIBIO Oslo,

What is the **true cost** of a tonne of P
from **phosphate rock** compared to **human excreta**?

P in phosphate rock

P in excreta

the ‘embodied’ sustainability costs:
ethical, environmental, geopolitical & societal

PHOSPHORUS: UNDERPINS FOOD SECURITY

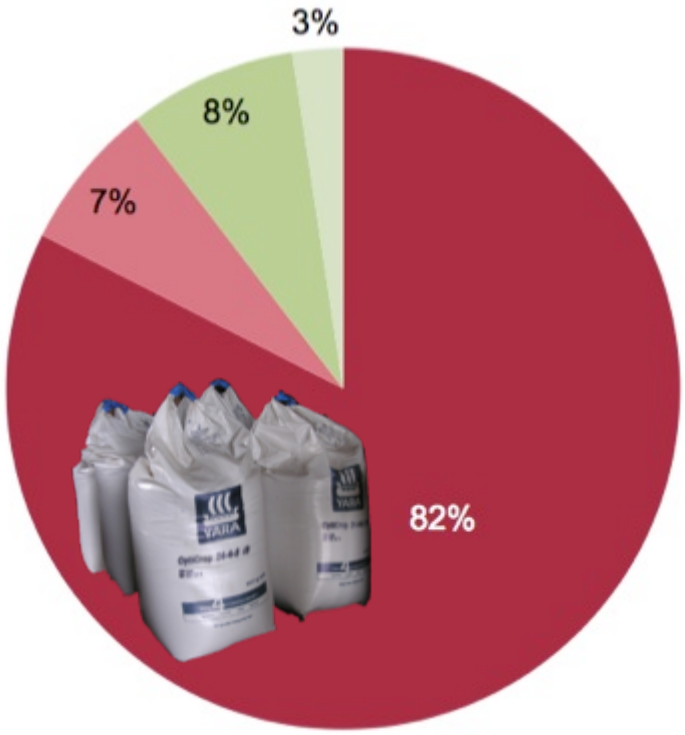
- Phosphorus is essential to all living organisms, has no substitute in food production & cannot be 'manufactured'
- There will always be a global demand for phosphorus
- Chemical fertilizers (N,P,K) have contributed to feeding billions of people by boosting crop yields

Photo: Franklin D. Roosevelt Presidential Library and Museum

PHOSPHORUS: THE CURRENT SITUATION

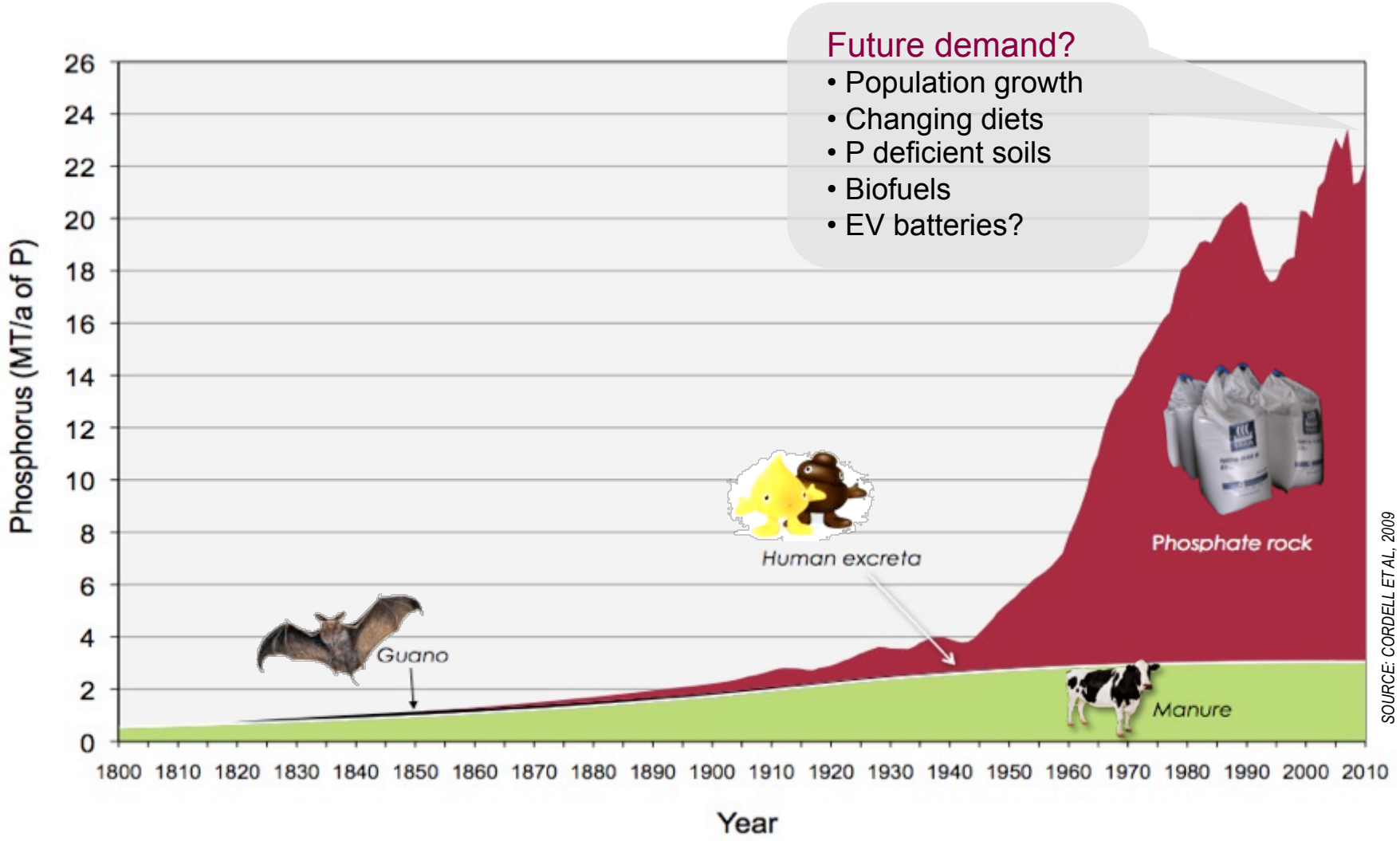
- Phosphate rock is a finite, non-renewable resource and the world's high-quality reserves are becoming scarce
- 90% of mined phosphate rock for food production
- Awareness and response to phosphorus pollution (eutrophication), but little on long-term phosphorus security

PHOSPHATE ROCK END USES



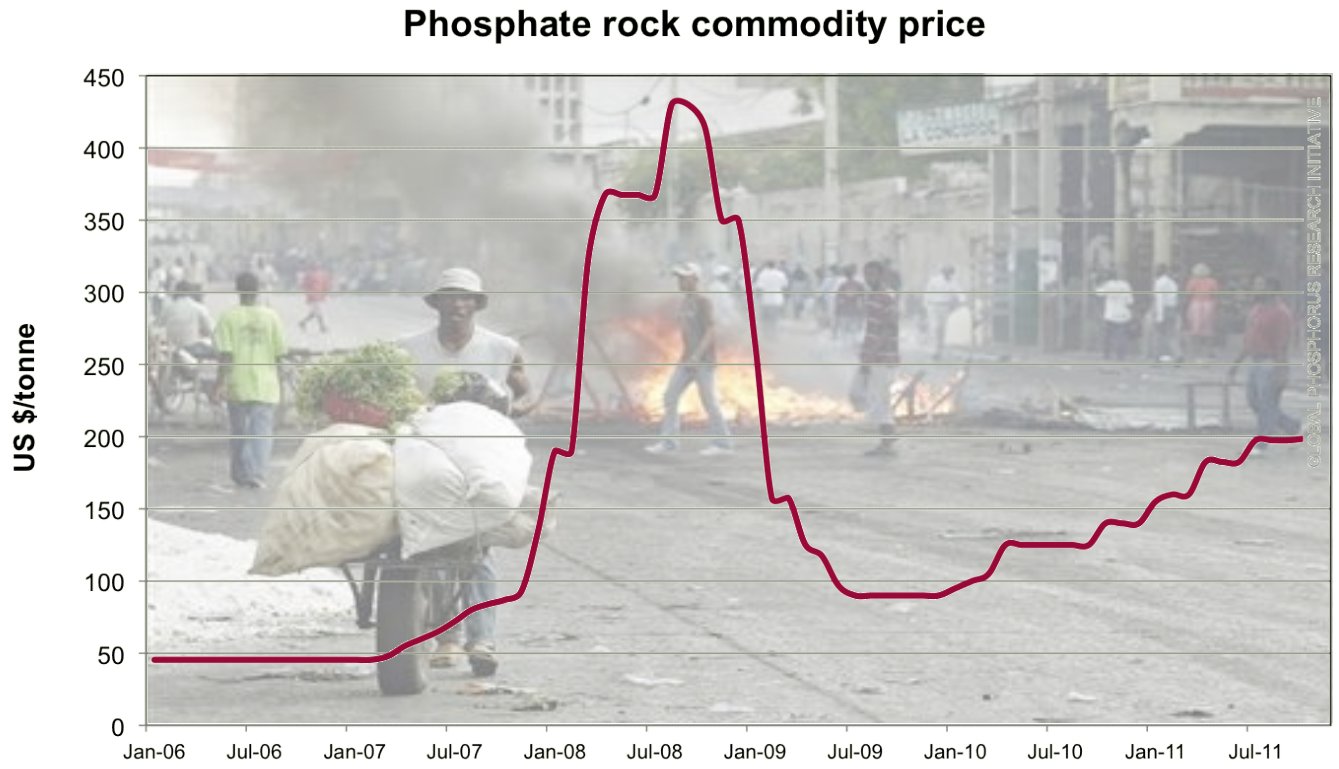
Data: IFA, 2010

PHOSPHORUS: HISTORICAL SOURCES OF FERTILIZERS



PHOSPHORUS: THE CURRENT SITUATION

2008 price spike: US$50/tonne to US$430/tonne

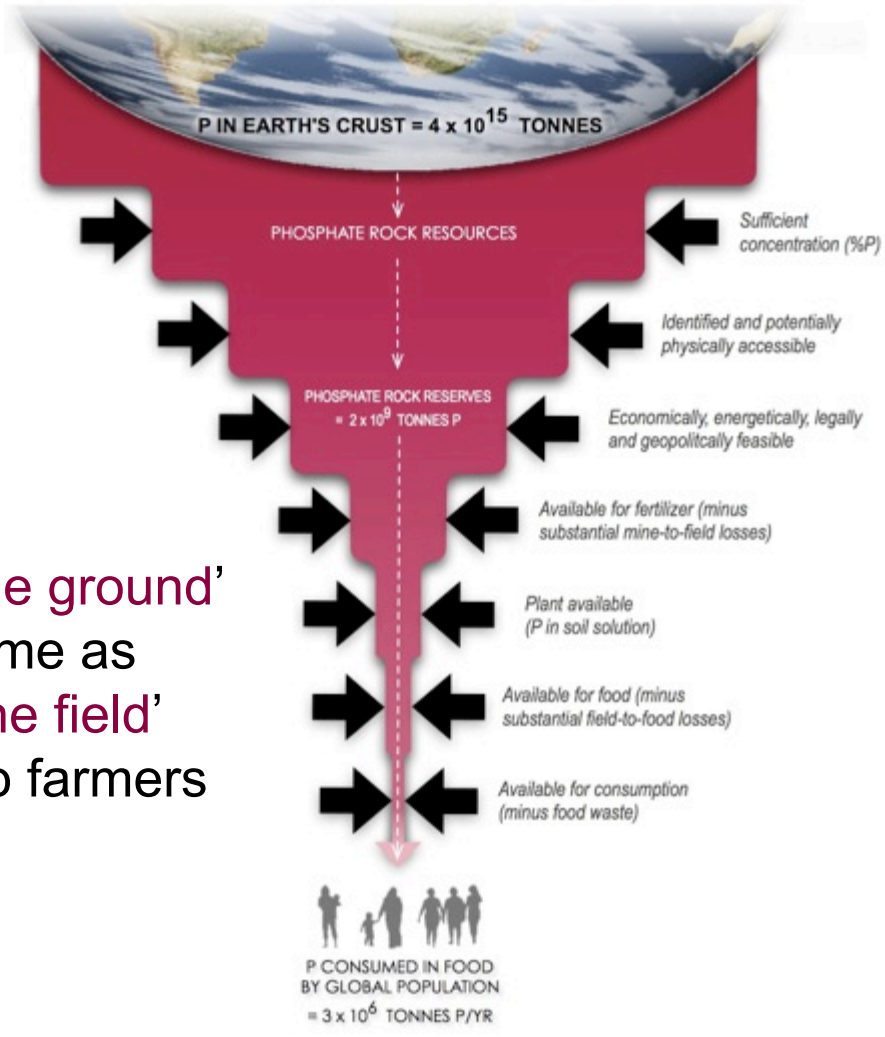


Data sources: World Bank Commodity Price Data; Minemakers Limited.

PHOSPHORUS: THE CURRENT SITUATION

- Crisis >> peak phosphorus in media
- Vigorous debate today: will we run out of phosphorus? 30 yrs – 300 years?

SCARCITY: MORE THAN JUST PHYSICAL



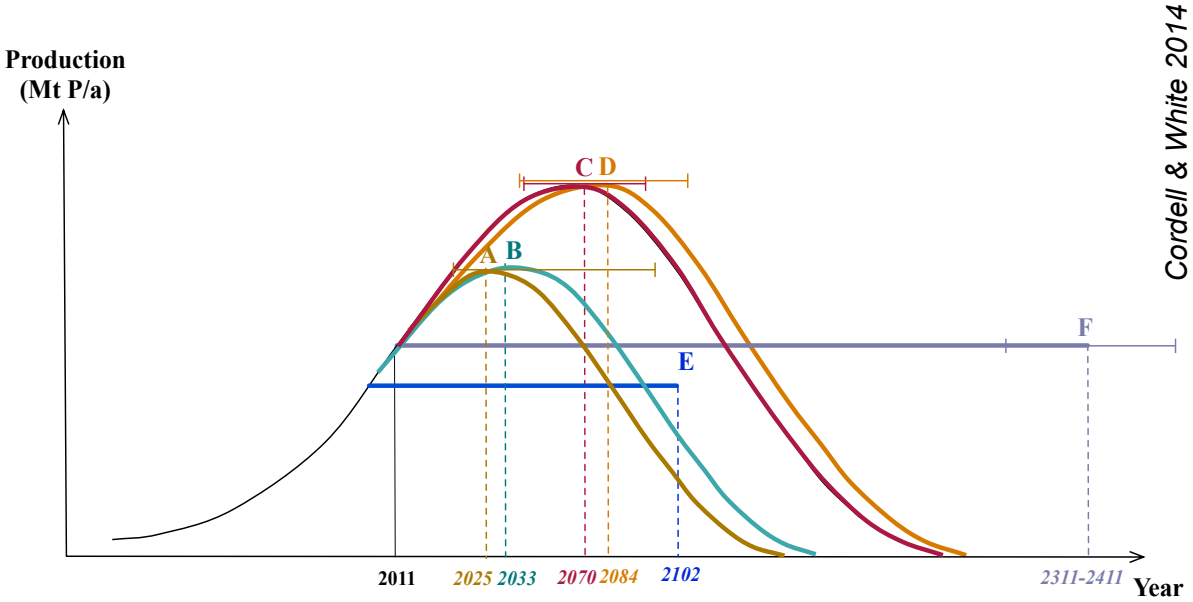
Tonnes 'in the ground' is <u>not</u> the same as tonnes 'on the field' accessible to farmers

IFA

REUTERS

PHYSICAL SCARCITY: PEAK PHOSPHORUS

- Global demand for phosphorus fertilizers will surpass supply of phosphorus this century, estimated between 2035-2075
- Timing of peak uncertain, but widely recognised:
  - quality is declining
  - access is more difficult
  - energy increasing
  - costs increasing
  - wastes increasing



LEGEND:
A=Mohr & Evans (2013); B=Cordell et al (2009a); C=GPRI, 2010; Cordell et al, 2011b; D=Walan (2013); E =Fixen (2009); F=IFDC (2010)

PHYSICAL SCARCITY

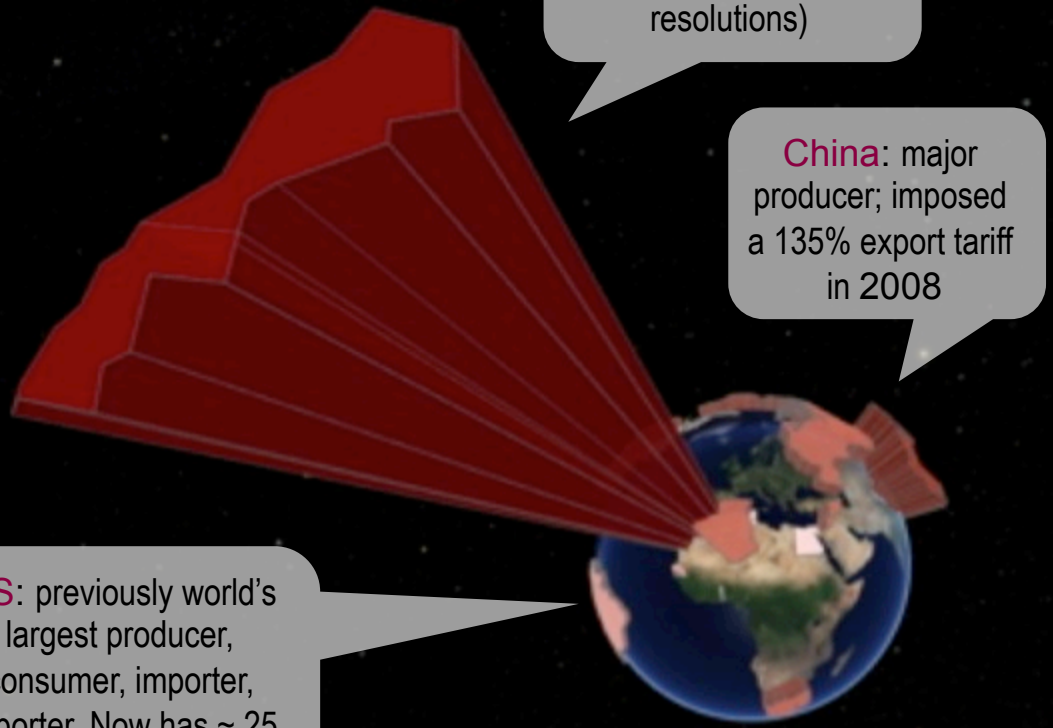
Environmental costs of phosphate rock:

- **Energy**: Mining, processing and transport (ship, rail, road) is energy intensive
  - 30 million tonnes transported each year
- **Radioactive waste**: 1 tonne of phosphate => 5 tonnes of radioactive phosphogypsum waste (stockpiled)
- **Heavy metals**: e.g. cadmium, uranium, thorium naturally present – can transfer to soils (yet accepted in organic agriculture)

www.epa.gov

GEOPOLITICAL SCARCITY: REMAINING RESERVES

Distribution of World Phosphate Rock Reserves



Data Visualization from Uniview visualization software by SCISS AB;
Data sources: USGS (2011)

All farmers need phosphorus, yet just **5 countries** control around **85%** of the worlds remaining phosphate rock reserves

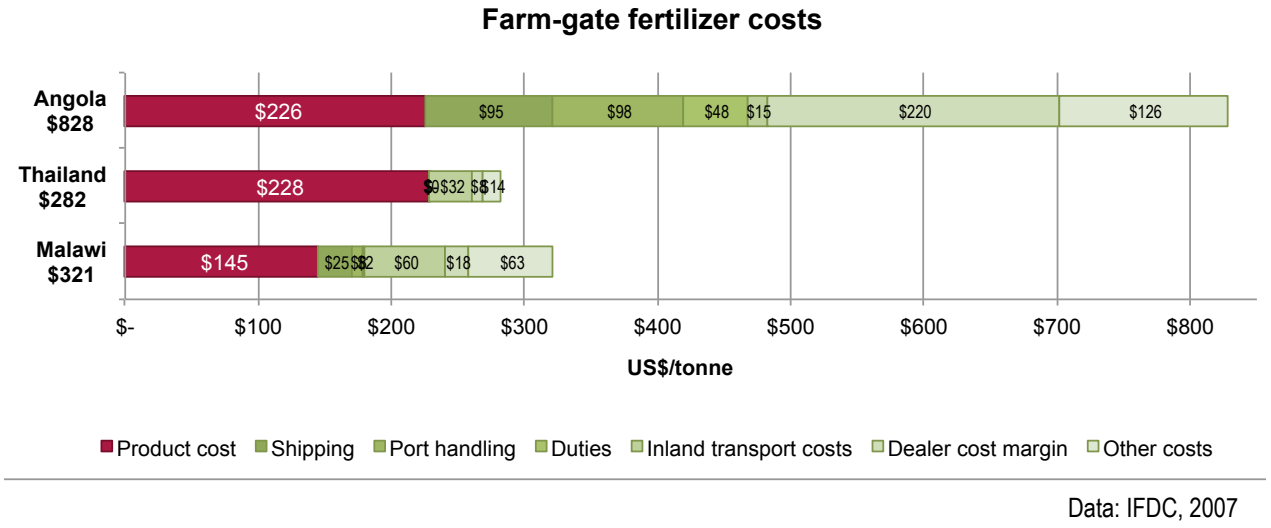
India, Australia, EU: all **dependent** on **imports** (vulnerable to price fluctuations and supply disruptions)

'conflict phosphates': companies, farmers & consumers knowingly or unknowingly supporting the conflict in Western Sahara


PORT
FOR PHOSPHATE
EXPORTS
world's longest
conveyor belt
WESTERN SAHARA /
MOROCCO
PHOSPHATE ROCK
MINE
(BOU CRAA)

ECONOMIC SCARCITY: LACK OF ACCESS TO PHOSPHORUS

- Farmers need both short- and long-term access to fertilizers
- Almost a billion farmers lack purchasing power to access fertilizer markets
- African farmers in some landlocked countries can pay 2-5 times more than European farmers for fertilizers, due to: high transport costs (road/rail), handling, duties, corruption

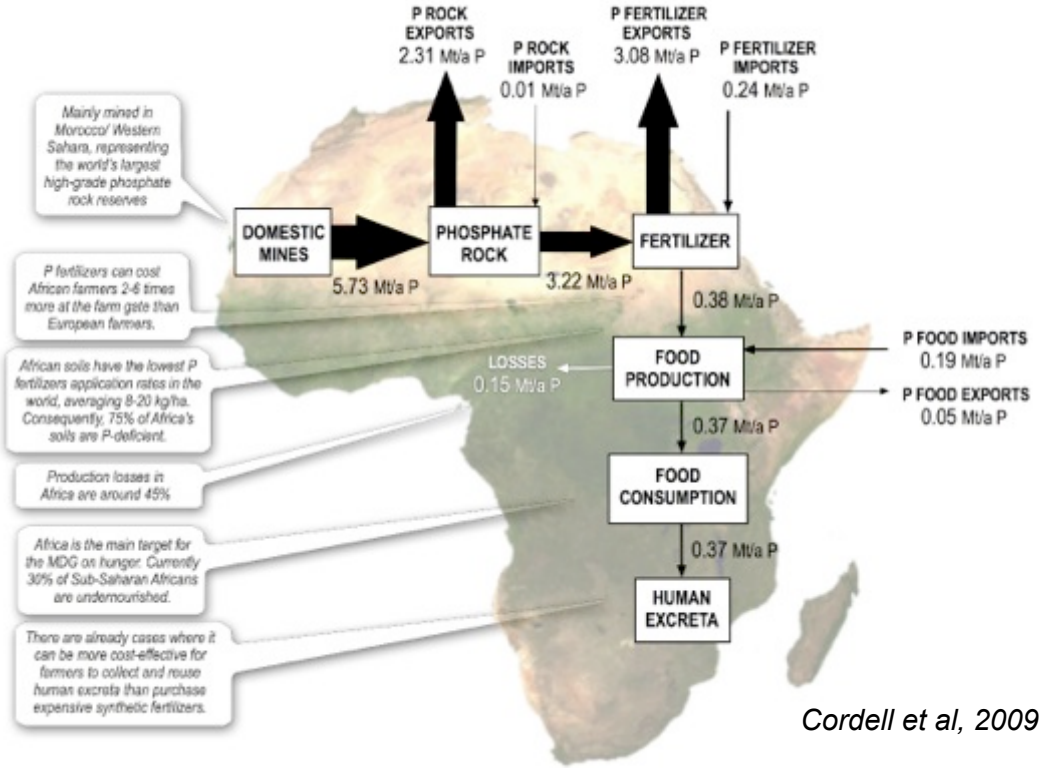


Data: IFDC, 2007

ECONOMIC SCARCITY: LACK OF ACCESS TO PHOSPHORUS

Phosphorus inequity: African continent

- > largest high quality phosphate rock
- > Low soil fertility
- > Poorest farmers
- > lowest P fertilizer application rates
- > High food insecurity



Cordell et al, 2009

MISMANAGEMENT: INEFFICIENT PHOSPHORUS USE IN THE GLOBAL FOOD SYSTEM

P lost
en mine
fork!

Cordell et al, 2009

LACK OF EFFECTIVE GLOBAL P GOVERNANCE

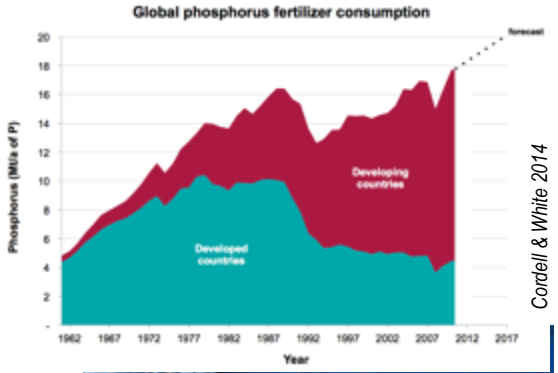
- there are currently no international or national policies, guidelines or organisations responsible for ensuring long-term **availability** and **accessibility** of phosphorus for food production
- "The market will take care of it" Market system governing by default – alone not sufficient to ensure **equitable**, **timely**, **sustainable**
- Whose responsibility is long-term phosphorus security? Governance of phosphorus is **fragmented** between many different sectors and stakeholders

Mining & fertilizer companies? Investors? Farmers? Food retailers? Consumers? Sanitation service providers? UN?

3rd Sustainable Phosphorus Summit, 2012

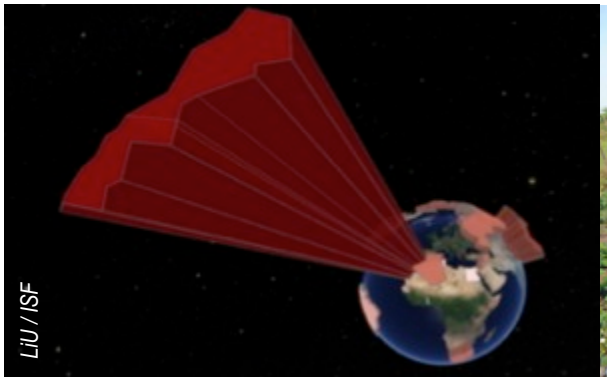
PHOSPHORUS CONTRADICTIONS

1. **Global challenge**: scarcity ★ pollution
2. **Food security**: obesity ★ undernourishment
3. **Distribution of reserves**: producers ★ importers
4. **Fertilizer use**: over-application ★ under-application
5. **Soil phosphorus**: surplus ★ deficiency
6. **Farmer issues**: accessibility ★ managing excess
7. **Fertilizer demand**: increasing ★ decreasing

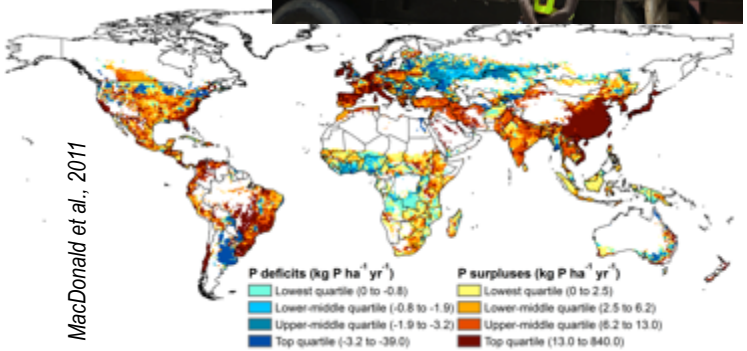


Cordell & White 2014

IFDC



LiU / ISF



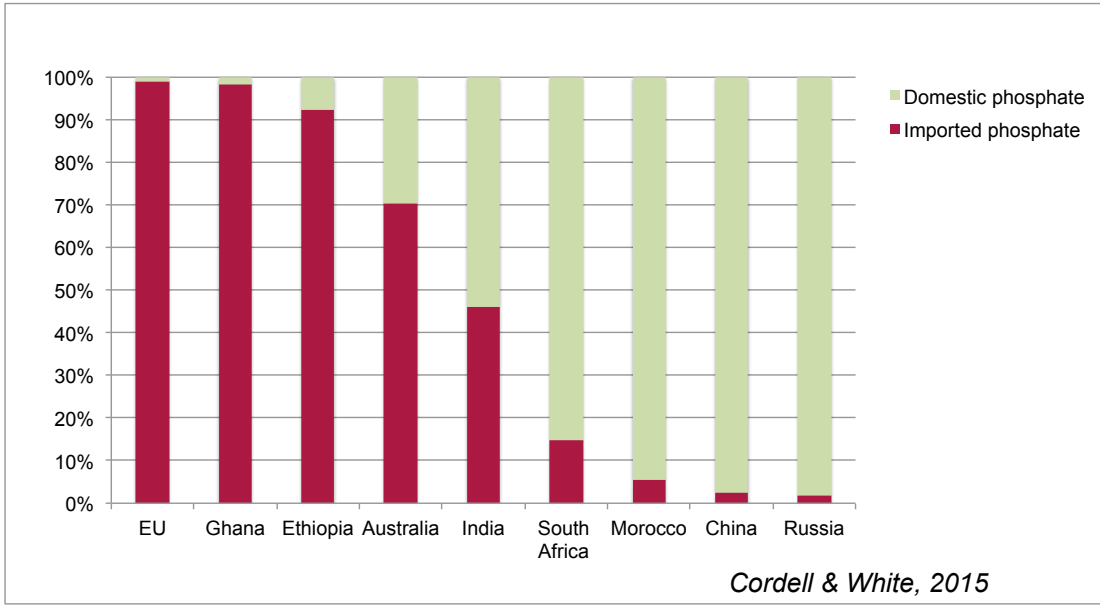
MacDonald et al., 2011

PHOSPHORUS VULNERABILITY

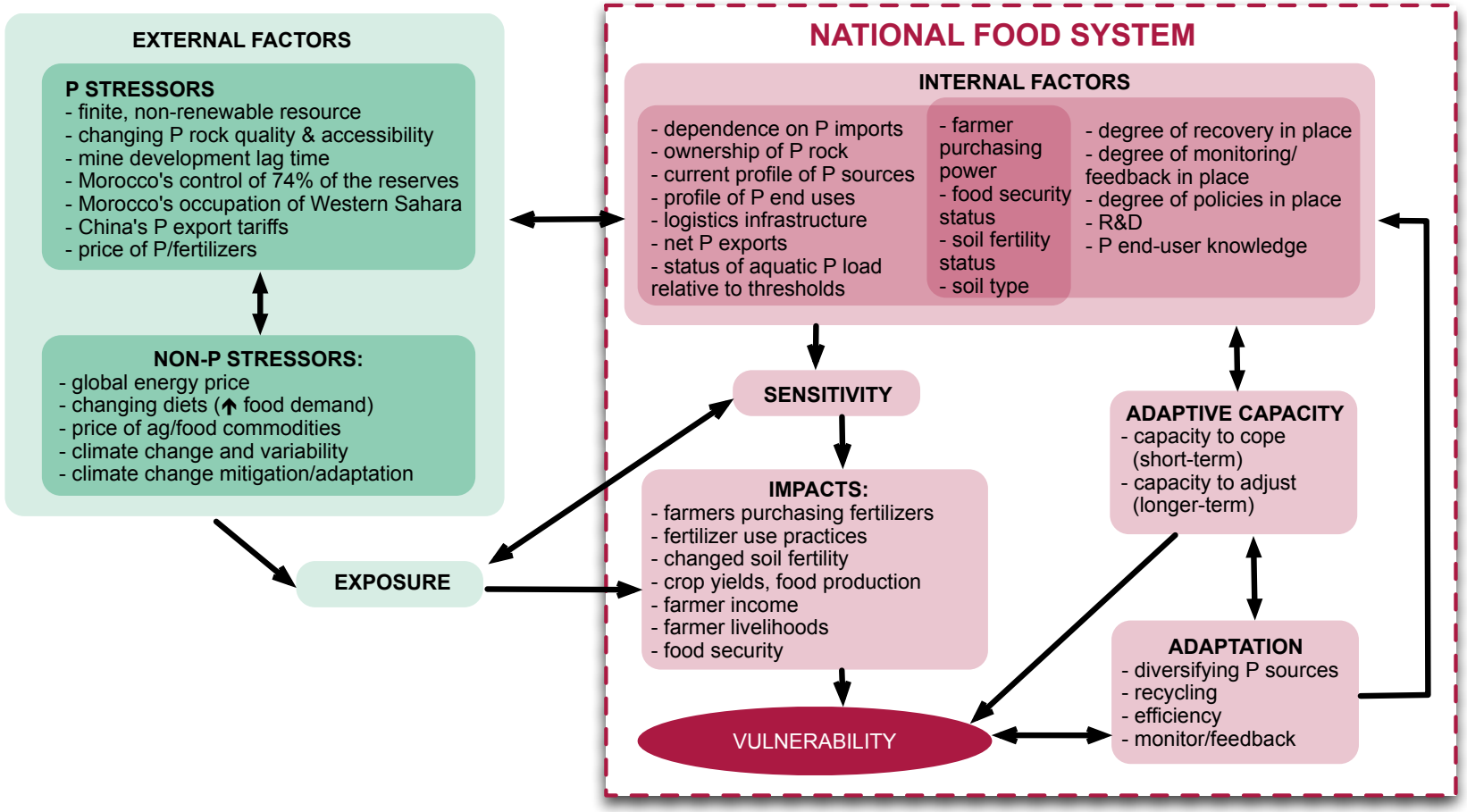
While all countries exposed to same global P drivers, vulnerability to phosphorus scarcity is **context-specific**.

Vulnerability depends on local factors like **dependence on imports**, **farmer purchasing power**, status of **infrastructure** (transport, sanitation etc).

What works in one region may be **inappropriate** and ineffective in another region. In what ways is **India** or **sub-Saharan Africa** or **Australia** most vulnerable to P scarcity?

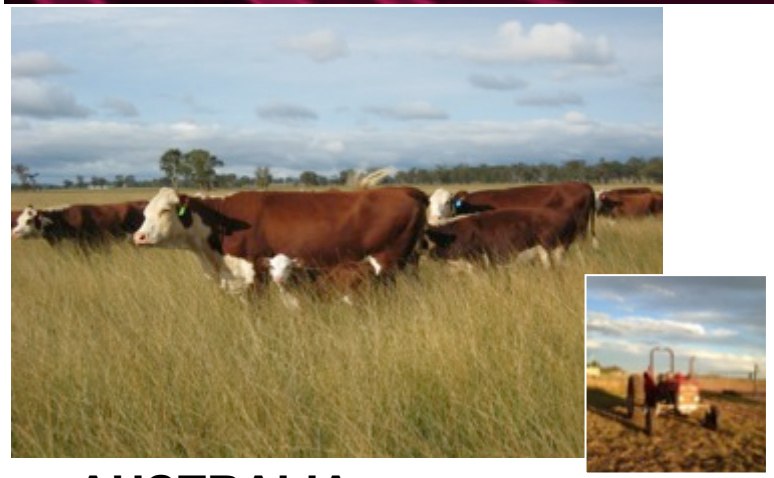


A FRAMEWORK FOR ASSESSING NATIONAL PHOSPHORUS VULNERABILITY



Cordell & Neset, 2014

NATIONAL PHOSPHORUS VULNERABILITY



AUSTRALIA:

- Net food exporter
- but net phosphorus importer – world's 5th largest
- Naturally phosphorus-deficient soils
- Invested in phosphorus-intensive agricultural exports (beef, live animals, wheat, dairy)

MALAWI:

- Subsistence farming (maize)
- Fertilizer subsidy
- Landlocked, and high dependence on P imports via Mozambique or SA
- Widespread water pollution
- P in excreta ~ P fertiliser demand
- 1 major fertilizer company (in Blantyre)

P-FUTURES

Transforming the way cities secure food and water through innovative phosphorus governance

Funding Partners

ISSC international social science council

SWEDEN

Research Partners

UTS:ISF

ASU

XÂY DỰNG BÁO HÓC

IESE

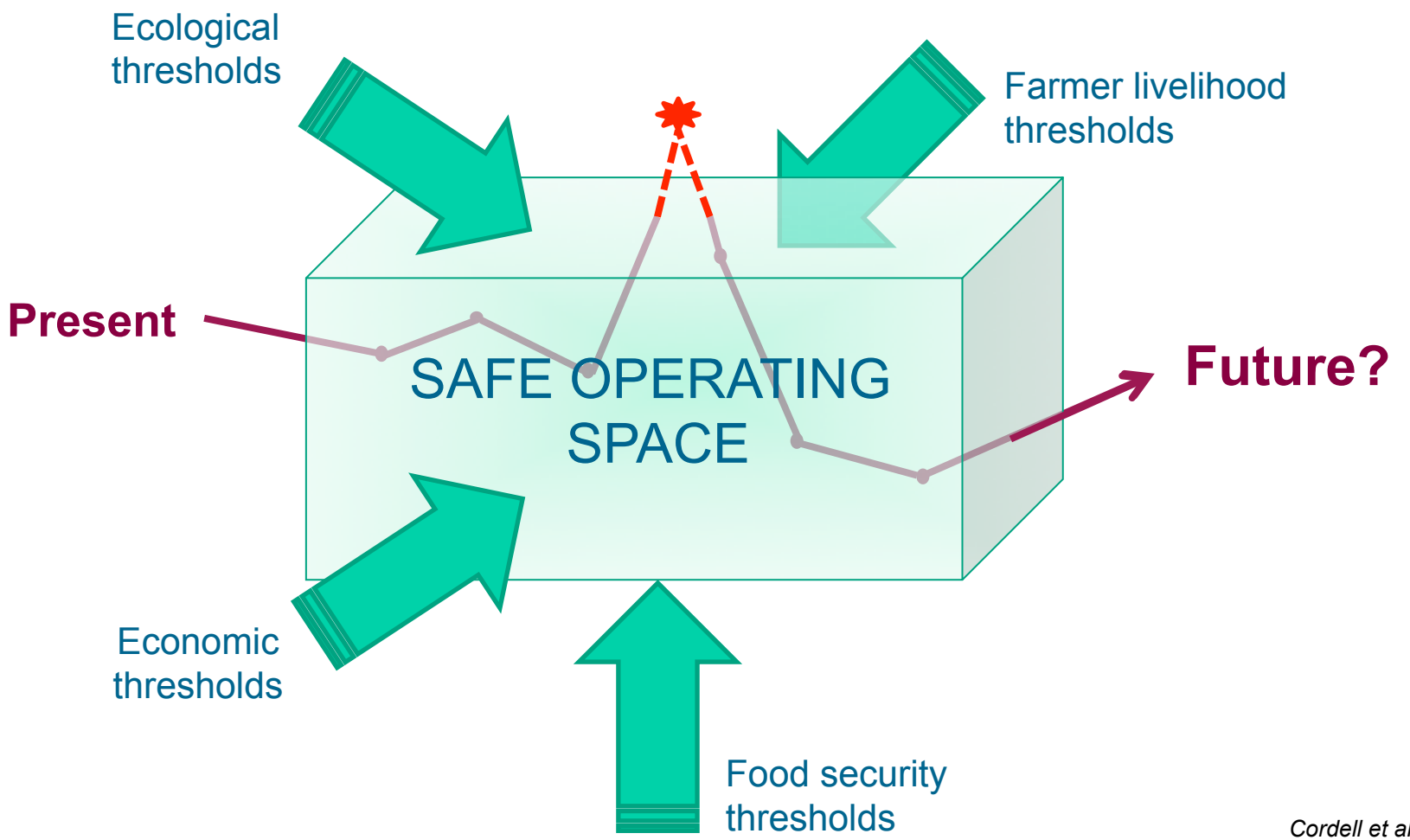
Phosphorus security *ensures all farmers have short- and long-term access to sufficient phosphorus to grow enough crops to feed the world, while maintaining healthy ecosystems & sustainable livelihoods*

Photo: 2014 US Committee for FAO

COLLECTIVE GOALS FOR PHOSPHORUS SECURITY

- **Agricultural productivity**: Increase overall phosphorus use efficiency of the food system by increasing the number of people fed per tonne P input, or reduce total P demand while maintaining food/agricultural output
- **National security**: Reduce dependence on phosphorus imports through diversification of sources, to buffer against price fluctuations and geopolitical risks in producing countries
- **Soil fertility**: Ensure soils are fertile in terms of total bioavailable phosphorus and C:N:P ratio, organic matter, moisture
- **Farmer livelihoods**: Ensure farmers have access to affordable phosphorus fertilizers and in a bioavailable & manageable form
- **Environmental integrity and productivity**: Close phosphorus cycles by reducing phosphorus losses/waste throughout the food system, from mine to field to fork
- **Ecological integrity**: Reduce leakage of phosphorus from land to avoid eutrophication & pollution of rivers, lakes and oceans

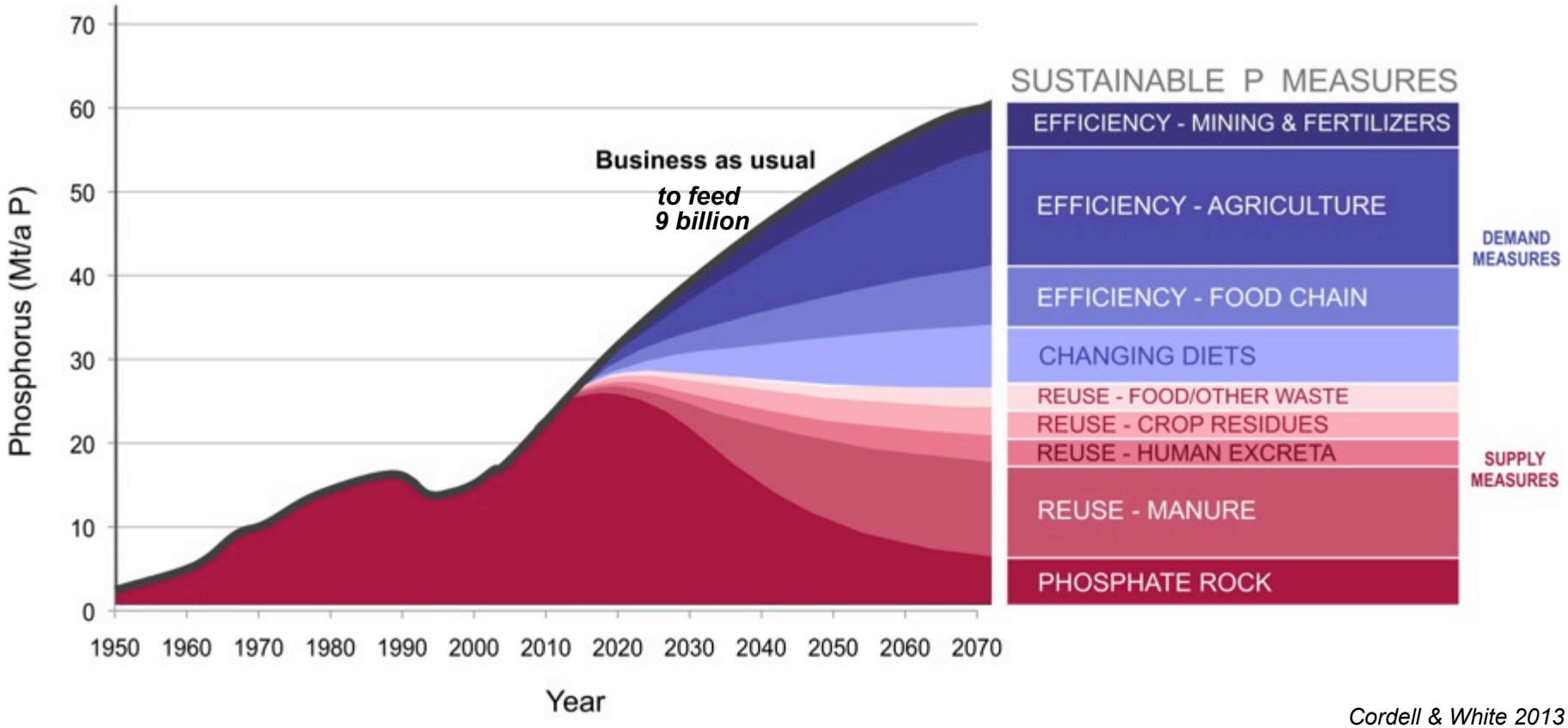
NAVIGATING WITHIN A 'SAFE OPERATING SPACE'



Cordell et al 2014

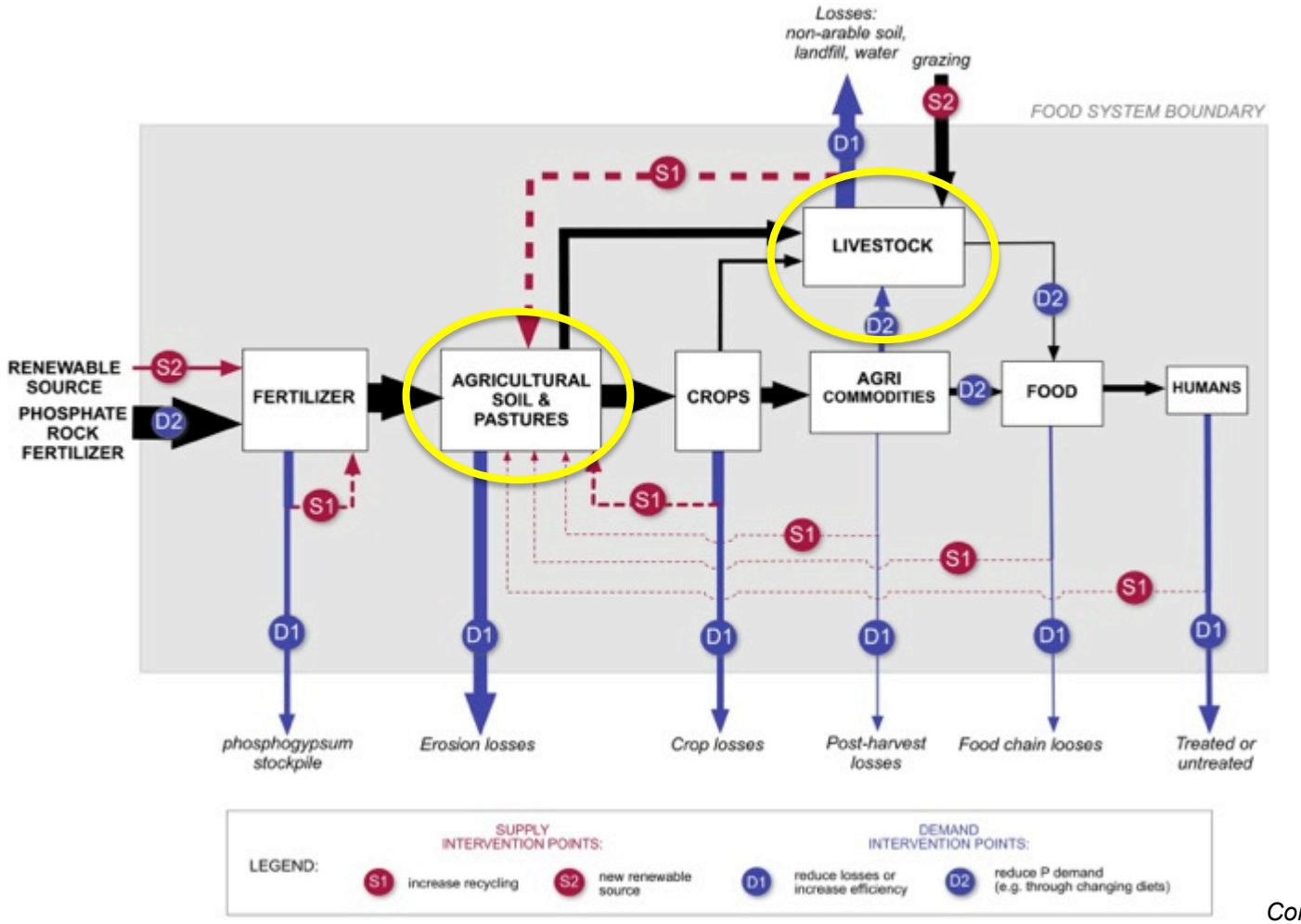
PHOSPHORUS SECURITY: FEEDING 9 BILLION PEOPLE

Averting a crisis is possible, but no single solution!



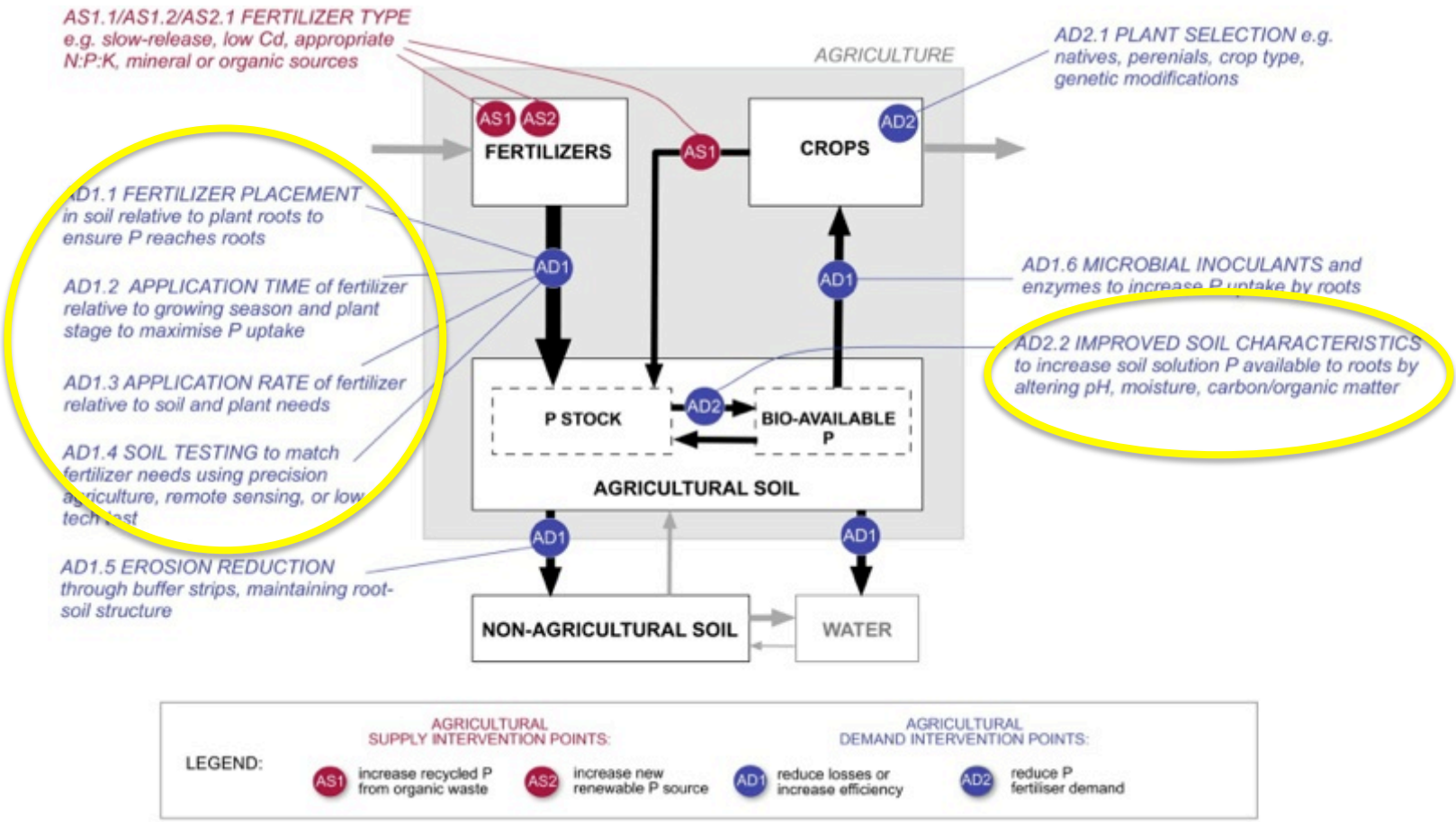
Cordell & White 2013

INTERVENTION POINTS IN THE FOOD SYSTEM



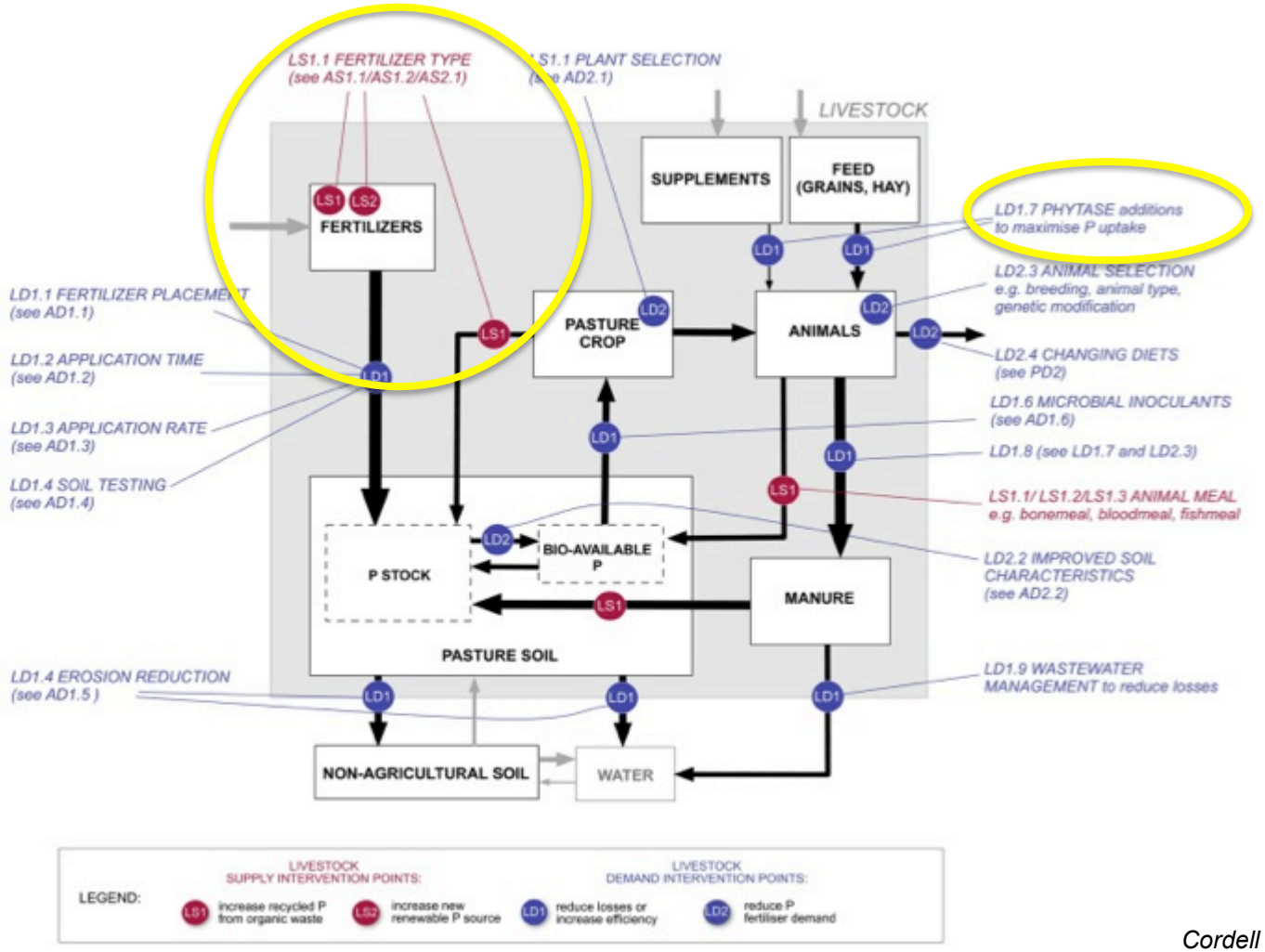
Cordell & White 2013

INTERVENTIONS IN AGRICULTURAL SECTOR



Cordell & White 2013

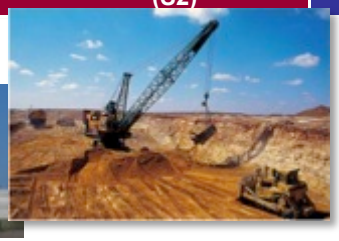
INTERVENTIONS IN LIVESTOCK SECTOR



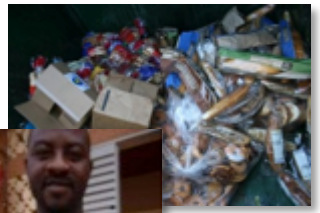
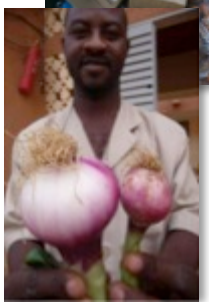
Cordell & White 2013

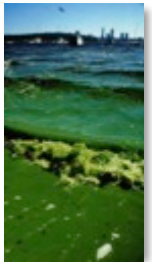
TOOLBOX OF SUSTAINABLE P SUPPLY & DEMAND MEASURES

Sector	SUPPLY MEASURE (S)		DEMAND MEASURE (D)	
	Recycling (S1)	New source (S2)	Efficiency (D1)	Reduce demand (D2)
Mining (M)				
Fertilizer (F)				
Agriculture (A)				
Livestock & Fisheries (L)				
Food production (P)				
Wastewater & human excreta (W)				



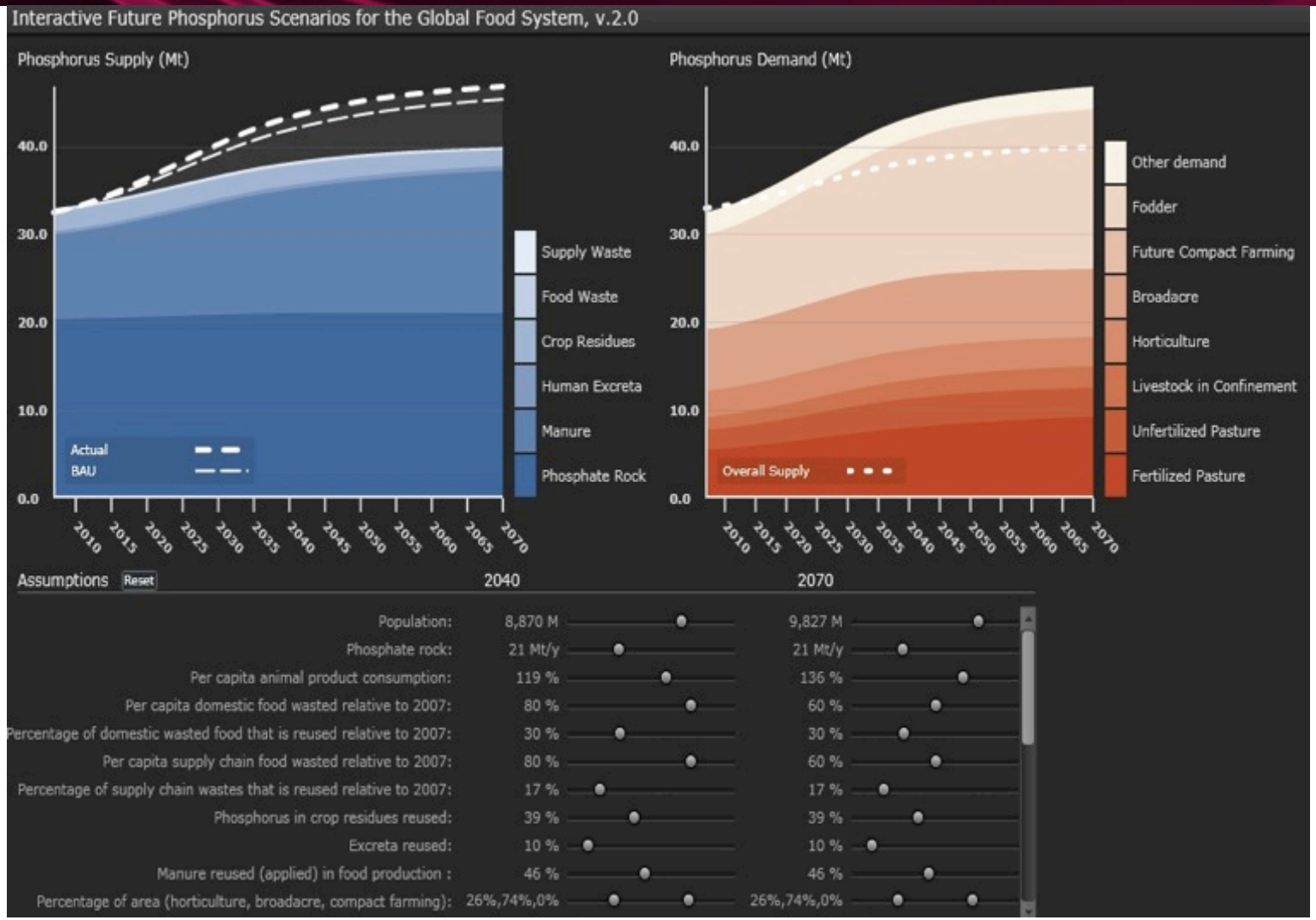






Cordell & White 2013

http://infviz.com/releases/phosphorus/australia/
http://infviz.com/releases/phosphorus/global/test/

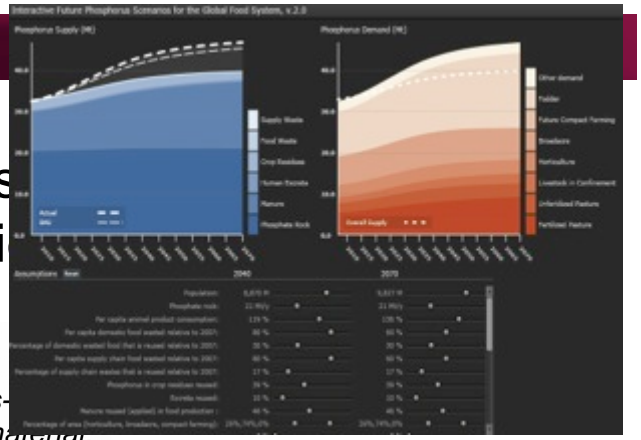
INTERACTIVE FUTURE P SCENARIOS



Linköping University & Institute for Sustainable Futures, UTS (2012)

POLICY PALETTE

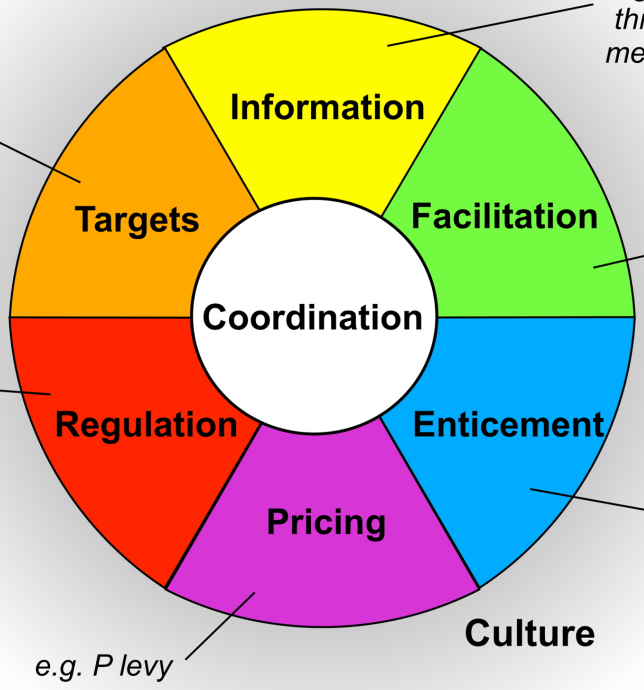
Technologies and practices don't **implement** thems
effective policy instruments (regulatory, economi
required to stimulate and support such measures.



Source: LiU & ISF 2013

e.g. Sweden's target of 60% recycled P from sewage

e.g. awareness- through web-mate media, popular science



e.g. International Ferti Industry Association "4R"s Nutrient Stewarc Framework

Source: ISU

e.g. P cap

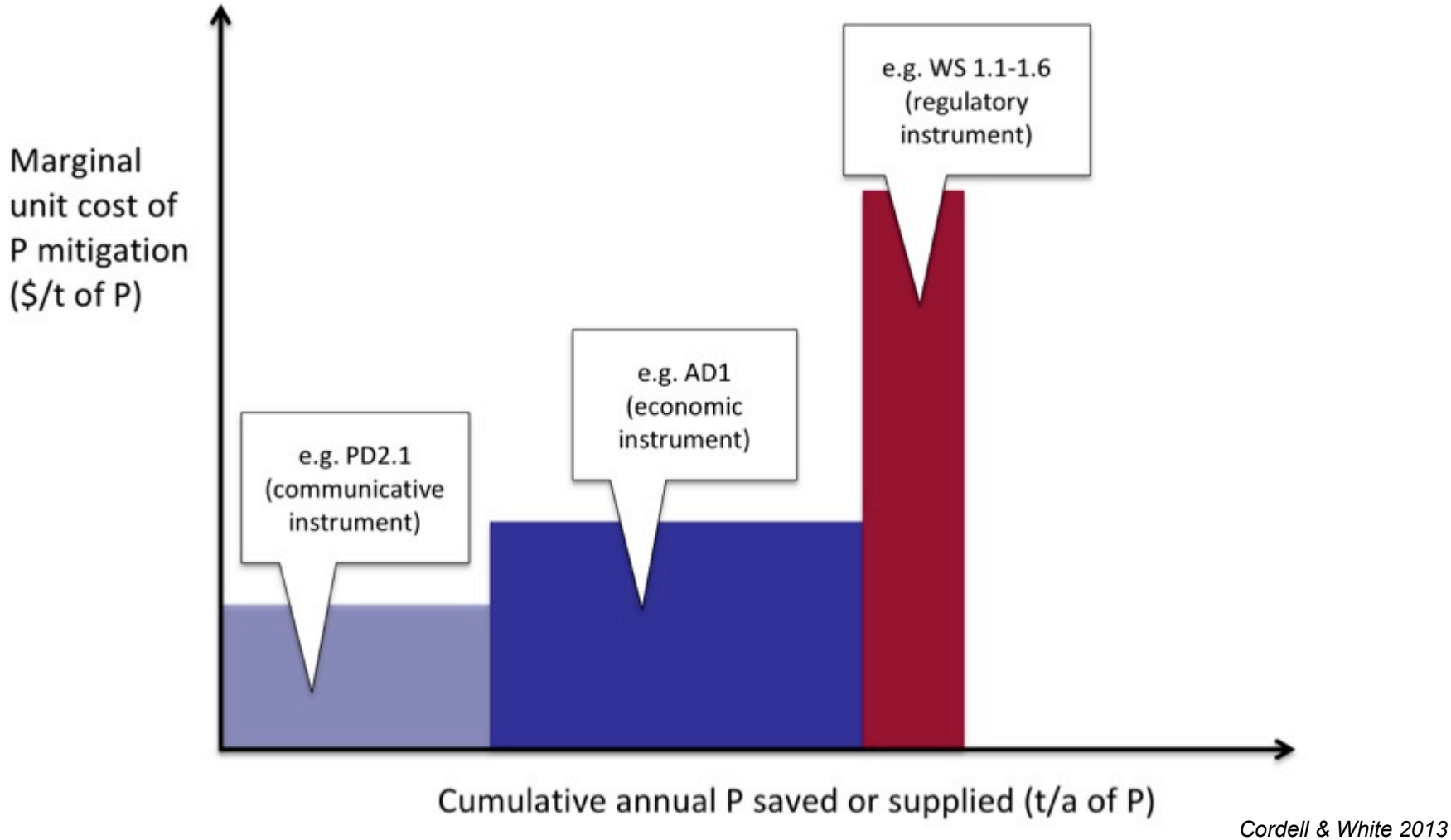
Source: US EPA

e.g. financial incentive for soil testing

e.g. P levy

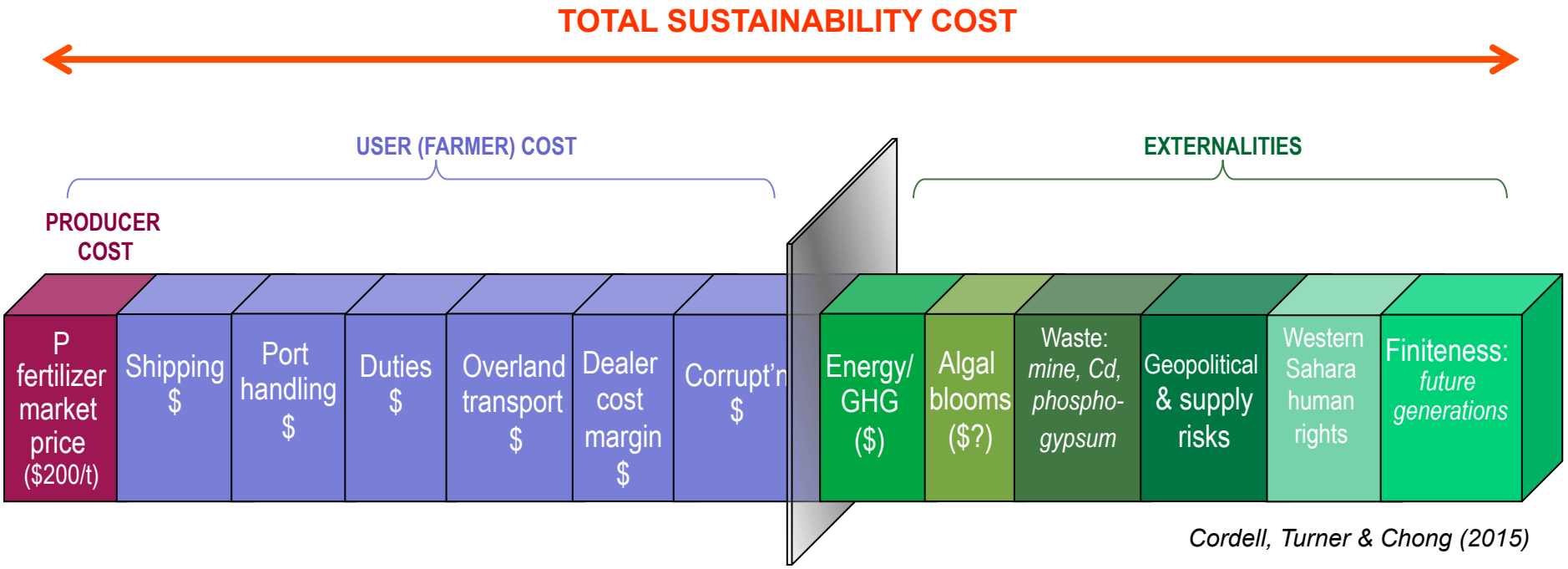
Cordell & White 2013 (after Dunstan et al 2009)

LEAST COST OPTIONS: SAVED OR SUPPLIED P



Cordell & White 2013

TOTAL COST OF A TONNE OF P?



Cordell, Turner & Chong (2015)

If we value the total cost and risks of phosphate rock, we might:

- Use it more sparingly (to extend the life of high quality rock for ourselves and future generations)
- Diversify P sources (with lower societal costs)
- Share responsibility for these costs and consequences (EPR)

INTERVENTIONS: MITIGATING & MANAGING RISKS

Interventions enable stakeholders to **reduce sustainability costs**

RISKS	MARKET / PUBLIC POLICY	PUBLIC POLICY	SOCIO-TECHNICAL	SOCIAL	INFORMATION
Geopolitical					
Ecological					
Human rights					
Intergenerational					
High/variable farm-gate distribution costs					

Cordell, Turner & Chong (2015)

IMPLICATIONS FOR AGRICULTURE & FOOD SECURITY

- If current trajectory not altered: impending phosphorus scarcity is likely to have serious consequences for food security: **reduce agricultural productivity** and **smallholder farmer access** to **fertilizers** and **food** - particularly in developing countries
- **Vulnerability** and **solutions** to phosphorus scarcity is **context-specific,** no single solution to phosphorus security
- **Future**-oriented and **systems** frameworks can guide identification of priorities to increase resilience of food systems (conversely, not doing so can result in perverse outcomes, investment in ineffective/insufficient sustainable phosphorus strategies)
- Look for **synergies** that can simultaneously address phosphorus scarcity, pollution, water scarcity, climate change, energy scarcity, etc.
- **Integrate phosphorus security** into development goals (e.g. SDGs) and agendas, including food security, environmental change, resource scarcity

IMPLICATIONS FOR NUTRIENT RECOVERY (1)

Nutrient-recycling systems can play a critical role in achieving phosphorus security:

- Creates locally available '**renewable fertilizers**'
- Reduces **dependence** on imports from geopolitically risky regions, and therefore buffer against future **price spikes** and **supply disruptions**
- Facilitating local communities' '**phosphorus sovereignty**', particularly in regions of low farmer access to fertilizers
- lower **life cycle energy** (from mine-to-farm to toilet-to-farm)
- lower **P waste/losses** in supply-chain
- Reducing **eutrophication** and algal bloom potential

IMPLICATIONS FOR NUTRIENT RECOVERY (2)

Considerations:

- Nutrient recovering systems will be **essential** for achieving global P security – 3 million tonnes/yr P in excreta (therefore plan/design in upfront)
- 30-50 **technologies** for recovery nutrients (assess which are optimal)
- need to understand end-user (**farmer**) needs & preferences (whole reverse supply-chain)
- New potential **partnerships** between fertilizer sector, sanitation sector, urban planning, scientists, etc
- **Cost-competitive** with phosphate rock? Consider not just market price of P, but farm-gate price, and full sustainability costs and risks

GLOBAL PHOSPHORUS RESEARCH INITIATIVE

- First platform of its kind addressing implications of **global phosphorus scarcity for food security**:
  - interdisciplinary **research**
  - **networking**, **dialogue** and **awareness raising** among policy makers, industry, scientists and the community
  - co-founded in **2008** (UTS & Linköping University). Today - 6 research organisations across Australia, Europe and North America

GLOBAL PHOSPHORUS RESEARCH INITIATIVE

THANK YOU!

For more information visit:

www.phosphorusfutures.net

or

www.isf.uts.edu.au

or email:

Dana.Cordell@uts.edu.au

3rd SUSTAINABLE P SUMMIT, SYDNEY 2012

RESEARCH SUPPORT & RECOGNITIONS

FUNDING SUPPORT

- Future Earth
- Commonwealth Department of Agriculture
- Rural Industries Research & Development Corp
- Grains Research & Development Corporation
- CSIRO Sustainable Agriculture Flagship
- Ian Potter Foundation
- Mercedes-Benz Environmental Research Award
- Swedish Research Council FORMAS
- Wentworth Group of Concerned Scientists
- Global Phosphate Forum
- Novozymes
- Minemakers Pty Ltd
- Yarra Valley Water
- University of Technology, Sydney
- Commonwealth Dept of Education, Science & Training

RECOGNITIONS

- Eureka Prize for Environmental Research (2012)
- Banksia Merc-Benz Environmental Research Award (2012)
- Top 100 Most Influential People (Sydney Magazine, 2012)
- UTS Vice-Chancellor's Award for Excellence in Leadership (2011) and Early Career Research (2013)
- 100 Women of Influence (Australian Financial Review & Westpac, 2013)

RESOURCES

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