Nitrogen: A Driver of Global Food Insecurity

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With nearly 870 million people chronically undernourished, and progress towards the Hunger Millennium Development Goal ebbing since 2008, feeding the world will continue to be a major global challenge. The limitations of arable land availability, water accessibility, and humanity's increasing population trajectory further compound the problem. Addressing the challenges to global food security while ensuring the sustainability of the planet will require changes to the way we interact with agriculture and a clear understanding of the driving factors behind it.

Food and Energy Price Volatility

World-Energy-PricesThe industrialisation of agriculture over the last five decades has contributed to massive gains in productivity, but it has also made food increasingly susceptible to energy supply and price fluctuations. Energy in the form of oil and gas is needed to run industrial farm equipment and to ship food around the world. Fertilizers, the driving factor behind most yield increases, are intimately tied to energy and therefore price volatility. Nitrogen fertilizers are particularly significant and are created through a process that combines natural gas and inert nitrogen from the atmosphere in a high-energy reaction to create ammonia. Fertilizer production is estimated to account for more than 50 per cent of total energy use in commercial agriculture (Woods, et al 2010). While shale gas has had a significant impact on the US natural gas market, globally, energy prices are expected to rise in the long term and become increasingly volatile, as shown by the graph to the right. Fertilizer costs will follow a similar trend, leading to variability in cost and availability. This can be especially difficult for small farmers in developing countries, whose resilience to price fluctuations is low.

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Natural means of increasing agricultural yields are possible through recycling manures and planting crops that add nutrients to the soil. However, barring a radical change in agricultural practices, globally we are locked into chemical fertilizer use, especially nitrogen fertilizers in the short and medium term. Approximately 45 per cent of the world's food supply is grown using chemical fertilizers, and that number is growing. Meat consumption, which requires large amounts of grain for animal feed, is on the rise. Consumption of animal protein in Europe and the United states together is double the world average (FAO 2006), and is expected to grow 10 per cent between 2005 and 2030. However, demand in developing countries for animal proteins is projected to increase 60 per cent in the same period (Reay 2011). Pressure from biofuel legislation in Europe and the United States puts further pressure on land and drives up global food prices.

Global land deals have increased dramatically in the last ten years, with an area of land eight times the size of the UK sold off globally in that time (Geary 2012). In addition to causing landlessness and poverty for local communities, the land is often used to grow large areas of single-species crops such as soy or eucalyptus, which use industrial agricultural methods requiring a high amount of chemical fertilizer, thus increasing dependence on global energy markets and locking new land into fertilizer dependence. Furthermore, nutrients and pesticides can make their way into local water supplies, degrading the environment upon which local communities depend. For example, water contamination from agricultural runoff can force communities to buy bottled or trucked water at higher prices, reducing their resilience to price fluctuations even further.

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But fertilizers are not evil. Increasing yields (either through better access to fertilizers or implementing natural yield improvement practices) can greatly impact poverty and inequality. There are many regions of the world in which more nutrients are urgently needed in order to ensure the land is not degraded. When fertilizer is introduced to degraded soils, it can have enormous trickle down effects for poverty reduction, health, and education. In the early stages of development, when a country is primarily agrarian, the most consistently effective methods to reduce poverty and improve equality involve the agriculture sector, particularly through methods that raise small farm productivity (Berry 2010, Deininger and Byerlee 2011). For example, a recent review of coffee grower data from Mexico and Peru, published in the World Development journal, found that increasing yields are most important for growers (Barham and Weber 2011).

Nitrogen: The Missing Link

So where does that leave us? The very thing that reduces poverty and hunger through increasing yields can cause insecurity through energy price volatility. Add increasing pressure from consumption choices, land degradation, population pressure and climate change and we have a situation of increasing food insecurity globally.

Population-and-Fertilizer-UseThere is no silver bullet answer to this conundrum. However, the solution will likely be a combination of improving the efficiency of chemical fertilizer use and increasing the productivity and adoption of natural methods. Cross-cutting all of these solutions is the main driver of yields: nitrogen. Phosphorous and potash are also important elements of fertilizer, but nitrogen is the nutrient needed in the largest quantities. Just as a basic knowledge of how CO_2 impacts climate change is important for developing solutions to the problem, so is knowledge of nitrogen important for developing solutions to food security.

Nitrogen is critical for all plants and animals to grow. Some plants build it naturally into the soil through a symbiotic process between bacteria and their roots called ‘biological nitrogen fixation’ (beans and clover, for example), but the majority comes from chemical fertilizers and as a by-product of burning fossil fuels.

For those that remember the nitrogen cycle from science class, we know that 78.1% of the atmosphere is inert nitrogen (N_2). In the 20th century, we developed a way to convert this inert, atmospheric nitrogen into a form of nitrogen accessible to plants and animals (known as “reactive nitrogen”). This has enabled food production to roughly keep pace with the explosion of population growth over the last fifty years. Whether through fertilizers or biological fixation, nitrogen will play a key role in meeting the food needs of the future.

When there is not enough nitrogen in the soil, loss of soil productivity and degradation occur. Because it is small farmers that often lack access to nitrogen, their yields decline year over year, reducing their annual income and thus exacerbating inequality within the global food system. This pushes them further into poverty, and in many cases can force them to purchase food when they cannot grow enough. Degraded land forces them to go in search of new, more fertile land, breaking apart families and communities.

However, the solution is not as easy as simply adding more nitrogen in areas where there is not enough. Too much nitrogen can cause serious problems for human health and the environment. While nitrogen is required by plants in order to grow, there is a limit to how much any plant can use. Beyond this “critical load”, nutrients that cannot be absorbed by plants will leach into the water and air. Once in the environment, nitrogen can change forms over an extremely long life (average of 120 years) and detrimentally affect many different systems before finally becoming denitrified back into atmosphere. Nitrogen exacerbates climate change, depletes the ozone layer and drives biodiversity loss. It causes low-oxygen zones in water systems that weaken or kill fish and marine habitats (known as eutrophication or hypoxia). Reactive nitrogen can also be very detrimental to human health through air and water contamination. It is a major contributor to smog, which is estimated to take six months off the life expectancy of over half the population in Europe (Sutton et al 2011). It is even worse in areas like China, where the density of air particulates have registered at twice the level considered “dangerous” in metropolitan centres like Beijing. Ingesting high levels of water-borne nitrates has been associated with cancer, diabetes and adverse reproductive outcomes (Ward et al. 2005).

The graph below shows nitrogen fertilizer application globally. In the red areas of the graph, many of the main water bodies suffer the detrimental effects of too much nitrogen, and the people that live in those areas suffer as a result of nitrogen pollution. Many of the green areas could benefit from more nitrogen to increase soil productivity.

WorldFertilizerApplication

The key is balance. On the one hand, improving the efficiency of fertilizer use will maintain crop yields while protecting the ecosystems humans and animals depend upon. On the other hand, developing biological nitrogen fixation methods or pro-poor fertilizer programmes to increase yields for small farmers will improve their situation economically and strengthen their resilience to price shocks and weather events. In both cases, proper nitrogen management will be a crucial part of solving our global hunger crisis while ensuring sustainability for future generations.

Lisa Dittmar is the CEO and founder of NitrogenWise, a website that brings together research and straightforward communication to explain the complexities of nitrogen in a meaningful and relevant way.

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