
“Eutrofización y biogeoquímica ambiental del fósforo”
Curso de posgrado
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UPEP
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Comienzo 8 de abril 2024. (intensivo/ presencial - distancia)
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P en la Biósfera

CURE Centro Universitario Regional del Este

FACULTAD DE AGRONOMÍA

UPEP Unidad de Posgrados y Educación Permanente

PEDECIBA MEC-UDELAR

Dr. Guillermo Goyenola goyenola@gmail.com 04/2024

“La historia de la ciencia
es la ciencia misma.”

Von Goethe (1749-1832)

738 *K. Ashley et al. / Chemosphere 84 (2011) 737–746*

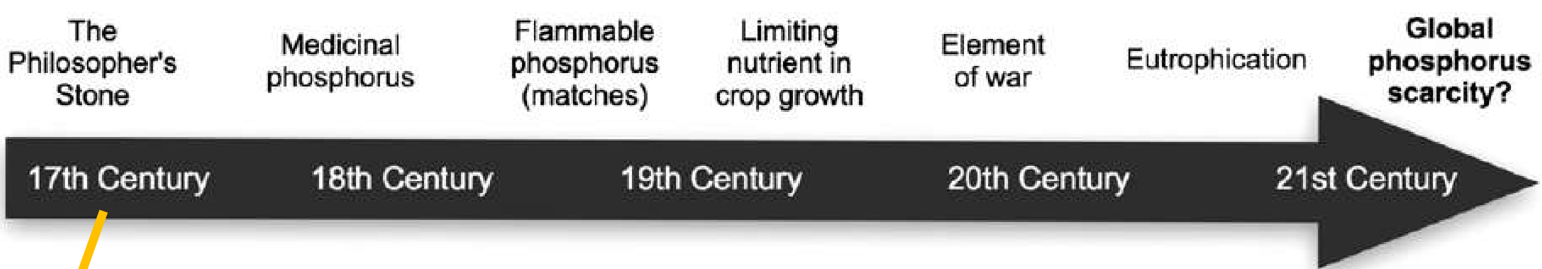
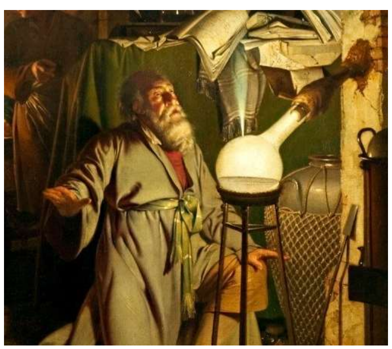
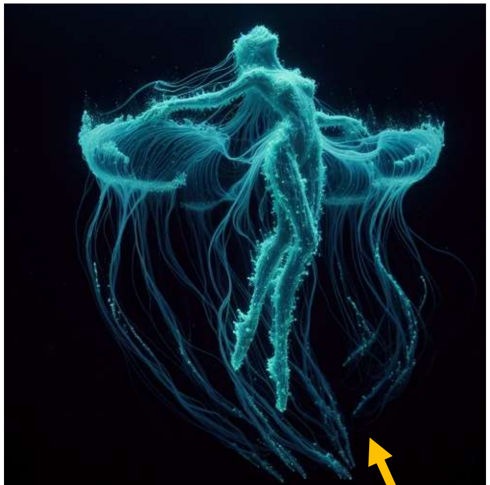
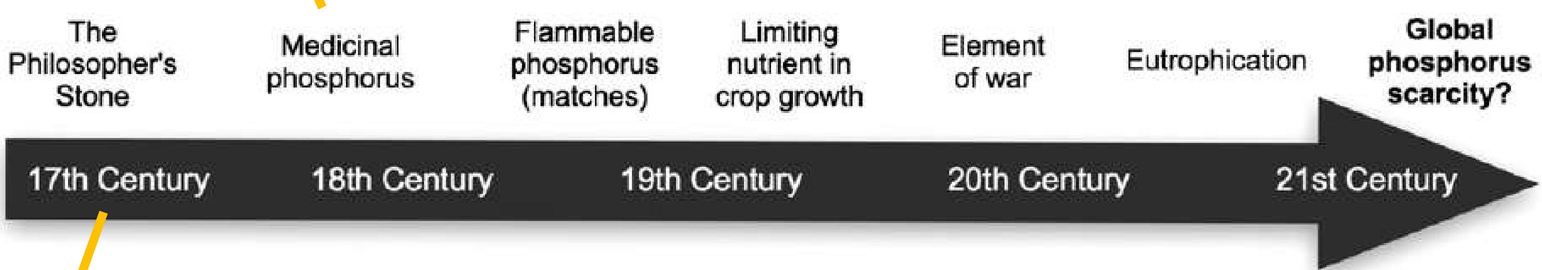


Fig. 1. The evolution of phosphorus use and abuse: from the Philosopher's Stone to use in war, food production, and more recently implicated in water pollution. A new emerging discourse of the 21st century may be global phosphorus scarcity. *Source*: Cordell (2010).



Ashley, K., D. Cordell and D. Mavinic (2011). "A brief history of phosphorus: From the philosopher's stone to nutrient recovery and reuse." Chemosphere 84(6): 737-746.





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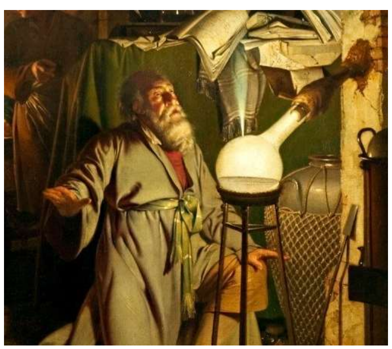
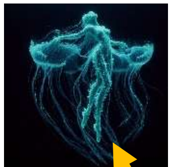
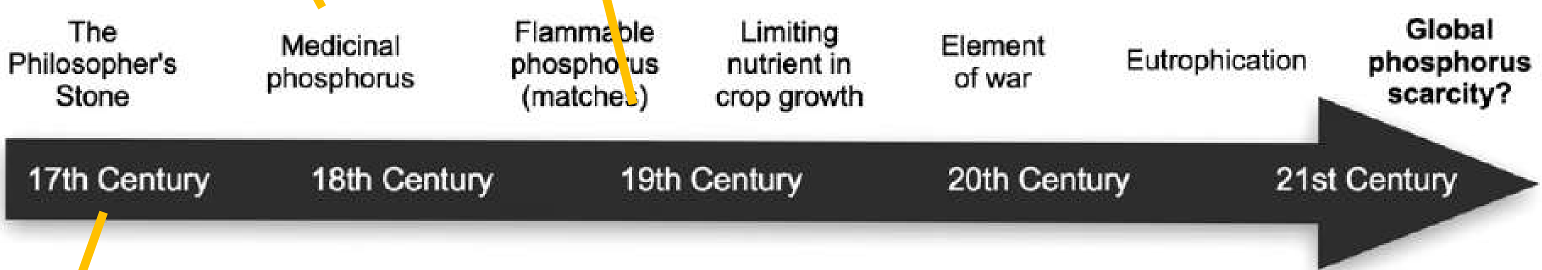


https://edu.rsc.org/feature/the-medicinal-history-of-phosphorus/2020257.article

1802
von Humboldt





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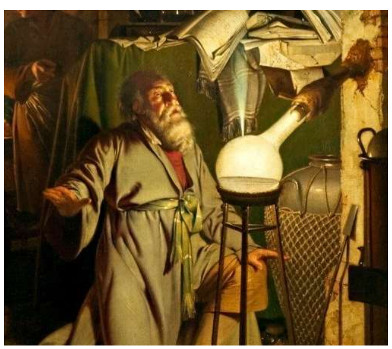
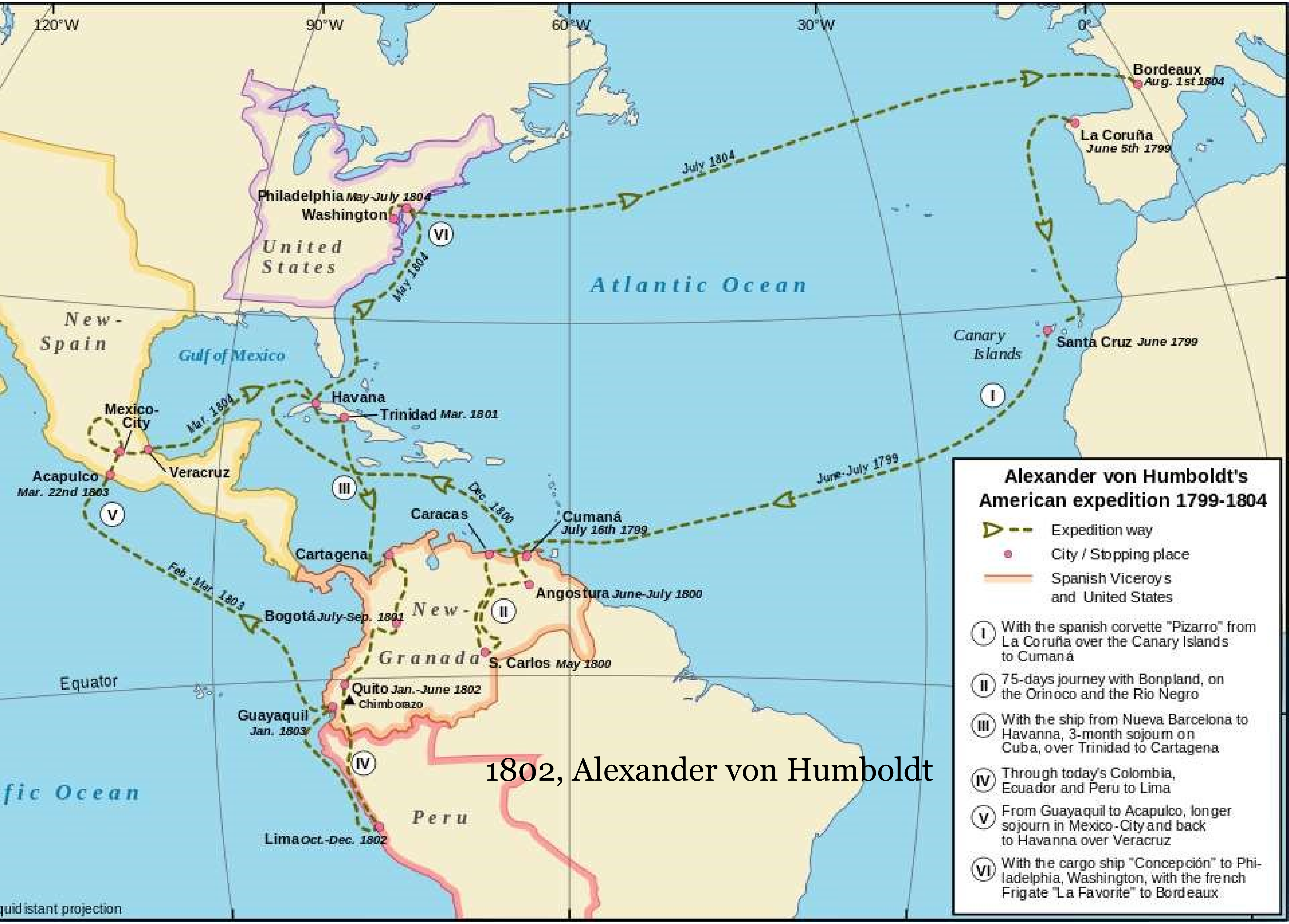


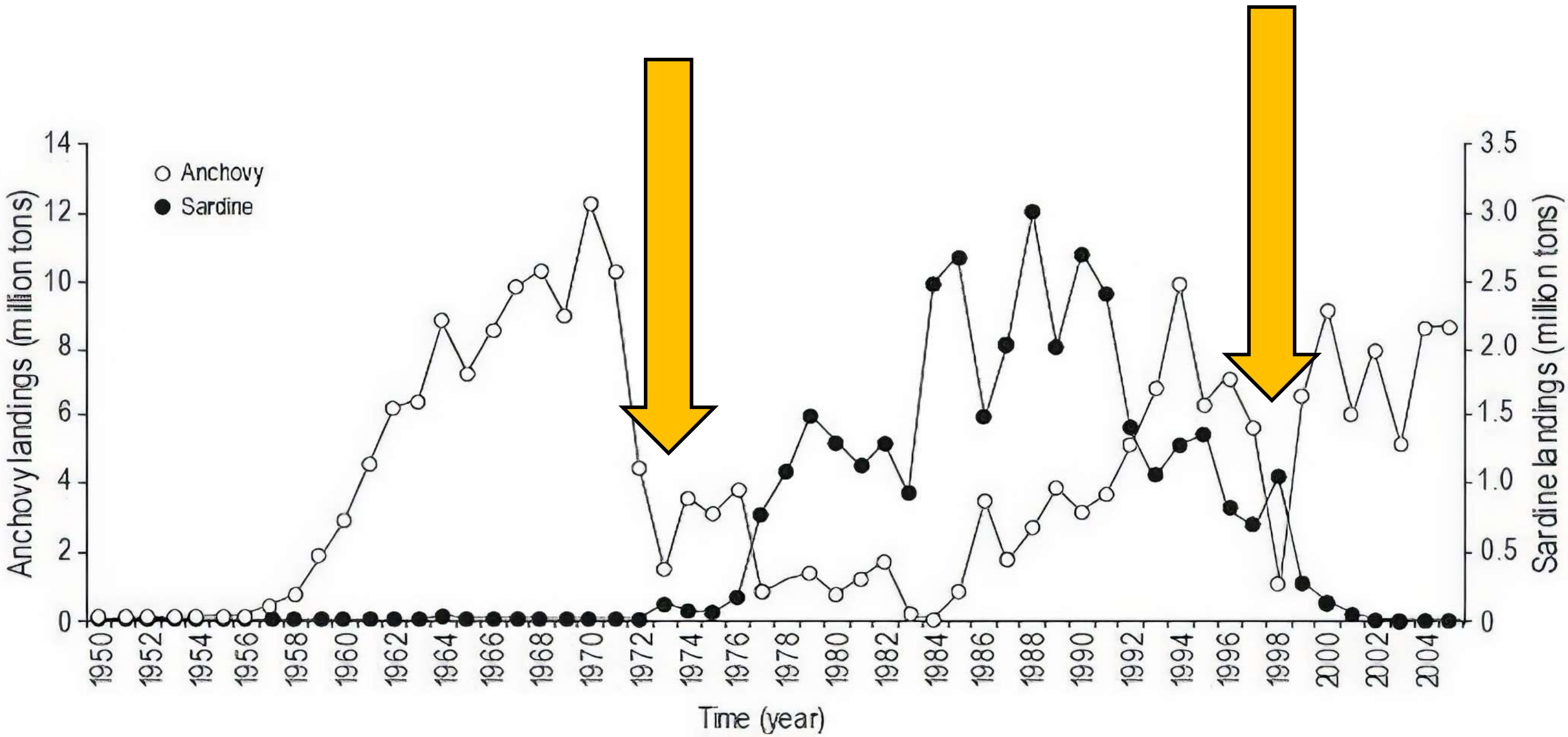


1802, Alexander von Humboldt

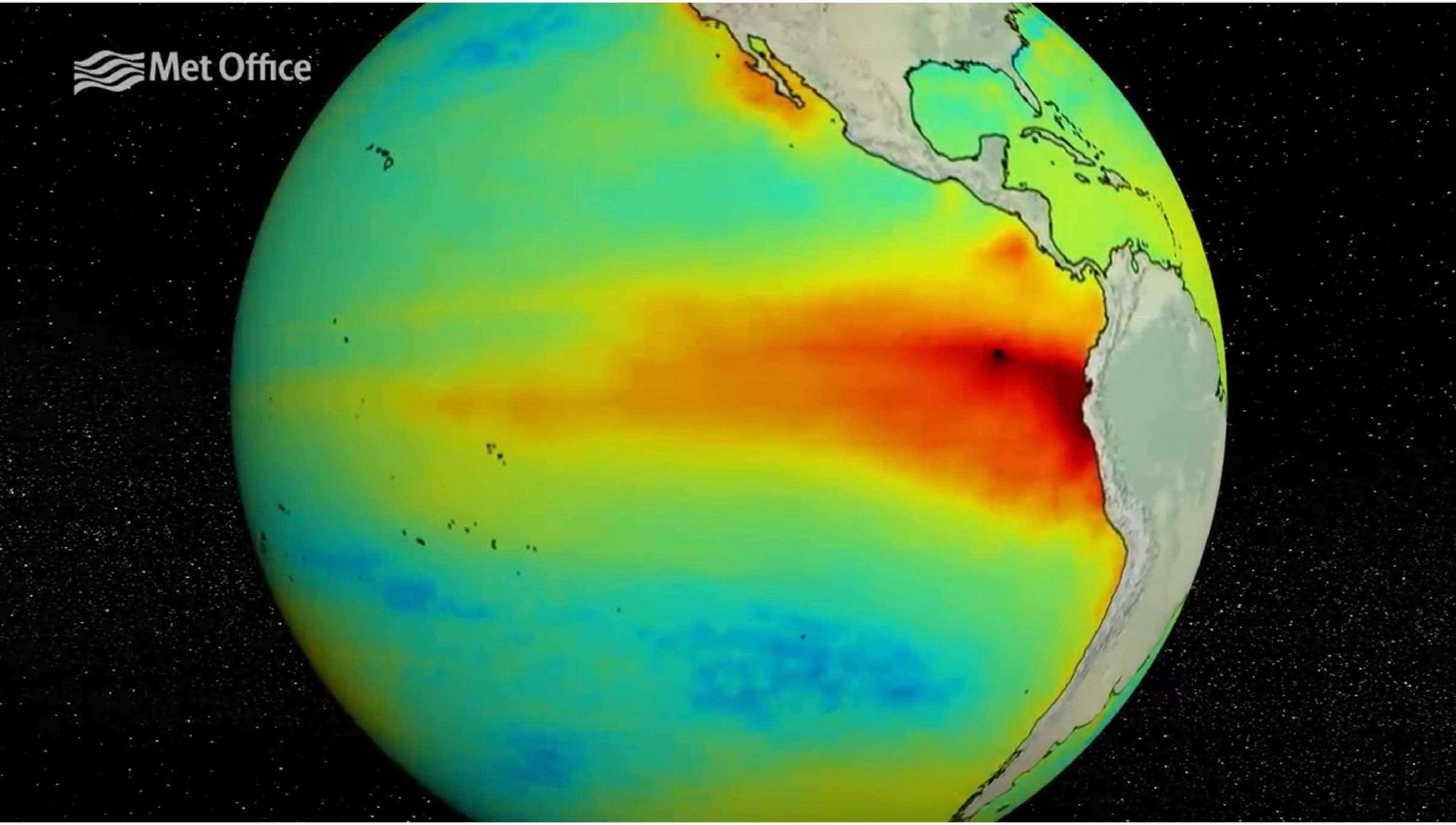
Cormorant guanay
(Leucocarbo bougainvillii)

Engraulis ringens

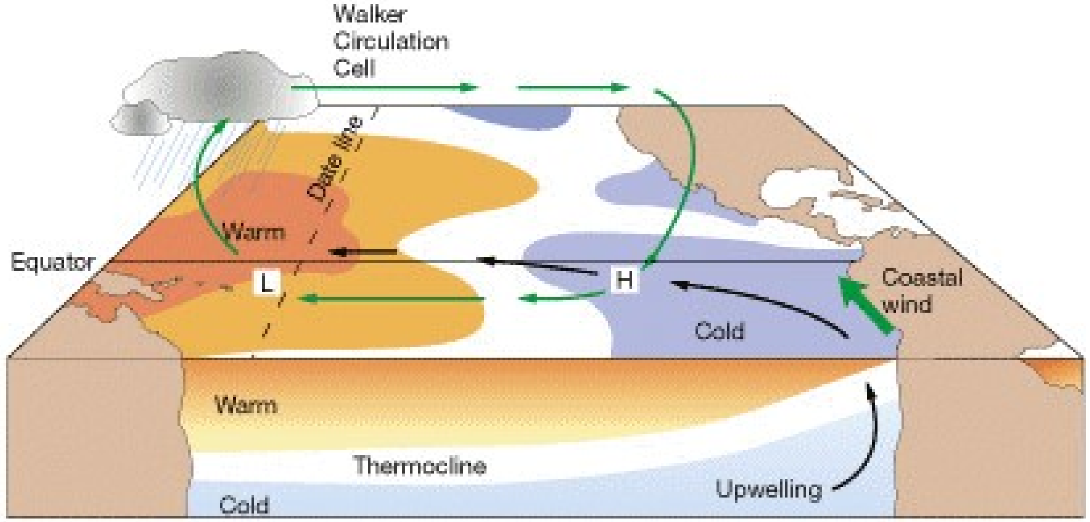
Sardinops sagax



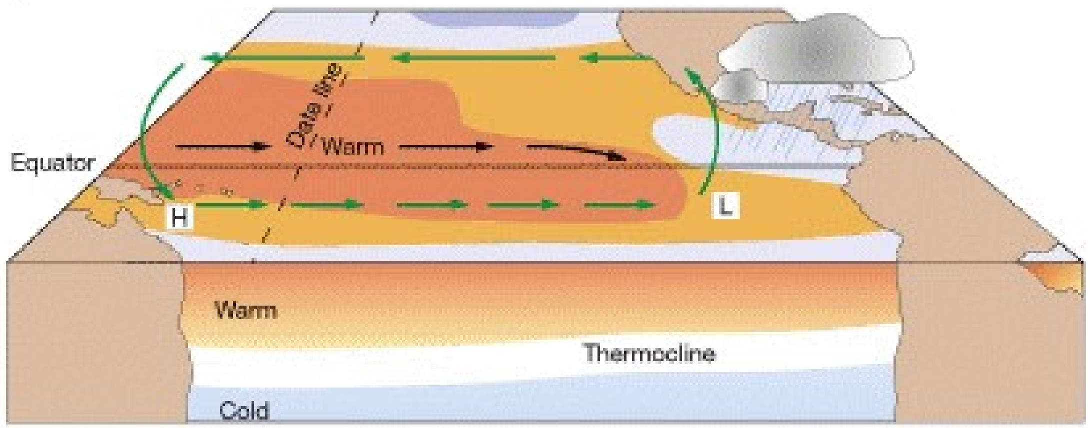
Cárdenas-Quintana et al 2015



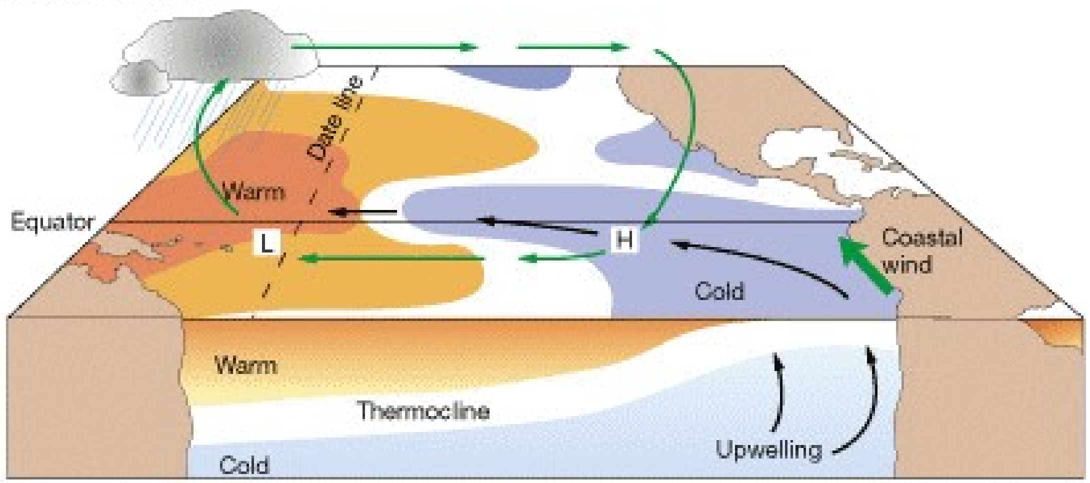
https://youtu.be/WPA-KpldDVc?si=_-CO1laY01Yasohy&t=189



(a) Normal conditions

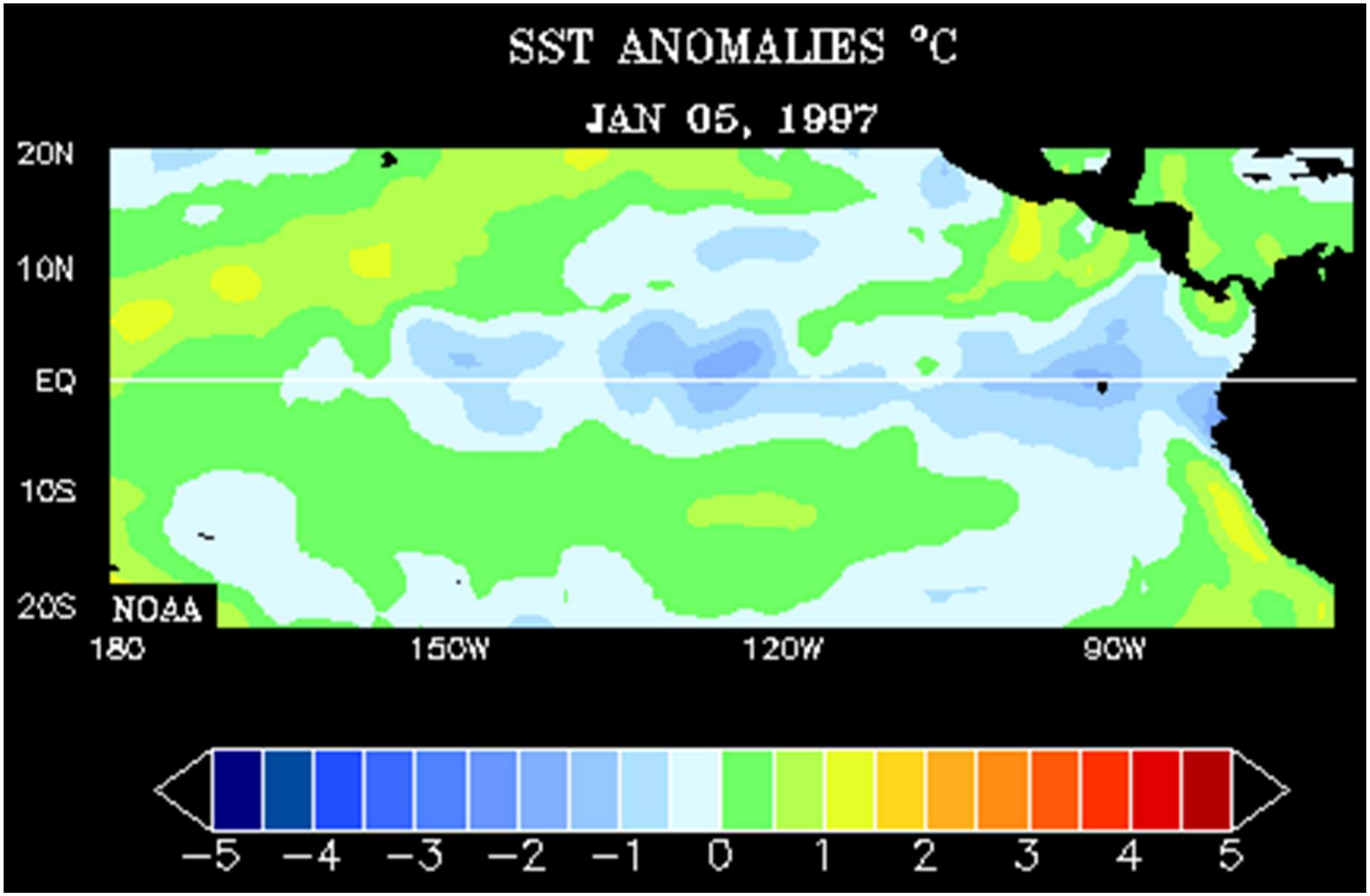


(b) El Niño conditions



(c) La Niña conditions

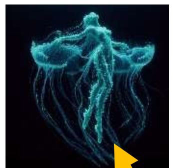
El niño 1997-1998

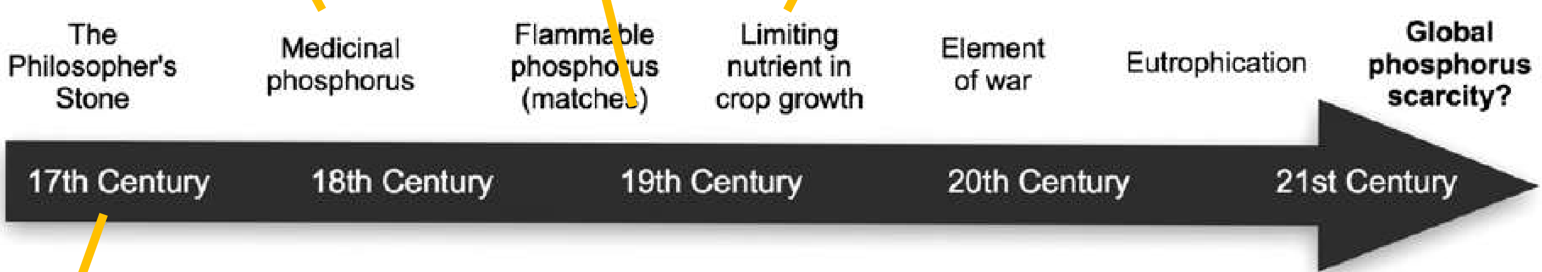


http://www.srh.noaa.gov/tbw/?n=spanishtampabayelninopage#

1802
von Humboldt

1840





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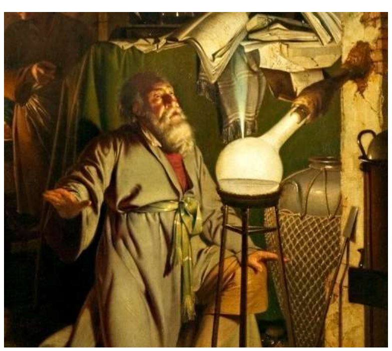
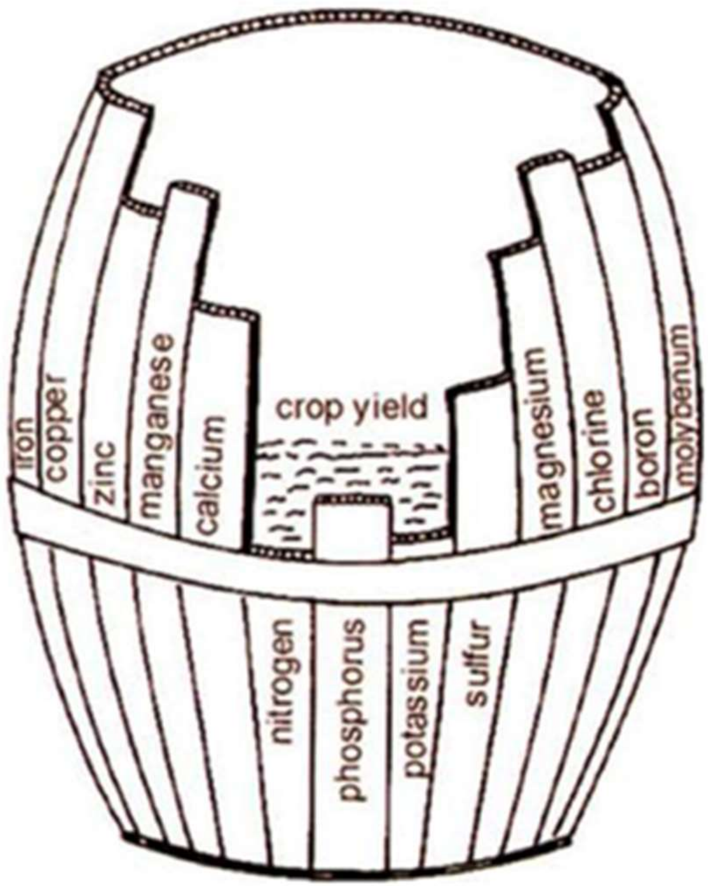
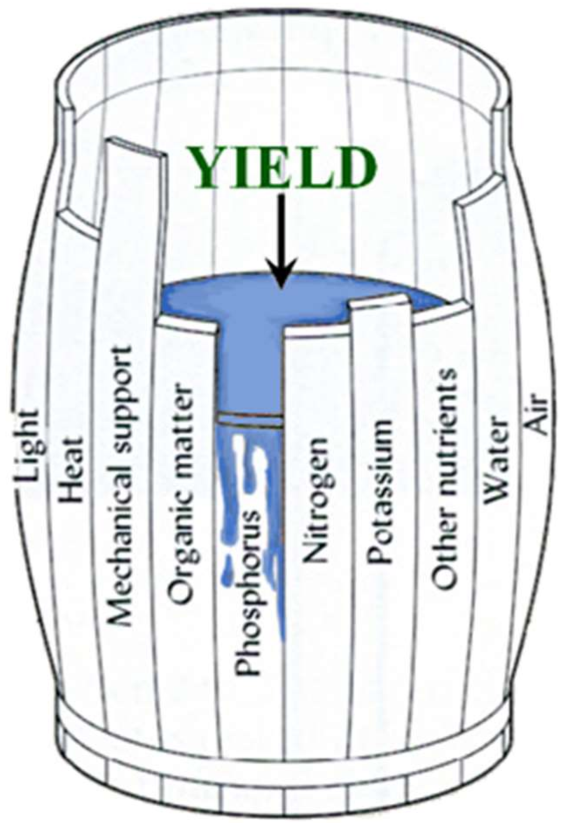


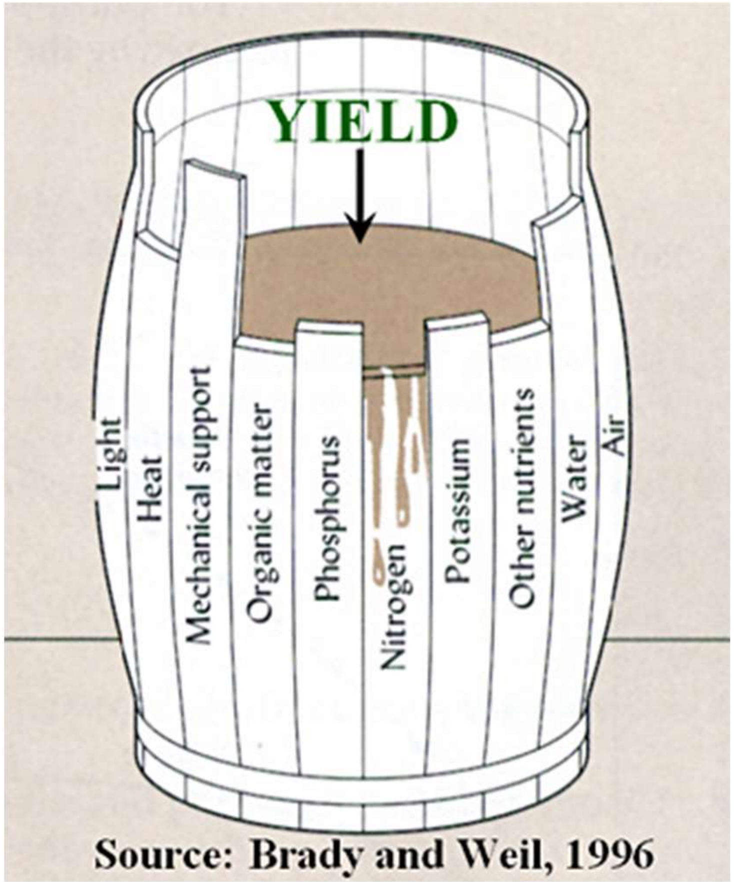
Ley del mínimo de Liebig



¿Cuál es la escala con la que se mide la altura de las tablas?

Carl Sprengel / Justus von Liebig





Relación demanda/disponibilidad

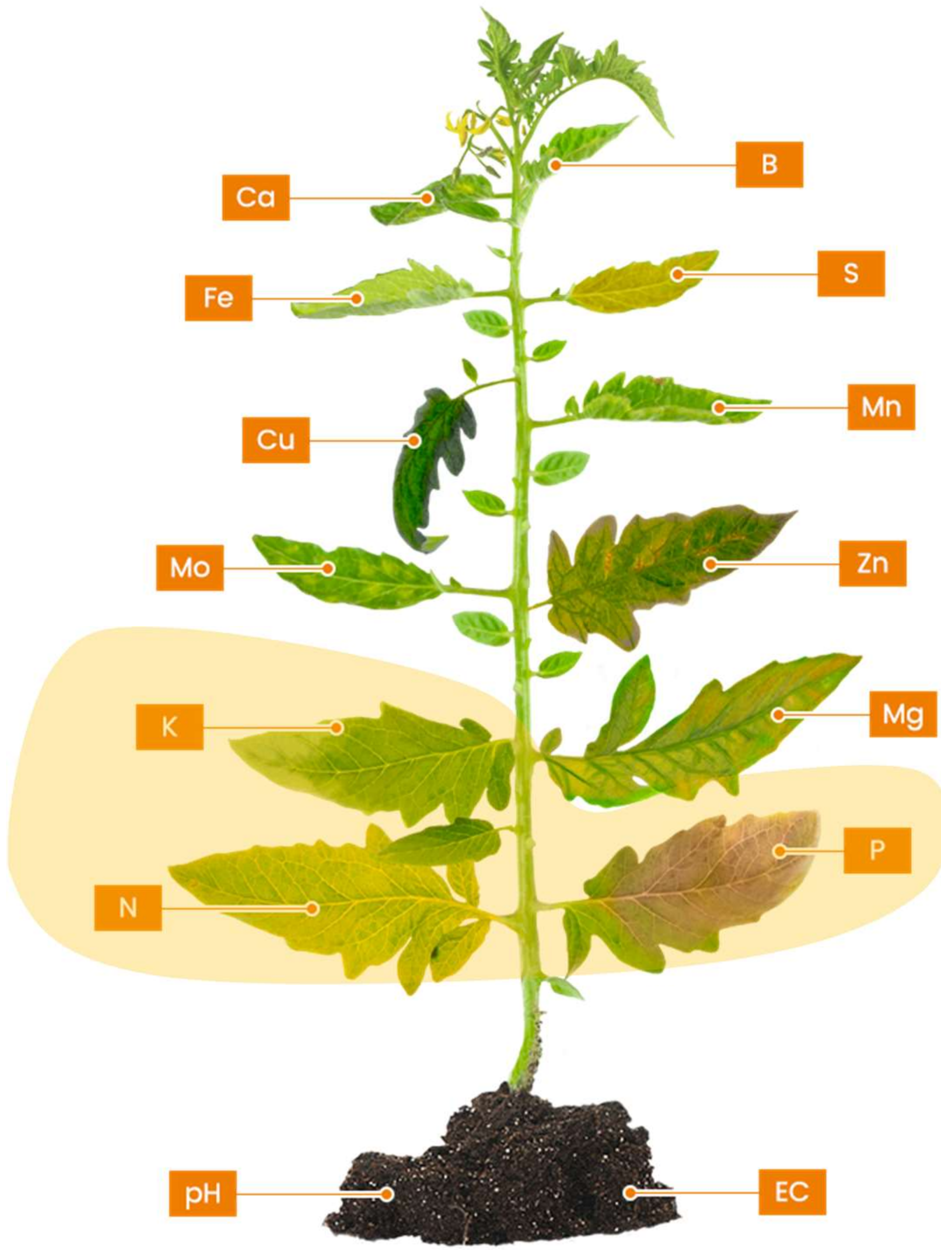
nutrientes

TABLE 36.1

Mineral Elements Required by Plants

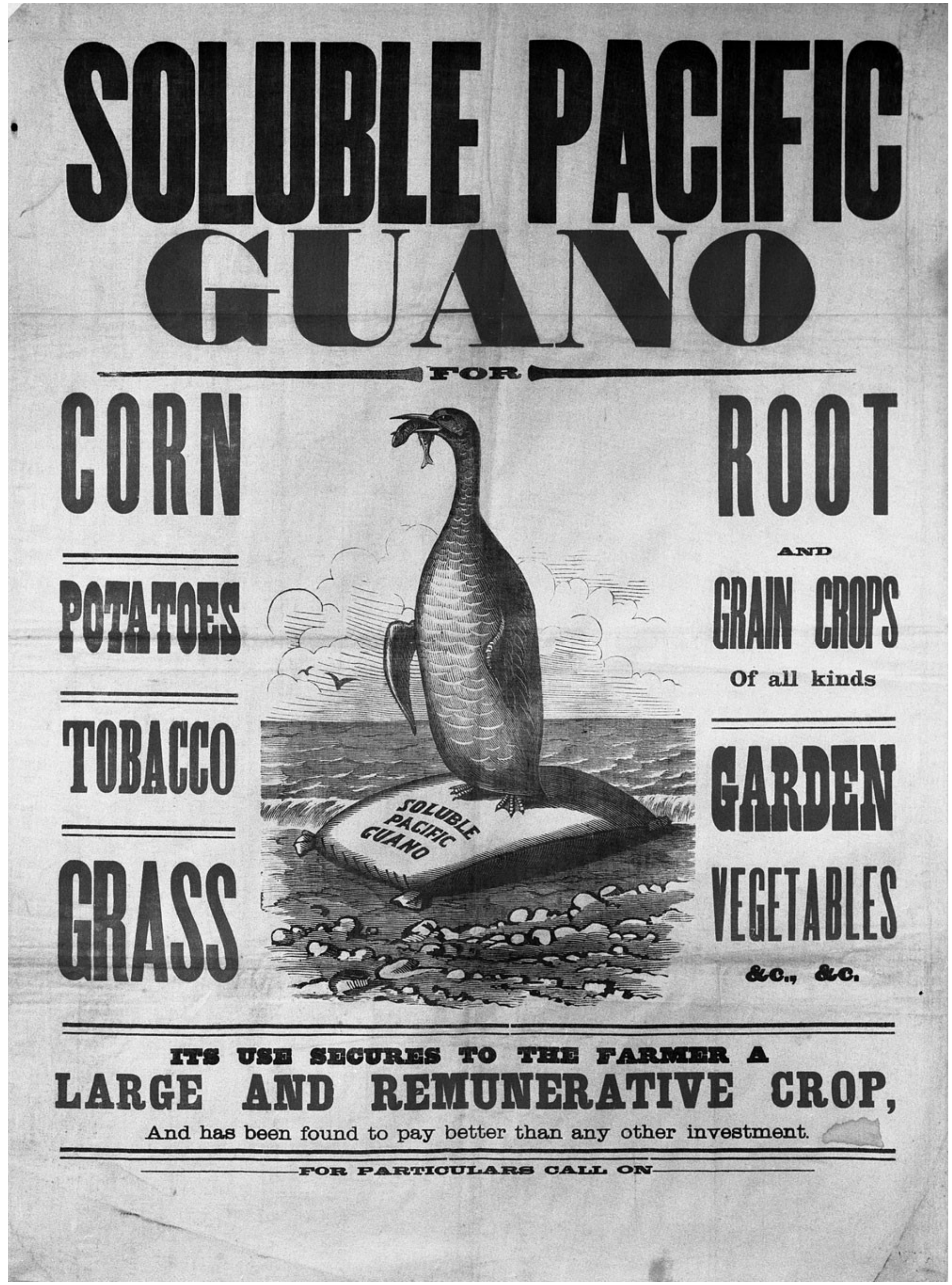
ELEMENT	ABSORBED FORM	MAJOR FUNCTIONS
MACRONUTRIENTS		
Nitrogen (N)	NO_3^- and NH_4^+	In proteins, nucleic acids, etc.
Phosphorus (P)	$H_2PO_4^-$ and HPO_4^{2-}	In nucleic acids, ATP, phospholipids, etc.
Potassium (K)	K^+	Enzyme activation; water balance; ion balance; stomatal opening
Sulfur (S)	SO_4^{2-}	In proteins and coenzymes
Calcium (Ca)	Ca^{2+}	Affects the cytoskeleton, membranes, and many enzymes; second messenger
Magnesium (Mg)	Mg^{2+}	In chlorophyll; required by many enzymes; stabilizes ribosomes
MICRONUTRIENTS		
Iron (Fe)	Fe^{2+} and Fe^{3+}	In active site of many redox enzymes and electron carriers; chlorophyll synthesis
Chlorine (Cl)	Cl^-	Photosynthesis; ion balance
Manganese (Mn)	Mn^{2+}	Activation of many enzymes
Boron (B)	$B(OH)_3$	Possibly carbohydrate transport (poorly understood)
Zinc (Zn)	Zn^{2+}	Enzyme activation; auxin synthesis
Copper (Cu)	Cu^{2+}	In active site of many redox enzymes and electron carriers
Nickel (Ni)	Ni^{2+}	Activation of one enzyme
Molybdenum (Mo)	MoO_4^{2-}	Nitrate reduction

LIFE 8e, Table 36.1

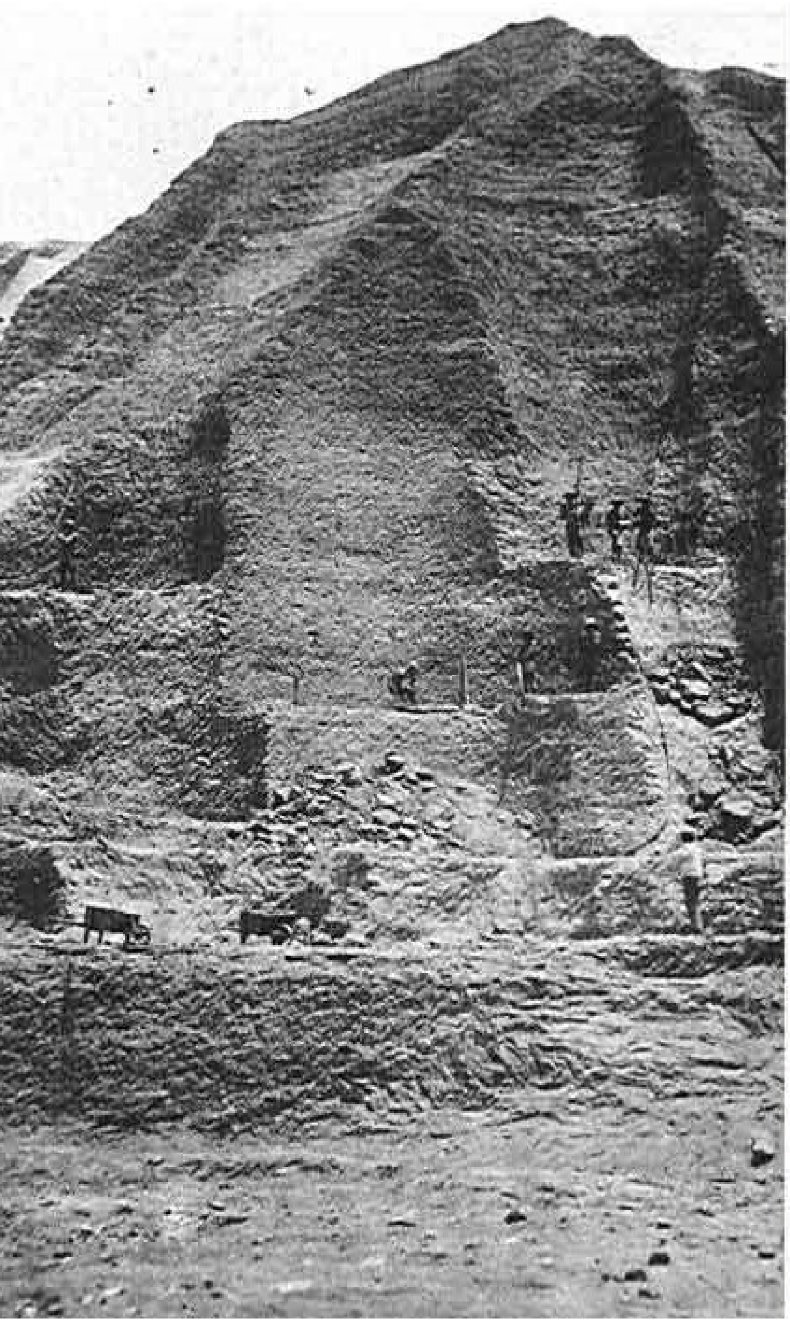


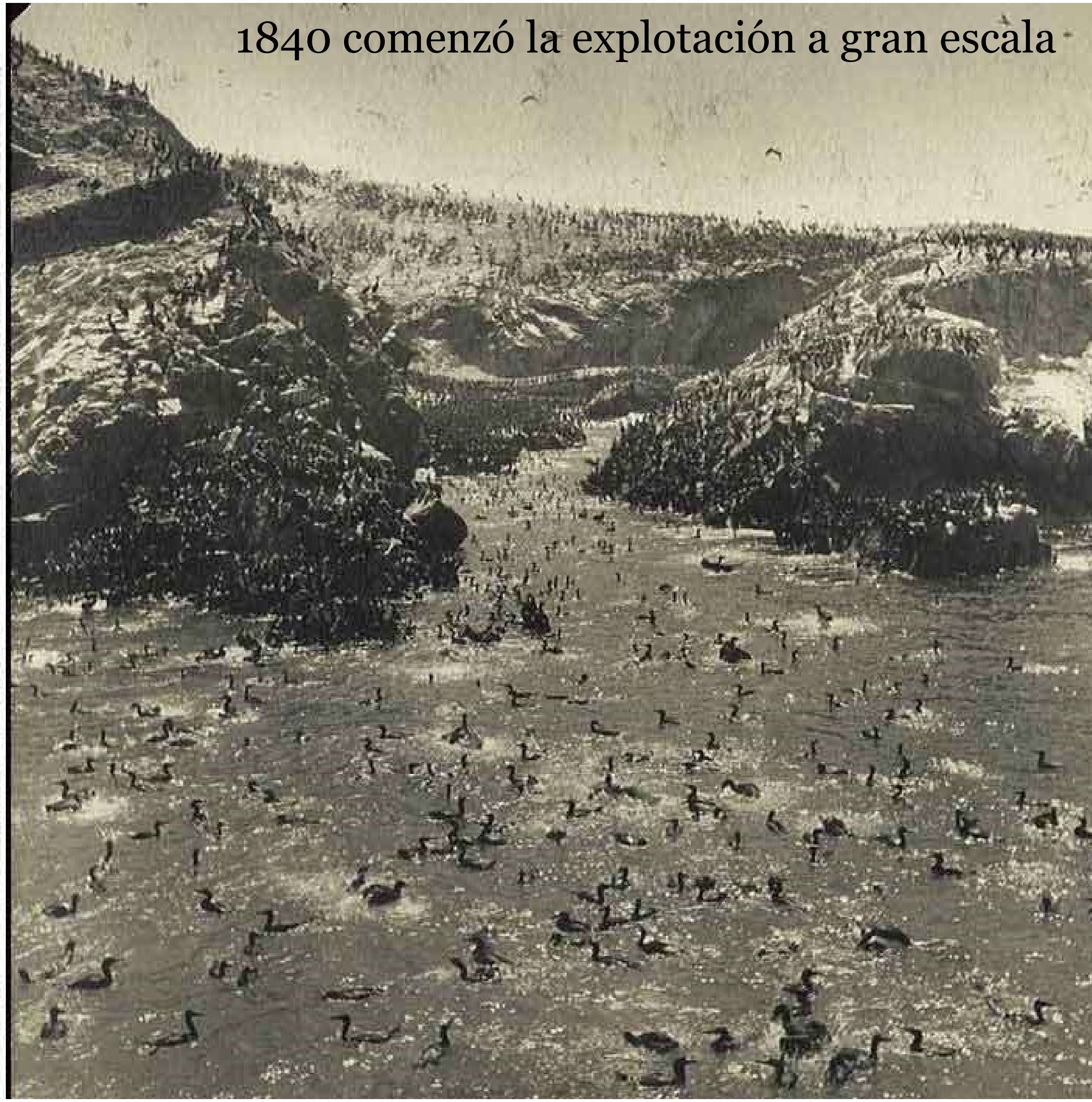
https://www.iperen.com/

La fiebre del guano



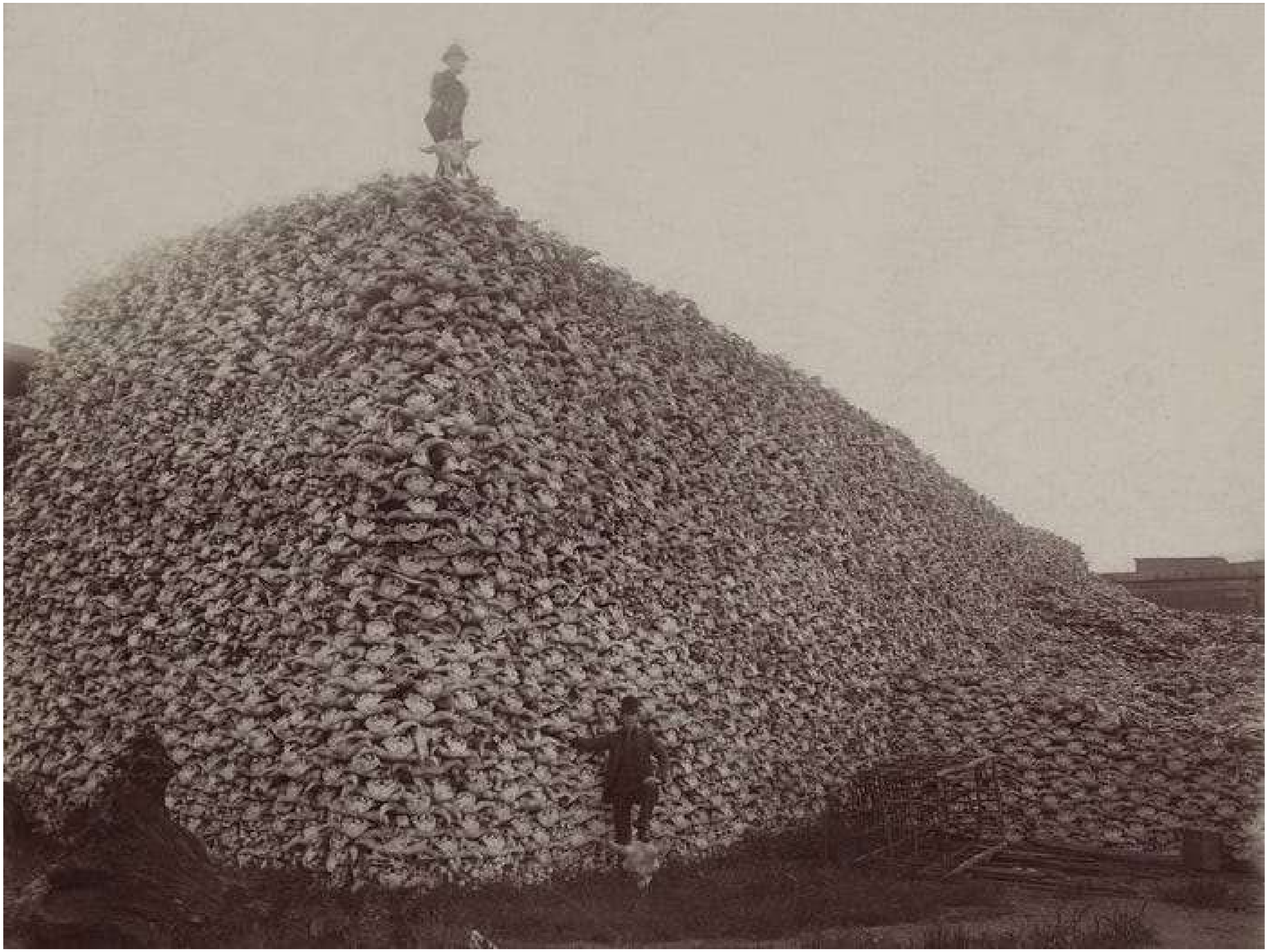
The Peruvian seabird guano will normally test out to
10% NITROGEN
10% PHOSPHORUS and
2% POTTASIUM.





http://www.anchoveta.info/fotoscontenido (2014)

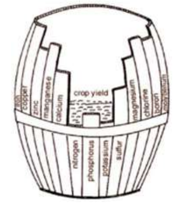

PERU



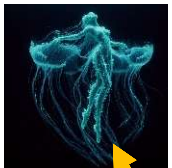
Large pile of bison skulls that will be ground into fertilizer in the US around 1870.

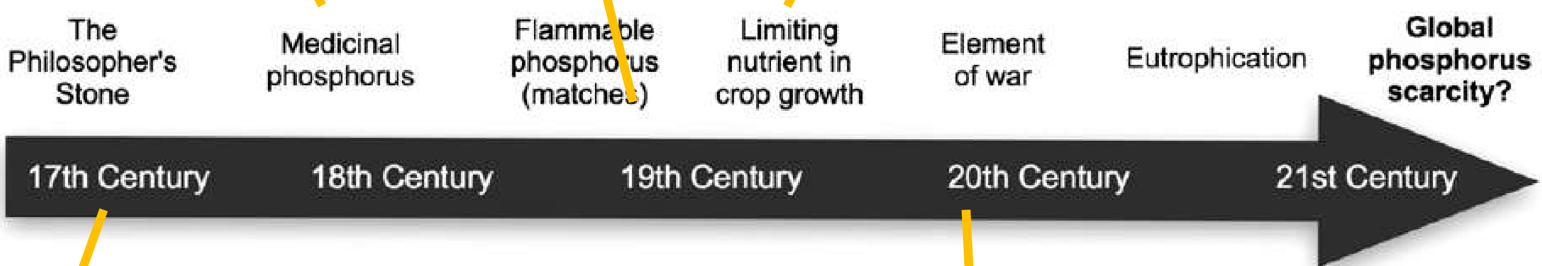
Ashley, K., Cordell, D., Mavinic, D., 2011. A brief history of phosphorus: From the philosopher's stone to nutrient recovery and reuse. Chemosphere 84, 737-746.

1802
von Humboldt



1840





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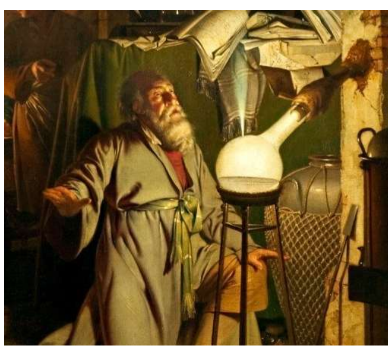


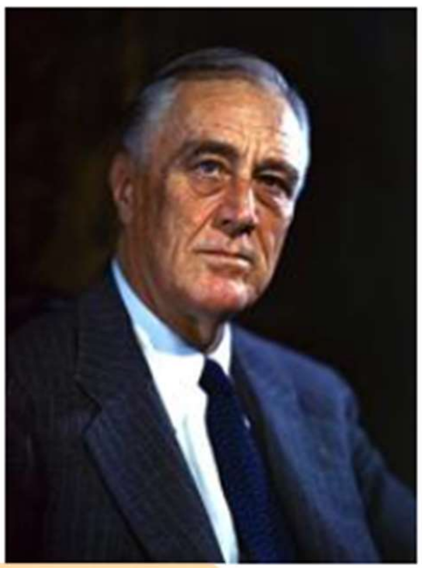
1938

FRANKLIN D. ROOSEVELT

32nd President of the United States: 1933 - 1945

Message to Congress on Phosphates for Soil Fertility.

May 20, 1938



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May 20, 1938

Franklin D. Roosevelt

XXXII *President of the United States: 1933-1945*

64 - Message to Congress on Phosphates for Soil Fertility.
May 20, 1938

“El contenido de fósforo de nuestra tierra, tras generaciones de cultivo, ha disminuido considerablemente. Necesita reponerse. Por lo tanto, la necesidad de un uso más amplio de los fosfatos y la conservación de nuestros suministros de fosfatos para las generaciones futuras es un asunto de gran preocupación pública. No podemos dar a nuestra agricultura una base permanente a menos que le prestemos atención.”

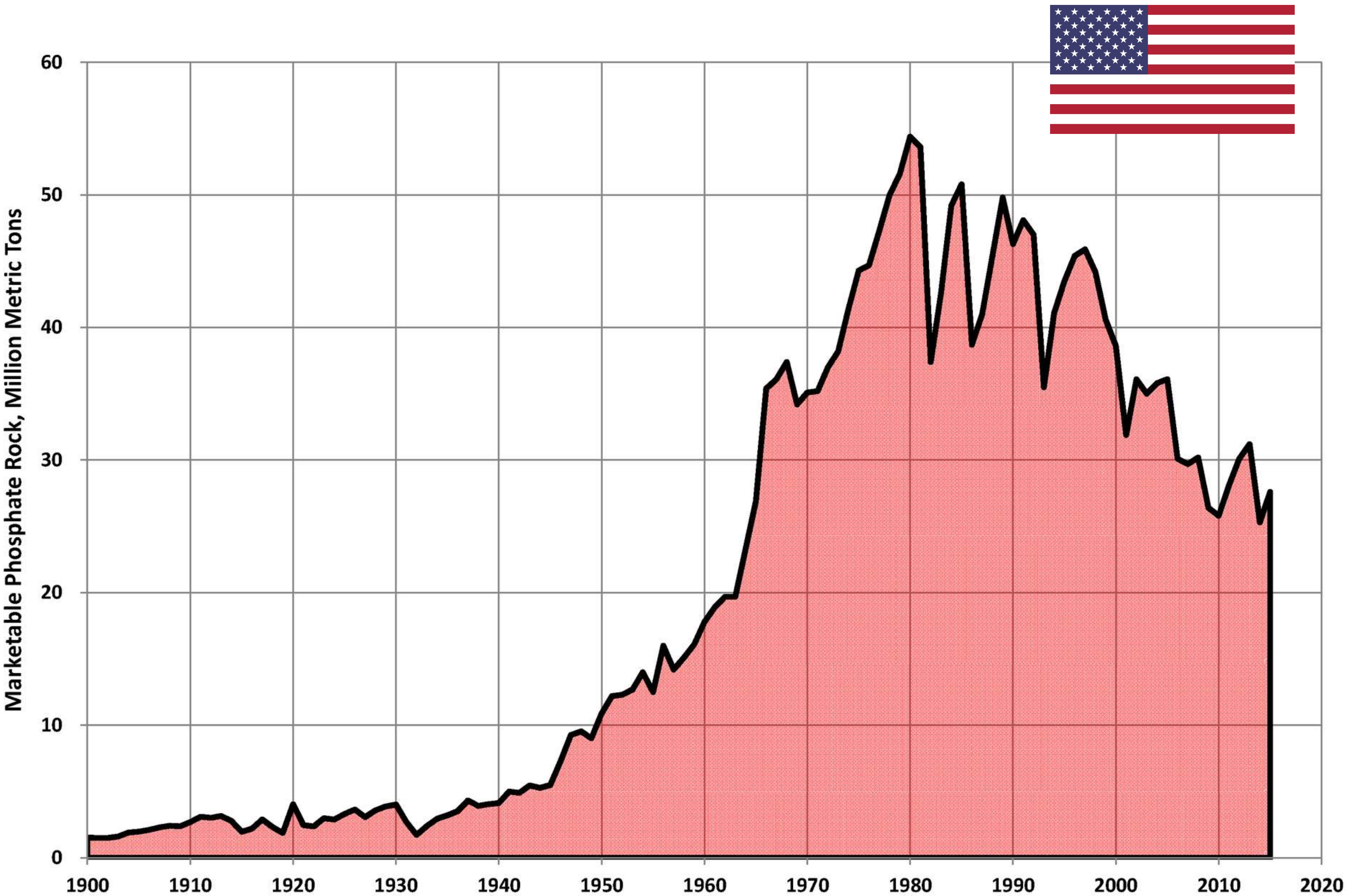
“No puedo dejar de enfatizar la importancia del fósforo no sólo para la agricultura y la conservación del suelo sino también para la salud física y la seguridad económica de la gente de la nación. Muchos de nuestros tipos de suelo son deficientes en fósforo, lo que provoca bajos rendimientos y mala calidad de los cultivos y pastos.”

64 - Message to Congress on Phosphates for Soil Fertility.
May 20, 1938

"Estimaciones recientes indican que la eliminación de fósforo de los suelos de los Estados Unidos mediante la cosecha, el pastoreo, la erosión y la lixiviación supera con creces la adición de fósforo al suelo mediante fertilizantes, estiércol animal, lluvia, riego y semillas.

Parece que incluso con un control completo de la erosión, lo que obviamente es imposible, no se mantendrá un alto nivel de productividad a menos que el fósforo regrese al suelo a un ritmo mayor que el que se hace actualmente. Los aumentos mediante la adición de fósforo al suelo deben realizarse en gran medida, si no en su totalidad, en forma de fertilizantes derivados principalmente de la roca fosfórica.

Por lo tanto, la cuestión del suministro continuo y suficiente de roca fosfórica atañe directamente al bienestar nacional."



(US Geological Survey)

Resources, Conservation & Recycling 146 (2019) 316–328

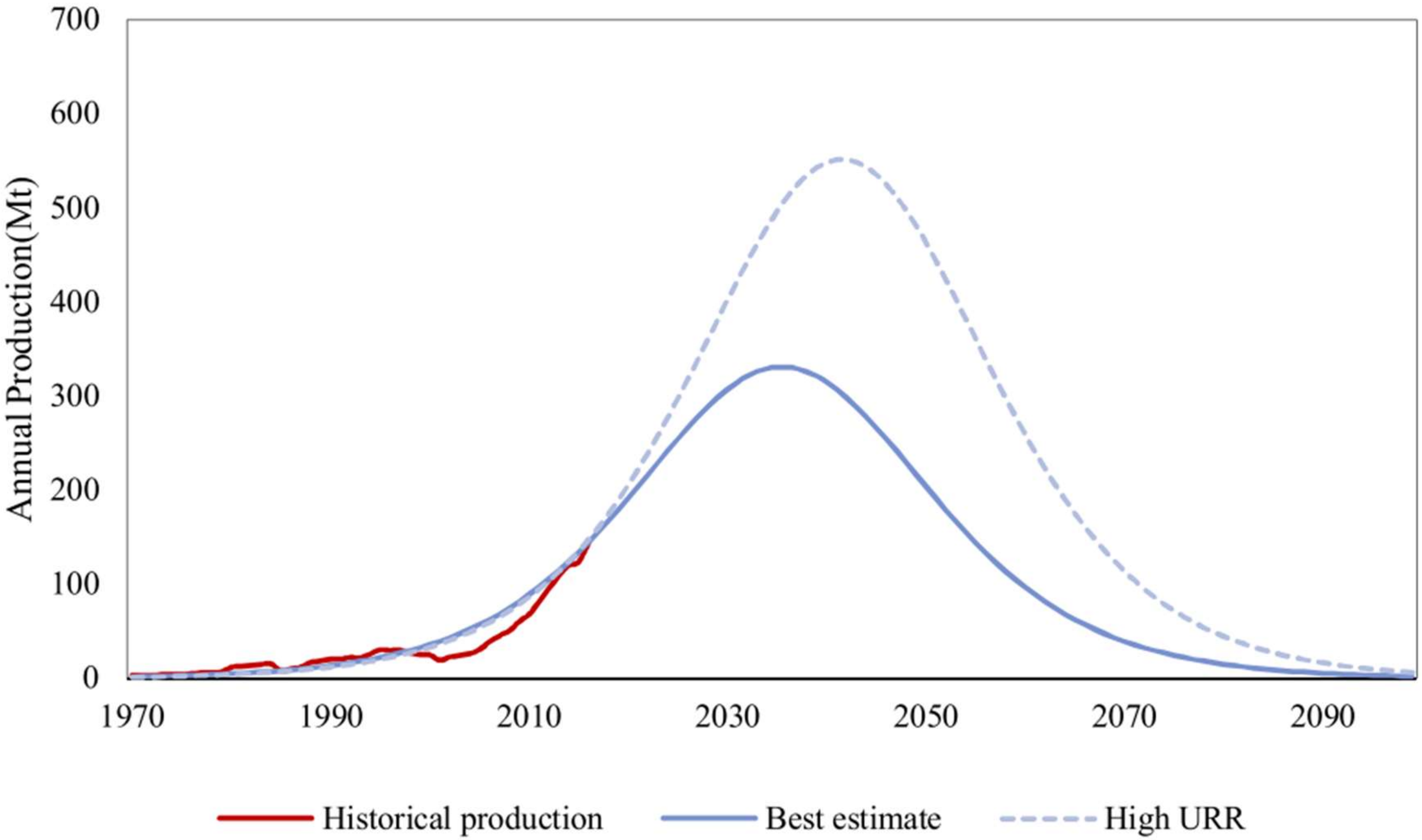
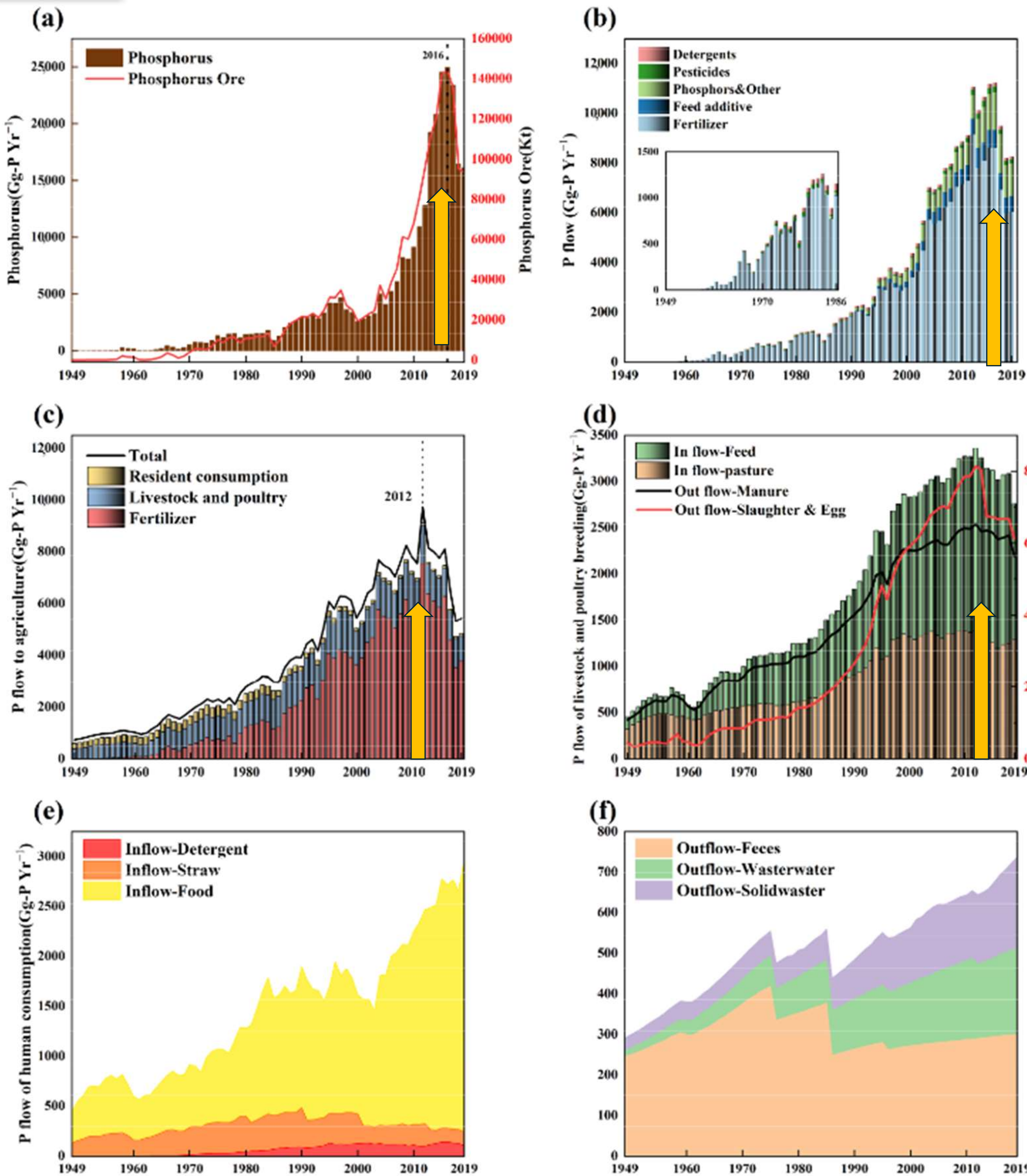


Fig. 4. PR production estimates for China.

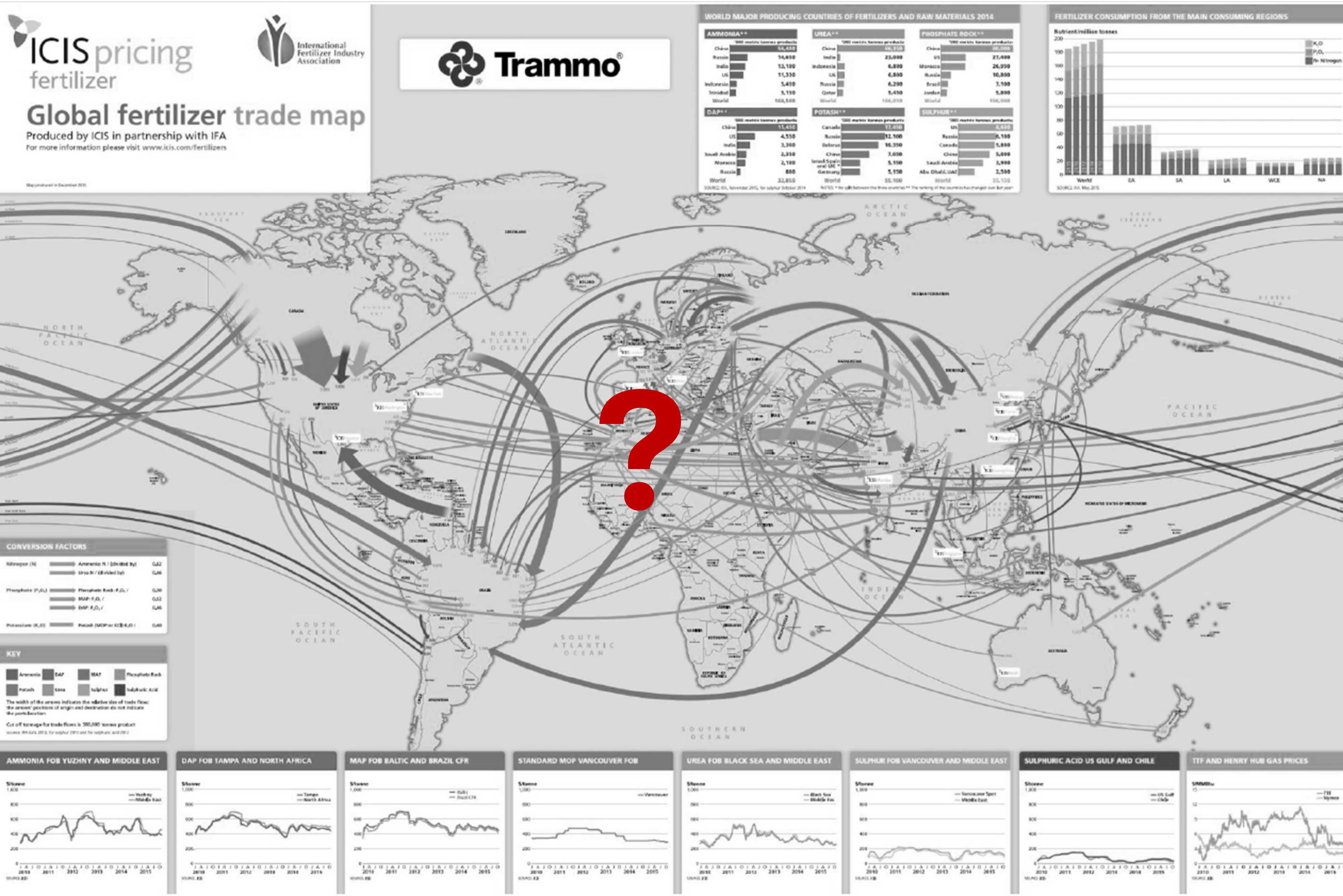
Li, B., Bicknell, K. B., & Renwick, A. (2019). Peak phosphorus, demand trends and implications for the sustainable management of phosphorus in China. *Resources, Conservation and Recycling, 146, 316-328. doi:https://doi.org/10.1016/j.resconrec.2019.03.033*

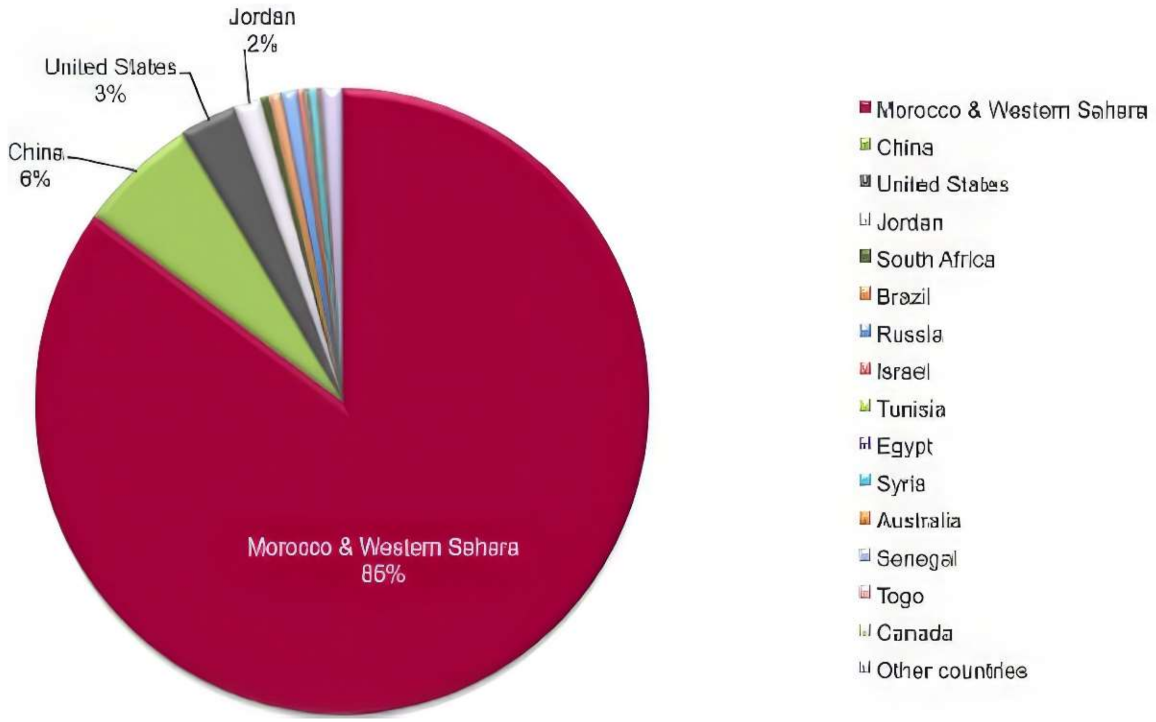


Wu, Y., Liu, J., Geng, Y., & Wu, D. (2023). Phosphorus Utilization Efficiency and Status of Phosphorus Reuse in China from 1990 to 2019. *Agriculture, 13*(12), 2262. *doi:10.3390/agriculture13122262*

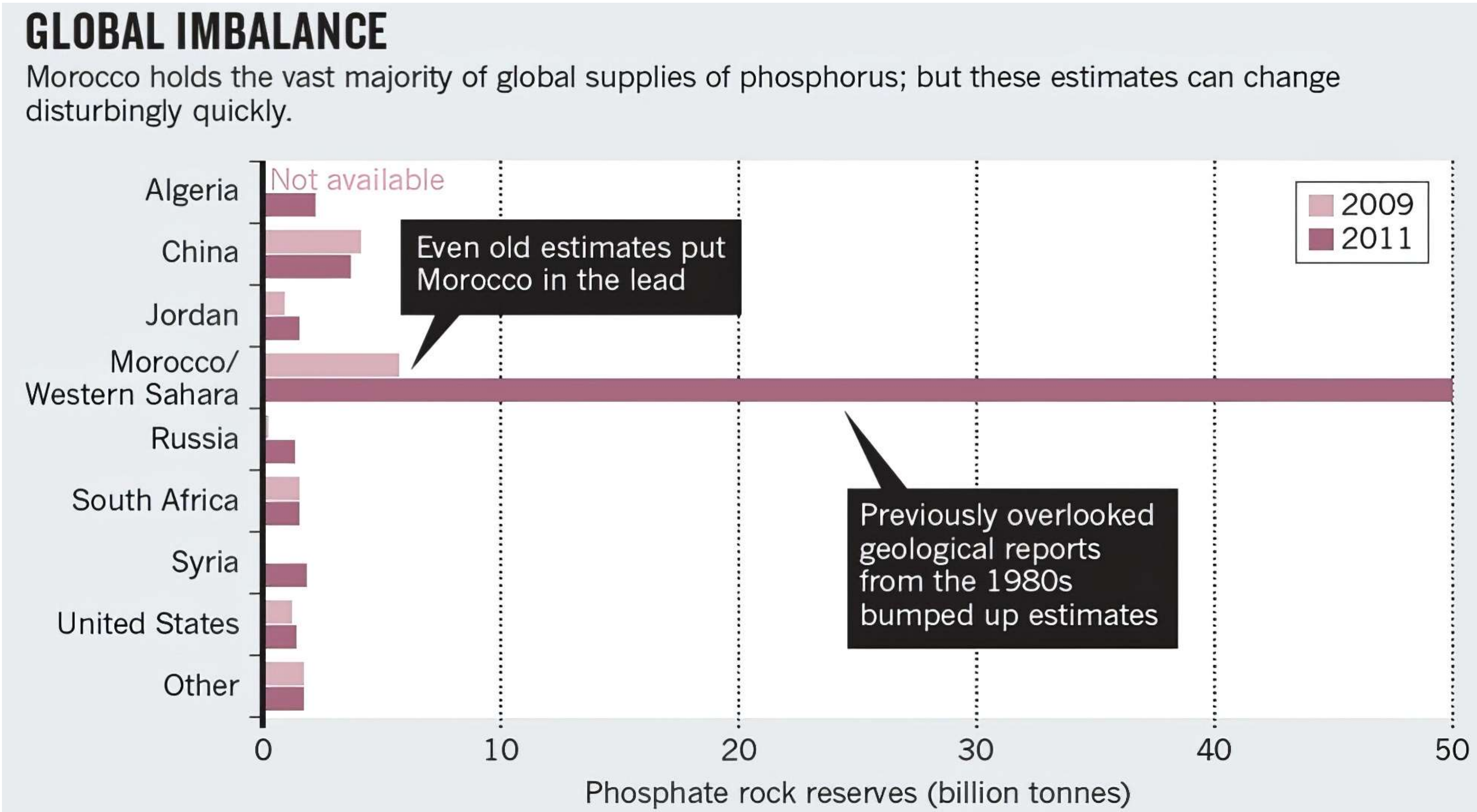
The results show that China's phosphate mining has reached its historical highest point and moved towards the green and healthy use of P resources. Since 1990, the P resource efficiency index system has revealed an overall increment in PUE in agricultural planting and product processing modules, PURP in agricultural planting and livestock and poultry breeding modules, PRR of straw, and PRR of human activities as a whole. Nevertheless, the PUE in aquaculture and livestock breeding modules have either decreased or remained relatively stable, suggesting that there is still room for further optimization in these areas. At the same time, the rational application of phosphorus fertilizers needs to fully consider the impact of past phosphorus legacy on the soil, which can effectively improve the effectiveness of phosphorus fertilizers, thereby reducing environmental impact [39].

Wu, Y., Liu, J., Geng, Y., & Wu, D. (2023). Phosphorus Utilization Efficiency and Status of Phosphorus Reuse in China from 1990 to 2019. *Agriculture, 13(12), 2262. doi:10.3390/agriculture13122262*


ICIS pricing
fertilizer
International Fertilizer Industry Association
Global fertilizer trade map
Produced by ICIS in partnership with IFA
For more information please visit www.icis.com/fertilizers
Trammo
WORLD MAJOR PRODUCING COUNTRIES OF FERTILIZERS AND RAW MATERIALS 2014
AMMONIA
UREA
PHOSPHATE ROCK
DAP
POTASH
SULPHUR
FERTILIZER CONSUMPTION FROM THE MAIN CONSUMING REGIONS
CONVERSION FACTORS
KEY
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
PACIFIC OCEAN
SOUTHERN OCEAN
?
AMMONIA FOB YUZHNY AND MIDDLE EAST
DAP FOB TAMPA AND NORTH AFRICA
MAP FOB BALTIC AND BRAZIL CFR
STANDARD MOP VANCOUVER FOB
UREA FOB BLACK SEA AND MIDDLE EAST
SULPHUR FOB VANCOUVER AND MIDDLE EAST
SULPHURIC ACID US GULF AND CHILE
TTF AND HENRY HUB GAS PRICES



Cordell, D., White, S., 2011. Peak Phosphorus: Clarifying the Key Issues of a Vigorous Debate about Long-Term Phosphorus Security. Sustainability 3, 2027.



Elser, J., Bennett, E., 2011. Phosphorus cycle: A broken biogeochemical cycle. Nature 478, 29-31.

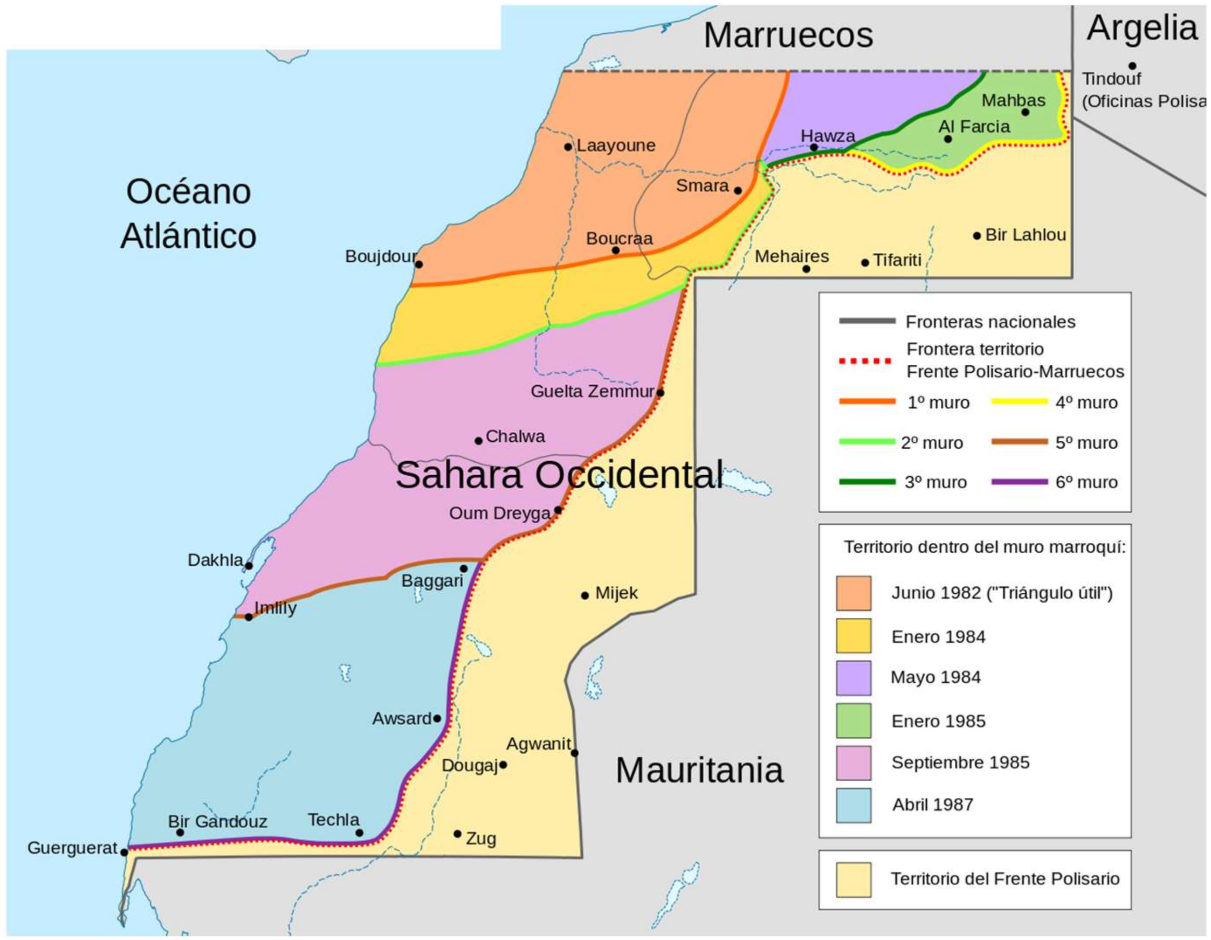
https://maps.app.goo.gl/SR5PZeaHwo7ZP7h86

Bu Craa (West Sahara)

Estatus político del Sahara Occidental

Artículo Discusión

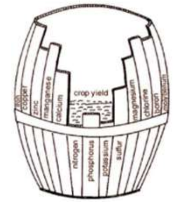
El **estatus político del Sahara Occidental** y la cuestión de su soberanía son objetos de controversia. Es uno de los diecisiete integrantes de la lista de territorios no autónomos de las Naciones Unidas bajo supervisión de su Comité Especial de Descolonización, y aunque para la ONU la potencia administradora sigue siendo España, lo cierto es que al retirarse del territorio en 1976 este país renunció a la administración del Sahara Occidental y a toda responsabilidad internacional sobre el territorio. Su soberanía es reclamada actualmente por el Reino de Marruecos y la República Árabe Saharaui Democrática, que se disputan el control de la totalidad del territorio.



How is phosphate formed?

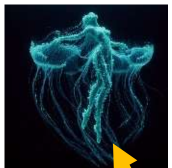
Phosphate is a sedimentary rock formed millions of years ago by the accumulation of organic matter on the ocean floor. Phosphate reserves are found in Africa, North America, Kazakhstan, the Middle East and Oceania but the world's largest deposits are located in Morocco, which is also one of the global leaders in phosphate extraction.

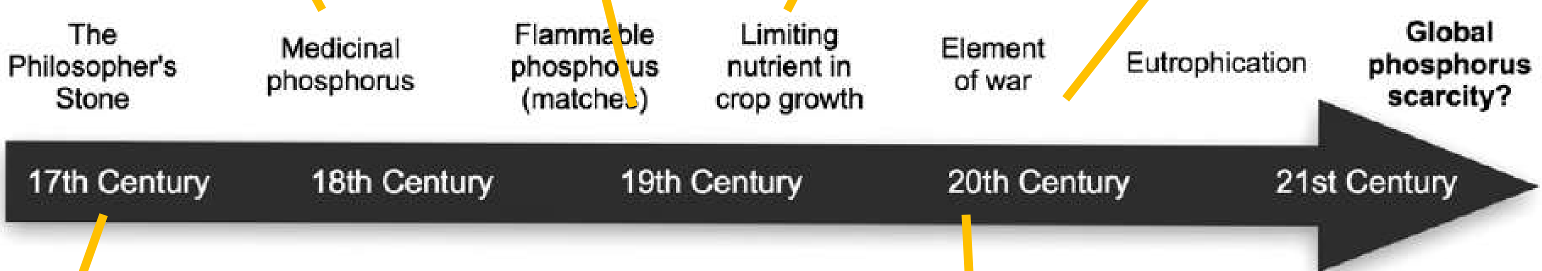
1802
von Humboldt



1840

Revolución verde
1960





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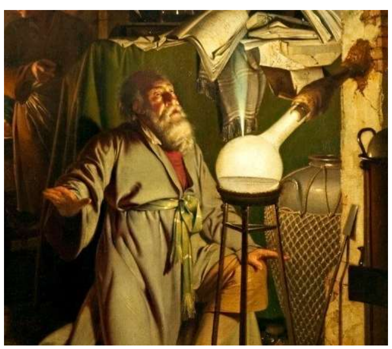

1938

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Revolución verde

Es la denominación usada internacionalmente para describir el importante incremento de la productividad agrícola y, por tanto, de alimentos entre 1960 y 1980 en Estados Unidos y extendida después por numerosos países.

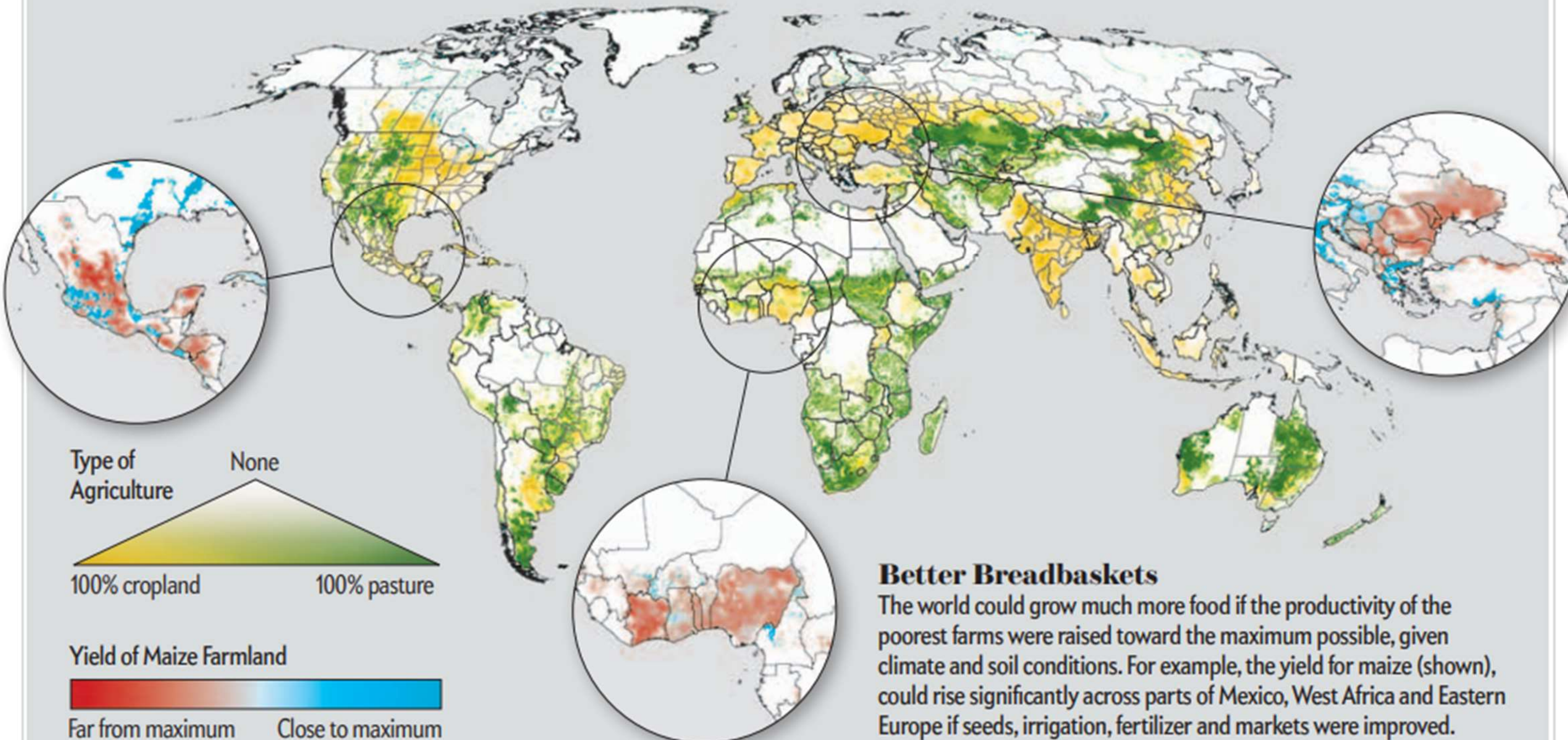
Norman Burlaug, fue un agrónomo, genetista, fitopatólogo, humanista estadounidense, considerado por muchos el padre de la agricultura moderna y de la **revolución verde**.
Ha sido llamado "el hombre que salvó mil millones de vidas“.

Revolución verde

Consistió en la adopción de una serie de prácticas y tecnologías siembra de variedades de cereal más resistentes a los climas extremos y a las plagas nuevos métodos de cultivo (incluyendo la mecanización) uso de fertilizantes, plaguicidas y riego.

Farming Hits the Wall, But Not the Ceiling

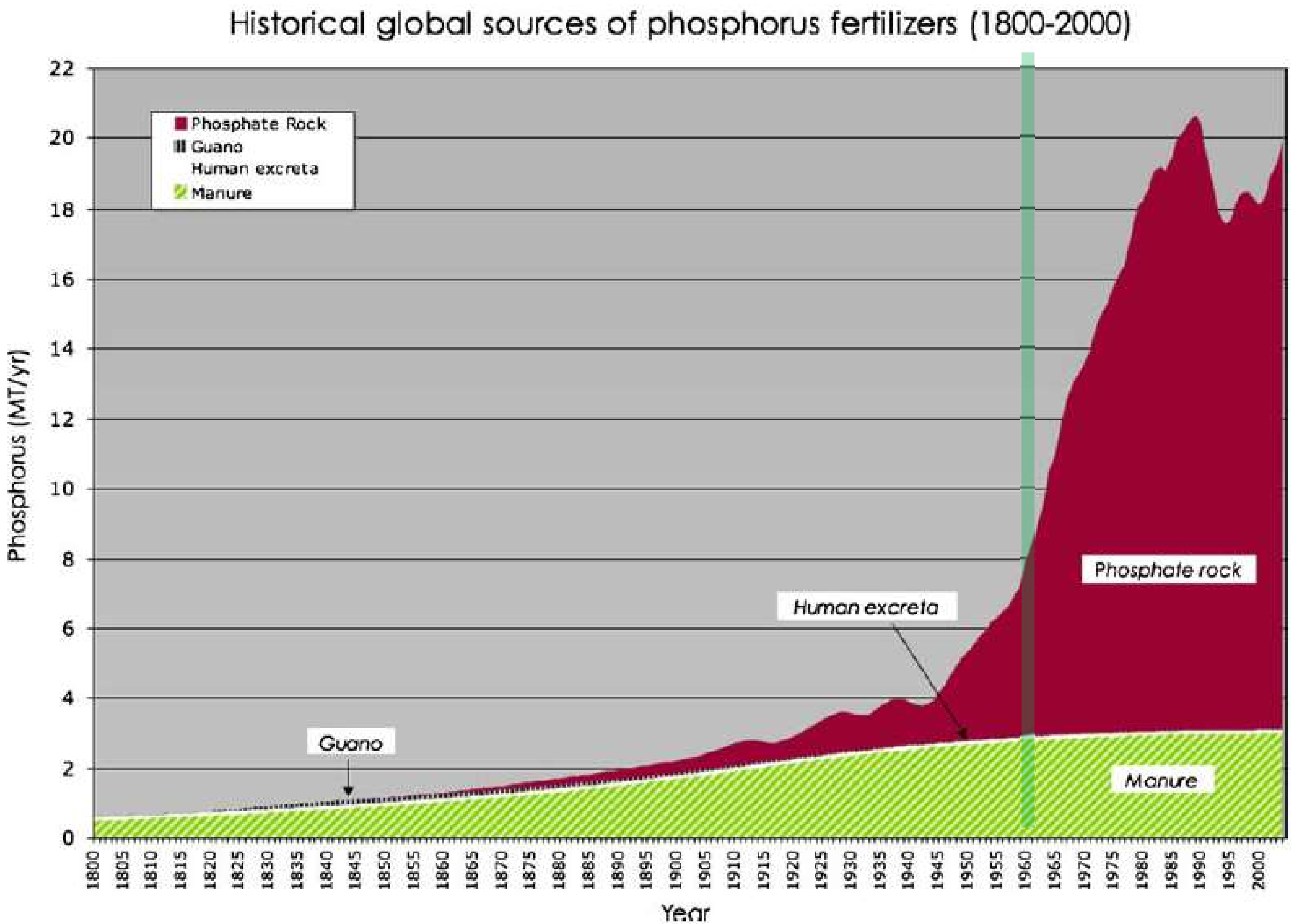
Humankind now farms 38 percent of the earth's ice-free land. Crops cover one-third of that area; pastures and ranges for livestock cover the rest. Little room exists for expansion because most of the remaining land is deserts, mountains, tundra or urban. Still, farms in many existing areas could be more productive (insets).



Better Breadbaskets

The world could grow much more food if the productivity of the poorest farms were raised toward the maximum possible, given climate and soil conditions. For example, the yield for maize (shown), could rise significantly across parts of Mexico, West Africa and Eastern Europe if seeds, irrigation, fertilizer and markets were improved.

https://www.scientificamerican.com/article/can-we-feed-the-world/



Cordell, D., J. O. Drangert and S. White (2009). "The story of phosphorus: Global food security and food for thought." Global Environmental Change 19: 292-305.

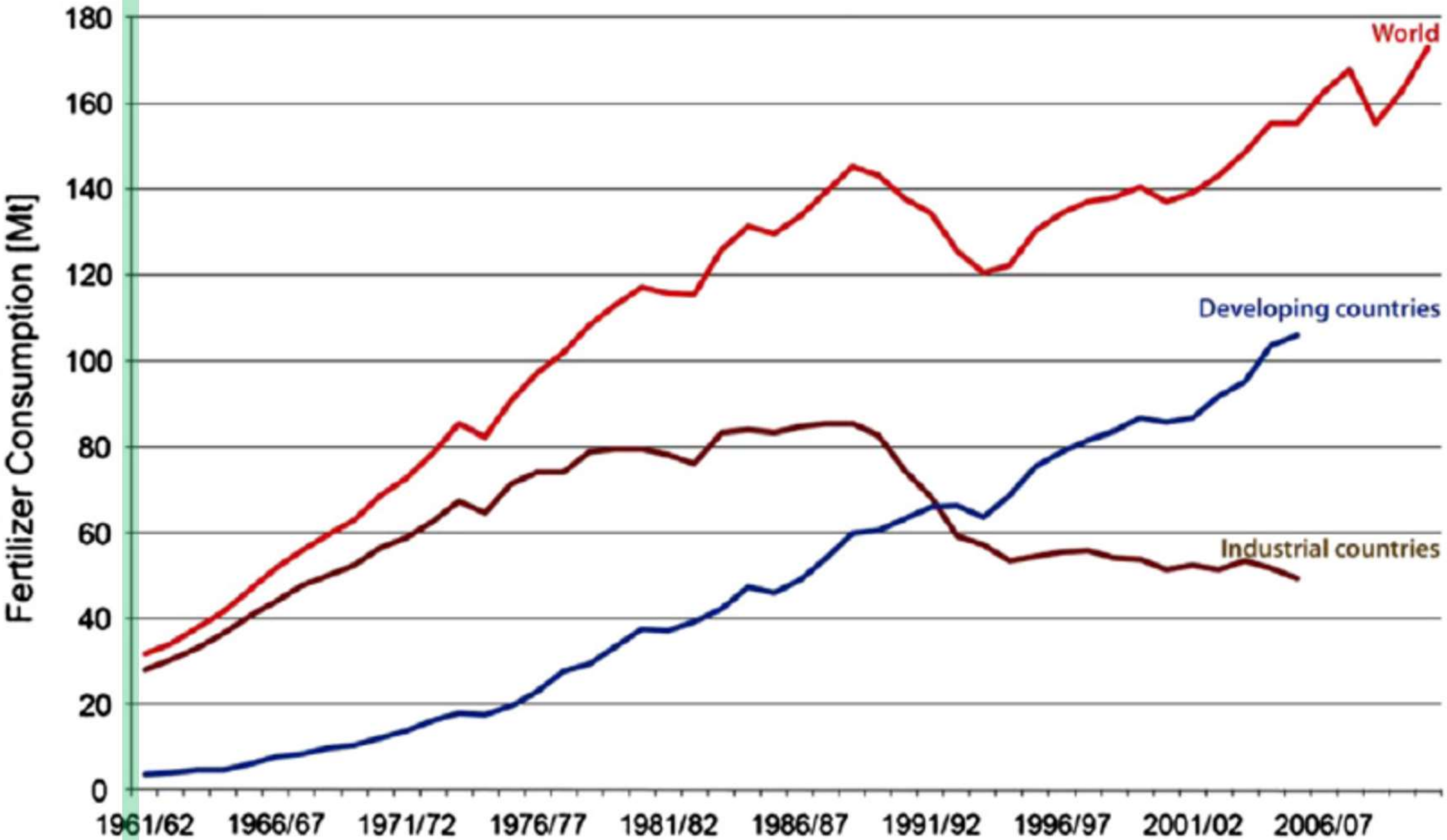
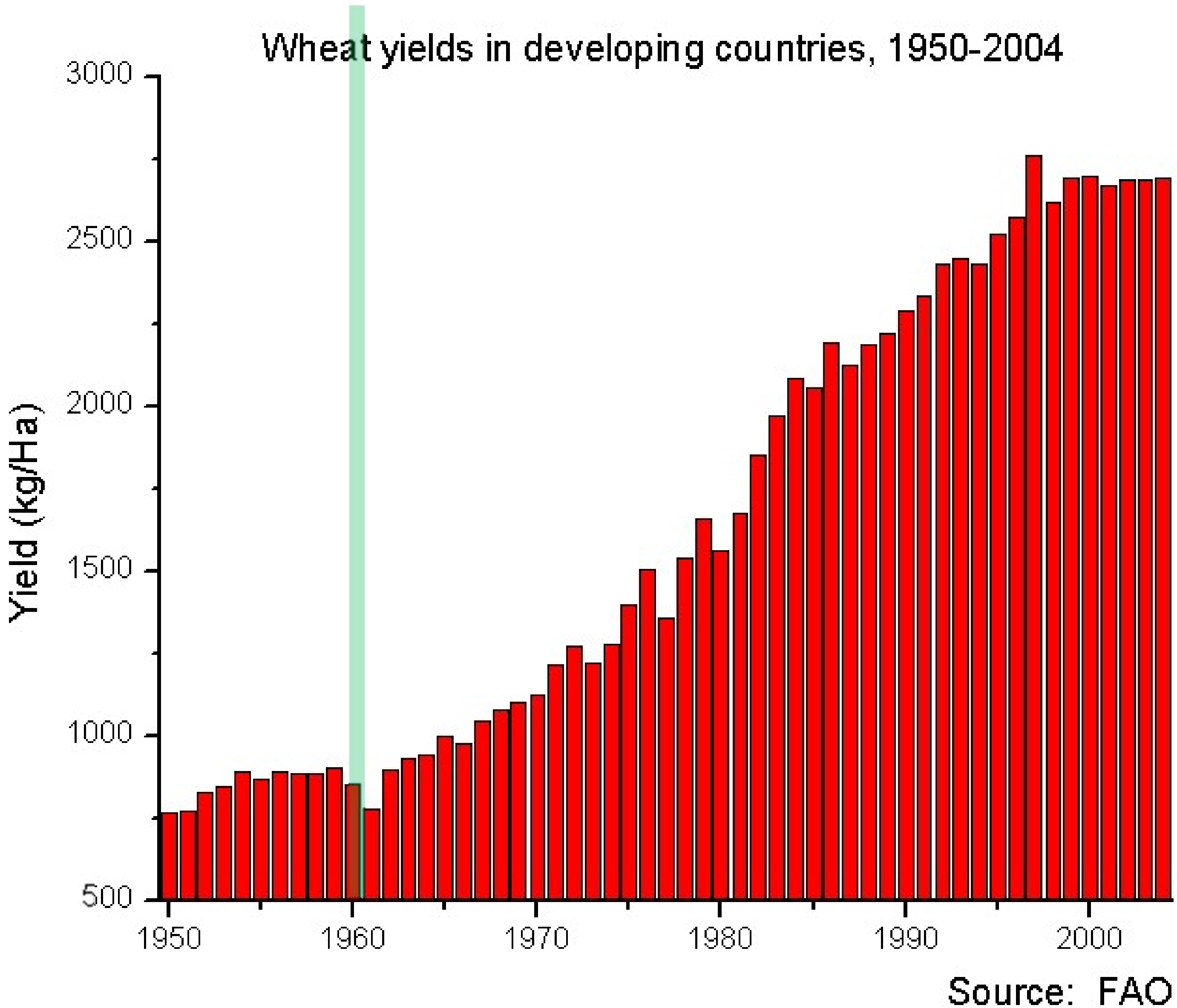
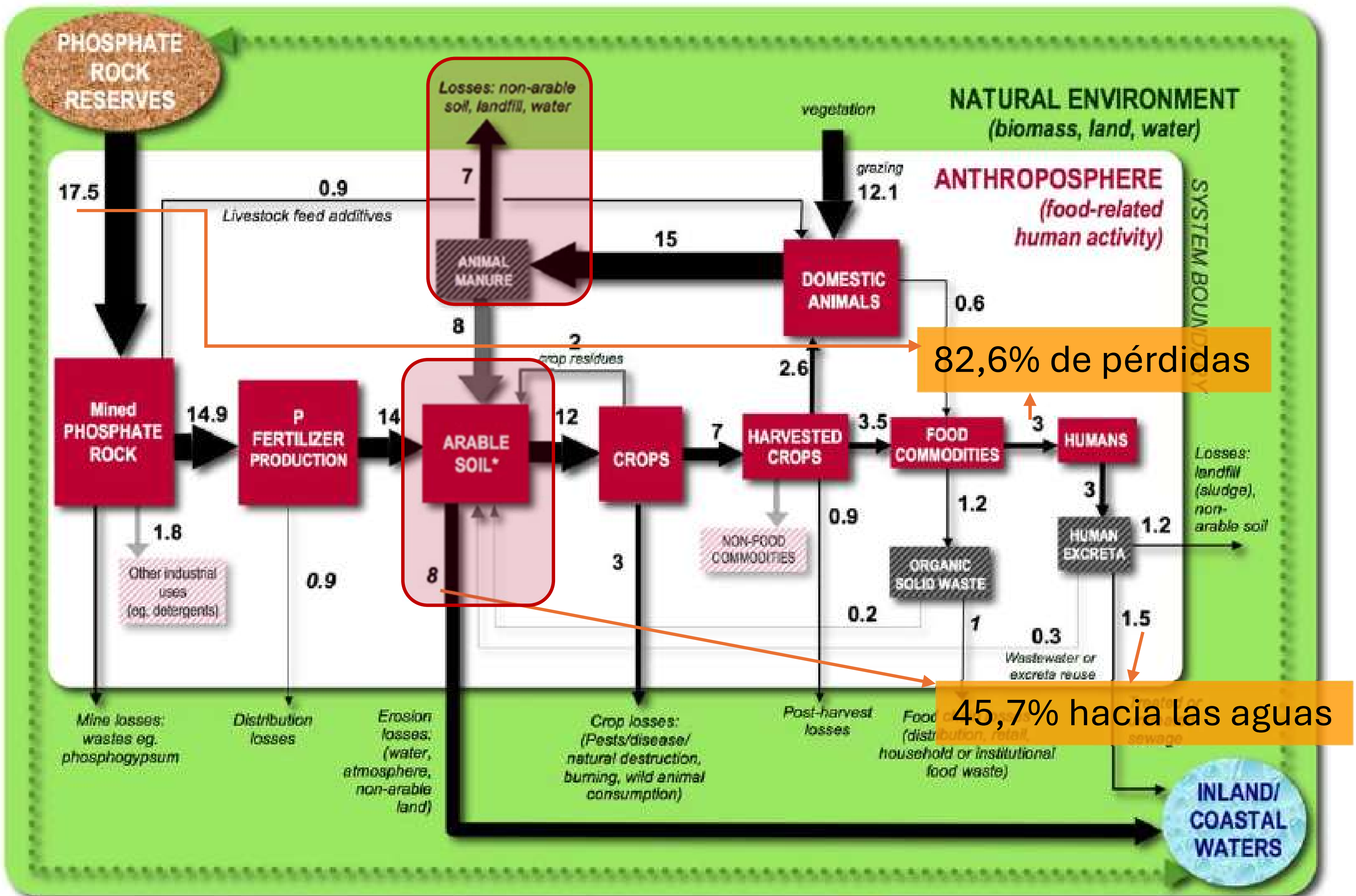


Fig. 1. Trends of fertilizer consumption in the world, developing countries and industrial countries (Röhling, 2010).

Revolución verde



1 teragramo = 10^{12} g



= Industrial P flows occurring at rate of 'days to years' = Recirculated P flows from organic sources to arable land = Natural biogeochemical P flows occurring at rate of 'millions of years'

* only a fraction of applied mineral P is taken up by crops in a given year, the balance comes from the soil stocks, either from natural soil P, or build up from previous years and decades of fertilizer application

Cordell, D., J. O. Drangert and S. White (2009). "The story of phosphorus: Global food security and food for thought." Global Environmental Change 19: 292-305.

P

Phosphate is mined to produce fertilizers for crops, but phosphorus leaching into water supplies is an environmental hazard.

A broken biogeochemical cycle

Excess phosphorus is polluting our environment while, ironically, mineable resources of this essential nutrient are limited. **James Elser** and **Elena Bennett** argue that recycling programmes are urgently needed.

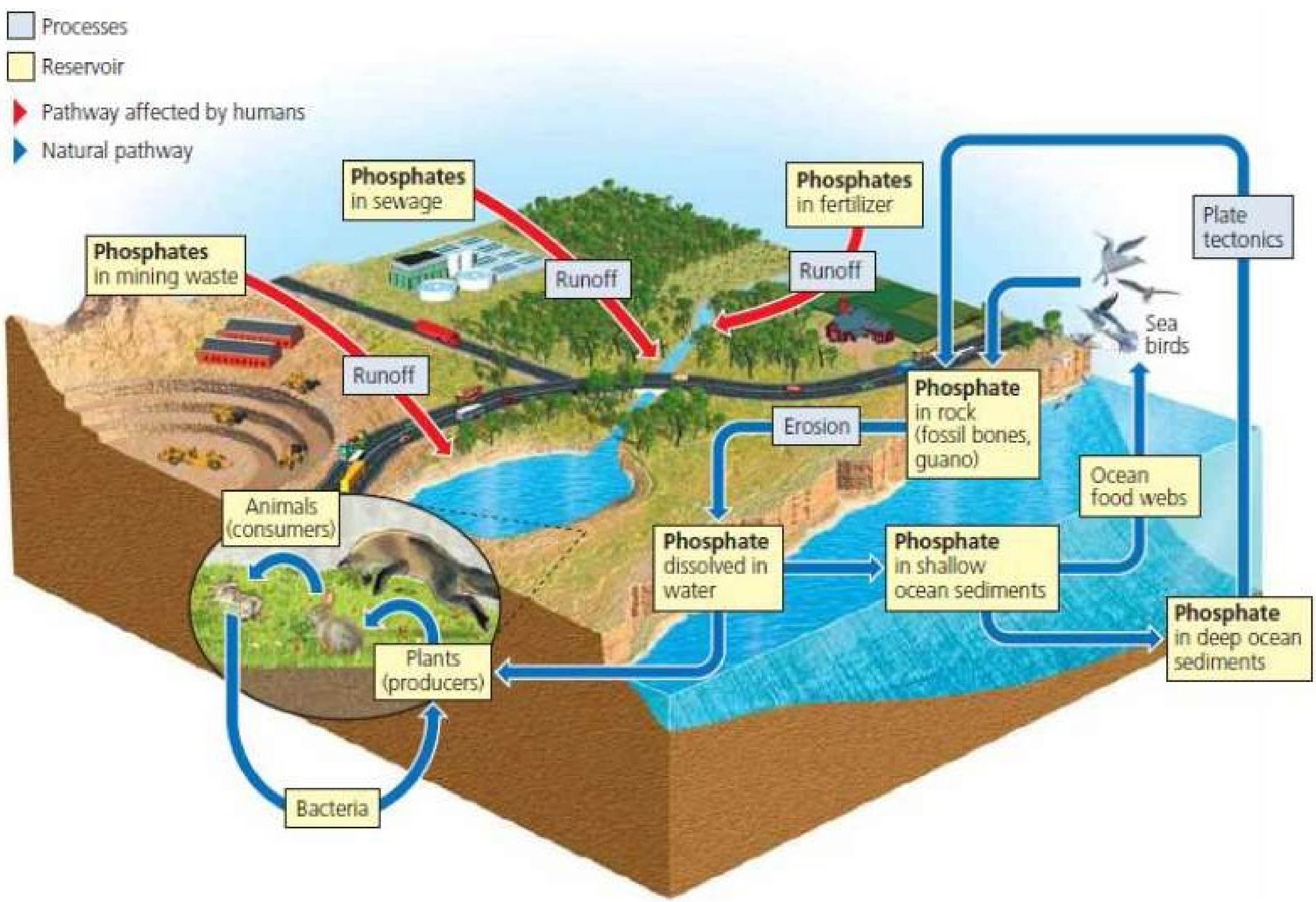
To meet our demands for energy, humankind has moved masses of carbon from deep underground into the atmosphere, wreaking havoc with the climate. To meet our demand for food, we have moved large amounts of nitrogen from the atmosphere to fields, rivers and forests, devastating ecosystems. To grow our crops we have interfered with Earth's reserves of a third element — phosphorus — which receives much less press and for which we face the unique problem of having both too much and too little.

Since the middle of the twentieth century, humanity has quadrupled the environmental flow of phosphorus[1], an essential element for all forms of life. We dig up geological phosphate reserves to produce fertilizers to feed the Green Revolution, creating a largely one-way flow of phosphorus from rocks to farms to lakes and oceans, and dramatically impairing freshwater and coastal marine ecosystems. Globally, oxygen-depleted marine coastal 'dead zones' caused by nutrient-stimulated algal blooms continue to expand. The Gulf of Mexico's dead zone, averaging more than 17,000 square kilometres in recent years,was forecast to reach record dimensions this year before a tropical storm stirred the waters.

At the same time, concern is growing about how long we can count on cheap supplies of phosphorus for fertilizer: easily mineable deposits of phosphate rock are limited. Unlike nitrogen, phosphorus cannot be pulled from the air and, unlike the carbon in our energy system, there is no known replacement. In 2009, Dana Cordell of the University of Technology in Sydney, Australia, and her colleagues published a 'peak phosphorus' forecast[2] that predicted maximum production around 2030 — an ▸

Elser, J. and E. Bennett (2011). "Phosphorus cycle: A broken biogeochemical cycle." Nature 478(7367): 29-31.

Ciclo del Fósforo en el ecosistema



Ciclo del P: no tiene componente atmosférico

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., 2015. The trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review 2, 81–98.

The human age

Momentum is building to establish a new geological epoch that recognizes humanity's impact on the planet. But there is fierce debate behind the scenes.

BY RICHARD MONASTERSKY

Almost all the dinosaurs have vanished from the National Museum of Natural History in Washington DC. The fossil hall is now mostly empty and painted in deep shadows as palaeobiologist Scott Wing wanders through the cavernous room.

Wing is part of a team carrying out a radical, US$45-million redesign of the exhibition space, which is part of the Smithsonian Institution. And when it opens again in 2019, the hall will do more than revisit Earth's distant past. Alongside the typical displays of *Tyrannosaurus rex* and *Triceratops*, there will be a new section that forces visitors to consider the species that is currently dominating the planet.

"We want to help people imagine their role in the world, which is maybe more important than many of them realize," says Wing.

This provocative exhibit will focus on the Anthropocene — the slice of Earth's history during which people have become a major geological force. Through mining activities alone, humans move more sediment than all the world's rivers combined. *Homo sapiens* has also warmed the planet, raised sea levels, eroded the ozone layer and acidified the oceans.

Given the magnitude of these changes, many researchers propose that the Anthropocene represents a new division of geological time. The concept has gained traction, especially in the past few years — and not just among geoscientists. The word has been invoked by archaeologists, historians and even gender-studies researchers; several museums

nature

http://www.nature.com/polopoly_fs/1.17085!/menu/main/topColumns/topLeftColumn/pdf/519144a.pdf


ARE WE THERE YET?...
YOU ARE NOW LEAVING THE HOLOCENE
THANK GOODNESS FOR ALL THE ELECTRONIC GADGETS THAT KEEP THEM OCCUPIED ON THESE LONG TRIPS!
NEXT SERVICES
POPE 17.1.15


WELCOME
TO THE Fabulous
ANTHROPOCENE
ERA

quaternary.stratigraphy.org/workinggroups/anthropocene/

Subcommission on Quaternary Stratigraphy

Home | Charts | News | Definitions | Stratigraphic Guide | Major divisions | Regional divisions | Members | Working Groups | Meetings | Annual reports

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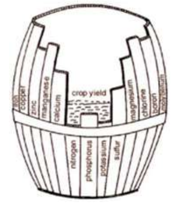
WORKING GROUP ON THE 'ANTHROPOCENE'

?

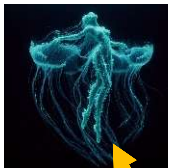
http://quaternary.stratigraphy.org/workinggroups/anthropocene/

1802
von Humboldt



1840

Revolución verde
1960



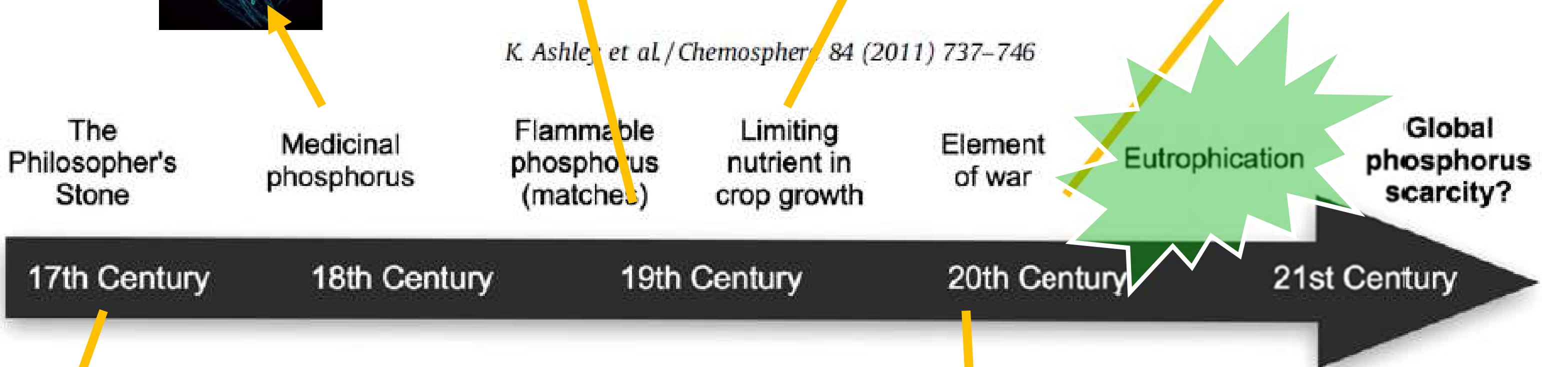
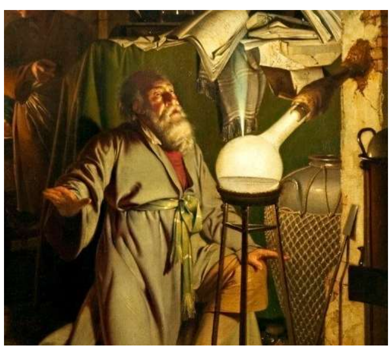


Fig. 1. The evolution of phosphorus use and abuse: from the Philosopher's Stone to use in war, food production, and more recently implicated in water pollution. A new emerging discourse of the 21st century may be global phosphorus scarcity. *Source*: Cordell (2010).



1938

FRANKLIN D. ROOSEVELT

32nd President of the United States: 1933 - 1945

Message to Congress on Phosphates for Soil Fertility.

May 20, 1938

Eutrofización

- Proceso natural
- Envejecimiento de sistemas acuáticos
- Aumento de la carga de nutrientes
- Acumulativa
- Fertilización
- Aumento de la productividad

"INMINENT" (2016)

Erik Johansson https://www.erikjo.com/

"LANDFALL" (2014)

Erik Johansson https://www.erikjo.com/

Lago Rodó
(Montevideo)


Lago Rodó
(Montevideo)


Lago Cachón
(Montevideo)


Lagomar
(canelones)

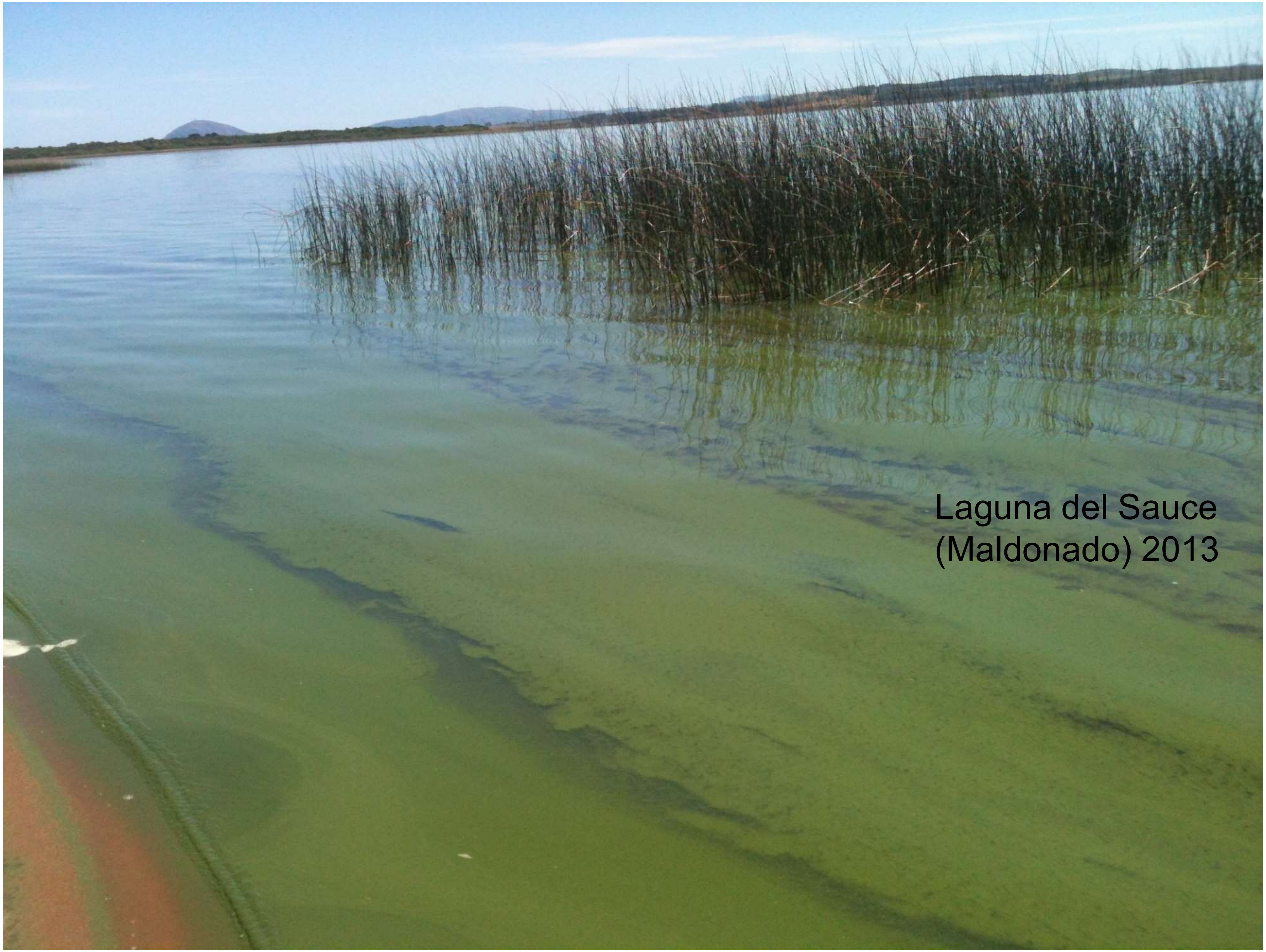

Laguna del Potrero
(Maldonado)


Laguna Blanca
(Maldonado)

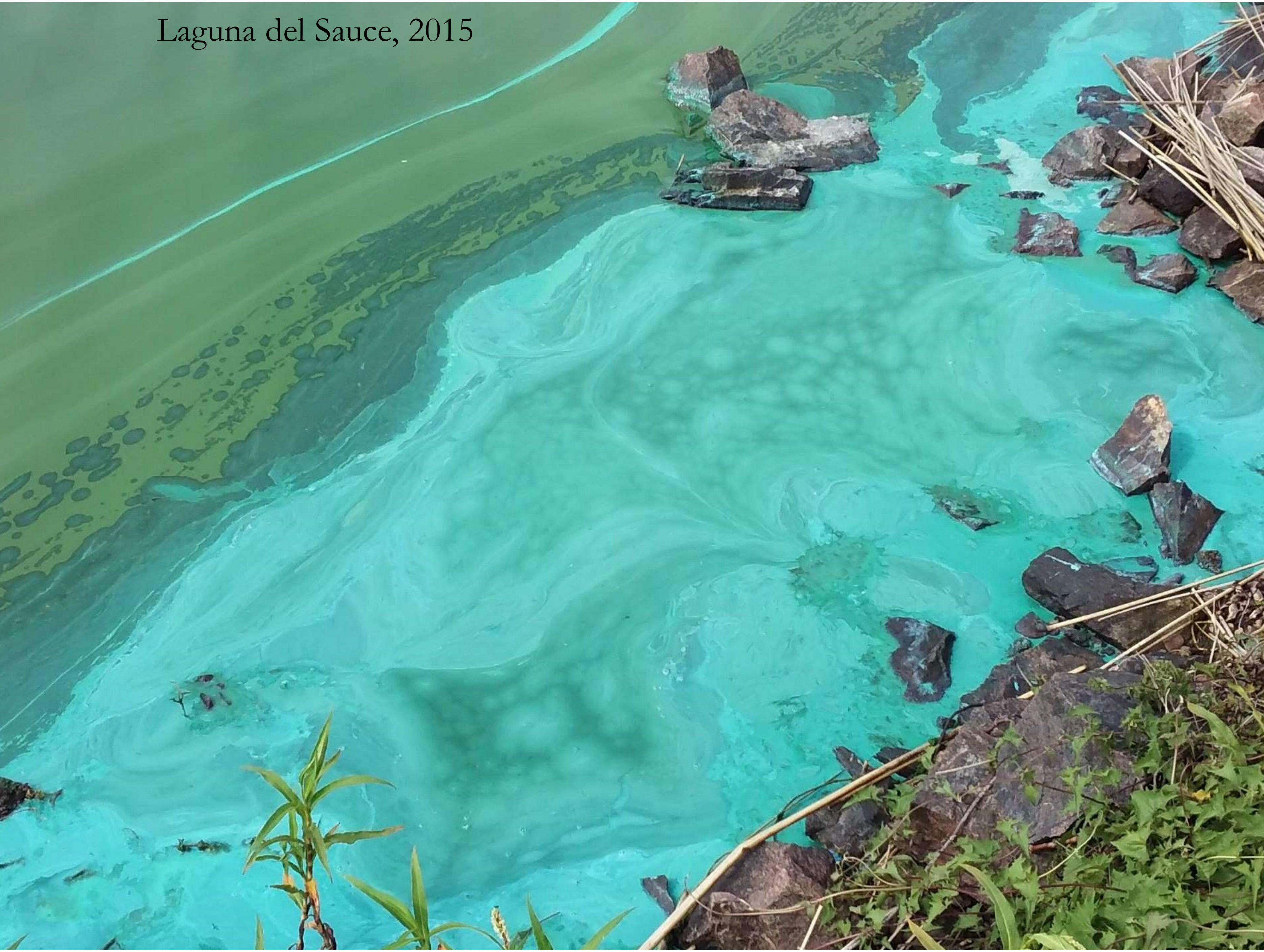

Laguna del Diario
(Maldonado)


Laguna del Sauce
(Maldonado) 2008
Guillermo Goyenola
ggoyenola@cure.edu.uy
CURE


Laguna del Sauce
(Maldonado) 2008
Guillermo Goyenola
ggoyenola@cure.edu.uy
CURE


Laguna del Sauce
(Maldonado) 2013


Laguna del Sauce, 2015



Laguna del Sauce, 2015

Eutrofización

Aumento de la disponibilidad de nutrientes

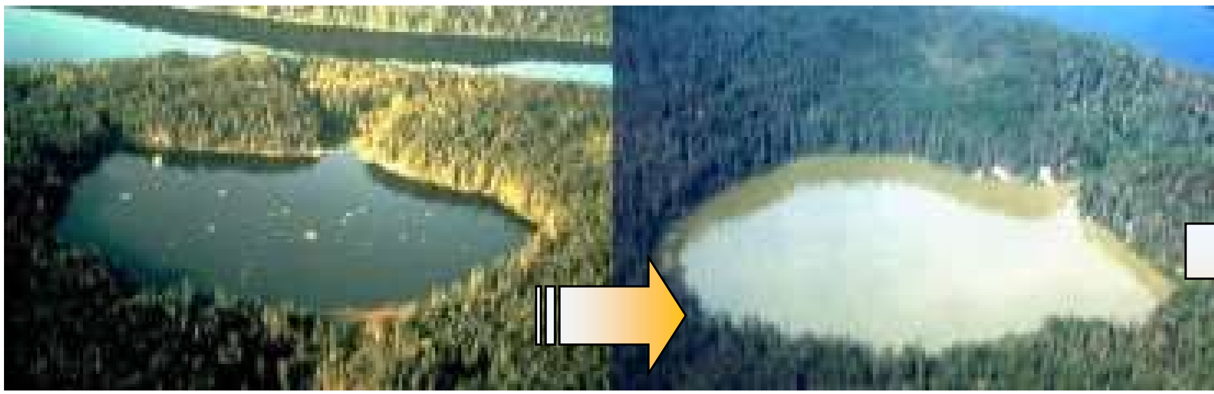
Aumento de la productividad primaria

R+

Cambio de la estructura y funcionamiento del ecosistema.

Pérdida de SSEE.

Interferencias múltiples



Descomposición
generación de malos olores

Anoxia o hipoxia

Floraciones o *blooms*
de organismos fotosintetizadores

Muerte masiva
de peces

Interferencias con
potabilización

Riesgos sanitarios
(Cianotoxinas)

Ambio 2018, 47(Suppl. 1):S3–S19
DOI 10.1007/s13280-017-0968-9

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

CrossMark

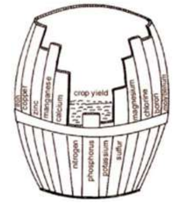
Handling the phosphorus paradox in agriculture and natural ecosystems: Scarcity, necessity, and burden of P

Peter Leinweber, Ulrich Bathmann, Uwe Buczko, Caroline Douhaire,
Bettina Eichler-Löbermann, Emmanuel Frossard, Felix Ekardt,
Helen Jarvie, Inga Krämer, Christian Kabbe, Bernd Lennartz,
Per-Erik Mellander, Günther Nausch, Hisao Ohtake,
Jens Tränckner

La Paradoja del P, simultaneidad de:

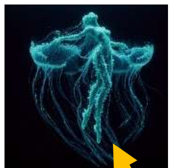
- escasez global para la producción agrícola
- sobreabundancia simultánea que perjudica la calidad del agua

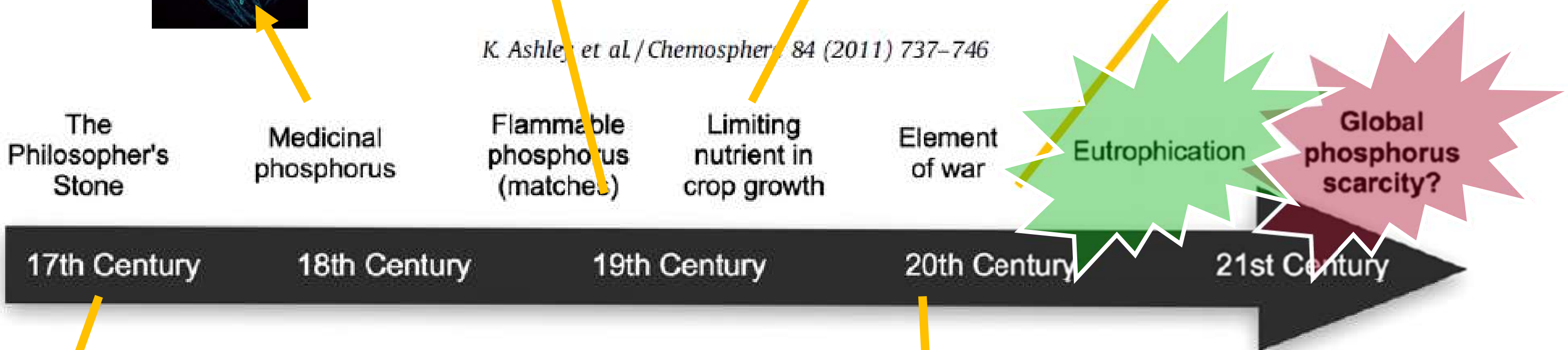
1802
von Humboldt



1840

Revolución verde
1960





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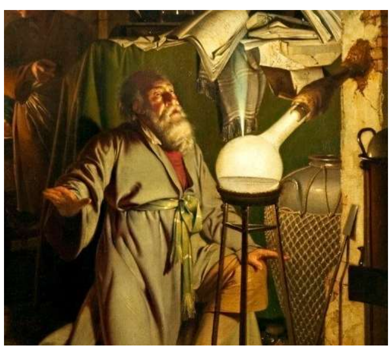

1938

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May 20, 1938

Table 2. Examples of human intervention in the global biogeochemical cycles of carbon, nitrogen, phosphorus, sulfur, water, and sediments. Data are for the mid-1900s.

Element	Flux	Magnitude of flux (millions of metric tons per year)		% change due to human activities
		Natural	Anthropogenic	
C	Terrestrial respiration and decay CO_2	61,000		
	Fossil fuel and land use CO_2		8,000	+13
N	Natural biological fixation	130		
	Fixation owing to rice cultivation, combustion of fossil fuels, and production of fertilizer		140	+108
P	Chemical weathering	3		
	Mining		12	+400
S	Natural emissions to atmosphere at Earth's surface	80		
	Fossil fuel and biomass burning emissions		90	+113
O and H (as H_2O)	Precipitation over land	111×10^{12}		
	Global water usage		18×10^{12}	+16
Sediments	Long-term preindustrial river suspended load	1×10^{10}		
	Modern river suspended load		2×10^{10}	+200

Falkowski, P., Scholes, R.J., Boyle, E., Canadell, J., Canfield, D., Elser, J., Gruber, N., Hibbard, K., Högberg, P., Linder, S., Mackenzie, F.T., Moore III, B., Pedersen, T., Rosenthal, Y., Seitzinger, S., Smetacek, V., Steffen, W., 2000. The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System. Science 290, 291-296.

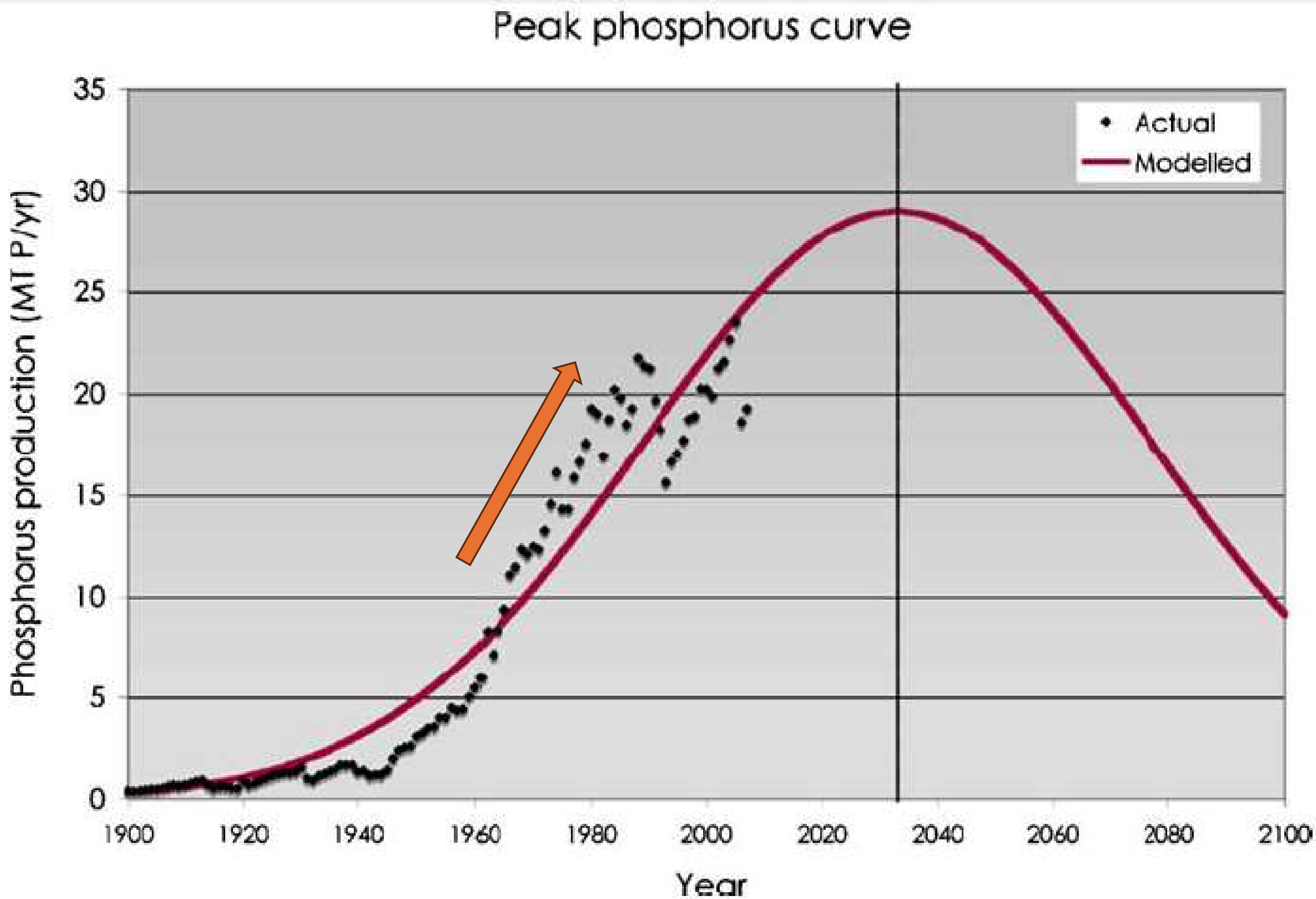

Fig. 4. Indicative peak phosphorus curve, illustrating that, in a similar way to oil, global phosphorus reserves are also likely to peak after which production will be significantly reduced (Jasinski, 2006; European Fertilizer Manufacturers Association, 2000).

Cordell, D., J. O. Drangert and S. White (2009). "The story of phosphorus: Global food security and food for thought." Global Environmental Change 19: 292-305.

Available online at www.sciencedirect.com

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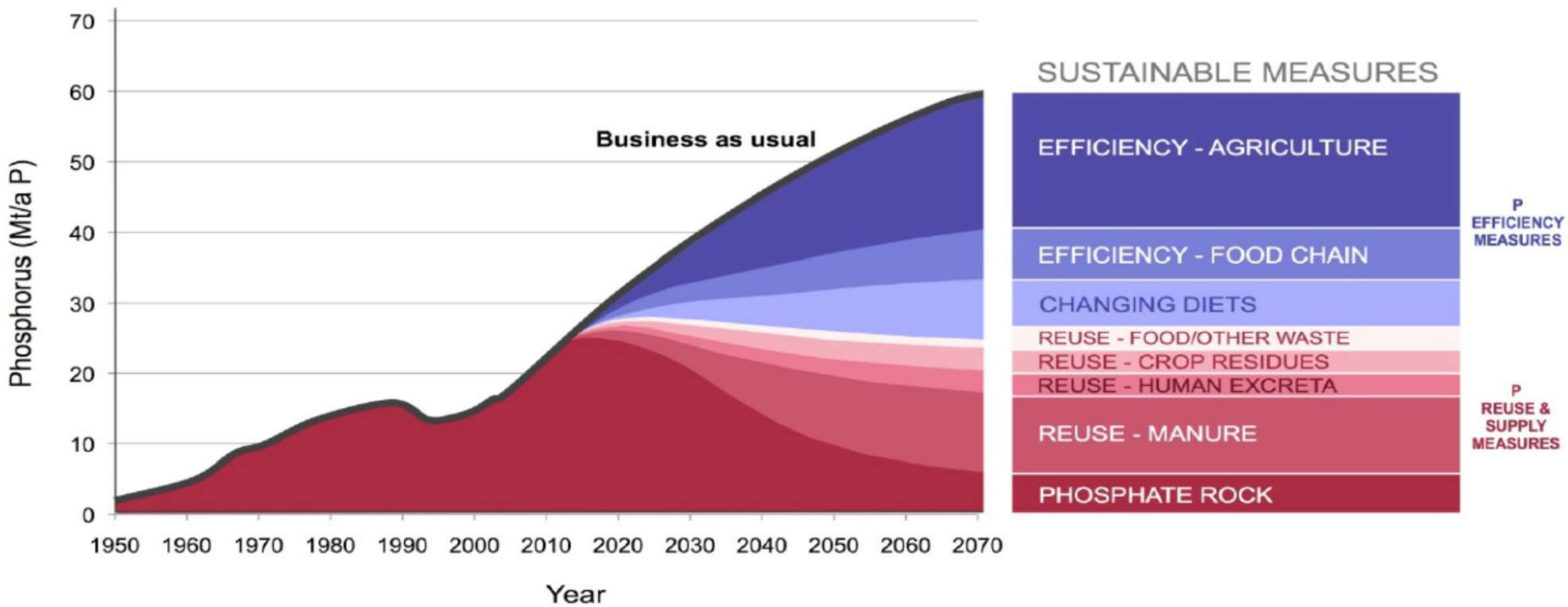
ELSEVIER

Phosphorus: a limiting nutrient for humanity?

James J Elser

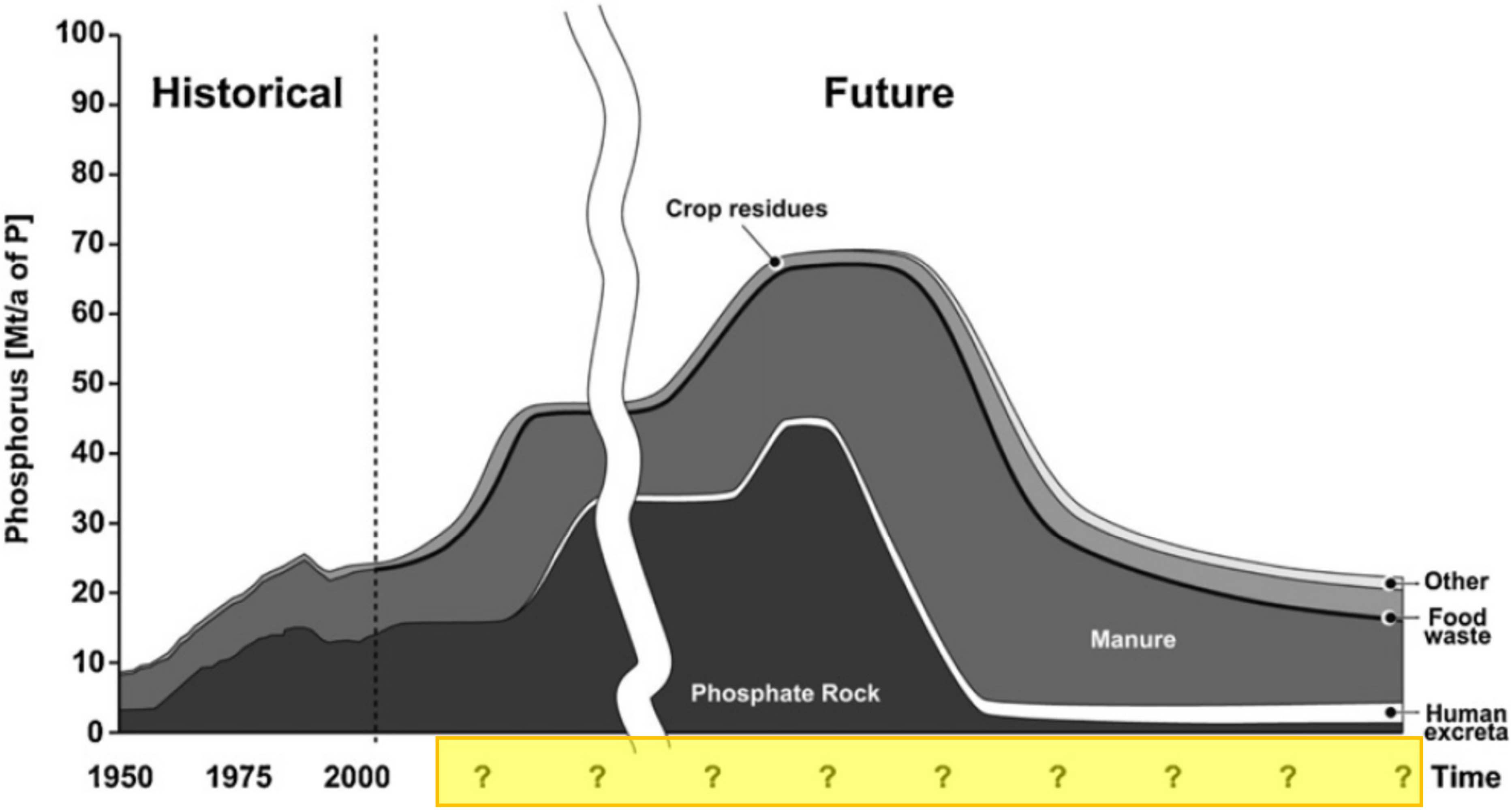
Elser, J. J. (2012). Phosphorus: a limiting nutrient for humanity? *Current Opinion in Biotechnology, 23(6), 833-838. doi:https://doi.org/10.1016/j.copbio.2012.03.001*



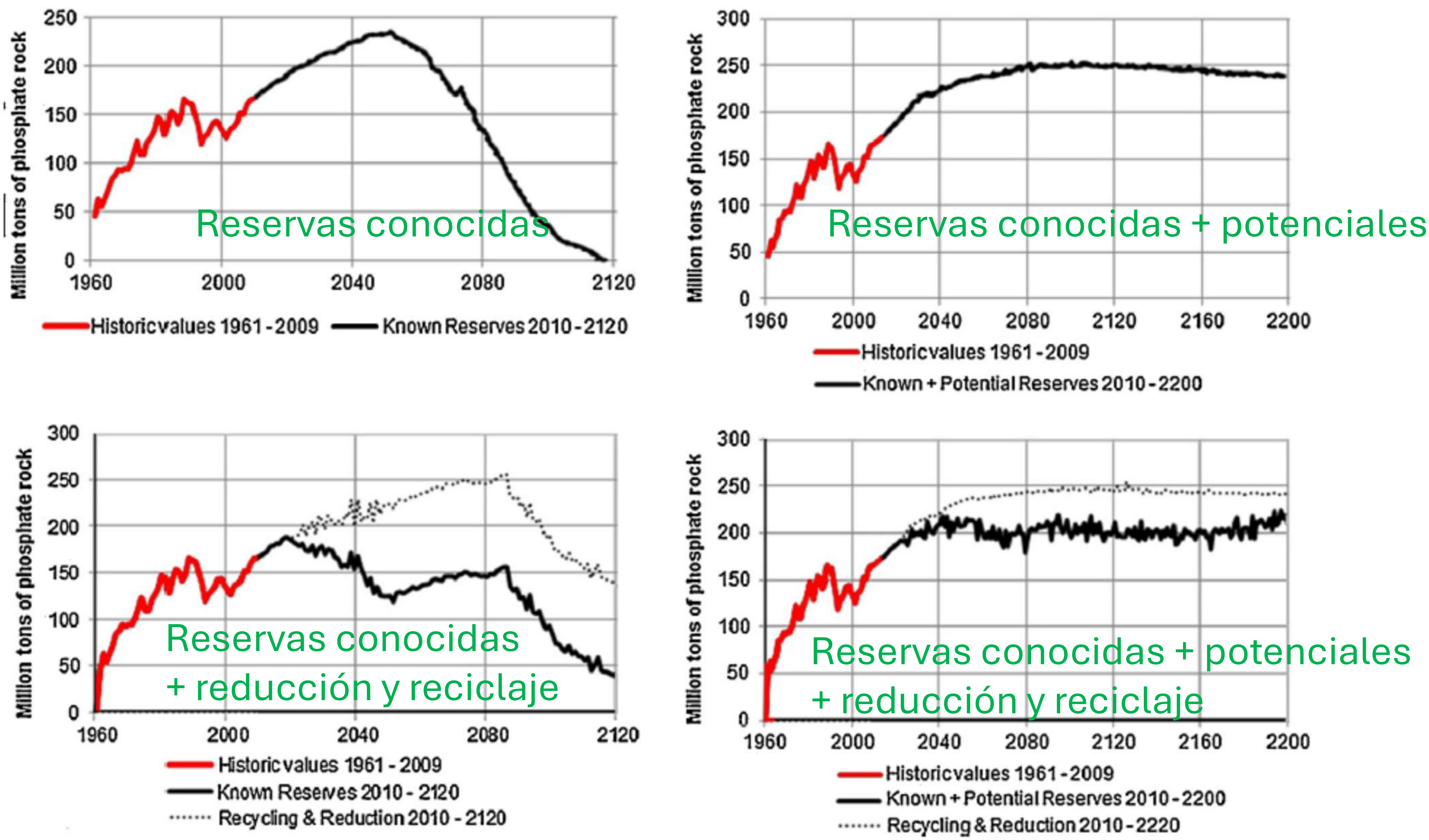
Un escenario preferido para satisfacer la demanda mundial de fósforo a largo plazo:

- Azul: medidas integradas de gestión de la demanda (eficiencia)
- Rojo: medidas del lado de la oferta (reutilización)

Cordell, D., White, S., 2011. Peak Phosphorus: Clarifying the Key Issues of a Vigorous Debate about Long-Term Phosphorus Security. Sustainability 3, 2027.



Scholz, R.W., Wellmer, F.-W., 2013. Approaching a dynamic view on the availability of mineral resources: What we may learn from the case of phosphorus? Global Environmental Change 23, 11-27.



Koppelaar, R.H.E.M., Weikard, H.P., 2013. Assessing phosphate rock depletion and phosphorus recycling options. Global Environmental Change 23, 1454-1466.

Elevada incertidumbre de la magnitud de las reservas globales de P.

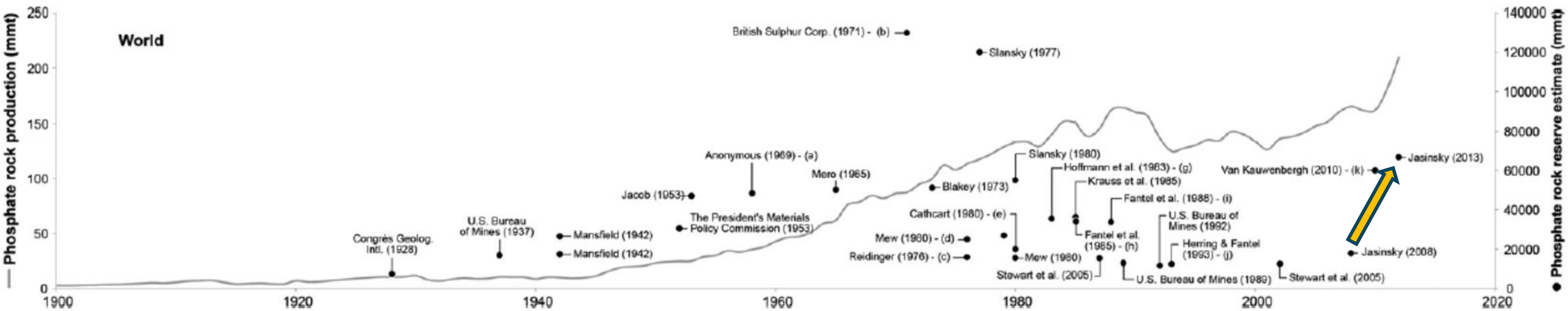


Fig. 1. Historic phosphate rock reserve estimates and production data for the world (1900–2012).

Ulrich, A.E., Frossard, E., 2014. On the history of a reoccurring concept: Phosphorus scarcity.
Science of the Total Environment 490, 694-707.

Evaluación de futuros escenarios

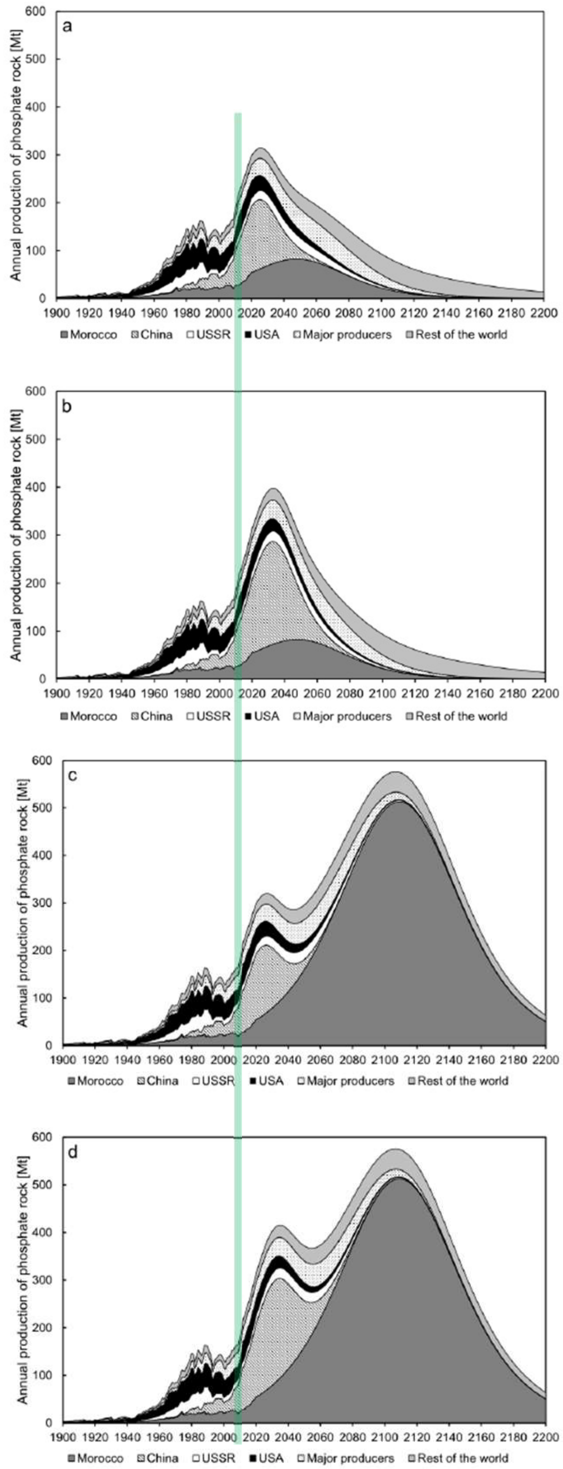


Figure 4. *Resulting production from disaggregated model using logistic curves. a) Case 1 with low URR estimate for China and Morocco. b) Case 2, low URR estimate for Morocco, high for China. c) Case 3: High URR estimate for Morocco, low for China. d)Case 4: High URR estimate for China and Morocco.*

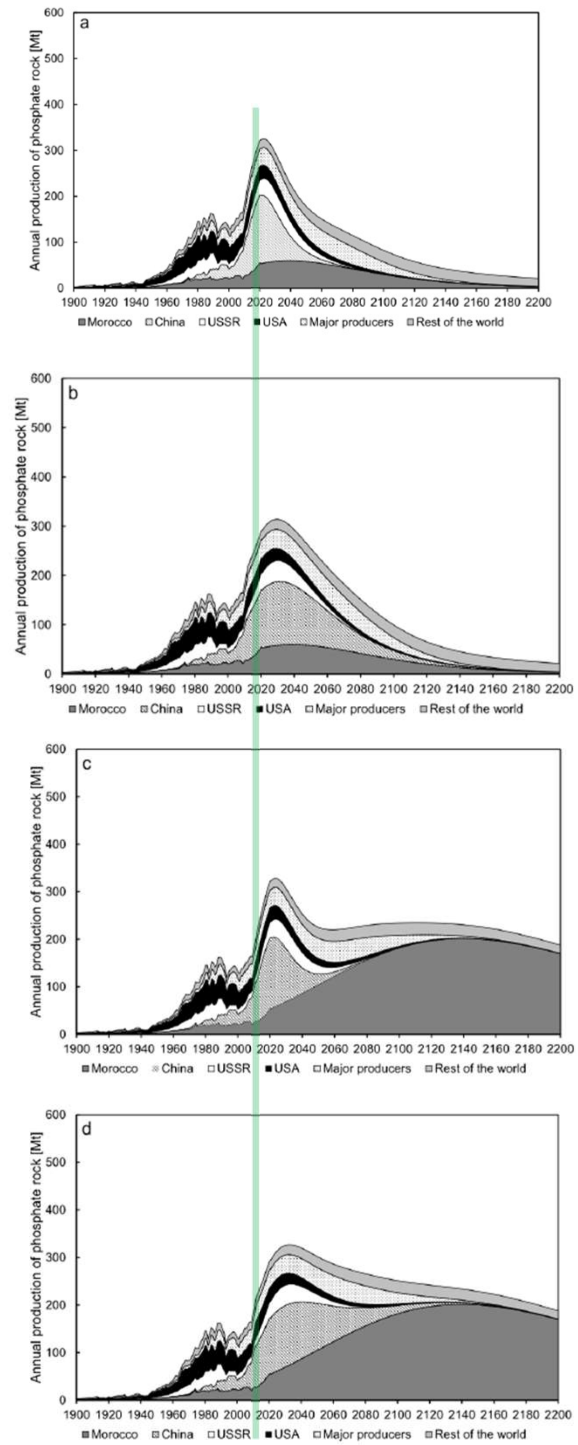
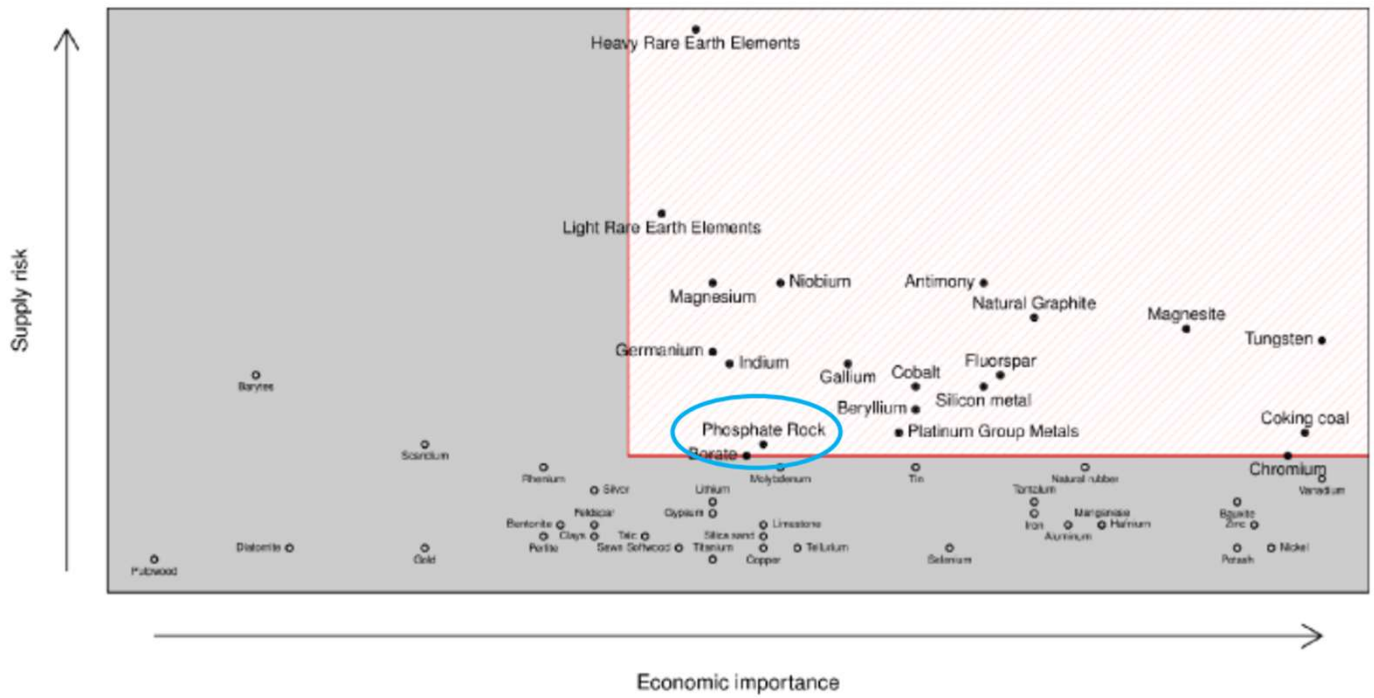


Figure 5. *Resulting production from disaggregated model using Gompertz curves. a) Case 1 with low URR estimate for China and Morocco. b) Case 2, low URR estimate for Morocco, high for China. c) Case 3: High URR estimate for Morocco, low for China. d)Case 4: High URR estimate for China and Morocco.*

Simple curve fitting modelling

Walan, P., Davidsson, S., Johansson, S., & Höök, M. (2014). Phosphate rock production and depletion: Regional disaggregated modeling and global implications. *Resources, Conservation and Recycling, 93(0), 178-187. doi:http://dx.doi.org/10.1016/j.resconrec.2014.10.011*

Desde 2014 La roca fosfórica está en la lista de Materias Primas Críticas de la UE:



https://eur-lex.europa.eu/resource.html?uri=cellar:903d35cc-c4a2-11ed-a05c-1aa75ed71a1.0023.02/DOC_2&format=PDF

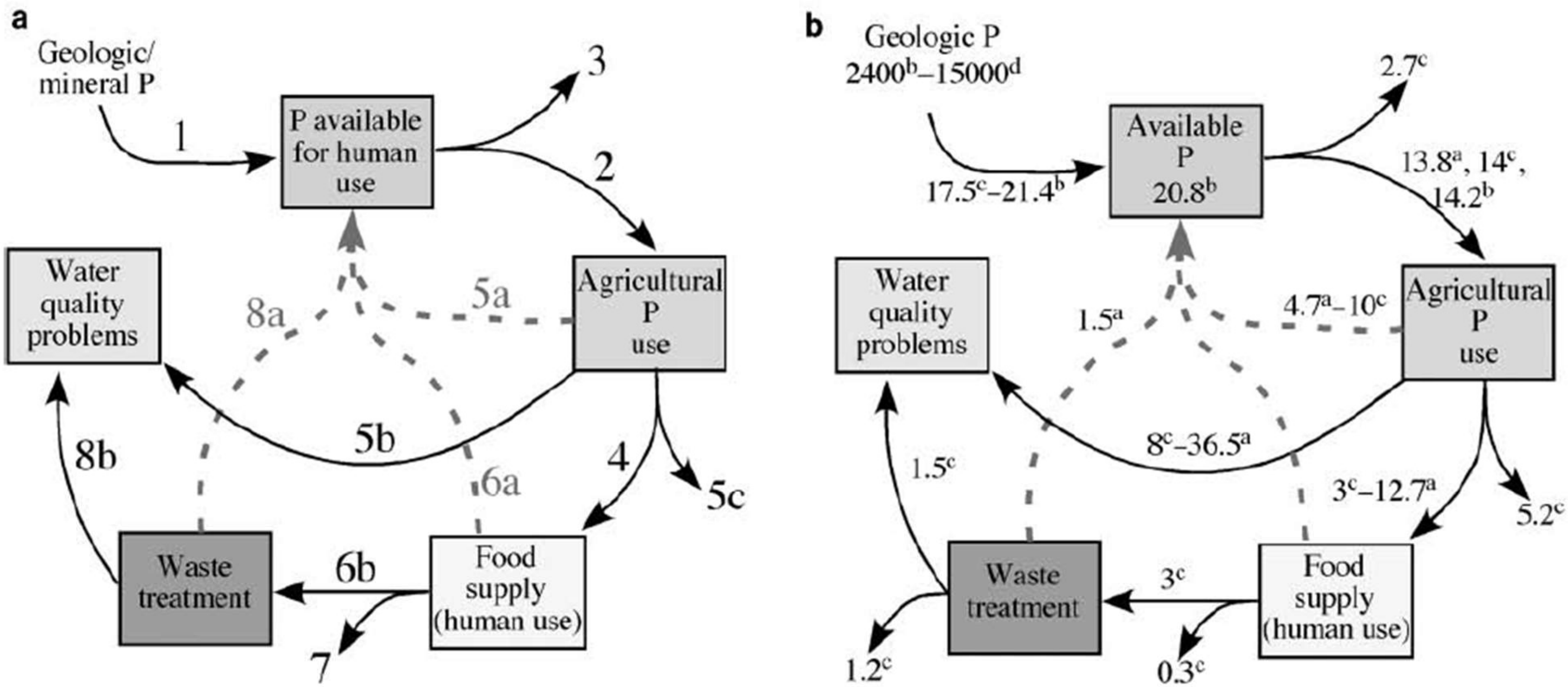
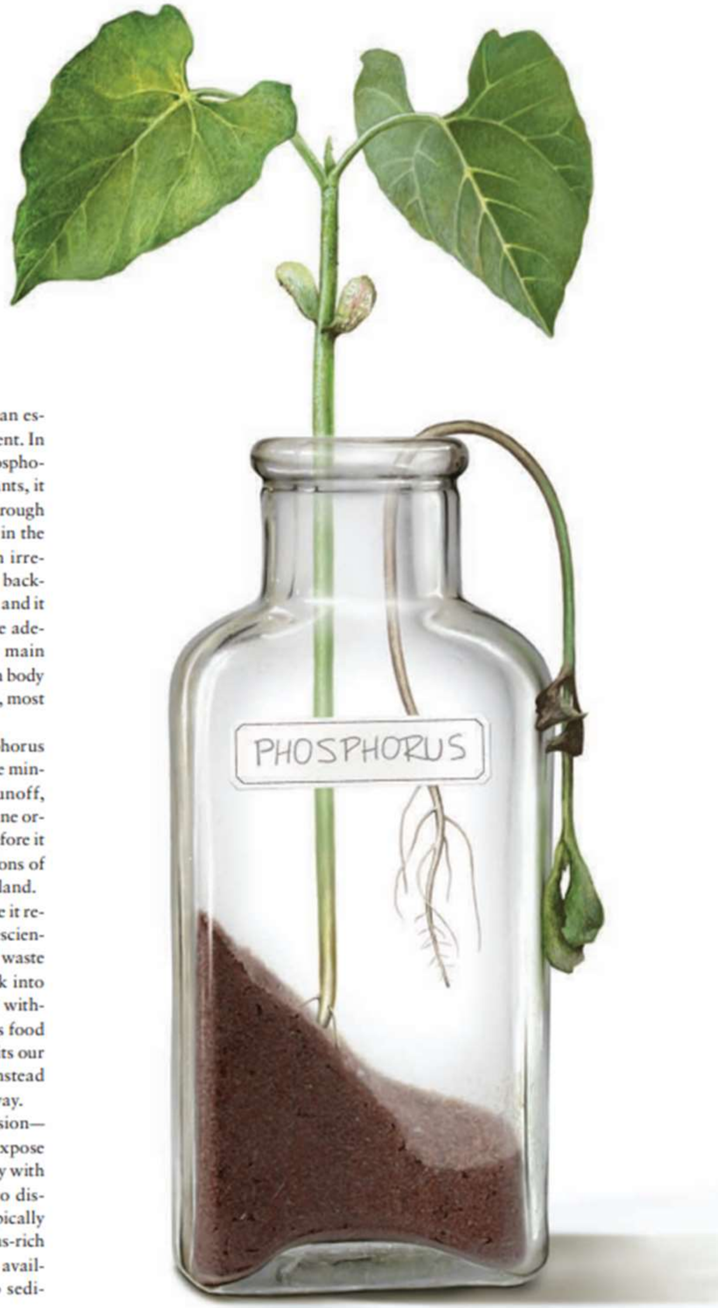


Figure 1. A conceptualization of the human phosphorus (P) cycle. (a) Solid arrows represent key P flows and dashed red arrows represent flows that close the human P cycle through sustainable solutions: (1) P mining and refining, (2) agricultural P use and efficiency, (3) nonagricultural P uses, (4) P in food, (5a) P recycled to agricultural production at the farm, (5b) P lost from farm fields, (5c) P lost in food processing and transportation inefficiencies, (6a) P in composted food waste, (6b) P in human excreta, (7) P in food waste lost to landfills, (8a) P from sewage treatment that is recycled to agricultural production, and (8b) P discharged from ineffectively treated sewage. (b) Estimates of P flows (arrows, in millions of metric tons [MMT] P per year) and P stocks (boxes, in MMT P). Superscripts correspond to the data sources: a, Liu and colleagues (2008); b, Villalba and colleagues (2008); c, Cordell and colleagues (2009); and d, Gilbert (2009). Note the large variability (and uncertainty) in many of the P flow estimates. Geologic supply is based on readily available mineral P reserves. Recycled agricultural P (dashed red arrow 5a) includes the reapplication of crop residues (2 to 2.2) and animal wastes (2.5 to 8) to fields. Agricultural P losses to water bodies (arrow 5b) include estimates of runoff and erosion.

Childers, D. L., Corman, J., Edwards, M., & Elser, J. J. (2011). Sustainability Challenges of Phosphorus and Food: Solutions from Closing the Human Phosphorus Cycle. *BioScience, 61(2), 117-124. doi:10.1525/bio.2011.61.2.6*

Crisis



Our planet is also a spaceship: it has an essentially fixed total amount of each element. In the natural cycle, weathering releases phosphorus from rocks into soil. Taken up by plants, it enters the food chain and makes its way through every living being. Phosphorus—usually in the form of the phosphate ion PO_4^{3-}—is an irreplaceable ingredient of life. It forms the backbone of DNA and of cellular membranes, and it is the crucial component in the molecule adenosine triphosphate, or ATP—the cell's main form of energy storage. An average human body contains about 650 grams of phosphorus, most of it in our bones.

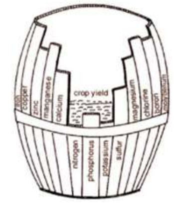
Land ecosystems use and reuse phosphorus in local cycles an average of 46 times. The mineral then, through weathering and runoff, makes its way into the ocean, where marine organisms may recycle it some 800 times before it passes into sediments. Over tens of millions of years tectonic uplift may return it to dry land.

Harvesting breaks up the cycle because it removes phosphorus from the land. In prescientific agriculture, when human and animal waste served as fertilizers, nutrients went back into the soil at roughly the rate they had been withdrawn. But our modern society separates food production and consumption, which limits our ability to return nutrients to the land. Instead we use them once and then flush them away.

Agriculture also accelerates land erosion—because plowing and tilling disturb and expose the soil—so more phosphorus drains away with runoff. And flood control contributes to disrupting the natural phosphorus cycle. Typically river floods would redistribute phosphorus-rich sediment to lower lands where it is again available for ecosystems. Instead dams trap sedi-

JEN CHRISTIANSEN

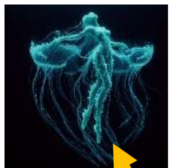
¿Estamos bien o nos fuimos de rosca?

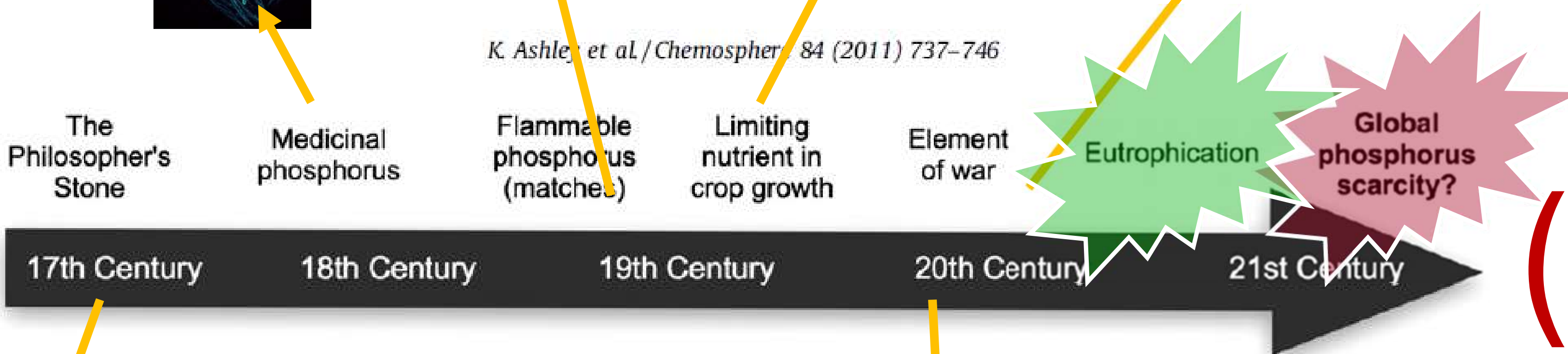


1802
von Humboldt

1840

Revolución verde
1960





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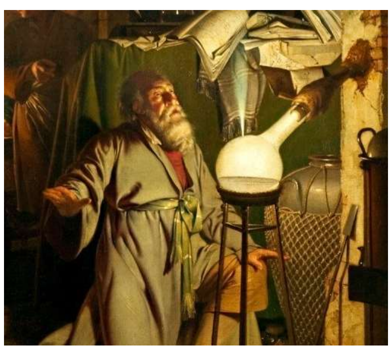

1938

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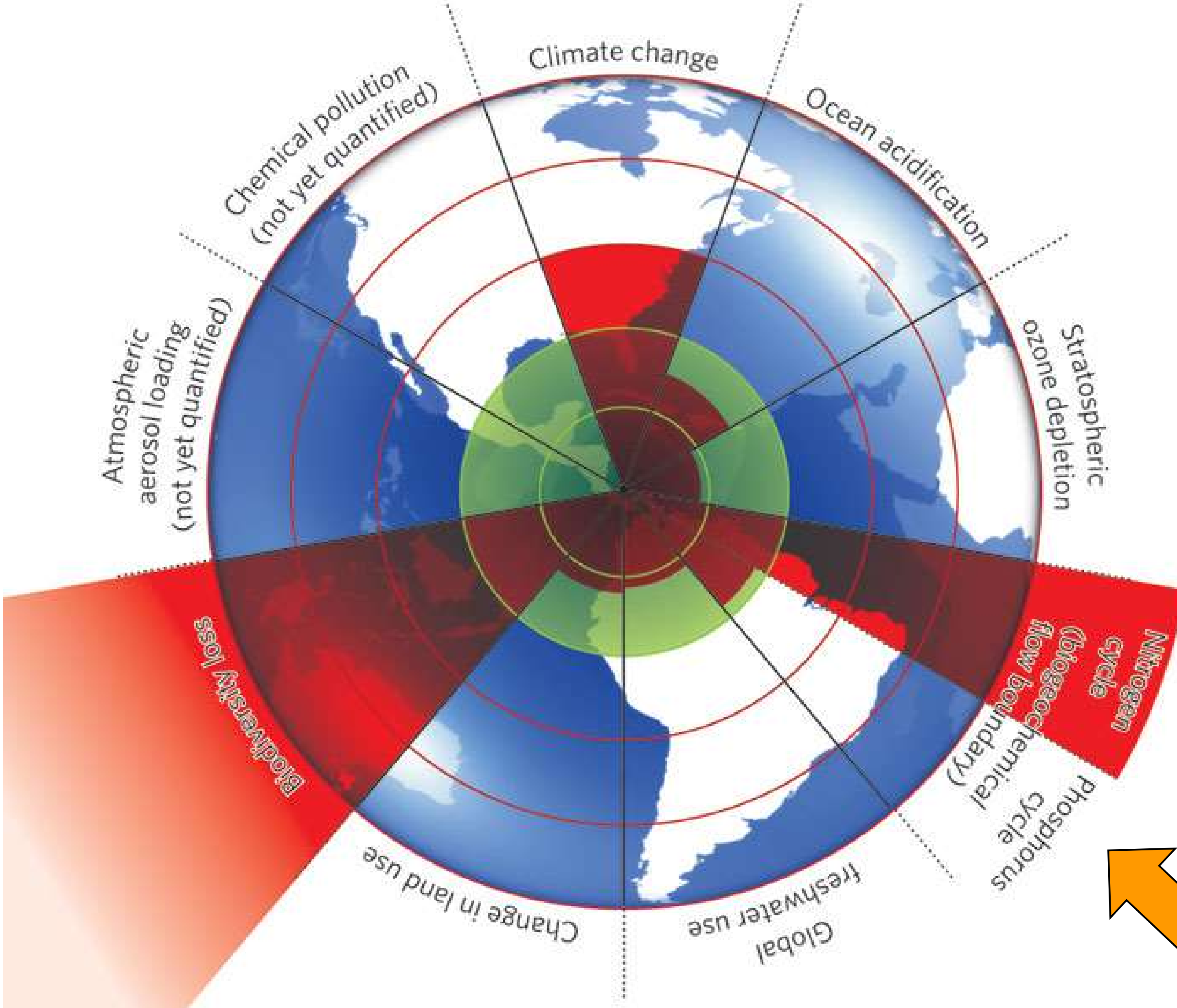
Límites planetarios

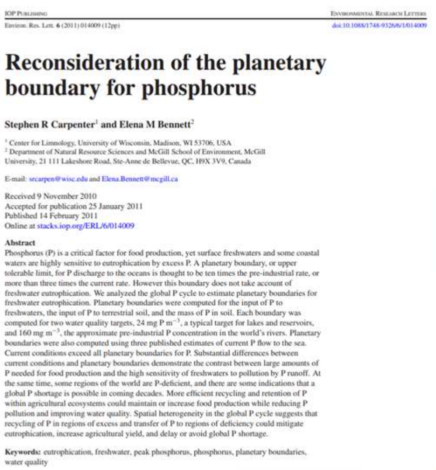
definen un espacio operativo seguro para la humanidad basado en los procesos biofísicos intrínsecos que regulan la estabilidad del Sistema Tierra.



2009

Rockstrom et al. 2009. A safe operating space for humanity. Nature 461, 472-475.

Los flujos biogeoquímicos reflejan la perturbación antropogénica de los ciclos globales de elementos. Actualmente, el marco considera que el nitrógeno (N) y el fósforo (P) constituyen elementos fundamentales de la vida, y sus ciclos globales se han visto notablemente alterados a través de la agricultura y la industria.



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Reconsideration of the planetary boundary for phosphorus

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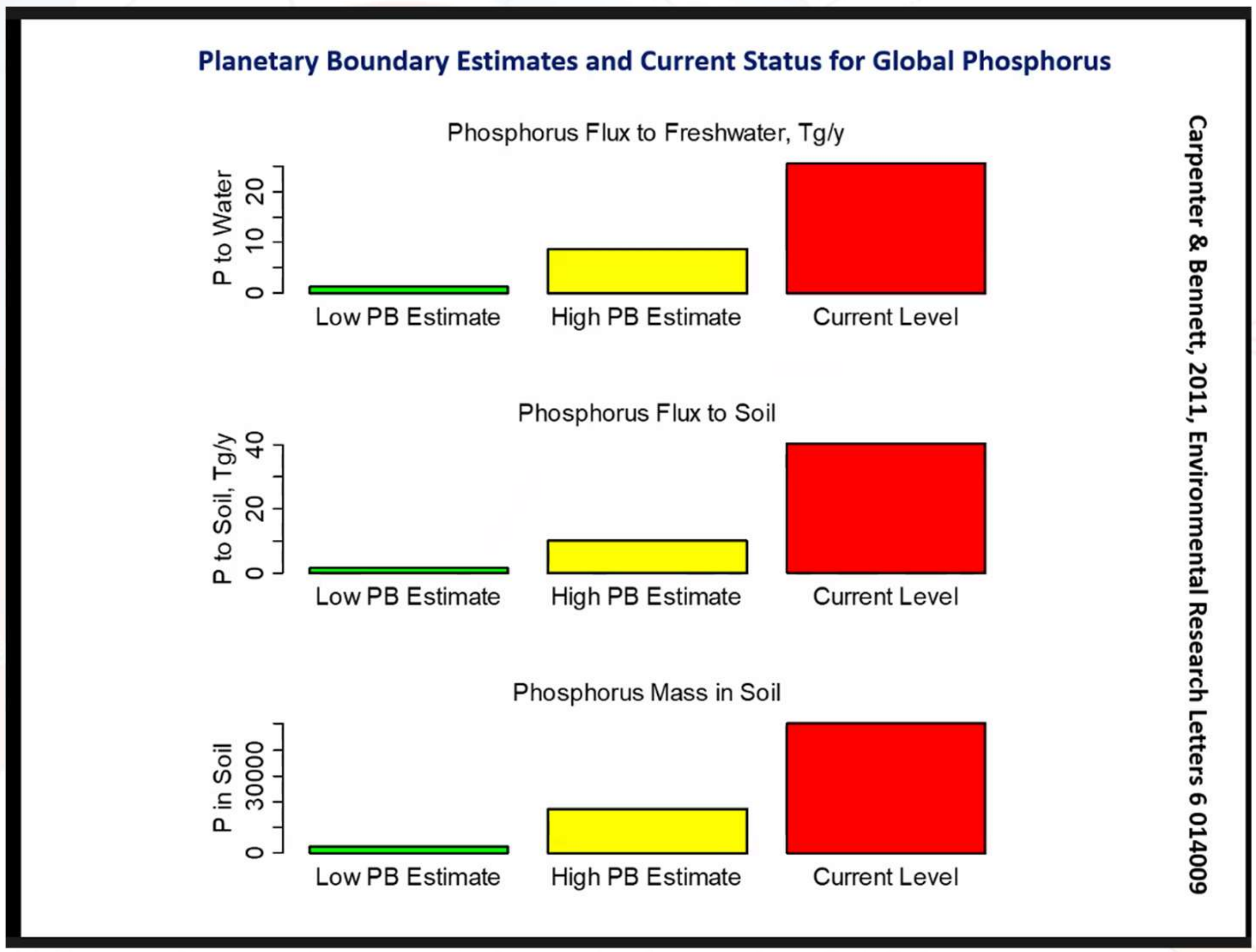
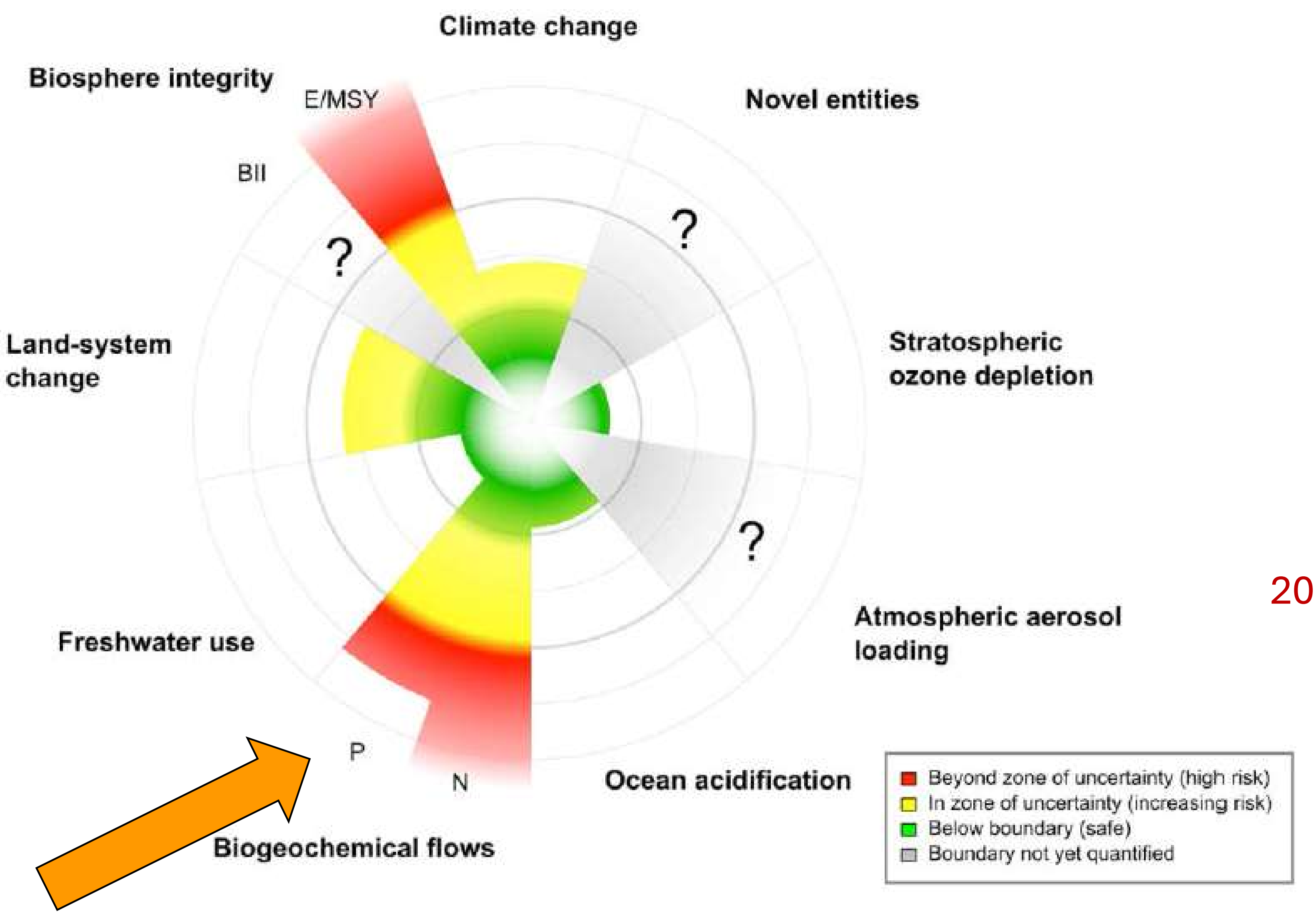
Abstract
Phosphorus (P) is a critical factor for food production, yet surface freshwaters and some coastal waters are highly sensitive to eutrophication by excess P. A planetary boundary, or upper tolerable limit, for P discharge to the oceans is thought to be ten times the pre-industrial rate, or more than three times the current rate. However this boundary does not take account of freshwater eutrophication. We analyzed the global P cycle to estimate planetary boundaries for freshwater eutrophication. Planetary boundaries were computed for the input of P to freshwaters, the input of P to terrestrial soil, and the mass of P in soil. Each boundary was computed for two water quality targets, 24 mg P m^{-3}, a typical target for lakes and reservoirs, and 160 mg m^{-3}, the approximate pre-industrial P concentration in the world's rivers. Planetary boundaries were also computed using three published estimates of current P flow to the sea. Current conditions exceed all planetary boundaries for P. Substantial differences between current conditions and planetary boundaries demonstrate the contrast between large amounts of P needed for food production and the high sensitivity of freshwaters to pollution by P runoff. At the same time, some regions of the world are P-deficient, and there are some indications that a global P shortage is possible in coming decades. More efficient recycling and retention of P within agricultural ecosystems could maintain or increase food production while reducing P pollution and improving water quality. Spatial heterogeneity in the global P cycle suggests that recycling of P in regions of excess and transfer of P to regions of deficiency could mitigate eutrophication, increase agricultural yield, and delay or avoid global P shortage.

Keywords: eutrophication, freshwater, peak phosphorus, phosphorus, planetary boundaries, water quality





2015

Steffen, W., K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers and S. Sörlin (2015). "Planetary boundaries: Guiding human development on a changing planet." Science 347(6223).

El **límite global** para el P es un flujo sostenido de 11 Tg de P.año^{-1} desde el agua dulce al océano, para evitar la anoxia a gran escala.

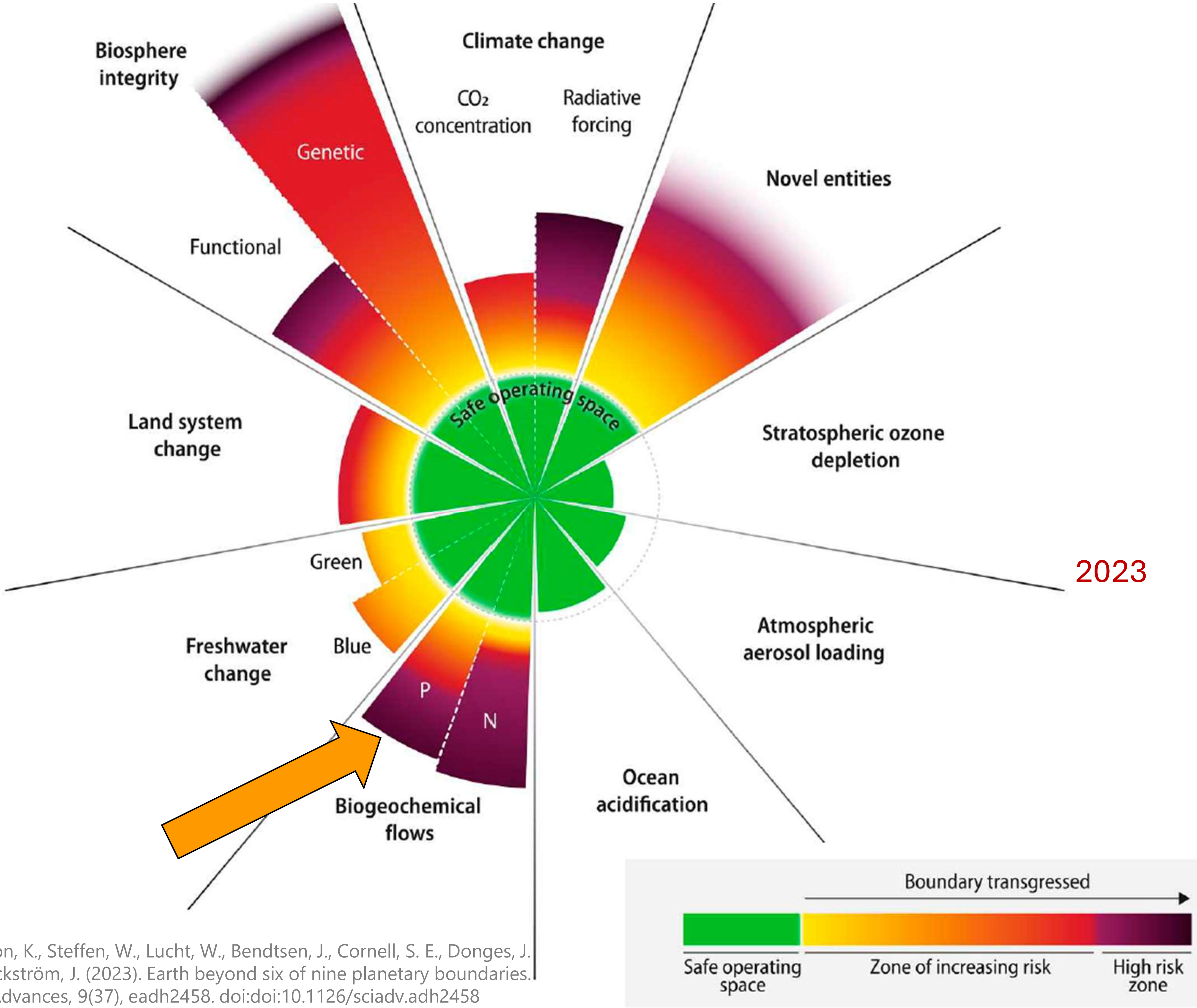
Los flujos de P en agua dulce hacia el mar desde el utilizado para la actualización del marco de 2015, es decir, un estimado de 22 Tg de P.año^{-1}.

El **límite a nivel regional** se establece en un flujo de **6,2 Tg de P.año^{-1}** desde fertilizantes a suelos erosionables, para evitar la eutrofización generalizada de los ecosistemas de agua dulce.

La tasa actual de aplicación de P en fertilizantes para tierras de cultivo es de **17,5 Tg de P.año^{-1}**, aunque el uso de P está aumentando y en otros estudios se han reportado estimaciones mucho más altas de hasta **32,5 Tg de P.año^{-1}**.

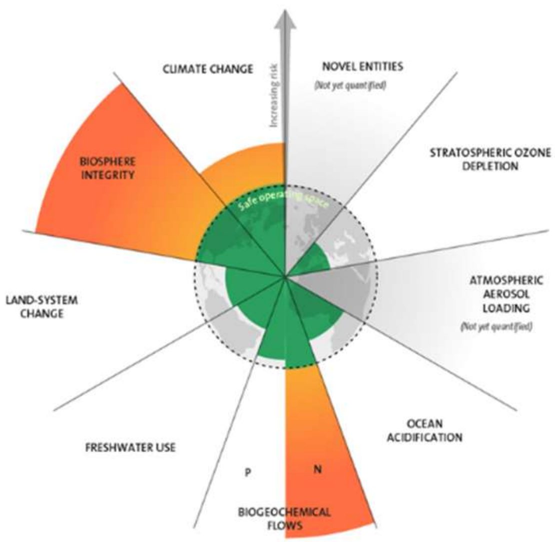
Por lo tanto, se exceden los límites globales y regionales de P.

Steffen, W., K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers and S. Sörlin (2015). "Planetary boundaries: Guiding human development on a changing planet." Science 347(6223).



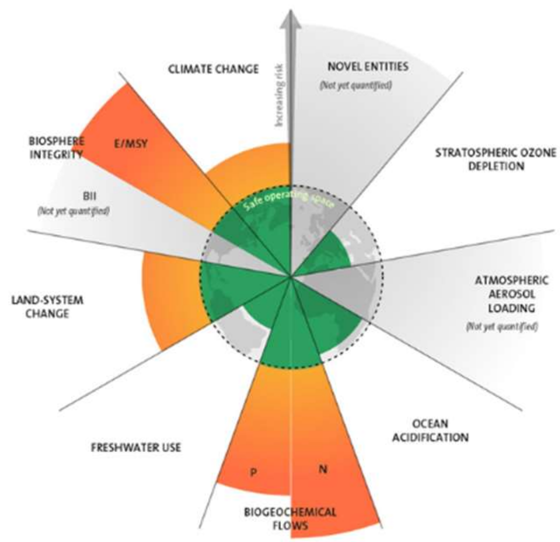
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., . . . Rockström, J. (2023). Earth beyond six of nine planetary boundaries. Science Advances, 9(37), eadh2458. doi:doi:10.1126/sciadv.adh2458

2009



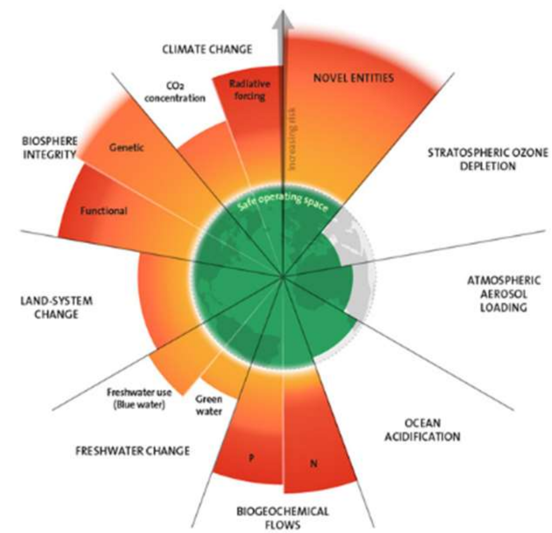
7 boundaries assessed,
3 crossed

2015



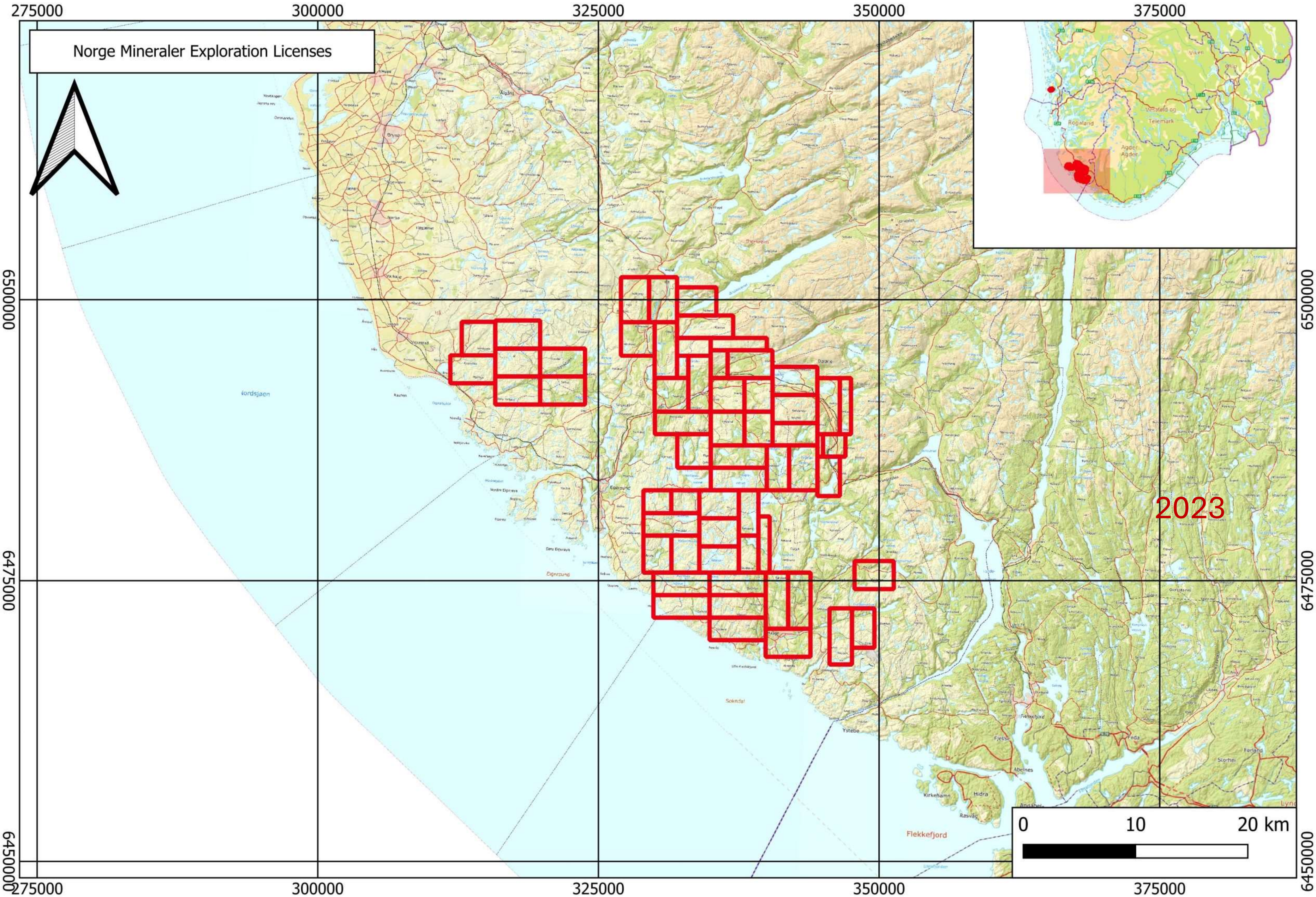
7 boundaries assessed,
4 crossed

2023



9 boundaries assessed,
6 crossed

https://www.stockholmresilience.org/research/planetary-boundaries.html



Norge Mineraler Exploration Licenses
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'Great news': EU hails discovery of massive phosphate rock deposit in Norway

By Frédéric Simon | Euractiv.com Est. 7min 29 jun 2023 (updated: 26 ene 2024)

Content-Type: News

The Norwegian deposit is estimated to be worth 70 billion tonnes at least, which is just under the 71 billion tonnes of proven world reserves as evaluated by the US Geological Survey in 2021. [Photo credit: Laszlo Kupi]

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8 Julio 2023

KEY POINTS

- CRITICAL RAW MATERIAL (EU: 2020)
- KEY INGREDIENT FOR GLOBAL FOOD SECURITY
- BOOSTS CROP YIELDS
- MARKET PREDICTED TO REACH $207 BILLION BY 2026
- ASIA IS LARGEST MARKET; EMERGING ECONOMIES SHOWING INTEREST

Phosphate

Phosphate fertilisers could provide the natural answer to global food security.

CROP YIELD BOOST

The use of phosphate fertilisers in the past 50 years has boosted crop yields and helped feed millions, if not billions, of people. Fertilisers are typically comprised of three major water-soluble macronutrients such as phosphate, potash and nitrogen.

BURGEONING MARKET

It's predicted the global phosphate fertiliser market will reach $207 billion by 2026 (Global Market Insights), registering a 5.1% CAGR therein. The world's increasing population (and, therefore, increasing meat consumption), limited availability of land and drive for food diversity have been key drivers of demand. Asia is currently the largest market, due to large farming communities in China and India. Awareness programmes in emerging economies in Latin America, Africa and Asia-Pacific are encouraging greater use in these areas.

SECURITY AND SUSTAINABILITY

The European Union once again named phosphate rock as a 'Critical Raw Material' in 2020. Its security is emerging as a vital global sustainability challenge. Supply strategies to ensure farmers have sufficient access to phosphates to feed the world are therefore becoming increasingly urgent.

communications materials

MATTERS ARISING

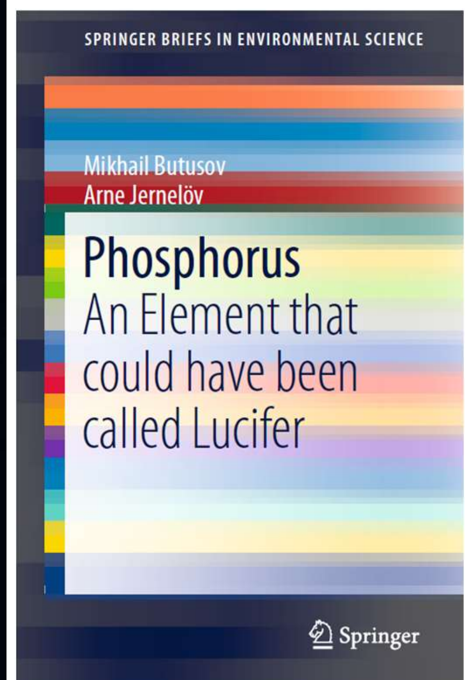
Check for updates

https://doi.org/10.1038/s43246-022-00236-4 OPEN

Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector

Bryan M. Spears[1,2]✉, Will J. Brownlie[1,2], Dana Cordell[3], Ludwig Hermann[4] & José M. Mogollón[5]

ARISING FROM Xu et al. *Communications Materials* https://doi.org/10.1038/s43246-020-00095-x (2020)



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Dr. Guillermo Goyenola goyenola@gmail.com 04/2024