The Limits of Energy-Based Agricultural Systems and the "North Korean Food Crisis"

Abstract

In recent years it has become clear that inadequate energy supplies are the immediate cause of the collapse of DPRK agriculture. Loss of soil fertility through economic mismanagement and the inability to trade on the world market for energy has made it impossible to maintain the domestic modern agricultural system and this has resulted in the inability of the DPRK to continue to provide sufficient food for its population through domestic production. This paper shows how shortages of commercial energy have a direct influence on the productivity modern agricultural systems.

1. Purpose

The purpose of this paper is to draw attention to the fragility of modern industrial (chemical- and fossil fuel-based) agricultural systems. If the timely supply of commercial inputs is disrupted, especially when this results in a shortage of energy (fossil resource) inputs over an extended period of time, agricultural systems are liable to catastrophic collapse, resulting in food shortages. The recent experience of the Democratic People's Republic of Korea (DPRK, North Korea) is examined in order to focus attention on the relevant aspects of this problem.

2.2 Overview of the DPRK Energy Crisis

The DPRK is heavily reliant upon indigenous sources of power, predominantly coal and hydropower, and has no known reserves of oil or natural gas. Since the end of the Cold War, major shortages have become chronic for all forms of modern energy supply, with petroleum products, coal, and electricity all reduced by more than 50% since 1990. These shortages have in turn affected all sectors of the economy, especially transportation, industry, and agriculture. The energy crisis is a result of the loss of subsidized Soviet oil imports, failure to maintain and modernize energy infrastructure, the impacts of natural disasters, and inefficiency in energy production and end use.

During the Cold War, the DPRK received heavily subsidized oil supplies from the Soviet Union. In 1990, crude oil imports amounted to about 2.5 million tons, from 3 sources: the USSR, the PRC, and Iran, and a further 600,000 tons of refined petroleum products such as diesel and gasoline from China. Crude oil delivered by tanker was refined at Raijin, and at the terminus of a pipeline from China. With the collapse of the USSR in 1990, subsidized oil supplies to DPRK and other former client states such as Cuba were curtailed. Unable to import oil at market prices, imports from Russia soon fell by 90%, as did imports from the Middle East. China is now the main supplier of oil to the DPRK, oil imports in 1996 being around 40% of their 1990 level (around 1.1 million tons). Imported oil, limited to non-substitutable uses such as motor gasoline, diesel, and jet fuel, accounts for about 6% of primary energy consumption.

In the same time period, coal supply fell 50% from around 34 million tons in 1990 to around 17 million tons in 1996. Electricity supply fell 52% from around 46 billion kWh in 1990 to around 24 billion kWh in 1996. Total estimated consumption of commercial energy in the DPRK fell by about 51% during the period. Biomass use is estimated to have risen about 8% from around 22.3 million tons to around 24 million tons in the same period. It is estimated that the transportation ability for the main forms of transportation for goods in the DPRK, electric and diesel trains, and diesel trucks fell to 40% of it's 1990 value by 1996. Iron and steel production is estimated to have been reduced to 36% percent of 1990 levels by 1996, cement production reduced to 32% in the same period.

In 1997, coal accounted for more than 80% of primary energy consumption and hydropower more than 10%, with hydroelectric power plants generating about 65% of North Korea's electricity and coal-fired thermal plants about 35%.

To summarize (see Table 1), the shortage of one relatively small but key element in the DPRK energy mix, imported oil, appears to have set off systematic shockwaves throughout the DPRK economy, causing a more than 50% drop in all economic activity, even in something as basic as food production. *What may well have occurred (although there is little direct evidence to back this up) is that a substantial proportion of the imported oil was being used to operate the coal mines. When the import of that oil ceased, the operation of coal mines became immediately problematical, causing the production of coal to plummet to half of its previous value.*

Table 1: DPRK Energy Situation 1990 and 1996

	units	1990	1996	1990 (PJ)	1996 (PJ)	96/90 %	% total 90	% total 96
Crude oil	million tons	2.5	1.1	114.3	50.3	44.0	9.9	8.8
Refined products	million tons	0.6	0?	27.1	0.0	0.0	2.4	0.0
Coal	million tons	34.0	17.0	928.2	464.1	50.0	80.8	81.3
Hydroelectricity	billion kWh	22.0	15.6	79.2	56.2	70.9	6.9	9.8
TOTAL				1148.8	570.5	49.7	100.0	100.0
Electricity (total)	billion kWh	46.0	24.0	165.6	86.4	52.2		

Note："Electricity (total)" here refers to electricity generated from coal, and thus is shown for reference and not included in the energy total.
The following conversion rates were used to convert between differing energy units (http://www2.dti.gov.uk/epa/annexa.pdf)
Electricity: 1 kWh = 0.0036 GJ
Coal: 1 m.ton = 27.3 GJ
Crude oil: 1181 liters/m.ton
Crude oil: 45.7 GJ/m.ton
Crude oil: 1 barrel = 159 litres
Crude oil: 1 barrel: 0.1346 m.ton = 6.15 GJ
Sources as in text.
Generation of hydroelectricity in 1990 is estimated from http://www.eia.doe.gov/emeu/cabs/nkorea.html
Generation of hydroelectricity in 1996 is calculated as being 65% of the total of generated electricity.

3. The Collapse of Modern Agriculture in the DPRK

3.1 The Collapse of Motive Power: The Substitution of Human and Animal Labor for Machines and Commercial Energy

Agriculture in the DPRK has been organized as co-operative and state farms and has concentrated mainly on the production of rice and maize. Since the 1950s, modernization of agriculture has been carried out through the promotion of irrigation, electrification, chemicalization (fertilizers, pesticides, herbicides, and so on) and mechanization. The seventies and early eighties saw fruition of these efforts, irrigation reaching 70 percent or more of the cultivated land by 1970; a total of 75,000 tractors as well as transplanters, threshers, trucks and other farm machinery were provided; rural electrification covered all rural areas by 1968; and fertilizers and other chemicals became available in large quantities.

Since the early 1990s, resource constraints brought about by an ailing economy, as described above, made it difficult to continue to provide previous levels of inputs, making it impossible to maintain land and labor productivity given the high input-based agricultural system which had been built up. Much of the agricultural machinery and equipment was purchased in the 1950s and 1960s and is now obsolete and/or in a very poor state of repair due to the inability to purchase or manufacture sufficient spare parts. It is estimated that 80% of the 3 million hp (2,200 MW) of motorized capacity in the DPRK agricultural sector was inoperable at the end of 1998.

Fuel to operate the machinery for critical mechanized operations has also become exceedingly scarce. Based on typical consumption rates of 110-140 l/ha/yr for rice and maize, annual fuel requirements for DPRK farms have been estimated at 140,000 tons of petroleum products, mostly diesel fuel. In 1990, DPRK agriculture is estimated to have used at least 120,000 tons of diesel fuel. Following the crisis, this declined to between 25,000 and 35,000 tons in 1996 and 1997. Total diesel supplies have fallen from 750,000 tons in 1990 to around 300,000 tons per year since 1996. Military allocations have remained almost steady at 160,000 tons, leaving only 140,000 (roughly equal to the annual requirements for agriculture alone) for all other allocations, resulting in a severe reduction in diesel fuel allocations to agriculture.

During field visits, the October 1998 FAO/WFP Mission saw a large proportion of tractors, transplanters, trucks and other farm machinery lying unused and unusable, as well as harvested paddy left in the fields in piles for three weeks or more, resulting in large post-harvest losses. Decreasing ability to carry out mechanized operations (including the pumping of water for irrigation), as well as lack of chemical inputs, was clearly contributing to reduced yields and increased harvesting and post-harvest losses.

Energy has been a critical factor in the operation of the irrigation system of the DPRK. Water is pumped into the main canals and reservoirs, but scarcity of fuel has made it impossible to guarantee timely supplies of water to the irrigation system. Around 1 million ha of rice, maize, and other crops are irrigated through more than 10,000 km of canals and pipes by more than 30,000 pumping stations, mostly electrical. UN irrigation experts estimate the electricity requirement for the DPRK averages 1,200 kWh/ha/yr, representing an annual national requirement of 1.2 billion kWh. 1n 1996, this figure was 0.9 billion kWh, a 300 million kWh (25%) shortfall for irrigation pumping. With 24 billion kWh of electricity generated in 1996, it might appear that the DPKR could reassign power from other sectors to agriculture. However, over half of irrigation pumping takes place in May. Peak pumping power demand during this period is at least 900 MW. Total national generating capacity in 1996 was 4.7 GW. With an average capacity factor of 0.65, the average generating capacity online was 3.1 GW. After transmission and distribution losses of 19 percent are accounted for, irrigation pumping demand represents over one-third of all of the DPRK's generating capacity! The 25 percent shortfall in electricity for irrigation pumping leads to a comparable shortfall in irrigation water provided to crops, decreasing crop yields. The condition of canals and pumping stations has also been severely affected by natural calamities, while the pumping stations and steel pipes used in the system have suffered from a lack of spare parts and poor maintenance. The breakdown of the irrigation system due to lack of spare parts and electricity shortages has been a major factor in the severe deterioration in rice production.

Total agricultural electricity requirement is estimated at around 1.7 billion kWh, some 460 million kWh being required to operate electrical machinery other than irrigation pumps. A further 1.2 billion kWh is required for domestic, public and commercial uses in rural areas, bringing the grand total of electricity required in rural DPRK to 2.9 billion kWh/yr. In the late 1990s, the actual supply was estimated at 1.9 billion kWh, a shortfall of roughly 1 billion kWh, agricultural uses receiving around 1.3 billion kWh and other uses being reduced by half to 0.6 billion kWh. Household coal consumption for cooking, heating, and preparing animal feed has declined on average by 40 percent. Where access to biomass as a substitute fuel is also limited, impacts on health and quality of life are likely severe. Public buildings such as schools and hospitals often have limited coal supplies. In some areas, relief workers have reported significant health effects from waterborne diseases, due to the lack of fuel to boil water.

In order to maintain agricultural production despite the declining availability of machinery and equipment, it has been increasingly necessary to perform operations by the use of manual labor and work animals. In the late 1980s, it was thought that approximately 25% of the civilian workforce was engaged in agriculture, and by the mid-90s this appears to have risen to about 36%, a rise of around a million people. The additional labor required to compensate for the lack of mechanized inputs is conservatively estimated at a minimum of 300 million person-hours per year. This could easily be supplied by the extra million people in the rural workforce. The June 1998 FAO/WFP Mission observed large numbers of the non-agricultural population, including school children, assisting with land preparation, planting and weeding activities. In October 1998, the Mission observed people carrying bundles of harvested paddy on their backs to threshing stations and school children collecting grains around the harvested crop bundles in the fields. Nevertheless, it has proved impossible to perform all operations previously carried out by machinery simply by use of manual labor or work animals (e.g. plowing, pumping of water for irrigation, harvesting, threshing and so on). Thus the timely and effective scheduling of farm operations, particularly at peak times around harvesting and planting of double crops, has been severely affected, reducing productivity and increasing post-harvest losses. Work animals have been increasingly substituted in operations previously carried out using farm machinery, but this is still quite limited due to low numbers of animals available. This practice is also problematical since animal health is poor due to lack of feed, the provision of which could lead to competition with humans for the use of arable land.

The dominant use of biomass fuels is for household cooking and heating. In 1990, it is estimated that rural sector biomass fuel consumption was 22.7 million tons. Since that time, biomass consumption has risen by an estimated 1.3 million tons per year to make up for shortfalls in coal and other fuels. The rise in biomass fuel consumption is cause for concern because of the burden it places on competing uses, such as animal fodder and compost, that in turn impact food supplies. Increased biomass harvesting also impacts rural ecosystems such as forests, streams, and croplands by reducing ground cover, disrupting habitats, and increasing soil erosion and siltation.

3.2 The Collapse of Soil Fertility: Mining the Soil

Modern agriculture relies on steady inputs of inorganic chemical fertilizers. For grain crops under North Korean soil and growing conditions, the amount required is 400-500 kg/ha of the basic macronutrients nitrogen, phosphate, and potassium (NPK). UN and DPRK agricultural experts estimate the total North Korean requirement at 700,000 tons/year (NPK). The actual bulk amount of fertilizer required to achieve this goal could range from 1.5 to 2.5 million tons year, depending on the nutrient contents of the different fertilizers employed (for example, urea contains more than twice the amount of nitrogen per ton that ammonium phosphate contains). The DPRK historically manufactured 80-90 percent (about 20 percent of phosphate fertilizer, and all of potassium fertilizer, not produced domestically, were imported) of its own fertilizer.

Prior to the current energy crisis, North Korean fertilizer production is estimated at 600,000 to 800,000 tons per year (NPK). Whether production fell steadily during the 1990s (Fig. 2), or precipitously around 1994 as North Korean government figures show, is uncertain. What is certain is that since 1996, domestic production has been less than 100,000 tons per year, and that even with aid and foreign purchases total availability between 1996 and 2002 was below 200,000 tons. Aid and foreign purchases have brought the 2003 total to 244,512 tons, still only about 35% of the amount required. The drastic decline in fertilizer production is a result of fertilizer factories being out of operation or operating at minimal levels. This is due at least in part to the poor condition of Soviet-built plants, which has been blamed on natural disasters. The DPRK has three fertilizer factories, at Namhung in the southwest and Hungnam and Aoji in the east and northeast, capable of a total annual production of over 400,000 metric tons of nitrogen nutrient. This would be sufficient for self-sufficiency if the plants were able to run at capacity. The important nitrogen fertilizer plant at Hamhung has been inoperable since at least 1994, and the DPRK government has requested international assistance to refurbish the plant. In addition to problems of damage or disrepair, however, the energy crisis affects fertilizer production in several important ways. The North Korean fertilizer industry uses coal as both energy source and chemical feedstock. Coal is hydrogenated (hydrogenolysis) to produce hydrogen, which is then reacted with nitrogen from the air to produce ammonia, the basic chemical starting-point for nitrogen fertilizers, through the Haber-Bosch synthesis. The amount of coal required to produce 700,000 tons per year (NPK) is estimated at 1.5 to 2.0 million standard tons of coal per year. (approximately 60:40 fuel:feedstock) This represents around 10 percent of the available annual coal supply, a very significant fraction and thus in competition with other high-priority uses. More important, transporting up to two million tons of coal represents a serious strain on the transportation system, especially the railways, which are already suffering from severe electricity shortages. The transportation bottleneck also limits the ability to ship fertilizer - another 1.5 to 2.5 million tons in bulk - from factories to farms. It was estimated in 2000 that freight shipments by ship, rail, and truck in the DPRK had declined by 55 percent, 60 percent, and 75 percent, respectively, since 1990. For these reasons, even if the DPRK's fertilizer plants were refurbished or rebuilt, energy shortages would continue to pose a serious constraint on domestic fertilizer supply.

Due to the fertilizer shortage, DPKR agriculture operated at 20 to 30 percent of normal levels of soil nutrient inputs between 1996 and 2002 (Fig. 1). This shortfall is the largest single contributor to reduced crop yields, and thus to food shortages. Soils in the DPRK are being heavily mined of nutrients, as more nutrients are being extracted than replaced. According to the DPRK Ministry of Agriculture, 244,512 nutrient tonnes of fertilizer were used in agriculture in DPR Korea during 2003 (Table 4), compared with only 189,000 tonnes in the previous year. Most was provided as humanitarian assistance by the Republic of Korea, the European Union, FAO and various NGOs. Just over 32,000 nutrient tonnes were produced in the country, and 37,706 nutrient tonnes were imported commercially. Of the total used, 68 percent was nitrogen, mostly in the form of urea; 15.5 percent was phosphorus; and 16.5 percent was potassium.

Table 2: DPRK fertilizer use (nutrient m.t.), 2003

N	P	K	NPK Total
166,438	**37,875**	**40,199**	**244,512**

Source: UN, FAO, Oct '03

The modern system of intensive agriculture introduced in the DPRK between the 1950s and 1980s enabled the continuous production, including double-cropping, of cereals, but has resulted in soils highly depleted in natural nutrients. Rotational systems including fallowing or planting with leguminous crops have been abandoned, as has largely the practice of using organic fertilizers. These systems can, of course, be reintroduced and would be expected to raise yields as they help to revive soil fertility. These are, however, systemically complex, long-term measures which can only be reintroduced with careful consideration for the overall productive capacity of the DPRK's agriculture, the ability to import substantial quantities of food, existence and location of relatively large numbers of livestock, availability of surplus organic matter (e.g. not in competition with livestock feed or biofuel production!) and so on. For the time being the DPRK remains heavily reliant for its food supply upon chemical fertilizers, which must either be manufactured at considerable energy and raw material cost or imported.

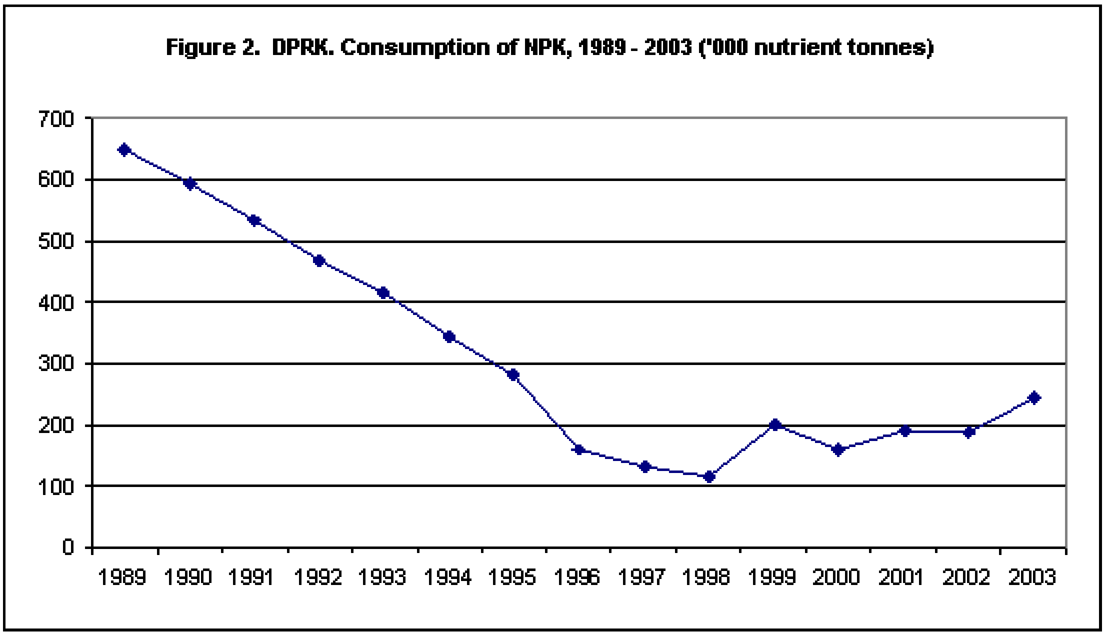


Figure 1. (ignore the original caption)

3.3 The Collapse of Cereal Production

The staple foods of the DPRK are rice and maize, and these crops are the main food grains produced in the country, accounting for about 1.2 million hectares of the country's total arable land of about 2 million hectares. Rice is grown predominantly in the southern plains, while maize is grown generally on sloping ground. Rice is transplanted from mid-May to early June, harvested from late September to October, and is almost totally irrigated. Maize is largely rainfed, planting being carried out from mid-April to early May, harvesting coming between the end of August and mid-September. Irregular or poor rainfall will therefore affect maize more than rice. Whereas the 1997 drought devastated maize production, rice production has been adversely affected by breakdowns in the irrigation system, as mentioned above. There has been a shift in recent years away from the cultivation of maize in favor of potatoes on low yielding and vulnerable (easily eroded or degraded) sloping land. This shift has been in the region of 110,000 hectares. Double-cropping of maize and potatoes has also been reported, the area planted being around 77,000 hectares.

Statistics showing approximate cultivated land areas and food production derived from FAO reports follow. Table3 shows land classification of arable land cultivated to paddy and maize in the DPRK in 1998 and gives a rough idea of total areas under these two main crops.

Table 3: Classification of Rice and Maize Areas Cultivated (1998)

Land type	Rice		Maize		Total Area
	Area (ha)	%	Area (ha)	%	
Good: Class I	188,000	32.4	202,000	32.1	390,000
Moderate: Class II	195,000	33.6	195,000	31.5	390,000
Poor: Class III	197,000	34	229,000	36.4	426,000
TOTAL	**580,000**	**100**	**626,000**	**100**	**1,206,000**

Source: FAO, 1998/11, Section 3.7.1
Notes:
Class I Lands: Flat and/or leveled, good soil, irrigated, farm machinery and equipment routinely used.
Class II Lands: Flat or undulated (gradient 0 to 10 degrees), irrigated or unirrigated, good to moderate soil, farm machinery and equipment often used.
Class III Lands: Sloped and hilly (flat for paddy), no irrigation except for paddy, unsatisfactory soil, farm machinery or equipment not normally used.

Table 4 shows estimated cereal production and availability for the 1999/2000 marketing year. Total arable land area available for food crops, approximately 1.4 million hectares, is shown.

Table 4: DPRK Cereal Area and Production, 1999/2000

Crop	Area (1000 ha)	Yield (m. tons/ha)	Production (1000 m. tons)	Total Cereal Area (1000 ha)
Rice (unhulled) [A]	580	4.04	2343	580
Maize [B]	496	2.49	1235	496
Potato (2000) [C]	180	10.07	1813	180
Wheat and Barley, double-cropped (1999-2000) [D]	123	1.96	241	123
Other cereals [E]	20	1	20	20
Rice in milled equivalent[1] [F]			1523	1399
Potato in cereal equivalent[2] [G]			453	
Total Production (cereal equivalent) [B+D+E+F+G]			3472	

[1] *Milling rate of 65 percent* [2] *Potato to cereal equivalent 25 percent (4:1)*
Source: FAO, 1999/11, Section 3.4 (Total production later revised to 3,421,000 m.t.)

Table 5: Total Cereal Equivalent Production, Requirement, and Import Requirement of DPRK 1989 to 2004 (1,000 m.t.)			
Year	Total	Required	Shortfall
1989/99	*6735	*5500	-1235
1995/96	4007	5478	1471
1996/97	2874	4808	1934
1997/98	2838	4674	1836
1998/99	3783	4823	1040
1999/00	3421	4751	1330
2000/01	2573	4769	2196
2001/02	3657	4957	1300
2002/03	3969	5011	1042
2003/04	*4156	*5100	944

Total = Total production of maize, milled rice (and potatoes converted to cereal equivalent from 1999 onward)
Required = Cereal required for food and feed use, seed requirement, other uses, and post-harvest losses
Shortfall = Import requirement to cover cereal production shortfall
* = estimated
Sources: UN Special Reports on FAO/WFP Missions to the DPRK, June 1998 to October 2003

Table 5 gives approximate production figures for cereals (as defined in Table 4) for the crop years 1989 /90, and from 1995/6 to 2002/3, plus an estimate for 2003/4 (the figures in Table 5 correspond to those shown in Figure 2). It is clear from the table and the graph just how much staple grain production declined in the DPRK, from being more than a million tons in surplus in the late 1980s to being more than a million tons in deficit in the mid-1990s. A comparison of Fig 1 (fertilizer availability) with Fig 2 and 4 (cereal production) suggests that there is a strong correspondence between fertilizer availability and cereal production. It appears that in the mid- to late 1990s, food production in the DPRK fell to about 45% of that of the 1980s (approximately the same level as the availability of commercial energy resources), and that it cannot regain its former level without the revival of substantial inputs of chemical fertilizer and the restoration of the former mechanical capacity of DPRK agriculture.

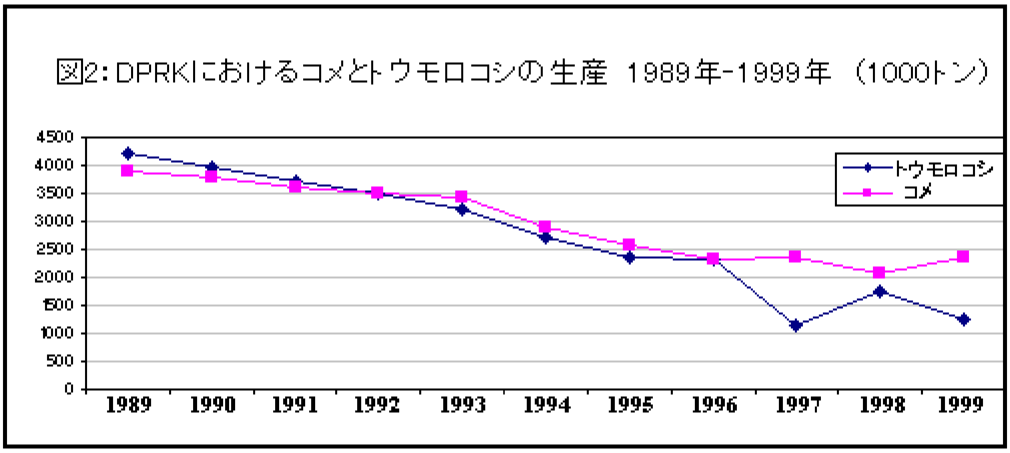
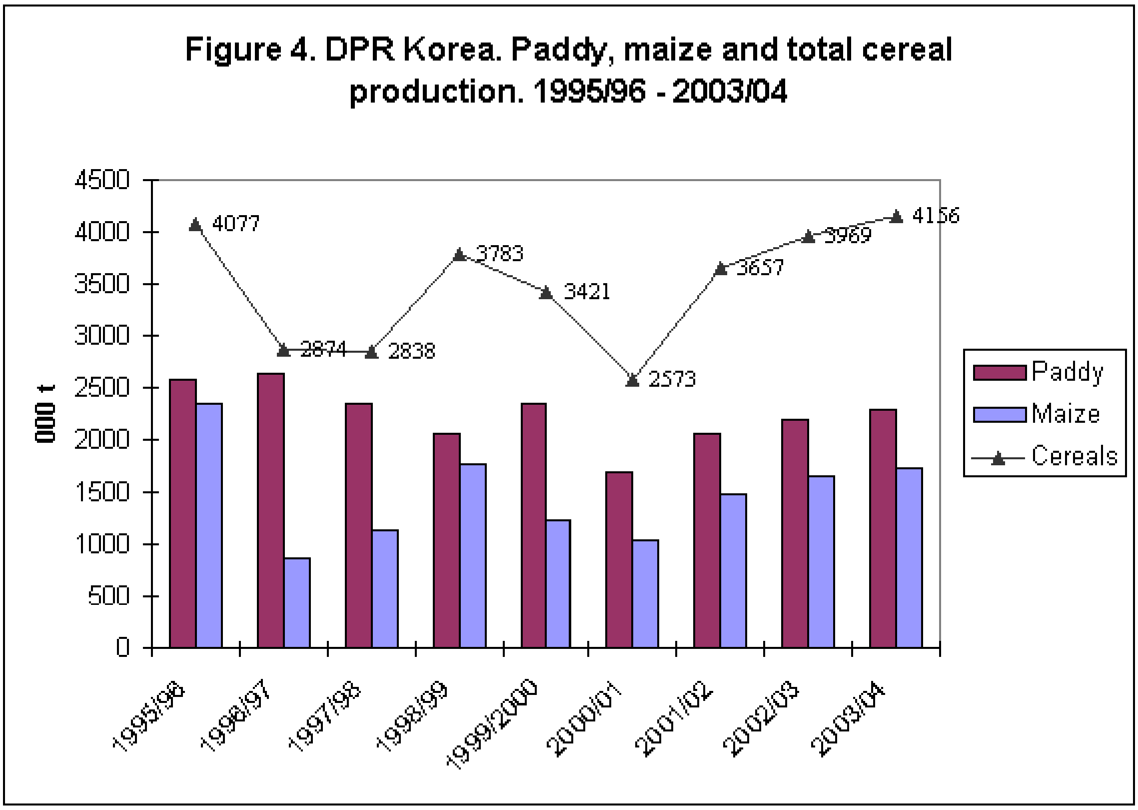


Figure 2 – Rice and maize production in DPRK, 1989-1999 [in 1000 tonnes]
Blue = maize, red = rice (value for rice is "unmilled")



3.4 The Collapse of Food Security: Malnutrition

4. Conclusion

The FAO Reports make several recommendations for agricultural rehabilitation in the DPRK. These can be summarized briefly as follows:

1. Recovery of chemical fertilizer production through rehabilitation of the DPRK fertilizer factories.
2. Rehabilitation and expansion of the irrigation system (pumps, pipes, drainage networks) and further emphasis on flood management.
3. Implementation of crop diversification should be carried out to reduce the emphasis on monocropping, enhance soil productivity in the long run and reduce risk of crop losses due to adverse weather conditions.
4. Research into effective crop rotation schemes including leguminous crops to promote soil fertility and productivity.
5. Research on seed improvement, and early and short-maturing and less chemical fertilizer dependent crop varieties.
6. Research and development of integrated crop and livestock systems.

Recommendations 1. and 2. depend heavily on the ability of the DPRK to develop its economy in the future. Naturally, if the DPRK is capable of achieving that (by no means mean) feat, restoration of motive power in the countryside will also take place. Recommendations 3. to 6. suggest a strong emphasis on what now generally comes under the rubric of "organic farming". With a high population to arable land ratio, as in the DPRK, intensive cultivation and increased land productivity (higher yields) are the only way to increase food availability, if we assume that substantial food imports and population reduction are not realistic options. Further, high rates of application of chemical fertilizers and other agricultural chemicals, usually combined with mono-cultures of grains, may exacerbate soil degradation and erosion, ultimately resulting in lower yields despite high levels of commercial inputs. ***Finally, the answer must be to attempt the transition to intensive organic agriculture; low levels of use of commercial energy sources and chemicals, a tight recycling of nutrients in combination with other methods of maintaining soil fertility, such as rotational systems, diversification of crops and the development (return to!) integrated crop and livestock production systems.*** This has been attempted fairly successfully in Cuba in recent years.

More generally, we can say the following concerning the **cause** of the DPRK food crisis:

Inability or unwillingness to participate in the global trading economy can cause difficulties in maintaining levels of commercial inputs necessary for continuous operation of a modern food producing agricultural system.

The experience of the DPRK, and perhaps Cuba, points to several **closely interlinked lessons** that need to be learned by countries which currently operate a modern industrialized agricultural system based on commercial chemical and energy inputs. Agriculture has now become simply one adjunct of the overall economic-industrial matrix of the human global social-economic entity. This matrix is a highly complex web of financial and industrial relationships backed up by fairly precisely timed operations, such as transport of raw materials, fuel, components, and so on. Adjuncts to the matrix are therefore sensitive to disruptions and other irregularities. Thus the modern agricultural system can very quickly get into deep trouble if we do not have the ability to:

1. fuel, maintain, repair, and replace agricultural and distribution-related machinery and infrastructure (trucks, tractors, transplanters, harvesters, irrigation pumps, fuel and chemical delivery systems, and so on)
2. fuel, maintain, repair, and replace factories and factory equipment for the manufacture of vital agricultural machinery and inputs, e.g. regularly replaced items such as spark plugs and filters, spare parts, fertilizers, herbicides, pesticides, plastic sheeting and so on.
3. ensure trade and transportation arrangements for steady supplies of fuel, raw materials, and feedstocks for agricultural operations and inputs, such as petroleum, natural gas, coal, potassium and phosphorus minerals, and so on.

Again, the final answer is to convert to ***low-input, yet land and labor intensive, organic farming***. Crucially, this would require perhaps a ten to twenty year transition period; something the DPRK has not had the luxury of.

As a final general statement, it can be said that once a country takes the decision to abandon traditional agriculture and switch to a modern agricultural system (a mechanized system making use of commercial chemicals and fuels), then in order to maintain food production levels it is essential to ensure that levels of fuel and other inputs are maintained, and that machinery and equipment is kept in good working order. Shortages of fossil resources (oil, natural gas and coal) can result in productivity collapses when soils are mined, and eventually destroyed, due to crop production without replacement of essential nutrients, and where agricultural machinery and equipment can no longer be kept operational because of lack of fuel and maintenance.

A transition to organic and/or traditional and sustainable forms of agriculture is not easily carried out in a short period of time (for instance due to lack of livestock and lack of sufficient numbers of farmers with the requisite knowledge and skills). Meanwhile the population must be fed; a population that has ballooned on food produced by the modern industrial agricultural system that has been built up thanks to fossil resources. This is now the paradoxical complex of problems faced by almost all of the world, including the great food-producing areas of North America, Europe, South America and Oceania; the central element that has made high agricultural productivity possible, oil, is at the same time responsible for the deterioration of our most important resource, soil fertility. How do we now ensure the maintenance of that high productivity in the face of future energy shortages? The end of cheap and abundant oil and other fossil resources, symbolized by the peak in conventional oil extraction, probably to occur during the first decade of the 21st century, means the end of our current methods of food production and thus it possibly spells the end of advanced industrial society as we know it. *The DPRK is an exceptional case only in the sense that, due to political miscalculation and mismanagement of its economy, it has manifested these symptoms before fossil resource shortage becomes a serious concern for most of the world.*

Bibliography:

Australia, (Department of Foreign Affairs and Trade) DFAT - Country Information - Democratic People's Republic of Korea - Economic Overview (http://www.dfat.gov.au/geo/dprk/dprk_brief_economic.html)

Eberstadt, Nicholas, *The End of North Korea*, The AEI Press, 1999

FAO, GLOBAL INFORMATION AND EARLY WARNING SYSTEM ON FOOD AND AGRICULTURE WORLD FOOD PROGRAMME, SPECIAL REPORT: FAO/WFP CROP AND FOOD SUPPLY ASSESSMENT MISSION TO THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA, 1998-2003: (http://www.fao.org/giews/english/alertes/sptoc.htm)

(30 October 2003: http://www.fao.org/docrep/006/j0741e/j0741e00.htm)

Rosset, Peter, and Medea Benjamin (eds.) The Greening of the Revolution -- Cuba's experiment with organic agriculture, Ocean Press, 1994

Smil, Vaclav, *Global Population and the Nitrogen Cycle*, Scientific American, July 1997, pp.76-81

Williams, James H., David von Hippel, Peter Hayes, Fuel and Famine: Rural Energy Crisis in the Democratic People's Republic of Korea, Institute on Global Conflict and Cooperation, IGCC Policy Papers, Paper #46, March 2000, (http://repositories.cdlib.org/igcc/PP/pp46)

Units

bbl	barrel (oil)
cap	capita, person
GJ	Giga Joule (10^9 Joules)
ha	hectare (10,000 m^2)
kg	kilogram
kWh	kilowatt hour
m	million (10^6)
MJ	Mega Joule (10^6 Joules)
m. ton	metric ton (tonne)
PJ	Peta Joule (10^{15} Joule)
tN	metric ton of Nitrogen
$	US Dollar, unless stated