

How organic can help curb nitrogen pollution:

The most overlooked cause of climate change...
and many other environmental disasters

Jessica Shade, PhD



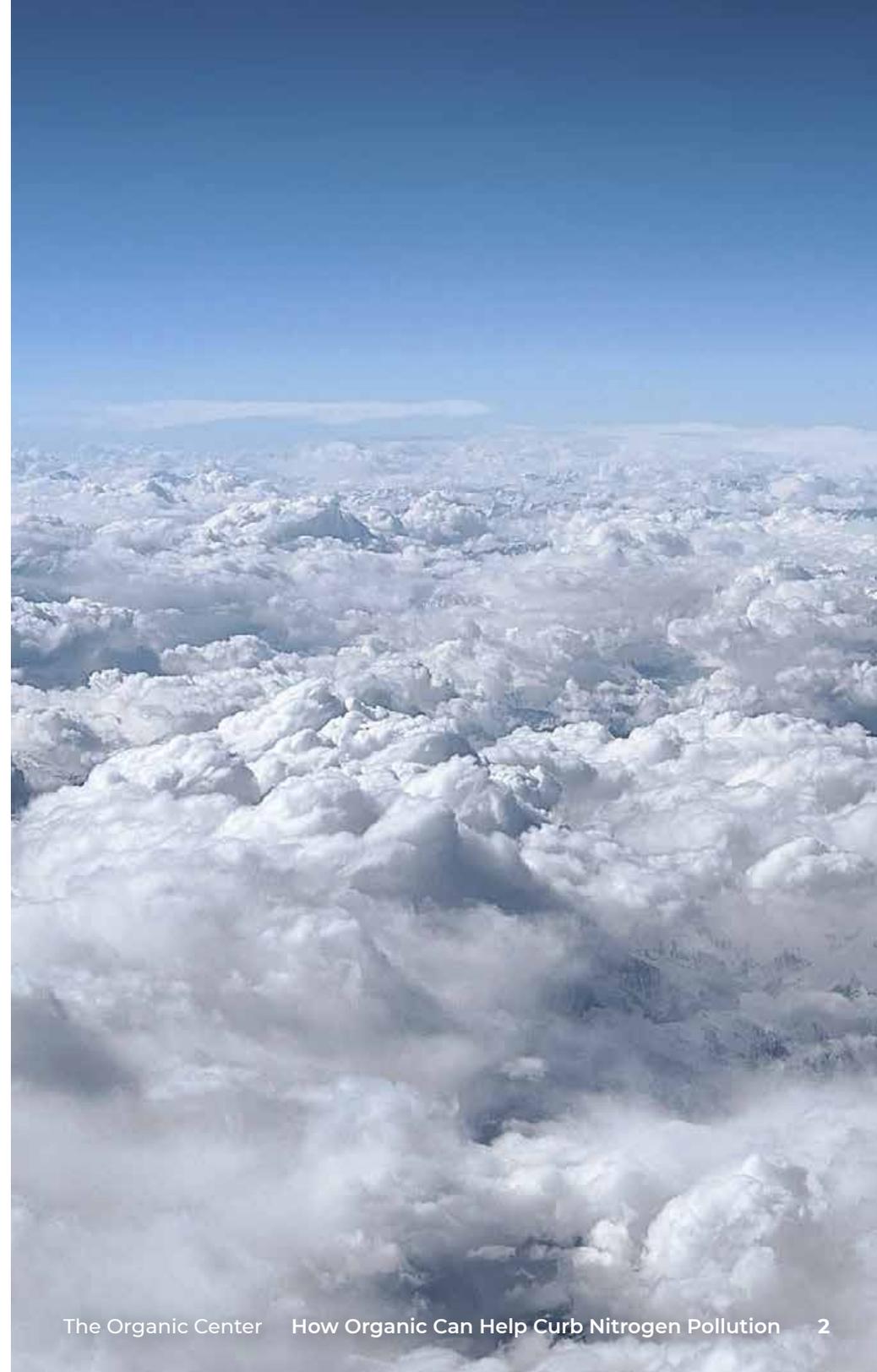
THE
ORGANIC
CENTER™



Introduction

You may know that organic farming bans the use of synthetic fertilizer in favor of natural soil amendments like compost and manure. But, did you know that a simple step combines with other beneficial organic practices to have a huge impact on mitigating climate change and reducing smog, acid rain, coastal dead zones and other environmental disasters?

Nitrogen in some form is required for all life. Most nitrogen is found in the air and can't be used by plants or other living things, and does not contribute to air or water pollution. But when that nitrogen goes through a process called "fixing," it becomes reactive. Reactive nitrogen is what's used for plant and animal growth, but also can cause a host of environmental problems. More and more of the benign nitrogen on earth is getting transformed into the reactive form, primarily through the creation of synthetic fertilizer.



The hidden hand of nitrogen in climate change

While most climate change media coverage focuses on carbon emissions, nitrogen is a critical – if often overlooked – part of the equation. Nitrous oxide (N₂O) is a potent greenhouse gas, with over 300 times the global warming potential of carbon dioxide. Agriculture is the largest source of N₂O, contributing over two thirds of N₂O emissions. Synthetic fertilizer application on conventional crops (especially corn and soybeans) is one of the leading sources of N₂O emissions in agriculture, because excess application of nitrogen fertilizer can lead to increased nitrification and denitrification, which creates N₂O as a byproduct and also leads to nitrate leaching into groundwater.

Organic does not use synthetic fertilizer. All the nitrogen on organic farms comes from recycled sources like compost/manure, or a small amount of new reactive nitrogen from nitrogen-fixing bacteria in the roots of cover crops or other legumes. Those same sources also build a complex and rich soil able to hold onto nitrogen longer rather than just allowing it to run off the field.

This report takes a deep dive into the impacts of nitrogen misuse and how organic practices can help prevent the global accumulation of an overabundance of reactive nitrogen.



What's the deal with nitrogen?

Nitrogen is critically important for life on this planet. It is an important part of amino acids and proteins, and is needed by plants to make chlorophyll, which is used in photosynthesis to make their food. Nitrogen is one of the most abundant elements in the universe, and makes up 78% of the earth's atmosphere. However, most of the nitrogen found on earth is inert: it doesn't react with the environment, and can't be used to support the growth of living organisms.

Reactive nitrogen

To turn inert nitrogen into a useful form for supporting life, it must be "fixed" into a reactive form. There are natural and human-mediated pathways for creating reactive nitrogen from inert nitrogen. Natural nitrogen fixation is dominated by microbes, while human activities include the creation of **synthetic fertilizer through the Haber-Bosch process** and the **burning of fossil fuels**.



Nitrogen makes up 78% of the earth's atmosphere

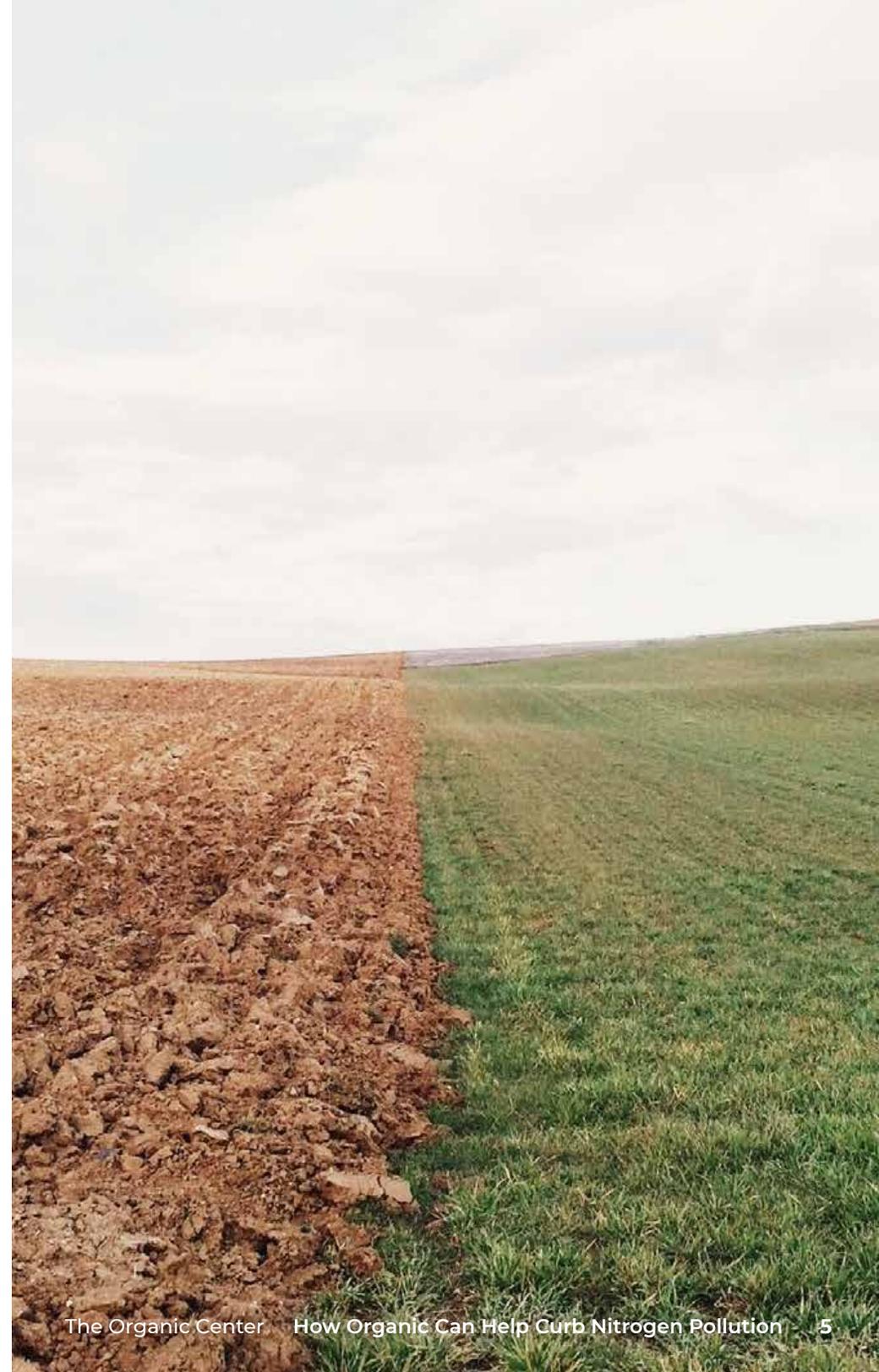
What is nitrogen pollution?

While reactive nitrogen is important for life on this planet, it can also react with the environment causing a cascade of negative impacts for both people and ecosystems. Nitrogen pollution contributes to smog, acid rain, forest dieback, coastal 'dead zones,' biodiversity loss, stratospheric ozone depletion, and climate change.

These environmental problems are the result of an overabundance of reactive nitrogen due to increased human-caused nitrogen fixation. Fixing of nitrogen by humans has by far surpassed natural nitrogen fixation, and is currently seven times higher than reactive nitrogen inputs from natural sources.

Agriculture and nitrogen pollution

Agriculture is a major source of human-enhanced nitrogen fixation, because the use of synthetic nitrogen is common as a fertilizer in conventional production. Unfortunately, a large portion of the nitrogen used in food production is lost to the environment, adding to the environmental disasters that nitrogen pollution can facilitate.



What does organic have to do with nitrogen pollution?

Organic farming practices range in their impact on nitrogen pollution, but many common organic strategies, including crop rotations, composting of plant and animal materials, and the prohibition of synthetic substance application to crops, result in decreases in nitrogen pollution. Crop rotations reduce N pollution by preventing nutrient stripping from soil, and composting plant and animal materials improves N recycling, reducing the introduction of new N pollution to the environment with fertilizer usage. The use of organic soil amendments rather than synthetic fertilizers provide crops with molecularly complex N sources that are slow to release N and therefore limit the loss of N from the field.

While these organic management practices decrease the loss of reactive N into the environment, organic farms also use green manure and leguminous cover crops, both of which have the potential to result in increased amount of nitrogen lost to the environment. Leguminous cover crops protect soil and reduce nutrient runoff and soil erosion, but they also fix atmospheric nitrogen. These cover crops are often tilled into the soil as green manure, which adds further nitrogen into the soil. Moreover, organic practices may result in crop yields that are lower than those of conventional practices because of lower nitrogen availability and greater pest pressure.



What does the latest research say about the benefits of organic?

A recent study out of the University of Virginia shows that the biggest difference between organic and conventional production is that organic farming helps reduce nitrogen pollution by relying on recycled nitrogen sources such as compost and other natural soil amendments. Across all food groups, organic production releases around 50% less new reactive nitrogen to the environment. Although organic and conventional farms have comparable on-farm nitrogen losses for crops systems, organic farming is recycling reactive nitrogen in its practices instead of adding to the global pool of reactive nitrogen in the environment.

This means that not only is organic adding significantly less to the global pool of reactive nitrogen, it can also help put nitrogen waste that could otherwise contribute to nitrogen pollution back into food production. By using manure and food waste as fertilizer, organic helps keep nitrogen losses from other farm systems from entering the environment.

Organic farming:

- ✓ Helps reduce nitrogen pollution
- ✓ Releases 50% less new reactive nitrogen pollution to the environment than conventional farming practices
- ✓ Recycles reactive nitrogen through the use of compost and manure





Future research needs

While organic has a clear advantage when it comes to preventing new reactive nitrogen from being added to the global pool, the study also highlighted areas where additional research is needed to improve the environmental impact of organic, especially on the local nitrogen loss scale. With the exception of beef, virtual reactive nitrogen losses in organic crop systems in the U.S. are comparable to those in conventional crop systems. However, the pathway for organic reactive nitrogen losses differs from conventional pathways, with distinctive opportunities for intervening to reduce nitrogen pollution. Organic has several advantages, including the use of recycled nitrogen, improved ability to access nutrients in the soil, and higher residue recycling rates. However, organic agriculture typically also has lower yields, resulting in reduced crop nitrogen uptake factors.

Despite the benefits of organic systems, lower organic yields reduce calculations of crop nitrogen uptake, i.e. the proportion of reactive nitrogen applied to the crop that is taken up by the plant, and thereby decreases the efficiency of the system. Although organic yields are, on average, lower than conventional yields, they can under some circumstances almost reach the levels of conventional agriculture. Improving yields in organic production and addressing non-nitrogen-related factors that currently limit organic yields (e.g., pest outbreaks, or the lack of crop varieties adapted to organic systems) is thus very important for improving the nitrogen use efficiency of organic systems.

Additionally, while on a per unit land basis the lower density of organic animal production could lead to lower nitrogen loss at the farm scale, organic beef also has a lower nitrogen use efficiency than conventional beef. This is likely due to the low nitrogen use efficiency of pasture, as organic cattle are required to be primarily pasture-raised. Future research could examine methods for improving nitrogen use efficiency in pasture-raised animals.

While improving organic yields and addressing nitrogen use efficiency in pasture will have the most dramatic impact on increasing nitrogen use efficiency in organic systems, there are several leverage points that could shrink nitrogen losses throughout the nitrogen food pathway for both organic and conventional systems. For example, increased

recycling of processing waste beyond field residues could prevent nitrogen losses between the field and the consumed vegetable. Reducing and recycling edible food waste would also have a positive impact on decreasing nitrogen-loss post farm-gate, as well as being critical for addressing a lack of food security. Another point that could enhance N_r recycling in organic agriculture would be to support the increased integration of crop and animal systems. In addition to matching nutrient flows, integrating crops with animal systems can lead to additional on-farm benefits, including reduced dependence on inputs, improved soil health, and diversified profit streams. However, it has a higher labor cost and may require additional equipment investment.



Where can I find out more?

A scientific paper recently published in the peer-reviewed journal, *Environmental Research Letters*, details the methodology used to develop the findings detailed in this report. [The paper can be accessed here.](#)

To understand more about the importance of organic on the environment and human health, [The Organic Center website](#) is the best place to start your research.



THE N-CALCULATOR

Additionally, the research team has developed a nitrogen footprint calculator where consumers can input their consumption data to estimate the amount of nitrogen released into the environment by their consumption choices and examine ways to contribute to reducing nitrogen pollution. Small changes in [lifestyle choices](#) can have a big effect on your nitrogen footprint and your impact on the environment. The [N-Calculator](#) can be used to calculate your personal N footprint, and the [N-Institution](#) tool helps universities and other institutions calculate and reduce their nitrogen footprints.

Organic and soil health: The big picture

It's important to think holistically when looking at organic production, because organic benefits to the environment interact synergistically to support ecosystem services. This is especially true for soil health. Multiple studies have shown that organically managed soils are better at supporting soil health than conventionally managed soils, which can lead to yield advantages in extreme weather events such as droughts and flooding, meaning that organic may fare better as our planet continues to experience climate change.

These soil health benefits can also confer advantages when it comes to nitrogen pollution. Organic systems have a higher rate of crop residue recycling in the form of green manure and compost. While crop residue recycling rates are not well documented throughout the U.S. for conventional or organic production, crop residues are typically recycled at higher rates under organic management due to increased reliance on organic amendments and the emphasis on recycling resources. This is paired with an active soil microbiome in organic systems that allows increased breakdown of those residues, resulting in higher levels of nitrogen storage from previous crop cycles.

Organic soils also have the potential to store more nitrogen rather than losing it to leaching and runoff. The higher organic matter content improves the cation exchange capacity of soils, allowing it to hold more positively charged molecules of mineral nutrients such as nitrogen. This can positively impact nitrogen pollution by keeping reactive nitrogen in the soils, where it can be used by crops, as opposed to being lost to the environment.

What's different about organically managed soils?

- [More biodiversity](#)
- Greater soil stability
- Better water-holding capacity
- [More porosity and aggregate stability](#)
- More carbon storage

Organic and Climate Change Mitigation

The research detailed in this study shows that organic contributes significantly less to the global pool of reactive nitrogen, which is important for climate change mitigation because synthetic fertilizer application on conventional crops is one of the leading sources of N₂O emissions in agriculture. This builds on past research showing that because organic bans the use of synthetic fertilizer, studies estimate that on a per-acre basis, organic soil management can reduce N₂O emissions by over 40%.

While nitrogen is an important component when thinking about climate change, it is also important to consider energy use and carbon contributions to climate change.

When it comes to energy use, research shows that organic farming is often more energy efficient, because it doesn't allow fossil fuel-based fertilizers or most synthetic pesticides. The production and transportation of these conventional inputs require major energy use. The manufacture of synthetic fertilizers alone comprises as much as 10% of global agricultural emissions. Organic production methods significantly reduce greenhouse gas emissions and use less energy because of the decreased use of fossil fuel-based inputs.

How does organic help mitigate climate change?

- Organic releases fewer greenhouse gasses
- Organic is less energy intensive
- Organic sequesters carbon in the soil

In addition to N₂O reduction and reduced energy use, organic also plays a part in carbon sequestration, another critical aspect of climate change mitigation. Organic soil management can increase the carbon pool in our soils – locking away carbon that would otherwise be in our atmosphere as the greenhouse gas carbon dioxide. A study conducted by The Organic Center, in collaboration with Northeastern University, quantified the non-labile, stable portion of carbon in over a thousand samples of organic and conventional soils in the United States. Findings showed that organic soils had significantly higher levels of sequestered carbon than their conventional counterparts. These results build on past research showing higher levels of total carbon in organic soils, highlighting the potential of organic agriculture to increase the amount of carbon sequestration in the soil, contributing to climate change mitigation.

Reactive Nitrogen & Pollution

Plants need nitrogen to grow, but that same nitrogen can cause a suite of environmental problems. Organic farming can help reduce the amount of new reactive nitrogen being introduced into the global system, helping to combat nitrogen pollution.

REACTIVE NITROGEN POLLUTION IN THE ENVIRONMENT



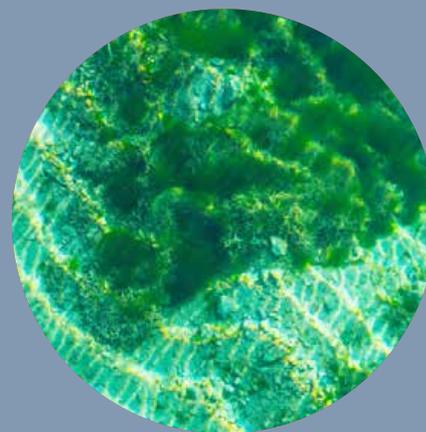
CLIMATE CHANGE

Fertilizer can be converted to nitrous oxide, a greenhouse gas 300x more powerful than CO₂ in contributing to the greenhouse effect.



SMOG AND ACID

Machinery used in food production emit nitrogen oxides, which forms smog formation and contributes to acid rain through the conversion to nitric acid.



DEAD ZONES

Nitrogen runoff from fertilized fields causes oxygen loss in coastal waters, leading to 'dead zones' that can be the size of New Jersey.



OZONE HOLE

Nitrous oxide stays in the lower part of the atmosphere for so long that it can enter the stratosphere, and is the primary cause of the depletion of ozone.

Introducing reactive nitrogen into the global nitrogen pool

SYNTHETIC FERTILIZER

The main way that new reactive nitrogen gets introduced into the global nitrogen pool is through the industrial production of synthetic nitrogen fertilizer. This process is called the Haber-Bosch process and artificially fixes nitrogen, turning it from an unreactive form into a reactive form.

NATURAL N FIXATION

Reactive nitrogen is also created, on a smaller scale, through natural fixation by bacteria (and fungi) in the roots of some plants, such as legumes.



Reactive nitrogen: New vs. Recycled

While new reactive nitrogen can be introduced into the global nitrogen pool through the creation of synthetic fertilizer and nitrogen fixation, reactive nitrogen can also be recycled within the global system by using compost or manure. This is beneficial to the environment, because it doesn't add to the overabundance of reactive nitrogen in the environment, and keeps reactive nitrogen where it does the most benefit rather than harm: helping plants.



Conventional versus Organic Agriculture

Organic agricultural systems are banned from using synthetic fertilizer, so the only way organic farms can provide their crops with the nitrogen they need to grow is through recycling and naturally nitrogen fixing organisms.

Preserving the environment on the global scale

Because organic farms predominantly use recycled nitrogen, they contribute much less new reactive nitrogen to the global environment than conventional agricultural systems.

This means that organic food production results in a cleaner global environment!

