Phosphorus Forum 2018

Sustainable Phosphorus Alliance

Note: assigned seating before lunch!
Your table # is on your name tag.

@sustainP

#PhosForum18

- Welcome!

What are we?

- The **Sustainable P Alliance** is a **members organization** that exists to catalyze the implementation of technical, organizational, and institutional **innovations to advance phosphorus sustainability** in North America.

Current Members / Founders

blinc.com
feeco.com
nacwa.org
ostara.com
ocpgroup.ma
werf.org
renewablenutrients.com
sustainabilityconsortium.org
mcgillcompost.com
green-edge.com

Strategic Alliances

www.epa.gov/agstar
www.wef.org

Who are we?

Leadership

Jim Elser
Director, Sustainable Phosphorus Alliance
Jim Elser is a limnologist with research focused on the effect of key limiting nutrients such as nitrogen and phosphorus in lake ecosystems. He is a Research Professor and Distinguished Sustainability Scientist in ASU's School of Life Sciences and School of Sustainability and serves as the Director for the Sustainable Phosphorus Alliance. He is also director of the Flathead Lake Biological Station of the University of Montana.

Matt Scholz
Program Manager, Sustainable Phosphorus Alliance
Matt Scholz is the Program Manager for the Sustainable Phosphorus Alliance. He worked for 3 years as a Senior Research Scientist for The Sustainability Consortium after completing a postdoc in the Department of Chemistry at Colorado School of Mines and a PhD at the University of Arizona, where his research focused on algal biofuels. He has worked in maize molecular genetics and holds an MS in environmental engineering from the University of Arizona.

Rebecca Muenich
Research Scientist, Sustainable Phosphorus Alliance
Rebecca Muenich is an environmental engineer with expertise in environmental modeling, especially in evaluating the impact of land management decisions on nutrient inputs into the environment. She recently completed a postdoctoral position at the University of Michigan where she focused on finding win-win solutions to address excess phosphorus inputs into Lake Erie. She is currently an Assistant Professor in ASU's School of Sustainable Engineering and the Built Environment and serves as a Research Scientist with the Sustainable Phosphorus Alliance. She holds a BS in biological engineering from the University of Arkansas, and MS and PhD degrees in agricultural and biological engineering from Purdue University.

Board of Directors

Kerry McNamara
Executive Director, OCP Research LLC.

OCP

Matt Kuzma
Vice President, Ostara

OSTARA

Michael Schmid
Chief Marketing and Operations Officer, Renewable Nutrients

RENEWABLE NUTRIENTS

Amit Pramanik
Chief Innovation and Development Officer, The Water Research Foundation

The Water Research Foundation

Chris Hornback
Chief Technical Officer, National Association of Clean Water Agencies (NACWA)

NACWA

Brian Madigan
Director of Business Development, FEECO International

FEECO INTERNATIONAL

Our mission

Our Mission

Our mission is to be North America's central forum and advocate for the sustainable use, recovery, and recycling of phosphorus in the food system.

Our Vision

We envision a food system that manages phosphorus more sustainably to provide abundant, nutritious food while protecting the health of rivers, lakes, and oceans.

Objectivity

Our decisions and actions are based in the best available science.

Stewardship

We support the implementation of technologies and practices that benefit ecosystems and not ones that facilitate their deterioration.

Inclusivity

We seek buy-in from diverse stakeholders about best policies and practices.

What we do

- **Facilitate networking** among diverse players from across the phosphorus value chain via knowledge sharing events.
  - Annual conference on phosphorus sustainability (Phosphorus Forum)
  - Technical webinar series on current issues in P sustainability
  - Quarterly newsletter, blog, and social media (twitter: @SustainP)
- **Orchestrate working groups**, including our just-launched Biosolids and Manure Task Force.
- **Provide technical input** on metrics development (e.g. TSC, WEF) and research prioritization (e.g. TWRF)
- **Represent the North American P-sustainability community** both within other N. American organizations and within the global collective of P-sustainability platforms (e.g. ESPP)
- **Offer a branding opportunity** to organizations working in the vanguard of phosphorus sustainability.

Current project: Biosolids and Manure Task Force

Motivation

- Desire to encourage *sustainable* reuse of organic residuals
- Regulatory complexity around land application of biosolids and manure
- Need to get stakeholders talking to each other

First stage deliverables

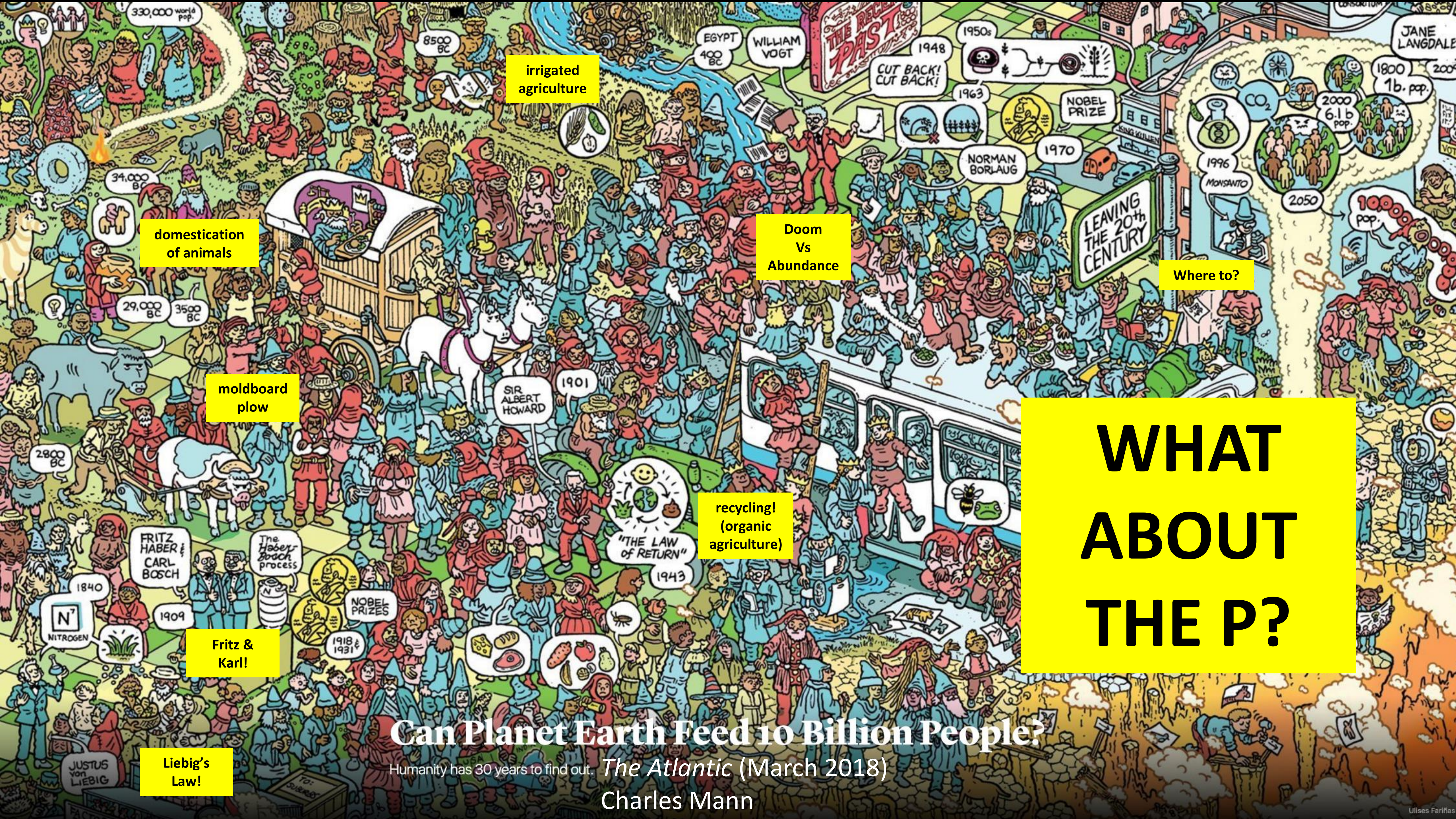
- White paper landscape analysis of regulations (May/June timeframe)
- Beta-version ArcGIS tool (August)
- Webinar (August/September)

Second stage deliverables

- Additional data layers TBD
- Scenario development sessions (in planning)

The Phosphorus Challenge / The Phosphorus Opportunity

Photos: foundationfar.org, via @rww, The Detroit News


irrigated agriculture
domestication of animals
moldboard plow
Fritz & Karl!
Liebig's Law!
Doom Vs Abundance
recycling! (organic agriculture)
Where to?
WHAT ABOUT THE P?
WILLIAM VOGT
NORMAN BORLAUG
NOBEL PRIZE
JANE LANGDALE
LEAVING THE 20th CENTURY
SIR ALBERT HOWARD
"THE LAW of RETURN"
FRITZ HABER & CARL BOSCH
The Haber-Bosch process
NOBEL PRIZES
JUSTUS von LIEBIG
NITROGEN
Can Planet Earth Feed 10 Billion People?
Humanity has 30 years to find out. *The Atlantic* (March 2018)
Charles Mann
Ulises Fariñas

Wizards vs Prophets

Wizards

- Abundance & opportunity
- Techno-fixes

Prophets

- Limits to growth (carrying capacity)
- Environmental consequences
- Harmony with natural processes

The Atlantic (March 2018)
Charles Mann (Illustrations by Ulises Fariñas)

A question for today:

Are you a ***wizard*** or are you a ***prophet***?

The Atlantic (March 2018)
Charles Mann (Illustrations by Ulises Fariñas)

A question for today:

OR: are you a ***wizard*** ***prophet***?

The Atlantic (March 2018)
Charles Mann (Illustrations by Ulises Fariñas)

TODAY'S AGENDA

- 8:30: **Dr Jim Elser** (ASU) Welcome and our job today.
- 8:45: Keynote: **Dr Sally Rockey** (FFAR)
- 9:30: **Dr David Vaccari** (Stevens Inst of Technology) "A Substance Flow Model for Global Phosphorus"
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- 3:30 – 5:30: Networking time (Postino's on College Ave)

Dr Sally Rockey, Executive Director
Foundation for Food and Agriculture Research (FFAR)

A distinguished career!

- NIH (Deputy Director for Extramural Research)
- USDA (Chief Information Officer)
- USDA (Cooperative State Research, Education, Extension Service)
- USDA extramural funding programs
- PhD (Entomology) from the Ohio State University

The Future of Agricultural Research

Sally Rockey, Executive Director
Foundation for Food and Agriculture Research
@FoundationFAR | @RockTalking

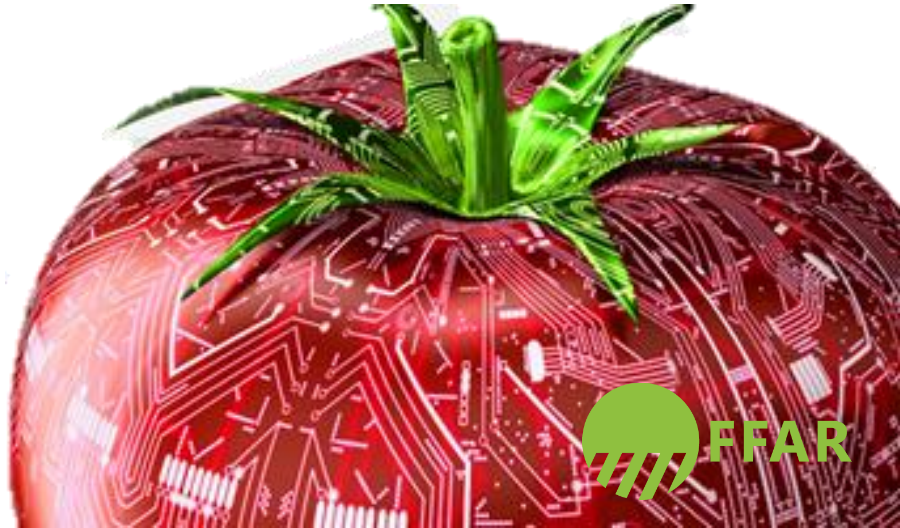
Phosphorus Forum 2018 | February 27, 2018

Human's closest relationship with Earth is through agriculture.

Innovations that have “done the most to shape the nature of modern life”

Top 10: printing press, electricity, penicillin, semiconductor electronics, optical lenses, paper, internal combustion engine, vaccination, Internet, and steam engine

11. Nitrogen fixation, 1918: Fritz Haber wins a Nobel Prize for the ammonia-synthesis Martinus Beijerinck
13. Refrigeration, 1850s:
22. Green Revolution, mid-20th century: Norman Borlaug’s green revolution
30. Moldboard plow, 18th century
32. Cotton gin, 1793
33. Pasteurization, 1863
38. Scientific plant breeding, 1866: Gregor Mendel
50. Self-propelled Combine harvester, 1930s



FFAR

Agriculture is the place to be these days in science!

- Importance of the issues
- Take fundamental knowledge almost immediately to application
- New technologies often apply directly to agriculture before a other sector
- Growing consumer interest in the food system

How quickly can science make a difference?

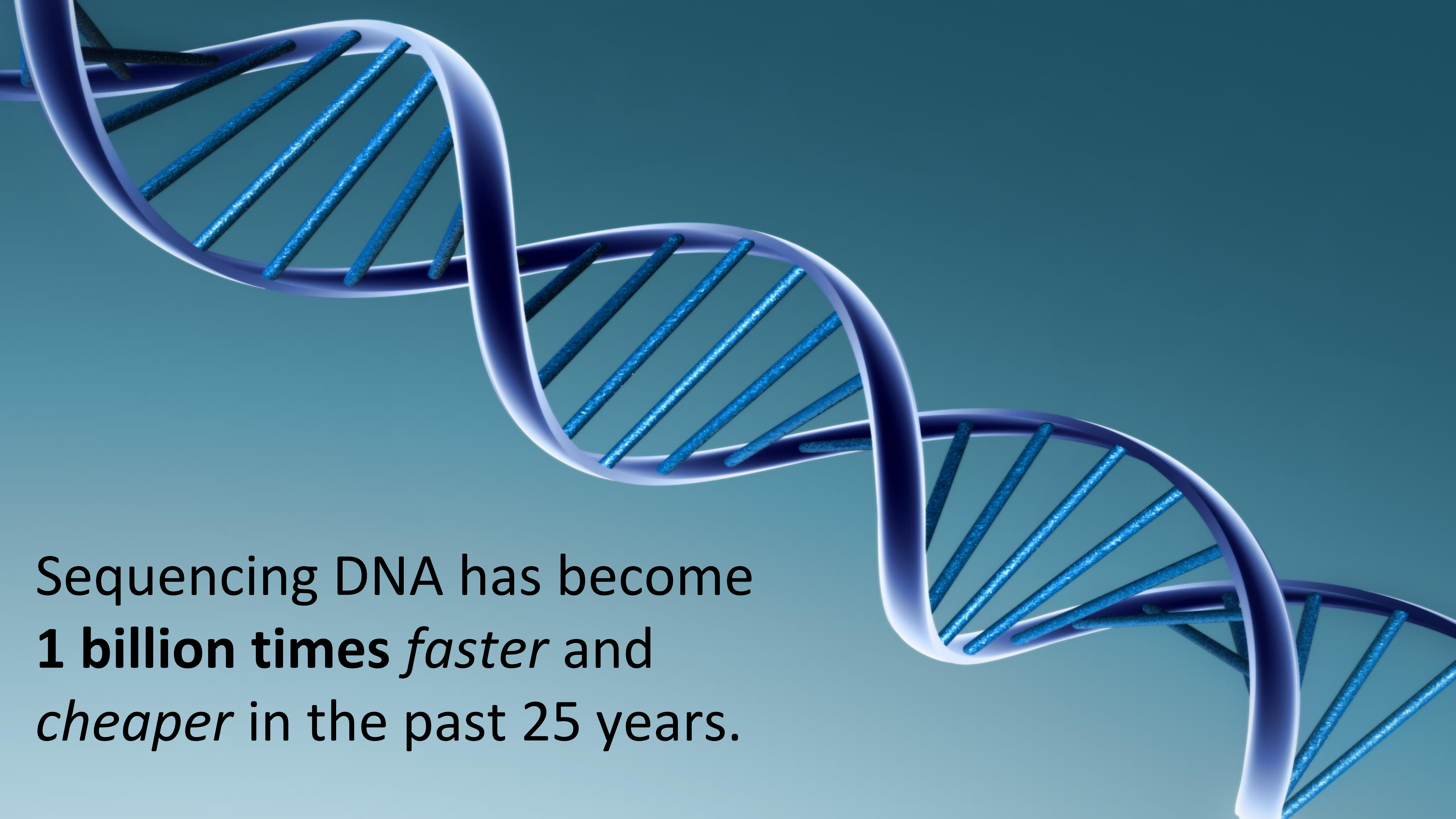
On average, public agricultural research undertaken today will begin to noticeably influence agricultural productivity in as little as 2 years and its impact could be felt for as long as 30 years.

More data generated in the past two years than in the entire history of the human race.

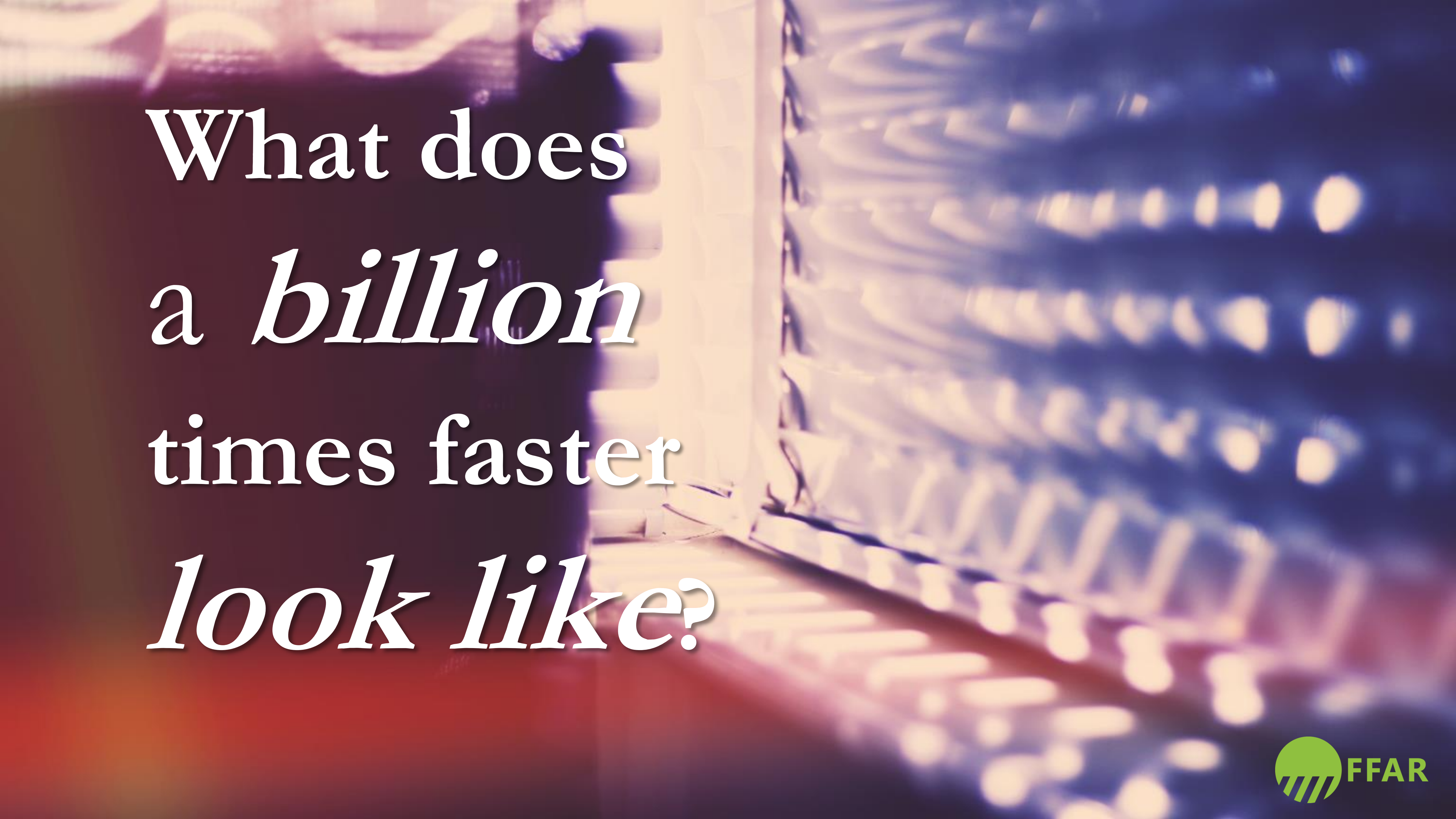
The pace of science continues to accelerate.

We must take advantage of this incredible time in science.

FFAR



Sequencing DNA has become **1 billion times** *faster* and *cheaper* in the past 25 years.


What does
a *billion*
times faster
look like?
FFAR

Only 125,000 times faster

FFAR

What does a billion times faster look like?

Imagine a 3.7 mile commute

1 hour walk

Home 3.7 mph **Work**

FFAR

What does a billion times faster look like?

Imagine a 3.7 mile commute

Home

1 hour walk

3.7 mph

Pluto

FFAR

Burgeoning Fields in Ag Research

Progress happens when our knowledge of how things work converges with technological advances to reveal new ways to approach problems!

Pic by Neil Palmer (CIAT).

- **Phenomic/Genomic Associations**
- **Big Data – Digital Ag**
- **New Technologies (imaging, drones)**
- **Reducing Environmental Impacts**
- **Systems Analysis**
- **Improving Plant Efficiency**
- **Soil Health => Human Health**

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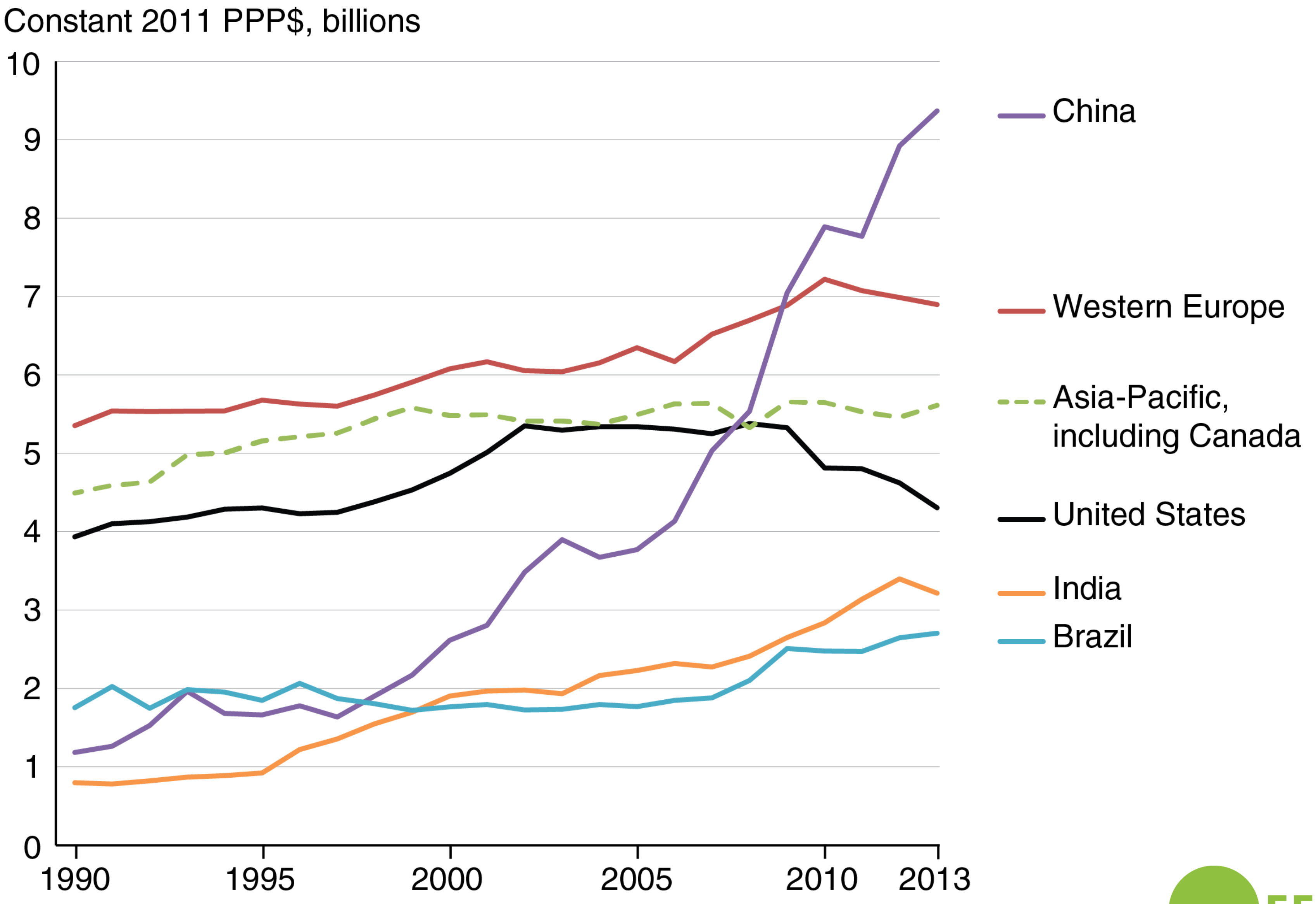
The Challenge

$9.7 billion is needed by 2050

Scientific innovation is critical to meet the needs of a growing global population.

Funding for Agricultural R&D

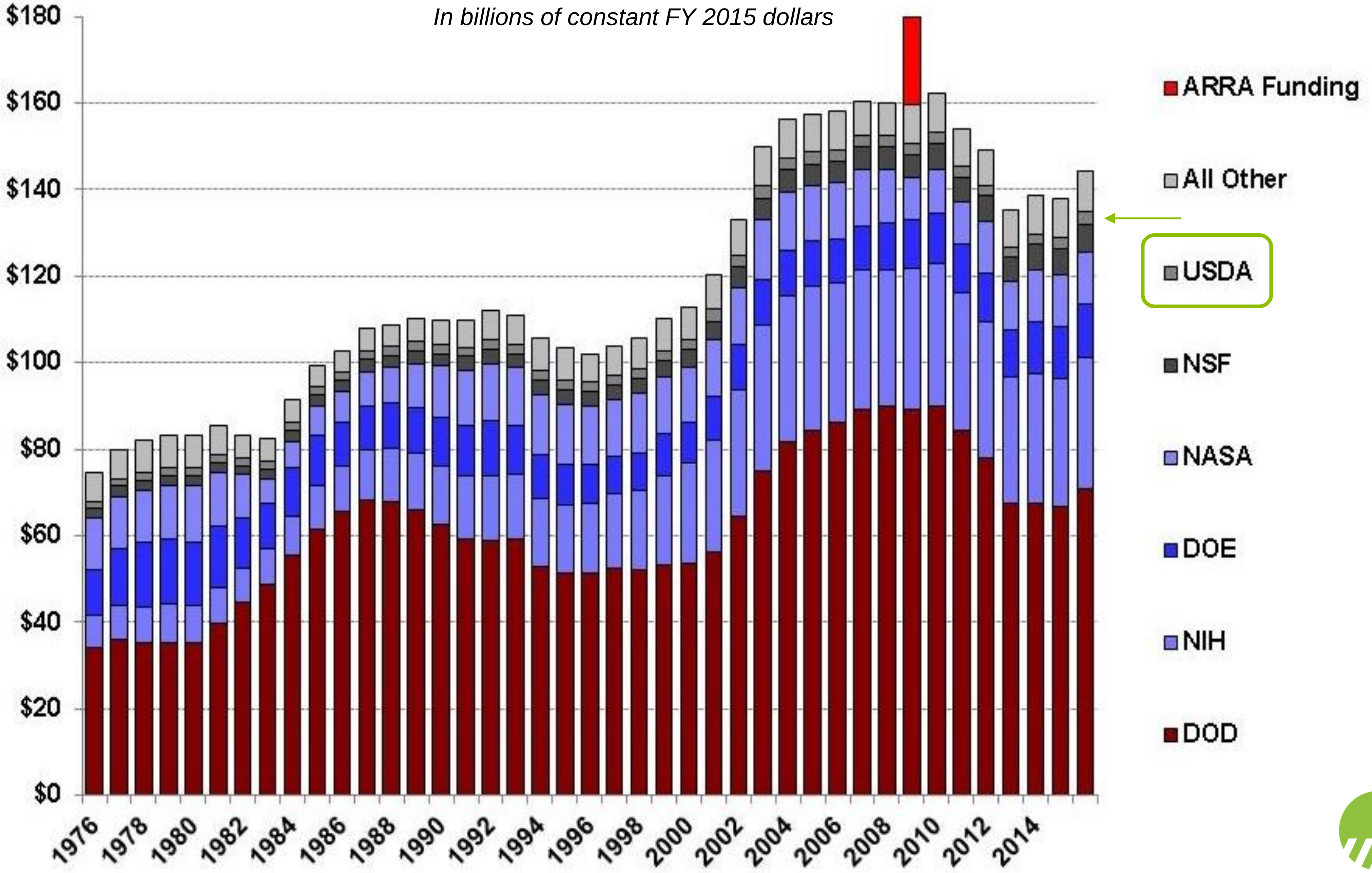


Source: UDA ERS and ASTI, Organisation for Economic Cooperation and Development

FFAR

Trends in R&D by Agency

In billions of constant FY 2015 dollars



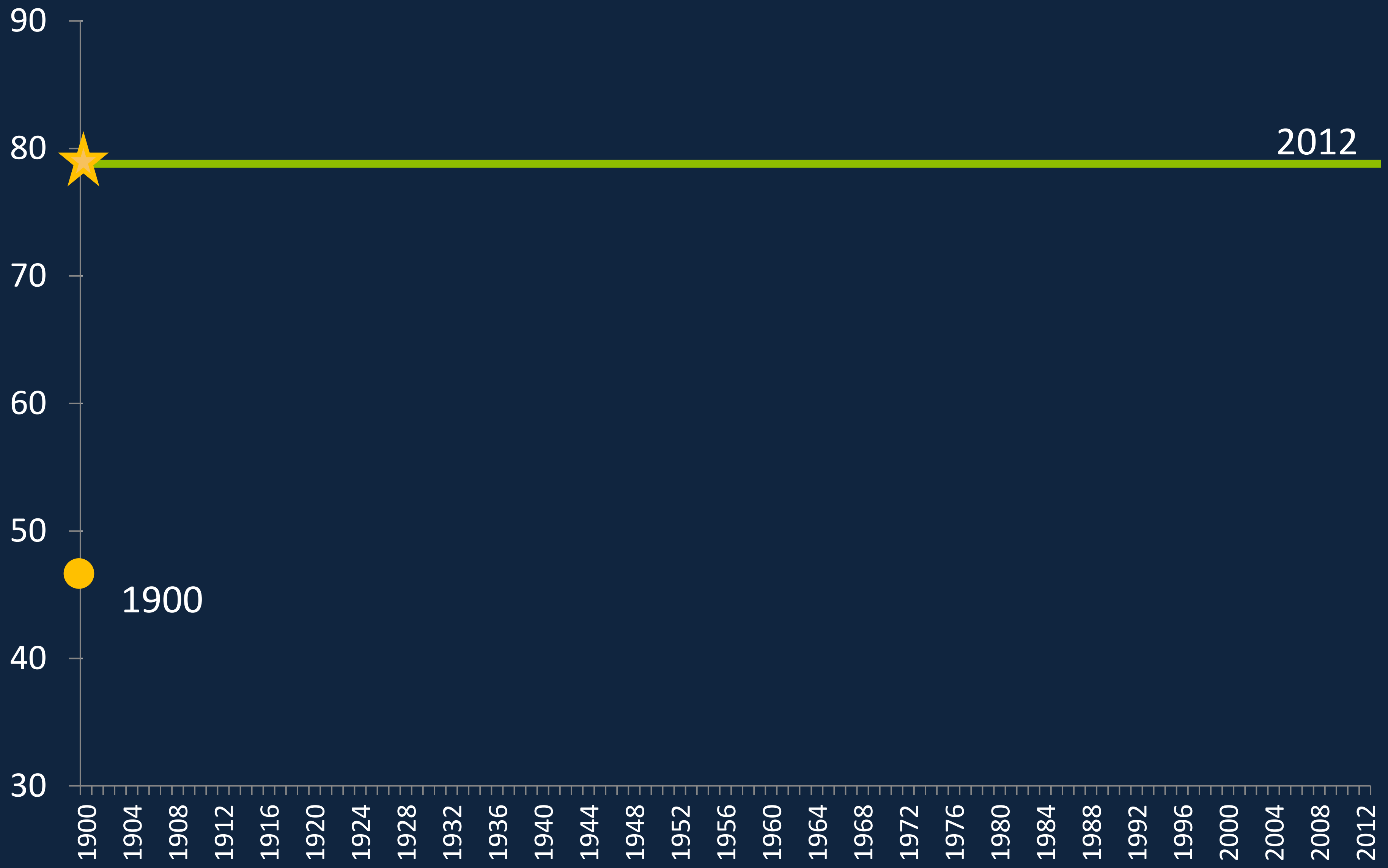
Why is agricultural research funding not commensurate with its value in improving the quality of life?

"When it comes right down to it, food is practically the whole story every time."

- Kurt Vonnegut, Galápagos

FFAR

U.S. Life Expectancy



More food will be eaten in the next 50 years than in the past 7,000 years.

How will we feed 10 billion people when public investment in food and agriculture R&D is declining?

FFAR

OUR VISION

We envision a world in which ever-innovating and collaborative science provides every person access to affordable, nutritious food grown on thriving farms.

FFAR

FFAR Mission

We build unique partnerships to support innovative science addressing today's food and agriculture challenges.

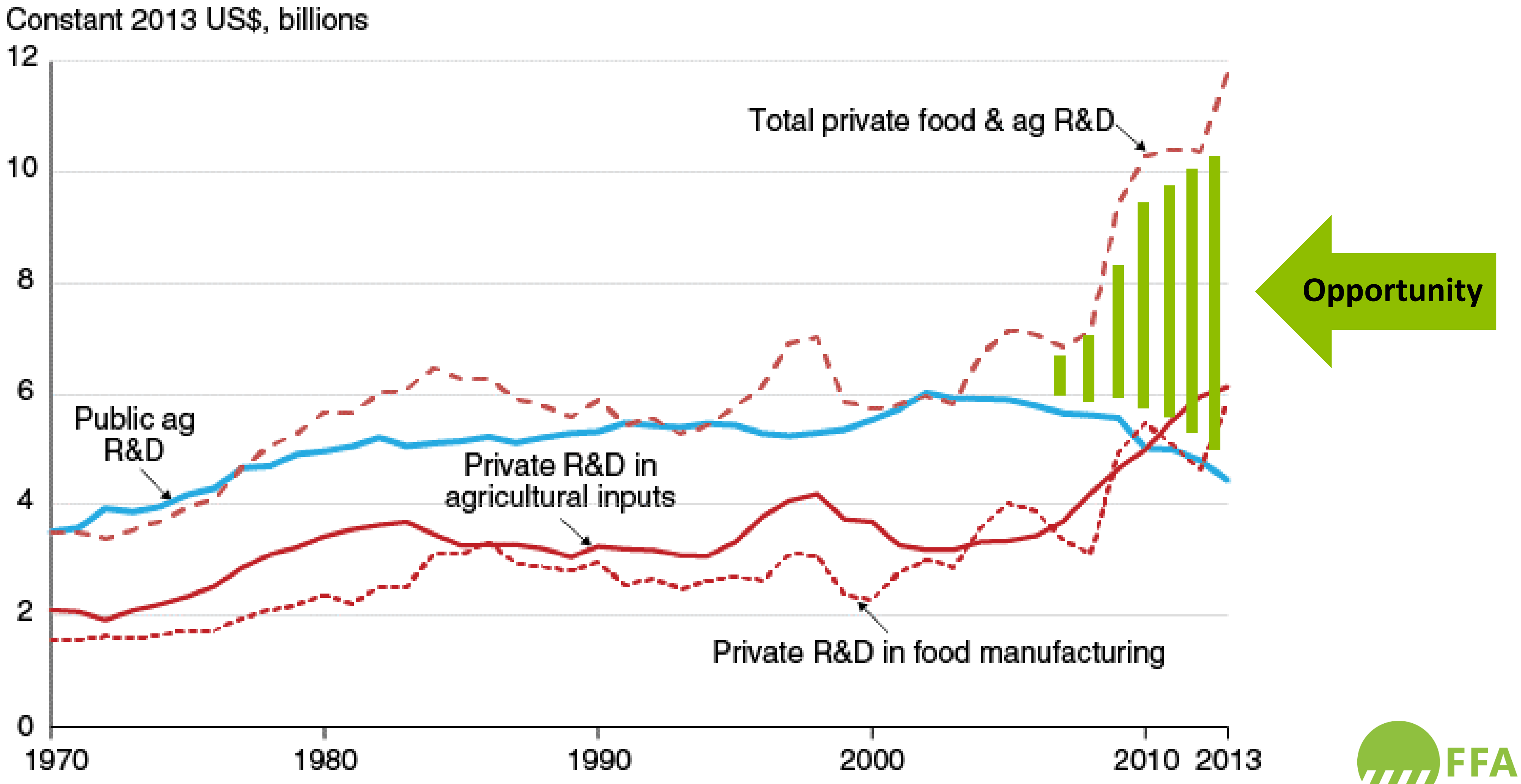
FFAR

The FFAR Model

- **Established with bipartisan** congressional support in 2014 Farm Bill
- **Creates novel research partnerships** across the food and agriculture sector.
- **Works nimbly** to efficiently address emerging issues in food and agriculture.
- **Leverages public dollars** with private dollars to expand research impact.
- **Fills research gaps** to ensure great science supports thriving farms, reduces food insecurity, and supports better health.

Image by Elliot Brown

The FFAR model leverages private funds for public good



Source: USDA ERS

FFAR

Why Engage Industry?

Shift to private and proprietary R&D in agriculture means we must move together.

FFAR

Figure out the Pre-Competitive Space

- *Pooling resources for public benefit.*
- *Accomplishing more, together.*

FFAR

Pre-Competitive Space

Areas of business in which a firm feels comfortable against competitive pressures, on the basis of its cost advantage and/or technological leadership.

Areas of business in which a firm feels uncomfortable against unambitious relaxation, on the basis of its cost disadvantage and/or technological inferiority.

FFAR

Pre-Competitive Space

Area of research where outcomes offer no particular advantage relative to peers and where there is potential to positively impact all parties.

Allows resources and data to be readily shared.

FFAR

Public-Private Partnership Incentives

Private sector incentives:

- Corporate social responsibility
- Rapidly overcome obstacles to advancement
- Cost savings
- Direct access to fundamental research
- Access to academic expertise
- Cultivate future employees

Public Sector incentives:

- Address real-world problems
- Transfer research quickly to the economy
- Access to resources and data otherwise unattainable
- Access to expertise

How to Make Public-Private Partnerships Work

- Shared Goals and Values (honesty)
- Agreement on responsibilities and rules of engagement (including IP)
- Transparent value proposition for each partner (trust)
- Synergy (goals cannot be achieved by any partner working alone)
- Skin-in-the-game from all partners
- Joint celebration of successes
- Shared responsibility for failures

FFAR

Who is Funding Ag Research?

Investments are coming from unconventional sources

- Venture Capitalists
- Philanthropists
- Private Foundations
- Industry
  - Including non-ag companies

FFAR

Grand Challenges in Agriculture

Feeding the World

Plant Efficiency

Sustainable Livestock

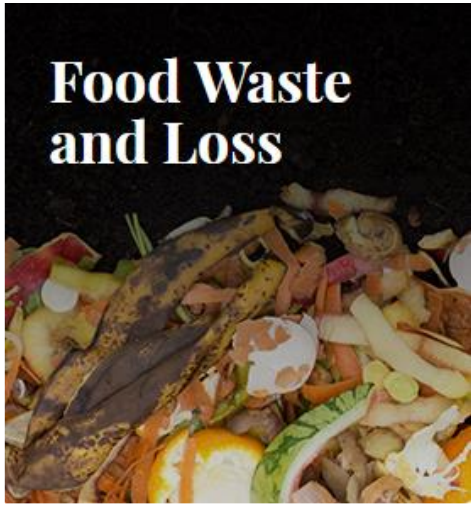
Environmental Stewardship

Improving Health & Nutrition

FFAR

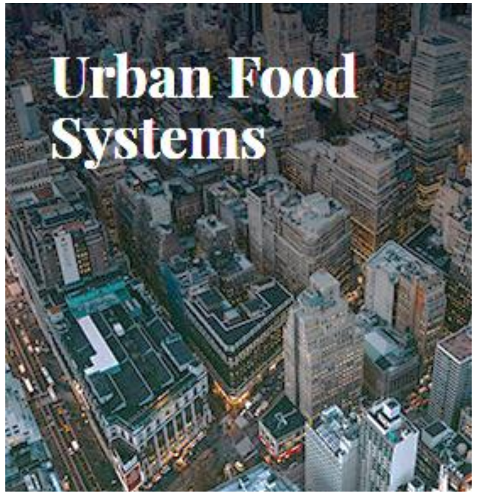
Icons by Alena Artemova, Atif Arshad, IconTrack, & Dream Icons via NounProject.com

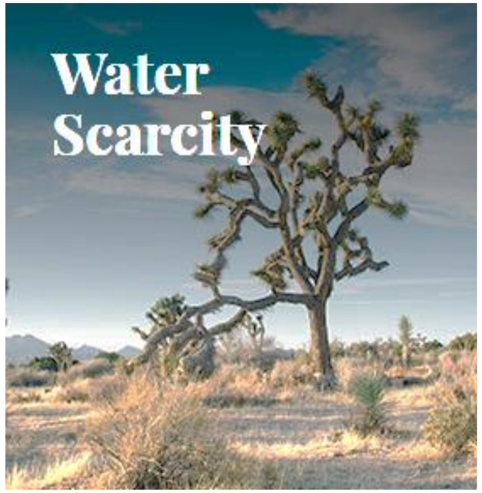
FFAR Challenge Areas



<u>March 1</u>

Seeding Solutions opens for applications.





FFAR

FFAR Funding in potential areas of interest to the Sustainable Phosphorus Alliance

FFAR

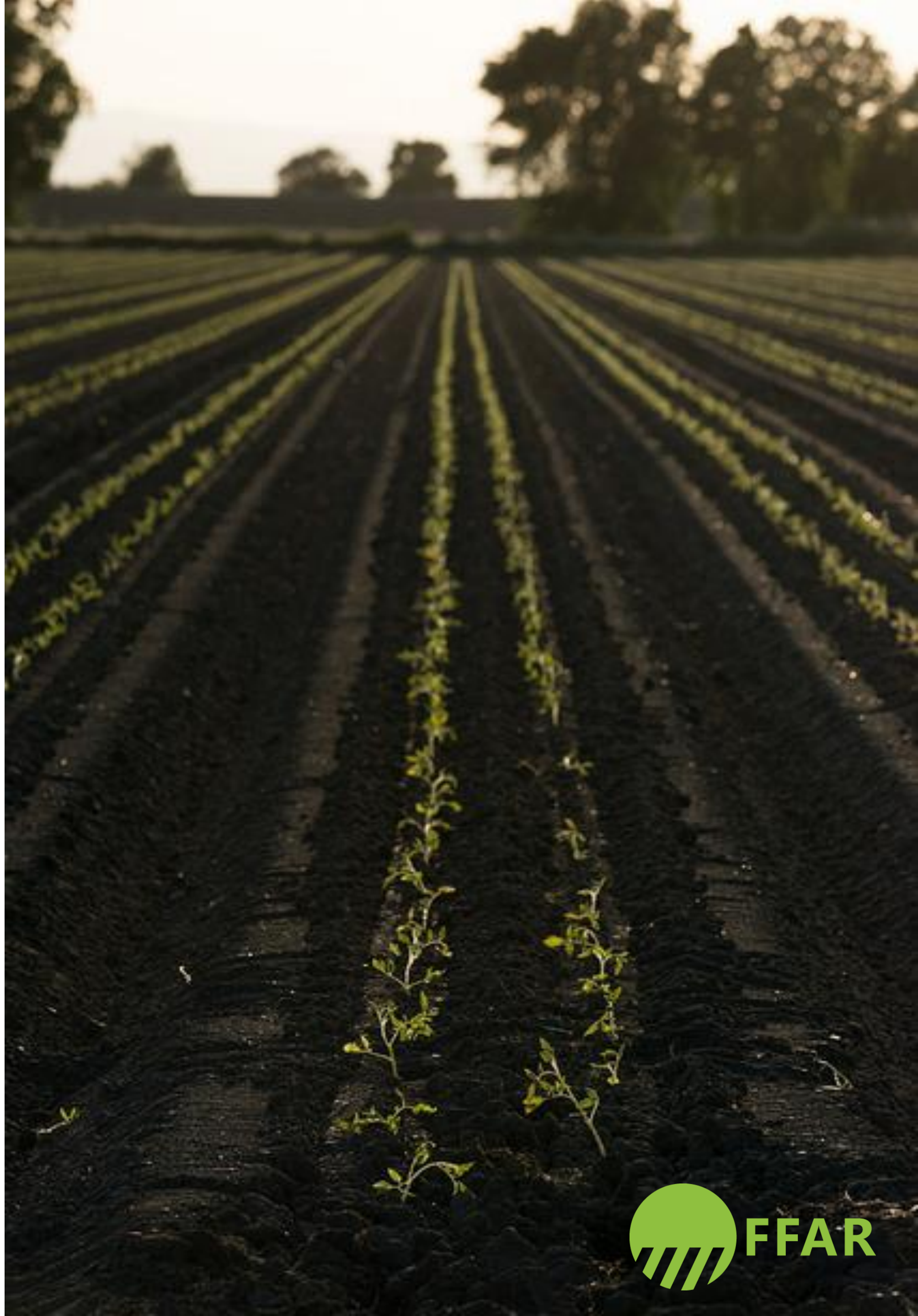
"The nation that destroys its soil destroys itself."

-Franklin D. Roosevelt

FFAR

Soil Health

- Nutrient management
  - Seeding Solutions grant for 4R Nutrient research
- National Cover Crop Initiative
  - FFAR provided $2.2 million in funding to the Noble Research Institute for cover crop research.
- Soil Health Initiative
  - FFAR provided $9.4 to Soil Health Institute, Soil Health Partnership, and The Nature Conservancy to collaborate on soil health measurement project.



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Improving Plant Efficiency

- Doubling photosynthetic efficiency can increase yields up to 40%
- Phenotype/genotype
  - Environmental resilience
  - Desired nutritional traits
- Taking advantage of the latest technologies – gene editing

BAYER
biogemma
CIMMYT
International Maize and Wheat Improvement Center
FAPESP
FFAR
KWS
PRECISION BIOSCIENCES
RIJK ZWAAN

Agricultural Water Use

- Irrigation technology innovations
- Reuse and recycling
- Water use efficiency
  - FFAR awarded a New Innovator Award to develop water use models to increase efficiency in the Corn Belt.

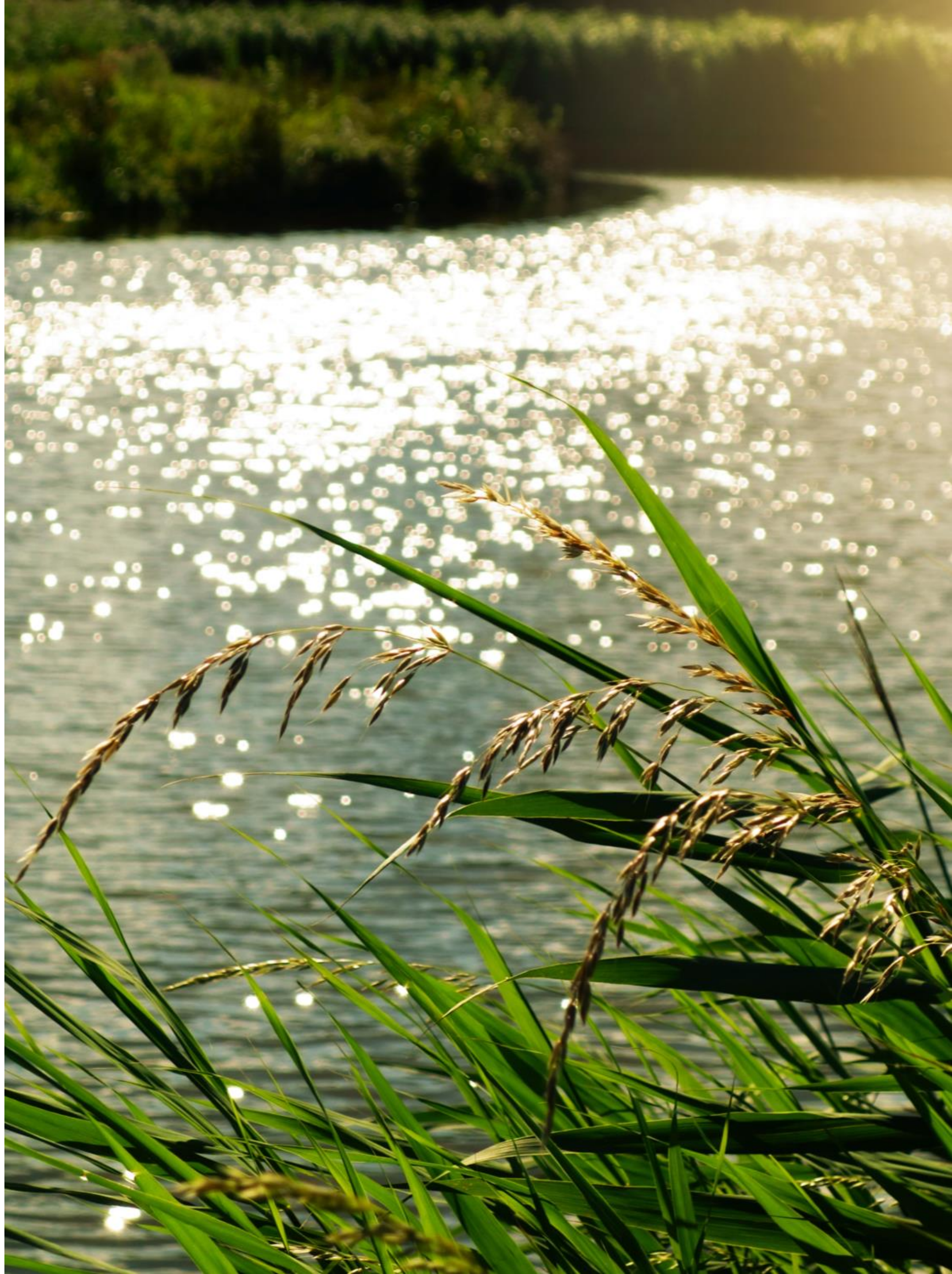
Sustainable Livestock Production

- Manure and runoff management
- Integrated livestock and crop production systems
    - FFAR Seeding Solutions grant to study integrated system for cattle and crops

FFAR

Environmental Stewardship

- Research into reducing the environmental impact of agriculture
- WWF Food Waste Project
  - FFAR awarded $650,000 for research on reducing farm-level food losses.
  - This project will reduce stressors on the environment and ensure that the resources used to produce food don't go to waste.



Partnerships

Advancing solutions to complex problems – TOGETHER

COMPLEX
PROBLEMS

COLLABORATION

- **POOLED RESOURCES**
- **POOLED KNOWLEDGE**
- **SHARED RISK**

CHANGE
TO BENEFIT HUMANITY

FFAR

Let’s work together to support and apply agriculture research that spurs the innovation we need for human, environmental and economic health in the future.

Connect with FFAR

Text FFAR to 22828 or
visit http://bit.ly/ffarnewsletter

Thank You

Dr. Sally Rockey
Executive Director
Foundation for Food and Agriculture Research

srockey@foundationfar.org

@RockTalking

Connect with FFAR

www.foundationfar.org

@FoundationFAR

FFAR

Phosphorus Forum 2018

February 27, 2018 | Tempe, AZ

phosphorusalliance.org/events
#Phorum18

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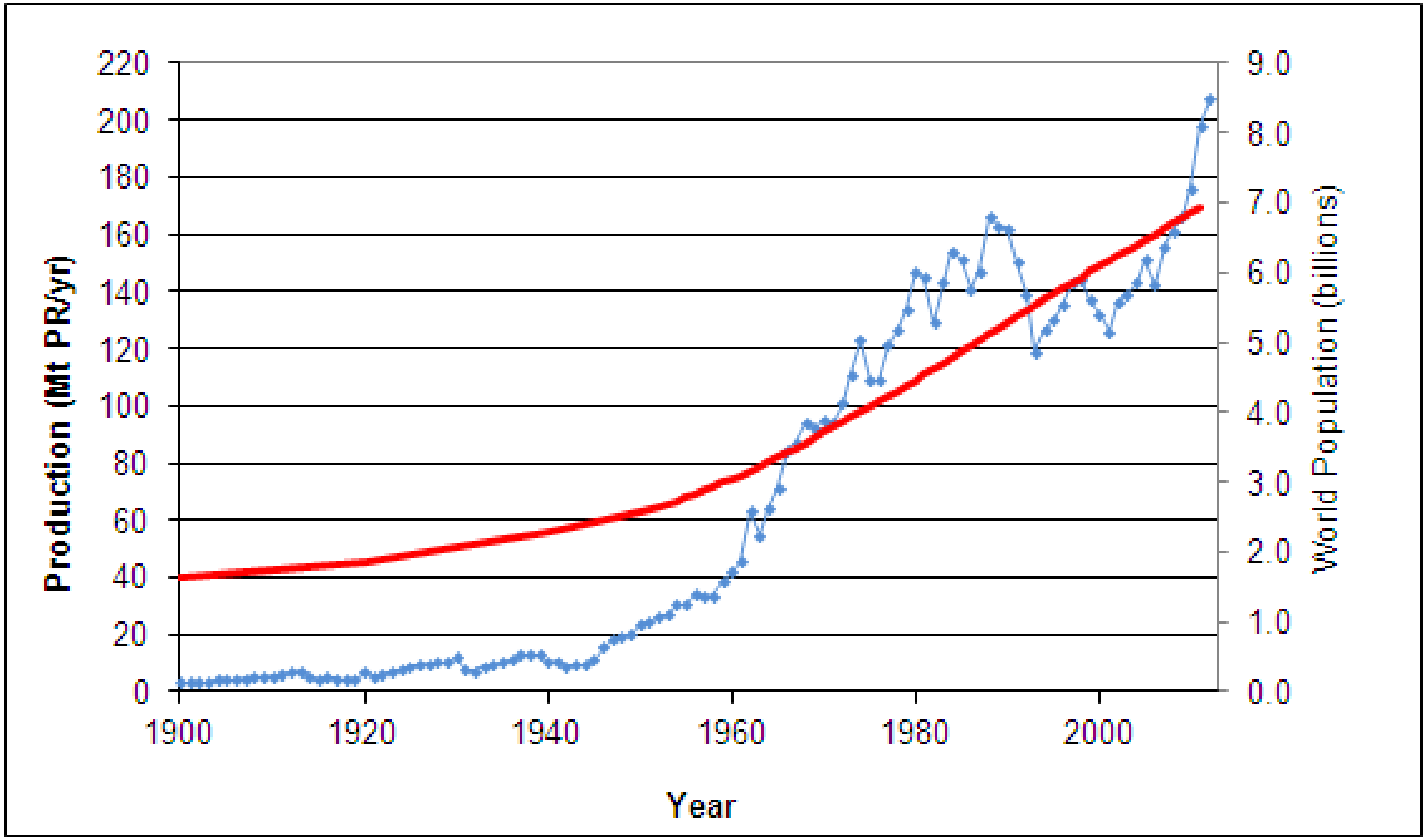
A Substance Flow Model for Global Phosphorus

Sustainable Phosphorus Alliance

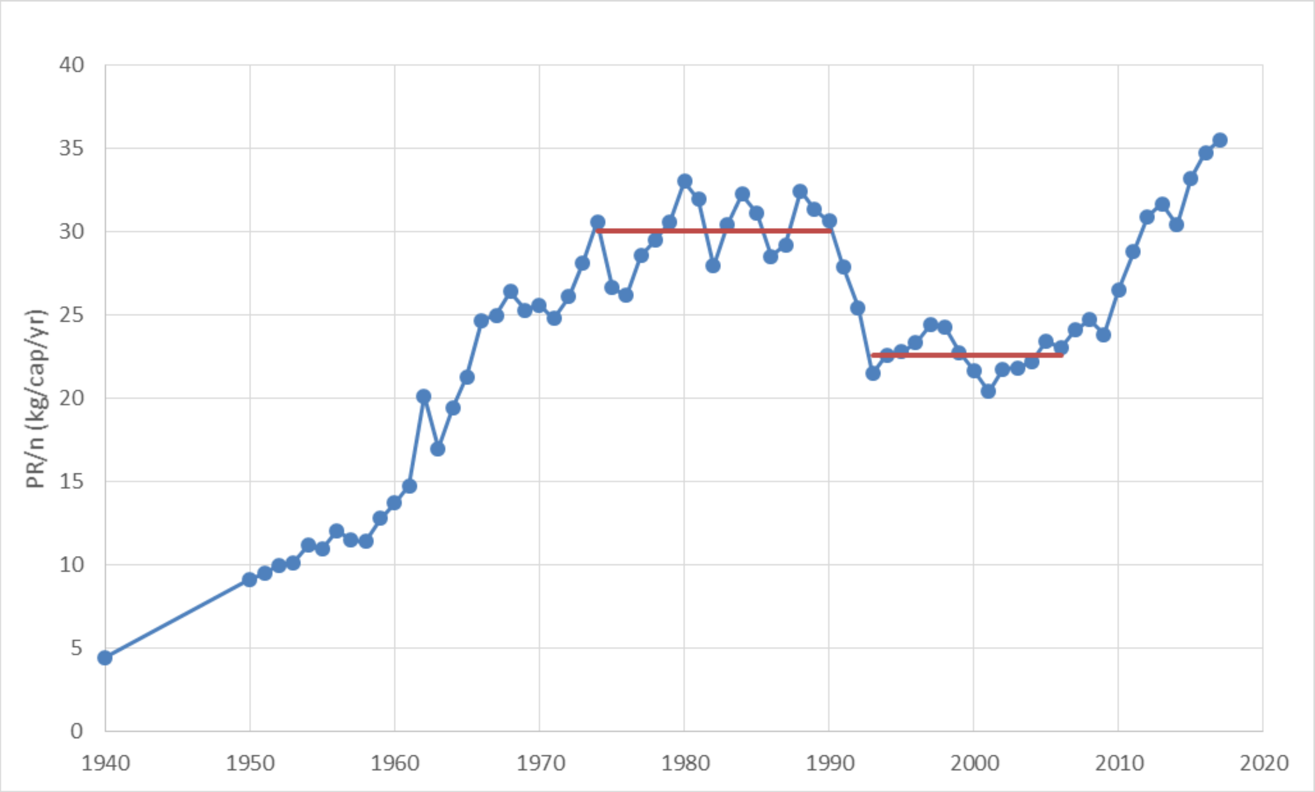
David A. Vaccari, Stephen Powers, Xin Liu, Tom Bruulsema

@sustainP

Global Trend in Production and Population

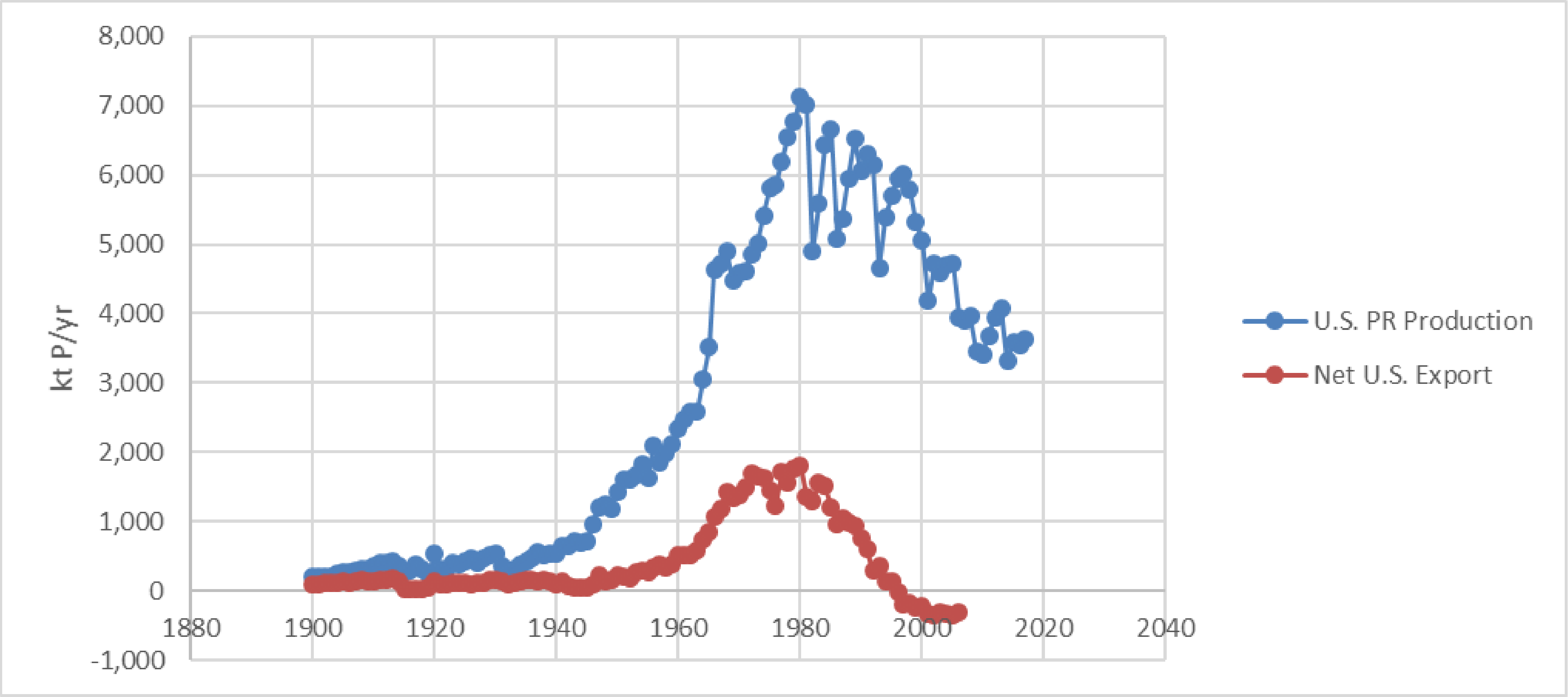


Per Capita Global PR Production



	Kg PR /cap/yr	g P /cap/d
Avg 1974-1990	30.1	10.8
Avg 1993-2008	22.7	8.15
2017	35.5	12.7

Trend in U.S. Production and Exports

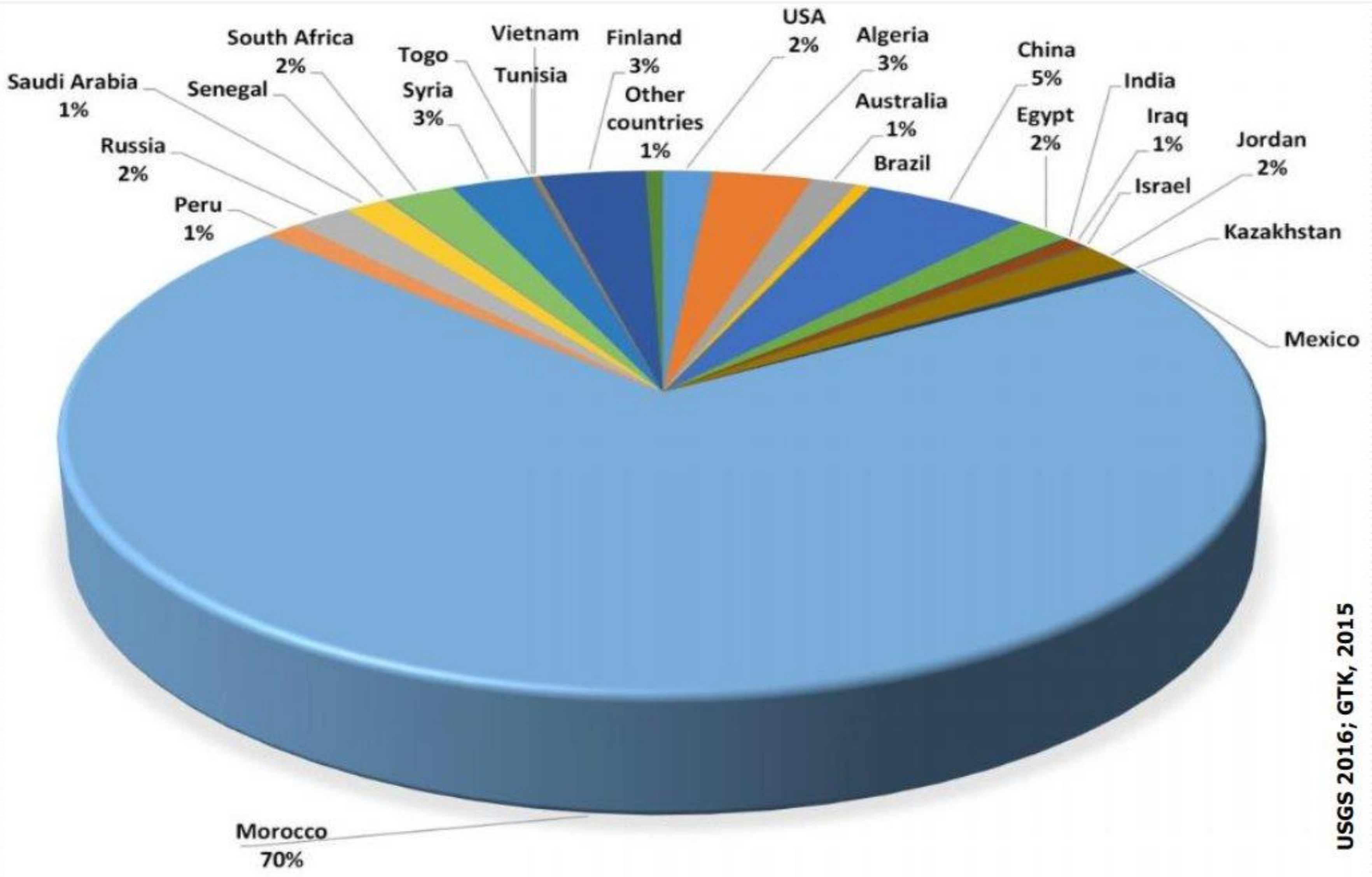


Sustainable Phosphorus Alliance

The Global Production and Reserves Situation

USGS 2017 Report	2017 Prod (Mt/yr)	Prod % of global	Reserves (Mt)	Reserves % of global	Life (yrs)
Morocco_and_Western_Sahara	27	10%	50,000	71%	1,852
China	140	53%	3,300	5%	24
United_States	28	11%	1,000	1%	36
Rest of the World	68	26%	15,939	22%	234
World_total_(rounded)	**263**	100%	70,000	100%	266

Global distribution of commercial phosphate rock reserves

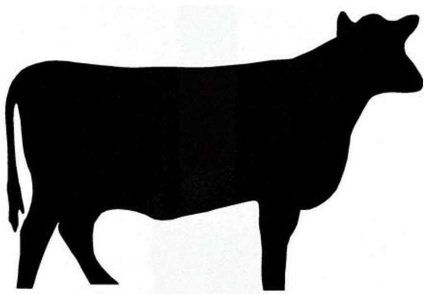


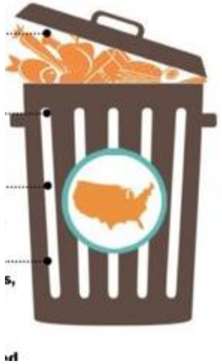
A Substance Flow Model for Global Phosphorus

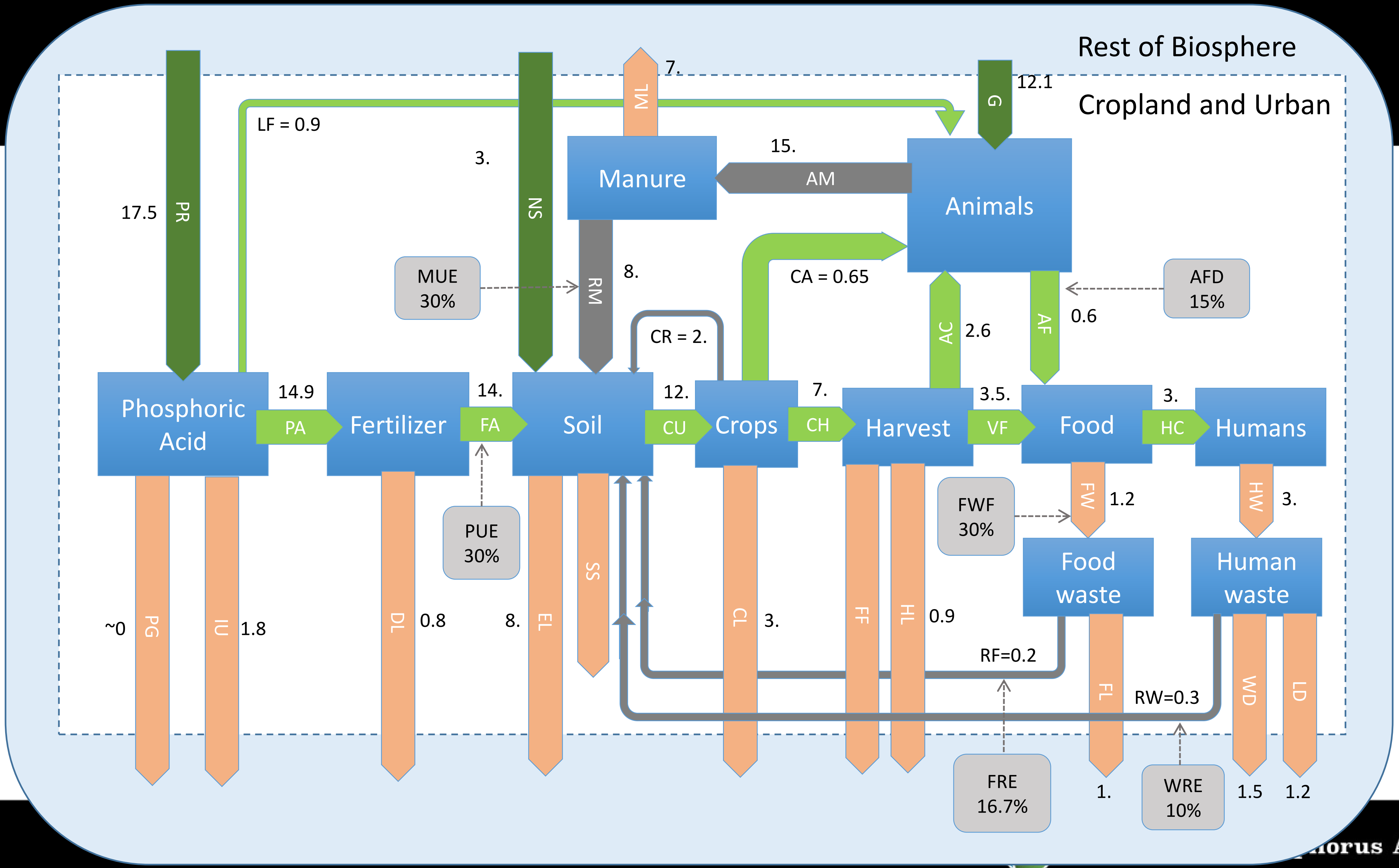
Goal: How effective are different approaches for conserving phosphorus resources?

Objective: Determine sensitivity and interactions of global phosphate rock demand with various efficiency parameters, including:

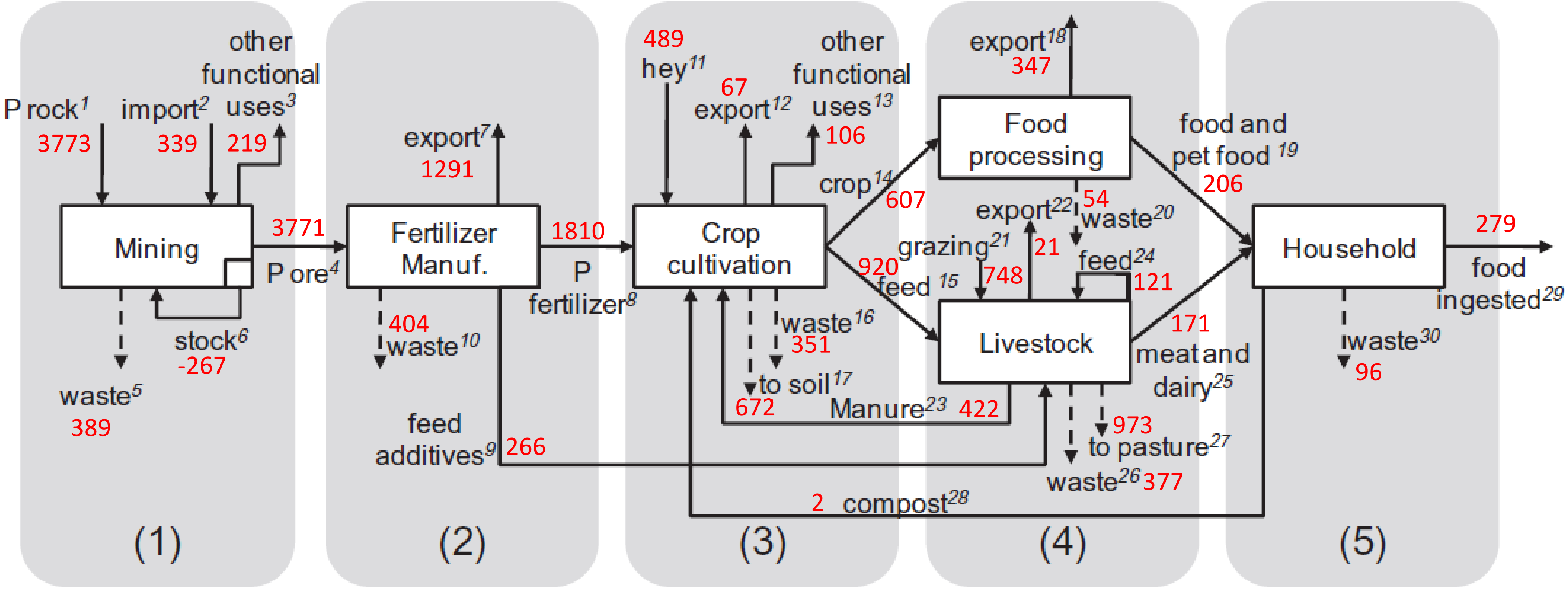
- AFD – Animal Fraction in the diet (meat and dairy)
- PUE – Agricultural Phosphorus Use Efficiency
- MUE – Manure Use Efficiency
- FWF – Food Waste Fraction
- FRE – Food Waste Recycling Efficiency
- WRE – Human Waste Recycling Efficiency






Rest of Biosphere
Cropland and Urban
PR
17.5
LF = 0.9
NS
3.
ML
7.
Manure
15.
AM
G
12.1
Animals
MUE
30%
RM
8.
CR = 2.
CA = 0.65
AC
2.6
AF
0.6
AFD
15%
Phosphoric Acid
14.9
PA
Fertilizer
14.
FA
Soil
12.
CU
Crops
7.
CH
Harvest
3.5.
VF
Food
3.
HC
Humans
PUE
30%
FW
1.2
FWF
30%
HW
3.
Food waste
Human waste
~0
PG
IU
1.8
DL
0.8
8.
EL
SS
CL
3.
FF
HL
0.9
RF=0.2
FL
RW=0.3
WD
LD
FRE
16.7%
1.
WRE
10%
1.5
1.2

Suh-Yee SFA for the Food System in the USA



Food ingested =
13.4% of
Mining + Imported PR
- All exports
- Non-food uses

Phosphorus use-efficiency of agriculture and food system in the US,
Sangwon Suh, Scott Yee, *Chemosphere* 84 (2011) 806–813.
Modified Figure 2, data from Table 1.

Model Inputs – Demand-driven Model

TABLE 1 - Model inputs including intervention parameters, system inputs and other parameters.			
	Intervention efficiency parameters	**Definition**	**Nominal**
WRE	Human Waste Recycling Efficiency	RW/HC	10%
FWF	Food Waste Fraction	FW/FS	27%
FRE	Food Waste Recycling Efficiency	RF/FW	18%
AFD	Animal Fraction in the diet (as P)	AF/FS	15%
MUE	Animal Manure Use Efficiency	RM/AM	50%
PUE	Ag Phosphorus Use Efficiency	CH/(FA+RI+NS)	30%
	System Inputs		
Gmax	Grazing maximum available (Mt/yr)		12.1
IU	Flow of PR to industrial uses (Mt/yr)		1.8
NS	Natural source of P to cropland (Mt/yr)		3.0
NP	Population (billion, Gp)		6.70
PPC	Avg per-capita dietary P demand (g/cap/d)		1.25
	Fixed model parameters	**Definition**	**Nominal**
b_LD	Landfill disposal ratio	LD/(HC+RW)	45%
b_WD	Waste discharge ratio	WD/(HC-RW)	55%
Y_A	Yield of animal products	AF/(AC+LF+G +CA)	3.8%
b_CA	Fertilizer grazing ratio	CA/AC	25%
b_LF	Feed additive ratio	LF/AC	35%
b_HL	Harvest loss ratio	HL/(VF+AC)	15%
b_CL	Crop loss ratio	CL/CU	25%
b_CR	Crop residue ratio	CR/CU	17%
b_EL	Erosion loss ratio	EL/CU	50%
b_HR	Harvest index	CH/CU	65%
b_FF	Fuel and fiber ratio (Mt/yr/Gp)	FF/NP	0.155
b_FPE	Fertilizer production efficiency	FA/PA	94%
b_PG	Fraction of PR to phosphogypsum	PG/PR	5%
Conv	Conversion factor (Mt/yr) / (g/cap/d):	NP*365.25/1000	2.45

Spreadsheet Implementation

Label	Flow Variable	Calculation	(Mt/yr)
HC	**P in diet**	**PPC*Conv**	**3.06**
	HUMANS AND WASTE		
HW	Excreta	HC	3.06
RW	Wastewater or excreta reuse (to ag soils)	WRE*HW	0.31
LD	Landfill	b_LD*(HW-RW)	1.24
WD	Surface water discharge to environment	b_WD*(HW-RW)	1.51
	FOOD SUPPLY		
FS	Total food supply (VF+AF)	HC/(1-FWF)	4.19
AF	Animal-based food supply (total)	FS*AFD	0.63
VF	Vegetal-based food supply	FS-AF	3.56

Spreadsheet Implementation

Label	Flow Variable	Calculation	Nominal
HC	**P in diet**	**PPC*Conv**	**3.06**
	HUMANS AND WASTE		
HW	Excreta	HC	3.06
RW	Wastewater or excreta reuse (to ag soils)	WRE*HW	0.31
LD	Landfill	b_LD*(HW-RW)	1.24
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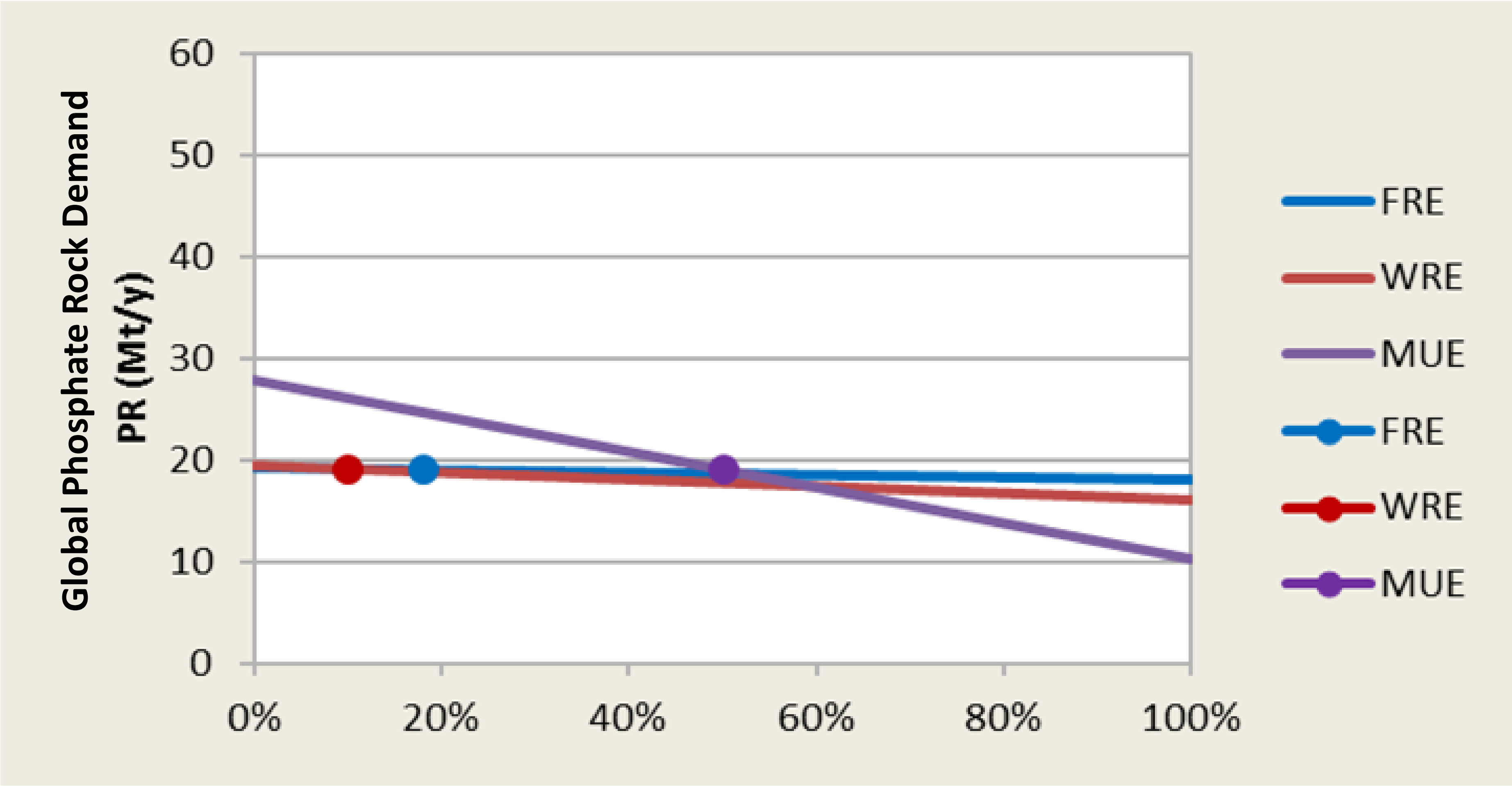
FS	Total food supply (VF+AF)	HC/(1-FWF)	4.19
AF	Animal-based food supply (total)	FS*AFD	0.63
VF	Vegetal-based food supply	FS-AF	3.56
	FOOD OUTPUTS		
FW	Food waste	FWF*FS	1.13
RF	Organic solid waste input (from food)	FW*FRE	0.20
FL	Food chain losses (food waste, distr. Etc.)	FW-RF	0.93
	DOMESTIC ANIMALS		
AI	Total animal P inputs (AC+LF+CA+G)	AF/Y_A	16.34
G	Grazing input utilized	MIN(Gmax,AI)	12.10
FI	Fertilized input to animals (AC+CA+LF)	AI-G	4.24
AC	Animal feed	FI/(1+b_CA+b_LF)	2.66
LF	Livestock feed additives	b_LF*AC	0.92

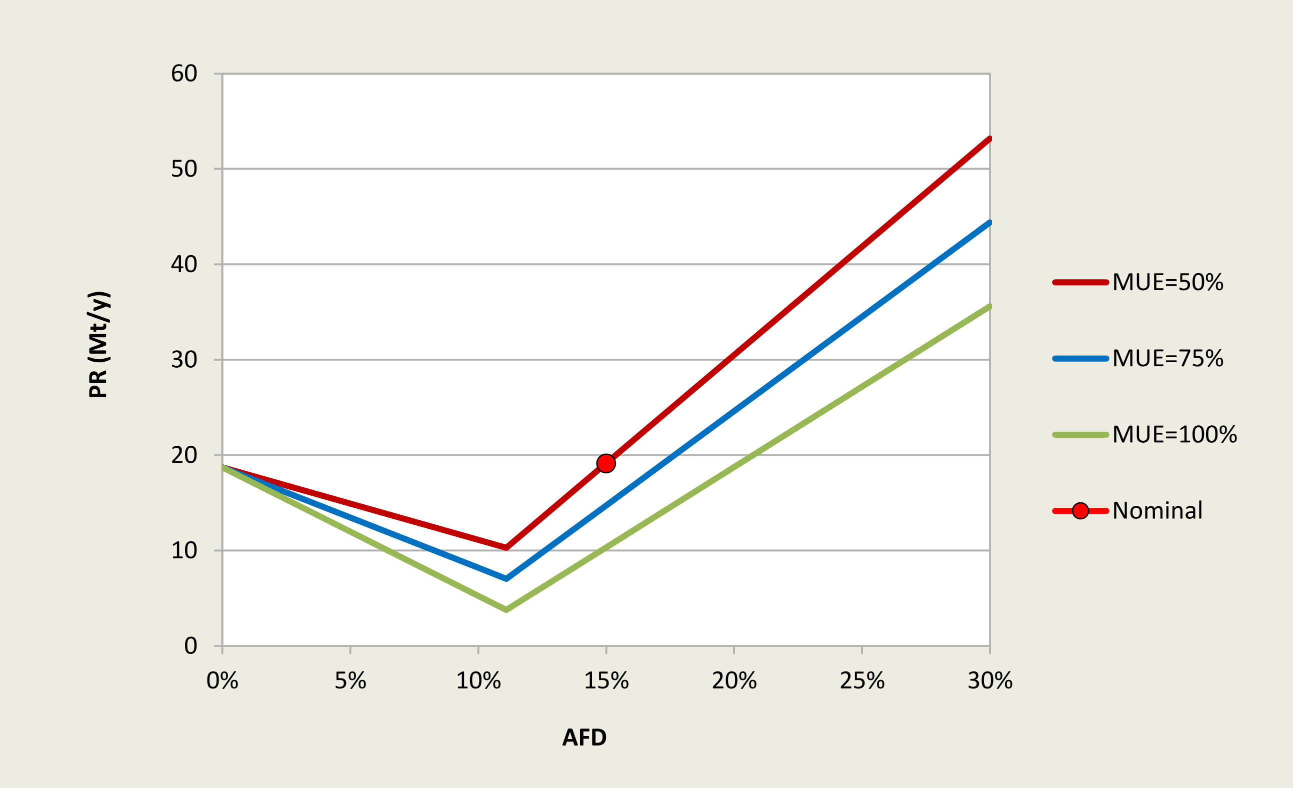
Label	Flow Variable	Calculation	Nominal
AM	**ANIMAL MANURE**	AI-AF	15.71
RM	Applied to soil	AM*MUE	7.86
ML	Lost to the environment	AM-RM	7.86
	HARVEST		
FF	Fuel and Fiber	b_FF*NP	1.04
HL	To post-harvest losses	b_HL*(VF+AC)	0.92
CH	Crop Harvest	VF+AC+HL+FF	8.18
	CROPS		
CR	Crop residues (recycled to soil)	b_CR*CH	1.36
CA	Fertilizer to pasture	b_CA*AC	0.66
CU	Crop uptake	(CH+CR+CA)/(1-b_CL)	13.60
CL	Crop losses to the environment	b_CL*CU	3.40
	ARABLE SOIL		
RI	Recycle inputs (CR+RM+RF+RW)	CR+RM+RF+RW	9.73
EL	Soil erosion losses to the environment	b_EL*CU	6.80
SS	Soil storage	FA+NS+RI-EL-CU	6.85
	FERTILIZER		
FA	Fertilizer Applied to Soil	MAX(0,(CH-PUE*(RI+NS))/PUE)	14.52
PA	Phosphoric Acid to Fertilizer	FA/b_FPE	15.46
DL	Distribution losses	PA-FA	0.93
	PHOSPHORIC ACID manufacturing		
IU	Industrial uses	IU	1.80
PR	**BENEFICIATED PHOSPHATE ROCK**	**(LF+PA+IU)/(1-b_PG)**	**19.14**
PG	Loss to phosphogypsum storage	b_PG*PR	0.96

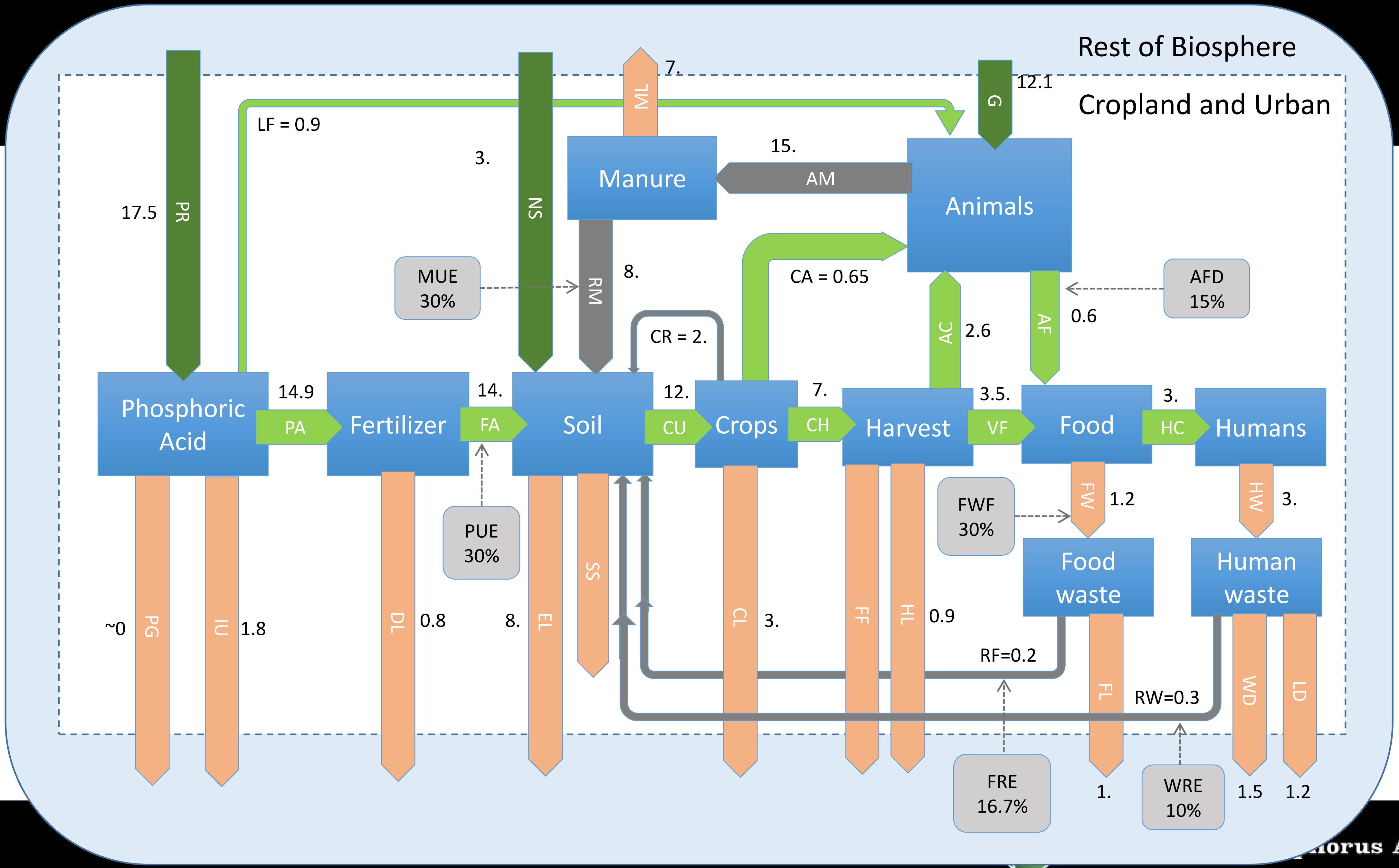
Sustainable Phosphorus Alliance

Results – Sensitivity of PR Demand to Recycling of Food, Human Waste, Manure



Interaction between Meat in the Diet and Manure Recycling



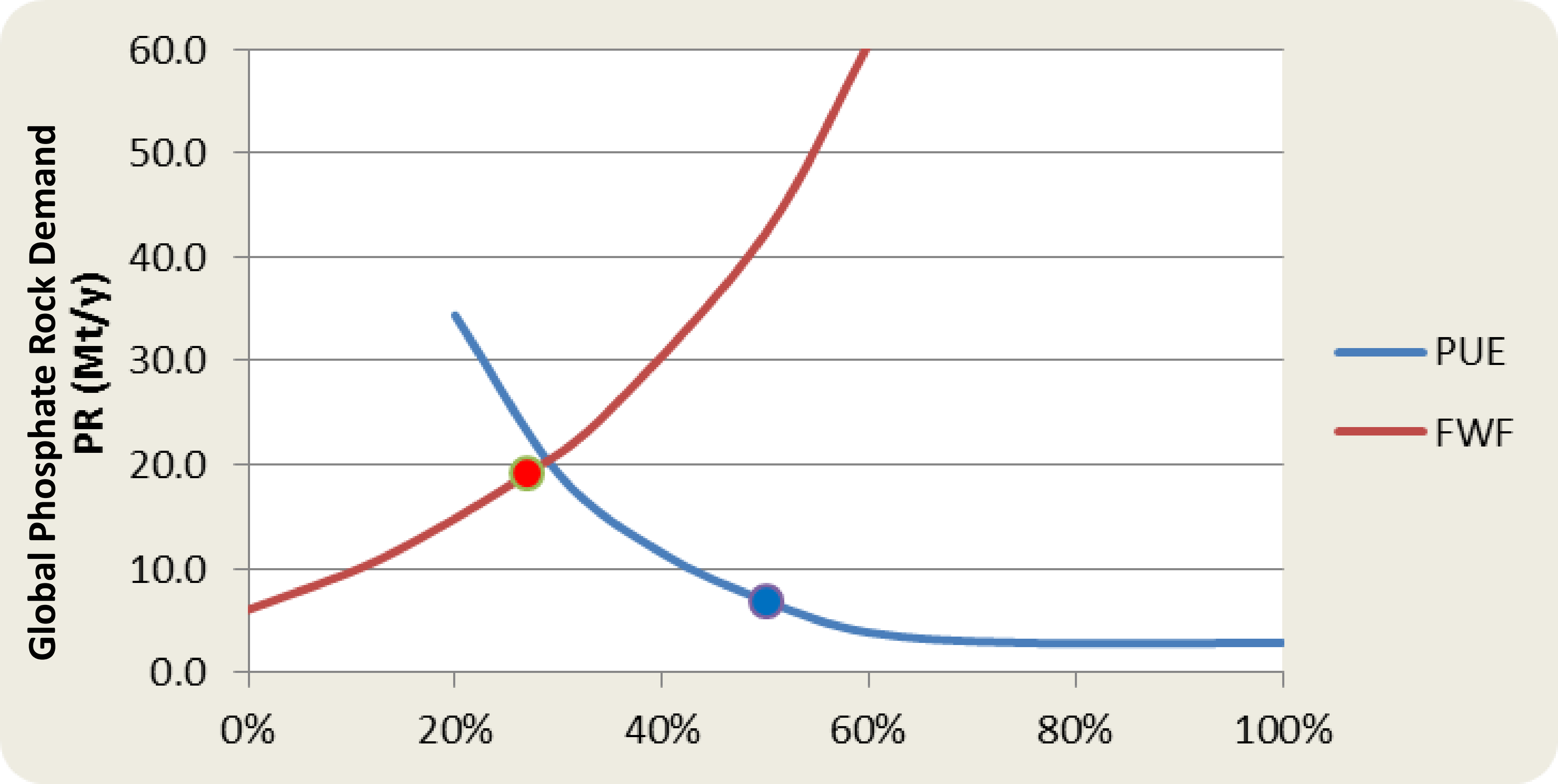

Rest of Biosphere
Cropland and Urban
Phosphoric Acid
Fertilizer
Soil
Crops
Harvest
Food
Humans
Manure
Animals
Food waste
Human waste
PR
17.5
NS
3.
ML
7.
G
12.1
LF = 0.9
15.
AM
MUE
30%
RM
8.
CR = 2.
CA = 0.65
AC
2.6
AF
0.6
AFD
15%
14.9
PA
14.
FA
12.
CU
7.
CH
3.5.
VF
3.
HC
PUE
30%
FWF
30%
FW
1.2
HW
3.
~0
PG
IU
1.8
DL
0.8
8.
EL
SS
CL
3.
FF
HL
0.9
RF=0.2
FL
RW=0.3
WD
LD
FRE
16.7%
1.
WRE
10%
1.5
1.2

Cost of Animal Food in Grain

	Milk	Carp	Eggs	Chicken	Pork	Beef
Feed conversion (kg of feed/kg^{-1} of live weight)	0.7	1.5	3.8	2.3	5.9	12.7
Feed conversion (kg of feed/kg^{-1} of edible weight)	0.7	2.3	4.2	4.2	10.7	31.7
Protein content (% of edible weight)	3.5	18	13	20	14	15
Protein conversion efficiency (%)	40	30	30	25	13	5

Figure 5. Protein contents of major animal foods and feed conversion efficiencies of their production. (Based on Figure 8.4 in ref. 2.) Calculations of feed conversion efficiencies based on the latest (1999) average US feed requirements from ref. (49); they include the feeding requirements of entire breeding and meat-producing populations.

PUE – Agricultural Phosphorus Use Efficiency, and FWF – Fraction of Food Wasted

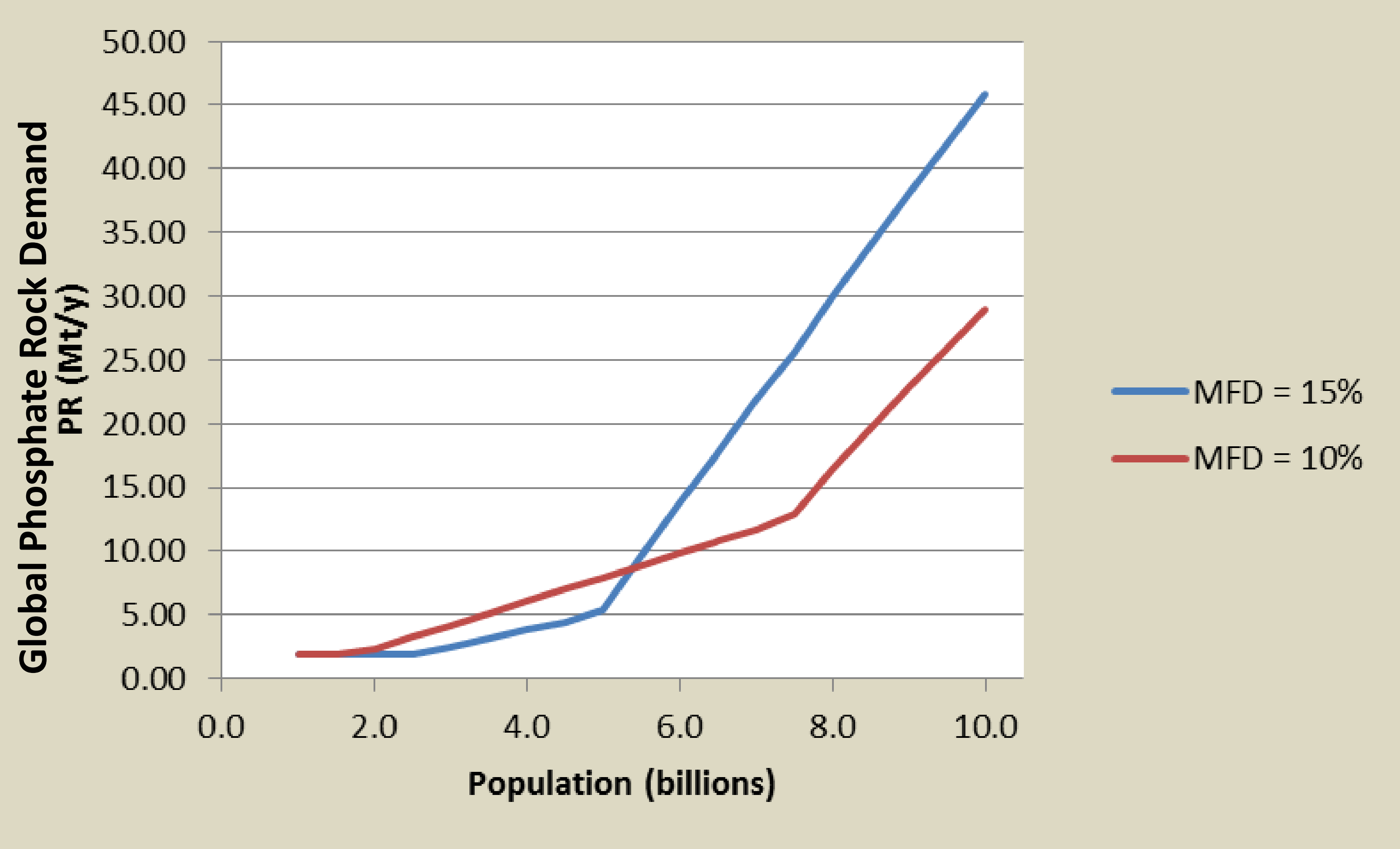


Relative Sensitivity of Interventions
(%Δ PR / %Δ Intervention)

	Intervention efficiency parameters	Rel. Sens.
FRE	Food Waste Recycling Efficiency	0.012
WRE	Human Waste Recycling Efficiency	0.018
MUE	Animal Manure Use Efficiency	0.46
FWF	Food Waste Fraction	-0.98
AFD	Animal Fraction in the diet (as P)	-1.78
PUE	Ag Phosphorus Use Efficiency	1.58
NP	World Population	-2.83

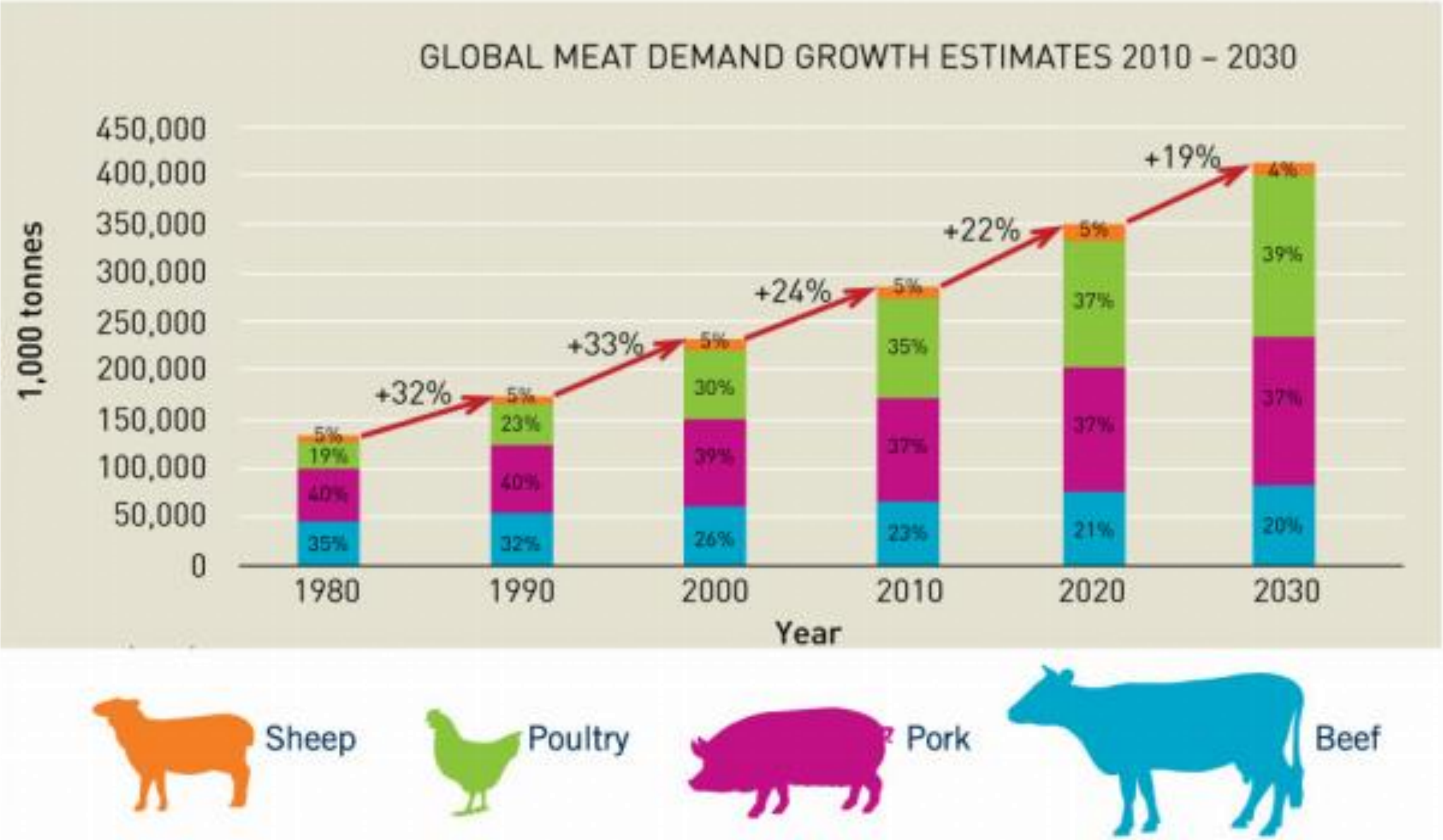
Reducing Food Waste Fraction (FWF) is 82 times as effective as increasing Food Recycling Efficiency (FRE)

Effect of Population
Interacting with % meat in diet

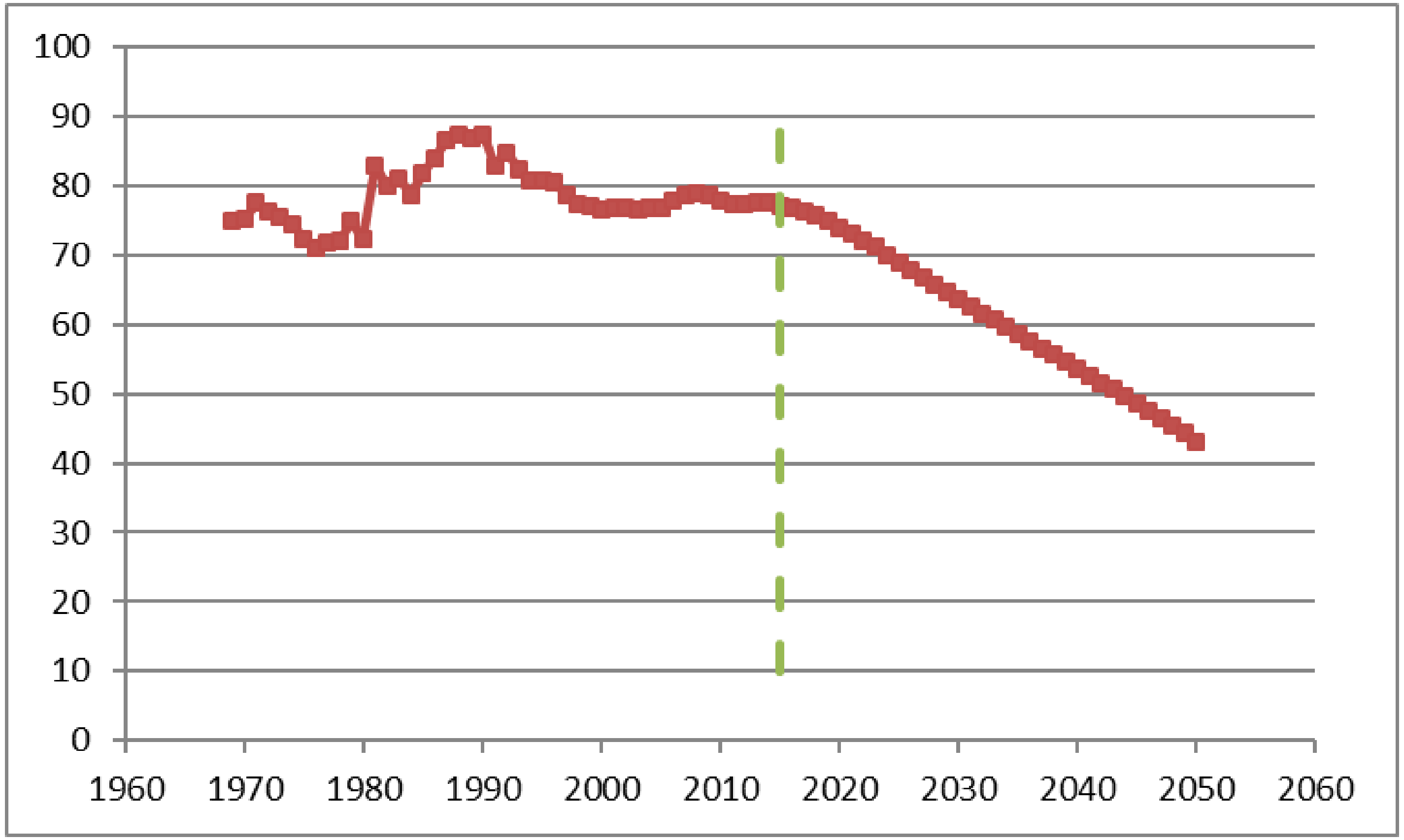


The Challenge with Animal Food in Diet

Source: Rabobank (2011)



UNEP Population change projections (Millions per year)



Conclusions

- [Animal Food in Diet] interacts significantly with [Manure Use Efficiency] and [Ag Phosphorus Use Efficiency], but retains its high sensitivity
- [Animal Food in Diet] has a non-zero optimum due to grazing input
- [Ag Phosphorus Use Efficiency] and [Food Waste Fraction] exhibit diminishing returns
- [Food waste fraction] is much more significant than [Food waste recycling]
- Effect of [Population] is significantly affected by [Animal Food in Diet]
- **Sensitivity** must be interpreted in terms of costs of implementation
- **Substance Flow Modeling** is a viable planning tool for resource sustainability

Recommendations

- De-aggregate by country or region
- De-aggregate food categories
- Develop dynamic models
- Develop cost factors for interventions and determine sensitivity to cost

Thank you and Save the P!

Sustainable Phosphorus Alliance

PhosphorusAlliance.org

Phosphorus Forum 2018

February 27, 2018 | Tempe, AZ

phosphorusalliance.org/events
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TODAY'S AGENDA

- 8:30 **Dr Jim Elser** (ASU) Welcome and our job today.
- 8:45 Keynote: **Dr Sally Rockey** (FFAR)
- **9:30 Dr David Vaccari** (Stevens Inst of Technology) "A Substance Flow Model for Global Phosphorus"
- **10:00 Coffee & networking**
- 10:30 **Dr. Luis Herrera** (CINVESTAV), GMO technology for phosphite fertilizer use
- 11:00 **Dr Kevin Dooley** (ASU) & **Allison Thomson** (Field to Market): Market drivers of nutrient sustainability
- 12:00 – 1:30 Lunch & networking
- 12:30 – 1:00 Lunch keynote: **Dr Paul Fixen** (IPNI, retired)
- 1:30 **Ned Beecher** (Northeast Biosolids & Residuals Association), regulatory challenges with recycling organic residuals
- 2:00 **Noel Lyons** (McGill Compost) and **Dr Amir Varshovi** (GreenTechnologies), commercialization of compost and recycled fertilizer products
- 2:45 **Dr Jim Elser** (ASU) Final discussion & closing comments.
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Crops only use 20-30% of the fertilizer applied in agriculture

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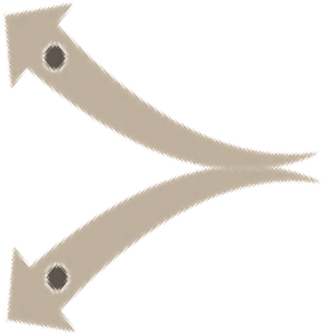
LOW-P SOIL P-FERTILIZED SOIL

20-30% efficiently utilized



P

70-80% lost

-Fixation in the soil
-Microbial activity

Over 35 million tons of Pi-fertilizer are applied annually to increase crop yield.

70% of the world's arable land has low Pi availability (red and yellow areas) and require Pi fertilization

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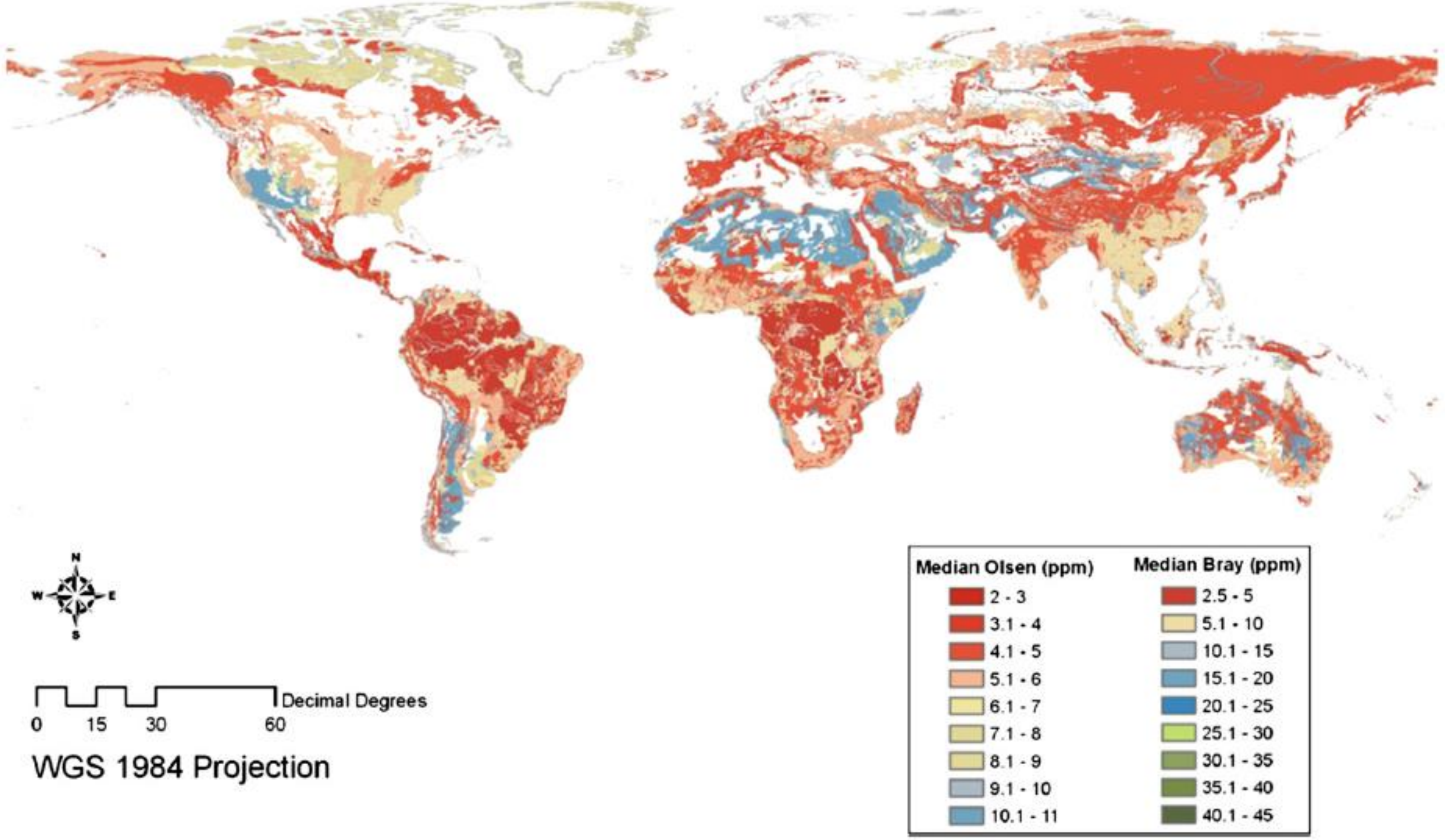

Figure 1. Map of global soil phosphorus availability. The dominance of red and light-gray colors, indicating suboptimal phosphorus availability for the growth of many plant species, indicates the importance of phosphorus availability as a primary limitation to plant productivity in terrestrial environments (from Jaramillo-Velastagui, 2011).

The fundamental problem is the chemical properties of Pi

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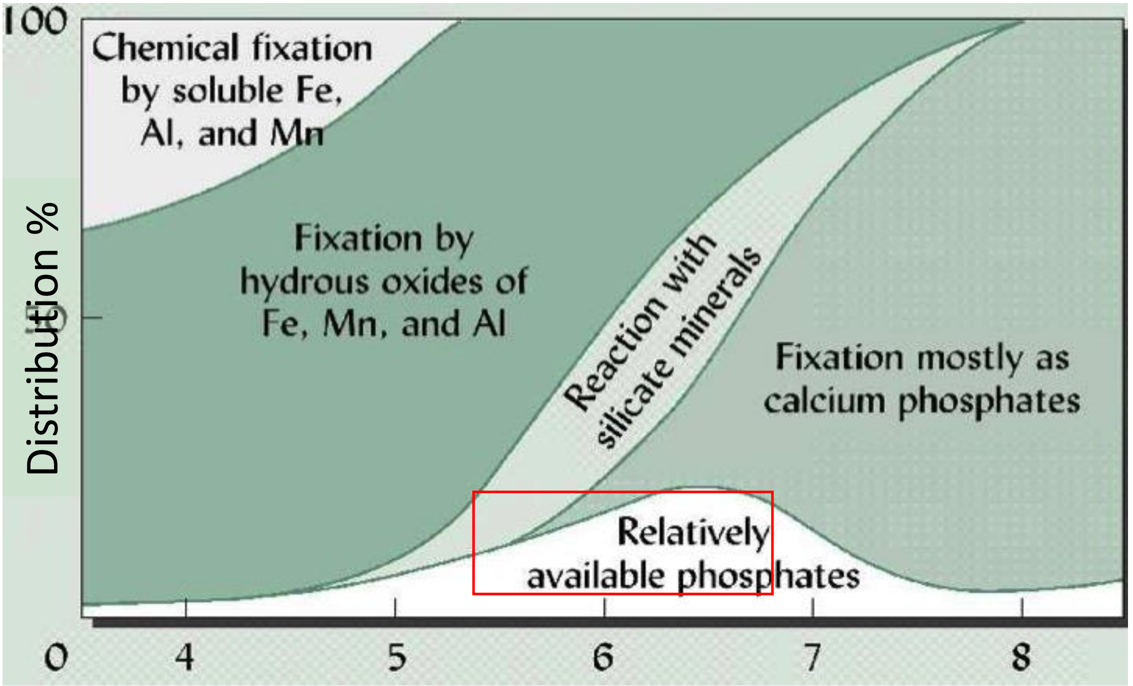

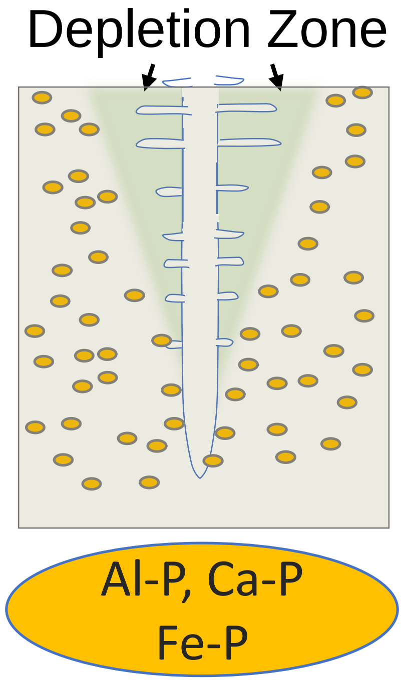

Because of its low solubility and low mobility, Pi is the most limiting nutrient in the soil.

Phosphites (Phi): a more efficient source of P

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Phi was proposed after Second World War as a superior alternative source of P fertilizer over Pi because of its physicochemical properties:

-Phi solubility is less dependent on pH than Pi.

-Phi is less reactive than Pi with soil components.

-Phi is already widely used in agriculture as an effective treatment against Oomycetes (i.e. Phytophthora, etc.).

-No toxicity reported for humans and animals (FDA).

The problem: plants cannot used phosphite as a P source

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Phosphate Phosphite No P

Phosphite **Phosphate**

Demonstrated in many species including monocots and dicots.

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Given the advantages of Phi as a potential fertilizer, can we engineer plants to metabolize phosphite?

Phosphite Phosphate

A few bacterial isolates are capable of using Phi as P source

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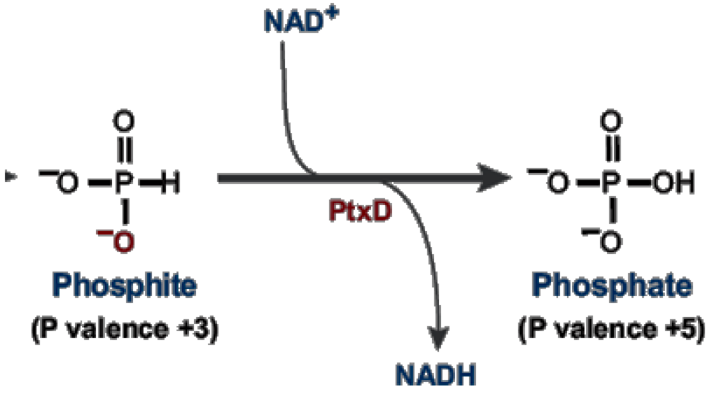

Substrate specificity of PTXD

Cofactors[a]	Activity	Substrates[b]	Activity
	%		%
NAD, 1 mM	100.0	Phosphite	100.0
NADP, 1 mM	0.4	Nitrite	ND[c]
NADP, 2 mM	1.1	Formate	ND
NADP, 4 mM	3.4	D-Glycerate	ND
NADP, 6 mM	7.1	D-2-Hydroxy-4-methylvalerate	ND
		D-3-Phosphoglycerate	ND
		DL-Hydroxyisocaproate	ND
		Methylphosphonate	ND
		Aminoethylphosphonate	ND
		Arsenite	ND
		DL-Lactate	ND
		Hypophosphite	ND
		Sulfite	ND

A phosphite assimilation operon was characterized in *Pseudomonas stutzeri WM88* by the Metcalf group.
This operon includes *ptxD*, a gene encoding a highly specific oxidoreductase for Phi that allows this bacterium to use it as a sole P source.

Metcalf and Wolfe, 1998.

Growth of transgenic tobacco plants in a sterile, inert substrate supplemented with Phi

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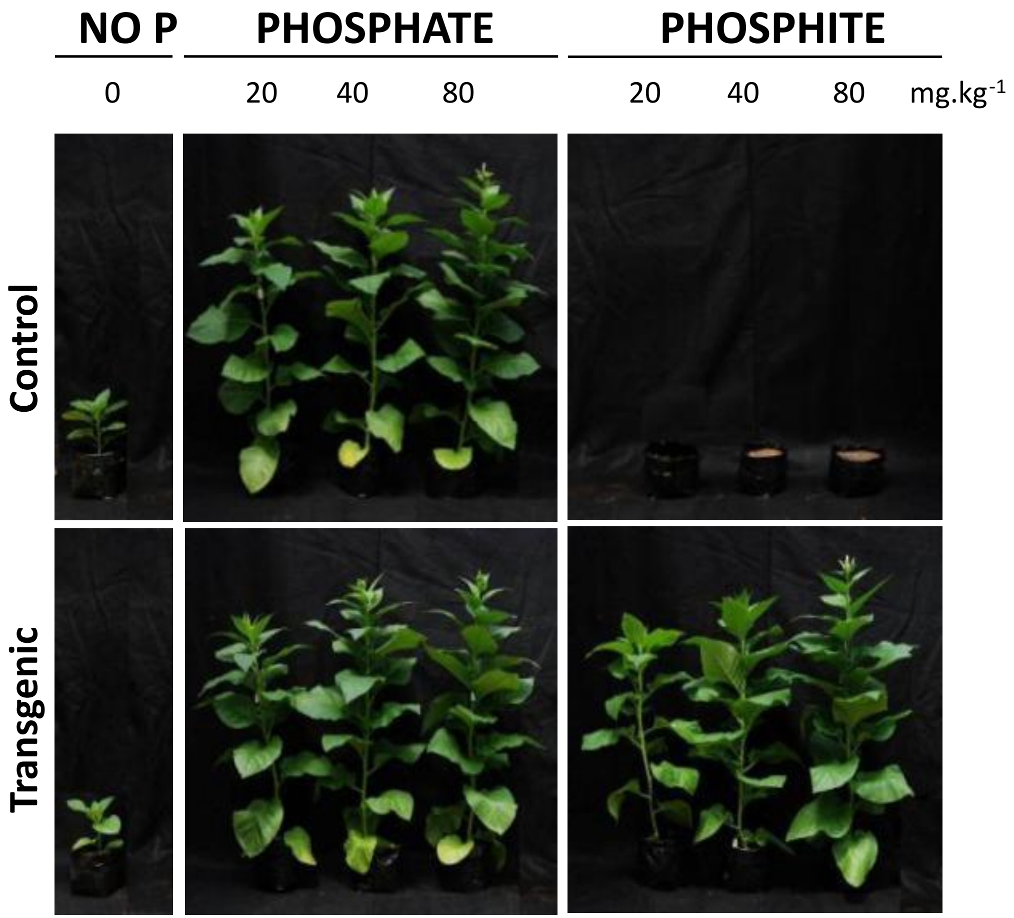

Transgenics are able to use Phi as sole P source with a phenotype and yield comparable to non transformed control plants grown in Pi.

López-Arredondo and Herrera-Estrella, Nat Biotechnol 2012.

In natural soils, PTXD plants fertilized with Phi require 50% lower P input to achieve maximum productivity

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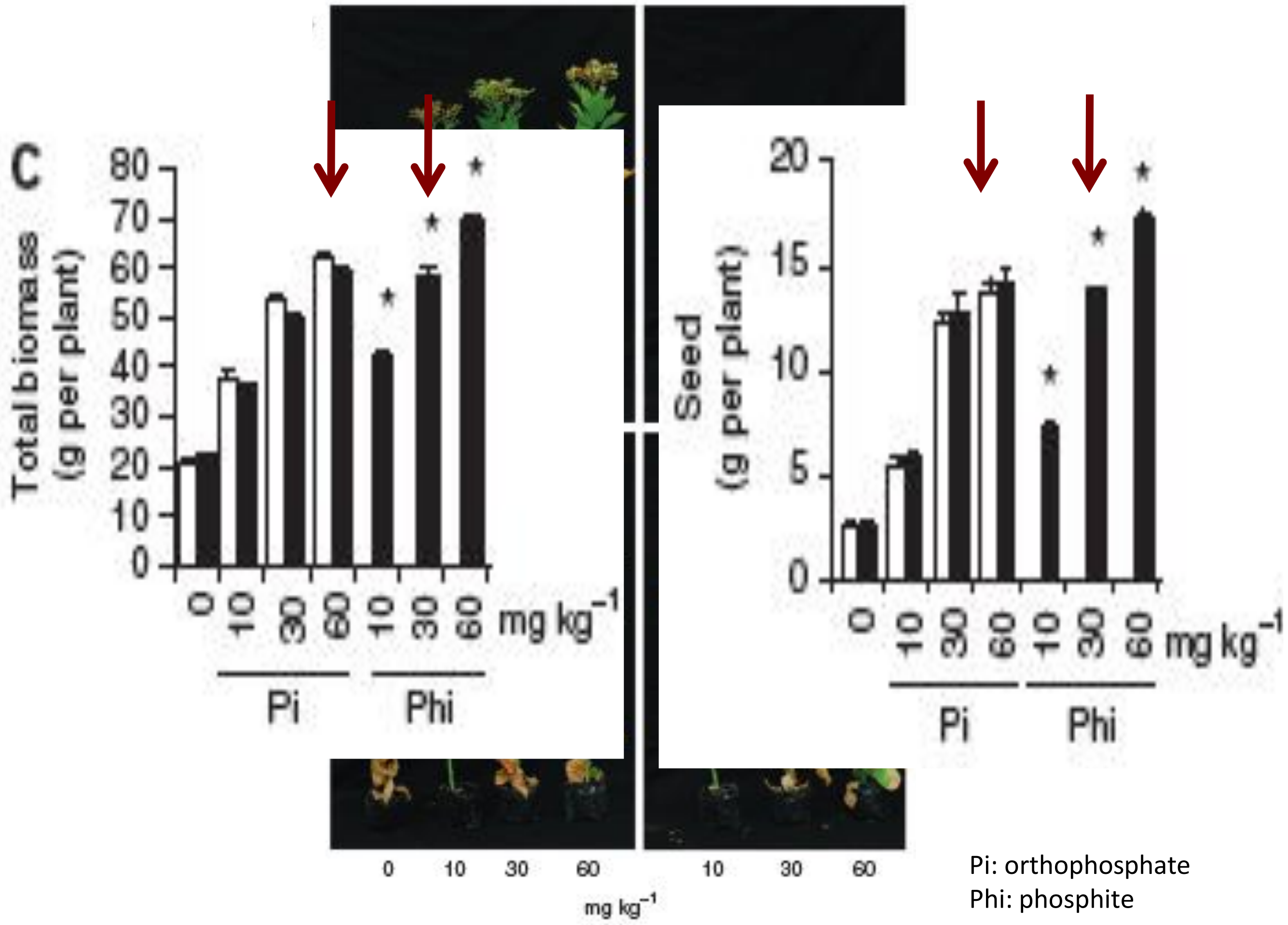

Pi: orthophosphate
Phi: phosphite

López-Arredondo and Herrera-Estrella, Nat Biotechnol 2012.

Herbicide resistant weeds are making herbicides obsolete


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The New York Times

Business Day

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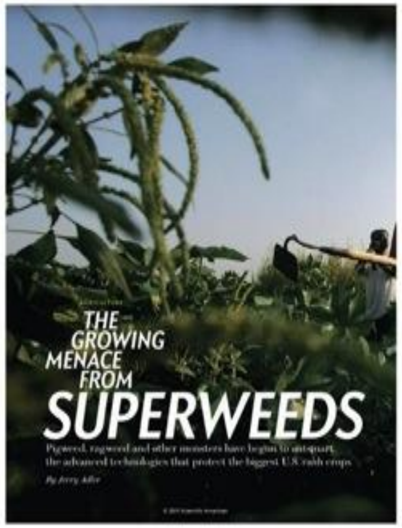
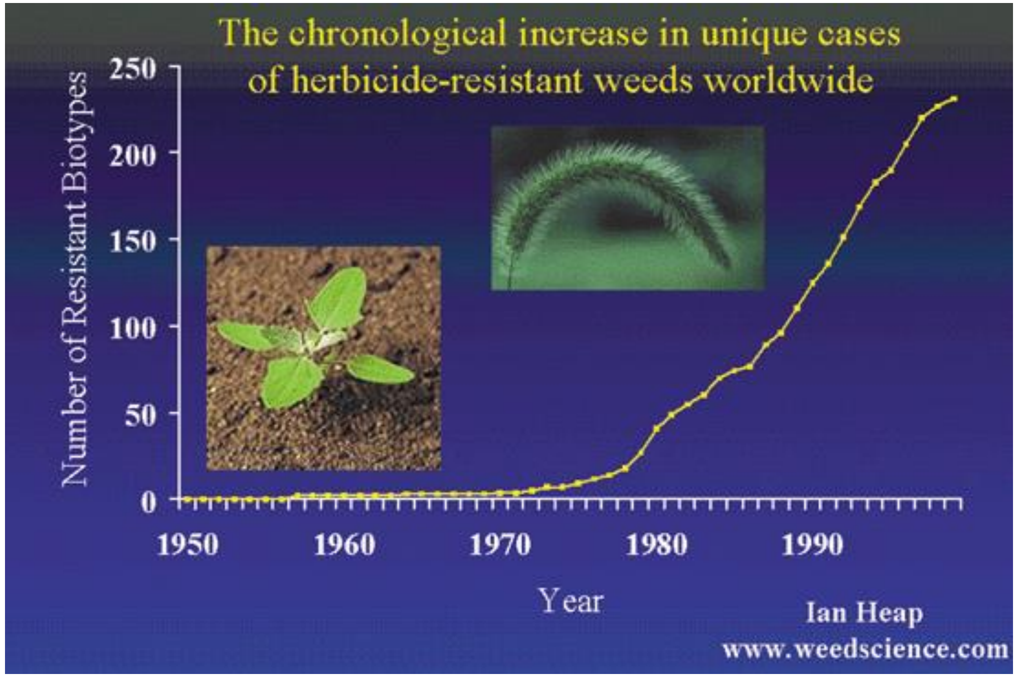
Farmers Cope With Roundup-Resistant Weeds

New York Times (March 2011)

Scientific American (May 2011)





The dramatic increase in herbicide-resistant weed biotypes; a major concern worldwide

Why is innovative weeding so important?

- Weeds are responsible for at least 10 % of all yield losses.
- Weeds are strong competitors for crop and tree seedlings.
- Weeding people cannot work in more qualified jobs.
- Herbicides residues produce health risks.
- Herbicide resitant weeds are becoming an increasingly important problem for agriculture
- Weedy algae and other biological contaminant prevent the cost effective use of microlagae for the production of biofuels and other high value products

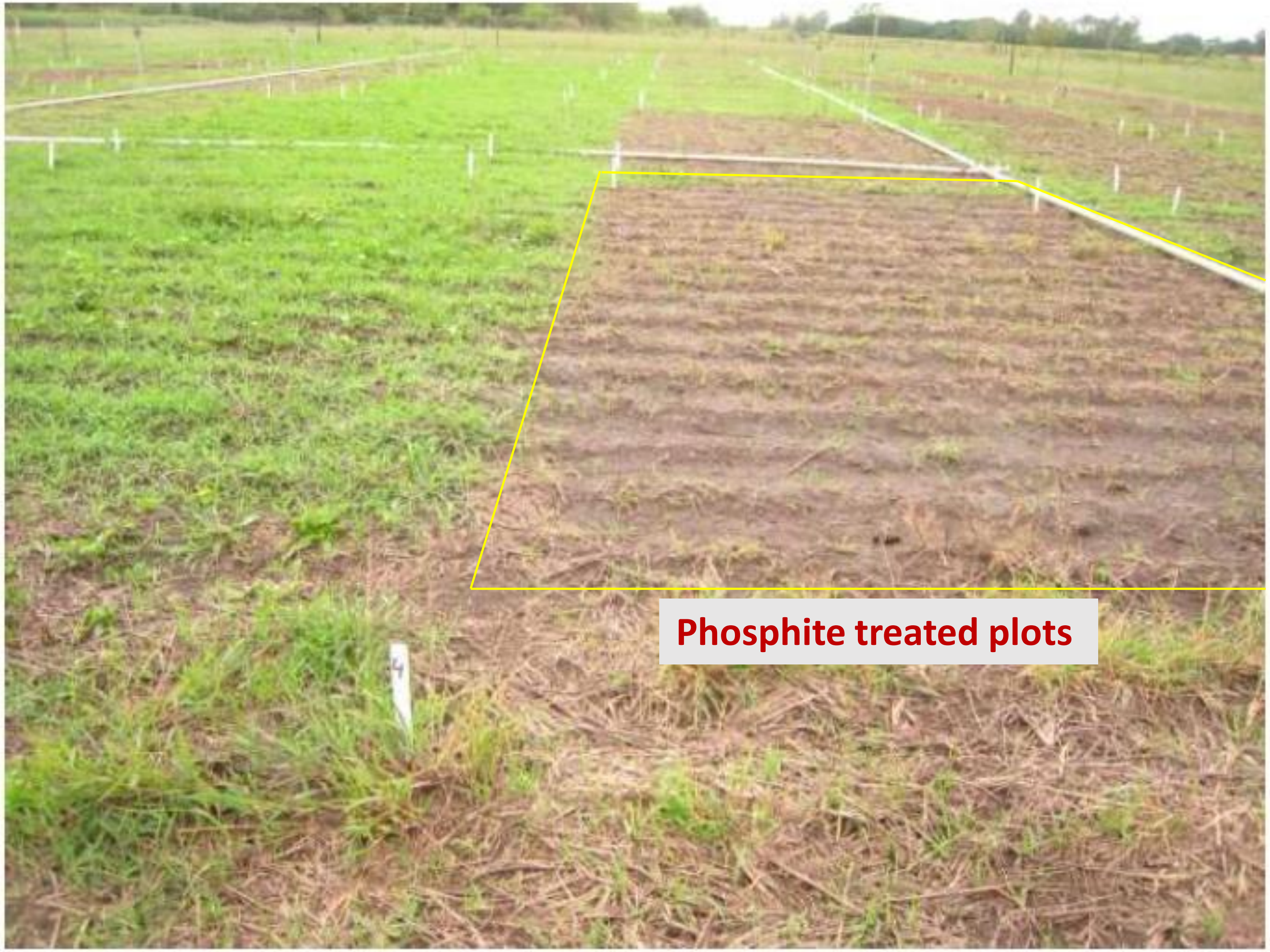
Cinvestav

Phi is not a herbicide, however, it cannot be used as a source of P by conventional plants and inhibits their growth because it competes with Pi for the entry into the plant via a common set of transporters.

Can Phi be used to selectively fertilize crops and reduce weed growth?

Can we replace Pi fertilizer and herbicides with Phi?

Phosphite fertilization effectively suppresses weed growth under field conditions (soil with low Pi availability; 8ppm)



Effect of phosphite 4 weeks after treatment compared to glyphosate

Phosphite Glyphosate

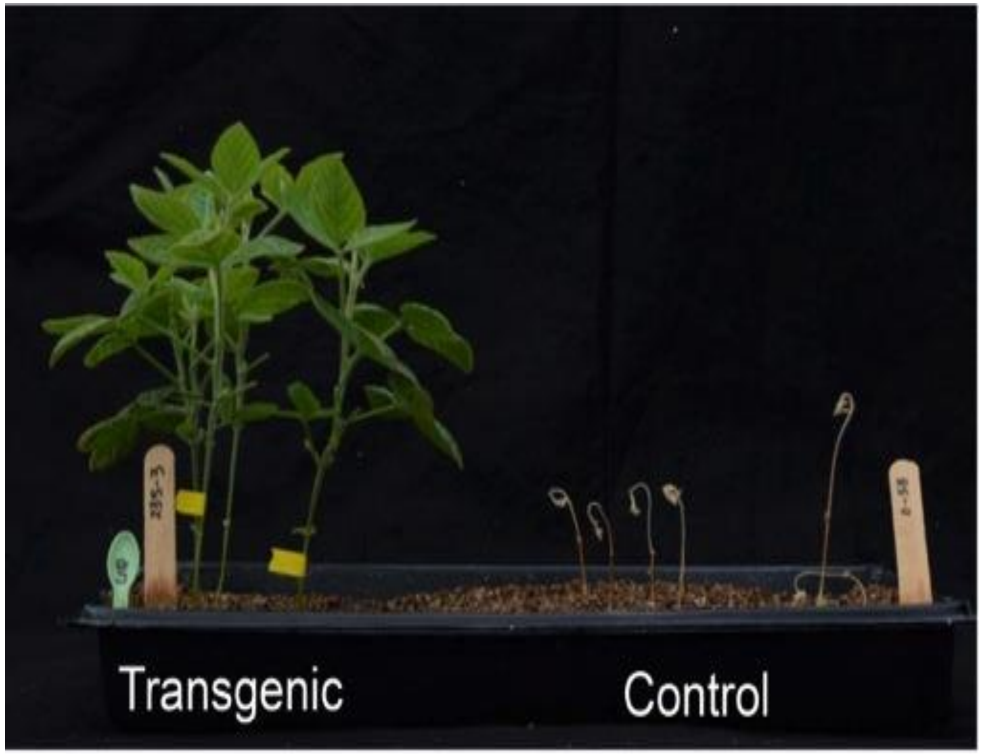
Field trial with transgenic tobacco in Argentina

No Phi | Phi 180 ppm | Phi 80 ppm

Pi: phosphate
Phi: phosphite

The Phi-technology is applicable to many crop species (maize and soybean)

StelaGenomics



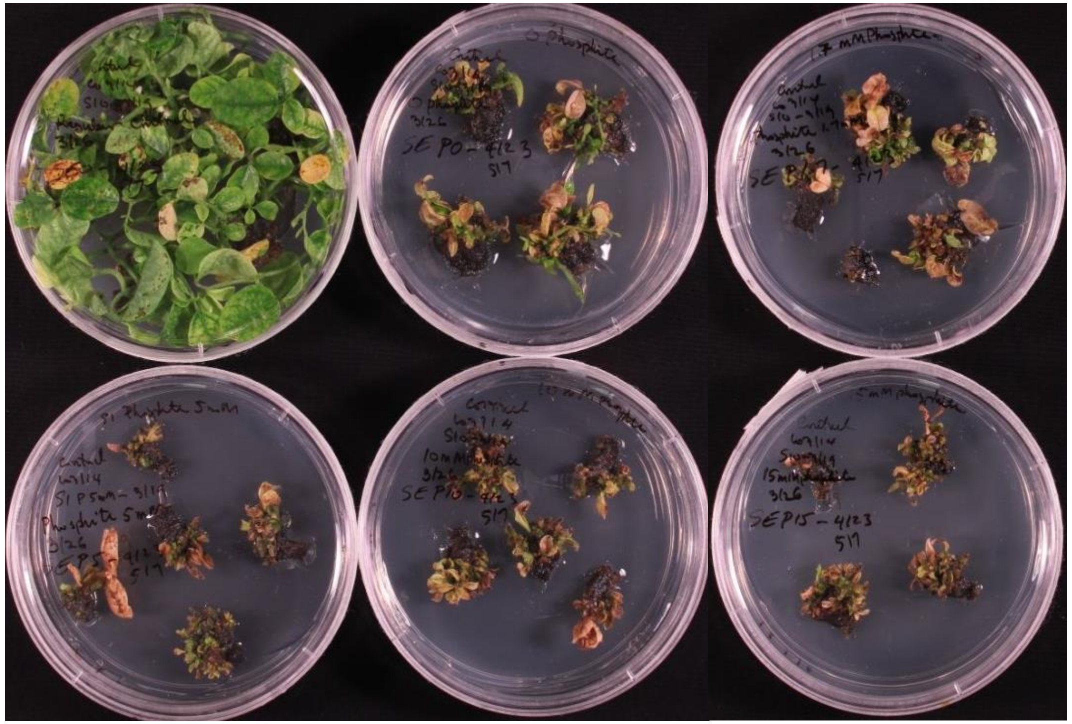
In collaboration with Kan Wang, ISU. *López-Arredondo et al., unpublished data.*

The PTXD gene can be used as an effective selectable marker for many plant species

StelaGenomics

Untransformed

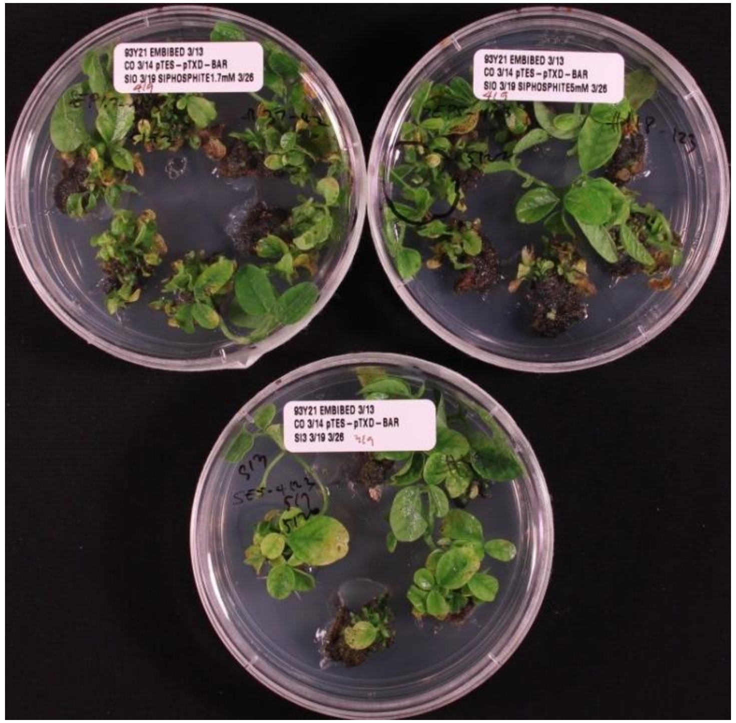
PO 1.25 mM | PO 0 | Pi 1.7



Pi 5 | Pi 10 | Pi 15

pTXD-Bar

Phi 1.7 | Phi 5



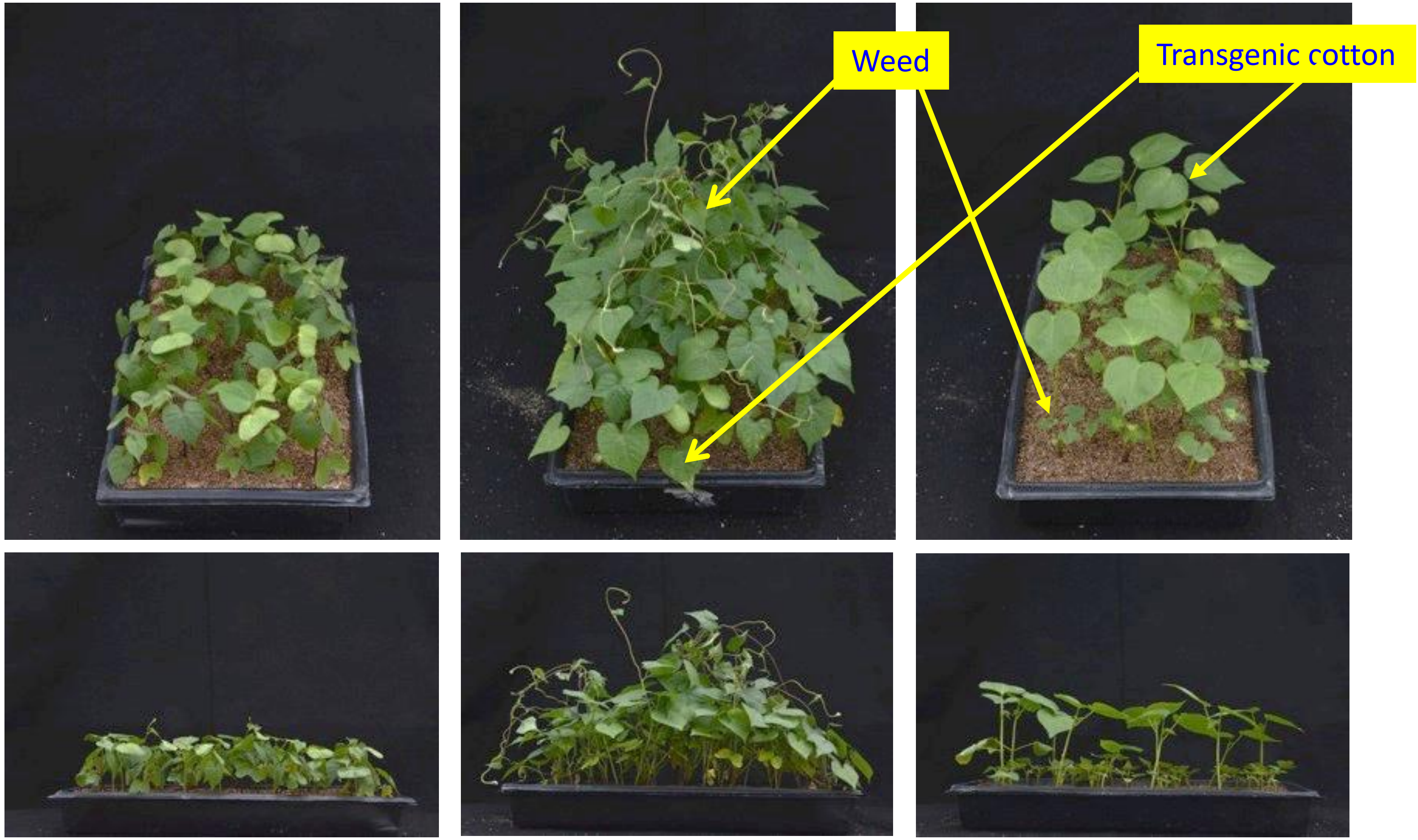
Bial 5 mg/l

In collaboration with the Pioneer/Dupont soybean transformation group and Kan Wang (Iowa State Transformation Center).

Competition experiment between *ptxD*-transgenic cotton and a broad leaf-type weed

StelaGenomics

NO P | **PHOSPHATE** | **PHOSPHITE**

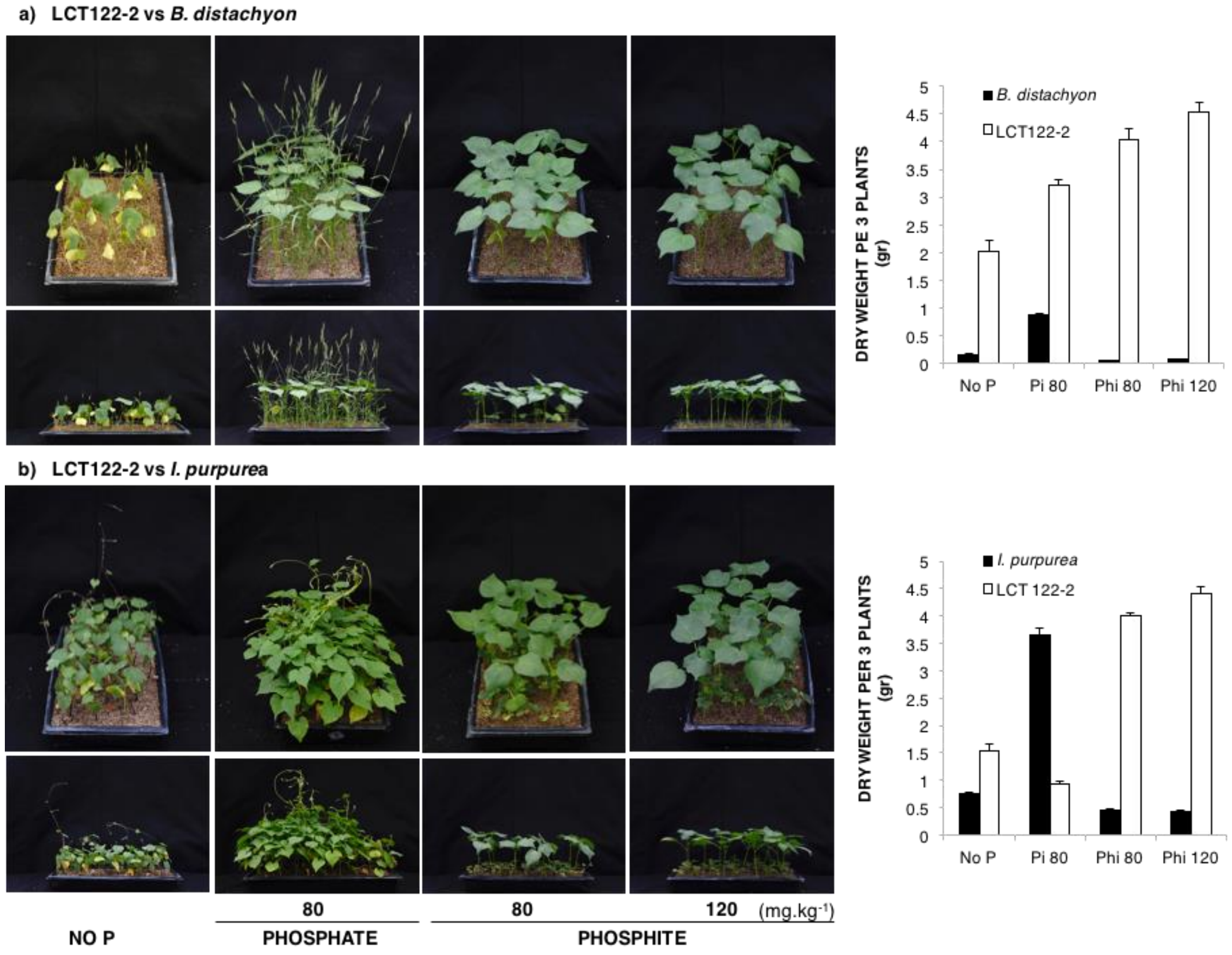


In collaboration with Kertii Rathore Texas A&M. *López-Arredondo et al., unpublished data.*

Pi: orthophosphate
Phi:phosphite

Biomass accumulation of weed and *ptxD*-transgenic cotton plants in phosphate and phosphite fertilized conditions

StelaGenomics

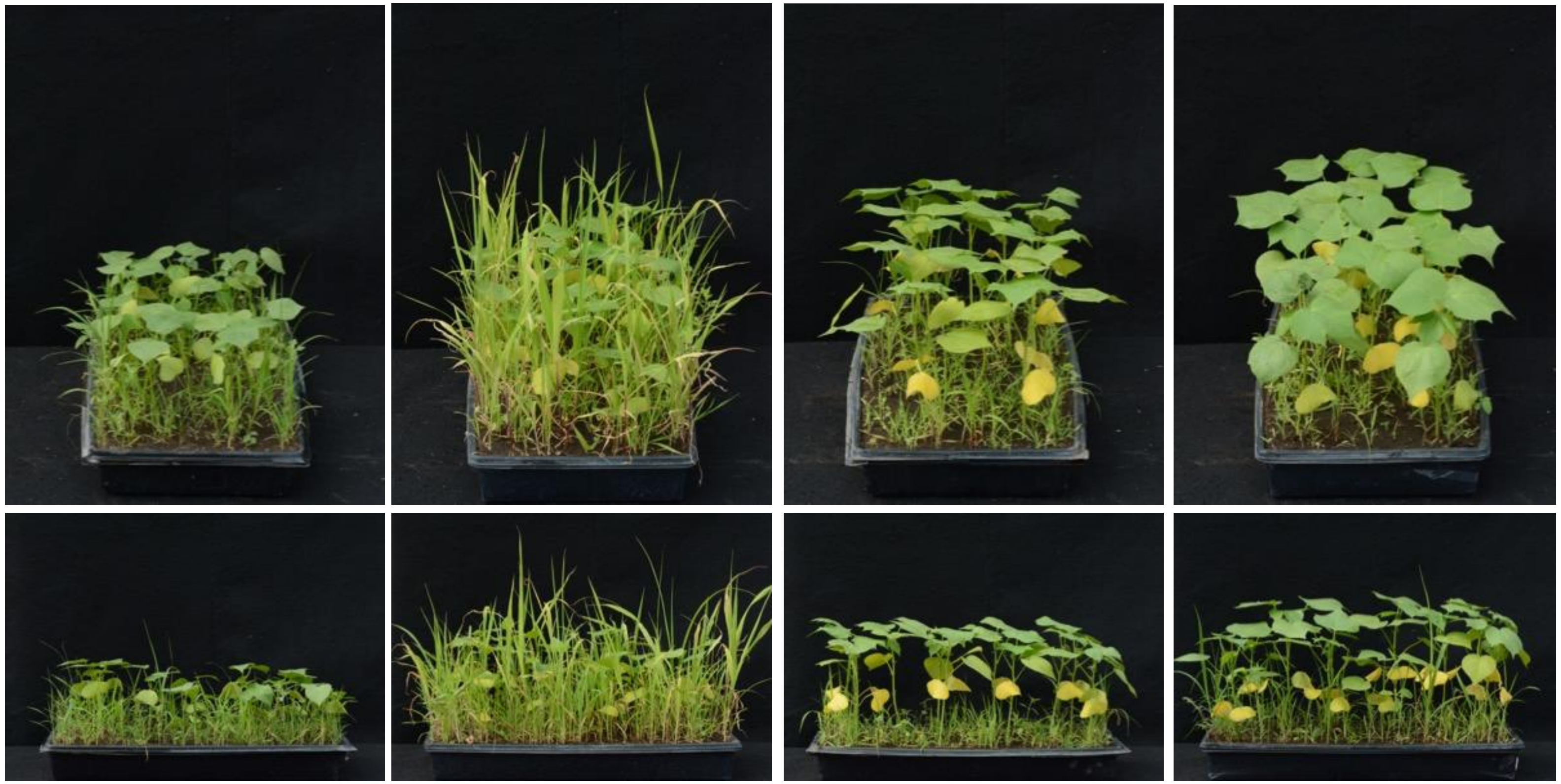


In collaboration with Kertii Rathore Texas A&M. *López-Arredondo et al., unpublished data..*

Competition of *ptxD*-transgenic cotton with natural weeds from an agricultural soil rich in weed seed

LCT-122-4/6 vs *Bd*

No P **Phosphate** **Phosphite**



80 **120** **mg.kg**

In collaboration with Kertii Rathore Texas A&M. *López-Arredondo et al., unpublished data.*

The phosphite system controls weed growth allowing weeds to decrease soil erosion and water evaporation

50% Phi fertilizer
10% herbicide

100% Pi fertilizer
100% herbicide

Field tests in Argentina.

Potential benefits of the Phi-technology

StelaGenomics

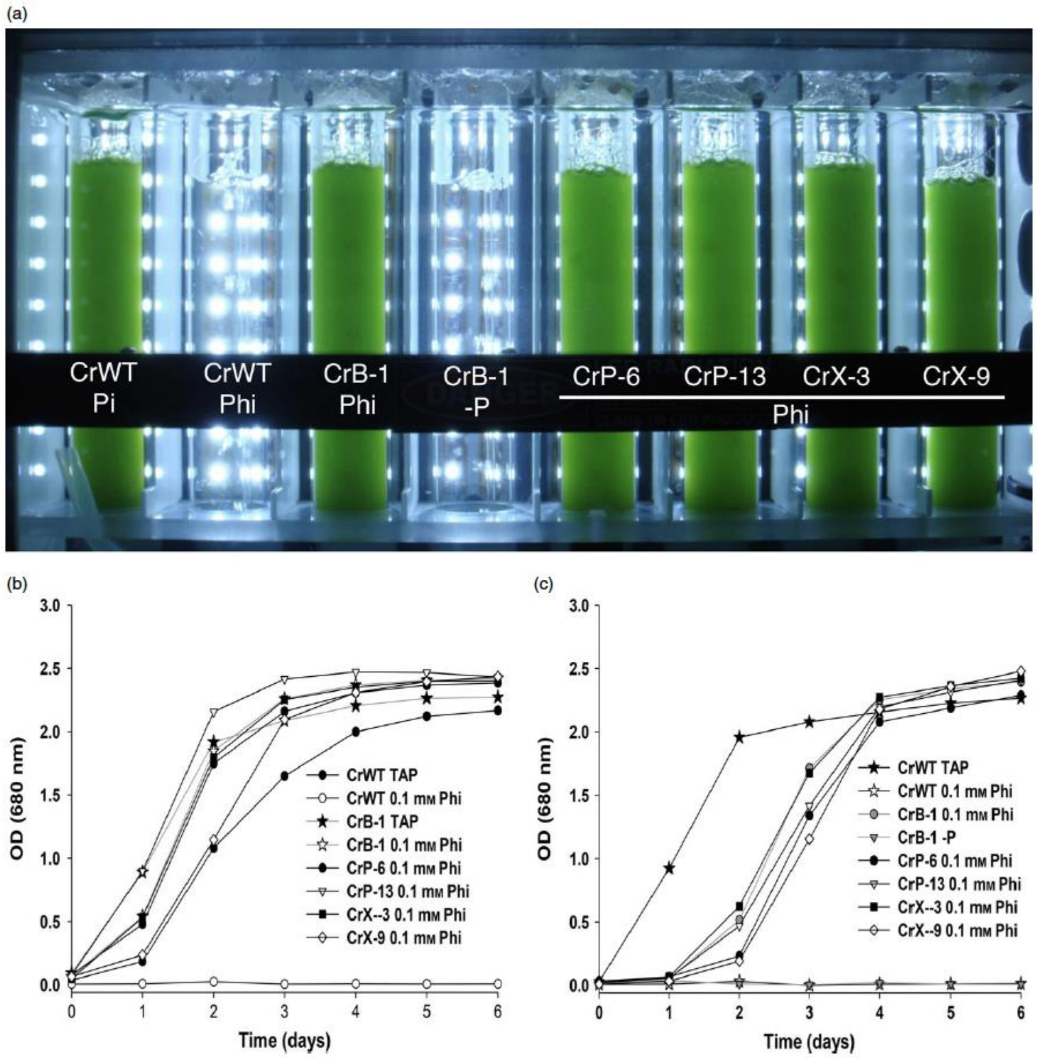
Advantages

1. A single gene can be used as selectable marker trait.
2. Reduction in the application of P-fertilizer.
3. Reduction in the application of herbicides.
4. Potential protection against fungal infections.
5. Reduction in contamination of rivers, lakes and oceans.
6. Benefits to human animal health by reducing the application of agrochemicals.
7. Less harm to native biodiversity because Phi is not a herbicide.
8. No permanent accumulation of Phi in the soil because it is naturally oxidized by atmospheric O_2 into Pi. It last only a few months (2-3) in the soil.
9. Reduced carbon emissions by replacing the application of two compounds by a single one with dual effects.

Disadvantages:

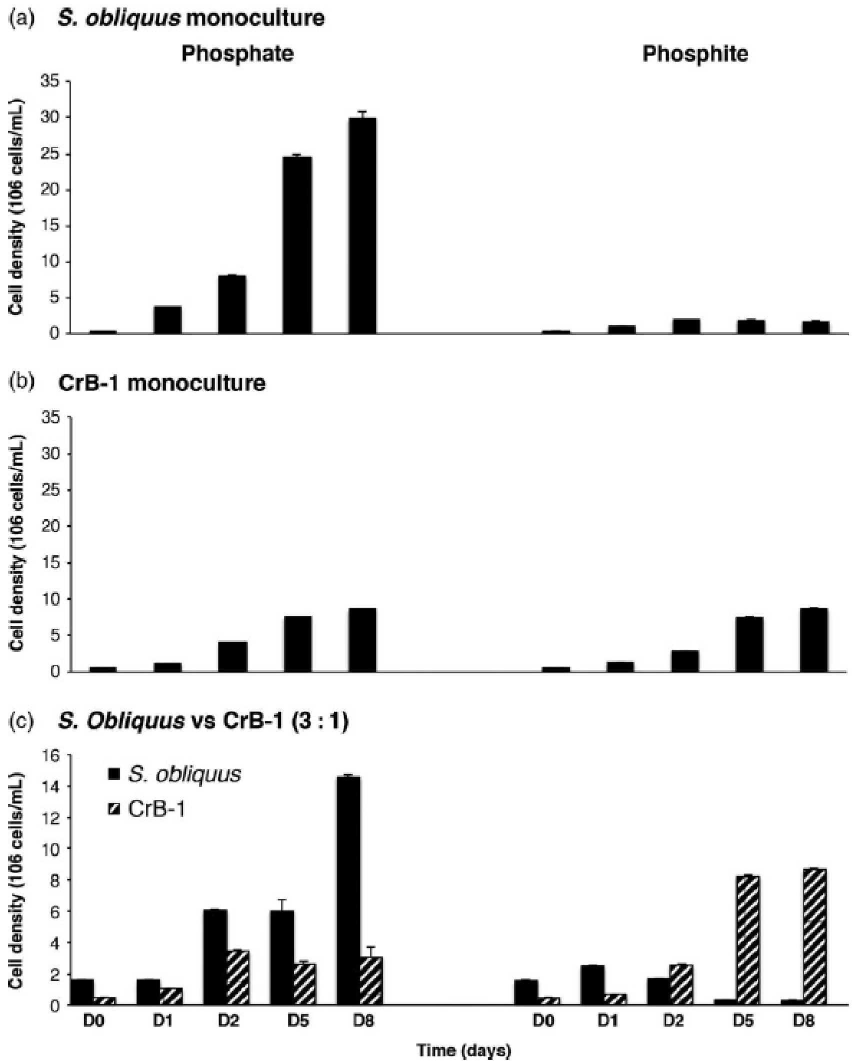
1. It does not work in soils with high Pi availability.
2. It needs to be integrated carefully to properly manage fertilization and weed control, to optimize application for different soils.

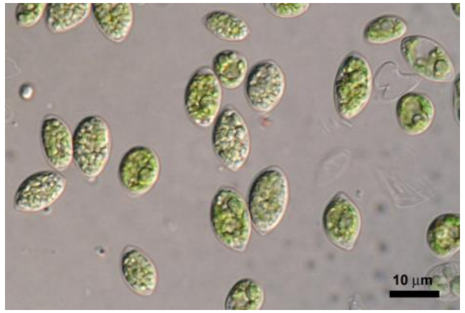
Transgenic *C. reinhartii* expressing PTXD are able of using phosphite as a sole phosphorus source

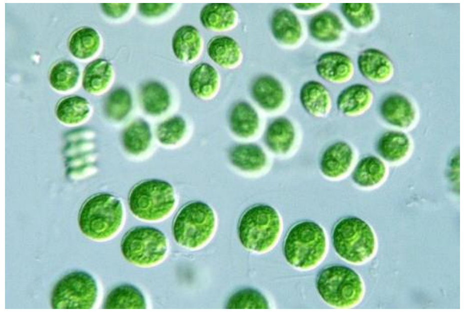


Engineered *C. reinhartii* outcompetes the faster growing *Scenedesmus obliquus* in media containing Phi as a sole P source

StelaGenomics

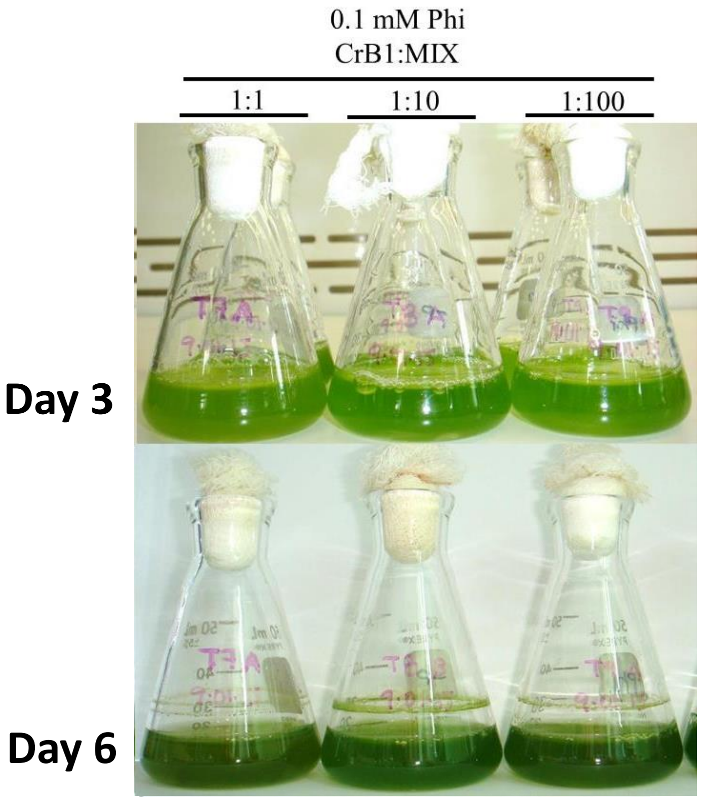






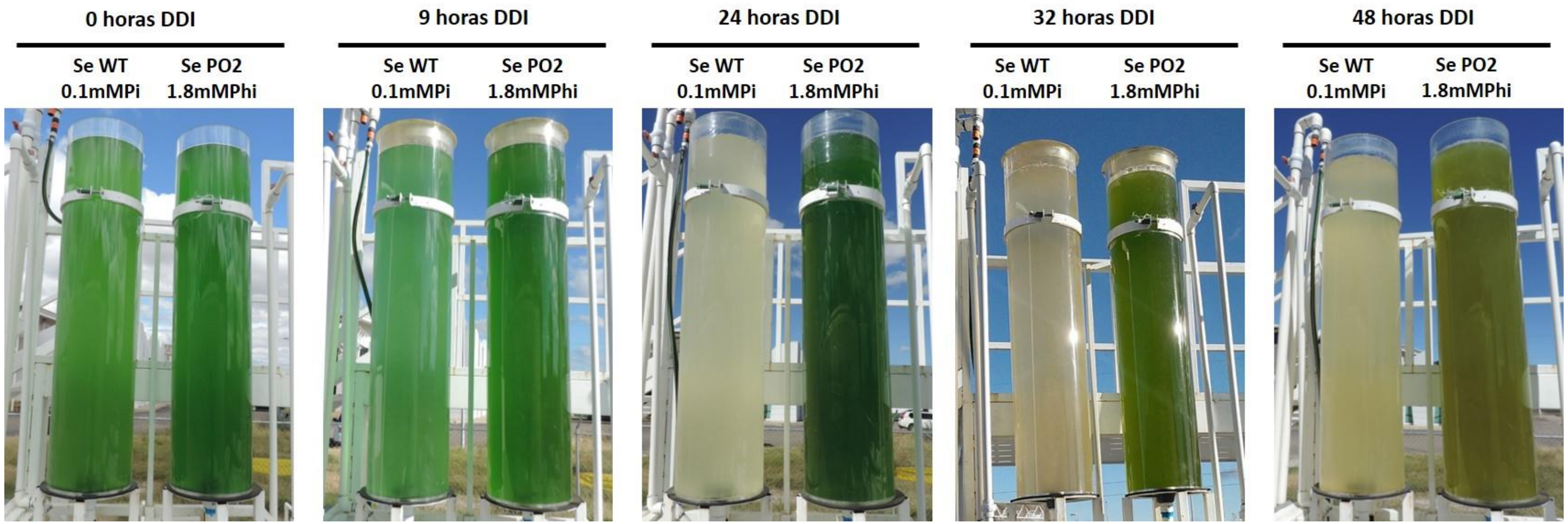
Transgenic *C. reinhartii* grown in media containing phosphite can outcompete a natural mix of bacteria and microlagae.

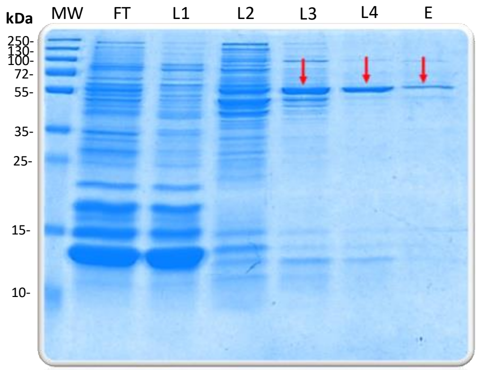
StelaGenomics



The phosphite system is also applicable for the selective growth of cyanobacteria in open air systems (*Synechococcus elongatus*)

StelaGenomics





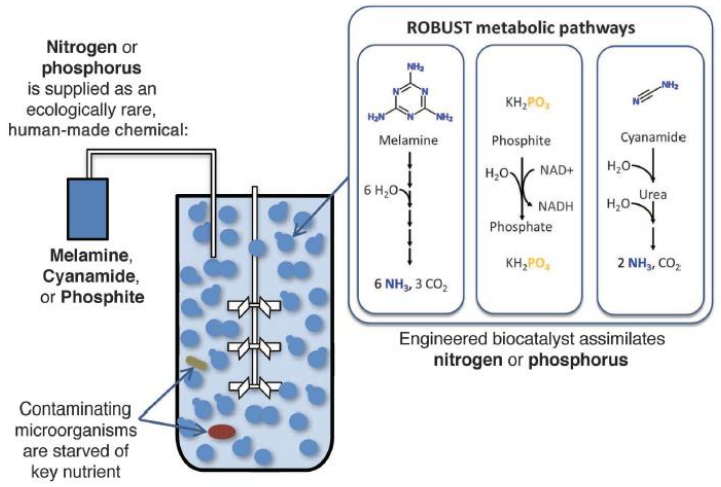
Camel chymosin

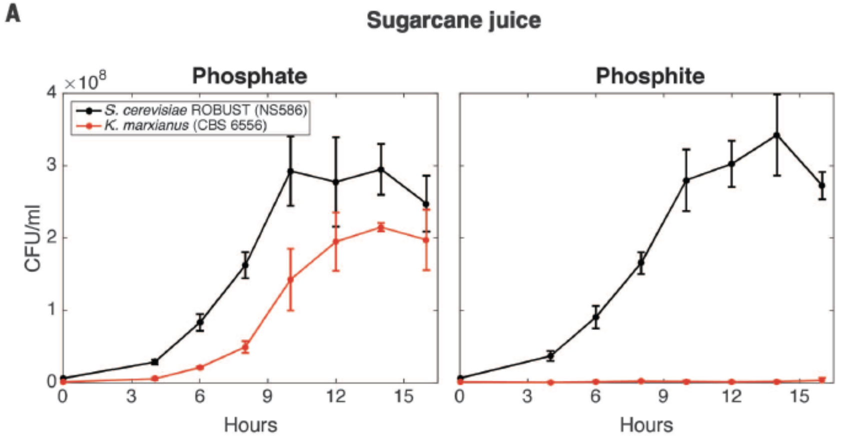
BIOENGINEERING

Science

Metabolic engineering of microbial competitive advantage for industrial fermentation processes

A. Joe Shaw,[1*] Felix H. Lam,[2] Maureen Hamilton,[1] Andrew Consiglio,[1] Kyle MacEwen,[1]
Elena E. Brevnova,[1,3†] Emily Greenhagen,[1‡] W. Greg LaTouf,[1] Colin R. South,[1§]
Hans van Dijken,[1] Gregory Stephanopoulos[1,2]





Kan Wang-Iowa State U
Kazimierz Wrobel -U Guanajuato
Keertii Rathore-Texas A&M
Eric Lyons U. Arizona
Victor Albert- SUNY-Buffalo

Funding

StelaGenomics

CONACYT

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TODAY'S AGENDA

- 8:30: **Dr Jim Elser** (ASU) Welcome and our job today.
- 8:45: Keynote: **Dr Sally Rockey** (FFAR)
- **9:30: Dr David Vaccari** (Stevens Inst of Technology) "A Substance Flow Model for Global Phosphorus"
- 10:00: Coffee & networking
- 10:30: **Dr. Luis Herrera** (CINVESTAV), GMO technology for phosphite fertilizer use
- **11:00: Dr Kevin Dooley (ASU) & Allison Thomson (Field to Market): Market drivers of nutrient sustainability**
- 12:00 – 1:30: Lunch & networking
- 12:30 – 1:00: Lunch keynote: **Dr Paul Fixen** (IPNI, retired)
- 1:30: **Ned Beecher** (Northeast Biosolids & Residuals Association), regulatory challenges with recycling organic residuals
- 2:00: **Noel Lyons** (McGill Compost) and **Dr Amir Varshovi** (GreenTechnologies), commercialization of compost and recycled fertilizer products
- 2:45: **Dr Jim Elser** (ASU) Final discussion & closing comments.
- 3:30 – 5:30: Networking time (Postino's on College Ave)

Field to Market®

Sustainable Supply Chains for Commodity Crop Sourcing

Allison Thomson, Science & Research Director

Phosphorus Forum, February 27, 2018

Meeting the Challenge

Producing enough food, fiber and fuel for more than 9 billion people by 2050, while conserving natural resources has become increasingly complex

- **50-70%** in middle class
- purchasing more protein rich foods
- doubling agricultural output
- facing a changing climate
- decreased rainfall
- extreme weather patterns
- **70%** fresh water used
- **37%** of land use
- **1/3** edible food lost or wasted

Changing Tastes

When shopping for food, consumers prize family satisfaction above all else, but increasingly, they consider sustainability as an important factor in their buying decisions.

More than

8 in 10

Americans consider sustainability when buying food and would like to see more options available that protect the environment.

Similarly, consumers are looking to companies to help them understand their impact on the environment – with

nearly 3/4

of consumers stating they want companies to do a better job explaining how their purchases impact the planet.

Increasingly, we're seeing Millennials voting with their wallets, with

6 out of 10

willing to pay more for environmentally friendly products.

Coca-Cola	• Reduce GHG emissions across value chain by 25% by 2020 • Sustainably source key agricultural ingredients by 2020 • Expand acreage in Field to Market to 1 Million acres by 2020
General Mills	• Sustainably source 100 percent of 10 priority ingredients by 2020 • Expand acreage in Field to Market to 2.5 Million acres by 2015 • Reduce GHG emissions in fertilizer management
Unilever	• Halve the GHG impact of our products across the lifecycle by 2020 • Source 100% of our agricultural raw materials sustainably by 2020 • Halve the environmental footprint of the making and use of our products as we grow our business by 2020
Walmart Save money. Live better.	• Fertilizer optimization on 14 Million acres of U.S. farmland by 2020 • Reduce emissions in our supply chain by 1 gigaton (1 billion metric tons) by 2030

Field to Market®

Field to Market: The Alliance for Sustainable Agriculture focuses on defining, measuring and advancing the sustainability of food, fiber and fuel production

Field to Market® | Uniting the Supply Chain to Deliver Sustainable Outcomes for Agriculture

AGREN
AGRIAN Ag Data from Field to Fork
AGRIBLE
Agricultural Retailers Association
AGSPRING Feeding a Changing World
American Bakers Association
The Amalgamated Sugar Company LLC White Satin
American Crystal Sugar Company
American Peanut Council
American Society of Agronomy Certified Crop Adviser
ASA American Soybean Association
ANUVIA
ADM
Ardent Mills
ASABE
AUBURN UNIVERSITY
BASF The Chemical Company
BAYER Bayer CropScience
bfa
Bio Biotechnology Industry Organization
BROWN-FORMAN
BUNGE
California Rice
Cargill
CF
CHS
C-AGG
Colorado State University
Columbia University School of Professional Studies Sustainability Management
CTIC
conservis
CONTEXT
Corn Refiners Association
cotton
CropLife America
DFA Dairy Farmers of America
Dartmouth
DOW
DUPONT PIONEER
Ducks Unlimited
Edge
EDF Environmental Defense Fund
Celebrating Environmental Initiative 25 years
FMC
Farm Journal Media
FLEISHMANHILLARD
GENERAL MILLS
Granular
GMA
HORTAU
Houston Engineering Inc.
Illinois Corn ilcorn.org
Illinois Soybean Association
Indiana Soybean Alliance
Ingredion
Innovation Center for U.S. Dairy
INTELLIFARMS
International Farming Corporation
IPNI International Plant Nutrition Institute
IAWA Iowa Agriculture Water Alliance
Iowa State University
John Deere
K-State Research and Extension
K·COE ISOM
Kellogg's
Keystone Policy Center
Land O'Lakes, Inc.
LEAF
LidoChem
LifeLine Foods
Marrone Bio Innovations
MARS
McDonald's
Michigan State University
MIT Joint Program on the Science and Policy of Global Change
MONSANTO
Mosaic
MyFarms
NACHURS
NAFA
National Association of Conservation Districts conserving natural resources for our future
NASDA
National Association of Wheat Growers
National Barley Growers Association
NCGA
National Cotton Council of America
NCFC
National Farmers Union
NMPF National Milk Producers Federation
National Sorghum Producers
Nestlé PURINA
New Leader
NC State University
Nutrien Feeding the Future
Penton Agriculture
PEPSICO
Pheasants Forever
Redox
RICELAND
The Rohatyn Group
RiceTec
Simplot
syngenta
TATE & LYLE
Texas A&M AgriLife Research | Extension
Texas Tech University
The Coca-Cola Company
The Conservation Fund
The Fertilizer Institute Nourish, Replenish, Grow
The Nature Conservancy Protecting nature. Preserving life.
The Seam
Thompson Coburn LLP
USA Rice Federation
U.S. Grains Council
USSEC U.S. Soybean Export Council
Unilever
United Soybean Board
USDA NRCS United States Department of Agriculture Natural Resources Conservation Service
University of Arkansas Division of Agriculture
The University of Georgia
N Extension
UF Extension
College of Agricultural & Life Sciences University of Wisconsin-Madison
Walmart Save money. Live better.
Western Sugar Cooperative (Grower Owned)
WestonFoods
WWF
Wrangler

Guiding Principles

- Engage the full supply chain
- Drive continuous improvement
- Focus on commodity crops
- Provide collaborative leadership
- Transparent
- Grounded in science
- Remain technology neutral
- Focused on outcomes
- Offer useful measurement tools & resources
- Coordinated and comprehensive approach

Delivering Sustainable Outcomes

Benchmarking
Sustainability Performance

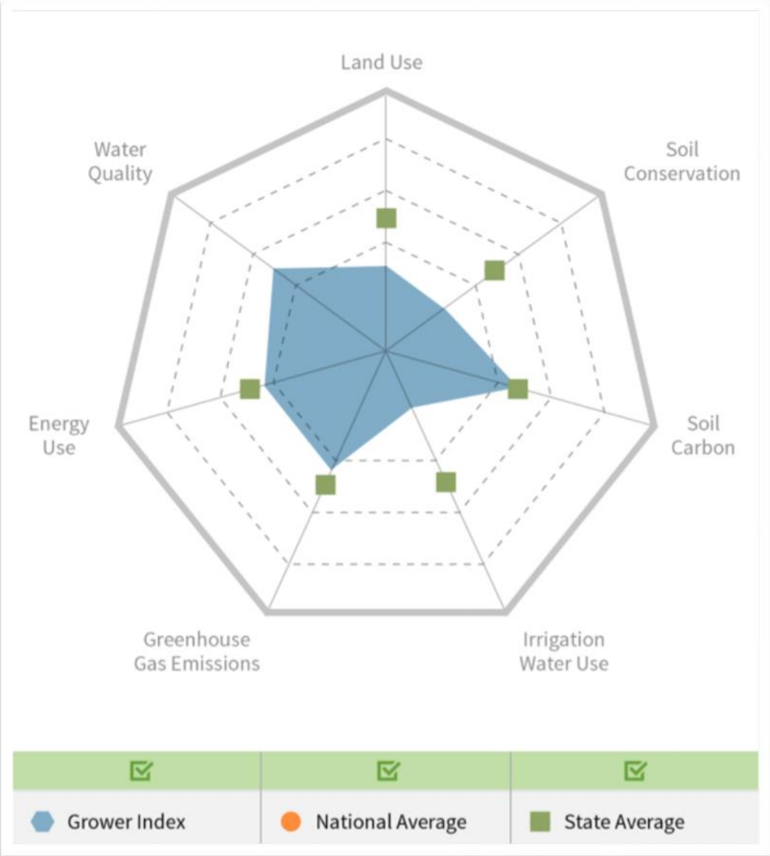
Catalyzing
Continuous Improvement

Enabling
Sustainability Claims

Fieldprint® Platform

Provides corn, cotton, potato, rice, soybean and wheat growers with a free and confidential tool to explore relationships between management practices and sustainability outcomes

- Helps growers evaluate their farming decisions in the areas of:
  - Biodiversity (Piloting)
  - Energy use
  - Greenhouse gas emissions
  - Irrigated water use
  - Land use
  - Soil carbon
  - Soil conservation
  - Water quality
- Farmers can save their information and compare the environmental impact of different management decisions on their operation



Phosphorus and Environmental Outcomes

- The Fieldprint Platform asks growers for the amount and timing of applications for organic and inorganic fertilizers

- **Energy Use and Greenhouse Gas Emissions Metrics**
  - The energy and greenhouse gas emissions associated with manufacture of inorganic fertilizer are accounted for
  - The energy and greenhouse gas emissions associated with field application of all fertilizers is accounted for

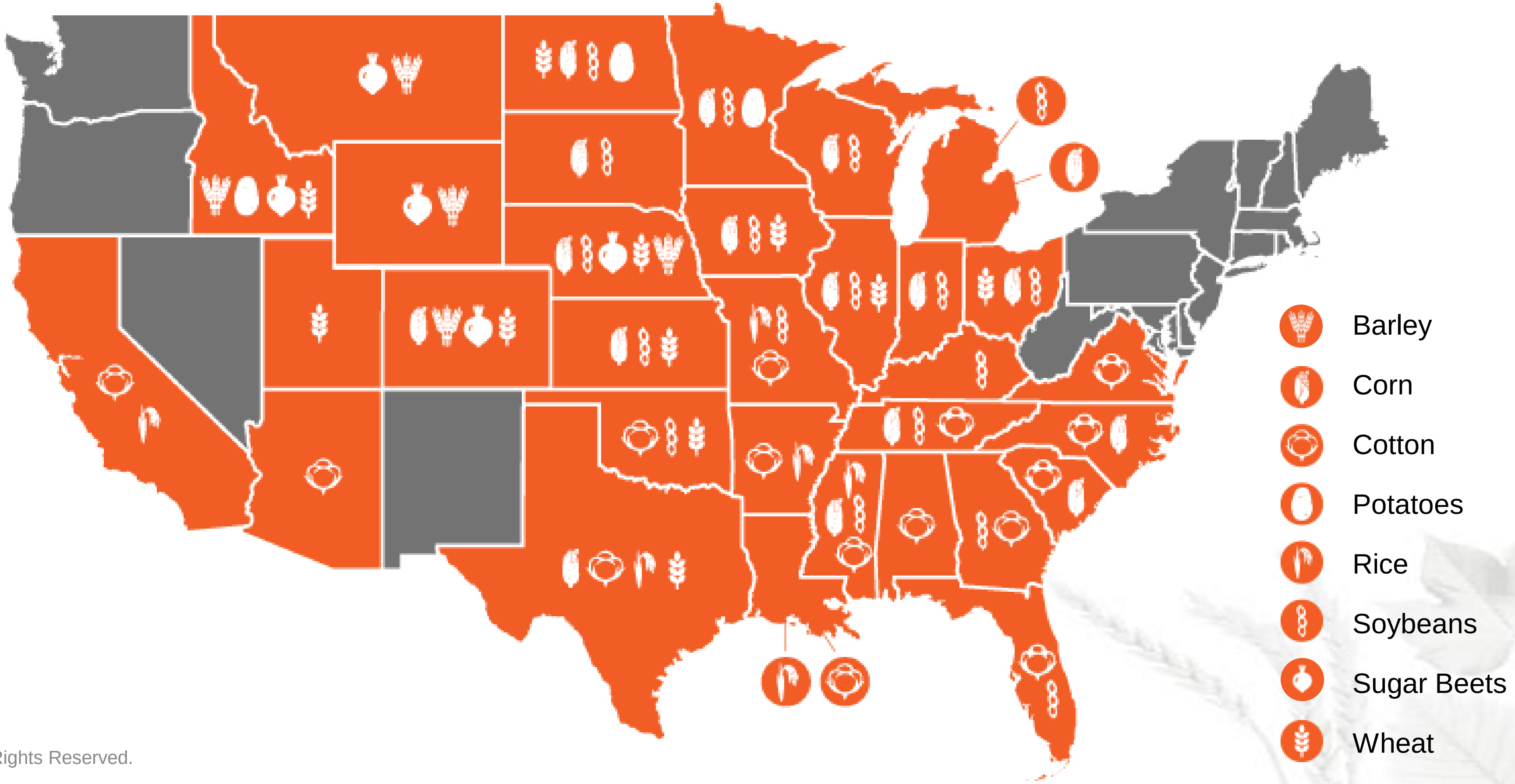
- **Water Quality Metric**
  - The amount of fertilizer applied and conservation practices adopted determine the nutrient component of the water quality score.

Field to Market efforts on water quality

- One of the eight sustainability outcomes we calculate is Water Quality
  - Using the NRCS Water Quality Index as a qualitative indicator of the risk of loss of nutrients, sediment and pesticides
  - Also include a quantitative measure of soil erosion (RUSLE2 and WEPS)
- Membership interest in a more informative, robust metric for driving continuous improvement and enabling supply chain reporting
  - Can we provide farmers with individual field performance – specifically surface and sub-surface nutrient losses – that are quantitative, accurate and actionable?
- Embarked on efforts to develop and test ideas for quantitative metrics based on scientific models
  - Initial proof of concept (2016)
  - Review of available tools and data (2017)
  - Field level pilot project (2018)

45 Fieldprint® Project Collaborations

Growers and members of the food, fiber and fuel value chain are partnering to demonstrate the value that outcomes-based sustainability metrics and the Fieldprint Platform bring to promoting continuous improvement in sustainability outcomes and helping advance more sustainable production.



Field to Market 2017 Collaboration of the Year: Kellogg's Origins Great Lakes Fieldprint Project

Kellogg's partnering with Syngenta and The Nature Conservancy

- Using the Field to Market Metrics to help farmers understand their sustainability outcomes
- Training Certified Crop Advisors through sponsorship of an RCPP in the watershed, ensuring technical assistance and cost-share programs are available to farmers to improve on their sustainability scores
- Annual grower workshop hosted by project partner organizations to share sustainability results and connect growers to additional resources
- Focusing on soil health (cover crops and reduced tillage) and nutrient management practices to improve water quality
- 7000 acres of soft winter wheat have been enrolled in the program
- Kellogg's can use the aggregate results in sustainability reporting and claims for their products

"To me, the real definition of 'sustainability' is ensuring that my kids are going to have somewhere to farm," said Rita Herford, participating wheat farmer, Minden City, Michigan. "It's doing things right, it's doing things environmentally friendly, keeping the soil healthy, replenishing nutrients into the soil, because if we don't have land to farm on, if we don't keep that quality up, we don't have a farm."

Conservation Technology Information Center leads project in Big Pine Creek Watershed

- Project partners include all elements of the supply chain:
  - Corn and soybean farmers, Indiana Soybean Alliance, National Soybean Board
  - Corporate members Tate & Lyle, Coca-Cola and Land O' Lakes
  - Conservation and technical assistance from The Nature Conservancy, local Soil & Water Conservation Districts, and NRCS
- Participating farmers required to enter data and meet with a Certified Crop Advisor to evaluate results and opportunities.
- Eligible and interested growers connected with cost share opportunities for conservation practice adoption and other NRCS programs.
- > 2000 acres enrolled in 2017

Independent Verification of Sustainability Claims

Collaboration and transparency within the supply chain is key to answering consumer questions on where and how their food, fiber and fuel are produced.

Field to Market supports the food and agriculture in answering these questions by aggregating field-level data in a standardized and anonymized fashion to make three types of sustainability claims:

Participation Claims

Measurement Claims

Impact Claims

Field to Market and Phosphorus

- **Water quality:** Moving towards adoption of improved NRCS tools and an eventual quantitative metric
  - Better characterization of the specific water quality risk
- **4R Collaboration:** Working with IPNI, TFI and others to advance the science and adoption of 4R management practices
  - Better guidance on what practices lead to improvements
  - Better measurements to give credit for improvements
- **Expanding the program**: Additional crops and cropping systems; account for other crop amendments and any difference in the energy/resource cost of production
- **Science Engagement**: Continue to collaborate with the scientific community on best representation of the environmental impacts resulting from crop management.

Thank You

For More Information

visit **www.fieldtomarket.org**

athomson@fieldtomarket.org

Sustainability Data in Agricultural Supply Chains

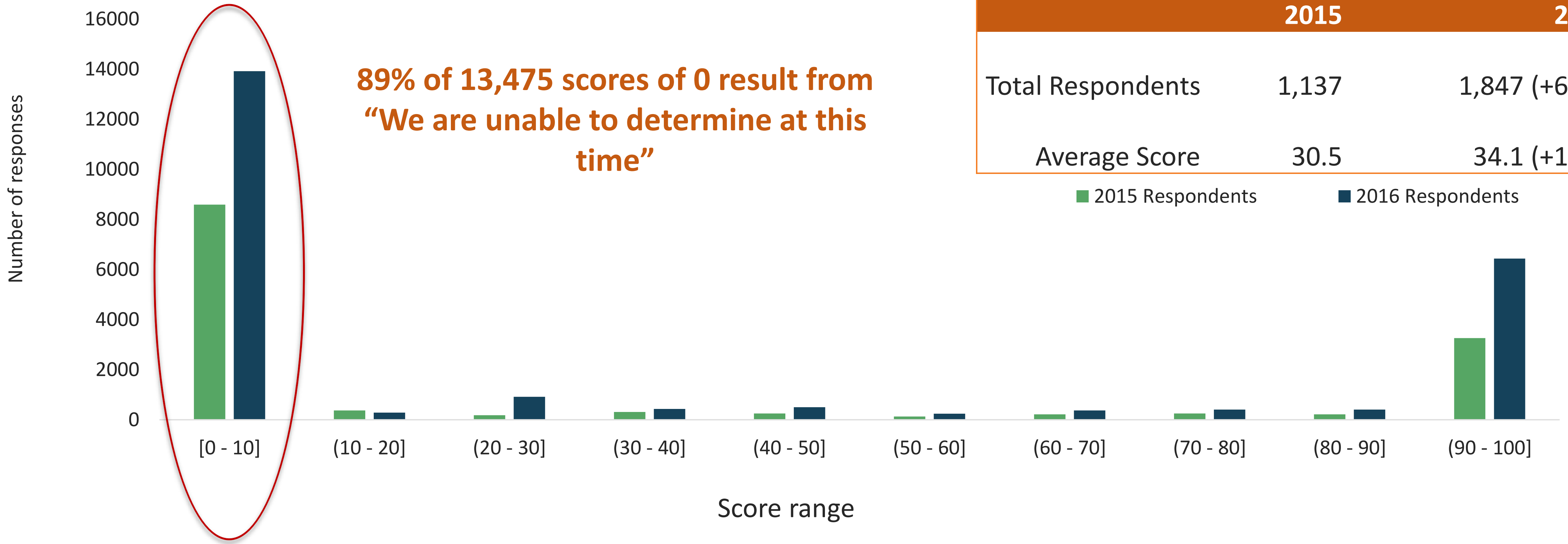
Dr. Kevin Dooley, Chief Scientist, TSC

February 2018

The “I don’t know” barrier in Walmart Sustainability Index

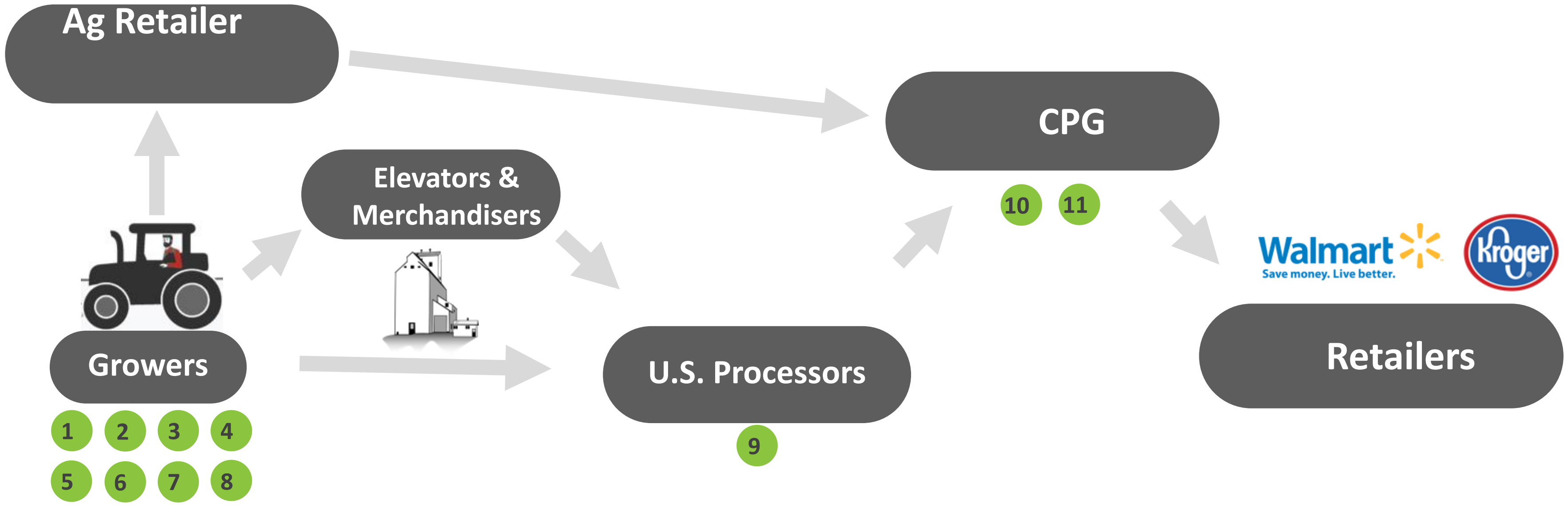
Food, Beverage, and Ag Products: 2015-16 Data

	2015	2016
Total Respondents	1,137	1,847 (+62%)
Average Score	30.5	34.1 (+12%)



Challenge: As commodities move downstream, sustainability data is left behind

Current TSC's KPI survey efforts highlight a breakdown in the ability for supply chains to address on-farm characterization stemming from a number of sources.



Sustainability Challenges Identified by The Sustainability Consortium

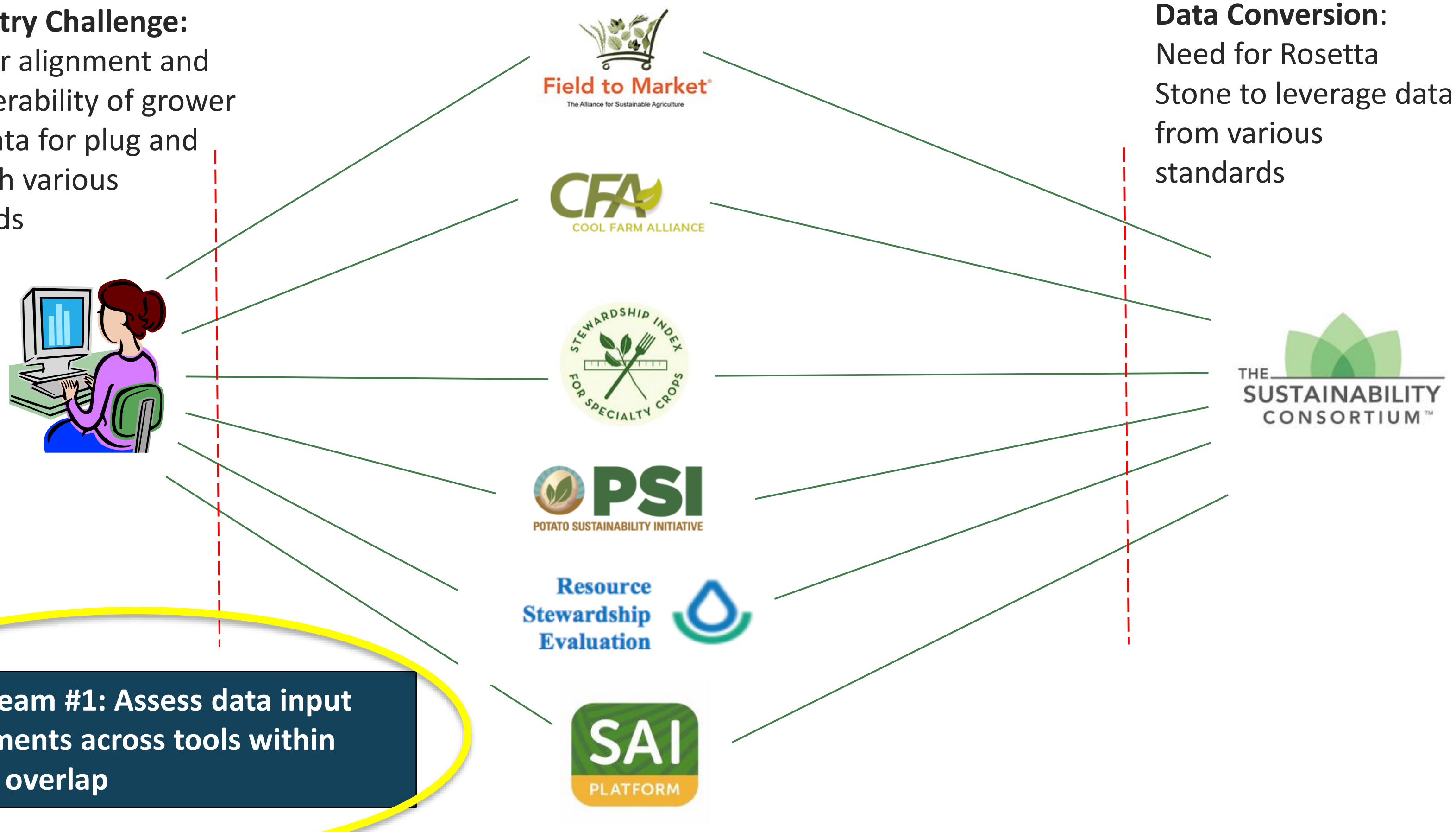
1 Energy consumption	4 Pesticide application	7 Water use	10 Energy consumption
2 Fertilizer application	5 Soil management	8 Worker health & safety	11 Water use
3 Land transformation	6 Supply chain traceability	9 Worker health & safety	

Data landscape mapping in Ag supply chains

Enhancing Data Flows through Interoperability of Systems

- **Traceability and data interoperability only first step**
- **Need to create incentives to engage in information request**
- **Need to create incentives, address barriers to adoption of sustainable ag practices**

Data Entry Challenge:
Need for alignment and interoperability of grower input data for plug and play with various standards



Data Conversion:
Need for Rosetta Stone to leverage data from various standards

Workstream #1: Assess data input requirements across tools within areas of overlap

A critical challenge for the ag supply chain is streamlining data entry for growers and converting this information into a useable format for retailers

Supply network mapping exercise

What are the market incentives, barriers, and solutions to adoption of more sustainable phosphorus practices?

1. Form into small teams
2. Draw a supply network for a particular commodity, from farm to retail to final disposition
   - Nodes are organization types (e.g. grower)
   - Arrows represent flow of material, information
3. Use network as basis to answer discussion question
4. Report out

TSC Summit 2018

Registration is open!

Tuesday, May 1, 11:00am-5:30pm - FREE

Why Brands and Retailers Need Farm-Level Sustainability Data: Use cases for IT solutions

- This session will highlight the need for IT solutions to mobilize data across farm, brands, and retailers and will also provide the business case for you to communicate the opportunities for software and system solutions in the agricultural data space to your company's sustainability and procurement teams
- Hear from brands and retailers about their needs for farm data – why they want it, how they use it, and how it can help them achieve their sustainability goals and commitments
- Learn from growers who view sustainability as a business opportunity and how the data help with farm management decision making

Wednesday & Thursday, May 2-3:
One hour sessions related to agriculture

- How Can TSC's New Deforestation Model Help You Meet 2020 Zero Deforestation Commitments?
- Sustainable Commodities Supply Chain Report and Framework in Action Workshop
- From the Ground Up: Soil to Denim
- Corporate Investment in Smallholder Agriculture: A Business Case for Reducing Supply Risk and Improving Livelihoods
- Cases & Conversations: Examining Water Solutions Across Sectors