Our Nutrient World

The challenge to produce more food & energy with less pollution.

Key Messages for Rio+20

Nutrient Benefits & Threats

- The sustainability of our world depends fundamentally on nutrients. In order to feed 7 billion people, humans have more than doubled global terrestrial cycling of nitrogen (N) and phosphorus (P).
- The world's N and P cycles are now out of balance, causing major environmental, health and economic problems that have received far too little attention.
- Insufficient access to nutrients still limits food production and contributes to land degradation in some parts of the world, while limited P reserves represent a risk for future global food security.
- Unless action is taken, increases in population and per capita consumption of energy and animal products will exacerbate nutrient losses, pollution levels and land degradation, further threatening the quality of our water, air and soils, affecting climate and biodiversity.

The Nutrient Challenge

- *A new global effort is needed to reduce nutrient losses and improve overall nutrient use efficiency in all sectors, simultaneously providing the foundation for a Greener Economy to produce more food and energy while reducing environmental pollution.*
- The new effort must cross the boundaries between economic sectors and environmental media, be underpinned by scientific evidence, share best practices and address the substantial cultural and economic barriers that currently limit adoption.

Options for Action

- *The global community now needs to agree which existing inter-governmental process is best suited to take the lead in improving nutrient management for the 21st century, or whether a new policy process is needed.*
- One option is to strengthen the mandate of the 'Global Programme of Action for the Protection of the Marine Environment from Land-based Activities' (GPA) to address the inter-linkages between land, air and water, in relation to the global supply of all nutrient sources and nutrient use efficiency across the full chain, considering their regional variation.

Developing the Mandate

- A central objective of the new inter-governmental effort must be to show how improved management of N and P at different scales over the whole cycle would simultaneously make quantified contributions toward meeting existing commitments for water, air, soil, climate and biodiversity, while underpinning improved food and energy security - with net social and economic benefits.
- *International authorization of the global nutrient focus is now essential, emphasizing the need for a mandate to assess the scientific evidence, share best practices, and work towards inter-governmental agreements that make quantifiable steps toward the sustainable development of Our Nutrient World.*

Too much & too few nutrients

Nutrients feed the world

The world needs nutrients, especially nitrogen (N) and phosphorus (P), which are essential to raise crops and animals to feed an increasing world population.

- Natural nutrient sources and recycling have been insufficient for increasing human needs since the 19th century. This has led to the exploitation of mined sources of nitrogen and phosphorus, and of using energy to convert non-reactive atmospheric nitrogen (N_2) into reactive nitrogen (N_r) compounds.
- Approximately 2% of world energy use is dedicated to the industrial manufacture of N_r, mainly through the Haber-Bosch process to produce ammonia.
- Phosphorus is still obtained from mining of finite deposits rich in phosphate, with current world supplies coming from just a few key countries.
- Fertilizer use has been essential to feed half of the world's population over the 20th century, and will be fundamental to ensure global food security over the 21st century.

Nutrient losses create a global web of pollution

There are major problems associated with high levels of nutrient use, especially in Europe, North America, South and East Asia and Latin America.

- The efficiency of nutrient use is very low: on average over 75% of added nutrients end up lost to the environment, wasting the energy used to produce them, and causing pollution through emissions of the greenhouse gas nitrous oxide (N_2O) and ammonia (NH_3) to the atmosphere, plus losses of nitrates (NO_3), phosphate and organic N and P compounds to water.
- Oversupply of nutrients, or imbalances between nutrients, reduces the efficiency of nutrient use. This is further reduced by including livestock in the food chain, substantially increasing N & P pollution levels.
- Burning fossil fuels produces a significant additional N_r resource (~20% of human N_r production) that could be captured and used, but which is currently wasted as emissions of nitrogen oxide (NO_x) to air, contributing to particulate matter and ground-level (tropospheric) ozone that adversely affect human health, ecosystems and food production systems.

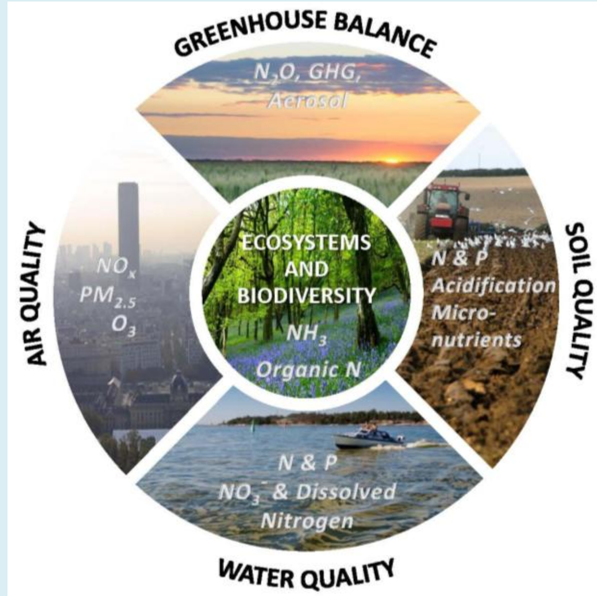
Insufficient nutrients exacerbate land degradation

In Africa, Latin America and parts of Asia there are still wide regions with too few nutrients. In particular:

- Many farmers do not have access to affordable mineral fertilizers, where lack of local sources and poor supply infrastructure increases already volatile prices, limiting agricultural yields. Biological nitrogen fixation and manure recycling are key local nutrient sources which are not always optimally exploited.
- The inability to match crop harvests with a sufficient nutrient return leads to depletion of nutrients and organic matter, reducing soil quality and increasing the risk of land degradation through erosion and of agricultural incursion into virgin ecosystems.
- Shortages of water and micronutrients (such as sulphur, zinc, selenium etc) can limit N and P use efficiency, preventing the best use being made of these major nutrients.

Key Nutrient Threats

Five main threats of nutrient pollution were highlighted by the European Nitrogen Assessment.[1] These can be extended to reflect the global threats of too much or too few nutrients, as shown below.



The diagram highlights the complexity of nutrient interactions, while offering a short-list of the 5 key issues that is easy to remember. Together they make the WAGES of too much or too few nutrients:

Water quality – including coastal and freshwater dead zones, hypoxia, fish kills, algal blooms, nitrate contaminated aquifers and impure drinking water, resulting from both N_r and P eutrophication.

Air quality – including statistical shortening of human life by particulate matter formed from NO_x and NH_3 emissions, and from increased concentrations of nitrogen dioxide (NO_2) and ground-level ozone (O_3).

Greenhouse gas balance – including emissions of N_2O plus interactions with other N_r forms, including tropospheric O_3, particulate matter and atmospheric N_r deposition. N_2O is now also the main cause of stratospheric ozone depletion, increasing the risk of skin cancer from UV-B radiation.

Ecosystems & biodiversity – including the loss of species of high conservation value, naturally adapted to few nutrients. Eutrophication from atmospheric N_r deposition is an insidious pressure that threatens the biodiversity of many 'protected' natural ecosystems.

Soil quality – over-fertilization and too much atmospheric N_r deposition acidifies natural and agricultural soils, while a shortage of N_r and P nutrients leads to soil degradation, which can be exacerbated by shortage of micronutrients, leading to loss of fertility and erosion.

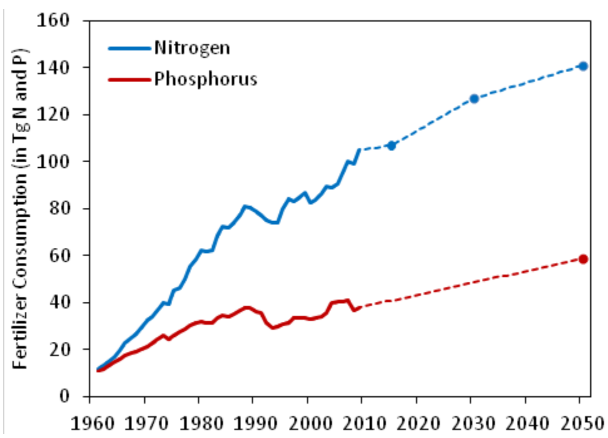
The increased loss of nitrogen and phosphorus into our environment can be seen in relation to present efforts to refine **'Planetary Boundaries'** for key global threats. The huge extent to which reactive nitrogen production and losses exceed the boundary has already been widely publicised. Efforts are now needed to improve the dose-response relationships and quantify regional variation.

Nutrients are an increasing threat requiring urgent action

Since the 1960s, human use of synthetic N fertilizers has increased 9 fold globally, while P use has tripled. Further substantial increase is expected over the next 50 years in order to feed the growing world population and because of increased consumption of animal products, reflecting ongoing changes in dietary lifestyle. These changes will exacerbate current environmental problems unless urgent action is taken to improve the efficiency of N and P use – maximizing the fraction that reaches useful products while minimizing wasteful pollution of the environment.

The consequences of not taking action include further warming effects from increasing atmospheric N_2O, continuing deterioration of water, air and soil quality, shortening human life, while threatening ecosystem services and biodiversity. The full damage cost has not yet been assessed, but annual global loss of ecosystem services including damage to fisheries from coastal N and P pollution alone costs an estimated $200 billion.[4] Making better use of nutrients will reduce these pollution threats, while improving food and energy production.

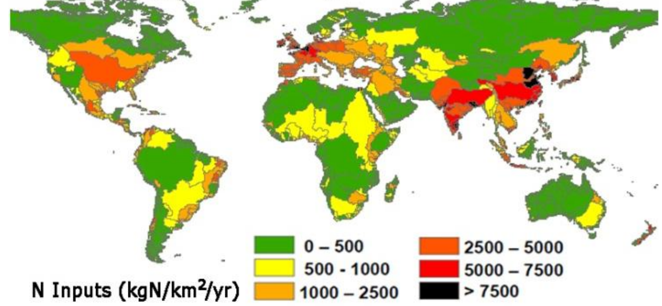
The possibility of future P shortage represents a major issue of recent contention. There are few countries whose known reserves cover their own P demand for a long period (e.g. Morocco, Algeria > 1000 years), others for a shorter time (USA, China, Brazil: 50 years)[5], while other countries have no notable reserves (e.g. Germany, Japan). Whether there are accessible global P reserves to feed humanity for decades or centuries, long-term access to P is a critical issue that calls for more efficient practices and consumption patterns that waste less nutrients.



Trends in global fertilizer nitrogen and phosphorus consumption and projected possible futures (expressed as N and P_2O_5).[2]

Effective solutions must address N & P cycles on local to global scales

Nitrogen and phosphorus cycles operate across multiple spatial scales, from the dynamics of a single field, through trans-boundary transport of air and water pollution, to the global increase in N_2O concentrations. Such inter-connections require an international approach that takes account of local and regional conditions, while addressing the necessary improvement in nutrient use efficiency at the global scale. The role of 'barriers to change' also necessitates a global approach. These include the global scale of trade in fertilizers, food crops, animal feed and livestock products, which can constrain the adoption of nutrient best practices.



Some regions use excess nutrients, with the waste causing environmental pollution, while other regions do not have enough. The map shows estimated net anthropogenic nitrogen inputs according to the world's main river catchments.[3]

Key actions to produce more food & energy with less nutrient pollution

We identify nine key actions as being central to improving nutrient use efficiency, thereby improving food and energy production while reducing N and P losses that pollute our environment.

Agriculture

1. Improving nutrient use efficiency in crop production,
2. Improving nutrient use efficiency in animal production,
3. Increasing the fertilizer equivalence value of animal manure,

Transport and Industry

4. Low-emission combustion and energy-efficient systems, including renewable sources,
5. Development of NO_x capture and utilization technology,

Waste & Recycling

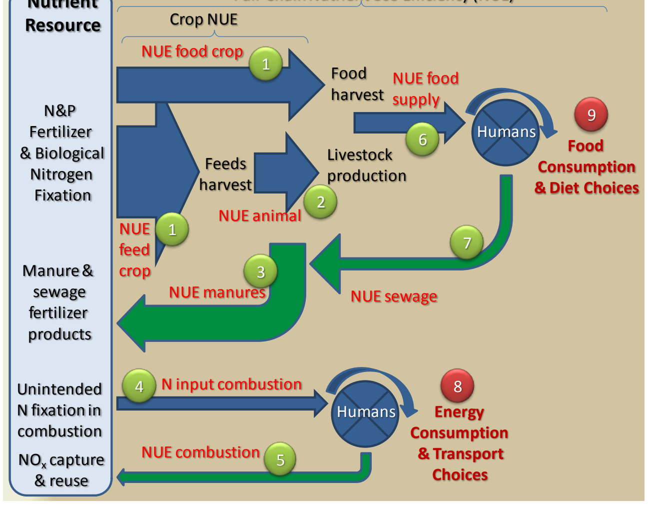
6. Improving nutrient efficiency in food supply & reducing food waste,
7. Recycling nitrogen and phosphorus from waste water systems, in cities, agriculture and industry,

Societal consumption patterns

8. Energy and transport saving,
9. Lowering the human consumption of animal protein (avoiding excess).

These actions must be seen in the context of the wider N and P cycles, considering acquisition, use and recycling. Efforts are needed to improve the nutrient use efficiency (NUE) of each stage, such as crop in crop and animal production. However, we emphasize especially the need to address the "full-chain NUE", defined as the ratio of nutrients in final products (e.g., human food consumed) to new nutrient inputs (e.g., Haber-Bosch N_r, biological N fixation, NO_x formation, mined P and N).

As the graphic overleaf illustrates, each of the component efficiencies contribute to the full-chain NUE. Actions promoting the recycling of available N_r and P pools, such as effective recycling of animal manures, human sewage and NO_x capture and utilization technology all contribute to increasing full-chain NUE. The options include many technical measures, such as improved fertilizer placement and timing, the use of manure storage and spreading methods that reduce emissions, and the processing of manures into more efficient fertilizers.



Nutrients flow can be seen as a cycle from resource through the stages of use (blue arrows) with recycling (green arrows). The system is driven by the 'motors' of human consumption. Numbered circles highlight nine key actions to increase NUE.

Our choices as citizens make a big difference. While some remain undernourished, people in many countries eat more animal products than is optimal for a healthy diet. Avoiding over-consumption of animal products (e.g., staying within World Health Organization guidelines for saturated fats) increases full-chain NUE, reducing N and P pollution, while benefiting our health.

The global economic benefits for the environment and human health by avoiding over-consumption of animal products still need to be quantified. However, the central role of livestock in contributing to nutrient pollution is well established. In the European Nitrogen Assessment, it was estimated that 85% of harvested N_r was used to feed livestock, with only 15% feeding people directly, while the average EU citizen consumed 70% more protein than needed for a healthy diet.[1]

A new intergovernmental focus

Nutrient management is currently addressed in part by divergent efforts on food, climate, water and air pollution, and biodiversity, but there is no international treaty that links the major nutrient benefits and threats.

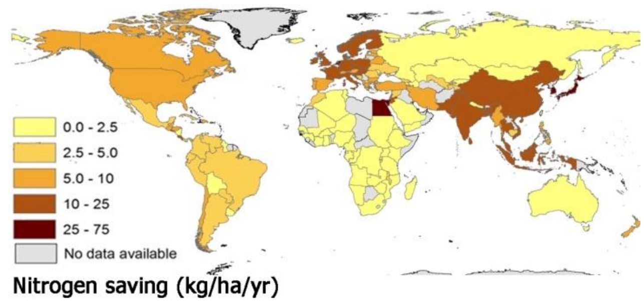
There is an urgent need to develop joined-up approaches that optimize the planet's nutrient cycles for delivery of our food and energy needs, while reducing threats to climate, ecosystem services and human health.

One option would be to strengthen the mandate of the intergovernmental 'Global Programme of Action for the Protection of the Marine Environment from Land-based Activities' (GPA). Although GPA has a current focus on the marine environment, it is already taking a lead in developing a cross-media approach through the Global Partnership on Nutrient Management (GPNM).

International consensus is now needed that mandates a strengthened GPA or other body to:

1. Establish a comprehensive global assessment of nutrient linkages, between air, land, water, climate and biodiversity, considering interactions with food and energy security, costs and benefits and the opportunities for the Green Economy,
2. Investigate options for improvement of nutrient use efficiency, demonstrating benefits for health, environment, and the supply of food and energy,
3. Address the barriers to change, fostering education, multi-stakeholder discourse and public awareness,
4. Establish internationally agreed targets for improved N_r and P management at regional and planetary scales,
5. Quantify the multiple benefits of meeting the nutrient targets for marine, freshwater and terrestrial ecosystems, mitigation of greenhouse gases and other climate threats, and improvement of human health,
6. Develop and implement an approach for monitoring time-bound achievement of the nutrient targets.

An illustration of the achievable gains is shown in the map below. Globally, a target to achieve a relative improvement in full-chain nutrient use efficiency by 20% would deliver an estimated saving of 20 million tonnes of N_r. Based on initial European estimates,[1] this would equate to an improvement in human health, climate and biodiversity of the order of \$100 billion per year.



The benefits of improved Nutrient Use Efficiency (NUE). The map shows the N_r savings that would be made, per ha of agricultural land, from a 20% relative improvement in full-chain NUE.

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Further information

www.gpa.unep.org/gpnm.html http://initrogen.org/

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