Planet Tracker

Financial markets need to focus on nitrogen

FIXING NITROGEN

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CONTENTS

KEY TAKEAWAYS

- Despite a lack of publicity, **nitrogen plays a vital planetary role**, ranging from the impact it has on food production to being a driver of pollution for land, sea and air. Nitrogen affects one of the nine planetary boundaries – biogeochemical flows. These limits need to be respected to avoid threatening the Earth's ecosystems and maintaining its biosphere. Presently, the nitrogen boundary has been exceeded by at least two times.

- When considering nitrogen, **we should be mindful of two limits**. There is a **maximum environmental limit** of nitrogen fertiliser that should be used to avoid the consequences of significant environmental changes, but also a **minimum social limit** to provide enough food to feed the global population.

- **For the financial markets, nitrogen is important.** The fertiliser sector is an important industry in its own right, evident in both trade flows and for various corporates, as producers and/or users. It is a crucial input for the USD 14 trillion global food system affecting both costs and efficiency measures.

- Nitrogen fertiliser can cause costly **pollution issues, damaging soils, water ecosystems and the oceans.** These environmental costs can impact agriculture, tourism, aquaculture, fishing, as well as insurance and healthcare providers, and the financiers of these businesses It also impacts climate change by both using fossil fuels in its production and by emitting nitrous oxide, which is 310 times as powerful as carbon dioxide.

- This paper explores a range of **case studies**, examining the balancing act of limiting nitrogen use while being mindful of food production levels, to the role of policymakers and exposure to rising litigation.

- By studying nitrogen, this analysis also demonstrates the need to **view climate and nature as interconnected** as well as highlighting **the close relationship between land-use practices and ocean health**.

EXECUTIVE SUMMARY

Governments and corporates have been debating the importance of carbon for some time, particularly after the Paris Agreement, the legally binding international treaty on climate change, entered into force in November 2016. However, **nitrogen has been largely ignored**.

This is surprising. **Nitrogen is found in all living organisms.** It is a vital element in organic molecules such as carbohydrates, proteins, lipids and nucleic acids (e.g., DNA and RNA) which in turn **supports the growth, development and metabolism of organisms**.

Nitrogen compounds are used in **fertilisers**. When applied properly, they supply nutrients to the soil assisting plants to grow healthily and maximising crop yields. Furthermore, nitrogen in fertiliser is crucial to **the Earth's nitrogen cycle**, which helps regulate ecosystems and nutrient distribution. **It's vital in sustaining life and maintaining the health of ecosystems**. So, only from a self-preservation viewpoint, we should be mindful of nitrogen.

However, as with many of nature's outputs, if it's free, **we rarely recognise its value**. Such externalities, when the costs and benefits of a transaction are not reflected in prices, are often ignored by corporates and financiers. Where nitrogen does get priced is in synthetic fertilisers, hence the development of a multi-billion-dollar industry.

It was fertilisers that played an important role in the **Green Revolution** in the mid-20th century – along with other factors such as developing high-yielding crop varieties, improved irrigation and the widespread use of pesticides. It was widely viewed as **the technological solution to providing improved food security** which alleviated hunger and famine in many parts of the world.

But the Green Revolution also came with a price, evident in the **unintended environmental impacts**. The increase in water use for agriculture, the widespread use of chemicals, the overapplication of fertiliser and monoculture farming, led to soil deterioration and pollution.

Now is an opportune moment to again assess the value of nitrogen. Clearly it plays an important role in food production. A rising global population will make this evermore relevant. But as we have already learned, its overuse can result in environmental issues, and these effects are not just limited to the land.

Nitrogen pollution can be airborne when compounds such as ammonia (NH3) and nitrogen oxides (NOx) are released. In turn these give rise to acid rain, smog, ground-level ozone and global warming. There is also waterborne pollution, notably nitrates (NO3-) and ammonium (NH4+). As shown in **case study 2,** when these enter waterbodies they can lead to algal blooms, oxygen depletion (hypoxia) and eutrophication (the excessive enrichment of nutrients), unbalancing ecosystems.

For capital markets it is clear why nitrogen should be factored into decision-making. Perhaps most obvious are the effects on fertiliser manufacturers. **Are we reaching peak nitrogen**, as **case study 1** suggests? Are the environmental impacts of nitrogen likely to be borne by the industry and its financiers? The even larger **global food system** – which Planet Tracker values at USD 14 trillion1 – is heavily reliant on nitrogen inputs and changes upstream will have effects further along the food value chain[38] - see **case study 3**. **Investments are needed**, both in new technologies, such as precision farming, and nature-based solutions - see **case study 4**. Furthermore, **case study 5** explains how **the global fossil-fuel industry** is also closely involved in the fertiliser industry. This is perceived by some oil & gas companies as one of its 'diversification' strategies away from refined products.

Sovereign states also need also to be cognisant of nitrogen's benefits and pitfalls -see **case study 6**. Finally, **excess nitrogen can have political effects**, as **case study 7** clearly demonstrates. Economies, especially nature dependent exporters,[2,3] can be highly dependent on nitrogen but must also be wary on the environmental impacts.

Simply put, nitrogen is too important to ignore.

INTRODUCTION: WHY READ THIS PAPER?

Nitrogen is an important input into a global food system which contributes 34% of global greenhouse gas (GHG) emissions per year.[4] It is used in **fertiliser[a]** to grow food around the globe - synthetic nitrogen fertiliser has been responsible for feeding 48% of the global population.[5] Its production is **fossil fuel** intensive and controlled by a small number of countries and companies. It releases **GHGs** in its production process and when applied to crops it is often inefficiently used and large quantities of it are lost after its application, causing significant financial impacts for various food system companies and financiers. Please see Appendix 3: The Nitrogen Cycle for more information on how nitrogen moves through the environment.

Nitrogen fertiliser plays an important role in many economies and affects companies both directly and indirectly. Some of the most important ways it does this are listed below:

- It has an impact on food production, and therefore food prices.
- It is becoming increasingly regulated at a national level due to pollution impacts.
- It is an integral part of the food system, which needs a sustainable transition in order to feed a global population within environmental limits by 2050.
- The impacts of nitrogen pollution are costly.
- Some countries are dependent on nitrogen for export revenue.
- Cutting emissions from fertiliser use can help achieve the Paris 1.5⁰ climate target.

The importance of nitrogen has been further emphasised as scientists decide on whether we have entered a new geological epoch, the Anthropocene. Under discussion is whether humans have had such a dramatic impact on the planet that this can be identified by geologists as a recognisable time unit. One of the measures being used to determine this is nitrogen.[7]

This paper highlights the importance of nitrogen as a key environmental and financial issue for companies and financiers which is often outshone by its periodic table neighbour, carbon. There is rightly a focus on solving carbon-related climate issues, but nitrogen is an integral part of this problem. However a report from McKinsey & Company suggested that 79% of Fortune Global 500 companies have not acknowledged soil nutrient pollution as an issue, nor do they have targets for reducing their impact.[8]

This report includes a series of **short case studies** which demonstrate the importance of nitrogen and highlight issues for companies and financiers to consider in their decision-making.

a When fertiliser is mentioned throughout the report, unless otherwise stated, it refers to synthetic (or human-made) fertiliser.

In each study, extensive references to other publications that address one or more aspects in greater detail are provided for the reader to explore further.

Figure 1: Planet Tracker nitrogen case study overview provides a brief overview of the case studies in this paper and Figure 2: Planet Tracker case study linkages illustrates how the case studies are connected.

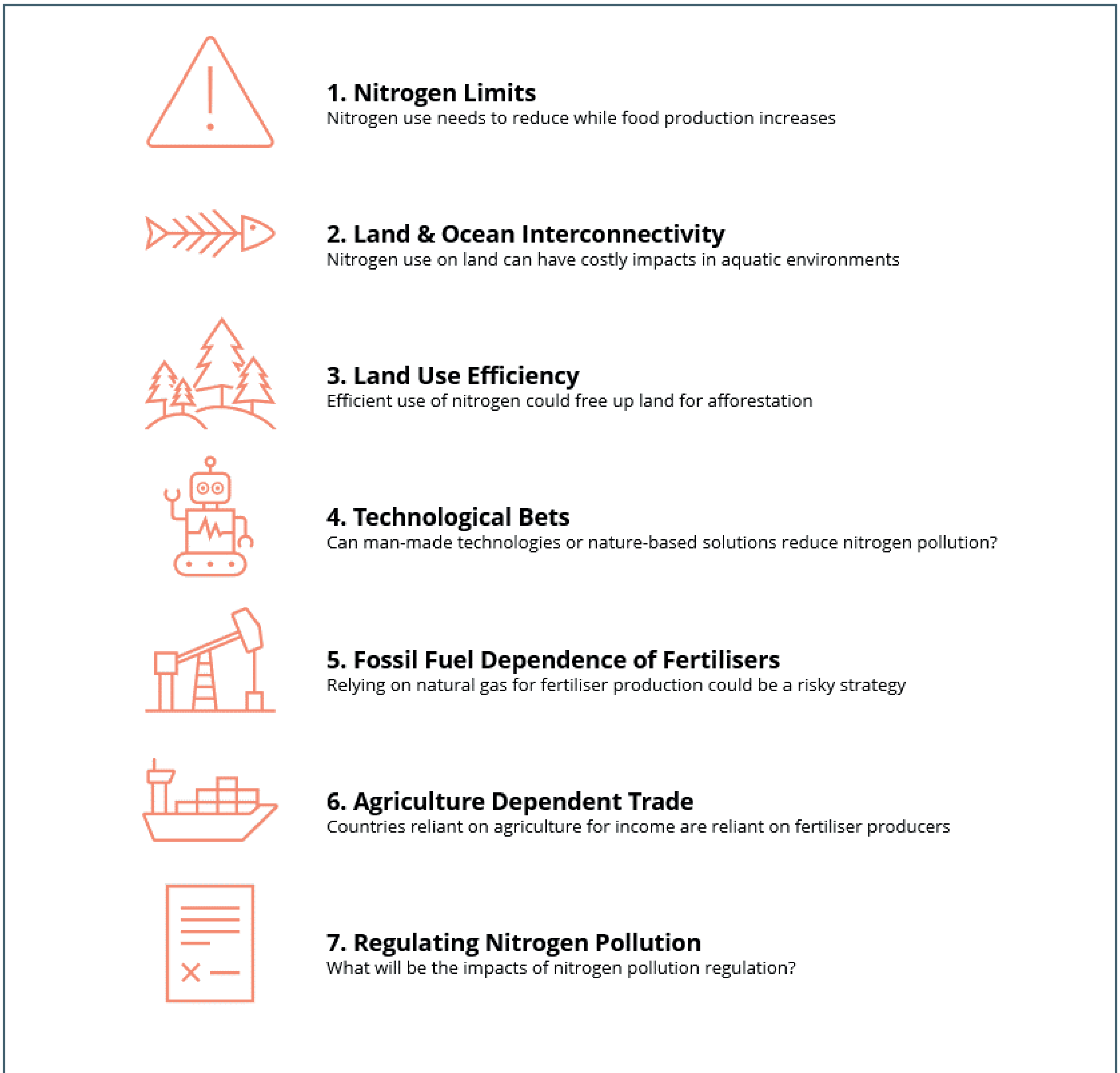

Figure 1: *Planet Tracker nitrogen case study overview*

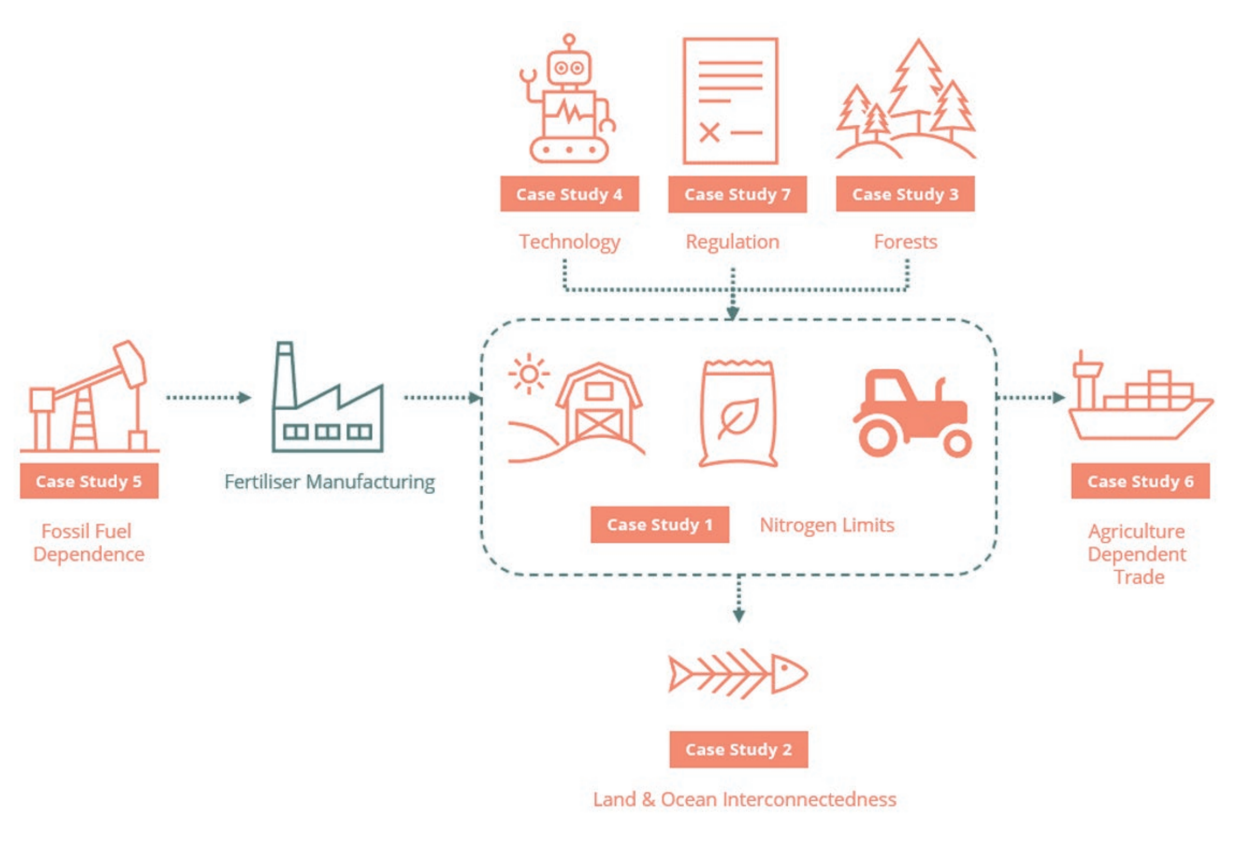

Figure 2: *Planet Tracker case study linkages*

WHY SHOULD FINANCIERS CARE ABOUT NITROGEN?

Planetary Boundaries

As the flow of many pollutants emitted to air, land, and water exceeds the ability of the Earth to cope with them, their concentration steadily increases. There are limits for these pollutants, which if breached, could irreversibly change key Earth system processes on a planetary scale. The same applies to limiting the unsustainable consumption of freshwater, conversion of forests, and loss of biodiversity. These limits are called **planetary boundaries**.

The planetary boundary framework was popularised in 2009 by Johan Rockström and colleagues, and subsequently updated in 2015 by Will Steffen et al at the Stockholm Resilience Centre.[9,10] Two smaller updates published in 2022 provided estimates for green water use (under the freshwater planetary boundary), and then for novel entities, including plastics.[11,12] A new paper was published in Science in September 2023 showing that six of the nine planetary boundaries have been exceeded.[13] The nine planetary boundaries assessed include: atmospheric aerosol loading; biogeochemical flows; biosphere integrity; climate change; freshwater change; land-system change; novel entities; ocean acidification and; stratospheric ozone depletion. The flow of **nitrogen** is captured under changes in the biogeochemical flow planetary boundary – see Figure 3: Current status of control variables for all nine planetary boundaries. First published in 2009 and last updated in 2023. (Source: Stockholm Resilience Centre)[13].

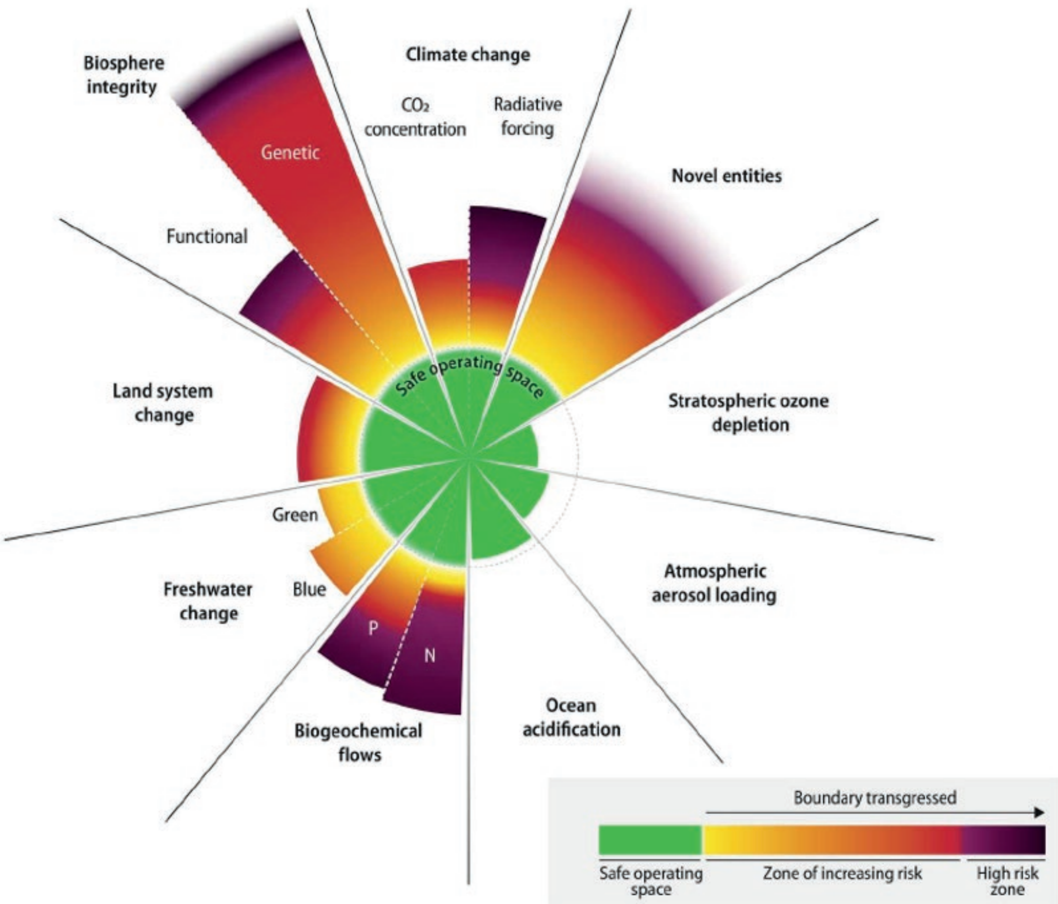

Figure 3: *Current status of control variables for all nine planetary boundaries. First published in 2009 and last updated in 2023. (Source: Stockholm Resilience Centre)*[13]

Each of the planetary boundaries contain ranges to reflect the uncertainty around when a tipping point or threshold is exceeded - the point at which a new state in the Earth system is reached. The range for nitrogen's **environmental limit** is thought to be between **62 to 82 million tonnes per year**. This is the quantity of synthetic nitrogen fertiliser and biological nitrogen fixation[b] by plants that should take place per year, which compares to the estimate of 162 mn tonnes of nitrogen input into the agricultural system annually.[14]

Three categories communicate the current **performance** in relation to a planetary boundary. These are shown below, and the values provided are specific to nitrogen:

- **Safe**: below the planetary boundary (<62 mn tonnes per year)
- **Uncertain**: between the lower and upper limits (>62 and <82 mn tonnes)
- **Danger**: application in excess of the planetary boundary (>82 mn tonnes)

We are exceeding our global nitrogen planetary boundary by between 2 and 3 times.

A complementary concept was proposed in 2012 which states that there is a certain amount of pollution that needs to occur in order for the basic needs of humanity to be met - a **social limit**. This notion, known as doughnut economics, can be viewed in the work of Kate Raworth.[15]

These needs should be met by staying below planetary boundaries so that global Earth system processes are not impacted, and that in the case of nitrogen, enough food can be produced to feed the world. One estimate of the minimum amount of nitrogen fixation needed to feed 9 billion people put the quantity in the region of **80 million tonnes** of nitrogen per year.[16,14]

The Importance of Nitrogen

FEEDING THE WORLD

- Human-made nitrogen fertiliser has been responsible for feeding 48% of the global population.[5] Ammonia, the key input for nitrogen-based fertilisers is produced by the Haber-Bosch process, which converts hydrogen (usually from methane) and atmospheric nitrogen into ammonia.

- Half of all industrially produced nitrogen is applied to just 3 cereals (wheat 18%, maize 16%, rice 16%)[17]

- Nitrogen is relevant for the achievement of nine Sustainable Development Goals (SDGs).[c] More nitrogen is needed to achieve SDG 1 and 2 (reducing poverty and hunger), but less (or more efficient use) is needed to achieve SDGs 3, 6, and 11 to 15.[18]

b Biological nitrogen fixation is the process by which soil microorganisms fix atmospheric nitrogen (N_2) into ammonia (NH_3), nitrites (NO_2) and nitrates (NO_3)

c SDG 1: No Poverty; 2: Zero Hunger; 3: Good Health and Wellbeing; 6: Clean Water and Sanitation; 11: Sustainable Cities and Communities; 12: Responsible Consumption and Production; 13: Climate Action; 14: Life Below Water; 15: Life on Land.

INEFFICIENCY

- Nitrogen application is a major source of inefficiency in crop production - only 30 to 35% of what is applied is taken up by plants.[19]

- The nitrogen-use efficiency - the ratio of nitrogen inputs to nitrogen contained in the plant - on the world's farmland has slipped from more than 50% in 1961 to about 42% today. China has gone from more than 60% to just 25%.[20]

COSTS

- The purchase cost of nitrogen lost to the environment each year amounts to USD 200 billion.[21]

- Nitrogen losses from agricultural land to waterbodies can cause significant economic consequences due to events like algal blooms. US citizens have spent USD 1.1 billion since 2010 dealing with associated damages, and a small group of aquaculture companies lost up to USD 358 million in revenue due to algal bloom events between 2013 to 2018.[50,56]

- WWF estimates a total societal cost of GBP 10.9 billion per year for the UK, which is almost 0.5% of its GDP. Of that, GBP 7 billion (64%) is mostly attributable to agricultural use of nitrogen fertiliser.[22]

CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS

- Production of nitrogen fertiliser consumes 2% of the world's energy and produces between 1.4% and 5% of global greenhouse gas emissions.[23,24,25]

- Approximately 60% of anthropogenic nitrous oxide emissions, a greenhouse gas 310x as powerful as carbon dioxide, is released by residual fertiliser left on croplands.[26,27]

The main source of nitrogen pollution is in its use as fertiliser for crop production and its subsequent loss from farmland through leaching and erosion. See Appendix 2 for more details. This loss causes problems, such as eutrophication and algal blooms, throughout the environment and across many economic sectors. It is in the interest of financiers that farmers efficiently use nitrogen and reduce losses in order to limit wastage and avoid damages to other sectors that they may be invested in, such as aquaculture, fishing and tourism. Reducing or improving the efficiency of nitrogen use can also reduce the impacts of climate change and protect drinking water sources.

A second nitrogen limit

Optimal crop growth requires the correct type of fertiliser to be applied at the right times and in the right places. Achieving optimal crop growth is difficult, and farmers often do not have the tools required reach optimal production. Farmers tend to apply more fertiliser as a lower yield is likely to cost them more than the wasted fertiliser, especially if they do not bear the costs of any subsequent pollution.

A recent study of long-term sustainable nitrogen inputs for three cereals were in the region of 150 to 200 kg per hectare, meaning application rates above this signified a waste of resources.[28]

Figure 4: The long-term nitrogen response for global wheat, maize, and barley shows the average yield curve for wheat, maize, and barley across Europe, Asia, and North America. It shows that each kilogram of nitrogen added to the plant increases the yield, but up to a limit.[28] Excessive amounts of fertiliser can damage the soil, by causing acidification (a decrease in soil pH) and aggravating soil diseases.[29] National averages show that China applies more than 210 kg of nitrogen fertiliser per hectare on its wheat crop, while Australia and Pakistan apply 255 and 222 kg per hectare on maize cropland.[30] Global average nitrogen use efficiency for crops is between 42-44% and the maximum allowable nitrogen loss from fields to remain within planetary boundaries is 21 kg nitrogen per hectare.[20,31] This suggests that these three countries could reduce their application of nitrogen per hectare to between 118 kg and 143 kg and maintain sustainable yields.

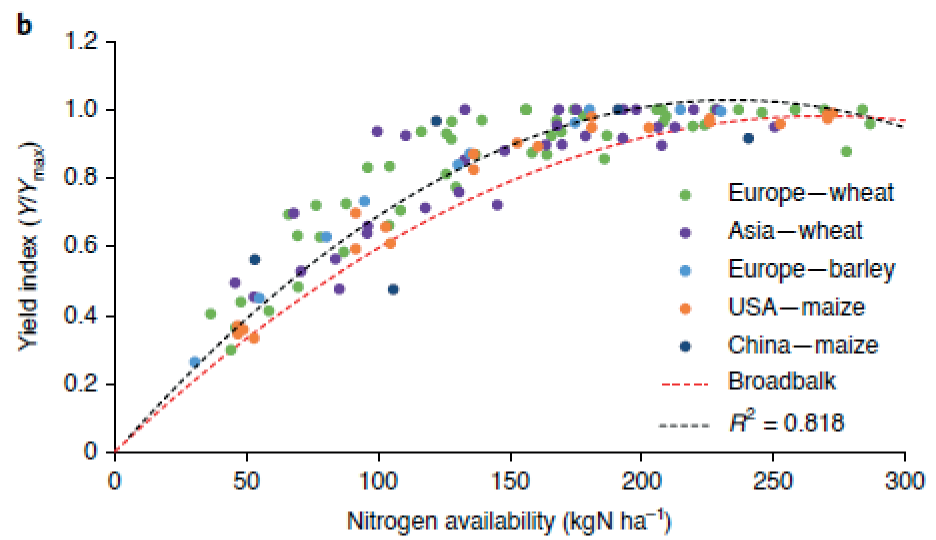

Figure 4: *The long-term nitrogen response for global wheat, maize, and barley[28]*

In order to solve this efficiency problem, investments are needed in precision farming tools, such as on farm sensors, auto-guidance systems, and decision support software, which would allow to lower fertiliser (and pesticide) inputs while maintaining or even increasing yields. Financiers have a central role to play in this.

Companies and financiers can be dependent on nitrogen in several ways

Staying within environmental limits while producing more food requires a huge increase in the efficiency of nitrogen fertiliser use. Nitrogen run-off from land can cause large economic losses to businesses dependent on waterbodies to generate an income. To increase food output, agricultural land has expanded into forested areas which, in turn, impacted ecosystem services on which farming relied, such as rainfall regulation, enhanced flood control, preventing erosion, and providing biodiversity protection.

Crop production is dependent on a small number of countries to produce key fertiliser inputs, such as Russia, which leaves crop producers exposed to unexpected shocks and volatile natural gas prices.

These topics, as well as the roles that technology and national policy can play in managing and mitigating nitrogen's impact, are discussed in more detail in the following seven case studies. **The case studies reveal that managing nitrogen limits is difficult we are faced with a delicate balancing act.**

NITROGEN FIXES

CASE STUDIES

1 CASE STUDY

EXAMINING NITROGEN LIMITS

ISSUE

Globally, we use about two times the amount of nitrogen fertiliser needed to feed the world. This is more than the environment can sustain. This causes significant economic and environmental damages. (Please see caveats in Appendix 5.)

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Investments are needed to meet the growing demand for food. Reducing input costs could make food production more profitable.
- Food companies' margins are dependent on the efficient and reliable production of these commodities.

Example: *Linking companies to planetary boundaries - Nestle's revenue is 21-30 % dependent on the use of coffee, with 28 % of it coming from Brazil. Yet the production of Brazilian coffee, worth USD 5.3 billion in 2020, uses nearly 10x as much nitrogen that planetary boundaries suggest it should.*
(Source: Planet Tracker analysis)

CASE STUDY

As outlined above, there are two types of limits to be considered when discussing nitrogen:

Environmental Limit: the *maximum* amount of nitrogen fertiliser that should be used to avoid the consequences of irreversible environmental changes – i.e. planetary boundaries.

Social Limit: the *minimum* amount of nitrogen fertiliser that should be used to provide enough food to feed the global population.

The concept of a lower limit to nitrogen fertiliser use was popularised by Kate Raworth's publication for Oxfam in 2012 which promoted the idea of *doughnut economics*. This lower limit represents a social foundation where access to a minimum amount of resources is needed, such as food, water, and energy.[16] Extending this idea to nitrogen fertiliser, there is a minimum amount that needs to be applied to global croplands to produce enough food to feed the world.

One estimate puts the nitrogen needed to feed the world at 80 mn tonnes per year, while current nitrogen input to agricultural systems is in the region of 162 mn tonnes per year. The environmental limit for nitrogen application lies somewhere between 62 and 82 mn tonnes per year. This suggests that we are using 2 times the amount of nitrogen needed to feed the world, and 2 to 3 times the amount of nitrogen the environment can sustain[14] - see Figure 5.

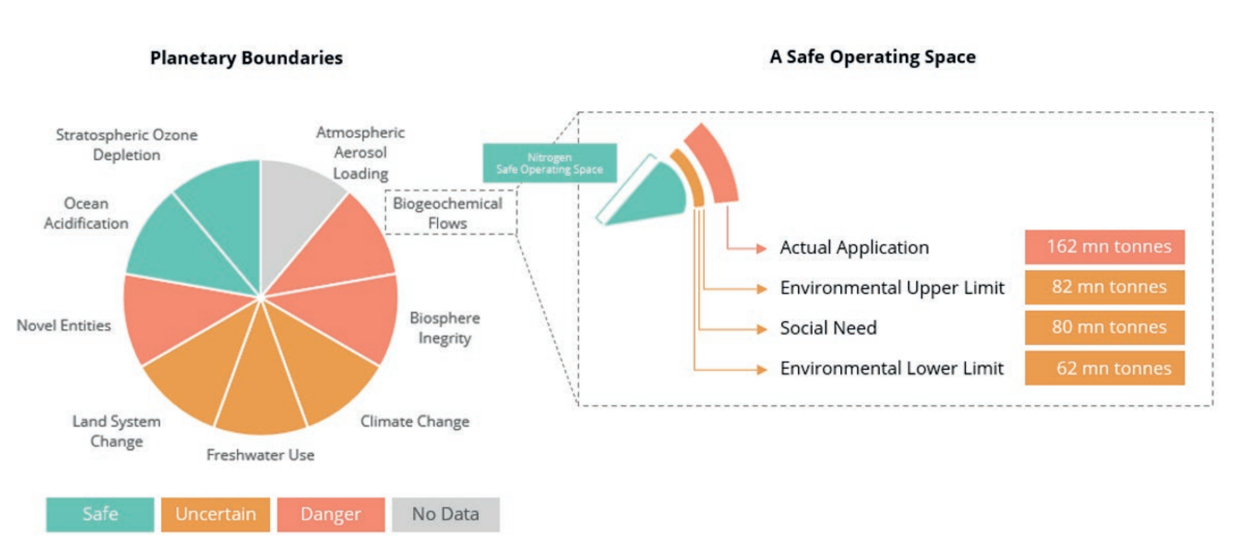

Figure 5: *Planetary boundary performance and the application of the doughnut economics concept*[16]

Planet Tracker has analysed how these limits could be applied to countries to highlight those that are using nitrogen inefficiently. The countries shown in red are those that are exceeding their share of the 82 million tonnes per year upper limit, and the countries in green are below their share the of 62 million tonnes per year lower limit.

Planet Tracker's calculations suggest that 42% of the global nitrogen planetary boundary can be apportioned to the crop production of 5 countries: China, India, Brazil, United States, and Russia. China is estimated to be applying 5x as much nitrogen for its maize production as planetary boundary limits would suggest, while also exceeding its boundaries for rice, wheat, and soybean production – see Figure 6.

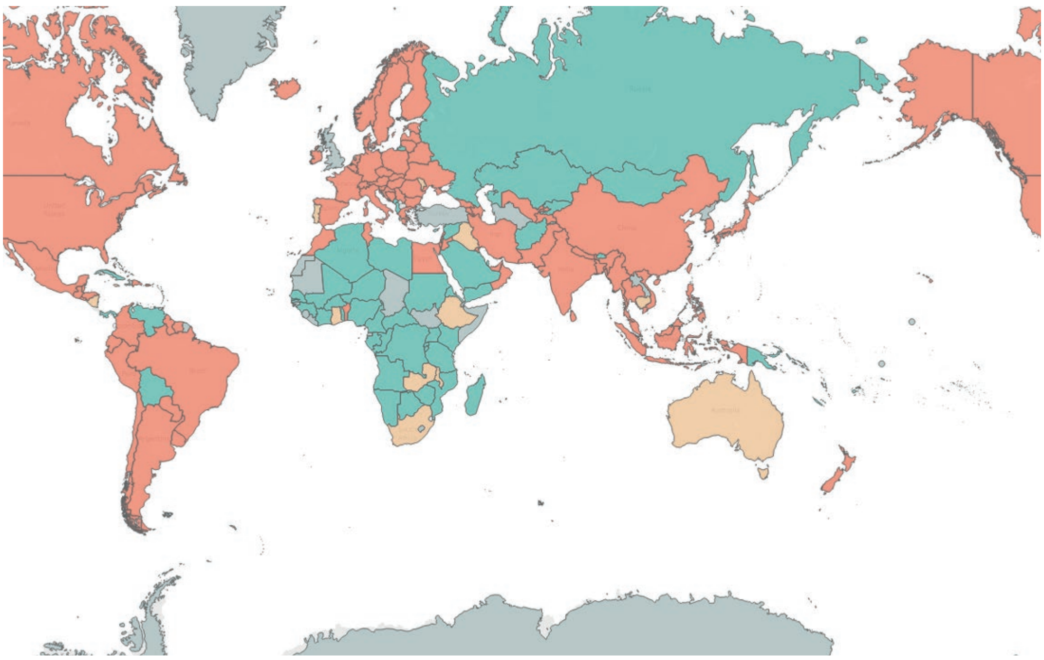

Figure 6: *Nitrogen environmental planetary boundary exceedance. KEY: RED = danger zone (exceeding upper limit); GREEN = safe zone (below lower limit); BEIGE = uncertain zone (between the two limits); GREY = not enough data. (Source: Planet Tracker)*

Staying Below Limits

However, reducing fertiliser application should be done carefully. Reducing nitrogen fertiliser use without making any improvements in how it is applied, used, or recycled within agricultural systems could lead to a 13% drop in both crop and livestock production by 2050 compared to 2010 levels. This would lead to food prices that are 26% higher over the same period. Therefore instead of a simple cap on nitrogen fertiliser use, interventions are needed to improve nitrogen use efficiency - producing more food for the same or less nitrogen input. These interventions include:

- Improve manure recycling.
- Improve sewage treatment and recycling.
- Reduce harvest loss and food waste.
- The consumption of less animal products.

A combination of these approaches (see Scenario 4, S4, in Figure 7) is projected to reduce food prices by 19% and decrease fertiliser demand by 65% by 2050 compared to 2010. They can also contribute between 50% and 80% of the non-CO_2 emission reductions from agriculture required by 2050 as part of the 1.5^{0}C Paris Agreement. The scenarios shown in Figure 7 are described in Table 1: Nitrogen reduction scenarios.

Table 1: *Nitrogen reduction scenarios*

Scenario	Scenario Name	Description
S1	BAU	Constant rates of manure recycling, constant rates of nitrogen removal, constant % of global population connected to wastewater treatment. Dietary changes follow GDP development.
S2	BAU within nitrogen planetary boundary	Same as S1 but nitrogen use reduced to be within the nitrogen planetary boundary.
S3	Within nitrogen planetary boundary & nitrogen use efficiency Improvements	Same as S2 but nitrogen use efficiencies improve in a linear fashion to 2050 to meet regional goals.
S4	Within nitrogen planetary boundary & deploying all interventions	Simultaneous implementation of improved nitrogen use efficiency, improved manure recycling, improved sewage treatment and recycling, reduced harvest loss and food waste, and a dietary shift to consume less animal products while staying within the nitrogen planetary boundary.

The figure below shows how food availability, commodity prices, and nitrogen flows change from 2010 to 2050 after implementing the four scenarios mentioned above.[32]

***Figure 7:** Global food availability, agricultural commodity price, nitrogen demand, and surplus under four nitrogen management scenarios*[32]

All scenarios shown in Figure 7: Global food availability, agricultural commodity price, nitrogen demand, and surplus result in enough food being produced to feed the world, taking into account projected population growth.

- The **business-as-usual scenario (S1)** reduces food prices by 4% compared to 2010 levels but nitrogen fertiliser demand and nitrogen surplus is far beyond planetary boundaries.
- **S2** shows an improvement in nitrogen demand and surplus, but results in food prices that are 26% higher than in 2010.
- **S3** shows the single best intervention for reducing fertiliser demand and nitrogen surplus, and results in a modest 2% increase in food prices.
- However, **S4** shows steeper decreases nitrogen fertiliser use and nitrogen surplus than all scenarios while also reducing food prices by 19%. Lowering fertiliser demand has the added benefit of decreasing agriculture's reliance on natural gas, and exposure to fluctuations in its price as it is a key input in making nitrogen fertiliser.

See Case Study 5: Fossil Fuel Dependence of Fertilisers for more information.

Are we at Peak Fertiliser Production?

As explained above, the world has presently breached the nitrogen planetary boundary. Furthermore, current global production of nitrogen fertiliser appears sufficient to meet future nitrogen fertiliser demand, even when accounting for a growing population. We don't need more nitrogen fertiliser; we just need to use it more efficiently. This raises the question is the world at peak nitrogen fertiliser production?

Annual nitrogen fertiliser consumption in the European Union is expected to drop by 6% by 2030, compared to 2020.[33] The International Fertilizer Association (IFA), which promotes the use of fertiliser, argues that climate change could affect fertiliser demand through droughts and floods, taking agricultural land out of production. It also argues that improvements in nitrogen use efficiency will continue in the future, which will affect demand. The IFA estimates that the annual growth in fertiliser use will drop from 4% in 2023 to 1.2% in 2027.[34]
However climate change could increase the demand for fertiliser as increased flooding and extreme weather events may wash away soil nutrients that need to be replaced. This effect may be seen greatest on farms with less or intermittent crop cover, where soil is exposed to the elements, and where the soil structure has been weakened due to poor management practices.

Nitrogen fertiliser market analyses often show a projected increase in the demand for fertiliser, mainly to meet growing demand in developing countries particularly in Latin America and South Asia. Some projections estimate that the global market will increase at a compound annual growth rate of 5-6% between now and 2030.[35] To support this, the IFA forecasts nitrogen fertiliser production capacity will grow from 191 to 202 mn tonnes between 2022 and 2027. We argue that from a planetary boundary perspective, increases in production capacity could result in stranded assets.

Companies' Dependence on Nitrogen

Companies have begun to disclose how their revenue is dependent on certain commodities through the CDP's Forest Questionnaire.[d] This highlights to financiers a company's link to the environment and provides a starting point to investigate how a company may be impacted by changing environmental conditions and inputs needed to produce these commodities. Nitrogen is one of the key inputs used to produce most agricultural products.

Table 2: Nestlé revenue dependence on commodities.37 shows Nestlé's revenue dependence on three key commodities - cocoa, coffee and palm oil. Using FAO and IFA fertiliser application data, Planet Tracker analysed three-year annual average nitrogen fertiliser use in relation to the planetary boundary for that crop-country combination.

Table 2: *Nestlé revenue dependence on commodities.*[36]

Commodity	Revenue Dependence (%)	Production / Consumption ('000 tonnes)	Sourcing Country		
			1st	2nd	3rd
Cocoa	6-10%	391	Côte d'Ivoire (55%)	Ghana (12%)	-
Coffee	21-30%	981	Viet Nam (30%)	Brazil (28%)	Mexico (7%)
Palm Oil	61-70%	423	Indonesia (19%)	-	-

d See CDP Guidance for Companies here

Coffee production in Brazil used over 300,000 tonnes of nitrogen fertiliser in the three-year period to 2018, the latest year data is available for. The planetary boundary for coffee production in Brazil is being exceeded by between 10x to 13x. Without more information from Nestlé on the farming practices and performance of their suppliers, a significant improvement in nitrogen use is needed to improve the sustainability of its coffee production - a crop linked to 30% of its revenue. Even ignoring the need for sustainability improvements, coffee production in Nestlé's supply chain is exposed to changes in fertiliser supply and prices.

Regenerative agriculture practices can help to reduce the reliance external inputs and build more resilient production systems. For more details see Planet Tracker's 'Financial Markets Roadmap for Transforming the Global Food System', priority 5.[37] Nestlé has a target to source 50% of its key ingredients from regenerative agriculture methods by 2050, which amongst other things, means using less chemicals and more organic fertiliser in production processes.[38] As of 2022 this figure was at 6.8%, or just over 1 million tonnes of ingredients. Nestlé has committed to invest CHF 1.2 billion by 2025 to achieve 20% of its sourcing through regenerative agriculture practices.

General Mills launched a target in 2019 to "advance regenerative agriculture" on 1 million acres (405,000 hectares) by 2030, which involves using fewer chemical inputs and keeping the soil covered year-round. Perhaps these examples provide inspiration for other companies to do the same, or even co-invest in solutions. It also provides a model for financiers to follow with the companies in its portfolio.[39,40]

A warning for how a poorly managed transition away from fertiliser inputs could play out has been seen in Sri Lanka. Sri Lanka reversed a ban on fertiliser imports six months after its implementation and then couldn't afford to restock its fertiliser supplies due to dramatic price increases. As a result, farmers have been attempting to decrease their dependence on nitrogen fertiliser by looking to cheaper, more readily available alternatives, such as organic compost. We can learn from this: farmers should be incentivised by companies further down the supply chain to gradually increase their use of organic sources of nitrogen, such as manure and compost. This would lower their environmental impacts as well as shield them from inorganic fertiliser price increases.[41]

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet**, that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

1. How dependent are the company's suppliers on the use of nitrogen fertiliser to produce key commodities?
2. What actions is the company taking to reduce the over application of nitrogen fertiliser, and reduce the dependence of its suppliers on nitrogen fertiliser?
3. Is nitrogen fertiliser being used within environmental limits in the production of key commodities that the company purchases?
4. How are the prices that the company pays for key commodities linked to the use of nitrogen fertiliser?

FURTHER READING

See Planet Tracker's **nitrogen planetary boundary** blog
See Planet Tracker's analysis of **Nestlé's climate transition plan** here

ISSUE

Nitrogen applied to agricultural soils can run-off the land and contribute to eutrophication in water bodies. This can create large dead zones where marine life used to thrive, impacting aquaculture, fishing, and tourism industries.

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Reputational risk from being directly linked to polluting activities.

- Financial losses by companies, such as those involved in seafood production, due to their direct exposure to changing environmental factors.

Example: *Company losses due to changing environmental conditions*
- *Planet Tracker estimates that Mowi, a global seafood company listed on the Oslo stock exchange, could have lost up to EUR 159 million in 2016 due to an algal bloom that killed 3.7 million salmon. Other seafood companies such as Camanchaca and Grieg Seafood both recorded losses of tens of millions of euros due to algal blooms.*

CASE STUDY

Nutrient run-off from agricultural fields can cause environmental and economic consequences. The loss of nutrients from these fields due to poor application of synthetic fertiliser represents:

- Wasted expenditure.
- Wasted resources which could be spent maximising yields in other ways.
- Excess greenhouse gas emissions from nitrous oxide emissions in the field.
- Loss of revenue in seafood and tourism industries from nutrient pollution and algal blooms.[42]

Nitrogen can be lost from the soil during heavy rains as it is washed away or can be lost due to wind erosion when soils are tilled. Nitrogen can accumulate in rivers and is eventually transported to the sea. The EU standards set a limit of 2.5 mg N/litre in rivers, but as Figure 9: Coastal sites where anthropogenic nutrients, such as nitrogen from fertilisers, have exacerbated or 8 shows, some rivers in Europe are above those values.[43] When there is an oversupply of nitrogen in waterbodies it can cause eutrophication – an excessive richness of nutrients and minerals in a waterbody. This causes algae to grow rapidly and then die off which can release toxins that are harmful to human and aquatic health. When the algae die it consumes oxygen in the water as it decomposes which can cause high fish mortality and can create dead zones, also known as hypoxic areas.[44]

Figure 8: *Nitrogen loading (mg N/litre) in rivers in Northern Europe (Source: calculated by Planet Tracker using GEMStat data, 2000-2022. River size based on average long-term discharge, estimated by HydroSheds).*[45,46]

Figure 9: Coastal sites where anthropogenic nutrients, such as nitrogen from fertilisers, have exacerbated or shows a map of dead zones and of oxygen concentration in the world's oceans. (In)famous dead zones known globally include Chesapeake Bay (Virginia, U.S), Gulf of Mexico, and the Baltic Sea, home to seven of the world's ten largest marine dead zones. Nitrogen run-off can also poison underground water reserves, as evident in California.[19]

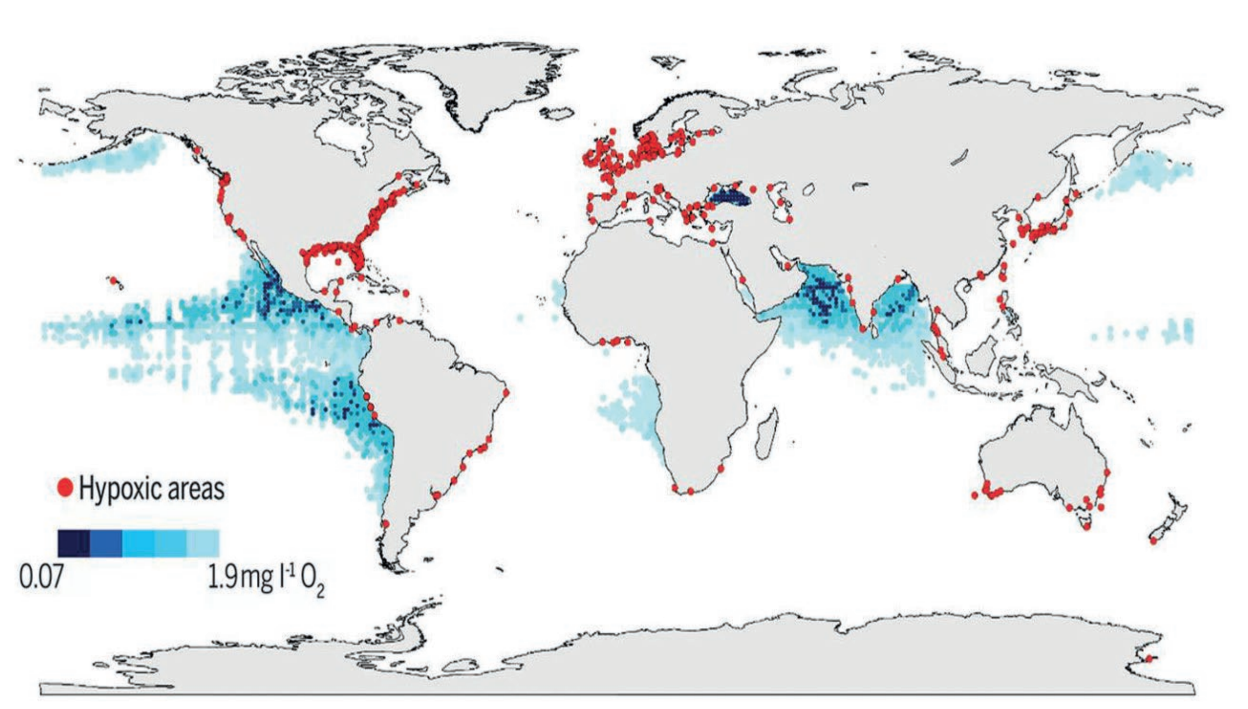

Figure 9: *Coastal sites where anthropogenic nutrients, such as nitrogen from fertilisers, have exacerbated or caused low oxygen levels in the water, leading to dead zones/hypoxic areas (shown by the red dots).*[48]

There are critical limits for nitrogen concentration in water to help prevent these impacts. These limits vary around the globe according to different regulatory and health authorities in charge of protecting waterbodies. In surface water these limits lie between 1.0 and 2.5 mg nitrogen per litre and can reach up to 50 mg nitrate (NO_3) per litre in groundwater.

The Financial Costs of Algal Blooms

Environmental Working Group, a U.S. based NGO, found that communities across the United States have spent more than USD 1.1 billion since 2010 dealing with the damages caused by algal blooms in lakes, rivers, bays, and drinking water. This covered more than 85 locations and 22 states.[45] Another study estimated that dead zones in the Gulf of Mexico cost U.S. seafood and tourism industries USD 82 mn per year. In some years, this can be much worse. Between 2017 and 2019, an agal bloom event in west Florida caused an estimated direct loss to the tourism industry of USD 184 million, with wider economic impacts over USD 670 million.[47]

In 2021, algal blooms in China's Yellow Sea covered an area of 1,746 km^2, over two-times larger than the previous record set in 2013. The city of Qingdao deployed over 12,600 boats to clean up the algae, collecting over 457,000 tonnes. The cause is thought to be seaweed aquaculture businesses in the neighbouring Jiangsu province.[52] These algal blooms can last three to four months, and in 2008 it cost China USD 100 mn to clean-up the algae in the run-up to that summer's Olympics.[53]

In Planet Tracker's report, 'Avoiding Aquafailure' we highlighted the dangers of algal blooms and showed that regenerative aquaculture (the farming of some seaweed and bivalve species, which are nature positive) can mitigate them.[54] Furthermore, another of our reports found that eight of the ten largest global salmon aquaculture companies lost over 51,000 tonnes of salmon due to algal bloom events between 2013 and 2018. This equated to losses of up to USD 0.4 billion from forgone revenue.[e] Grieg Seafood reported losses in each of these years due to algal blooms, totalling over 6,750 tonnes of salmon.[55]

e Annual average salmon prices from Fish Pool were used to estimate monetary losses. Also note that salmon lost to these events can be turned into alternative produce, such as fish meal and fish oil, so all the potential revenue from these salmon may not be lost by these companies. This information was not available to calculate the net loss.

Other significant algal bloom events include:

- In 2014, Norway Royal Salmon reported extraordinary mortality due to poisonous algae and disease which resulted in the loss of 575 tonnes of salmon, or USD 3.3 million.
- In 2016, Mowi's Chilean division was hit by algal blooms in February and March which they estimated killed 3.7 million salmon, or 25,500 tonnes of salmon, with an estimated value of USD 176 million.
- In 2018, Bakkafrost experienced an algal bloom event at in the Faroe Islands which killed around 630,000 salmon, or 243 tonnes of salmon, with an estimated value of USD 1.6 million.
- In 2022, Blumar reported mass mortalities in southern Chile associated with an algal bloom event, causing estimated losses of USD 3 million.

Algal bloom events not only cause fish mortality, but also reduced growth in the fish that survive as gills are damaged and sub-optimal environmental conditions affect the fish. Poor environmental conditions can mean that the salmon are also more vulnerable to other threats, such as sea lice and diseases. The same study found that losses due to sea lice and diseases over the same period topped USD 0.8 billion, a loss of over 138,000 tonnes of salmon.

The marine impacts of nitrogen should be rising up the agenda of financial institutions. A recent article from Bloomberg New Energy Finance reported that 16% of marine areas in their study are at high or the highest risk of eutrophication from excess nutrients. An important point for financiers is that 188 governments have adopted the Global Biodiversity Framework[f] which, among other things, sets out that nutrient loss should be reduced by at least 50% by 2030 - see Target 7.[56] Governments and companies should soon take action.

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet,** that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

1. How often has the company has been impacted by events related to nitrogen, such as algal blooms?
2. Has the company experienced any financial and physical losses due to nitrogen pollution, and what are the reasons for them?
3. How is the company going to reduce its exposure to nitrogen pollution events?
4. Does the company or its key suppliers have targets to limit the impact of nitrogen pollution on the business?

FURTHER READING

See Planet Tracker's **Loch-ed Profits** report
See Planet Tracker's **Avoiding Aquafailure** report and dashboard
See Planet Tracker's **Financial Markets Roadmap for Transforming the Global Food System** report

f Adopted in at the fifteenth meeting of the United Nations Conference of the Parties (COP15), the Global Biodiversity Framework contains 23 targets for 2030, and 4 goals for 2050 to protect biodiversity and reverse its loss.

ISSUE

Inefficient fertiliser use causes suboptimal land use. Addressing nitrogen inefficiencies could free up land for afforestation, thus providing a nature-based solution for climate change and the land-system change planetary boundary. (Please see caveats discussed in Appendix 5.)

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Inefficiencies in fertiliser use causes suboptimal crop yields, which are costly for companies
- Better nitrogen management can create potential for afforestation, thus helping to meet net zero and nature positive targets.[57]

Example: *Forestry companies that could be key partners in afforestation efforts.*
Companies with large forestry holdings, like Stora Enso (2 mn ha), Klabin (625,000 ha), and Oji Holdings (573,000 ha), have the experience and expertise to help reforest large swathes of land. The largest investors in these companies, should consider encouraging them to work together with agriculture producers and to practice sustainable forest management.

CASE STUDY

A Balancing Act: Restoring Forests and Feeding the World

The world has lost 39% of its forest cover since 1700.[g] High income countries, for example most of Western Europe, had already deforested most of their land before the 20th century. Low-income countries typically started large scale deforestation more recently[58] - see Table 3. Global deforestation reached its peak in the 1980s, when the world lost 150 mn hectares – an area half the size of India – during that decade. Since then, deforestation rates have steadily declined, to 47 million in the last decade.[59] But most countries have failed to bring deforestation to zero, and in some countries, rates are increasing. Around 73% of recent global deforestation is driven by agricultural expansion (compared to 96% between 1840 and 1990), and pasture expansion for beef production is by far the largest driver, followed by oilseeds and cereals.[60,61,62] Deforestation and agriculture are closely linked: Planet Tracker highlighted in ‘No Rain on the Plain’ how deforestation can threaten food supply, by changing rainfall patterns and affecting harvests.

g 1700 is considered as the benchmark century in the Planetary Boundary methodology, as explained below.

Table 3: Percentage of forest remaining compared to 1700 baseline, and minimum reforestation required to meet land-system change planetary boundary. For 10 selected countries.Note: the model used applies different reforestation rates depending on the forest type (Source: Planet Tracker).

Country	Forest remaining (% of 1700 baseline)	Reforestation required to meet Planetary Boundary (m ha)
United Kingdom	38%	1.6
India	45%	57.6
Pakistan	47%	0.3
Germany	48%	0.6
Netherlands	21%	0.5
China	57%	-
United States of America	59%	-
Brazil	62%	171.5
Congo	67%	5.9
Italy	94%	-

In this case study we examine whether increasing efficiency in nitrogen fertiliser use could reduce the amount of land needed to grow crops. The land freed up in the process would become available for afforestation projects, thus contributing positively to another planetary boundary: that of land-system change. The land system change planetary boundary, which the world has already breached, applies to the conversion of land from its natural state for human purposes, for example the deforestation of land for growing crops.[9] Afforestation, if done right, can help us realign to the planetary boundary. Companies with large forestry holdings could be key partners in such efforts by increasing sustainable forestry management activities. This can include Stora Enso, a Finnish pulp and paper producer with 2 mn ha of land under management, Klabin, a Brazilian paper company that manages 625,000 ha, or Oji Holdings a Japanese paper company managing 573,000 ha. However, financial institutions should be aware that covering large swathes of land with plantations of a single tree species is often not sustainable and should be avoided, as this does not contribute positively to biodiversity and land-system change.[63,64,65]

Increase Yields and Convert Inefficient Cropland to Forest

A recently published paper shows that global wheat production could double if countries managed to close their yield gap.[67] The yield gap is the difference between the achievable crop yield (yield potential) and the actual yield obtained, in tonnes per hectare. The Global Yield Gap Atlas shows that Brazil is 39% below the yield potential for sugarcane, and India is 80% below the yield potential for wheat. This means they could grow the same amount of crop in half the land or less if the achievable crop yield were to be attained.

India and Pakistan are inefficient at turning nitrogen inputs into outputs, measured in terms of the amount of nitrogen fertiliser required to produce one tonne. They rank as the 61st and 68th out of 73 wheat producing countries ranked by Planet Tracker. Somewhat surprisingly, India and Pakistan are also the 2nd and 7th largest producers of wheat globally, harvesting over 31 million ha and nearly 9 million ha in 2020 respectively. India needs to reforest over 57 mn ha to get back to within its forest planetary boundary, whereas Pakistan requires a minimum of 305,000 ha. If yield gaps were to be closed, some of the land savings could be considered for reforestation.

Increase Yields and Convert Largest Nutrient Removers to Forest

Nutrient inputs are costly, and if crops are going to require large amounts of synthetic fertiliser or will take large quantities of nutrients from soil reserves, the option of converting some of this cropland to forest should be evaluated. Planet Tracker estimates the top five crops removing the largest combined amount of nitrogen, phosphates, and potash (NPK) from soils are, in order:[67] sugarcane, maize, rice, soybeans, and wheat.

Planet Tracker estimates that global sugarcane production is the 5th largest nitrogen remover of all crops, 2nd for phosphate, and 1st for potash. Brazil exceeds its forest planetary boundary, with only 62% of its original forest cover remaining, and requires over 171 million ha. of land to be reforested to get back within its planetary boundary. In Brazil, sugarcane is grown at 39% below the yield potential, on over 10 million ha. of land.

Despite this, the value of Brazilian farmland used to grow sugarcane has increased 94% over the last three years, from USD 1,915 to USD 3,710 per acre. In comparison, the value of planted Brazilian forests over that time has only increased 54%, from USD 938 to USD 1,442 per acre. A shift from sugarcane production to planted forests would therefore imply a loss of over 60% of the value of the farmland. This stresses the need for diverse and new income streams from planted forests that would increase its value and incentivise the transition.[68]

Reducing some sugarcane production makes sense, as sugar consumption in much of the world needs to decrease if we are to shift to healthier diets, such as the one proposed by The EAT-Lancet Commission global planetary health diet.[69] Funding for such reforestation efforts could be found through a deforestation-linked sovereign bond, as previously proposed by Planet Tracker, in their Deforestation-Linked Sovereign Bond report.

h The estimates are calculated by applying nutrient removal factors per kilogramme of crop to the total production of that crop. Nutrient removal factors were sourced from the IPNI Nutrient Removal Calculator.

Could Pastureland be Converted to Forest?

A reduction in pasture-fed livestock production could also create potential for afforestation. If this were accompanied by a dietary shift away from animal protein towards a plant protein, it would also free up land that currently grows feed crops. Large nitrogen losses are attributed to livestock systems, as much as 75% of the total nitrogen is lost from manure, grassland, and from the cropland used to produce the feed for livestock.[31]

Figure 10: Feed conversion ratios for beef, pork, chicken, and crop production71,72,73 shows feed conversion ratios for three animals - cattle, pigs, and chickens - and shows how crops can be used to feed animals or be used to directly feed humans. This increased efficiency, of directly eating crops rather than feeding them to livestock, would allow for an increased amount of food to be grown on a smaller amount of land, further freeing up land for afforestation.

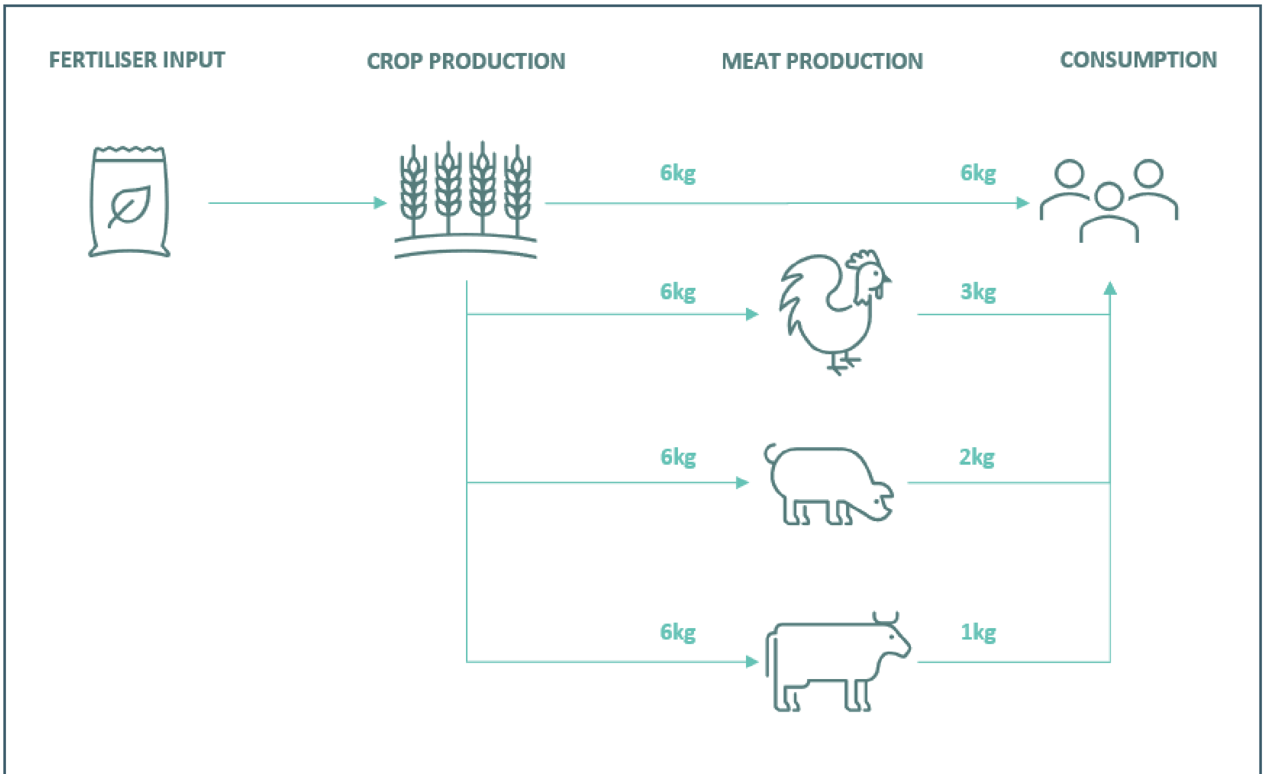

Figure 10: *Feed conversion ratios for beef, pork, chicken, and crop production*[70,71,72]

The countries with the greatest area of permanent meadows and pastures that can be used for livestock are China, Australia, the U.S., Kazakhstan, Brazil. We acknowledge that some pastureland might not be suitable for converting to forests, so in our example we take a conservative estimate for the U.S., where 265 million hectares are used for pasture and range land and 51 million hectares of cropland are used to produce animal feed.[73] If meat production and thus demand for animal feed was reduced by 30%, the U.S. could selectively free up 95 mn hectares of cropland and /or pastureland for reforestation. This equates to more than 30% of U.S. forest cover in 2020.

Can countries reforest land without impacting food production?

Inefficient uses of nitrogen related to suboptimal crop yields and to consumption of animal proteins cause inefficiencies in land use. If these inefficiencies were to be addressed, at least in part, there could be options for selective afforestation.

The need for action is further reinforced as an EU Regulation on deforestation-free imports was formally adopted by the EU Council on 16 May 2023, but applies retroactively from 31 December 2020. Companies have 18 months to comply.[74,75]

What is needed are afforestation opportunities that can generate environmental and financial benefits. Forests can be planted in conjunction with revenue generating flora, sometimes called non-timber forest products, which include tree resins, bamboo, fruits, seeds, honey, and ornamental plants to name just a few.[76] These types of agroforestry are also a viable solution for producing crops while maintaining some level of forest cover.[77] To help get these activities started, the US Department of Agriculture, as part of the Inflation Reduction Act, has started to distribute funds to incentivise these climate smart agriculture practices, including agroforestry and forest management practices.[78]

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet**, that financiers could ask companies when undertaking due diligence or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

1. What is the actual and potential yield of key commodities being purchased by the company?
2. Has cropland, which is used to produce goods for the company, been planted on land deforested within the last 5 years?
3. Is reforestation of land part of the company's net zero or nature positive plans?

FURTHER READING

See Planet Tracker's **No Rain on the Plain** report
See Planet Tracker's **Deforestation-Linked Sovereign Bond** report
See Planet Tracker's **Nature Dependent Trade** dashboard

4 CASE STUDY
TECHNOLOGICAL BETS

ISSUE

Technologies have been used repeatedly throughout history to help solve humanity's environmental problems, but this has also led to many unintended consequences. Should we bet that these technologies will solve the planet's nitrogen pollution crisis, or invest in natural solutions?

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Do technological solutions come with too many unquantifiable and unintended environmental risks?
- Do natural solutions to environmental problems offer a greater risk-return profile? Can they adapt to changing conditions and provide longer term benefits?

Example: *Incorporating natural and man-made solutions to solve environmental issues*

- *New methods of fertiliser production are emerging. CCm Technologies, a UK company, is capturing carbon from industrial power generators to produce fertiliser.*
- *Bioreactors are being deployed on farmers' fields which convert nitrates in water into nitrogen gas, thus preventing run-off into waterways.*
- *Kelp forests can be grown in highly polluted water bodies to reduce pollution and provide habitats that increase seafood production.*
- *Research on developing genetically modified crops with higher nitrogen use efficiency has had mixed successes.*
- *Alternative proteins, vertical farming, and machines for the precision application of fertiliser and pesticides are further examples of recent ag-tech developments.*

CASE STUDY

Man-made technologies (simply referred to as technologies from hereon) attempt to work within well-defined operating boundary. Technologies need these well-defined boundaries so that they can account for a finite number of variables. This makes them easier to maintain, optimise, and invest in. McKinsey & Company recently published a nature cost curve, one aspect of which was showing the unit cost to reduce freshwater consumption. Many of the costliest technologies, such as desalination and water-efficient power plants, may be more familiar to financiers than the technologies with lower or negative unit costs, such as regenerative agriculture or food loss reduction techniques.[8]

Natural solutions have the disadvantage of being … natural, therefore susceptible to a much larger number of inputs and influences which could affect the quality of what is being produced - see Case Study 2. However, natural systems are able to evolve and adapt to changing environmental conditions, making the system resilient to change.

We have seen something similar emerge from within modern technology companies - artificial intelligence. The attraction for financiers is that there is a supply of new technologies and companies being created to address the shortcomings of older ones. Should investors continue to believe in the ability of technology to realign our society with planetary boundaries, or should they, at least partially, turn towards natural solutions when seeking returns?

Figure 11: Example of the tech bet cycle (Source: Planet Tracker) shows how this cycle of betting on man-made technological solutions to solve environmental problems, at least in part caused by previous man-made technological interventions, has worked in an agricultural context.

	BAU →	New State (1) →	New State (2) →	New State (3) → ?
Description	Global agricultural production without any synthetic inputs	Increased yields through over-application of synthetic fertiliser	Continued over-application of fertiliser and use of lime	Use of GMO-crop-specific pesticide to limit crop losses due to insects
Problem	Agricultural production limited by soil fertility	Increase in soil pH leading to soil acidification	Loss of soil structure leading to less resilient crops	Insects develop resistance to pesticides and/or new invasive species attack the crop
Solution	Development of synthetic fertiliser through the Haber-Bosch process	Application of lime to agricultural soils to reduce pH	Development of genetically modified crop varieties	Continued development of GMO crop varieties and pesticides

***Figure 11:** Example of the tech bet cycle (Source: Planet Tracker)*

Investment is needed to reduce the impact of nitrogen pollution while enhancing the ability of the land to produce food.

A cost-benefit analysis of reducing nitrogen pollution in Chinese agriculture assessed four nature-based interventions; (i) improved management practices, (ii) enhanced-efficiency fertiliser, (iii) machine application, and (iv) manure management. It found that the largest benefits from these interventions came from increasing crop sales (USD 15.7 billion pa), the sale of new organic fertiliser produced on farms (USD 5.1 billion pa), and then reduced expenditure on fertiliser (USD 1.6 billion pa). The resulting cost-benefit ratio was 1.29.[79]
Figure 12: Example of the potential natural tech bet cycle (Source: Planet Tracker) shows how natural solutions could be used to solve nitrogen-related environmental problems and replace a reliance on technology. This can include the following methods to remove nitrogen from water, reduce nitrogen lost from fields, or reduce the amount of fertiliser used for food production:

1. Use of regenerative agriculture practices
2. Creation of oyster beds or kelp forests[80]
3. Use of bioreactors to remove nitrates from water running-off the field[81]
4. Replacing meat consumption with plant-based alternatives

It could be extended to include a mix of natural and man-made solutions, for instance, by introducing the use of field-level robotics to precisely deliver fertiliser and other chemicals to plants, which could enhance productivity and reduce environmental impacts. Some fertiliser companies are investing in ways that could produce fertiliser from water utility sewage, dramatically reducing its carbon footprint.In the UK, CCm Technologies thinks that up to 500,000 tonnes, or one-third of UK fertiliser use, could be supplied by converting sewage into fibrous fertiliser pellets.[82]

Natural solutions, depending on the local context, could involve increasing the use of cover crops on the field, intercropping, agroforestry and increasing flora around the edges of farms. The benefits of these interventions include the reduction in soil and nutrient loss, an increase in soil water retention, and increased yields. This means that when there are periods of heavy rain the soil is more able to absorb and hold that water, meaning that there is less surface run-off, less soil loss, and more water available to plants for a longer period.

	BAU	New State (1)	New State (2)	New State (3)
Description	Increased yields through over-application of synthetic fertiliser	Reduction in nitrogen pollution while maintaining yields	Crop yield maintained but production still dependent on synthetic nitrogen inputs	Crops more resilient to extremes in weather so steady yield is produced
Problem	Increase in soil pH leading to soil acidification	Residual amounts of nitrogen pollution in marine water bodies	High cost of synthetic fertiliser and high carbon emissions from Haber-Bosch process	Demand for crop produce increasing with growing global population
Solution	Improved crop management, such as crop rotation, to reduce fertiliser need	Creation of oyster beds to reduce nitrogen pollution and provide alternative income	Use of manure as a natural source of fertiliser which improves soil structure	Diverting crops from feeding livestock to feeding humans

Figure 12: *Example of the potential natural tech bet cycle (Source: Planet Tracker)*

If investors prefer to stick to technological solutions, then researchers at Princeton University may have found a way to produce hydrogen atoms, a key input to the production of synthetic nitrogen fertiliser, without generating a carbon by-product, therefore providing a way for producers and users to break away from its dependence on fossil fuels.[24] This is what Yara's CEO says is an important approach to support a transition to producing greener fertiliser.[83]

Genetically Modified Seeds

Investors may also consider the deployment of genetically modified (GM) seeds as part of this tech bet cycle. The problem that faces agricultural companies now is that climate change is causing greater extremes of weather to be experienced around the globe. This requires agricultural systems that are able to produce food with more unreliable rainfall, meaning they are more resilient to short periods of heavy rain and longer periods of no rainfall.

GM seeds have the advantage of being designed to have specific traits, such as the need for less water and for tolerating longer periods without receiving rainfall. Brazil recently approved a gene edited drought tolerant variety of soybean developed by an Argentinian company, GDM.[84] Brazil though has long used GM soybean, planting 34.9 million ha and harvesting 34.8 mn ha in 2018.[85,86]

Scientists have also sought to use gene editing to improve the nitrogen use efficiency of crops, with mixed successes. The aim is to make plants absorb nitrogen more easily, which would allow for less fertiliser application, and therefore less fertiliser waste. Hopeful articles have been appearing in the scientific literature since at least the early 2000s,[87] although a recent meta-review of the topic concluded that the results are mixed and that more research is required to understand how this could be achieved.[88]

However, concerns are that betting on GM seeds puts too great an emphasis on a smaller genetic pool, and that a diverse gene pool of seeds is needed to build a healthy and resilient food system. For more information on how to assess seed companies, see the Access to Seeds Index, which scores companies on how well they provide seed services to smallholder farmers in Africa, Asia, South and Central America.

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet**, that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

1. What is the company's plan for reducing its nitrogen pollution in its operations and supply chain?
2. Has the company investigated the deployment of both man-made and natural solutions to solve its nitrogen pollution footprint?

FURTHER READING

See Planet Tracker's **Avoiding Aquafailure** report and dashboard

5 CASE STUDY
FOSSIL FUEL DEPENDENCE OF FERTILISERS

ISSUE

Nitrogen fertilisers are dependent on natural gas for their manufacture. A heavy reliance on fertilisers leaves agricultural producers vulnerable to changing natural gas prices as well as playing a part of the global carbon emissions problem.

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Potential drop in demand for fertiliser products if nitrogen is used more efficiently by farmers or is regulated more tightly.
- High dependence and exposure to natural gas supplies and prices.

Example: *Key nitrogen fertiliser producers*

- *Key nitrogen fertiliser producing companies include CF Industries, EuroChem and Yara International. Each produces 8.9, 8.9, and 6.5 mn tonnes of nitrogen fertiliser annually. The cost of these company's products is highly dependent on natural gas which can cause sharp spikes in the cost of fertiliser, and therefore food. Is revenue from these companies at risk as producers look to decrease their exposure to volatile input prices and increase their nitrogen use efficiency?*

CASE STUDY

The dependence of nitrogen production on natural gas can leave agricultural producers, and therefore consumers, directly exposed to price shocks. It's estimated that natural gas costs account for 70% to 80% of the total cost of fertiliser production, and a recent study estimated that energy price shocks can impact food prices nearly 30x more than the recent export restrictions from Russia and Ukraine.[90,91]

The production of nitrogen fertiliser using the Haber-Bosch process, while efficient in the early 1900s, produces more than two tonnes of carbon for every tonne of fertiliser. Research is underway for a less carbon-intensive way to produce hydrogen, one of the key elements in synthetic nitrogen fertiliser production.[21] See for example Yara Clean Ammonia.[92] However the carbon emissions from the production of fertiliser only account for one-third of its emissions, with the remaining two-thirds occurring in the crops and fields after application.[82]

One way to transition away from the Haber-Bosch process, according to Yara's CEO Svein Tore Holsether, is to produce green hydrogen and create the same tax incentives in the EU that the United States has introduced with its Inflation Reduction Act. Along with this is a need for greater investment in renewable energy infrastructure which can aid the production of green hydrogen for the fertiliser industry.[83]

Nitrogen Fertiliser and Natural Gas Prices

Natural gas is a key input into the production of nitrogen fertiliser, and the prices of the two tend to correlate. Natural gas accounts for about 80% of the variable costs of nitrogen fertiliser production, and in October 2021 natural gas price rises led to temporary halts in European fertiliser production by Yara, BASF, CF Industries and Fertiberia. Common types of nitrogen fertiliser include urea, which was responsible for 41%, or 64 mn tonnes, of all agricultural fertiliser use in 2020.[i 93,94,95] shows how futures contracts for urea - the most common type of nitrogen fertiliser - and natural gas have changed over the last five years.

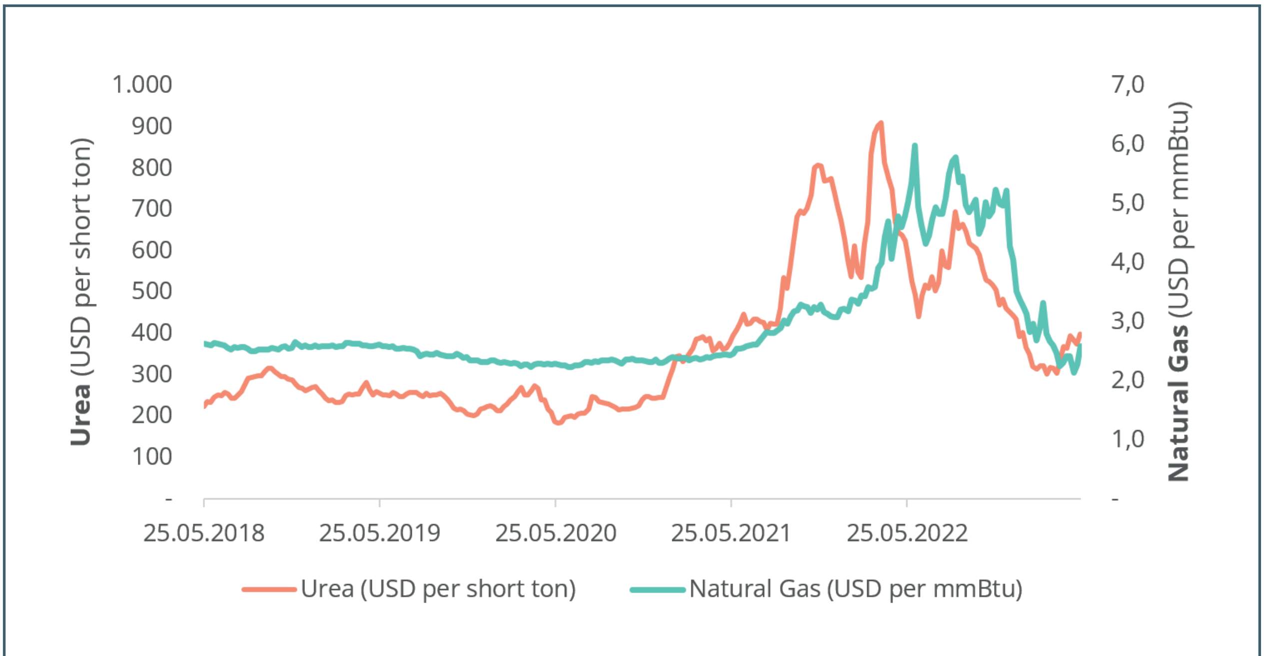

***Figure 13:** Weekly urea and natural gas closing prices from May 2018 to May 2023 (Source: Bloomberg)*

Figure 14 shows the yearly import/export price of urea which increased from USD 400 per tonne to USD 550 per tonne between 1995 to 2021 at 2022 prices also shows that the price spikes of urea in 2008 and 2021 partly align with the prices spikes of natural gas, following the global financial crisis and COVID-19. However, we note that the 2013 spike in natural gas price did not translate into increased price of urea.

i At the time of writing Planet Tracker believes that urea agricultural usage for Nicaragua and Panama in 2020 as reported by FAOSTAT has been overstated by a factor of 1,000 due to stark contradictions with previously reported data. As such, these disclosures have been revised downwards by the same factor to arrive at the value of 41%. There are also data gaps as countries such as the United States and China do not report their urea use, though their total annual nitrogen use is 11.6 and 25.7 mn tonnes respectively.

***Figure 14:** Median urea and natural gas prices between 1995-2021. Values inflated to 2021 USD. (Source: CEPII, Planet Tracker)*[96]

Nitrogen Fertiliser and Natural Gas Producers

The production of nitrogen fertiliser is concentrated in a few countries with large supplies of natural gas. Table 4: Top 10 nitrogen fertiliser producers in 2020, and their level of natural gas production in 2020, shows that six countries of the top 10 nitrogen fertiliser producers are also in the list of top 10 natural gas producers. China not only dominates the manufacturing of nitrogen fertiliser, with one quarter of global production, but is also its largest consumer and second-largest exporter, as will be show in the next chapter.[97]

***Table 4:** Top 10 nitrogen fertiliser producers in 2020, and their level of natural gas production in 2020, if in top 10. (Source: FAOSTAT, IEA)* [99,100]

Rank	Country	Production of Nitrogen Fertiliser ('000 tonnes)	Production of Natural Gas (Bn m^3)
1	China	31,942	191
2	India	13,745	Not in top 10
3	United States	13,262	949
4	Russia	11,190	722
5	Egypt	4,500	Not in top 10
6	Indonesia	4,293	Not in top 10
7	Pakistan	3,370	Not in top 10
8	Qatar	2,937	167
9	Saudi Arabia	2,761	99
10	Canada	2,726	184
11	Others	32,420	1,489
Total		**123,145**	**3,850**

Table 5: Top 10 publicly traded fertiliser and chemical companies according to GICS sector classification ranked by market capitalisation. (Source: Bloomberg) shows the most important publicly traded fertiliser and agricultural chemical manufacturers from a market capitalisation perspective. These ten companies represent 50% of the total market capitalisation in this sector, with over 260 companies making up the rest of the universe. The top three shareholders in each company have also been provided, which shows that two of the "big five" global investors have a considerable say at these companies - BlackRock appearing seven times and Vanguard six times.

Table 5: *Top 10 publicly traded fertiliser and chemical companies according to GICS sector classification ranked by market capitalisation. (Source: Bloomberg)*

Rank	Company Name [Ticker]	HQ	Market Cap (USD bn)	Top 3 Institutional Shareholders
1	Corteva [CTVA]	United States	40.42	Vanguard BlackRock Capital Group
2	Nutrien [NTR]	Canada	31.47	Royal Bank of Canada T Rowe Price Vanguard
3	Sociedad Quimica y Minera [SQM]	Chile	17.05	Banco de Chile State Street Banco Santander
4	SABIC Agri Nutrients [SAFCO]	Saudi Arabia	16.53	SABIC Vanguard BlackRock
5	Qinghai Salt Lake Industries [000792]	China	15.92	Qinghai State-owned Assets Investment Management ICBC China Development Bank
6	FMC [FMC]	United States	13.99	Vanguard BlackRock Wellington Management
7	CF Industries [CF]	United States	13.66	Vanguard BlackRock FMR
8	Mosaic [MOS]	United States	12.82	Vanguard Capital Group BlackRock
9	PhosAgro [PHOR]	Russia	11.74	Adorabella Ltd Chlodwig Enterprises BlackRock
10	Yara International [YAR]	Norway	10.20	Norwegian Ministry of Industry and Fisheries Folketrygdfondet BlackRock

In addition to the companies above, BASF is also a major player in the nitrogen fertiliser business.

It operated the first industrial-scale ammonia production plant that utilised the Haber-Bosch process in 1913. In 2019 it had a total nitrogen-based fertiliser production capacity of 1.7 million tonnes.[100,101] Petrobras, a Brazilian oil and gas company, is an important player in helping Brazil to decrease its dependence on imported fertiliser from 85% to 45% by 2050.[90] It is 80% of the way through building a fertiliser facility that is expected, once operational, to produce 2,200 tonnes of ammonia and 3,600 tonnes of urea daily, or 20% of Brazil's urea consumption.[102]

There are also important private fertiliser producers. Five private companies from the top ten largest urea manufacturers include:[103]

- Acron Group (Russia)
- EuroChem (Switzerland)
- Koch Fertilizer LLC (United States)
- OCI Nitrogen (Netherlands)
- Qatar Fertiliser Company (Qatar)

In Table 4: Top 10 nitrogen fertiliser producers in 2020, and their level of natural gas production in 2020, we highlighted the overlap between the top ten fertiliser and natural gas producing countries and find this is also a feature for some private companies above. Koch Fertilizer LLC is headquartered in the United States, the largest natural gas producer globally, and Acron Group in Russia, the second largest. EuroChem and OCI Nitrogen, European headquartered companies, both have significant operations in the Middle East. EuroChem's operations are mainly found in Russia, and in 2020 they produced 8.9 mn tonnes of nitrogen fertilisers.[104] OCI Nitrogen in 2019 announced a joint venture with Abu Dhabi National Oil Company, for a combined production of 6.5 mn tonnes of nitrogen fertilisers.[105] This is in addition to the Qatar Fertiliser Company which has a production capacity of 5.6 mn tonnes of urea.[106] For context, the largest publicly traded producers of nitrogen fertilisers from Table 5: Top 10 publicly traded fertiliser and chemical companies according to GICS sector classification ranked by market capitalisation. (Source: Bloomberg) are CF Industries (8.9 million tonnes),[107] SABIC Agri Nutrients (8.3 milion tonnes, all fertilisers incl. nitrogen),[108] Yara International (6.5 million tonnes),[109] and Nutrien (2.7 million tonnes).[110]

For fossil fuel companies, fertilisers could appear an attractive diversification strategy away from the traditional refined products. However, as we explain in Case Study 1, there is a strong argument that the world is already past peak nitrogen. The world does not appear to need more nitrogen fertiliser, but rather better and more efficient distribution and use.

As we observed in Case Study 1, we are exceeding our nitrogen planetary boundary and we should not be fixing more than 62 million tonnes of nitrogen per year. However, global urea capacity alone increased by 40 million tonnes from 2015 to 2023. The pace of expansion is slowing as *only* 4 million tonnes of new capacity is planned to become operational by 2026. This begs the question of whether these assets are at risk of becoming stranded in a transition of the food system to a more sustainable economy.[111]

Financiers should be aware of the interdependencies of nitrogen fertiliser and natural gas prices. Six countries appear in the top ten list for both nitrogen fertiliser and natural gas production, reinforcing the connection and concentration of both activities. There are large public and private companies in fossil fuel rich states that can turn-off the tap if gas prices rise and make nitrogen fertiliser production uneconomical. Should countries and agricultural producers start to mitigate these risks and find alternatives for synthetic nitrogen fertiliser?

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet**, that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

1. What plans does the company have to decarbonise the production of its nitrogen fertiliser manufacturing process?
2. What are the main threats to traditional fertiliser production?
3. Does the company have a strategy for developing and transitioning to green fertiliser products?
4. Are there any co-revenue generation opportunities with developing greener fertiliser, such as selling biodiversity and carbon credits?

FURTHER READING

See our politics of **Nature Dependent Trade** blog and data dashboard

6 CASE STUDY
AGRICULTURE DEPENDENT

ISSUE

The economies of countries that are dependent on agriculture for its GDP are more exposed to (i) changing environmental conditions and (ii) countries that control the trade in fertilizer.

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Climate change leaves agricultural dependent countries vulnerable to financial and social volatility.
- Agriculture dependent exporters are exposed to price fluctuations and the availability of agricultural inputs, such as fertiliser, pesticides, and natural gas.

Example: *Sovereign dependence on agricultural exports and nitrogen fertiliser.*

- *Argentina, Brazil, and India are dependent on agriculture for their financial health. 66% of Argentina's export revenue is derived from agricultural goods. Brazil is the largest nitrogen fertiliser importer in the world, at least driven in part, by converting large amounts of rainforest for agricultural production. India is the third largest nitrogen fertiliser importer and 16% of its GDP is derived from agriculture, forestry, and fishing. Investment managers such as Legal & General, Capital Group and HSBC, each a top 30 holder of the sovereign bonds for these countries, should understand these country's dependence on fertiliser and agriculture, and the long term plans they have to reduce it.*

(Shareholder Data: Bloomberg)

CASE STUDY

Fertiliser Trade and Agriculture Dependent Economies

Exports of fertiliser and natural gas are controlled by a handful non-democratic regimes (see Planet Tracker's The Politics of Nature Dependent Trade and data dashboard). This raises questions regarding the security of the supply of critical inputs for global food production. As Bloomberg reported in February 2023, "the Russian invasion of Ukraine highlighted the role of fertilisers, and who controls them, as a strategic lever of global influence".[112]

Figure 15 shows that from 2016 to 2020, Russia was the largest exporter of nitrogenous fertilisers, nitrites, and nitrates, at USD 15.1 billion, closely followed by China, at USD 14.7 billion. Russia exports most of its nitrogen fertiliser to South America and Europe, whereas China's exports are mainly to Asia. Note that China is the world's largest producer of nitrogenous fertiliser, producing nearly 3x more than Russia, as shown in Table 4.

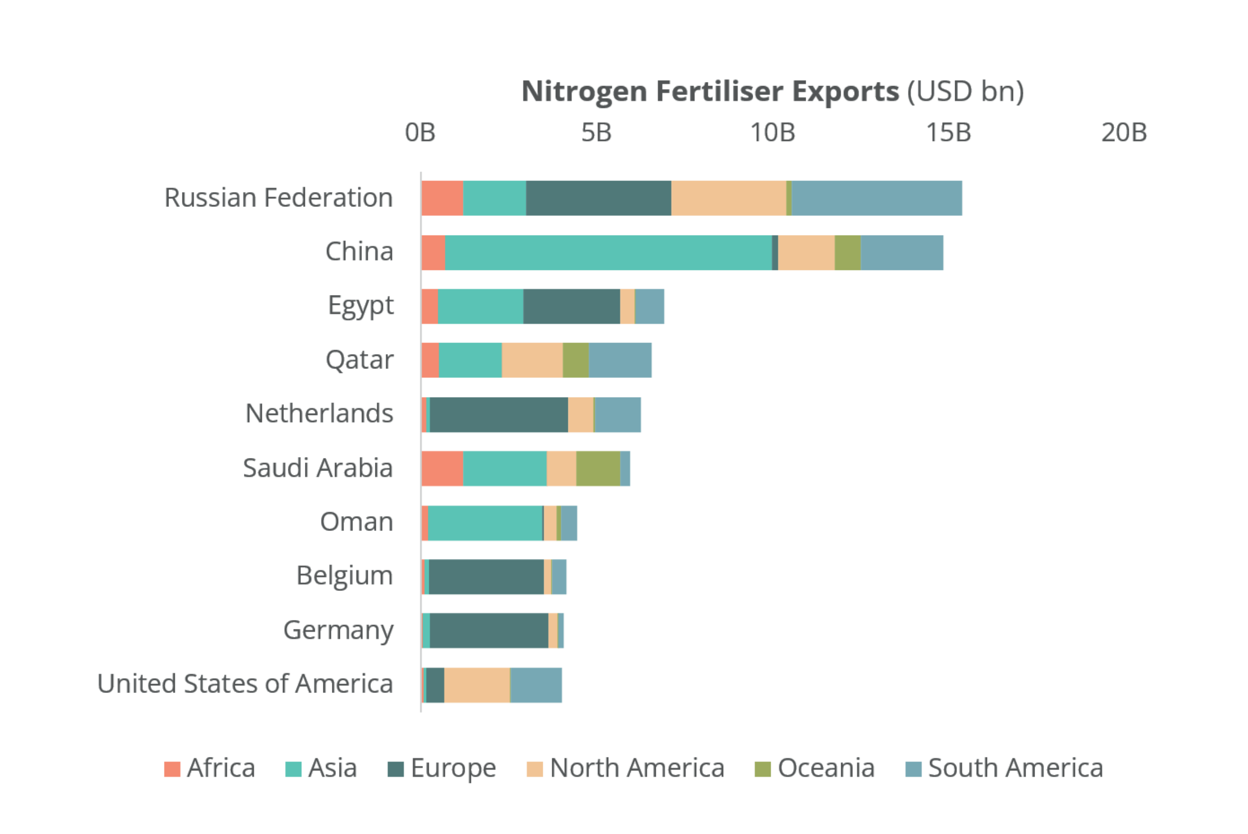

Figure 15: *Top exporters of nitrogenous fertilisers from 2016-2020. (Source: Planet Tracker, CEPII)*[96]

shows the top 15 importers of the same fertiliser products, their dependence on agriculture as measured by the World Bank indicator "Agriculture, forestry, and fishing, value added (% GDP)", and the share of their exports that are agriculture dependent as measured by Planet Tracker. These two metrics were chosen to give an indication of the relative importance of fertiliser inputs and agriculture for the country's economy.

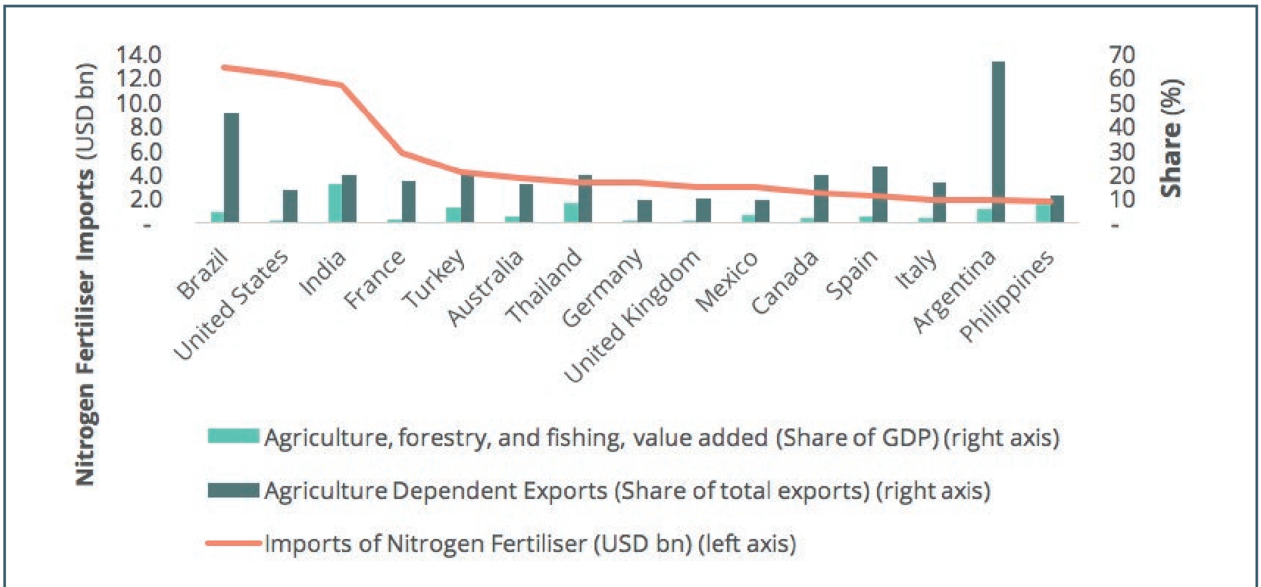

Figure 16: *Top 15 importers of nitrogenous fertilisers (2016-2020), their dependence on agriculture as a share of GDP (2020), and their dependence on agriculture for export revenue from 2016-2020. (Source: Planet Tracker, World Bank, CEPII)* [96,113]

The countries that are more dependent on agriculture for their GDP and their exports are more exposed to fertiliser supply shocks and price rises. Changing environmental conditions and economic events can affect both.

Brazil: High Fertiliser Imports (USD 13 bn); High Nature Dependent Exports (45%)

Brazil is the largest importer of nitrogen fertilisers in the world - USD 13 billion from 2016 to 2020 - and it is also very dependent on agricultural products for its exports - 45% of total exports. In Planet Tracker's Nature Dependent Exporters data dashboard Brazil was classified as a "High Nature Dependent Exporter", meaning it is in the top third of countries ranked by the value of their exports that are dependent on nature for their production. This places Brazil in a delicate position since changes in the international supply of fertilisers could compromise its exports and therefore its economy. As will be explained in the subsequent case study, Brazil is attempting to mitigate this. It launched a national fertiliser plan in March 2022 that aims to reduce its dependence on imported fertiliser from 85% to 45% by 2050.[90]

Brazil has a particularly interesting food trade relationship with China, one of interdependence:

- China is the 3rd largest supplier of nitrogen fertiliser to Brazil (10% of Brazil's nitrogen fertiliser imports), and the largest importer of Brazilian agriculture dependent commodities (30% of Brazilian agricultural exports).
- Brazil is the largest exporter of Chinese agriculture dependent imports (15% of China's agricultural imports).[96]

In other words, China provides the fertiliser Brazil needs to grow the crops that China then buys back.

India: High Fertiliser Imports (USD 11 bn); High Agriculture Dependence (16%)

Another country potentially vulnerable to global fertiliser supply is India: not only is it the 3rd largest importer of nitrogen fertiliser (with 27% of such imports coming from China), but its GDP is also very dependent on the agricultural sector.[96] However, as shown in Table 4: Top 10 nitrogen fertiliser producers in 2020, and their level of natural gas production in 2020, of Case Study 5, India is also the 3rd largest producer of nitrogen fertiliser. This means it has the domestic infrastructure to partly absorb changes in international fertiliser supply.

These considerations are particularly important for companies such as Unilever, which reports 11% of revenues, 13% of invested capital and a significant proportion of key goods, such as tea and timber, coming from India.[115]

**Argentina: Moderate Fertiliser Imports (USD 1.8 bn);
High Nature Dependent Exports (66%)**

Argentina is worth highlighting because, although its nitrogen fertiliser imports are smaller than that of Brazil or India, they still totaled more than USD 1.8 billion in the last five years (2016-2020), which makes it the 14th largest importer of nitrogen fertiliser in the world. Moreover, with 66% of its exports dependent on agriculture, it is amongst the highest in the world - the global average being 30%.

This is of high relevance to companies such as Coca-Cola, which sources 23% of its soy from Argentina alone and Danone, which sources 11% of its dairy products from Argentina, Brazil and Mexico.[115,116]

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet,** that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with agricultural dependent countries are:

1. What is the expected change in agricultural production under a 1.5^{0}, 2^{0} and 4^{0} climate change scenario?
2. How diversified is the production of key crops within the country - the diversity within and between crop types?

FURTHER READING

See Planet Tracker's **Nature Dependent Exporters** report and data dashboard
See Planet Tracker's **Nature Dependent Exporters and Credit Ratings** report.
See Planet Tracker's report on **The Politics of Nature Dependent Trade** report.
See Planet Tracker's **climate transition reports** on Unilever, Coca-Cola and Danone.

7 CASE STUDY
REGULATING NITROGEN POLLUTION

ISSUE

Policies are needed to reduce the dependence on nitrogen fertiliser. However, their implementation can meet stiff resistance. This prolongs wasteful practices, attracts negative corporate press coverage, and increases the risk of legal action related to associated pollution.

RELEVANCE FOR FINANCIAL INSTITUTIONS

- Sovereign investors in the most polluted countries.
- Corporate shareholders that could be impacted by upcoming regulation and potential litigation.

CASE STUDY

Example: *Will increasing litigation mean nitrogen pollution is regulated more tightly?*

- *The EU Commission in February 2023 sued Belgium over its failure to manage nitrate pollution. In Ireland the National Trust is taking the Government to court for the same reason. The US Environmental Protection Agency is being sued after failing to come up with a plan to regulate water pollution stemming from animal farming. Below, we also examine the example of the Netherlands and the political effects of attempting to control nitrogen. As court cases increase, will this incentivize Governments to take a tougher stance against nitrogen pollution? When will companies be impacted?*

Governments across the world have started to realise that nitrogen is a problem that needs fixing. Not only are we seeing a rise in new regulations, but also in legal proceedings against those who breach nitrogen limits. This will put increased pressure on companies in the food system and their financiers (see Planet Tracker's Food System Transition Roadmap), which could face legal costs on top of the inefficiency costs we highlight in this paper.

Governments can control nitrogen pollution. The impact of national policies on nitrogen pollution can be highlighted by looking at neighbouring countries that share similar environmental and agronomic conditions, but different policies and socio-economic contexts. One study found that countries that cause 35% less nitrogen pollution than their neighbours only show a 1% larger yield gap (the difference between attained and attainable yields). This means that nitrogen policies can improve the environment with only a minimal impact on yield.[117]

Regulation Begins...

The United States, India, Germany, and Sweden have commissioned the creation of national nitrogen budgets.[118]

Brazil launched a national fertiliser plan in March 2022 which aims to reduce its dependence on imported fertiliser from 85% to 45% by 2050 and the EU has a goal to reduce fertiliser usage by 20% and halve nitrogen losses by 2030 under its Farm to Fork Strategy.[119]

...And So Does Litigation

Europe's nitrogen issue is starting to be picked up by regulators as well. Last February, the EU Commission sued Belgium over not doing enough against nitrate pollution.[120] Spain was referred to the European Court of Justice (ECJ) by the EU Commission in December 2021 for poor implementation of the Nitrates Directive.[121,122,123] In 2018, Germany was found to have breached EU law by the ECJ for failing to deal with its nitrate pollution problem. The German states of Lower Saxony and North Rhine-Westphalia are being sued by campaigners for failing to tackle the issue.[124] In Ireland, the National Trust is taking the Irish government to court over its failure to protect waterways from nitrogen pollution.[125]

In the US, advocacy groups filed a lawsuit against the Environmental Protection Agency, claiming the federal department has failed to come up with a plan to regulate water pollution from large-scale animal farms where thousands of animals can be kept. The suit follows a 2017 legal petition from more than 30 environmental groups demanding the agency tighten its Clean Water Act enforcement for factory farms.[126]

But Governments Must Act Wisely

Sri Lanka provides a cautionary tale of how not to reduce the use of nitrogen fertiliser. In April 2021 the Government announced an abrupt ban on the imports of synthetic fertiliser, which led to the collapse of the country's agricultural output and its economy. Subsequently Sri Lanka was the first Asia Pacific country to default on its international debt in more than two decades as food production collapsed and foreign currency reserves ran low.[127]

Netherlands

The Netherlands is the biggest nitrogen polluter in the EU and has the highest livestock density.[128] In December 2021 the Dutch government unveiled a €25 billion plan to radically reduce the number of livestock in the country.[129] Finance Ministry calculations suggest more than half of livestock farmers will have to stop or slim down.

The Government stated that Dutch farmers will be compensated for the land, livestock, and machinery that will be taken out of production because of the new rules. Farms will also receive subsidies to convert to ecological farming practices.[130] A permit system was introduced to regulate nitrogen emissions, and in 2023 some companies were reportedly closing farms after buying them in order secure such permits.[131]

In December 2022, the Dutch government offered to buy out up to 3,000 "peak polluter" farms and major industrial polluters. The government also said that forced buyouts will follow next year if the voluntary measures fail. Large scale protests followed the Dutch Government's announcements, attracting media attention around the world.

The Farmer-Citizen Movement, the BoerBurgerBeweging (BBB) party, was established in 2019 and became a public voice of farmers' and rural protests and conservative, anti-establishment anger more broadly. The party won almost 20% of votes in the March 2023 provincial elections, appearing to deal a serious blow to the government's nitrogen plans.[132]

The Netherlands has introduced a permit system for emitting polluting nitrogen compounds, which companies could buy and sell when needed. This could be a possible solution to combatting nitrogen waste elsewhere.

Simultaneously, the Belgian Prime Minister Alexander De Croo proposed that countries could be allowed to emit more nitrogen if they were more ambitious in areas such as clean power generation.[133] Perhaps this is more in the interests of the Netherlands (NL) and Belgium (BE) as they were found to be the two European countries most exceeding three nitrogen limits: (i) ammonia (NH3) emissions to air, (ii) nitrogen in surface water runoff, and (iii) nitrogen in leachate to groundwater - see Figure 17.

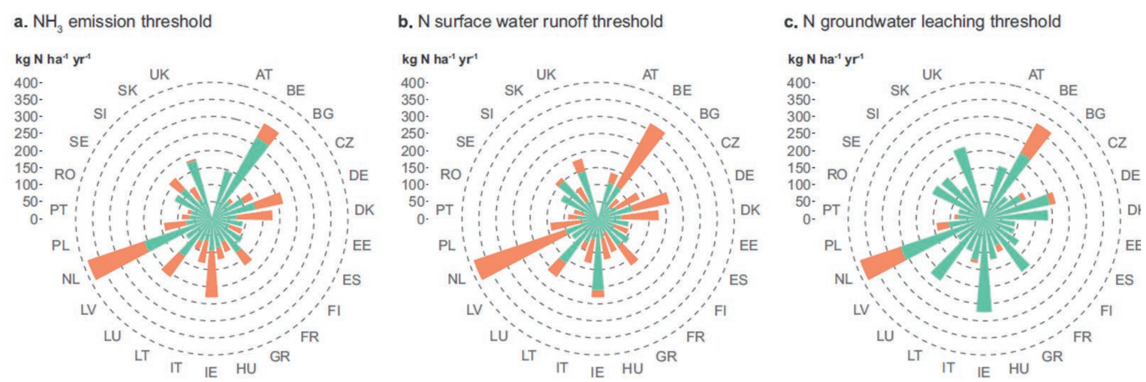

Figure 17: *Three nitrogen limits by European countries. The red section of the bars show where excess is occurring (Units: kg N ha-1 yr-1)*[134]

New Zealand

Similarly, New Zealand saw large scale protests in July 2021 against cattle pollution environmental regulations. Over the past 30 years, New Zealand has experienced a large shift towards intensive dairy farming. In that time New Zealand has almost doubled the number of dairy cows in the country to 6.3 million and increased the use of nitrogen fertiliser by over 600%. As a result, a quarter of its national export revenue now comes from dairy. This rapid expansion was largely unregulated and caused severe nitrogen pollution - both from poor manure management and from fertiliser runoff, alongside increased GHG emissions. Although the government has repeatedly attempted to tackle this, it always met strong resistance, and has so far failed to find a solution.[135]

This highlights how delicate the topic of nitrogen management is in rural communities, and that nitrogen reduction plans need to be carefully drafted in order to be accepted by farmers. The critical issue is that nitrogen reduction plans are often seen as bad for business. However, as we have shown, there are opportunities to invest in technologies, policies, and production practices that can benefit both the environment and the companies that use them. Financiers have a key role in catalysing this transition.

The Regulatory Challenge

The Netherlands and New Zealand are two examples of developed countries exporting agricultural products and experiencing large environmental damage as a result. Examples of developing countries include Indonesian palm oil and South American soybean causing deforestation. Both sets of countries are struggling with a similar problem: rural communities who depend on the agricultural economy feel their livelihoods are threatened and thus fight against environmental regulations. However, if rich countries fail to clean up their own agricultural pollution, how do they expect poorer countries to do so?

ACTIONS FOR FINANCIAL INSTITUTIONS

Planet Tracker has provided a list of priority questions in **Appendix 1: Financial Institution Engagement Sheet**, that financiers could ask companies in their due diligence process or engagement activities with the company. Some other factors financiers may wish to consider when dealing with companies in the food value chain are:

- Are nitrogen emissions monitored from the company's operations?
- Can nitrogen pollution problems be traced back to a company's operations?
- What are the anticipated costs of nitrogen-related litigation likely to cost the company?

FURTHER READING

See Planet Tracker's **Financial Markets Roadmap for Transforming the Global Food System** report

CONCLUSION

The Problem

Compared to other planetary boundaries like climate change and biodiversity, nitrogen has been largely ignored by governments, corporates and financial institutions. Nitrogen is necessary for producing food and is a key input in the USD 14 trillion global food system.

However, inefficient use of nitrogen fertiliser is widespread, costly, creates significant pollution and contributes to climate change. Nitrogen fertiliser applied on agricultural soils travels through the environment, pollutes water ecosystems, aquifers, rivers and oceans, contributes to climate change and damages human health. Costs caused by nitrogen pollution are often treated as externalities by corporates but estimates of societal costs of nitrogen pollution are significant and run in the tens of billions across all sectors for some European countries. Litigation related to nitrogen pollution is likely to increase, evidenced by nitrogen becoming a sensitive political topic in some countries. The world might already be at peak nitrogen production production and assets could be at risk from stranding, and as we are currently exceeding the nitrogen planetary boundary by at least two times, this could become much worse in the future if the nitrogen problem is not fixed.

The Solutions

Fixing the nitrogen problem requires investments to increase fertiliser efficiency, better management of waste and improved pollution control and mitigation. Technological improvements will no doubt help, but political and societal action is also required. Government intervention is needed to provide the right legislation and incentivise more sustainable practices in agriculture. Corporates should start by understanding their dependence on nitrogen inputs, and the costs this entails, which would allow for clearer estimates for total societal costs. Financiers are key players in forcing and catalysing this action.

A global redistribution of nitrogen use is required: although many regions, especially in high income countries are using too much nitrogen, other regions, notably in low-income countries, are using too little. Increasing global efficiency in nitrogen use will not only reduce pollution but could create potential for afforestation and contribute to biodiversity and net zero targets.

The Role of Financial Institutions

Financial institutions are crucial in funding nitrogen solutions and incentivising sustainable practices. Precision agriculture and other innovations in farming practices can reduce nitrogen waste and increase crop yields at the same time, but they require investments. Financial institutions should ask companies to report on their nitrogen costs – incurred both through wasted fertiliser and for pollution. They may discover that within their portfolio, one company's excess use of fertiliser is creating costs for other companies whether that be in tourism or aquaculture. This report has shown that there is money to be made in fixing the nitrogen problem, as this will not only reduce costs, but create enhanced revenue opportunities in other sectors.

NITROGEN FIXES

APPENDIX

1 APPENDIX
FINANCIAL INSTITUTION ENGAGEMENT SHEET

Questions for **fertiliser producers**

Q1: Are we past peak nitrogen demand and what are your production plans?

BACKGROUND

Globally we are over applying nitrogen fertiliser in the range of two to three times - a total of 162 mn tonnes is applied per year. Academic studies estimate that nitrogen fertiliser demand may only reach 61 mn tonnes in 2050 if it is used more efficiently, or even drop to 35 mn tonnes if this is accompanied by a shift in diets where less meat is consumed. Human-made and natural technological solutions, such as the precision application of fertiliser and the better use of manure and farm waste, could see much less fertiliser wasted. Regulations are being increasingly adopted to limit the use of nitrogen fertiliser used, and even nitrogen trading schemes are emerging. This is due to the environmental and human health impacts of nitrogen pollution, as well as the GHG emissions associated with its use and production. See the following case studies for more information.

1. Nitrogen Limits **4. Technological Bets** **7. Regulating Nitrogen Pollution**

DESIRED OUTCOME / ACCEPTABLE RESPONSE

Acceptable	Unacceptable
Move towards technologies relating to the precision application of fertiliser	Move to markets with less strict environmental standards
Improved nitrogen fertiliser characteristics (less run-off...)	Capacity expansion plans
Reduced scope 1 (production) and scope 3 (in-use) GHG emissions	No plans to reduce impact of products

Questions for **food producers, manufacturers, and retailers**

Q1: How is the company and/or its suppliers adopting regenerative agriculture and agroforestry practices? What are the anticipated benefits?

BACKGROUND

In general, current agricultural practices are heavily reliant on human-made inputs, mainly fertiliser and pesticides. Repeated overuse spanning decades has damaged soils and caused much pollution. Regenerative agriculture practices aim to improve soil health by reducing synthetic inputs and minimizing soil disturbances. Agroforestry integrates trees into farming landscapes to, amongst other things, promote biodiversity, reduce nutrient loss and improve soil quality. They can also provide new streams of income - new food products, carbon and biodiversity offsets, and recreation services. The Global Biodiversity Framework requires a 50% reduction in nutrient loss by 2030 and the deployment of these two practices will help to achieve that. See the following case studies for more information.

1. Nitrogen Limits

5. Fossil Fuel Dependence of Fertilisers

4. Technological Bets

7. Regulating Nitrogen Pollution

DESIRED OUTCOME

Acceptable	Unacceptable
Company specifies practices that will be deployed, where, and the area (hectares and percentage) pertinent to the company	The producer has no plans to adopt any practice
Quantifiable and timebound goals to reduce synthetic inputs.	The manufacturer or retailer has no plans to require its suppliers to adopt these practices

Q2: How dependent is the company on the use of synthetic nitrogen fertiliser, directly and indirectly, to produce its products?

BACKGROUND

Synthetic nitrogen fertiliser is an expensive input for farmers. Its cost is susceptible to natural gas prices and trade restrictions and these costs are passed on directly to farmers and eventually to consumers. It is typically overused, which represents a financial waste, but this also causes significant pollution impacts. As such, nitrogen is being increasingly regulated by national governments and trading schemes are emerging. These regulations impose extra costs on businesses who could also face costs from pollution incidents and the associated reputational damage. Finally, there are environmental limits related to nitrogen which must be adhered to. As such, the Global Biodiversity Framework requires a 50% reduction in nutrient loss by 2030 and companies must therefore reduce their dependence on synthetic nitrogen fertiliser. See the following case studies for more information.

1. Nitrogen Limits **5. Fossil Fuel Dependence of Fertilisers**

DESIRED OUTCOME

Acceptable	Unacceptable
Company reports physical quantity and financial value of goods linked to nitrogen use - all crop and livestock products,	No disclosures relating to production or purchase of crop or livestock products

Questions for **all companies that may incur the costs of nitrogen pollution**

Q1: When has the company been impacted by events related to nitrogen? What were the physical and financial costs of these events to the company?

BACKGROUND

Nitrogen pollution can result in costs for companies involved agriculture, but also in sectors like tourism, fishing, aquaculture, water and sewerage, as well as insurance and the health care system. This report has shown that estimates of such costs are significant and run in the tens of billions across all sectors for some European countries. However, they are often not recorded by companies as being caused by nitrogen pollution. In order to fix the nitrogen problem, companies need to start to record these costs in their balance sheets. See the following case studies for more information.

2. Land & Ocean Interconnectedness **7. Regulating Nitrogen Pollution**

DESIRED OUTCOME

Acceptable	Unacceptable
Company reports total costs caused by nitrogen pollution, across all business sectors	Company is not aware of the total costs of nitrogen pollution to their business

2 APPENDIX
NITROGEN FERTILISER BASICS

Nitrogen Loss

There are four main ways in which nitrogen can be lost from the soil:[137]

1. **Erosion**: as nitrogen binds to the soil it can be lost due to the wind, or by surface run-off when it rains.
2. **Leaching**: a physical process that occurs with the drainage of water through the soil profile. While nitrate movement within the profile is common in cracking clay soils, large-scale loss of nitrate below the root zone is minimal in most conditions.
3. **Denitrification**: a biological process that converts ammonia nitrogen into nitrates by microorganisms. The nitrates are further metabolized by another species of bacteria, forming nitrogen gas that escapes into the air.
4. **Volatilization**: a chemical process that occurs at the soil surface when ammonium from urea or ammonium-containing fertilisers is converted to ammonia gas at high pH. Losses are minimal when fertiliser is incorporated but can be high when fertiliser is surface-applied.

Nitrogen Fertiliser Types

Urea

Is the most common type of nitrogen fertiliser in the world, with 71 mn tonnes applied in 2020. In the last five years it was traded at an average price of 437 USD per tonne.[96]
By weight nitrogen constitutes 46% of its mass.

It converts to nitrate, which is the form of nitrogen that can be taken up by crops. However, when soils become waterlogged, soil organisms take the oxygen they need from nitrates, leaving the nitrogen in a gaseous form which escapes into the air. This is known as denitrification and is the common source of nitrogen loss. Denitrification and leaching can be a problem with urea, depending on weather conditions.[137]

Urea and ammonium nitrate solutions (UAN)

In 2020, 17 mn tonnes were applied to agricultural land globally. In the last five years it was traded at an average price of 318 USD per tonne.[96] By weight nitrogen constitutes 28-32% of its mass.

The nitrate in UAN is subject to leaching and denitrification from the time it is applied to the field. The urea components are subject to the same loss mechanisms as urea.[138]

Ammonium sulfate

In 2020, 9.5 mn tonnes were applied to agricultural land globally. In the last five years it was traded at an average price of 274 USD per tonne.[96] By weight nitrogen constitutes 21% of its mass.

It is a nitrogen source with little or no surface volatilization loss when applied to most soils. Ammonium sulfate is also a good source of sulfur when it is needed.

However, its disadvantage is that it is the most acidifying form of nitrogen fertiliser - it requires approximately 2 to 3 times as much lime to neutralize the same amount of acidity as formed by other common nitrogen carriers.[138]

Anhydrous ammonia

In 2020, 5 mn tonnes were applied to agricultural land globally. In the last five years it was traded at an average price of 796 USD per tonne.[96] By weight nitrogen constitutes 82% of its mass.

It is the slowest of all nitrogen fertiliser forms to convert to nitrate. Therefore, it would have the lowest chance of nitrogen loss due to leaching or denitrification. The disadvantage of anhydrous ammonia is that it is hazardous to handle, and it has to be injected into the soil.[136]

Ammonium nitrate

In 2020, 4.7 mn tonnes were applied to agricultural land globally. In the last five years it was traded at an average price of 430 USD per tonne.[96] By weight nitrogen constitutes 34% of its mass.

The ammonium nitrogen quickly converts to nitrate. For soils subject to leaching or denitrification, ammonium nitrate is not preferred.[136]

THE NITROGEN CYCLE

Figure 18 shows how natural and human-made nitrogen circulates through the environment.

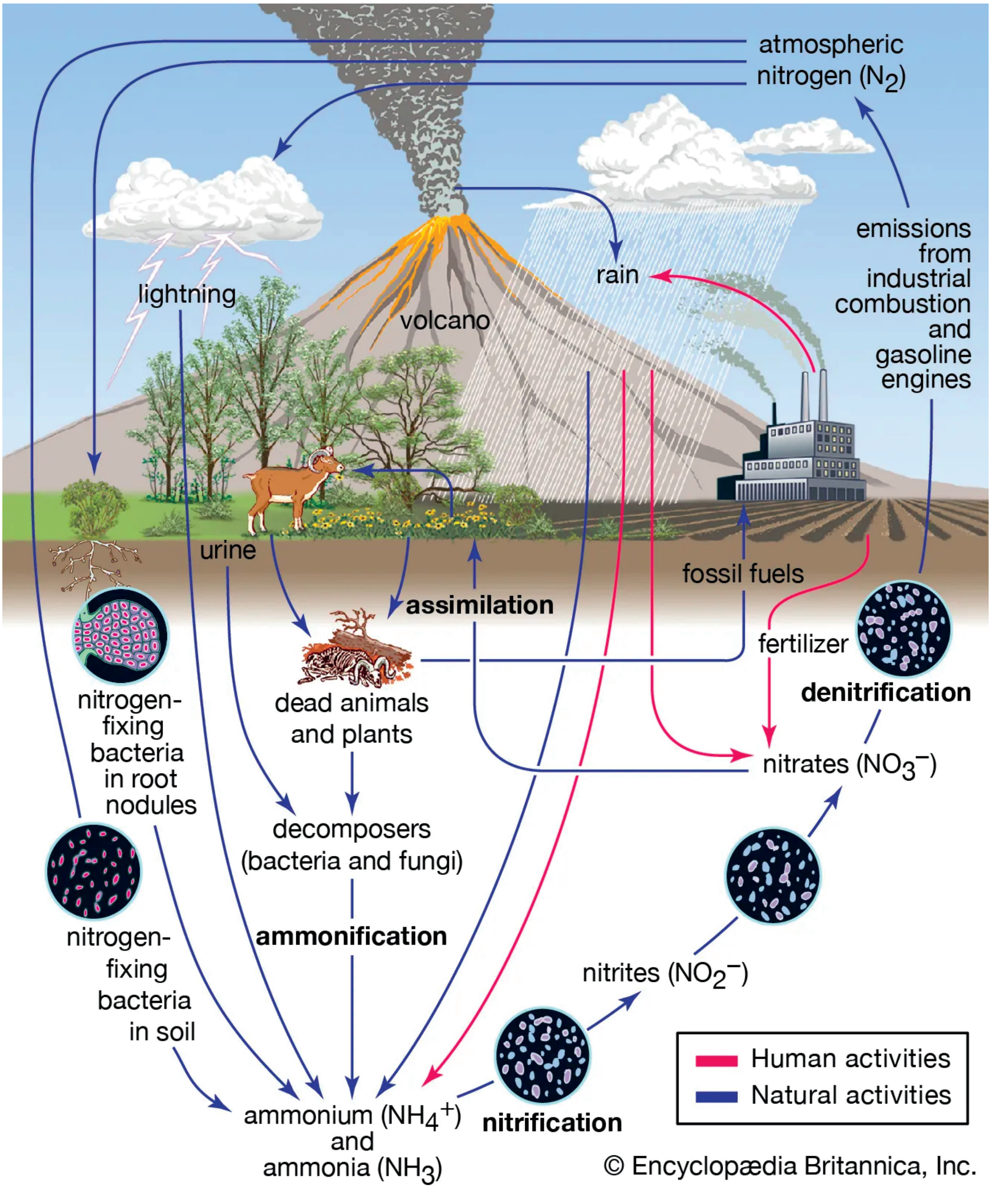

Figure 18: The Nitrogen Cycle[138]

4 APPENDIX
FERTILISERS

What are fertilisers?

Fertilisers, whether artificial or natural, are any matter or chemical applied to land to enhance soil fertility that promotes plant growth. Naturally, soil comprises very fine rocks, different minerals, and organic matter caused by the decomposition of the biological species. At the time of plant growth, essential nutrients are required by the plant for unimpeded growth. Using fertilisers on the soil can assist plants in getting proper nutrition during their development and promoting growth.

Types of Fertilisers

There are two main types of fertilisers: synthetic (man-made) and organic (mainly derived from plant or animal).

Organic fertilisers, also called natural fertilisers, are derived from plant and vegetable residues, animal matter and animal excreta, or mineral sources. A basic advantage of organic fertilizers is that they have complex biological structure and contain natural nutrients for plants. They can be prepared locally being made from nearby materials, which are renewable.

The main types of organic fertilisers are manure (e.g., cattle manure which is a good source of nitrogen and organic carbon while goat manure is rich in nitrogen and potash as is chicken litter), compost, commonly from vegetable and plant waste, minerals such as rock phosphate, which is used naturally to fix phosphate levels of soil, and bone meal, which is a very good source of phosphorous and amino acids. For those able to access seabird and bat excrement – guano – it provides a highly effective fertilizer with a high content of nitrogen, phosphate, and potassium. There are many other types of organic fertilisers which can be used to target particular issues. For example, corn gluten meal is an excellent soil stabiliser while fish meal is one of the faster acting natural fertilisers.

Present-day **synthetic** fertilisers, also called man-made or inorganic, incorporate at least one of the three components that are most significant in plant sustenance: nitrogen (N), phosphorus (P), and potassium (K). NPK fertilisers are the three primary nutrients in such fertilizers. Each of these fundamental nutrients plays a key role in plant nutrition.

Nitrogen is considered to be the most important nutrient. Plants absorb more nitrogen than any other element and it is essential in making sure plants are healthy as they develop. **Phosphorus** is important in allowing the plant to use and store energy, including the process of photosynthesis. **Potassium** helps strengthen plants’ resistance to disease and plays an important role in increasing crop yields and overall quality. Potassium also protects plants in different weather conditions by strengthening its root system.

There are many variations of inorganic fertilisers which can include other elements such sulphur, magnesium, or calcium. For further details on nitrogen fertilisers please see Appendix 2.

Applying fertilisers

There are four main ways of applying fertilisers: broadcasting, top dressing, placement, and liquid fertilisation. **Broadcasting** is a method of application which is uniform over the entire field. It is used when soils are highly deficient of nutrients, especially nitrogen, or where fertilisers like basic slag, bone meal and rock phosphate are to be applied to acid soils, or when potassic fertilisers are to be applied to potassium deficient soils. **Top dressing** is the application of fertiliser to the standing crop, especially nitrate nitrogenous fertilizers. **Placement** is undertaken by inserting or drilling or placing the fertilizer below the soil surface at the desired depth to supply plant nutrients either before sowing or in the standing crop. There are many types of placement such as plough, pellet and drill. **Liquid fertilisation** can be applied in a number of ways, ranging from direct soil application, spray and fertigation (i.e., via irrigated water).

The type of fertiliser and how much should be used is dependent on a number of factors. It will depend on the needs of the plants and the soil's nutrient composition. Soil testing will determine nutrient deficiencies and pH levels. Different growth stages will require different ratios with high-nitrogen fertiliser often used during the vegetative growth phase, while a higher phosphorus fertiliser may be more suitable during flowering and fruiting stages.

5 APPENDIX
CAVEATS

What We Are Not Saying

Although Planet Tracker presents nitrogen related issues which we hope companies and financiers will further explore, it is worth emphasising that the deployment of solutions is context specific and further investigation is required to explore the practicalities of implementing each solution in each location. Below we have provided a couple of examples.

- **Problem**: As described in Case Study 1, nitrogen fertiliser is being overused. Some important caveats and nuances to take note of include:
    - Some areas, such as sub-Saharan Africa, do not use enough fertiliser in their food production.
    - Fertiliser can also be applied at the wrong time, in the wrong form, and in the wrong quantity.
    - Nitrogen fertiliser is needed to produce enough food for the world.

- **Problem:** As outlined in Case Study 3, large areas of the world have experienced deforestation because of agricultural expansion. Reforestation is one solution being proposed to help limit the impacts of climate change. This reforestation could take place on inefficient or low productivity agricultural land.

From a food security and sustainability perspective, locally produced food is an important part of the food system. Decreasing local food production at the expense of reforesting the land while increasing food imports may not make social or economic sense in many cases.

ACRONYMS

Units

Unit	Full Name
mn	Million (10^6)
bn	Billion (10^9)
tn	Trillion (10^{12})
pa	Per annum

Terms

Acronym	Full Name	Description
GhG	Greenhouse gas	These are gases, such as carbon dioxide, that prevent heat from escaping the atmosphere, and therefore have a warming effect on the planet.[139]
NUE	Nitrogen use efficiency	The ratio of total nitrogen input compared to total nitrogen uptake by the plant.[140]
PB	Planetary boundary	Theoretical limits within which humanity can continue to develop with a greatly reduced risk of large-scale abrupt or irreversible environmental changes.[141]
RA	Regenerative agriculture	A way of farming that focusses on improving soil health, which has been degraded by the use of heavy machinery, fertilisers and pesticides.[142]
SDG	Sustainable development goal	A set of 17 international goals, made up of 169 targets, which call for all countries to contribute to, for instance, ending poverty, hunger, reducing inequality while tackling climate change and preserving forests and oceans.[143]

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ABOUT PLANET TRACKER

Planet Tracker is a non-profit financial think tank producing analytics and reports to align capital markets with planetary boundaries. Our mission is to create significant and irreversible transformation of global financial activities by 2030. By informing, enabling and mobilising the transformative power of capital markets we aim to deliver a financial system that is fully aligned with a net-zero, nature-positive economy. Planet Tracker proactively engages with financial institutions to drive change in their investment strategies. We ensure they know exactly what risk is built into their investments and identify opportunities from funding the systems transformations we advocate.

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