Nitrous oxide emissions from agriculture and mitigation options

N. Raghuram

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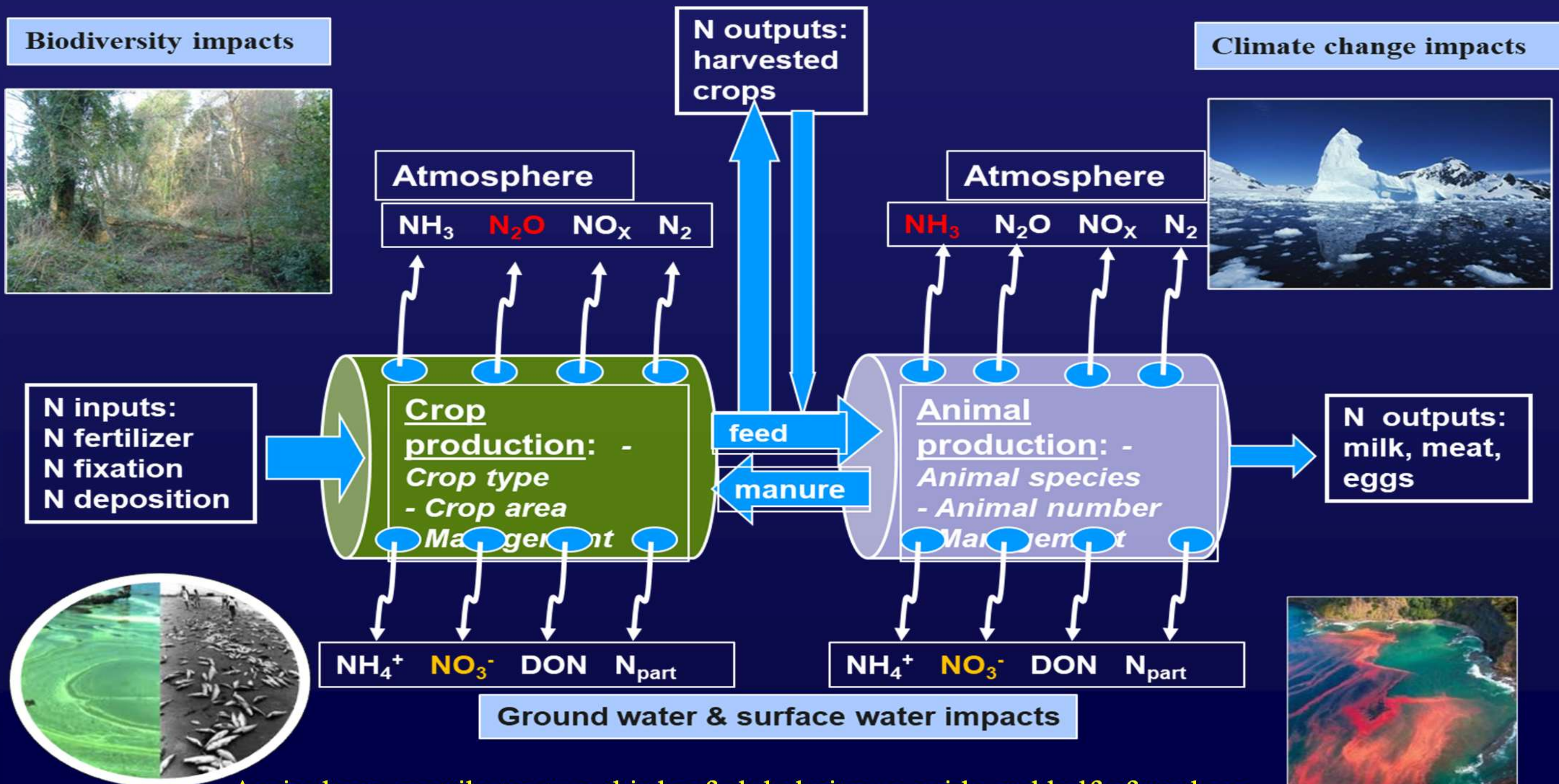
Training cum workshop on sustainable food systems, AAETI, Nimli, 9-11 Feb 2026

Reactive Nitrogen pollution involves different N compounds/sources/deptts

Ammonia (NH_3)	Nitric Oxide (NO) and Nitrogen Dioxide (NO_2)	Nitrate (NO_3^-)	Nitrous Oxide (N_2O)
Source Manure, urine, fertilizers and biomass burning	**Source** Combustion from transport, industry and energy sector. NO and NO_2 are collectively known as NO_x.	**Source** Wastewater, agriculture and oxidation of NO_x	**Source** Agriculture, industry and combustion
Benefits NH_3 is the foundation for amino acids, protein and enzymes. Ammonia is common used as fertilizer.	**Benefits** NO is essential in human physiology. NO_2 has no known benefit.	**Benefits** Widely used in fertilizers and explosives	**Benefits** Used in rocket propellants and in medical procedure as laughing gas
Effects NH_3 causes eutrophication and affects biodiversity. It forms particulate matter in air which affects health.	**Effects** NO and NO_2 (or NO_x) are major air pollutants, causing heart disease and respiratory illness.	**Effects** It forms particulate matter in air and affects health. In water, it causes eutrophication.	**Effects** N_2O is a greenhouse gas–300 times more powerful than CO_2. It also causes depletion of stratospheric ozone.

N losses are worth ~ $200 billion/year. Sutton et al. 2019, UNEP Frontiers Report

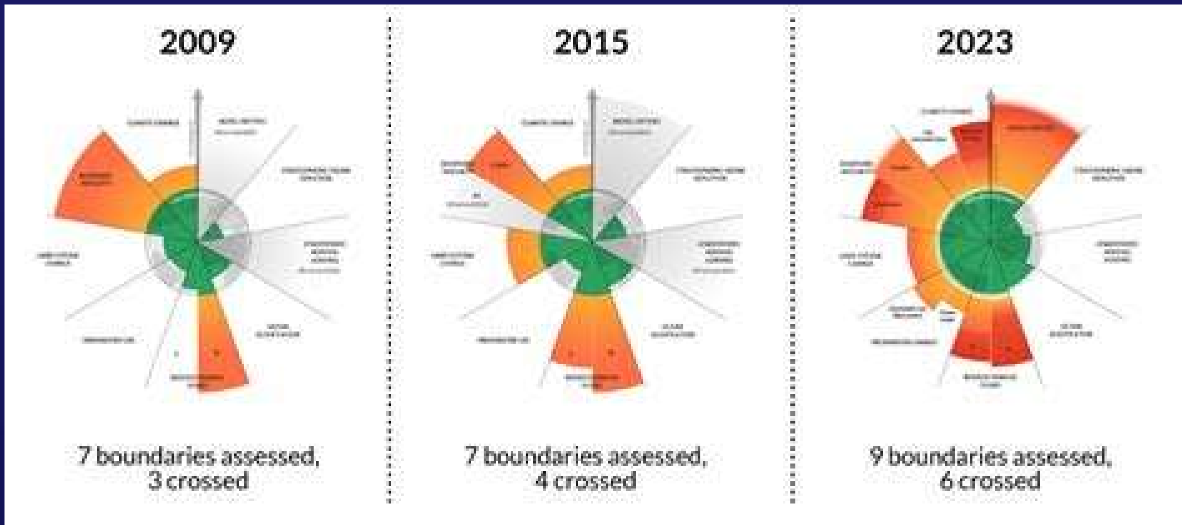
Food system elements: Nutrient losses worsen pollution, climate change, biodiversity

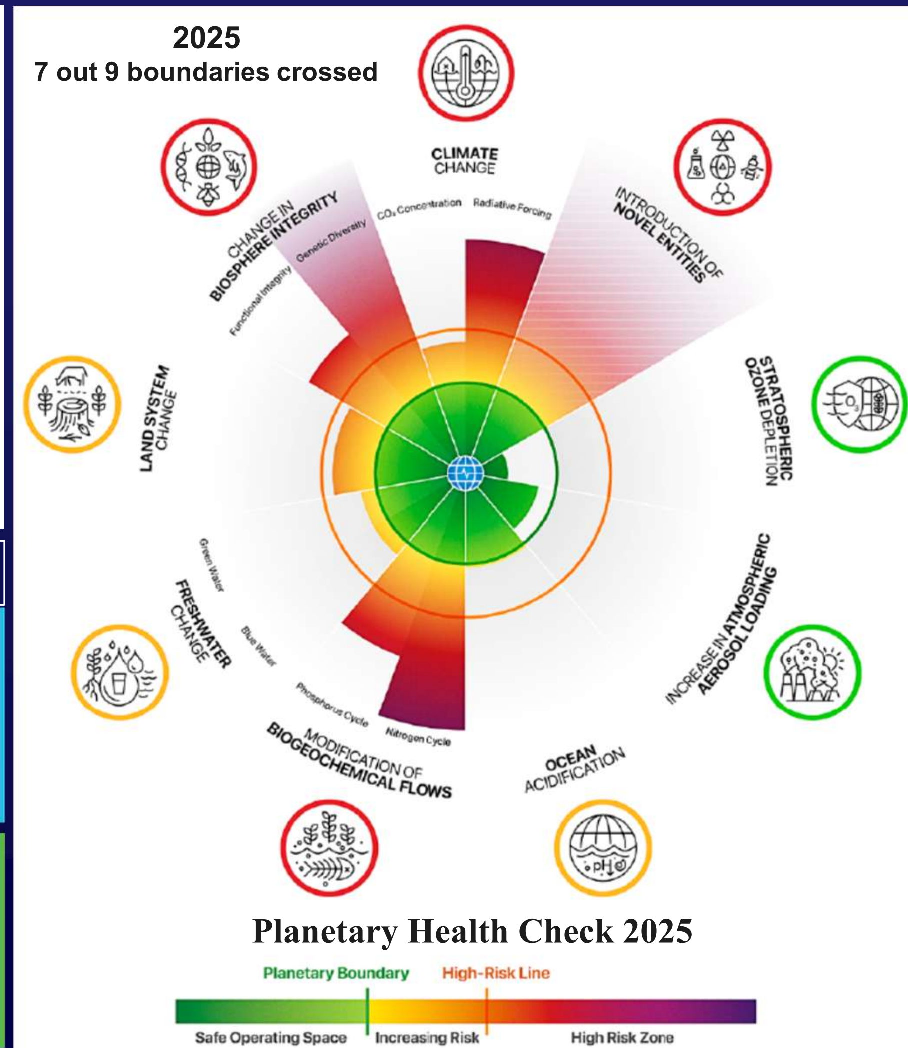


Agriculture contributes two-thirds of global nitrous oxide and half of methane

Reactive N pollution involves different N compounds/sources/deptts and costs >300 b $/year

Nutrients among anthropogenic influences crossing planetary boundaries (7/9)





Core SDGs on nutrient management

Reactive Nitrogen is at the heart of the triple planetary crisis of pollution, biodiversity & climate change

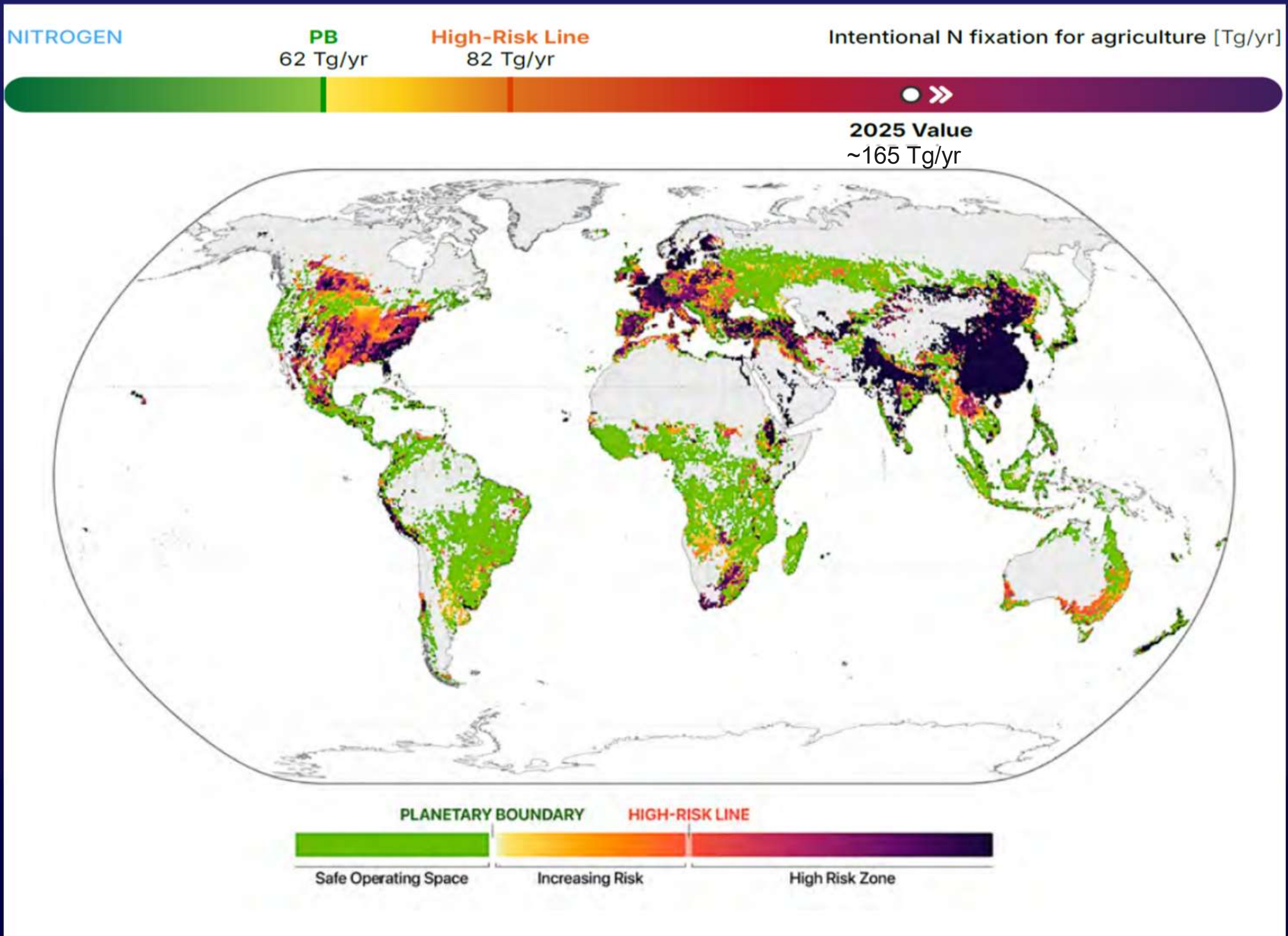
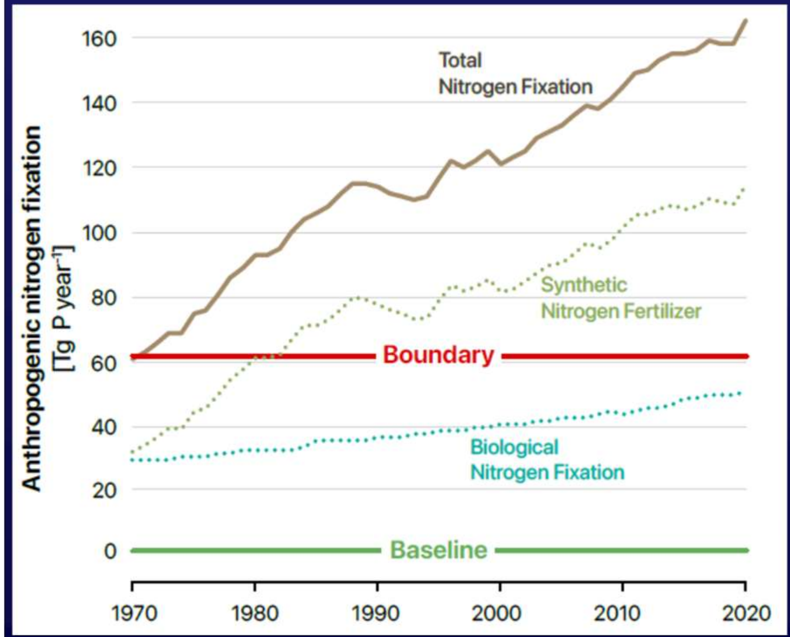


FIGURE 36 - Global risk map for the transgression of the Modification of Biogeochemical Flows boundary – Nitrogen cycle.

N planetary boundary was crossed soon after green revolution



Planetary Health Check 2025

Phosphorus also contributes to the triple planetary crisis through water pollution and biodiversity impacts

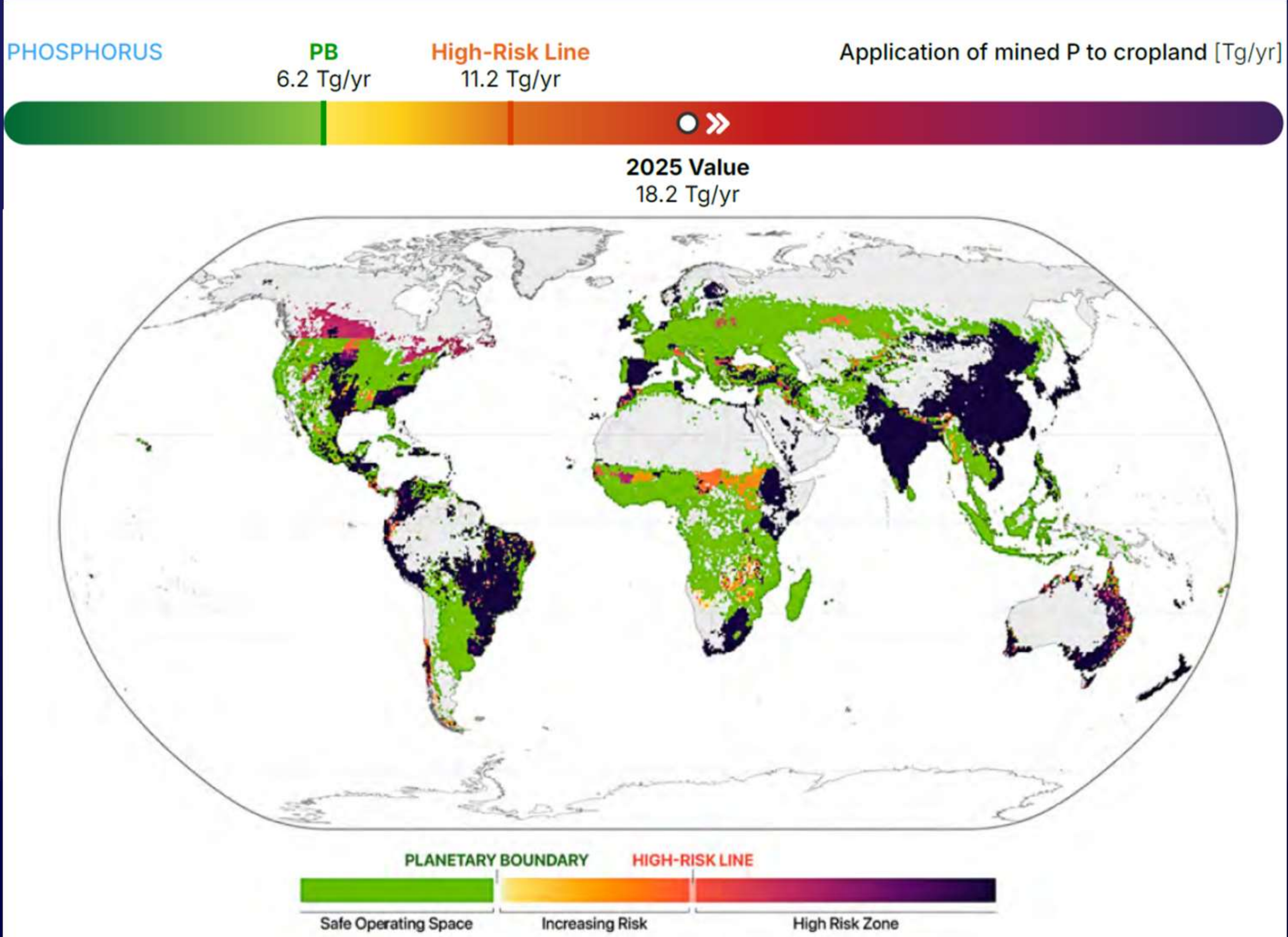
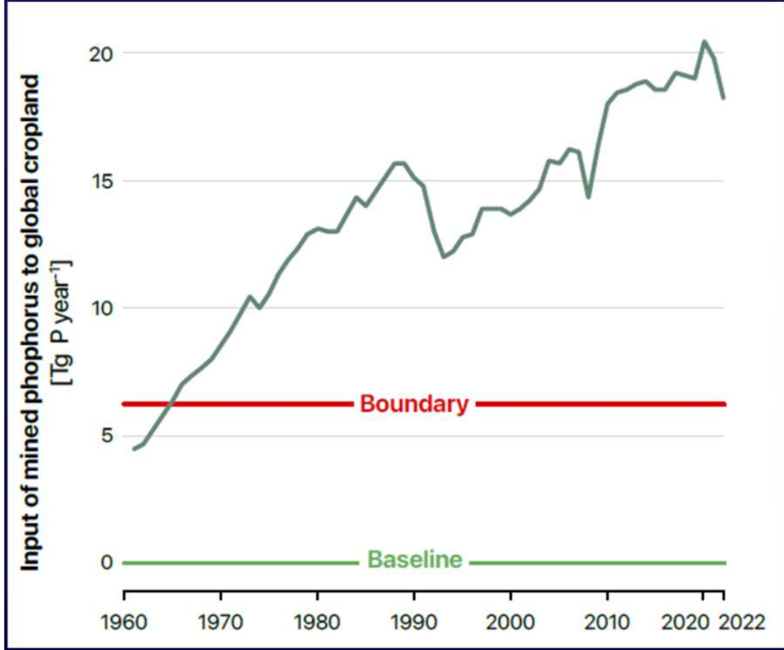


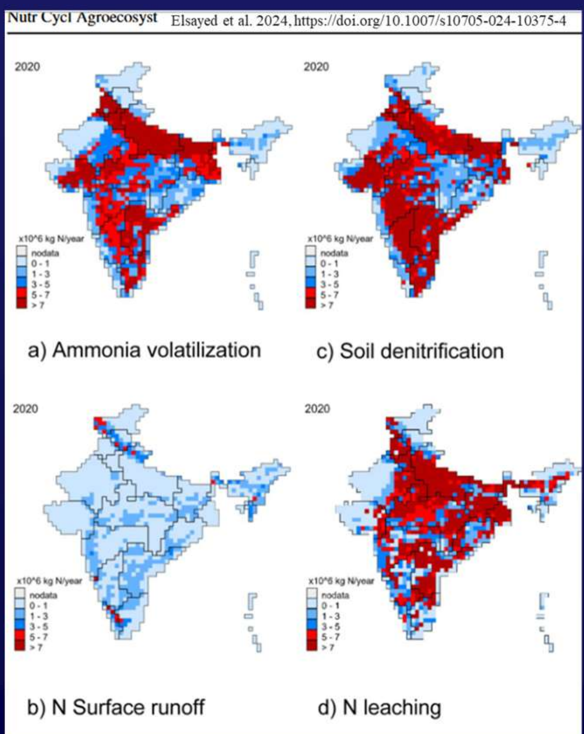
FIGURE 34 - Global risk map for the transgression of the Modification of Biogeochemical Flows boundary – Phosphorus cycle.

P planetary boundary was crossed soon after green revolution



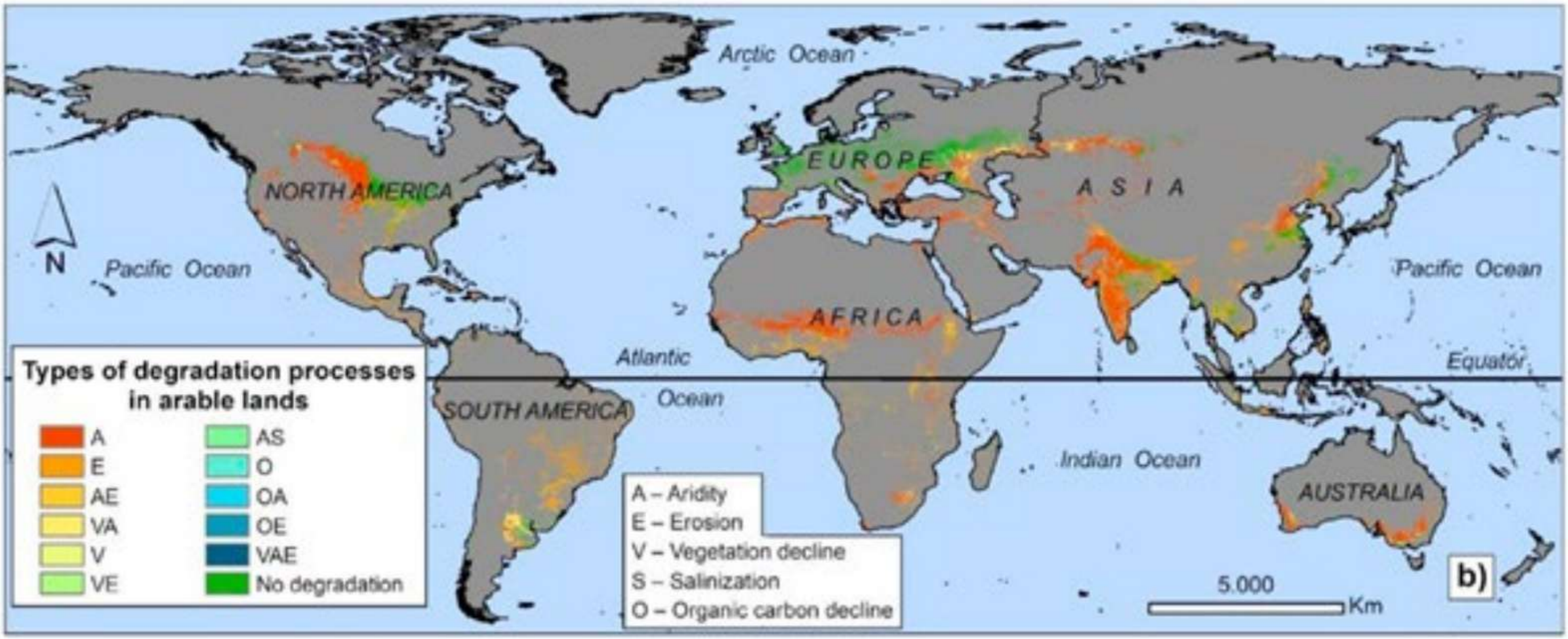
Planetary Health Check 2025

Nutrients in the food systems, emissions and the planetary triple crisis



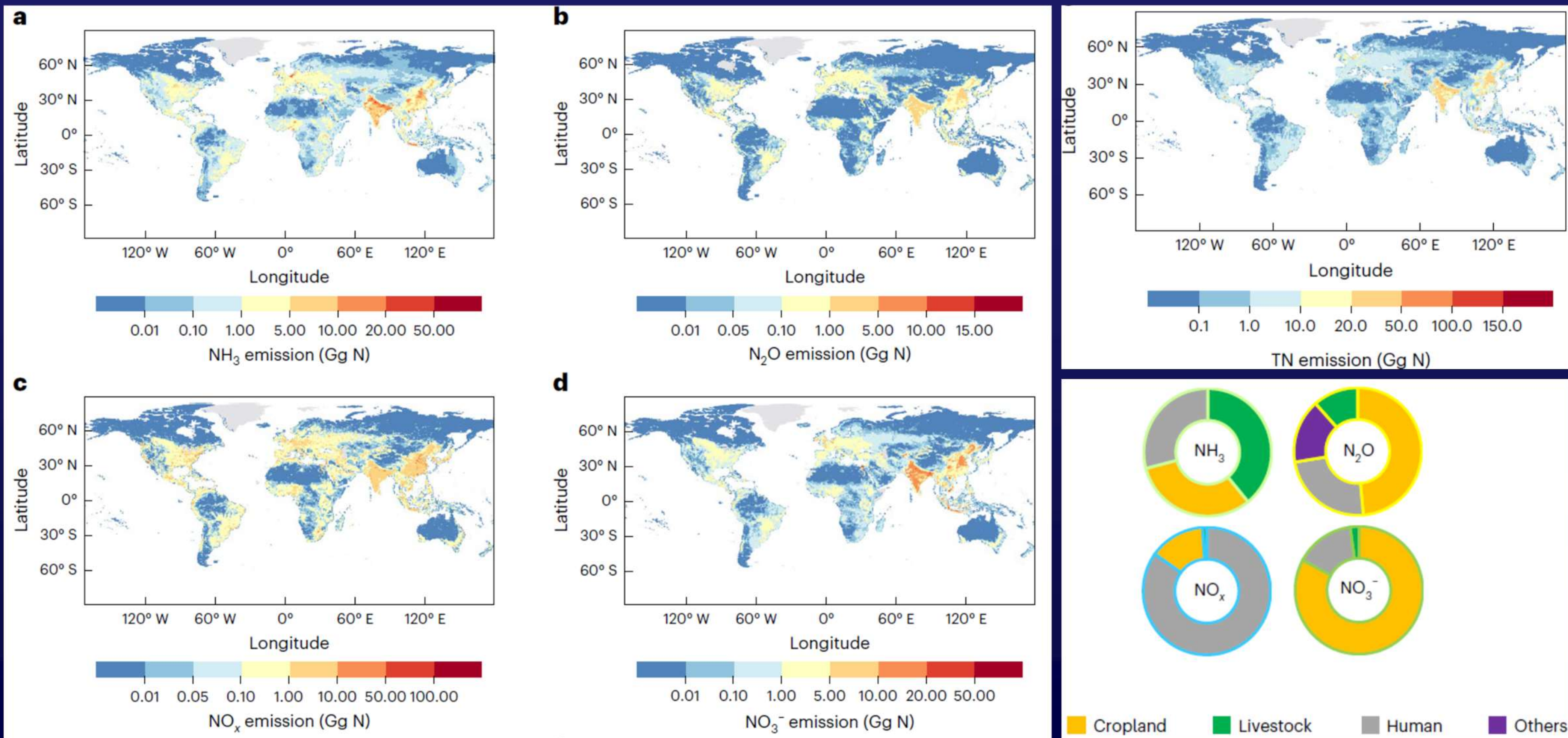
- The triple crisis of pollution, biodiversity & climate change, interactive effects
- Agriculture is not only harmed by them but also causes those problems
- Global agriculture (directly & indirectly) emits ~30 % of 2010 GHG emissions
- Agri contributes 60% of global nitrous oxide (N_2O) & 50% of methane (CH_4)
- Indian agri alone contributes 14% to global GHG, though 6.7% per capita
- Most N inputs pollute air as NH_3, N_2O (a GHG) & NO_x from fuels
- Nitrates, phosphates, sulfates etc. pollute water, cause eutrophication
- Poor agricultural nutrient use efficiency is the main cause of nutrient pollution
- Green & White revolutions worsened nutrient pollution by not recycling wastes
- Crop choice: Exporting rice/N, importing P, pulses, oils is unsustainable
- Legumes central to sustainable food system, tackling malnutrition, diabetes
- Recycling wasted nutrients & crop improvement for NUE are needed urgently

Soil degradation of arable lands due to multiple processes, 2021



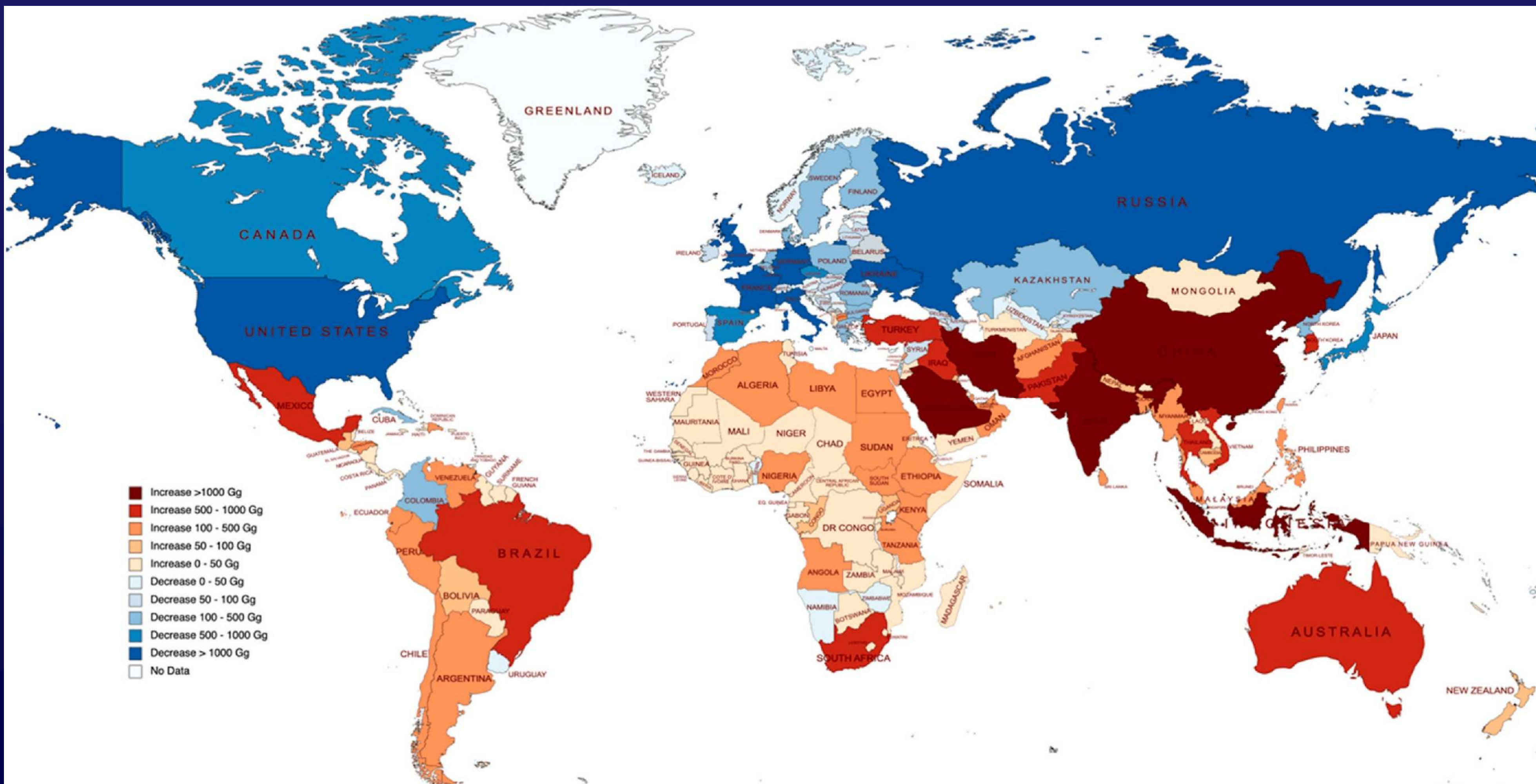
Source: Prăvălie, R., Patriche, C., Borrelli, P., Panagos, P., Roșca, B., Dumitraşcu, M., Nita, I.A., Săvulescu, I., Birsan, M.V. & Bandoc, G. 2021. *Arable lands under the pressure of multiple land degradation processes. A global perspective. Environmental Research,* 194: 110697.

India is among the global hotspots for nitrogenous pollution in air and water



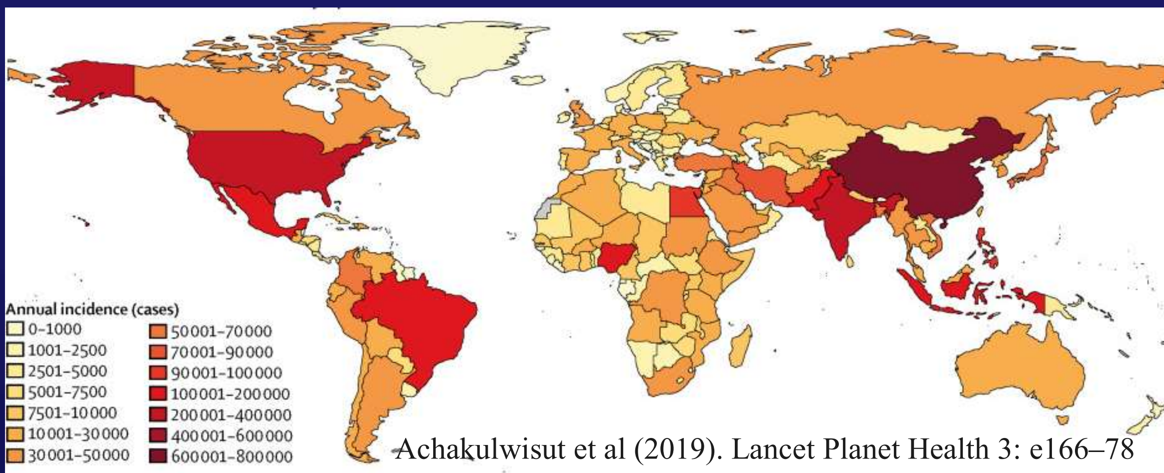
Geographic distribution of global nitrogen waste in 2020. a, NH_3 emission. b, N_2O emission. c, NO_x emission. d, NO_3^- emission. e, Total N waste, f, The proportion of each system contributing to different N waste (He et al. 2026). Colour intensities towards red indicate high emissions

Country-wise change in annual NOx emissions between 1990 and 2015

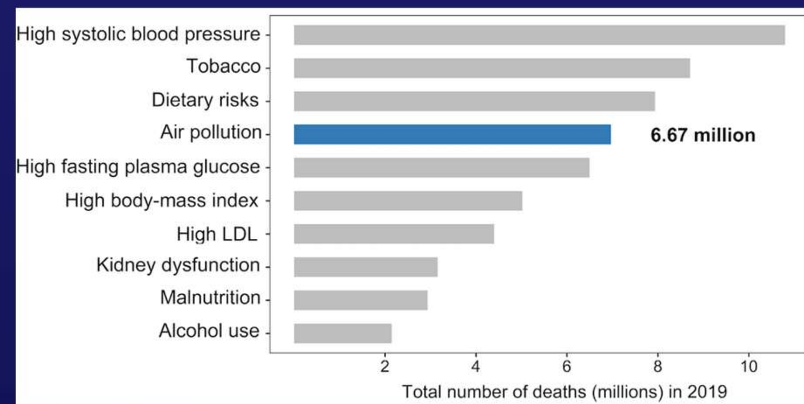


Shaw and Heyst (2022). Environmental and Sustainability Indicators

Health Impact: Asthma cases due to NO_2 & deaths due to air pollution ($PM_{2.5}$)



Achakulwisut et al (2019). Lancet Planet Health 3: e166–78

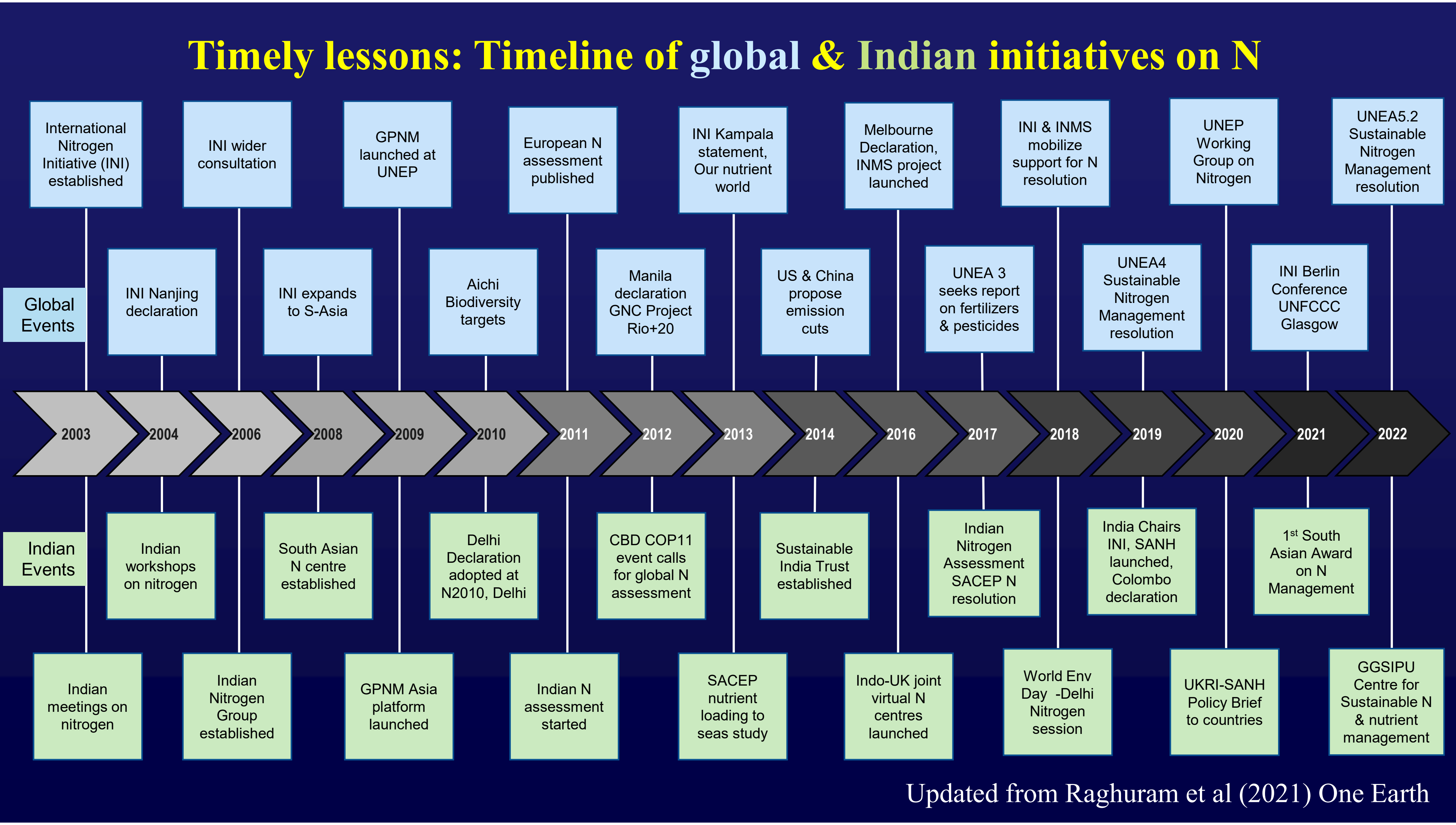


	Health Effect					Climate Change	
Pollutant	Direct	Indirect	Acid rain	Eutrophication	Visibility	Direct	Indirect
CO_2						X	
CO	X						X
HC	X	X					X
NOx	X	X	X	X	X	X	
PM	X				X	X	
SOx	X		X		X		X

CO = carbon monoxide, HC = hydrocarbon, NOx = nitrogen oxides, PM = particulate matter, SO2 = sulfur oxide

Source: CPCB, 2010

In India >**1.6 million deaths/yr** attributed to air pollution and growing at alarming rate (WHO data). 60% of world's most polluted cities are now in India. Years lost to Nr pollution are highest for China now, but for India in future


Timely lessons: Timeline of global & Indian initiatives on N
Global Events
Indian Events
International Nitrogen Initiative (INI) established
INI wider consultation
GPNM launched at UNEP
European N assessment published
INI Kampala statement, Our nutrient world
Melbourne Declaration, INMS project launched
INI & INMS mobilize support for N resolution
UNEP Working Group on Nitrogen
UNEA5.2 Sustainable Nitrogen Management resolution
INI Nanjing declaration
INI expands to S-Asia
Aichi Biodiversity targets
Manila declaration GNC Project Rio+20
US & China propose emission cuts
UNEA 3 seeks report on fertilizers & pesticides
UNEA4 Sustainable Nitrogen Management resolution
INI Berlin Conference UNFCCC Glasgow
2003
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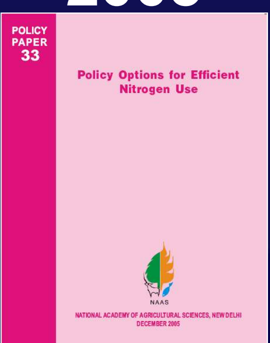
2022
Indian workshops on nitrogen
South Asian N centre established
Delhi Declaration adopted at N2010, Delhi
CBD COP11 event calls for global N assessment
Sustainable India Trust established
Indian Nitrogen Assessment SACEP N resolution
India Chairs INI, SANH launched, Colombo declaration
1st South Asian Award on N Management
Indian meetings on nitrogen
Indian Nitrogen Group established
GPNM Asia platform launched
Indian N assessment started
SACEP nutrient loading to seas study
Indo-UK joint virtual N centres launched
World Env Day -Delhi Nitrogen session
UKRI-SANH Policy Brief to countries
GGSIPU Centre for Sustainable N & nutrient management
Updated from Raghuram et al (2021) One Earth

Indian journey: Nitrogen Assessment in citizen science mode

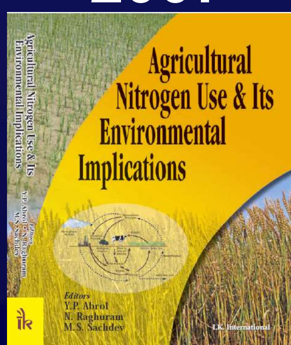
and engagement with INI, UN, GPNM, INMS, Indo-UK, SANH

2005



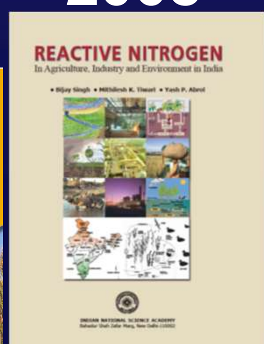
NAAS Policy Paper

2007



Edited Book

2008



IGBP-WCRP-SCOPE Report 3, INSA

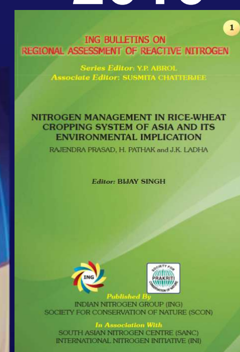
2008

Journal Spl. Issue on N in India

2010

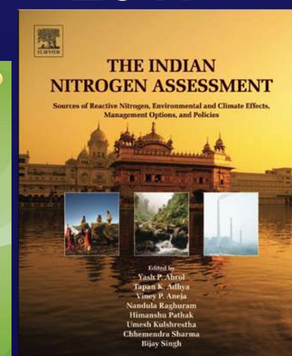
ING Bulletins on Nr

2010



ING Bulletins on Nr

2017



Indian N Assessment

2026

South Asian and global N Assessment

UNEP Resolutions on sustainable N management and CBD GBF target 7 to 'halve nutrient waste from all sources' by 2030

UN environment

FRONTIERS 2018/19

Emerging Issues of Environmental Concern

The Nitrogen Fix:
From Nitrogen Cycle Pollution to Nitrogen Circular Economy

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Nandula Raghuram, Guru Gobind Singh Indraprastha University, New Delhi, India
Tapan Kumar Adhya, Kalinga Institute of Industrial Technology Bhubaneswar, Odisha, India

Kunming-Montreal
GLOBAL BIODIVERSITY FRAMEWORK
2022

UNEP/EA.4/L.16
Distr.: Limited
9 March 2019
Original: English

United Nations
Environment Assembly of the
United Nations Environment
Programme

United Nations Environment Assembly of the United Nations Environment Programme
Fourth session
Nairobi, 11–15 March 2019

Sustainable nitrogen management*

UNEP/EA.5/Res.2
Distr.: General
7 March 2022
Original: English

United Nations
Environment Assembly of the
United Nations Environment
Programme

United Nations Environment Assembly of the United Nations Environment Programme
Fifth session
Nairobi (hybrid), 22 and 23 February 2021
and 28 February–2 March 2022

Resolution adopted by the United Nations Environment Assembly on 2 March 2022

5/2. Sustainable nitrogen management

The United Nations Environment Assembly,

Noting with concern that excessive levels of nutrients, in particular reactive nitrogen and

GEF-UNEP-INMS & UKRI-GCRF South Asia N Hub: Policy-relevant publications

IOP Publishing
Environ. Res. Lett. **20** (2025) 094014
https://doi.org/10.1088/1748-9326/adf07c

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16 July 2025

LETTER

Valuing damages and benefits of the altered global nitrogen cycle; lessons for national to global policy support

Hans J M van Grinsven[1,*], Baojing Gu[2], Alfredo Rodríguez[3], Laurence Jones[4,5], Roy Brouwer[6], Lena Schulte-Uebbing[1], Felipe S Pacheco[7], Luis Lassaletta[8], Kentaro Hayashi[9], Jan van Dam[1], Nandula Raghuram[10], Markus Geupel[11], Peter Ebanyat[12], Xiuming Zhang[13], Steven Lord[14], Sander de Bruyn[1] and Mark A Sutton[15]

Environ. Res. Lett. **17** (2022) 050401
https://doi.org/10.1088/1748-9326/ac6226

ENVIRONMENTAL RESEARCH
LETTERS

EDITORIAL

Focus on reactive nitrogen and the UN sustainable development goals

Wilfried Winiwarter[1,2], Barbara Amon[2,3], Benjamin Leon Bodirsky[4], Henning Friege[5], Markus Geupel[6], Luis Lassaletta[7] and Nandula Raghuram[8]

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8 School of Biotechnology, Guru Gobind Singh Indraprastha University, New Delhi, India
* Author to whom any correspondence should be addressed.

CellPress

Gold Standard for the Global Goals
1 ton of CO_2 offset

One Earth

Reflection

From South Asia to the world: embracing the challenge of global sustainable nitrogen management

Nandula Raghuram,[1,2,3,4,*] Mark A. Sutton,[5] Roger Jeffery,[6] Ramesh Ramachandran,[7] and Tapan K. Adhya[8]
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[5]UK Centre for Ecology & Hydrology, Edinburgh Research Station, Bush Estate, Penicuik, UK
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Environ. Res. Lett. **17** (2022) 025007
https://doi.org/10.1088/1

ENVIRONMENTAL RESEARCH
LETTERS

LETTER

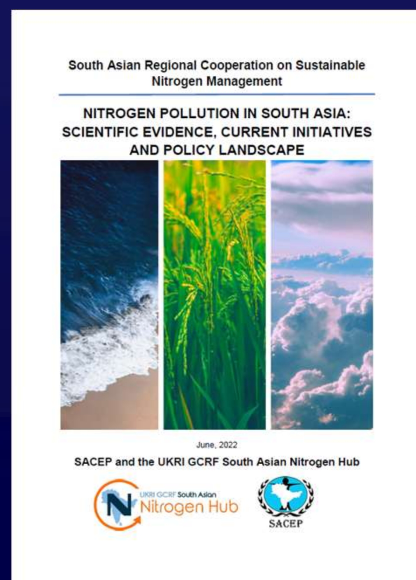
Policies to combat nitrogen pollution in South Asia: gaps and opportunities

Anastasia L Yang[1,*], Nandula Raghuram[2,10], Tapan Kumar Adhya[3], Stephen D Porter[1], Ananta Narayan Panda[3], Himadri Kaushik[3], Anuradha Jayaweera[6], Sarath Premalal Nissanka[6], Asif Reza Anik[4], Sharmin Shifa[4], Shaima Chowdhury Sharna[4], Rajendra Joshi[5], Muhammad Arif Watto[7], Anju Pokharel[8], Aminath Shazly[9], Rifaath Hassan[9], Sangeeta Bansal[10], David Kanter[11], Smriti Das[12] and Roger Jeffery[1]

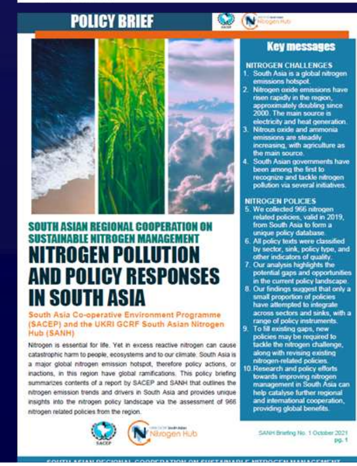
Policy documents on N for India and South Asia

Policies to combat nitrogen pollution in South Asia: Gaps and opportunities. Environmental Research Letters. DOI https://doi.org/10.1088/1748-9326/ac48b2

SACEP & SANH (2022) Regional report: Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape http://www.sacep.org/pdf/Reports-Technical/SANH_SACEP-Policy-report_draft-as-of-6-April-2021.pdf

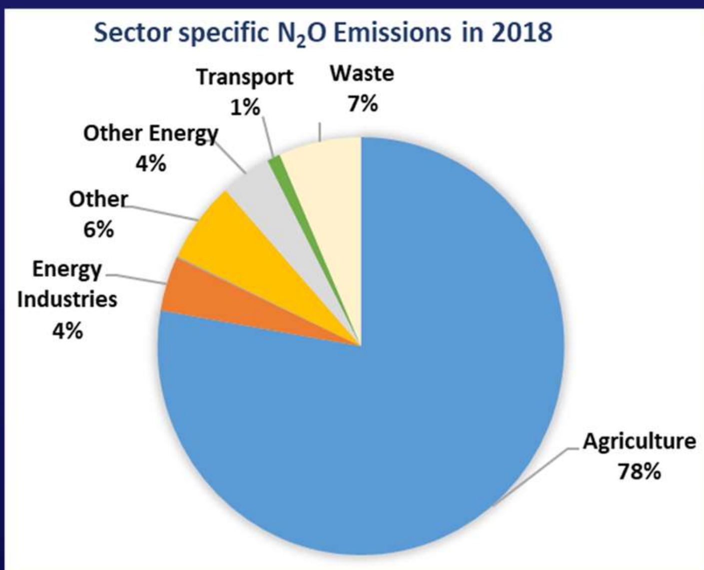


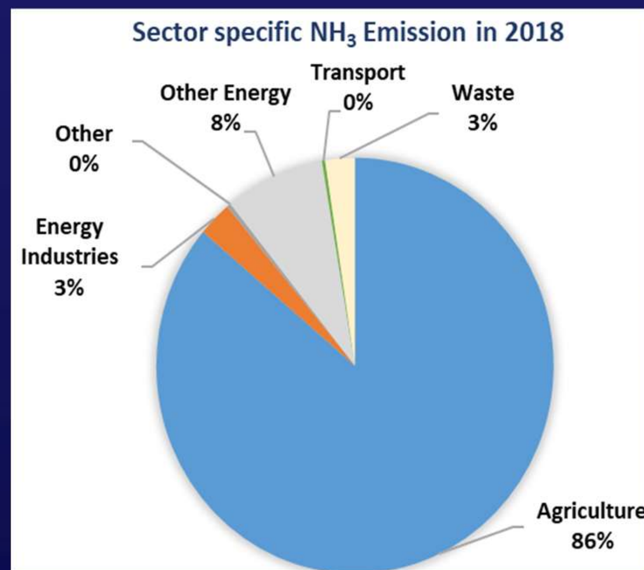
SANH policy open access database, NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/e2f248d5-79a1-4af9-bdd4-f739fb12ce9a

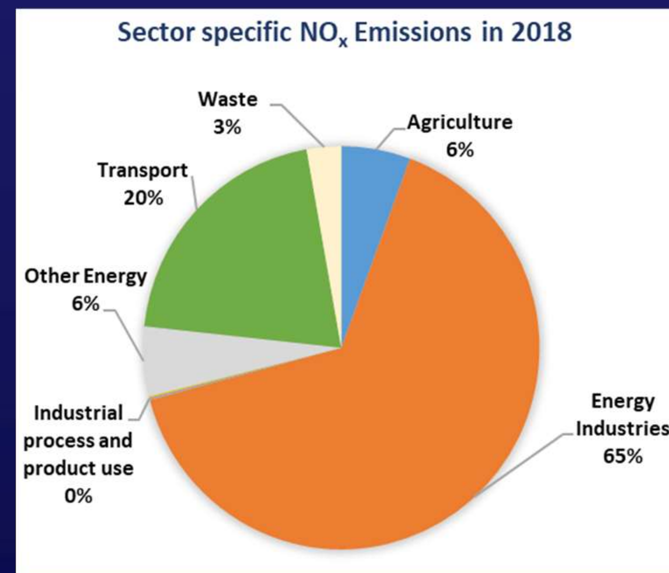


Sectoral nitrous oxide, ammonia & NO_x emissions in S. Asia in 2018

(SANH Policy Brief 2023, based on EDGAR v6.1 & Crippa et al. 2021a)







Controlling both agricultural ammonia emissions and industrial NOx emissions together is critical for significant reduction in PM2.5, water N

100 Tg N yr−1 in 1970 to nearly 210 Tg N yr−1 in 2010 (Malik et al., 2022).

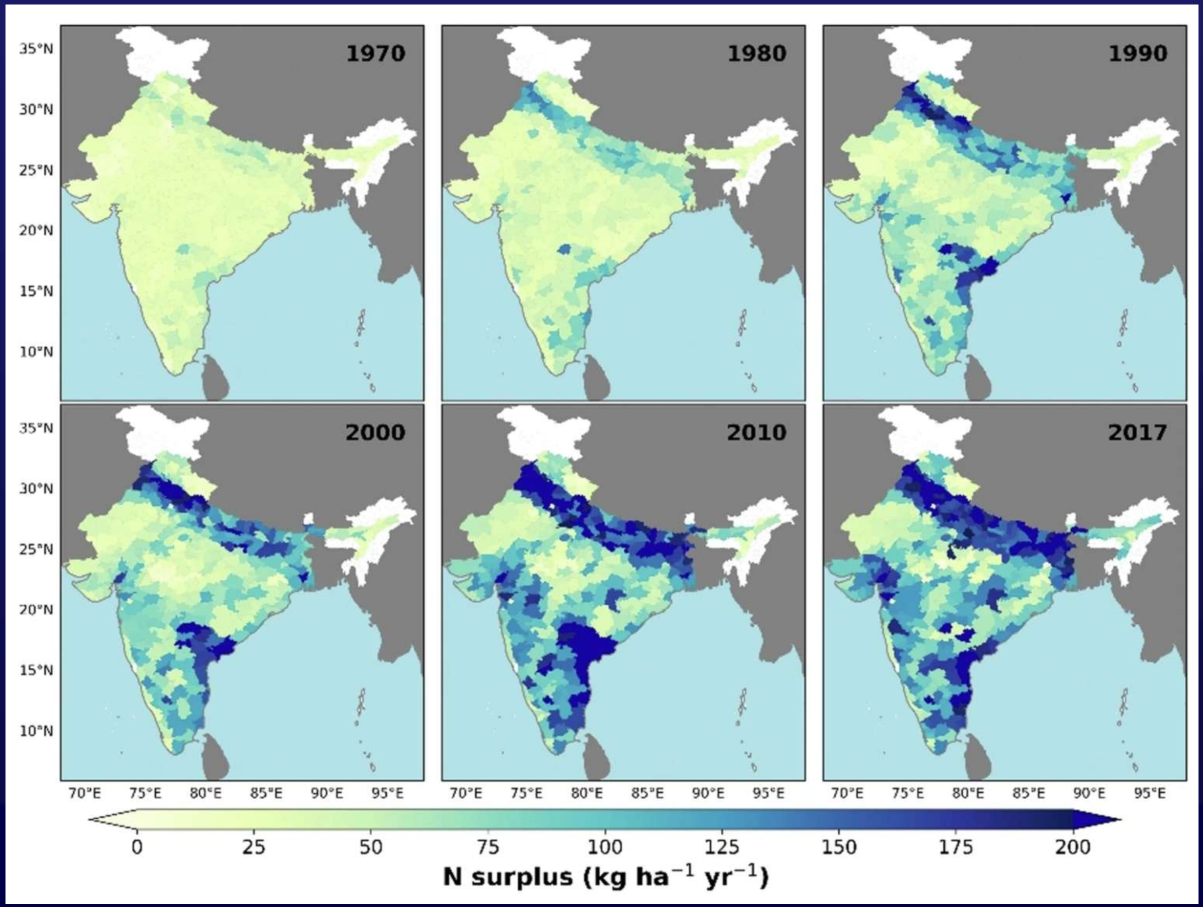
Nitrogen oxides and ammonia are precursors of $PM_{2.5}$ and affect the chemical reactions that lead to $PM_{2.5}$ formation (Gu et al. 2021). Ammonia contributed to 32% $PM_{2.5}$ pollution in 2013, and nitrogen oxides to 28% (Gu et al., (2021). Rises in ammonia and NOx were linked to increases in deaths caused by $PM_{2.5}$.

In this briefing all N emission data are sourced from the Emissions Database for Global Atmospheric Research (EDGAR), which provides independent emission estimates, using international statistics and a consistent Intergovernmental Panel on Climate Change (IPCC) methodology.

Spatial variation of Nitrogen Surplus (Kg/ha/yr) in Indian croplands

(Mean data from 12 different N surplus estimates for each year. Regions in white indicate lack of data)

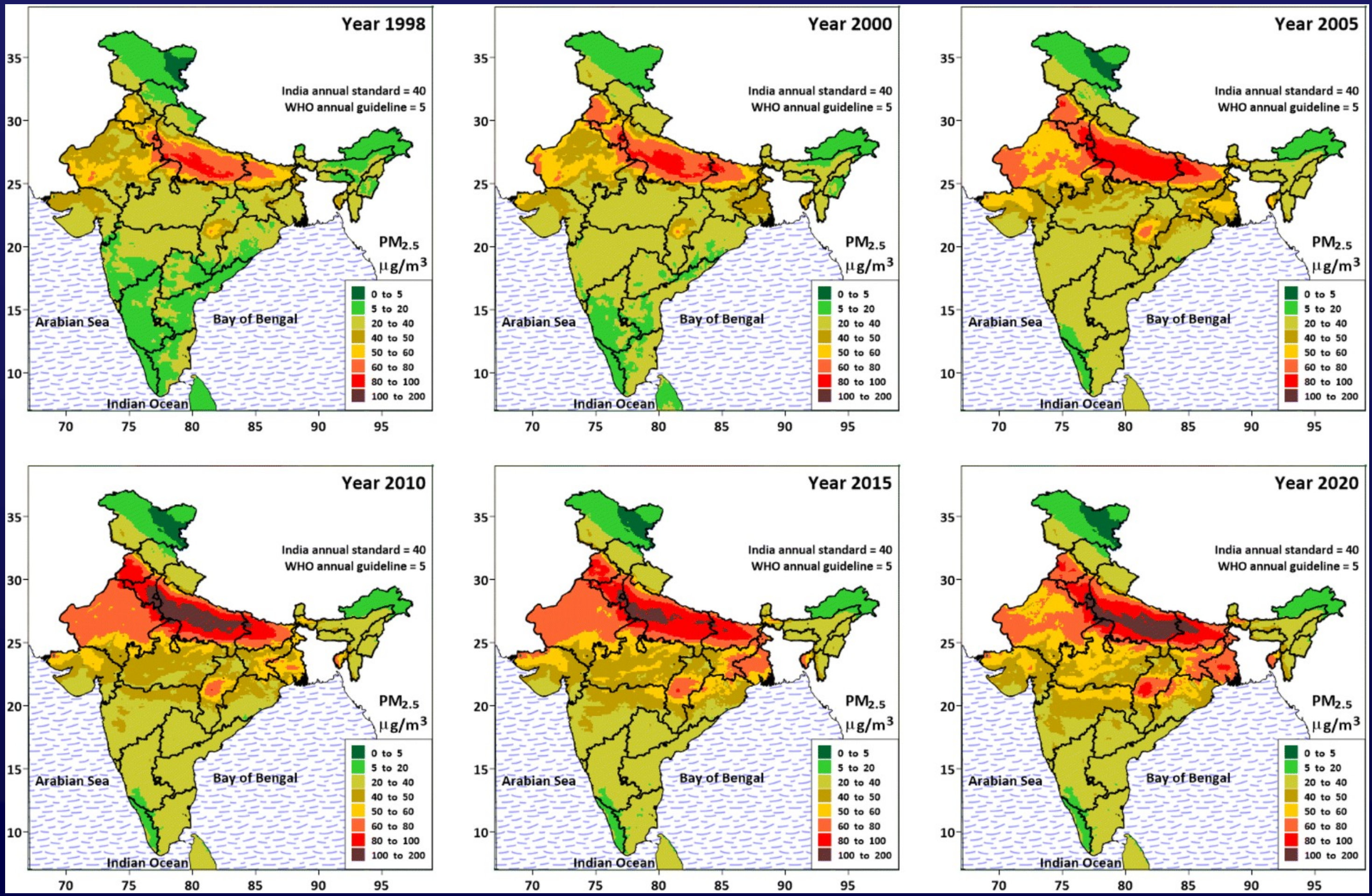
Research data shows N-surplus



Soil health card data shows N-deficiency

Goyal, S.S., Kumar, R. & Bhatia, U. Assessing temporal dynamics of nitrogen surplus in Indian agriculture: district scale data from 1966 to 2017. *Sci Data* 11, 1191 (2024). https://doi.org/10.1038/s41597-024-04023-3

Northwest focus: Growth in surface annual $PM_{2.5}$ levels



Amm. nitrate/sulfate deposition accounts for over half of all PM2.5 pollution in India

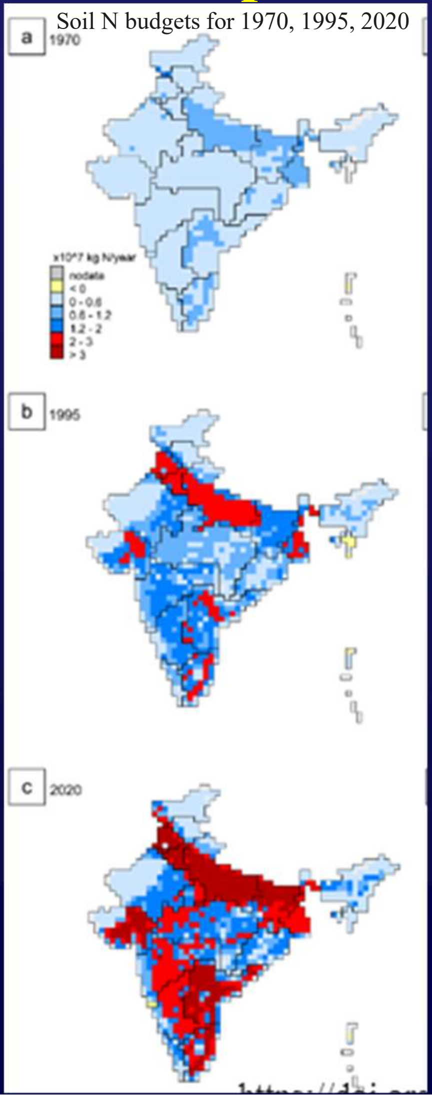
Source: Guttikunda & NIshadh. (2022). Environ. Sci.: Atmos., 2, 1502-1515

Neglect of BNF, legume-based crop rotations and the 'fertilizer trap'

Comparison of land area (Mha) sown to major cereals or grain legumes in different geographies and the percentage of the total area used for cereal and legume production under grain legumes in 2019[a].

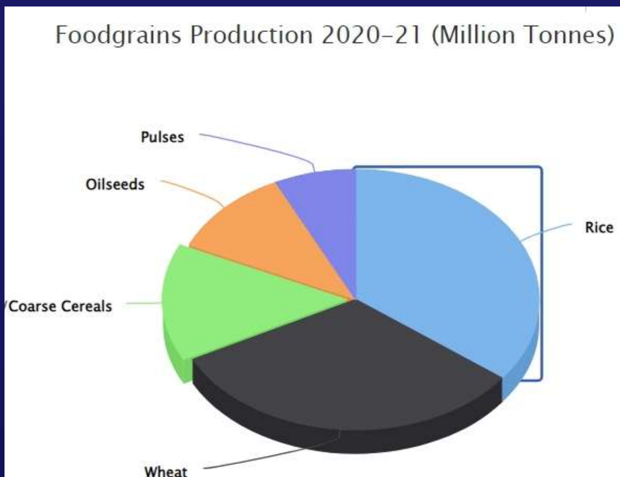
Region	Wheat	Rice	Maize	Total 3 cereals	Legume oilseeds[b]	Pulse legumes[c]	Total grn legumes	% Area legumes[d]
Americas	34.6	5.7	71.7	112.0	92.7	11.6	104.3	48%
S.America	9.3	4.1	28.2	41.6	59.5	3.9	63.4	60
N.America	24.7	1.0	34.5	60.2	33.2	4.7	37.8	39
Asia	98.6	138.6	66.5	303.7	32.1	43.7	75.8	20
South Asia	49.4	61.4	12.2	123.0	16.1	33.6	49.7	29
East Asia	24.3	32.7	41.9	98.9	13.3	3.1	16.4	14
S-E Asia	0.06	43.9	11.2	55.2	2.5	5.1	7.6	12
West Asia	10.7	0.2	0.9	11.8	0.1	1.3	1.4	11
C. Asia	14.1	0.4	0.3	14.8	0.1	0.6	0.7	5
Africa	9.7	17.1	41.2	68.0	19.6	27.3	46.9	41
Europe	62.3	0.6	18.3	81.2	5.6	4.9	10.5	11
Oceania/Au	10.4	0.02	0.1	10.5	0.05	3.4	3.5	25
World(Mha)	215.6	162.0	197.8	575.4	150.1	90.9	240.6	

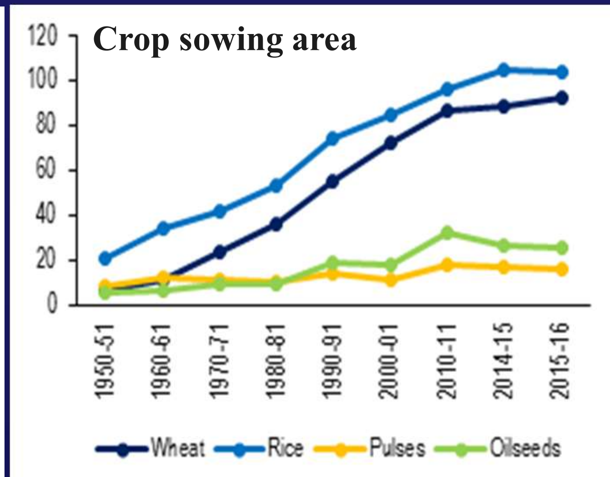
[a]Data obtained from FAOSTAT (2021) and presented in declining regional areas sown to grain legumes.
[b]Soybean and groundnut.
[c]All other legume crops grown for dry grain.
[d]% area under legume crops = 100× (area total grain legumes)/ (area total grain legumes)+ (area of wheat+rice+maize).

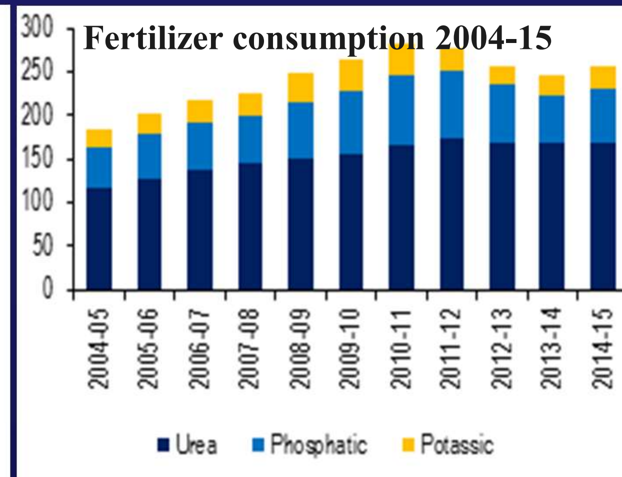


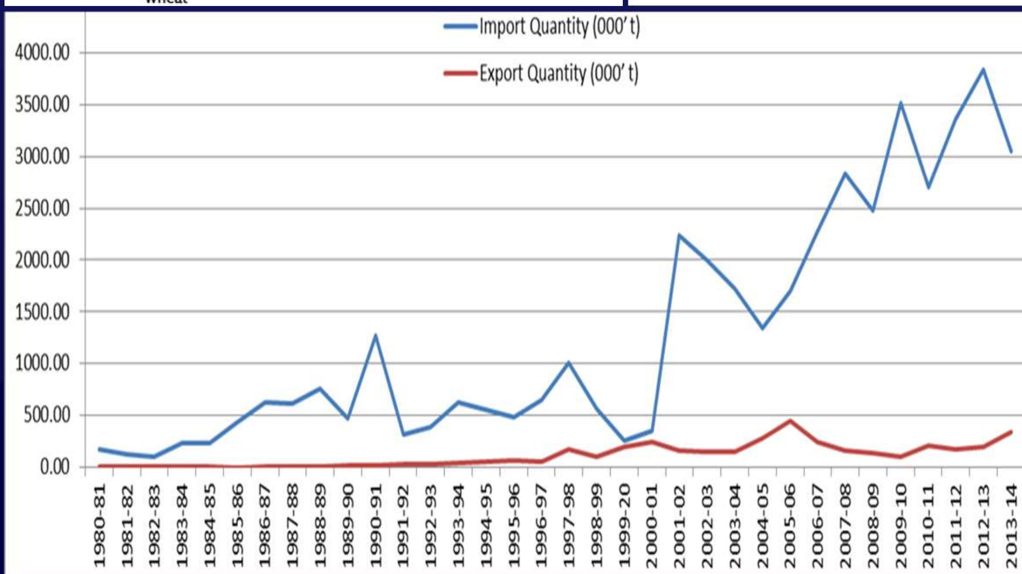
Ladha et al. (2022). Field Crops Research, 283, 108541,

Growing gap between legumes & cereals enhanced urea use & legume imports









- Global Hunger Index ranked India at 111 out of 124
- Protein Malnutrition in India is worse than ss Africa
- India's child-wasting rate is the highest at 18.7%
- 58.1 per cent of Indian women aged 15-24 are anaemic
- India has the highest % of diabetics and pre-diabetics
- Groundnut & soybean oil are better than palm, sunflower

Benefits of legumes

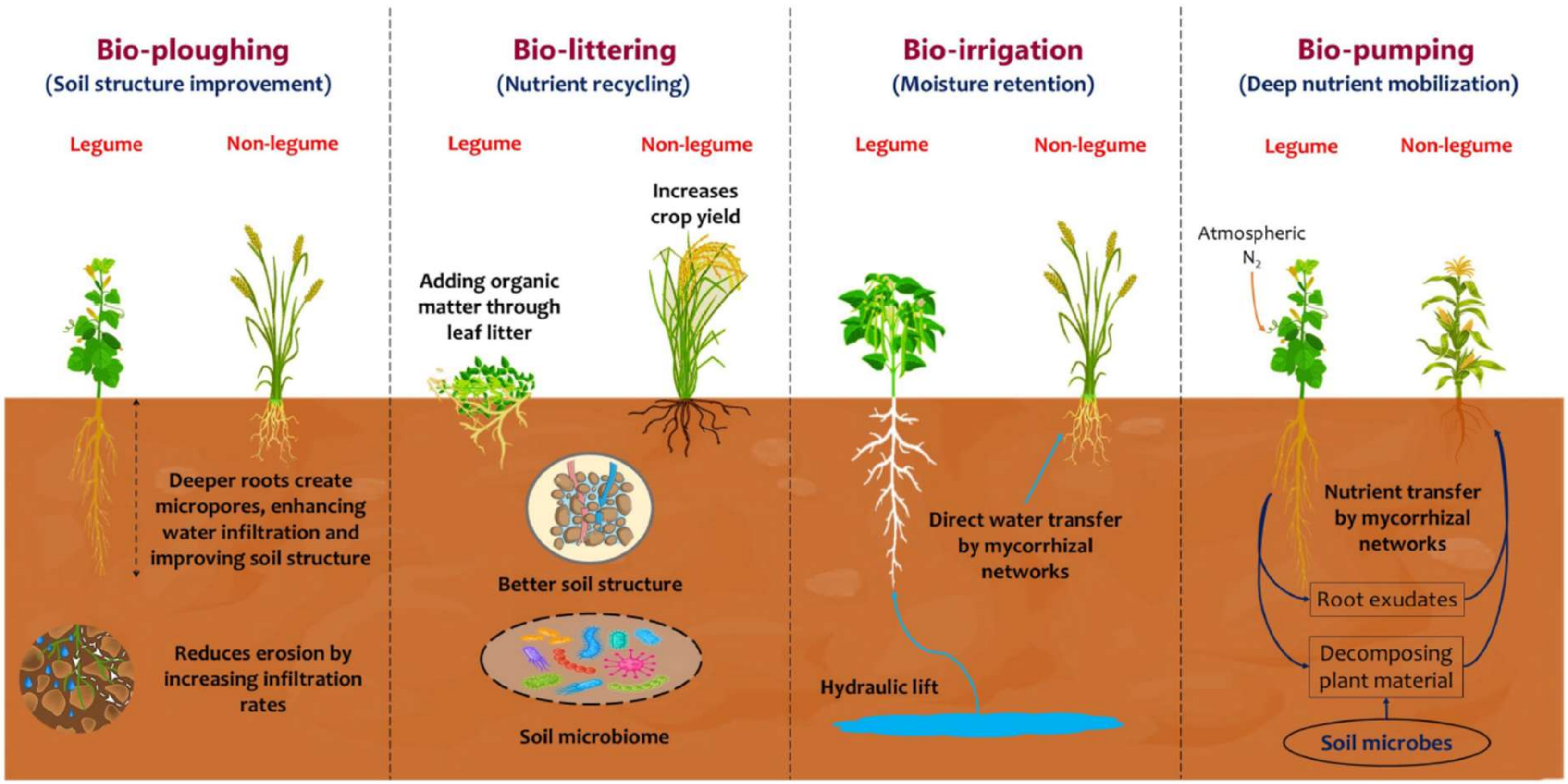


FIGURE 3
The four 'B's concept for leguminous crops in enhancing resource use efficiency.

Akchaya et al. (2025). Boosting resource use efficiency, soil fertility, food security, ecosystem services, and climate resilience with legume intercropping: a review. Front. Sustain. Food Syst. 9:1527256. doi: 10.3389/fsufs.2025.1527256

Benefits of legumes

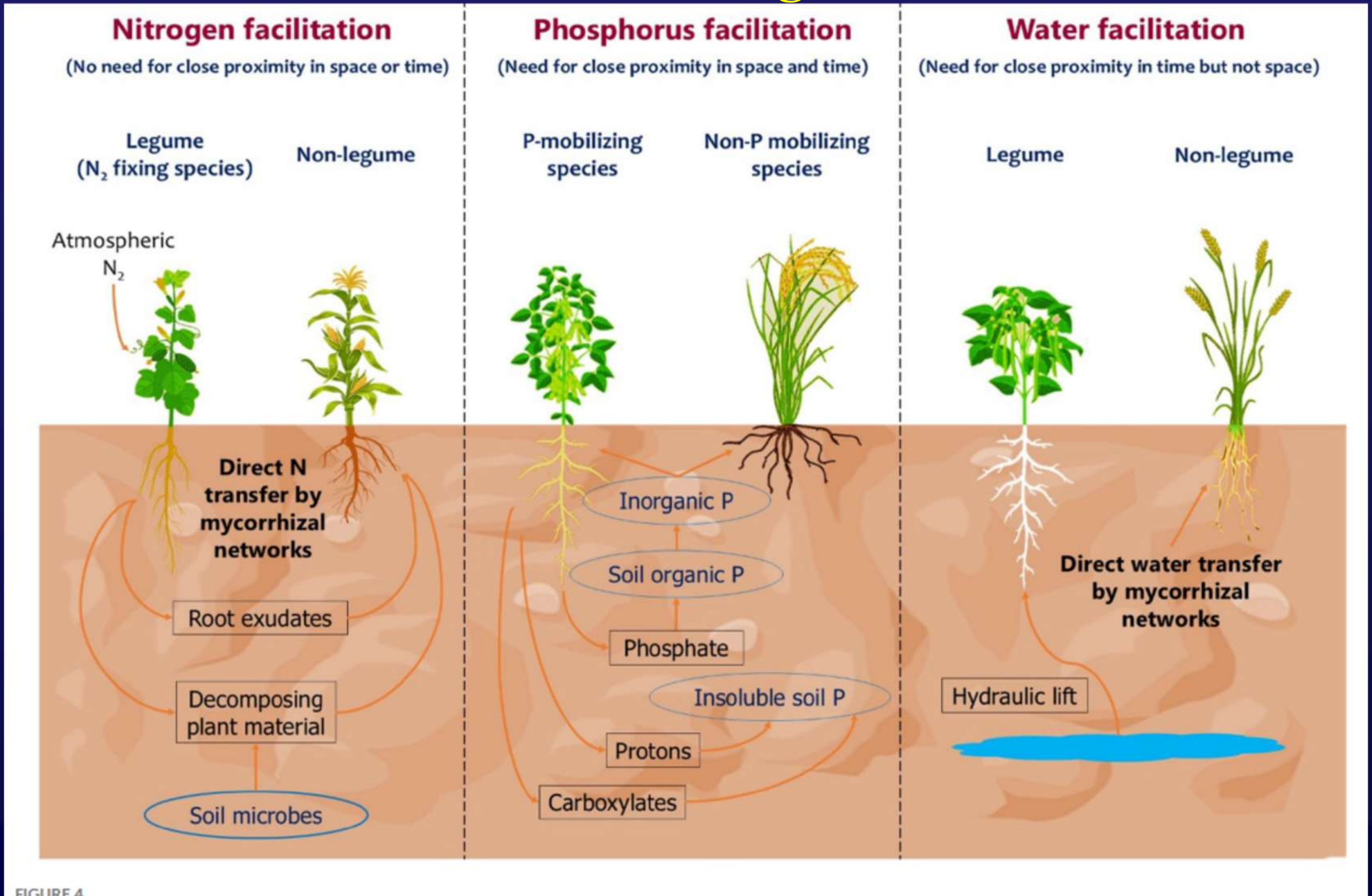
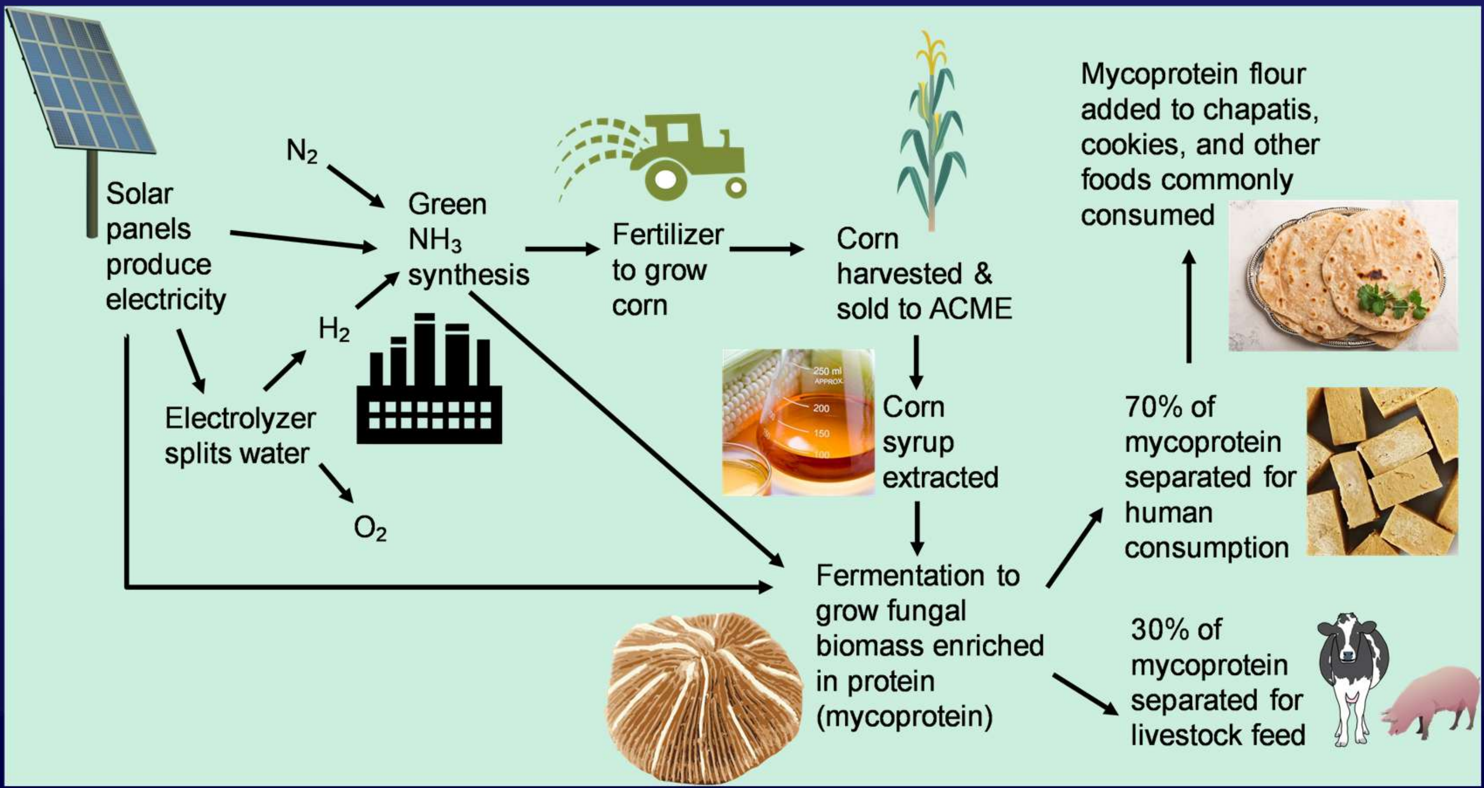


FIGURE 4
The physiological mechanism behind interspecific facilitation in nitrogen, phosphorus, and water acquisition (adapted from Homulle et al., 2021).

Akchaya et al. (2025). Boosting resource use efficiency, soil fertility, food security, ecosystem services, and climate resilience with legume intercropping: a review. Front. Sustain. Food Syst. 9:1527256. doi: 10.3389/fsufs.2025.1527256

India is a global leader in green ammonia for fuel, fertilizer and protein



ACME built the world's first demo GA plant in the at Bikaner in 2021, producing 1800 MT/yr

Several billion-dollar plants coming up, each producing 0.4-1.2 MMT/yr, mostly for fuel production & export

GA projects get incentives under national/state governmental policies

Solar Energy Corporation of India issued a tender to procure 0.75 MMT/yr of GA fertilizers

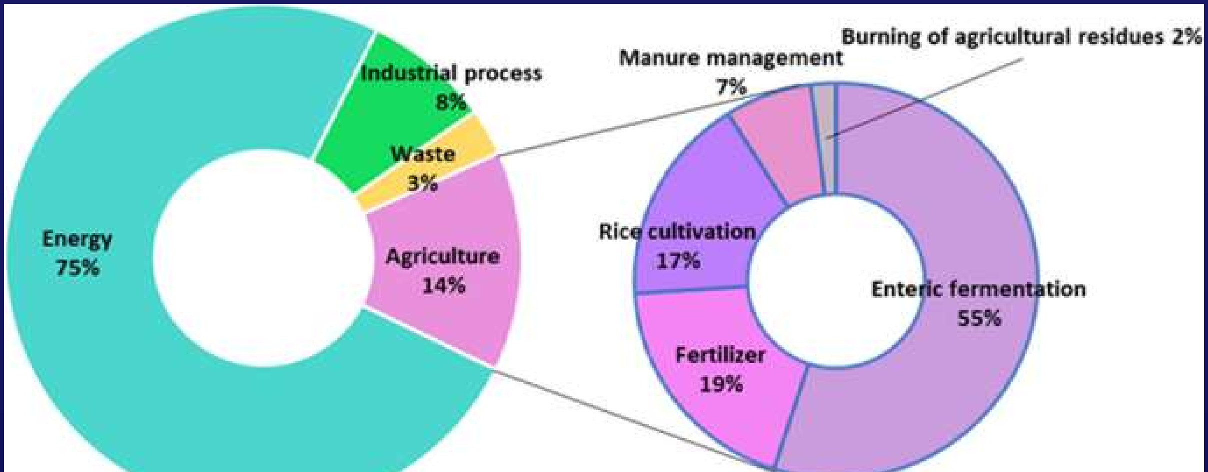
Ammonia as fertilizer needs trials, but is used widely for cold storage

Sector-wise growth of N_2O emissions in India (2000-2010)

SECTORAL EMISSION	2000 (N_2O Gg)	2010 (N_2O Gg)	CAGR (%)
Other Comm/Instt	0.03	1.08	43.10
Waste water-domestic	13.23	43.67	12.68
Navigation	0.04	0.13	12.51
Aviation	0.12	0.35	11.30
Refinery	0.03	0.07	8.84
Non specific Industries	0.79	1.82	8.70
Mining and quarrying	0.02	0.04	7.18
Road Transport	4	7.4	6.35
Iron and steel	0.85	1.5	5.84
Energy Industries	7.78	11.85	4.30
Electricity	7.75	11.68	4.19
Agriculture Soils	186.49	261.55	3.44
Railways	2.06	2.58	2.28
Pulp and paper	0.08	0.1	2.26
Crop residue burning	6.17	7.07	1.37
Manure Management	0.07	0.08	1.34
Grand Total	264.16	370.38	3.44

(NATCOM, 2012 & INDBUR1, 2015)

Wastes account for upto 5% of GHG emissions from India



Chachei (2024) Environ Sci Pollut Res.

- Nutrient-rich wastes can come from domestic, industrial & agricultural sources
- Most greenhouse gases emerge from nutrients in wastes and can be minimized
- CO_2, methane, nitrous oxide, NH_3, NOx, SOx, nitrates, phosphates, sulfates
- Most solid wastes contain 0.5 to 1% of N/P/K/S and over 40% of C
- Most liquid wastes contain about 0.015 % of N, 0.03% P and 0.02% K
- The 60 million tons/yr solid waste generated now could yield >1 million tons of nutrients/year
- The 20 trillion litres/yr liquid waste generated now could yield 2b kg or 2m tons nutrients/yr
- Total nutrients in wastes currently cross 3 million tons/year of which reuse is not even 0.5 mt/y
- We must triple to recycle >1.5 million tons of wasted nutrients/year to “halve the waste”

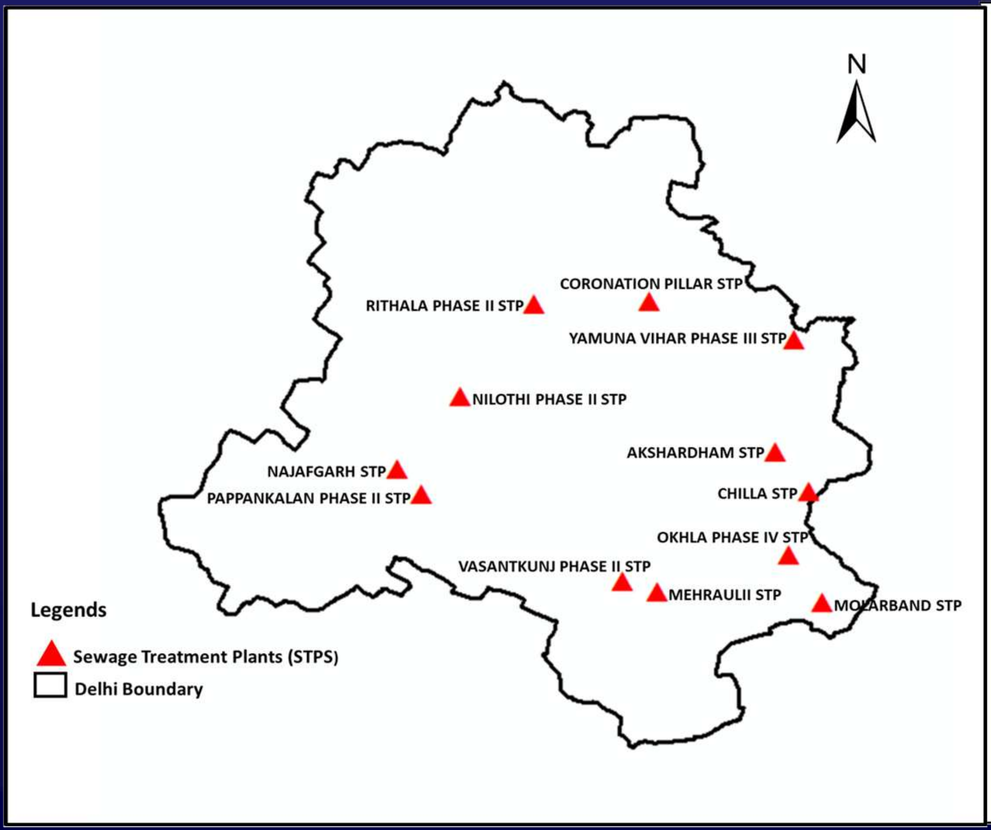
Nutrient management of wastewater to prevent eutrophication in Delhi
(UNEP projects, 2022-24)

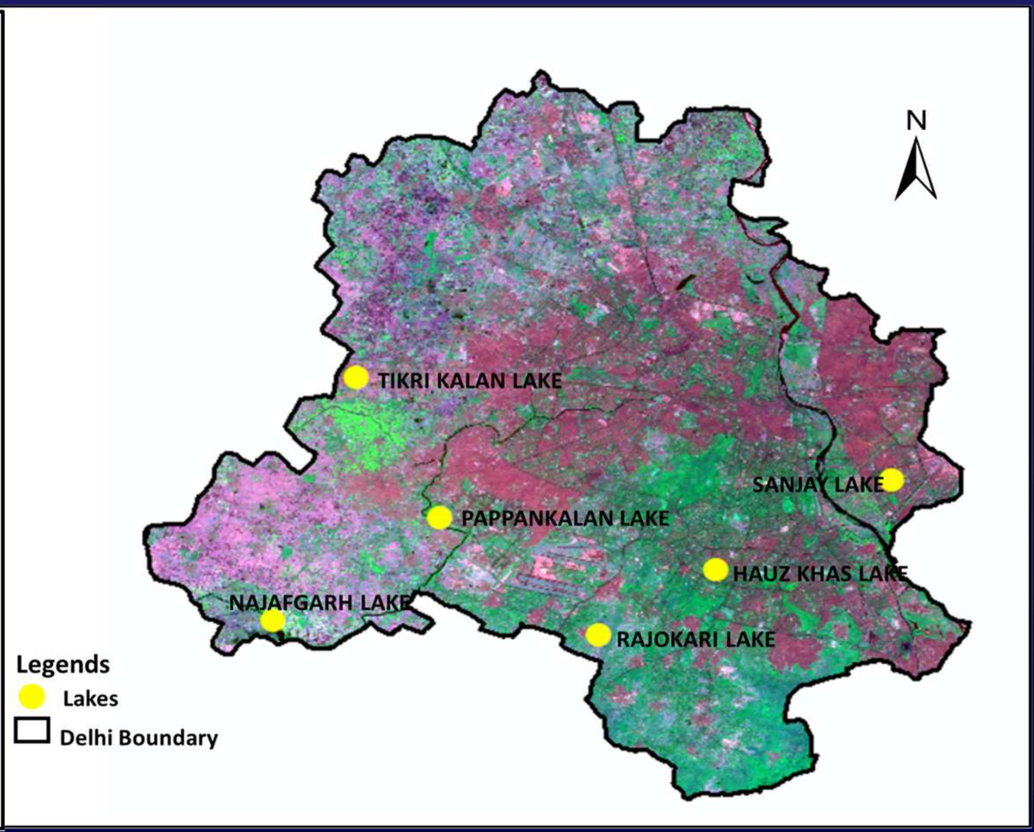
In Delhi, 3330 Million Litres per Day (MLD) of wastewater is generated of which 918 MLD is discharged untreated in inland water bodies polluting them heavily.

Objectives

- Assess nutrients lost through waste water in Delhi and their recovery/reuse potential
- Map the current nutrient recovery/recycling/reuse practices in Delhi against available options/technologies and best practices for efficient and sustainable nutrient cycling
- Develop ecosystem health card based on water quality parameters to monitor the revival of selected water bodies by regulating nutrient loading from waste water

Nutrients in Wastewater: Study of 12 Delhi STPs and 6 Lakes





Nutrients in wastewater monitored before and after treatment at each STP during Monsoon & Winter & at each lake

Delhi adds heavily to the nutrient and other pollutants in Yamuna river

- Untreated or inadequately treated wastewater from STPs adds to Yamuna pollution
- Najafgarh Lake's water flows into the Yamuna via the Najafgarh drain (Sahibi river)
- Barapullah Drain carries STP water from Mehrauli to the Yamuna
- Okhla STP water goes to Yamuna via old Agra canal & Abul Fazal drain
- Pappankalan Phase II water occasionally reaches Yamuna via Najafgarh drain
- Nilothi STP water occasionally reaches Yamuna via local drains and Najafgarh drain
- STPs at Mehruli, Okhla and Yamuna Vihar are also linked to the Yamuna
- Ensuring that no untreated wastewater flows into Yamuna is as important as its full treatment
- Improving wastewater management is important for sustainable water & nutrient management & TPC

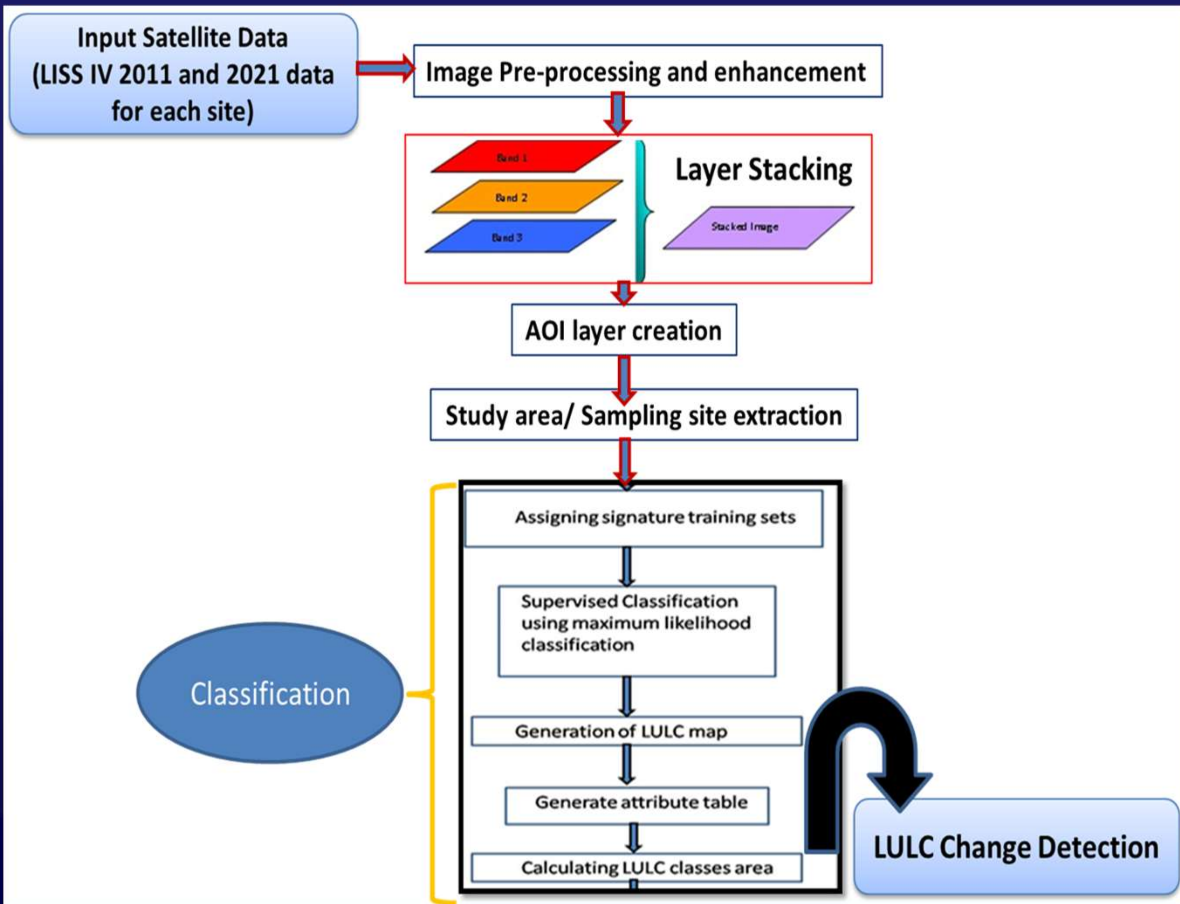
Nutrient Assessment of STPs and lakes in 2023 and 2024

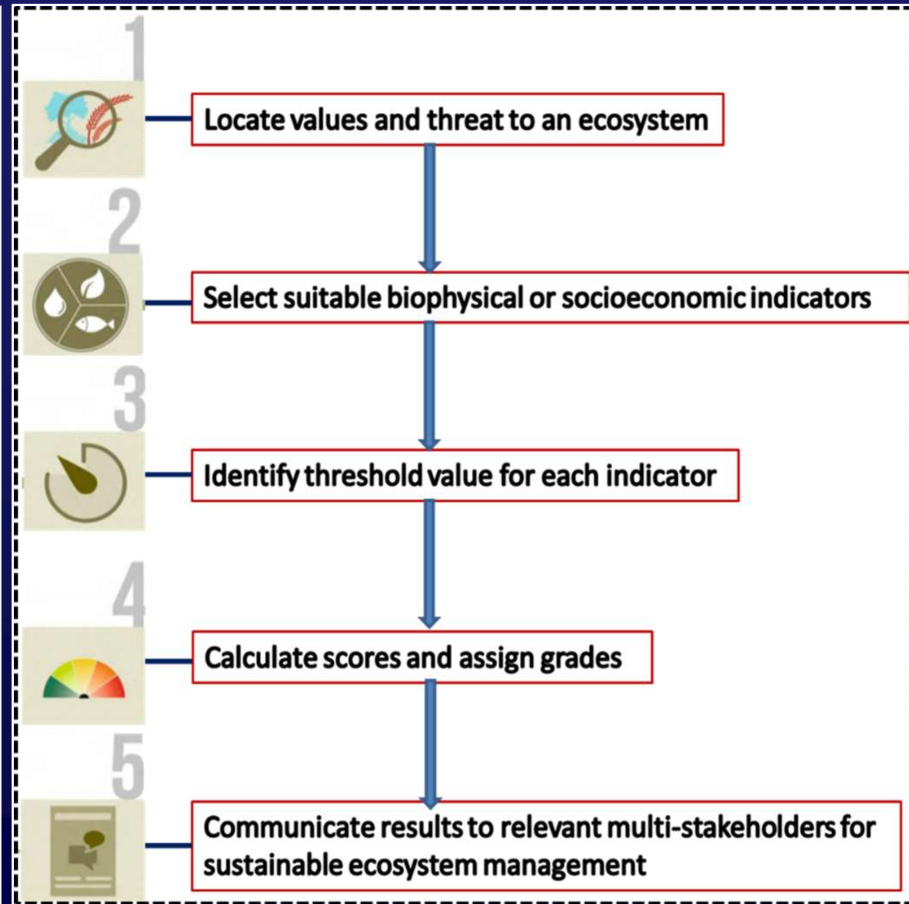
STP	NO_3 (%)		PO_4 (%)		NH_4 (%)	
	Monsoon Season (2023)	Winter Season (2024)	Monsoon Season (2023)	Winter Season (2024)	Monsoon Season (2023)	Winter Season (2024)
Akshardham	62.67	60	43.45	43.75	59.57	68.18
Okhla Ph IV	52.63	46.67	68.5	61.54	73.38	70.55
Molarband	58.26	67.26	50.37	48.18	20.83	49.38
Pappankalan Ph II	62.61	72.94	44.69	36.61	23.57	39.19
Vasant Kunj Ph II	61.67	58.33	58.94	47.93	61.97	61.09
Coronation Pillar Ph II	92.67	84.5	68.94	71.82	67.15	83.41
Rithala Phase II	71.84	64.17	89.44	91.25	33.82	51.33
Yamuna Vihar Ph III	65.79	59.77	50.31	55.71	35.86	46.12
Nilothi Ph II	61.03	63.48	77.58	76.62	11.49	18.1
Chilla	56.03	57.26	95.6	88.89	14.74	31.68
Najafgarh	50.21	48.76	54.9	51.53	24.17	34.63
Mehraulli	55.62	64.36	58.62	62.5	53.37	54.44
Total	**65.1**	**62.1**	**63.53**	**61.35**	**40.39**	**50.22**

	Hauz Khas Lake			Sanjay Lake			Najafgarh Lake		
	Spring Season 2022	Monsoon Season 2023	Winter Season 2024	Spring Season 2022	Monsoon Season 2023	Winter Season 2024	Spring Season 2022	Monsoon Season 2023	Winter Season 2024
DO	5.8	3.6	9.8	5.47	2.1	5.3	1.6	4.1	5.4
TDS	1073.2	314.2	393.8	888	482.9	630.7	1242.5	794.8	1134.8
NO_3	8.7	55.2	66	28	98	6.4	3.57	50.5	74.1
NH_4	2	17.3	27.3	2	14	2.1	5.53	19.6	28.1
PO_4	4.9	6.8	10.5	2.57	15	14	2.58	13.8	13.3

	Pappankalan Lake		Tikri Kalan Lake		Rajokari Lake	
	Monsoon Season 2023	Winter Season 2024	Monsoon Season 2023	Winter Season 2024	Monsoon Season 2023	Winter Season 2024
DO	5.8	9.8	0.58	3.3	2.4	8
TDS	831.5	767.5	2807.2	1744.4	778	922.3
NO_3	5.1	64.8	69.8	92.8	49.3	45.3
NH_4	16.3	32.3	63.36	30	25.9	18.3
PO_4	11.7	17.4	9.08	6.5	3.3	4

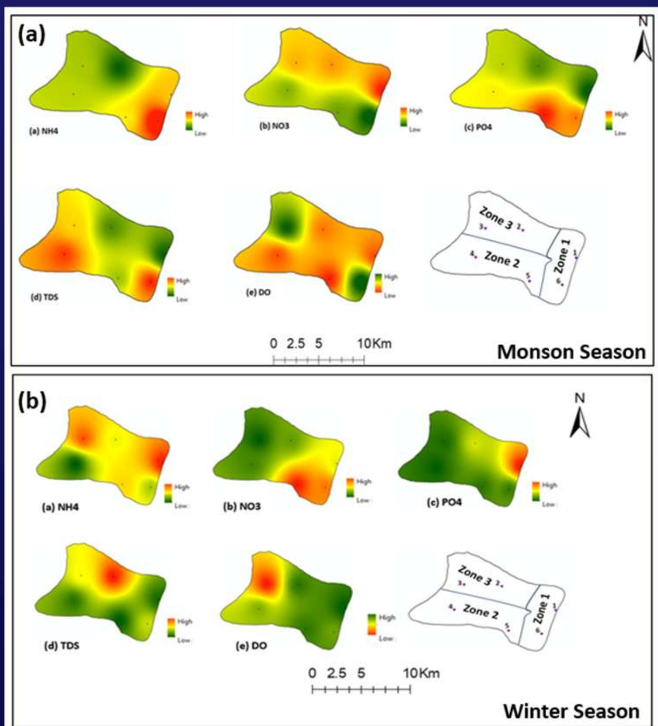
Land Use/Land Cover (LULC) Analysis & Ecosystem Health Report Card (EHRC)

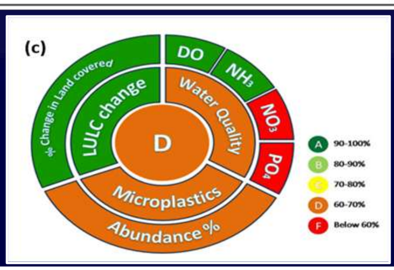




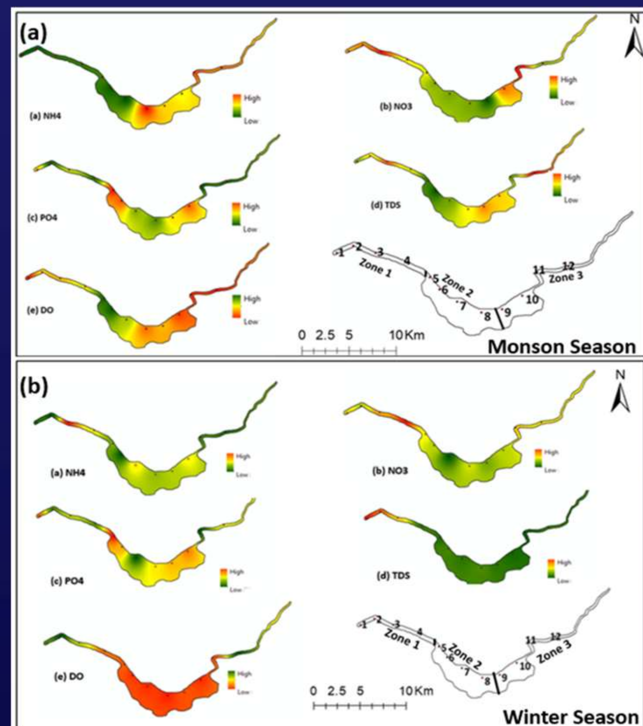
Lake nutrient status and ecosystem health in NCT of Delhi - 2024

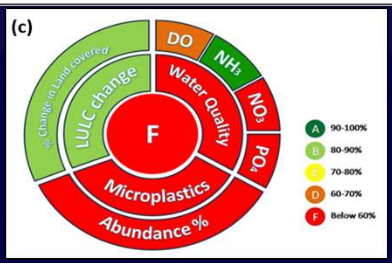
Hauz Khas lake



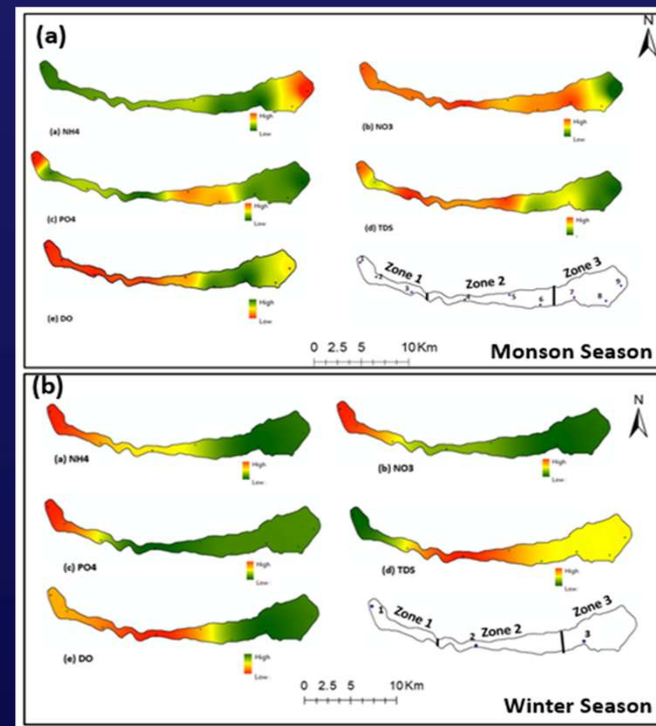


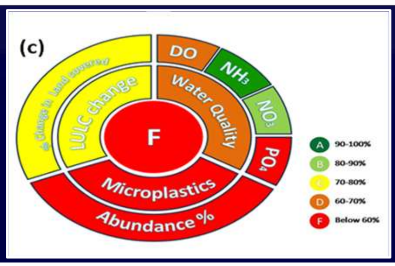
Nazafgarh lake





Sanjay lake





Role of wastes (crop/livestock/human sources) in circular nutrient economy

STP	NO_3 (%)		PO_4 (%)		NH_4 (%)	
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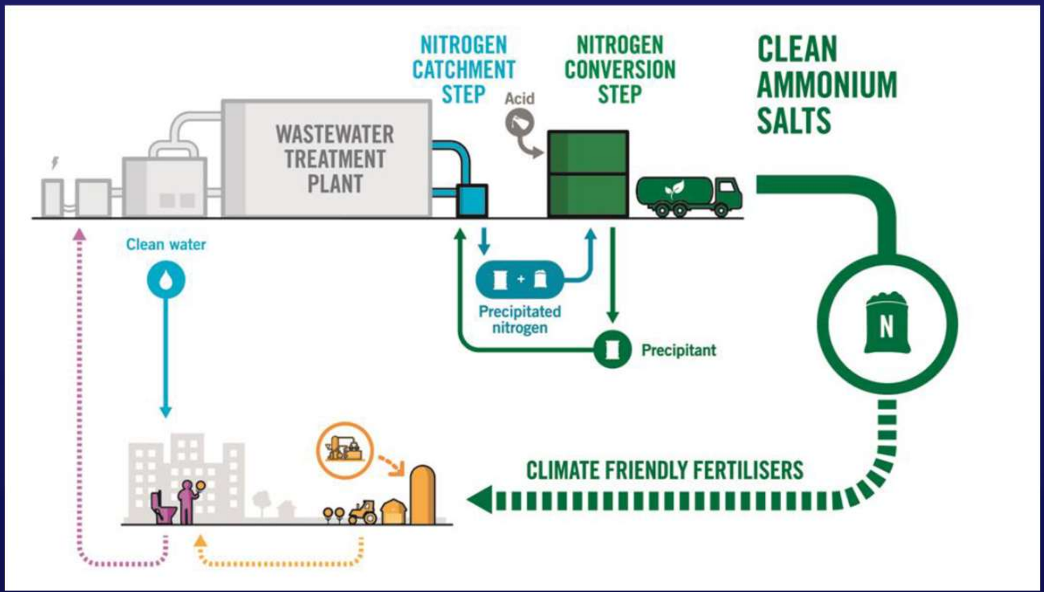
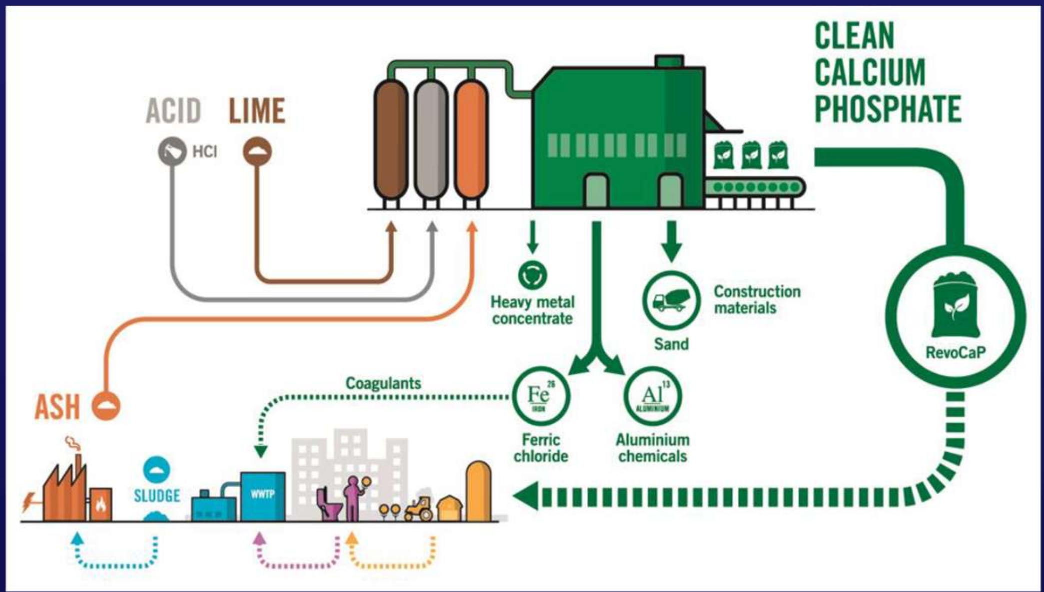
COMMENT | 16 November 2022

Recycling crop and animal waste is a win for green farming

- ➢ Wastewater & solid waste are important sources of nutrients
- ➢ India’s current capacity for nutrient recovery/recycling is < 20%
- ➢ 84% of the 65,250 metric tonnes of nutrients lost daily in India
- ➢ Half of daily fertilizer demand can be saved by wasted nutrients
- ➢ Technological upgradation of STPs needed for better nutrient removal
- ➢ Tech allows >95% removal/recovery of nutrients from wastewater
- ➢ Manure & urine can meet 60% more nutrients than fertilizers in India
- ➢ Legumes can further reduce the demand for fertilizers and manures
- ➢ New tech allows industry-grade fertilizers (N/P) from wastewater
- ➢ Sewage treatment plants can soon become fertilizer plants

Technologies available to recover N/P from wastewater to produce fertilizers

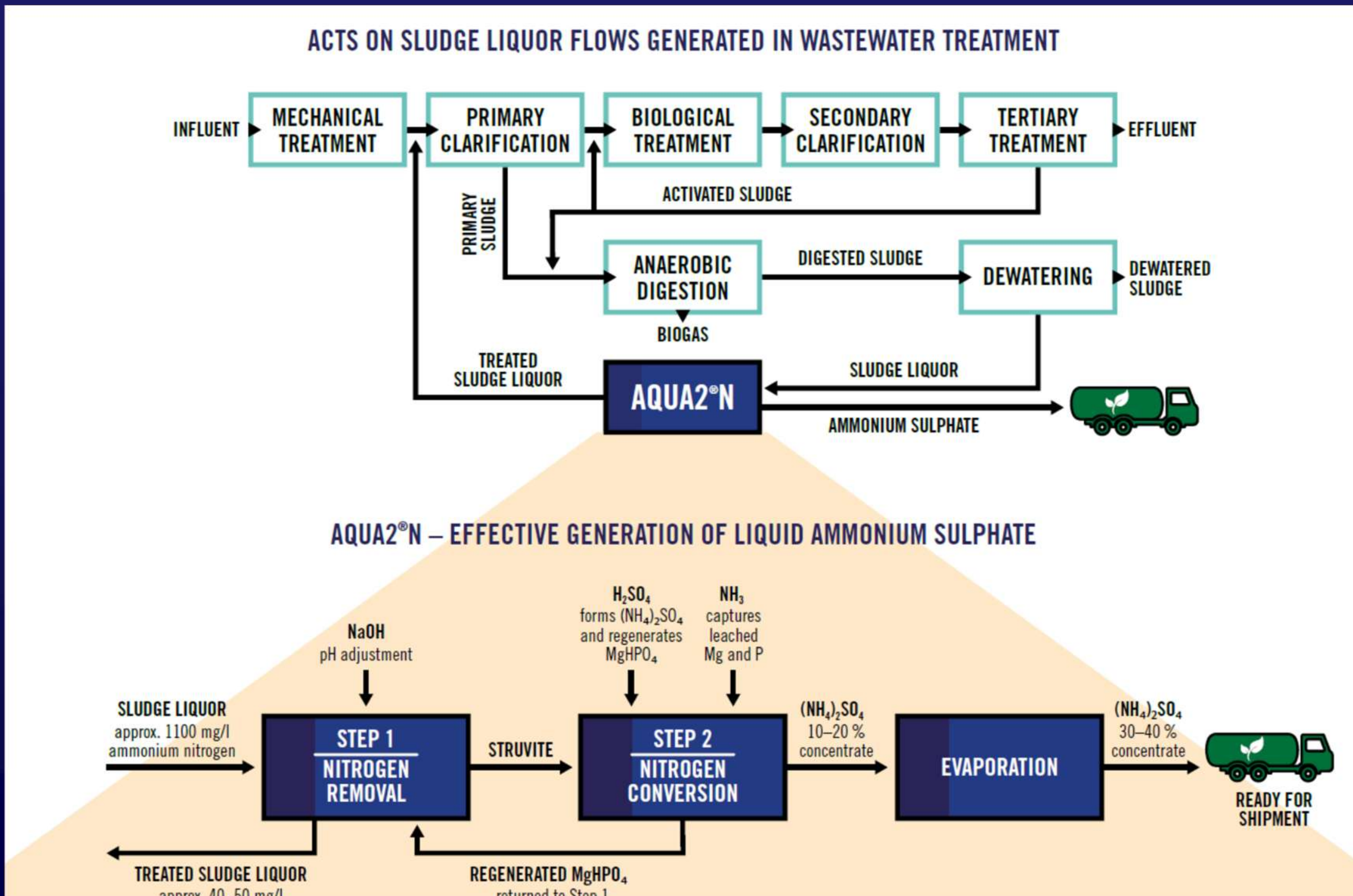




Source: Ragn Sells, www.easymining.se

1. Prevents emission of ammonia and nitrous oxide (GHG) and recycles Nr as industry-grade fertilizer
2. Prevents phosphorus loss by recovering over 90% of it as fertilizer plus other valuable chemicals
3. Prevents methane emission and recycles it as fuel for electricity generation to save power/emission
4. Prevents heavy metal pollution by recovery of high value metals like iron, aluminium, etc
5. Utilises >95% of ash to prevent ash pollution and produce nutrients and chemicals from it

Process to produce ammonium sulphate fertilizer from wastewater



Aqua2N is a two-step chemical process followed by evaporation.

In step 1 – nitrogen removal – ammonium nitrogen is precipitated with magnesium phosphate, forming struvite. If needed, the pH of the incoming sludge liquor is adjusted with sodium hydroxide. Treated liquor is returned to the main wastewater flow.

In step 2 – nitrogen conversion – sulphuric acid is added to break up the struvite, forming ammonium sulphate and regenerating the magnesium phosphate precipitant, which is returned to step one for reuse in removal. Added ammonia then removes leached magnesium and phosphate, which are also returned to the process.

Finally – the ammonium sulphate is **evaporated** to a 30–40 % liquid concentrate usable as a fertiliser.

RESOURCES NEEDED:

Process chemicals

- H_2SO_4
- NaOH
- NH_3

Make-up chemicals

- $MgSO_4$
- H_3PO_4

Utilities

- Water
- Energy
- Compressed air

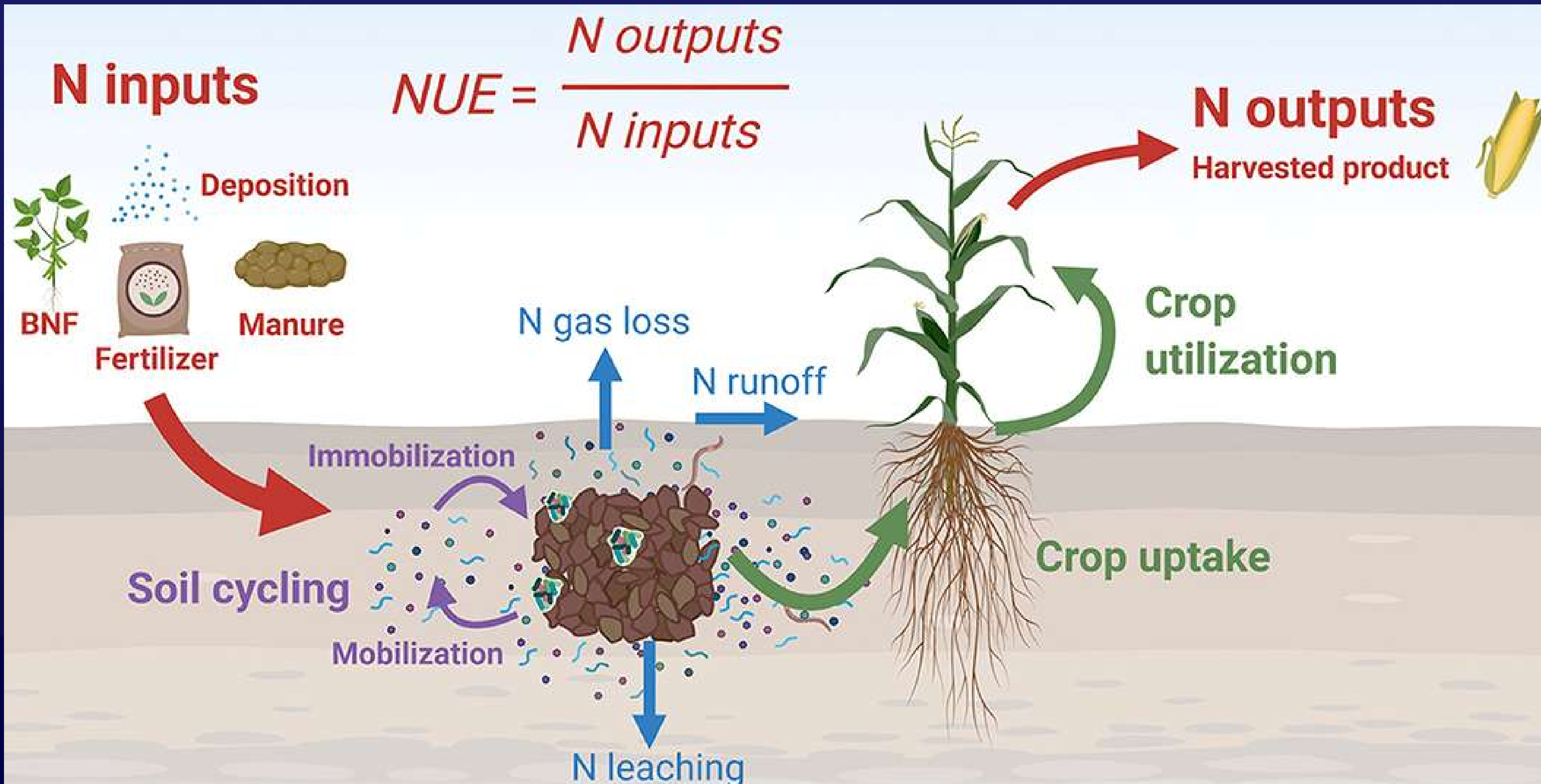
Space requirement

For a 10 m³/h-plant:

- Plant building 18x11x9 m
- Tank farm 24x7.5 m (embankment)
- Customised according to site prerequisites

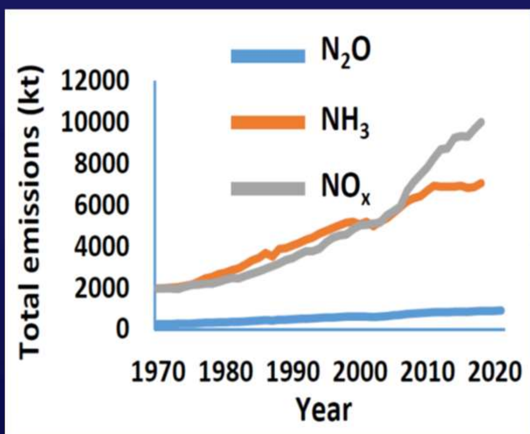
Source: Ragn Sells, www.easymining.se

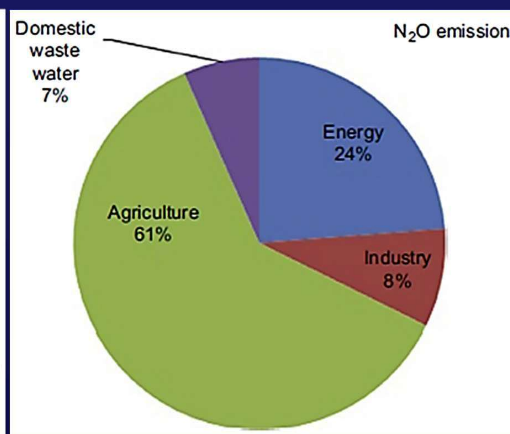
Crop Nitrogen use efficiency (NUE): Maximizing outputs with minimal inputs

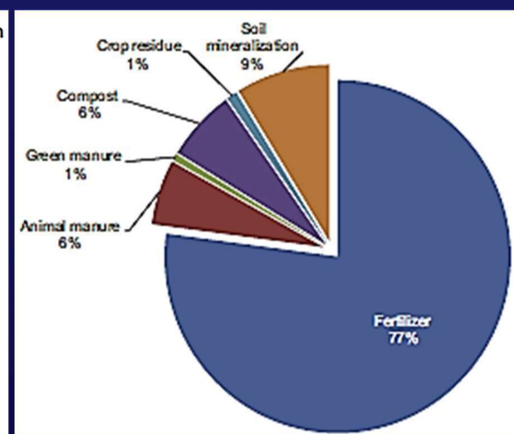


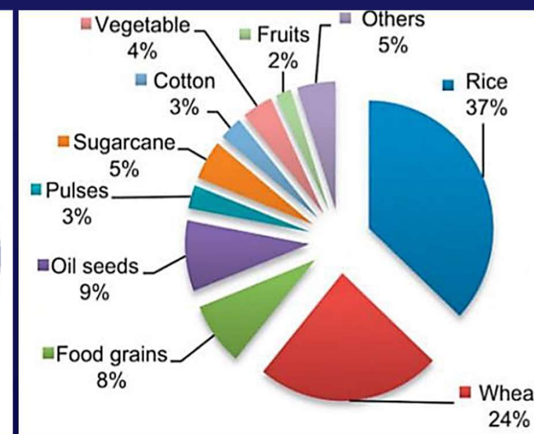
Crop Improvement for Nitrogen/Phosphorus Use Efficiency in rice

- Poor nutrient use efficiency of P/N (25-30%) is a huge economic and environmental problem
- Crop improvement is the best way to halve nutrient waste (target 7 Kunming-Montreal GBF)
- Rice is the highest fertilizer-consumer crop in India, with 5-fold variation of NUE in germplasm









The N policy report (Adhya etal. 2023)

Indian nitrogen assessment (Abrol et al. 2017)

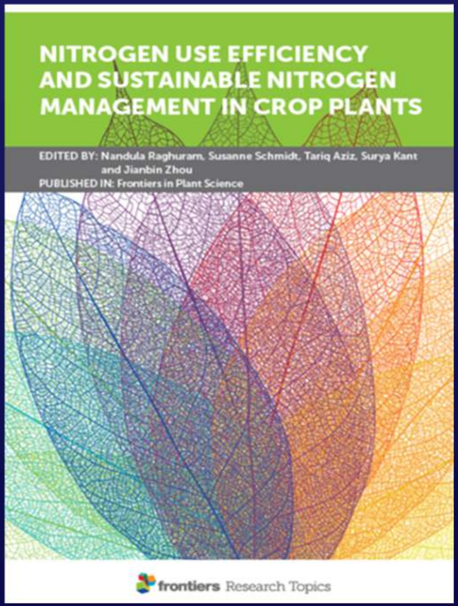
- Characterized phenotype for NUE & PUE, contrasting rice genotypes identified for NUE/PUE
- Comparative transcriptomics done, associated with yield/QTLs etc. and candidate genes identified
- Genome editing in progress with Samba Mahsuri & Swarna for candidate genes involved in NUE/PUE

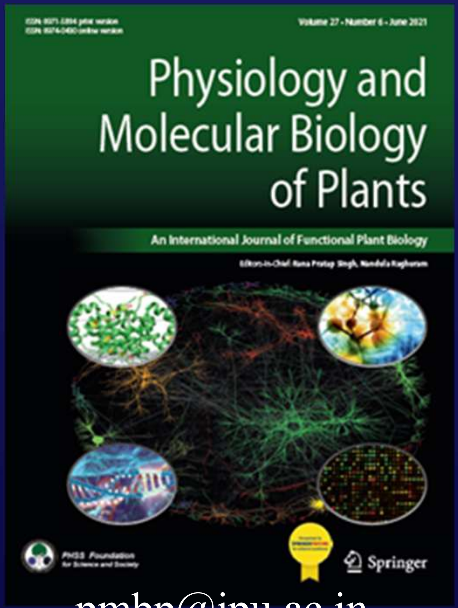
Sustainable nutrient management to avoid fertilizer trap & triple crisis

1. Promote legume rotation for nitrogen use efficiency in crop production
2. Incentivize pulses and oilseed legume production by procurement at MSP
3. Replace half of fertilizer with organic nutrients, use fertilizers only as topup
4. Adopt best practices to manage mulch, manure, urine, biochar nutrients
5. Fertilizer formulation improvements address only a fraction of the problem
6. Recycle nutrients from livestock wastes for cropping and vice-versa
7. Restore integrated crop-livestock farming for sustainable nutrient recycling
8. Reduce food losses during storage, processing & transport, recycle waste
9. Recycle N, P and other nutrients from wastewater & solid wastes
10. Bring back PSU seed corporations for self-reliance in affordable seeds
11. Low-input screening of germplasm, crop improvement and extension
12. Regulate irrigation in dry season to help restore legume-based rotations

Thanks!

raghuram@ipu.ac.in





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