
CURSO DE POSGRADO · 3ª EDICIÓN
LIMNO.CUENCAS.UY
Eutrofización
y biogeoquímica
ambiental
del fósforo.
INICIO
15 de junio
2026
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Intensivo
Presencial / Distancia
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Dr. Guillermo Goyenola
Dra. Mariana Meerhoff
aguadulceuy@gmail.com
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AMBIENTALES
FACULTAD DE
AGRONOMÍA
UPEP
CURE

# P en la Biósfera


Guillermo Goyenola
goyenola@gmail.com

Laboratorio de
Ciencia de Cuencas
y Limnología
del Antropoceno
CATCHMENT SCIENCE - ANTHROPOCENE LIMNOLOGY

DEGA
Departamento de Ecología
y Gestión Ambiental

UNIVERSIDAD
DE LA REPÚBLICA
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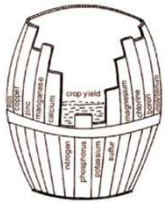
CURE

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

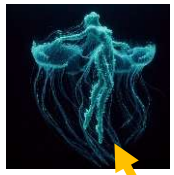
Von Goethe (1749-1832)

1802
von Humboldt




1840

Revolución verde
1960







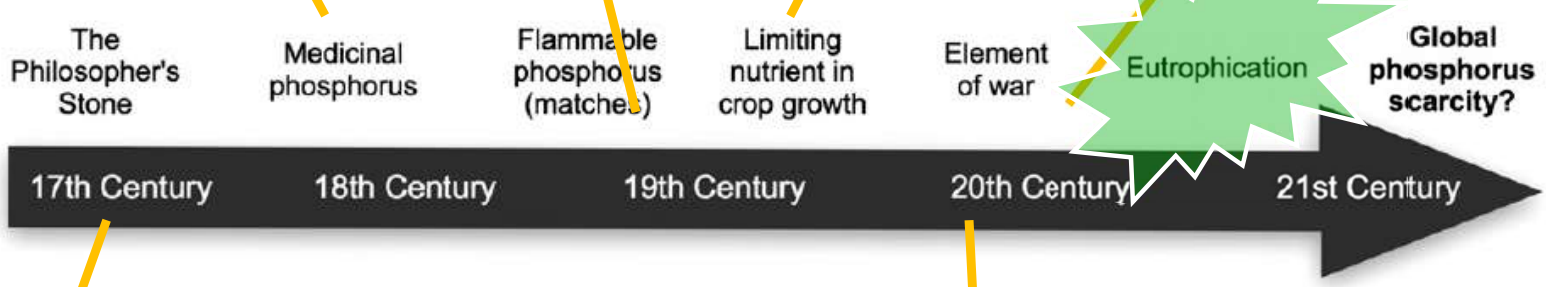
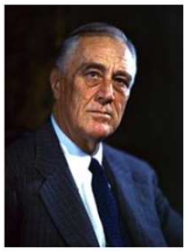



**Fig. 1.** The evolution of phosphorus use and abuse: from the Philosopher's Stone to use in war, food production, and more recently implicated in water pollution. A new emerging discourse of the 21st century may be global phosphorus scarcity. *Source*: Cordell (2010).

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
- En la teoría clásica, se le entendía como el envejecimiento de sistemas acuáticos
- Aumento de la carga de nutrientes
- Acumulativa
- Fertilización
- Aumento de la productividad

“INMINENT” (2016)

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


Eutrofización antrópica
Eutrofización cultural
• Proceso artificial
• Acelerado
“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)


Guillermo Goyenola
ggoyenola@cure.edu.uy

Laguna del Sauce
(Maldonado) 2008

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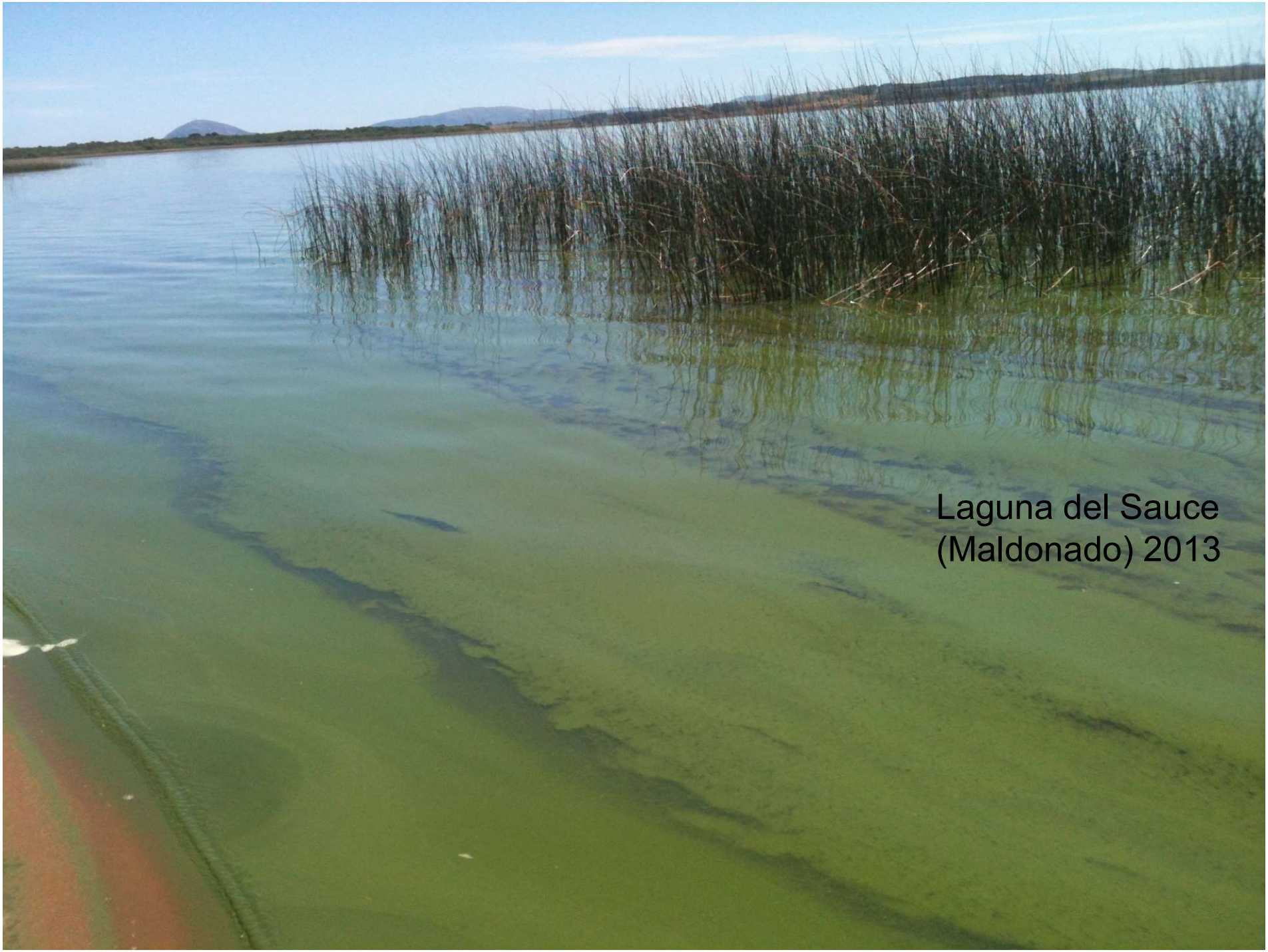
ggoyenola@cure.edu.uy


Laguna del Sauce
(Maldonado) 2013

Laguna del Sauce, 2015

Laguna del Sauce, 2015

# Eutrofización

Aumento de la disponibilidad de nutrientes

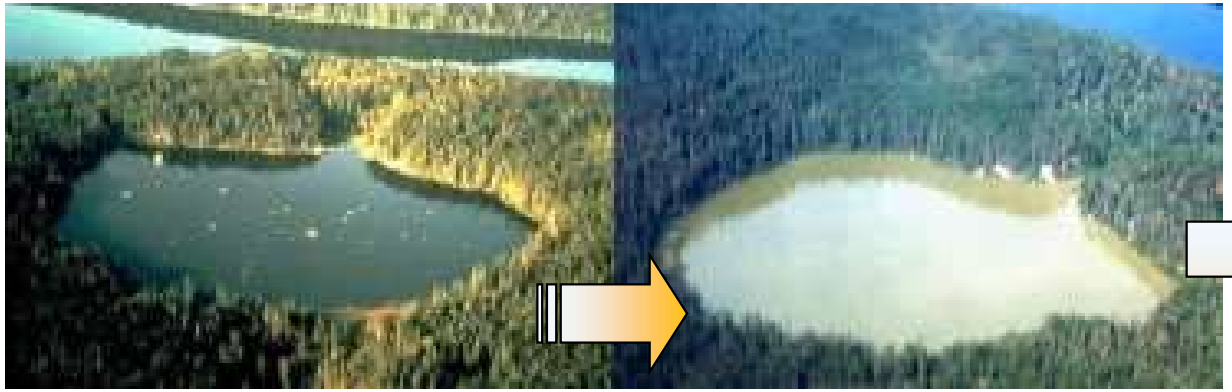
Aumento de la productividad primaria

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

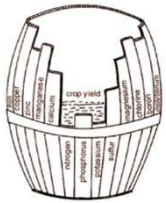
# Handling the phosphorus paradox in agriculture and natural ecosystems: Scarcity, necessity, and burden of P

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
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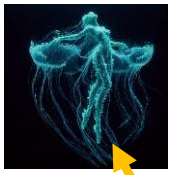
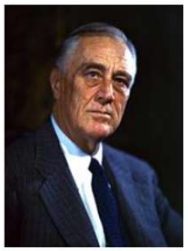







**Fig. 1.** The evolution of phosphorus use and abuse: from the Philosopher's Stone to use in war, food production, and more recently implicated in water pollution. A new emerging discourse of the 21st century may be global phosphorus scarcity. *Source*: Cordell (2010).

1938



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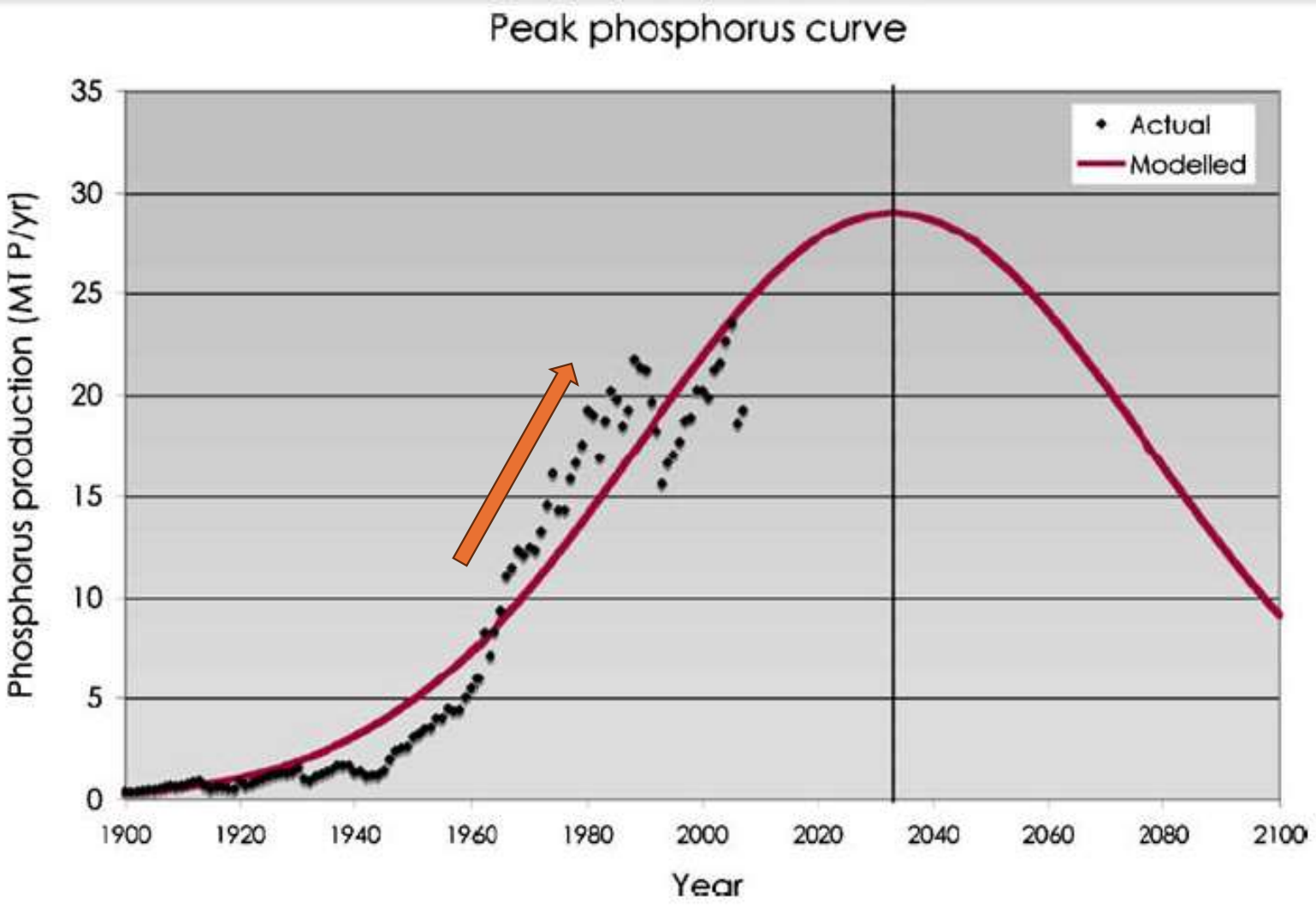
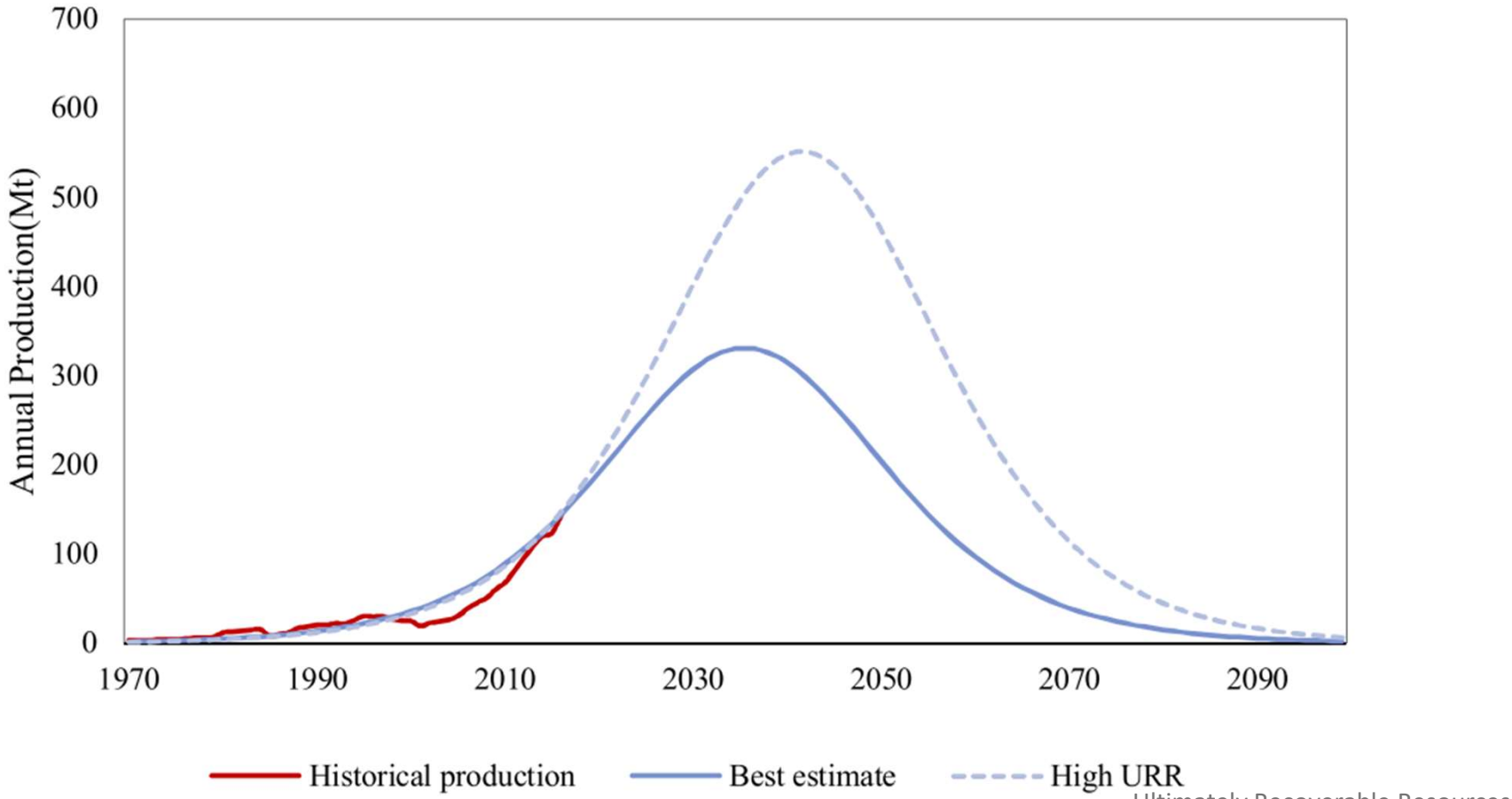



**Fig. 4.** Indicative peak phosphorus curve, illustrating that, in a similar way to oil, global phosphorus reserves are also likely to peak after which production will be significantly reduced (Jasinski, 2006; European Fertilizer Manufacturers Association, 2000).

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.

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




Ultimately Recoverable Resources

**Fig. 4.** PR production estimates for China.

Phosphate Rock

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*

Available online at www.sciencedirect.com

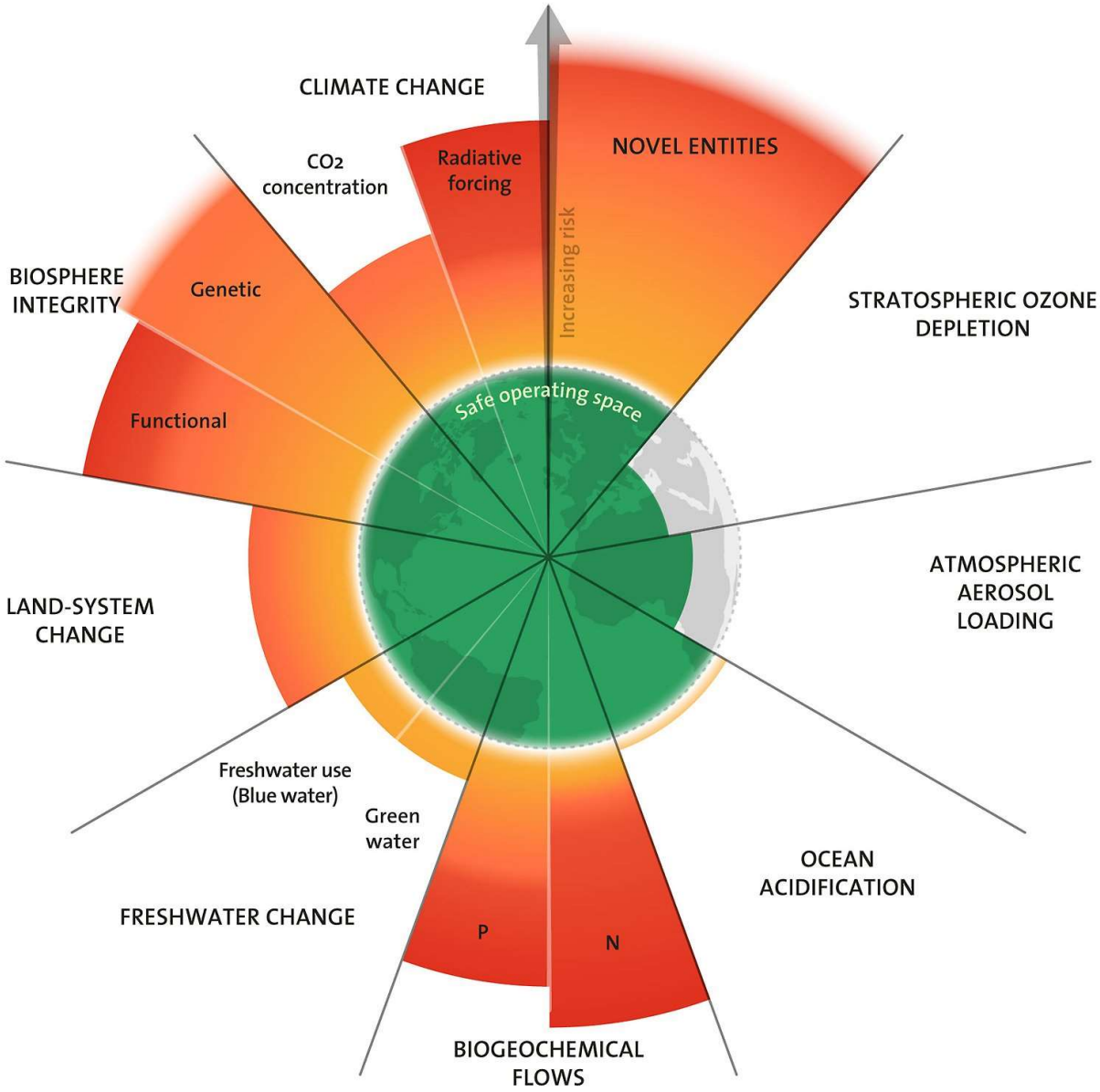
SciVerse ScienceDirect

# 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*

# Los límites planetarios

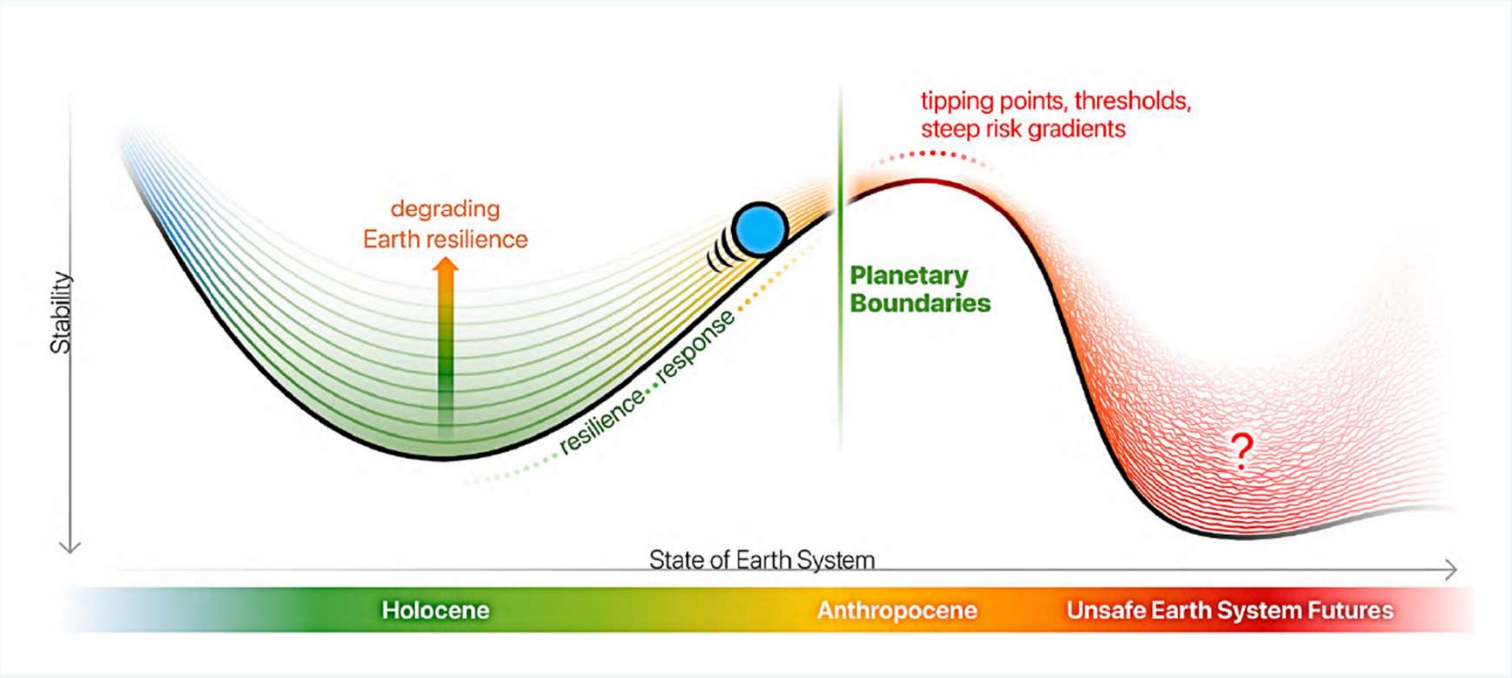



https://www.stockholmresilience.org/research/planetary-boundaries.html

# Los límites planetarios

## Earth Resilience

*Earth resilience* is the capacity of the biogeophysical Earth system to absorb human pressures (anthropogenic greenhouse gas emissions, degradation of biosphere integrity, land use changes, etc.) such that the system remains in (or returns to) a Holocene-like state. Only this state can provide the essential structures and functions that are the foundation for sustainable development of human societies. Staying within a habitable Holocene-like state will require active stewardship to revitalize and strengthen Earth's resilience.



# Los límites planetarios

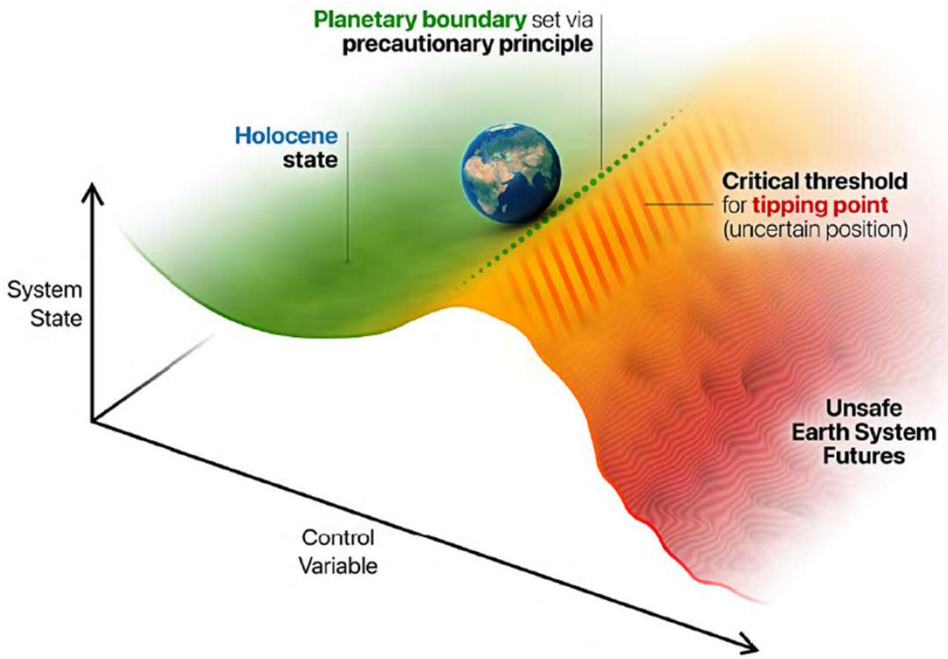


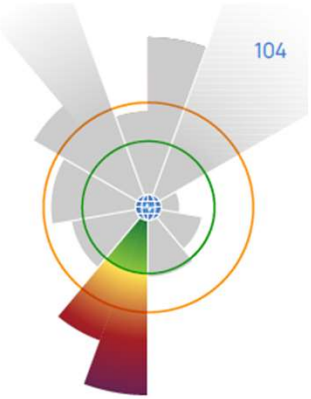

**FIGURE 7 - Stylized stability landscape of the Earth system.** Tipping points and Planetary Boundaries are interconnected – both address Earth system stability, but they serve distinct roles. Beyond a *tipping point*, a system fundamentally changes due to a shift in feedback dynamics: When stabilizing feedbacks are dominated by destabilizing ones, they drive the system to a qualitatively different state, often abruptly and/or irreversibly. Where quantifiable, the *Planetary Boundaries* are set in a safe distance away from risks of crossing tipping points.

# Los límites planetarios





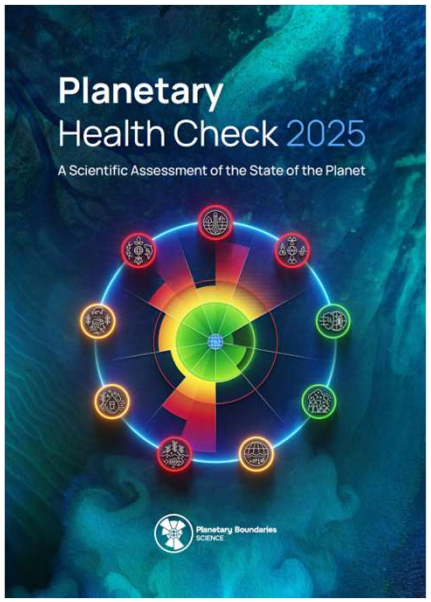
## 4.5 Modification of Biogeochemical Flows



### Main Takeaways

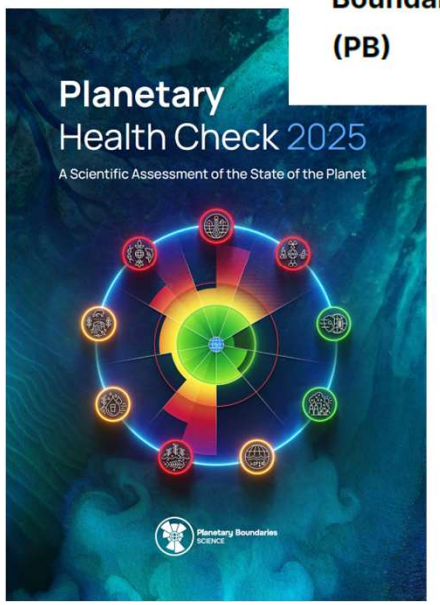
In the 20th century, the invention of industrial nitrogen fixation made it possible to convert molecular nitrogen from the atmosphere into reactive forms, such as those used in inorganic fertilisers. Combined with the mining of phosphate rock, this led to a drastic increase in fertilizer application on agricultural land.[336] Because only a part of the fertilizer is actually taken up by crops, large quantities of both nutrients remain in the environment.[337,338]

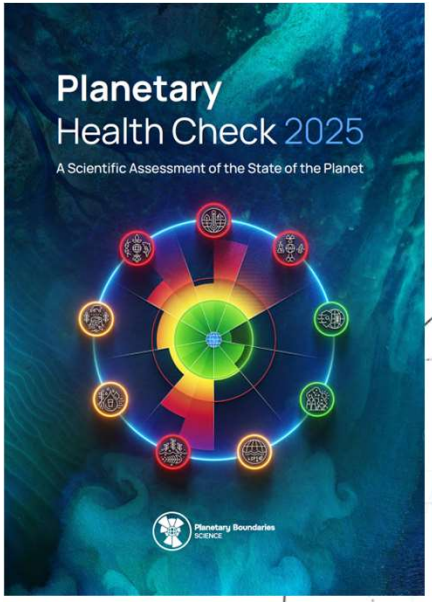
Nitrogen is released into the air and stored in groundwater and surface waters. Phosphorus accumulates in soils and is released into surface waters via soil erosion and surface runoff. Excess nutrients can have negative effects on biodiversity and the resilience of ecosystems on land, in freshwater and in the ocean, which are adapted to specific nutrient levels. Currently, losses of both nutrients to the environment are disrupting ecosystems beyond the safe level.




# #1 Phosphorus (P) Flows

| | |
|---|---|
| **Definition** | The phosphorus boundary consists of a regional component, aiming to prevent eutrophication of freshwater systems, and a global component, aiming to prevent large-scale ocean anoxia. The regional boundary uses the application of mined phosphorus to erodible soils as an indicator of phosphorus flow into freshwater systems, while the global boundary is based on riverine transport of phosphorus to the ocean. |
| **Unit** | Teragrams of Phosphorus per Year (Tg of P $year^{-1}$). 1 teragram equals 1 million metric tons. |
| **Historical Range** | Before human intervention, phosphorus flows were low (~2.5 Tg P $year^{-1}$ from land to freshwater and ~1.3 Tg P $year^{-1}$ of export to the ocean).[340] Human activities have increased flows from land to freshwater systems through a global application of mined phosphorus to cropland of around 18.2 Tg P $year^{-1}$ (regional, aggregated) and have increased phosphorus flows to the ocean to around 4.4 Tg P $year^{-1}$ (global), largely due to fertilizer use.[340,341] |
| **Planetary Boundary (PB)** | The regional boundary is set to an application of 6.2 Tg P per year,[3] while the global boundary is established at a flow of 11 Tg P per year, which is roughly ten times the natural flow rate.[342] Here, we focus on the regional boundary, as it is more limiting than the ocean boundary. |





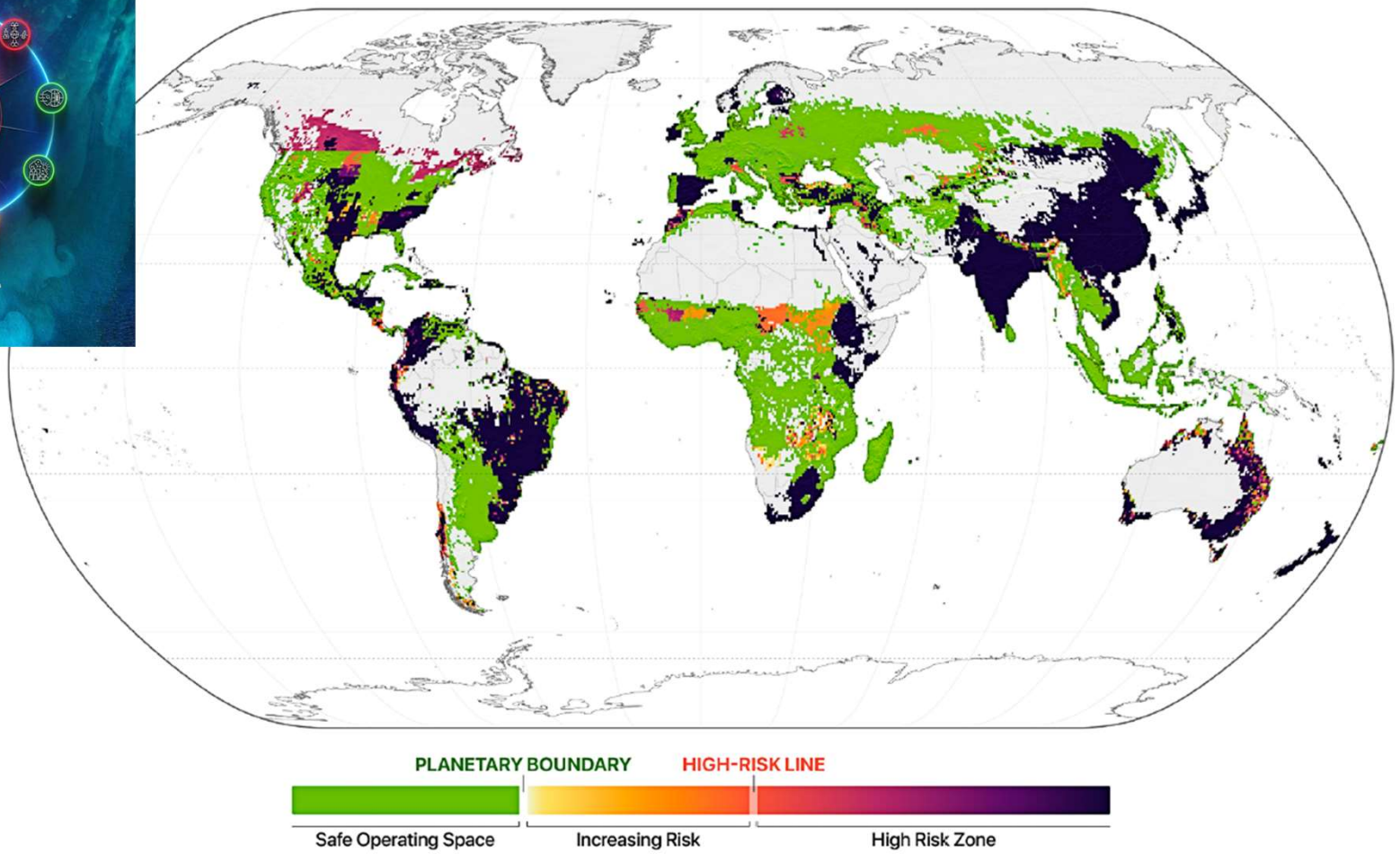




**FIGURE 34 - Global risk map for the transgression of the Modification of Biogeochemical Flows boundary – Phosphorus cycle**. The regional boundary status is calculated based on agricultural phosphorus surplus in the year 2020. This graphic aligns with the suggestion for a control variable definition that is more closely related to phosphorus losses to the environment (phosphorus surplus instead of input).[103] The regional boundaries were preliminarily derived from the global boundaries, assuming a uniform rate of fertilizer surplus on cropland. Regional pollution limits may deviate significantly from these boundaries.[3] Based on data from model runs with IMAGE-GNM, using the methodology of van Vuuren et al. (2025).[103]

***Key takeaway:*** *The transgression of the phosphorus cycle boundary is particularly notable in parts of South America and Asia, where phosphorus use has exceeded safe ecological limits, indicating potential environmental threats.*

# '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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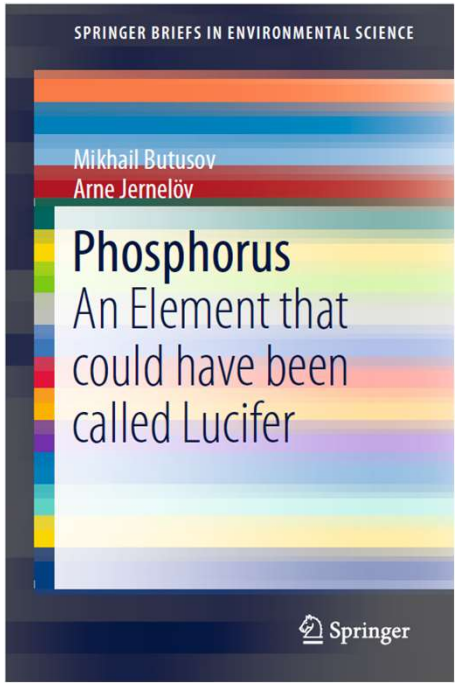

# P en la Biósfera

"DEMAND & SUPPLY" (2017)

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