# A Game-Changing Goal: Fixing the Nitrogen Cycle

## Introduction

A sustainable nitrogen cycle is one in which excess nitrogen produced by humans is returned to the atmosphere as inert gas while still producing enough food to feed the world population. Human activities cause a disproportionate amount of reactive nitrogen to be released into the environment. This excess can have unintended effects on food, water, atmosphere, human health, and the economy. However, nitrogen is vital to agricultural production, making the balance between yield and sustainability what truly qualifies to manage the nitrogen cycle as an engineering grand challenge.

## The Impact of Nitrogen on Food and Water

The current nitrogen cycle pollutes freshwater, taints aquatic food sources and brings harm to the general population. Excess nitrates caused by crop fertilizer contaminate water sources and create harmful algal blooms (HAB) which can release toxins which contaminate fish that humans consume. Ciguatera fish poisoning, for example, has no cure and affects up to 3% of travelers to the Caribbean, Pacific and Indian oceans [1]. Not only do the harmful algal blooms affect the world's fastest-growing food source but it also affects drinking water. Desalination plants are predicted to grow by 12% percent per year due to drinking water needs [2]. These facilities are also being affected by the algal blooms which can stop production for months at times [3]. As the world's population grows, so does the amount of fertilizer needed, only furthering the effects of eutrophication. While the use of surplus nitrates to produce food may seem acceptable by a utilitarian view initially, as cheap and abundant nourishment benefits the masses, this is not the case. Globally, HAB's have been doubling each decade since 1960 [4]; this inflation will affect a growing percentage of the population, thus becoming a long-term ethical issue. Without action taken to reverse the effects of the lopsided nitrogen cycle, food and water sources are at risk of choking themselves to the point at which they can no longer support the growing human population.

## The Atmospheric Effects of Reactive Nitrogen

The substantial amount of nitrogen being fixated on the ground level due to human activity has caused the chemical composition of natural nitrogen compounds found in the atmosphere to drastically change within the past 150 years (Figure 1) [5]. The largest contributor to the chemical change is increased emissions of three common compounds: nitrous oxide, nitric oxide, and ammonia.

Nitrous oxide is a long-lived chemical that contributes greatly to the greenhouse effect by trapping heat in the atmosphere while absorbing outgoing radiation from the earth. Though it cannot react with many chemicals in the lower

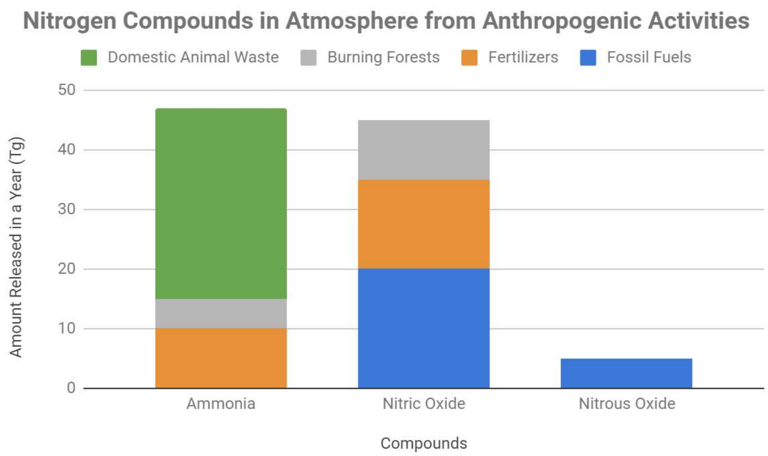



Figure 1 - The three most common nitrogen compounds that make their way into the atmosphere originate from similar human activity. This bar graph is based on data in the *Ecological Applications* journal about how much nitrogen is released per year from various sources [7].

atmosphere, it tends to rise and become more reactive with particles in and around the ozone layer, furthering ozone depletion. As for nitric oxide and ammonia, both are much shorter-lived than nitrous oxide but more highly reactive. Nitric oxide's reactivity causes it to often be transformed into nitric acid, a major component of acid rain. Limiting fossil fuel combustion can prevent various effects of acid rain on people such as respiratory issues, brain damage, and kidney failure, thus being ethical by consequentialism standards [6]. Ammonia has a contrasting effect and acts as an acid-neutralizer, but it is usually the main source of deposition for acidic pollutants within the atmosphere [7]. Most ammonia originates from the Haber-Bosch process where atmospheric nitrogen is consumed to form necessary fertilizer components which can be controlled to lessen ammonia's contribution to atmospheric pollution [8]. Nitrogen issues at the atmospheric level stem from human-produced fixation which must be restricted to minimize harmful effects on the nitrogen cycle.

**The Economic Impact of Human Created Nitrogen**

The changing nitrogen cycle can also be seen having a deep economic impact on humans. This can be seen when looking at nitrogen-based fertilizer used in agriculture. Nitrogen-based fertilizer contributes the most to the total reactive nitrogen being made by humans (Figure 2). This makes sense when looking at how much food needs to be grown for the human population. Vaclav Smil, a professor of geography at the University of Manitoba, said, "'For at least a third of humanity in the world's most populous countries the use of [nitrogen] fertilizer makes the difference between malnutrition and adequate diet'" [9]. There are approximately 7.5 billion people on this planet, meaning at least 2.5 billion people

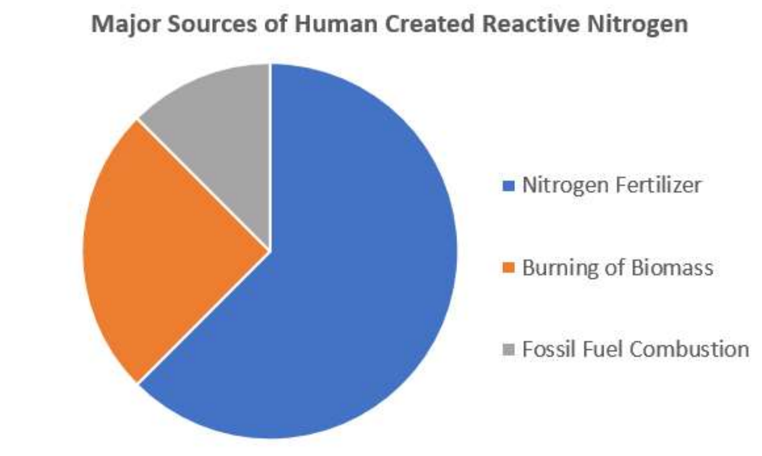


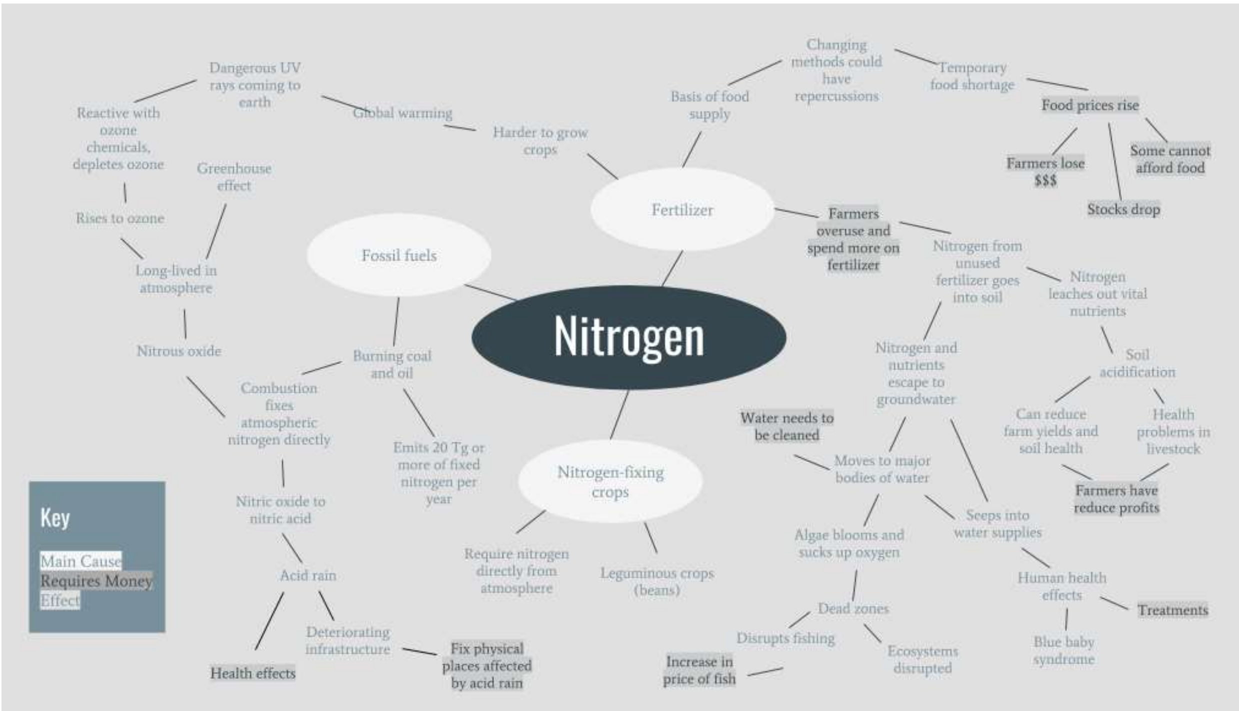

Figure 2 - To understand the effects on the nitrogen cycle, it's important to know the causes of the issues. The pie chart takes data from Scott Field's research [9] and portrays how the three major sources of human-created nitrogen relate to one another. It shows that nitrogen-based fertilizer contributes the most, while the burning of biomass and fossil fuel combustion follow respectively.

base their food supply off of food supported by nitrogen-based fertilizer. Issues such as over fertilizing and soil acidification add to the costs of farmers when producing these foods. By finding a more efficient method of raising crops than nitrogen-based fertilizer, less nitrogen would be added to the cycle as well as farmers would spend less money growing crops allowing for more food to be grown at cheaper prices. Solving issues concerning fertilizer would restabilize the nitrogen cycle as well be ethically desirable based on the theory of justice due to the opportunities afforded to impoverished people with a need for food.

**Conclusions**

The human population has been skyrocketing over the past century. The nitrogen-based fertilizer used to grow crops for all these people has had unintended consequences. In particular, it has had lasting impacts on the earth's water and atmosphere, as well as the human economy. A more detailed image on these issues can be found in the appendix. The impact of these issues could also be analyzed from a consequentialist point of view. If these problems are not resolved then the environment will continue to deteriorate and face the point of no return. Fixing the nitrogen cycle is a game-changing goal for the long term benefit of human economy and quality of life as a whole.

# Appendix


Nitrogen
Fossil fuels
Fertilizer
Nitrogen-fixing crops
Dangerous UV rays coming to earth
Reactive with ozone chemicals, depletes ozone
Global warming
Harder to grow crops
Greenhouse effect
Rises to ozone
Long-lived in atmosphere
Nitrous oxide
Burning coal and oil
Combustion fixes atmospheric nitrogen directly
Emits 20 Tg or more of fixed nitrogen per year
Nitric oxide to nitric acid
Acid rain
Deteriorating infrastructure
Health effects
Fix physical places affected by acid rain
Key
Main Cause
Requires Money
Effect
Basis of food supply
Changing methods could have repercussions
Temporary food shortage
Food prices rise
Farmers lose $$$
Some cannot afford food
Stocks drop
Farmers overuse and spend more on fertilizer
Nitrogen from unused fertilizer goes into soil
Nitrogen leaches out vital nutrients
Soil acidification
Can reduce farm yields and soil health
Health problems in livestock
Farmers have reduce profits
Nitrogen and nutrients escape to groundwater
Water needs to be cleaned
Moves to major bodies of water
Seeps into water supplies
Algae blooms and sucks up oxygen
Human health effects
Treatments
Blue baby syndrome
Dead zones
Disrupts fishing
Ecosystems disrupted
Increase in price of fish
Require nitrogen directly from atmosphere
Leguminous crops (beans)

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