Peak Phosphorus

A Potential Food Security Crisis

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"There are no substitutes for phosphorus in agriculture."

~ United States Geological Survey, 2009

Summary

- ***Phosphorus is an element necessary for all life***. Phosphorus is one of the three major nutrients required for plant growth: nitrogen (N), phosphorus (P), and potassium (K).

- ***Global phosphorus production most likely peaked in 1989***. If global phosphorus production has not yet peaked, it will likely do so by 2033.

- The quality of remaining phosphate rock is decreasing and the production costs are increasing.

- ***Global reserves will start to run out within 50–100 years***.

- Once phosphorus supplies are exhausted, ***phosphorus will need to be recovered and reused in order to avoid a massive global food security crisis***. ***There are no substitutes for phosphorus in agriculture***.

- In 2007–2008, the price of phosphate rock increased dramatically worldwide due to increased agricultural demand and limited supplies of phosphate rock. The average U.S. price in 2008 was more than double that of 2007, and was four-times greater than that of 2004. Average spot prices from North Africa and other exporting regions increased more than five-times the average price in 2007.

- ***Most of the world's farms do not have or do not receive adequate amounts of phosphorus***. Feeding the world's increasing population will accelerate the rate of depletion of phosphate reserves. Future generations ultimately will face problems in obtaining enough to exist.

- ***Policy responses are necessary soon to prepare society for declining phosphorus supplies***, to promote efficient phosphorus use, and to develop phosphorus recycling programs.

Introduction

Reserves of phosphate rock, the main source of phosphorus used in fertilizers, are running out. Few reports have examined the implications of the world's dwindling phosphorus supplies, but based on the data that are available, peak global phosphorus production likely occurred in 1989 (Déry and Anderson, 2007; Ward, 2008).

Phosphorus is an essential nutrient for all life – including plants, animals and humans. Phosphorus is one of the three key components (together with nitrogen and potassium) of fertilizers, and therefore, it is crucial for the world's food supply system. Since the Green Revolution following World War II, the global human food supply has become depend on high-yield agriculture using artificial phosphorus fertilizers. This phosphorus is derived from finite, exhaustible reserves of guano (bird and animal droppings) and phosphate rock. With continued population growth, improving diets, and rising global demand for food (especially meat) and biofuels, the need for phosphate fertilizers to secure crop production will only increase.

The excessive and inefficient use of fertilizers has led to an ever-increasing demand for natural phosphorus. As phosphorus reserves decline, and in the absence of an adequate system to efficiently use and recycle phosphorus, the impacts will likely be severe, and include declining farm output, higher food prices, growing food insecurity, and increasing social and economic challenges for which the world would be unprepared. If societies do not prepare, global economic development and food security could be constrained by oil supplies and by the availability of phosphorus within a few decades.

Phosphorus : Its Role in Nature and Agriculture

Phosphorus (chemical symbol P) is an element necessary for all life. Phosphorus is one of the three major nutrients required for plant growth: nitrogen (N), phosphorus (P), and potassium (K). Phosphorus is often a limiting nutrient in natural ecosystems, in which the supply of available phosphorus limits the size of the population possible in a given ecosystem (Déry and Anderson, 2007).

Phosphorus does not naturally occur as a free element, because it is highly reactive. Instead, phosphorus is bound up in phosphates, which typically occur in inorganic rocks. Most phosphorus is obtained from mining phosphate rock (Déry and Anderson, 2007). Phosphorus is also obtained from deposits of guano (Déry and Anderson, 2007).

The major use of phosphate is in fertilizers (Déry and Anderson, 2007). Growing crops remove phosphorus and other nutrients from the soil. Philip Abelson (1999) warns,

"*Most of the world's farms do not have or do not receive adequate amounts of phosphate. Feeding the world's increasing population will accelerate the rate of depletion of phosphate reserves...resources are limited, and phosphate is being dissipated. Future generations ultimately will face problems in obtaining enough to exist.*"

Further, the U.S. Geological Survey (USGS, 2009) states, "*There are no substitutes for phosphorus in agriculture.*" Therefore, phosphorus production and distribution is a bottleneck in agriculture.

Reserves of phosphate rock are found in several countries, but the largest commercially recoverable reserves are located in just three – China, the United States and Morocco/Western Sahara (Cordell et al., 2009). At current rates of extraction, the US will deplete its reserves within 30 years, and global reserves will start to run out within 50–100 years (Cordell et al., 2009; USGS, 2009). Phosphorus cannot be manufactured from alternative sources, but it can be recovered and reused (i.e. recycled). Some can be recovered from human, animal and organic waste, but as yet there have been few initiatives to promote recycling (Cordell et al., 2009).

Cordell et al. (2009) predict that phosphorus production will peak in 2033 (see Figure 1). Although the authors argue that the observed peak in 1989 was not a true maximum production peak – claiming that it was instead a consequence of political factors like the collapse of the Soviet Union (formerly a

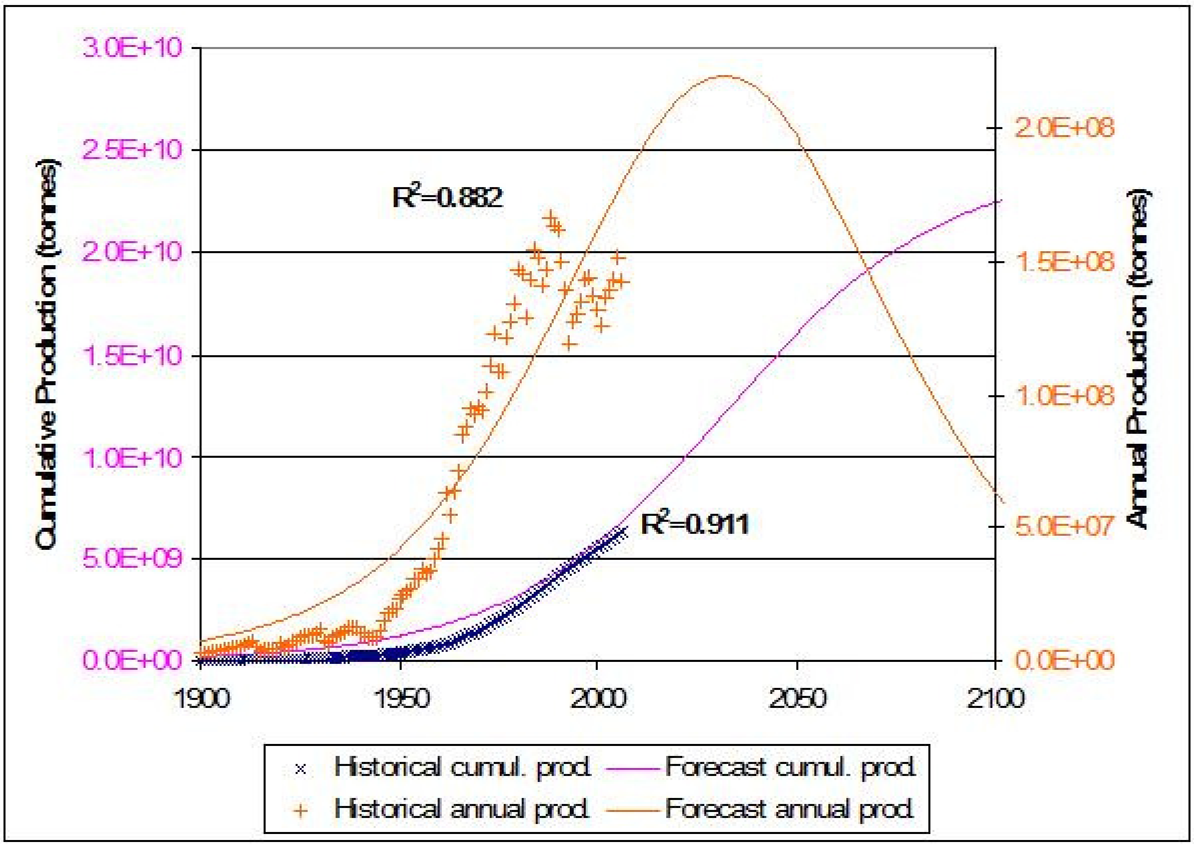

Figure 1: *The annual and cumulative production predicted by Cordell et al. (2009), based on URR = 24.3 billion tonnes (URR from USGS, 2009). According to this graph global peak phosphorus occurs in 2033. Graph produced by Ward (2008).*

significant phosphate rock consumer) and decreased fertilizer demand from North America and Western Europe – their 2033 prediction is based on forcing the behavior of their model to accommodate the Ultimate Recoverable Reserve (URR refers to the total amount of resource that will ever be produced including yet-to-find fields) estimates of the U.S. Geological Survey (Cordell et al., 2009).

Projections based on applying the technique of Hubbert Linearization to the rock phosphate production historical data series from the U.S. Geological Survey (USGS, 2007) to predict peak phosphorus suggest that global phosphorus production peaked in 1989 (see Figure 2) (Déry and Anderson, 2007; Ward, 2008). This same model was used to successfully predict the peak phosphorus production year for two major phosphorus exporters: the U.S. (1988) and the island state of Nauru (1973) (Déry and Anderson, 2007). The historical data, declining production rates, the depletion of high quality phosphate rocks, increasing demand, and increasing prices suggest that the 1989 prediction for peak phosphorus may be a more reliable prediction.

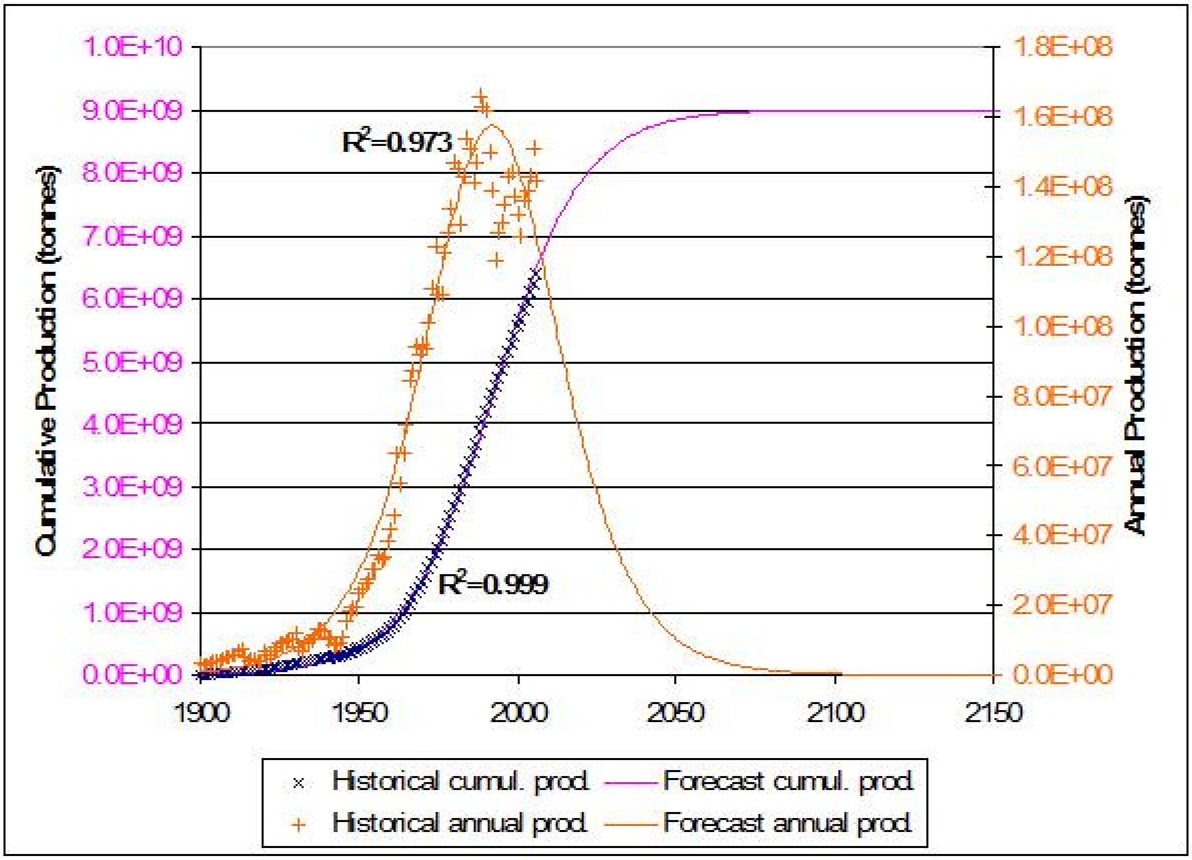

Figure 2: *The annual and cumulative production predicted by Ward (2008). Global peak phosphorus occurs in 1989.*

Although Ward's analysis suggests that the 1989 downturn is a final peak with no recovery, the author indicates that lower-quality phosphate rock that is less economically viable to extract may allow for a less steep decline in phosphorus production in the future, if unconventional low-grade phosphate supplies can be brought online to replace declining conventional supplies in the near future (Ward, 2008). Even though Cordell et al. (2009) disagree with the 1989 peak phosphorus estimates, the authors admit that the fertilizer industry widely acknowledges that the quality of remaining phosphate rock is decreasing and that the production costs are increasing (Cordell et al., 2009). Besides the issues of declining phosphorus supplies and the environmental cost of mining low-grade phosphate, it may not be economically viable in the long-term to continue mining low-grade phosphate rock as energy costs and the price of fertilizer rises. Furthermore, once phosphorus supplies are exhausted, phosphorus will need to be recycled in order to avoid a massive global food security crisis.

The availability of phosphate is reflected in the price of fertilizer and in the cost of food. In 2007–2008, the price of phosphate rock increased dramatically worldwide due to increased agricultural demand and limited supplies of phosphate rock. The average U.S. price in 2008 was more than double that of 2007, and was four-times greater than that of 2004 (USGS, 2009). Average spot prices from North Africa and other exporting regions increased more than five-times the average price in 2007 (USGS, 2009). Prices for nitrogen (dependent on energy prices), potash (a source of potassium), and sulfur (used to process phosphorus from phosphate rock) also increased, which caused the price of fertilizers to reach record highs (USGS, 2009). This relationship between nitrogen, phosphorus and potassium prices is complicated since fertilizers are made up of nitrogen, phosphorus and potassium, and therefore, the price of one of these components can directly affect the prices of the other two (Cordell et al., 2009). The International Fertilizer Industry Association expects the fertilizer market to remain constrained for at least the next few years (IFA, 2008). Consequently, the price of phosphate rock and related fertilizers will likely remain high in the near future, until new mining projects are commissioned (Heffer and Prud'homme, 2007).

In 2007–2008, the price increase of phosphate fertilizer was due in part to the increasing popularity of meat- and dairy-based diets, especially in growing economies like China and India, and to the expansion of the biofuel industry (Cordell et al., 2009). Increasing concern about oil scarcity and climate change resulted in the recent sharp increase in biofuel production. The biofuel industry competes with food production for grains, productive land, and phosphorus fertilizers. The year 2007 was the first year a clear rise in phosphate rock demand could be attributed to ethanol production (Cordell et al., 2009). Biofuel production pushed fertilizer into a pricing structure determined directly by the rising oil prices, which resulted in a sharp increase in food prices (Cordell et al., 2009). Therefore, the volatility of the phosphate market due to biofuel and oil production may also affect the prices of nitrogen and potassium, the two other components of fertilizer, and ultimately the price of food in general.

Phosphorus reserves are expected to be depleted in 50–100 years (Cordell et al., 2009; USGS, 2009). Regardless of whether peak global phosphorus production occurred in 1989, or will occur by 2033 or sometime in between these two years, it is clear that policy responses are necessary soon to prepare society for declining phosphorus supplies, to promote efficient phosphorus use, and to develop phosphorus recycling programs. Otherwise, the growing global population, the increasing demand for phosphorus, the decreasing phosphorus supply, and rising fertilizer prices will threaten a massive global food security crisis.

Responses to Peak Phosphorus

The challenge of peak phosphorus is more difficult than other peak energy resources issues, like peak oil, in some ways. For instance, energy sources other than oil are available, although they all have their own associated problems and limitations. However, unlike fossil fuels, phosphorus can be recycled.

If phosphorus is wasted, it cannot be replaced by any other source. Currently, the limited supplies of concentrated phosphates are being depleted (Déry and Anderson, 2007; Ward, 2008). Phosphate fertilizer is often applied carelessly, which leads to waste and pollution. Food is consumed by people and animals, who excrete most of the phosphorus. In developed societies, the excreted phosphorus goes into the sewage which drains into the sea, waterways, or is buried (Déry and Anderson, 2007).

A critical response to peak phosphorus would be to recreate a cycle of nutrients. For example, human and animal manure can be returned to the soil to enabled agriculture to continue to be productive. Applying sewage sludge is another method currently used for returning nutrients to agriculture, although there are safety concerns about the process (Déry and Anderson, 2007). Other possible methods include: using composting toilets, composting organic waste, diverting urine, more efficient application of fertilizer, and developing technological innovations (Déry and Anderson, 2007).

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