How Might We Be Fed? Part One

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This is a guest post by Phil Harris, a plant scientist based near the Scottish border in the UK. He has worked for government agencies in such areas as food safety and plant quarantine. Since 1997, he has worked amid the agricultural results of system-collapse in ex-communist countries of Europe.

While there has never been more food around, modern production is not really a 'success' story. In the face of a long term decline in fossil energy, there is significant doubt whether production relying on nitrogen fertilizer can ramp-up to feed the expected world population, or can even maintain existing levels. Similarly, in almost wholly urbanized industrial countries, 'Western' production equates to mechanized farming, which requires very significant fossil fuel. Future problems are potentially exacerbated by the spread of the up-market 'Western', urban, dietary pattern. Already much of global primary calories and protein are diverted to the meat sector. In addition, this dietary pattern exacts a high price on health. In this post (part 1), I discuss these and related issues.

Through the years, most of the world has lived in village ecosystems, and produced most of its food locally through those ecosystems. An important part of this farming is recycling the nutrients and exporting only relatively little outside the system, unlike the demands made on farming by our urban world. In Part 2, I will talk more about village ecosystems, and will discuss approaches that might be used to overcome deficiencies of our current system.

Western food and the spread of cancer and cardiovascular disease

'Western' eating is bizarre in historical terms, and contrasts with remaining large agrarian populations that must rely on mostly vegetarian diets. By comparison, we appear embedded in an atherogenic (arterial plaque inducing) and carcinogenic system. We cannot just blame smoking.

The world database GLOBOCAN reveals startling differentials in incidence rates. For example, in countries such as Bangladesh or Sri Lanka, incidences of prostate and colorectal cancers (necessarily age-weighted for comparison) are very low. In many of the OECD countries, incidence is more than an order of magnitude higher. Colorectal cancer rate in Czech Republic is 34 per 100K males compared with 0.6 in Bangladesh. Modern 'western eating' has horrible downsides as well as a few advantages.

This presentation provides a review from the point of view of Japan of diet-related world cardiovascular morbidity. Death rates from heart disease are far lower in Japan, China, and Hong Kong than in much of the West. The big decline in death rates from heart disease is at least partly due to a reduction in smoking.

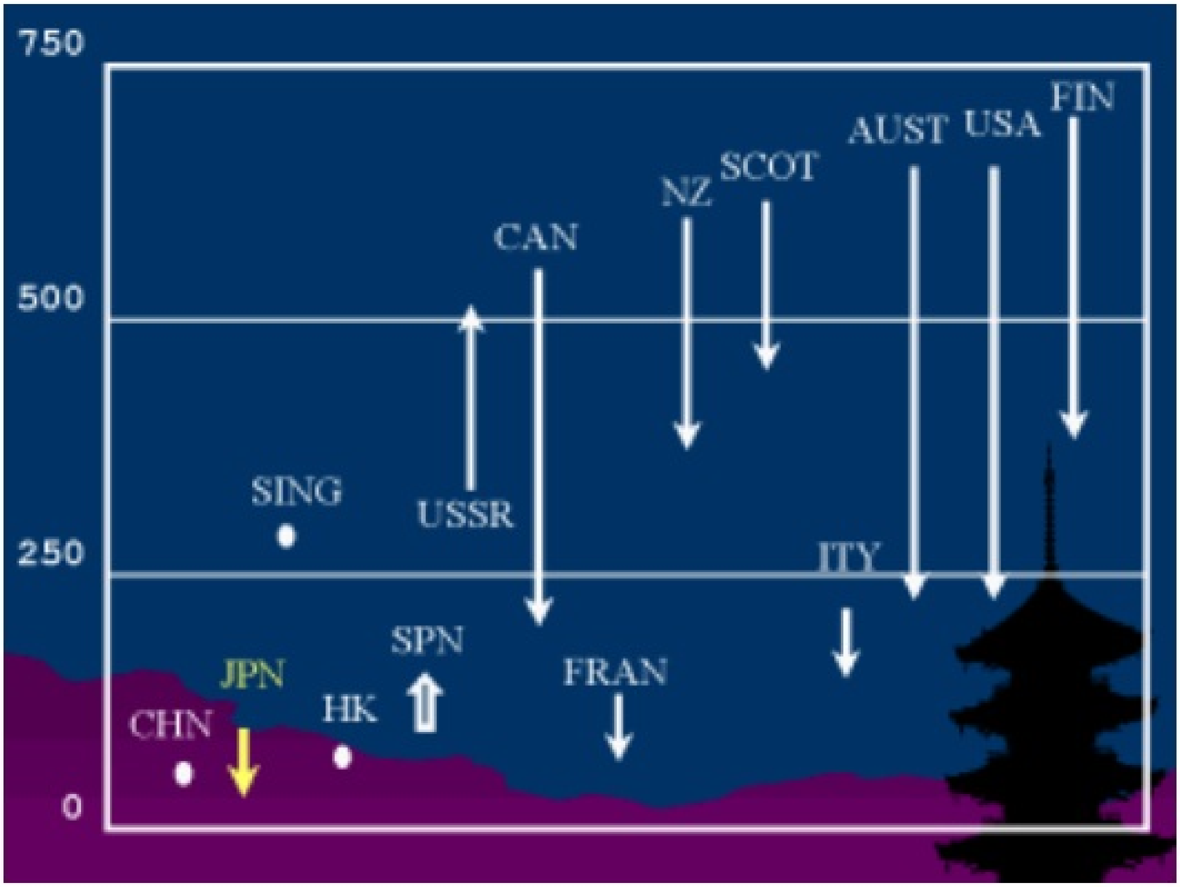

Figure 1. Death Rates for Coronary Heart Disease by Country Men Ages 35-74, 1970 and 1993 (Rate/100,000) Source NIH AUST: Australia, CAN: Canada, CHN: China, FIN: Finland, FRAN: France, HK: Hong Kong, ITY: Italy, JPN: Japan, NZ: New Zealand, SING: Singapore, SCOT: Scotland, SPN: Spain From here.

Modern agriculture depends on huge amounts of fertilizer, requires pesticides and in fully industrialized countries is almost wholly mechanized.

Modern agriculture as developed in the 'West' requires large amounts of fertilizer and other critical 'system-ingredients' including pesticides. Much of the rest of the world in recent decades has also significantly increased production using these inputs, and must rely on fertilizer, even in countries where the total requirement for fossil energy, fuel and fertilizer, and for example, herbicides, can be significantly lower than required for a Western farm.

Since the 1960s, new varieties of cereal have enabled much larger yields because they can use higher soil nitrogen N (NH_4 and NO_3 ions maintained in soil solution), and thereby make use of more synthetic N fertilizer. According to a publication of the International Fertilizer Industry Association, nitrogen fertilizer production requires perhaps 5% of world natural gas; 1.2% of total energy.

The energy budget for a fully mechanized crop is difficult to compute, but one example in Scotland suggests that N fertilizer accounts for 10 – 43% energy input into oil seed production on any one farm. A lot of energy is used directly by machinery. Farming in fully industrialized countries is almost wholly mechanized. In favorable locations high yield modern cereal crops require >200kg/ha N fertilizer. In the box, I provide more detail for particular crops.

Wheat

World record wheat yields, Scotland, Denmark, New Zealand are around 15t/ha. Average wheat yields in parts of Europe, e.g. France, UK, have reached more than 7 – 8t/ha, using high NPK fertilizer inputs from world sources: based on map from here.

Wheat however can also be grown economically in areas where yields are inherently limited, and fertilizer input correspondingly lower. Mechanization allows vast areas to be cultivated at a lower intensity, in much of the USA wheat lands (and in Australia). In parts of USA wheat is often optionally used as a forage crop for livestock.

The limiting factor for wheat yield is usually soil moisture, or the combination of higher temperature and lower moisture, not the input of fertilizer. Average 2007 US yields were ~40bu/acre, (2.6t/ha) and in Montana rarely reach a potential of 70 – 80bu/acre (5t/ha). In Nebraska an irrigated crop could use N at 150kg/ha, but dry-land crops mostly need <112kg/N. Similarly, for the other key fertilizer components. Although wheat responds to an increase in available phosphate (P) during early growth, US farmers often minimize inputs: “All soils are not phosphorus deficient for wheat, so good soil sampling and testing are necessary to minimize unnecessary phosphorus applications and to maximize profits, according to this University of Nebraska publication.

“Most Nebraska soils have enough potassium (K) for maximum wheat production, according to another University of Nebraska publication.

Corn

Corn, like sugar cane, is more photo synthetically efficient than other grains, and is a high yielding carbohydrate (‘energy’) crop with lower protein content. In the US ‘heartland’, fertilizer input and yields for high-yielding corn (maize) are comparable with high-end world standards. USA in 2007 averaged 148bu/ac, 9.9t/ha, with some Iowa yields >13t/ha comparable with 5 year averages for corn in highest yielding EU countries; Netherlands, France, Belgium (see previous link for EU).

This Iowa State Extension Service publication provides a readable description of nitrogen requirements for Iowa corn and the rather complex interaction of fertilizer, crop and soil nitrogen residues. About 180 lb/ac (~200kg/ha) fertilizer N per acre is required for a high 200bu/acre (13.4t/ha) yield. This document is also helpful for those interested in the issue of replacing the amounts of soil nutrients inevitably ‘exported’ off-farm. For instance, it looks at yields after a few years without N fertilizer. Yields continue, but at a much lower level, and in Iowa are down to a quarter.

Even when rotated with the soybean legume that self-fixes N, corn yields are half normal peak values. For P & K the fertilizer ‘budget’ this publication indicates the following: “Phosphorous and potassium varies from state to state or region to region. One bushel (27.2kg) of corn generally has about 0.4 lbs of P2O5 and 0.350 lbs of K2O

> [6.7kg and 5.8kg per metric tonne]. However fertilizer recommendations will not exactly follow these nutrient removal benchmarks. Proper soil testing along with fertilizer recommendations is necessary for proper fertilizer application.
>
> **Soybeans**
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> In the United States, soybeans are most commonly grown in a crop rotation with corn. This can give a year's break from fertilizer, but not pesticide applications, according to Agricultural Production Management: AREI, 2006 Edition.
>
> > "Soybean pesticide use (nearly all of which are herbicides) ranks second only to corn. Commercial fertilizer was applied to less than 40 percent of soybean acreage, a much lower rate than for most row crops (e.g., corn and cotton). Unlike other crops, soybeans can fix their own nitrogen and require minimal nitrogen fertilizer.

The globalizing Western food pattern requires a large amount of grain to be fed to livestock, making feeding the world's human population more difficult.

Cereal grains are increasingly used for livestock feed. Most, for example, of the huge USA corn (maize) and soybeans crops goes for animal feed. When this use is combined with the increased demand for biofuels, it puts a serious strain on resources such as fertilizer that underpin grain supply. Asia—with 57% of the world's population--is now attempting to adopt more of a Western style diet as well. This pattern is not sustainable, especially if oil and natural gas supplies are expected to decline over the long term.

According to Dyson 1999, World food trends and prospects to 2025:

> ...roughly half of the world's cropland is devoted to growing cereals. If we combine their direct intake (e.g., as cooked rice or bread) with their indirect consumption, in the form of foods like meat and milk (about 40% of all grain is currently fed to livestock; ref. 3), then cereals account for approximately two-thirds of all human calorie intake. ... "

> "Although the U.S., Canada, and Australia together contain less than 6% of the world's population, they currently produce about 20% of the global cereal harvest." [This raises questions on how it is used, and future dependability.]

Current world cereals: Production and Trade

Current world cereals production approaches 2200Mt on a rising trend. Production varies significantly from year to year, as shown in the graph below. The rise in the last few years is essentially driven by the biofuels and meat sectors.

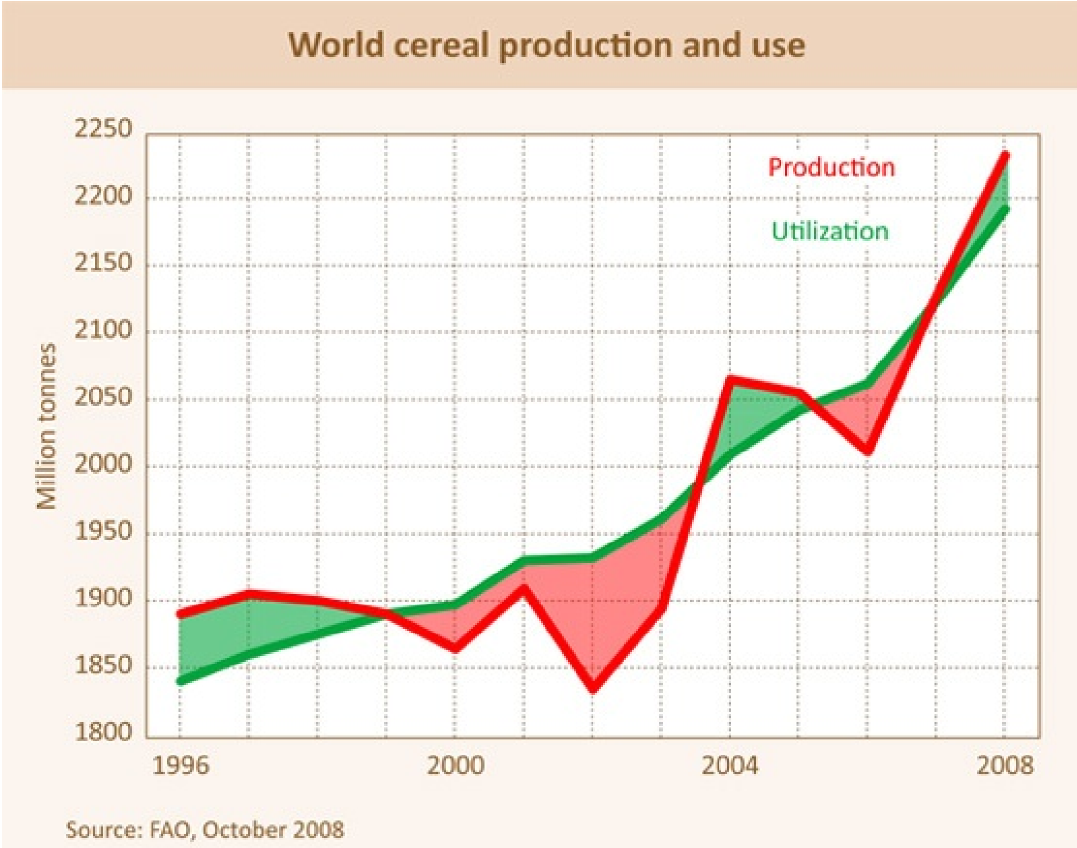

Figure 2. Slide from publication of International Fertilizer Industry Association, based on data of Food and Agriculture Organization of the United Nations.

While population continues to grow, and food use by animals increases, there are likely to be regional shortages of affordable fertilizers, and increasing food scarcity.

The Western part of world food is especially dependent on fossil fuels for long distance transport as well as for highly mechanized production.

Most of the world, even now, produces food near where it is eaten. Much of Asia more than kept up with population, increasing per capita cereals production between 1970 and 2000. Only around 12% of total world major cereals (wheat, maize (corn), rice, barley) is internationally traded. The amounts traded vary greatly from product to product and location. In general, much more of the food generated by Western agriculture is traded internationally than is the case across the rest of the world. For example half of US wheat is exported. Similarly 43% of US soybeans and soy product are exported, mostly for livestock. The EU imports a very large 80% of non-cereal primary protein required for animal feed, e.g. soybeans. Production and consumption, however, of cereals in situ in much of the world remains relatively vast compared with international trade, and uses less fossil fuels.

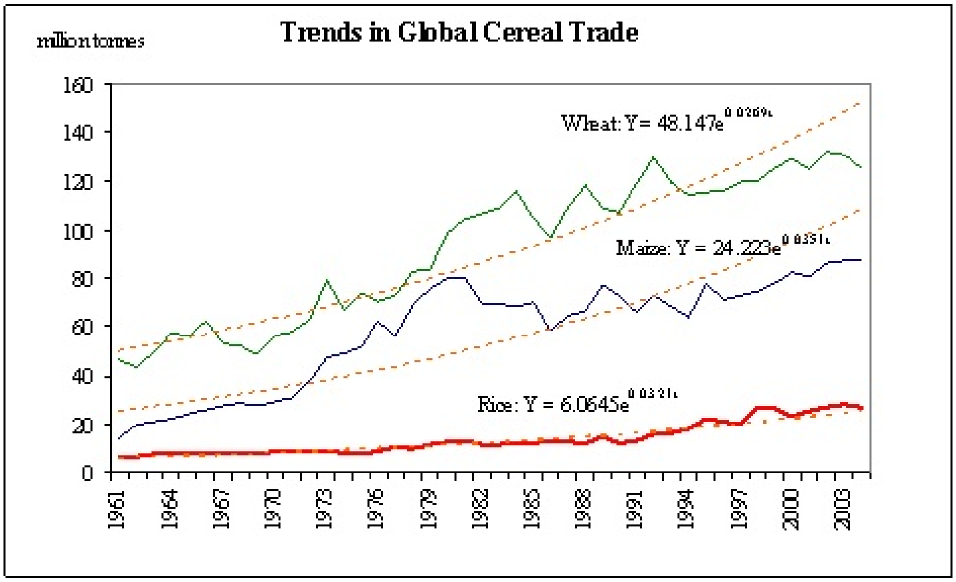

Figure 3. Growth in Trade of Grain from Food and Agriculture Organization of the United Nations.

According to information published by the International Grains Council, since 2005, production of the major grains have ranged thus: wheat 598 – 687Mt; maize (corn), 696 – 787Mt; barley 134 – 156Mt; rice 424 – 429Mt. For these major grains, the amount internationally traded is little more than 258Mt or 12% of production (see also graph above). For wheat the proportion is around 17% and ~10% for maize. Rice is internationally traded at much lower percentages, although the trade has more than doubled in recent decades.

Fuel oil is vital especially for the Western food system. It is needed for transport of resources, for cultivation, harvest, drying/storage, as well as processing, packaging and refrigeration and transport to market of food products. There are some uses we don't always think of. A farmer in England tells me that if his John Deere equipment breaks down the parts are flown the same day from Texas.

Fertilizer Production – all that natural gas

Industrialization requires competitive bulk transfers of commodities and economies of scale to minimize unit-costs. Natural gas - or coal-bed methane, or gasified coal – appears less than 'fungible'. The regional nature of gas supplies (and cost structures) has exerted a major influence recently on N fertilizer production in for example both the USA and China.

US manufacture has been usefully reviewed already by Neal Rauhauser here, (including possible renewable energy for ammonia production). A recent USGS analysis of US nitrogen fertilizer supply can be found here. N fertilizer production in the USA has been reduced significantly over recent years in the face of imports.

In China, because of changes in cost-structures ('marketization'), urea produced from coal has oscillated in competition with urea made from natural gas, in this case even within a single country, according to this article. "While natural gas is the major feedstock internationally, China has been using coal as feedstock for 70% of its urea production, due to the country's particular energy structure of coal-rich but gas-poor. Prioritization appears to have been difficult, (see oddball but fascinating fragment here), but China's investment in manufacture of fertilizer in Mongolia near to gas supplies, and forward investment in possible coal-bed methane, speaks of strategic needs.

The attempts of China to secure P&K supplies - as well as soybeans - outside the country appear ongoing. Interestingly half the most recent growth of fertilizer use in China was for horticulture and fruit, according to a publication of the International Fertilizer Industry Association. Will we see a future reversion to austerity or ongoing development following an 'American' model?

What is ahead?

Perhaps we can get some insight regarding what is ahead by looking at Dyson's forecast from 1999 and what has actually happened in recent years. Dyson focused on cereals because they provided two thirds of human calorie intake. His conclusion was cautiously optimistic and was based on region by region analysis including previous per capita increases achieved to 1999 across large parts of Asia. He estimated that 3 billion tons of grains could feed around 8 billion by 2025. He projected increasing cereals yield productivity in EU/Former Soviet Union and North America/Oceania and a broadly 'adequate' world production, relying on a doubling of total synthetic N fertilizer use.

His caveats included inter alia weather-induced harvest volatility in North America already observed by 1999, to which presumably we can now add similar worries over Australia and others. Dyson was pessimistic for Sub-Saharan Africa. He expected South Asia to remain largely vegetarian on a not necessarily adequate diet, and China to largely feed itself, but said of China, "... as everywhere, socio-political stability will be a crucial ingredient for continuing food security."

Are Dyson's projections bearing up? Total cereals are up if erratically ~16% in 10 years; latterly driven essentially by bio-ethanol and meat sectors, according to Outlook for World Fertilizer Demand, Supply, and Supply/Demand Balance by Patrick Heffer, Michel Prud'Homme of the International Fertilizer Industry Association.

EU cereals and USA corn and to certain extent soybeans yield/hectare continue to improve. Significant fertilizer is now used in fruit & horticulture: massively so in China recently (IFA 2008).

According to The Fertilizer Institute, world nitrogen demand grew by 17 percent, phosphate demand grew by 18 percent and potash demand grew by 23 percent from fiscal year 2000/2001 to 2006/2007. China, India and Brazil are the three largest contributors to the growth.

Thus, cereal grains are not rising as rapidly as Dyson predicted, but fertilizer use is still growing rapidly. With the growth in biofuels and meat, much of the additional grain does not proportionally feed more people.

Trends have been driven by profitability, and in the USA most of the monetary value of agriculture is 'up-market' in the livestock sector. Slightly over half is provided by livestock, slightly less than a quarter by horticultural crops and, less than a quarter by primary production, grain and oilseed crops (the remainder comes from cotton and other commodity crops).

Expanding the global 'business as usual' approach appears to guarantee poor success in the future.

Are there other other approaches that are more sustainable, that can be expected to provide adequate food on a hungry planet? In Part 2, I will examine some options that might lend themselves toward a long term strategy for food security.