

RURALISATION A WAY TO ALLEVIATE VULNERABILITY PROBLEMS

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1. INTRODUCTION

1.1. The first lesson: You shall not be dependent of a storage

A long, long time ago, about 2000 million years, the storage of organic material in the primeval soup started to end up. This was a deadly threat to the life on Earth, since it consisted mainly of methanogenic protobacteria. This threat, however, was averted by the emergence of photosynthetic bacteria, which was able to synthesize new organic material from scrap. A by-product of this conduct, however, was a deadly gas, oxygen, but the biosphere learnt to cope with that too.

The anaerobic methane gas producing ecosystems prevailing during Archeozoicum, the first billion years of life on Earth, was not sustainable. It was dependent on a stock of organic material in the primeval seas. When that stock was exhausted, the entire global system was threatened. The solution was the introduction of photosynthesis, which was a dreadful experience to most of the inhabitants of the ancient biosphere, but actually saved the situation for some more billions of years.

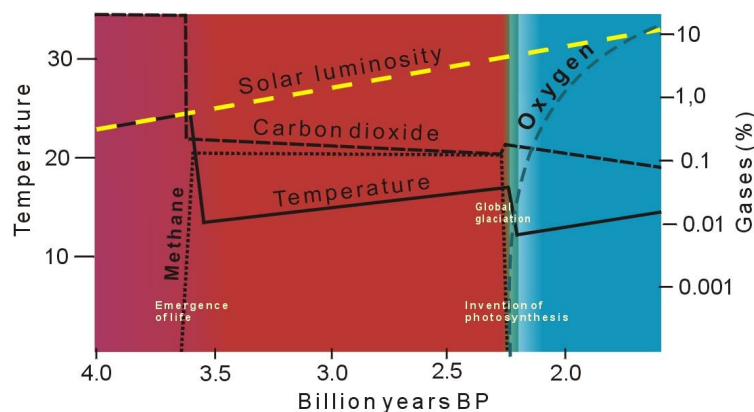


Figure 1. Global catastrophe associated with the formation of an anaerobic atmosphere

1.2. Sustainability is a multi-level concept

Sustainability is a multi-level quality, where some of the constituting quality levels are more basic than other. Basic qualities must be fulfilled if higher-levelled qualities can have any influence on the sustainability of the system. If a basic quality is not fulfilled, the fulfilments of less basic qualities are not enough, albeit sophisticated or well-developed.

To explain the concept of multi-levelledness of sustainability, compare the concept 'seaworthiness', which is also a multileveled quality. The most basic need for

seaworthiness of a ship is that it doesn't sink. Next, it should stand the weather prevalent on sea. If it can't float, weather resistance is superfluous. On the next level, navigation capacity is necessary, and so on. *To be of use, all new qualities need the fulfilment of those more basic.* The same thing goes for the concept of sustainability. Some qualities are basic, other are necessary, but not basic. All the basic qualities must be fulfilled for a higher levelled quality to have any effect. It must also be understood that sustainability is a long-term concept. One hundred years of sustainability is not worth the name.

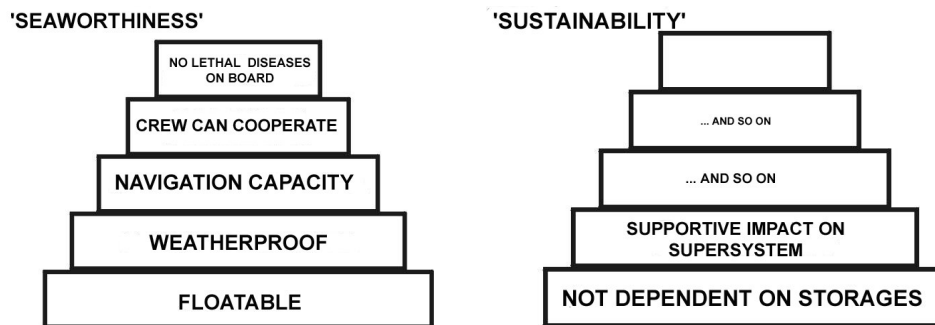


Figure 2. Correlation between Seaworthiness and Sustainability

Another basic requirements for a sustainable society is the capacity to be of supportive value to its supersystem, e.g. the ecosystem it inhabits. This is a clue to understand the long-term sustainability of some 'primitive' societies.

1.2.1. One basic factor for sustainability: Stock independence

A society that is dependent on a certain stock in order to survive can per definition not exist longer than the stock. Therefore, it is not sustainable. Our current human system has in the course of a mere two hundred years become addicted to a stock of energy from fossil fuels. The decline of this supply poses a genuine threat to the society as we know it.

It is high time to seek a solution for escaping this blind alley. Basic for our current society is also mineral stocks. Most of them can be substituted in different ways, but some are critical. Among the critical are the nutrients that have no important gaseous phases, which mean that they can be depleted. (Nutrients with gaseous phases, like nitrogen, can be extracted from the atmosphere.) Shortfall of non-volatile nutrients are however quite rare, since most of them are common in the Earth crust. One exception is phosphorus. Phosphorus is about ten times more common in our bodies than in the Earth crust. This means that we always have to concentrate phosphorus from the surroundings. Lack is imminent.

1.2.2. The other necessity: Support your support system

Another requirement is; To be sustainable, any society or group of organisms need to have some form of supportive effect on the supersystems, the ecosystem(-s), that provides its life-support services. If not, it takes up the attitude of a cancer towards the system, and the effect of such an attitude is the annihilation of either the supersystem or the subsystem, both of which is lethal for the subsystem. The necessity of a supportive relationship towards the supersystem is imperative. A third approach toward the supersystem is possible, in between the parasitic or mutualistic alternatives; to be strictly neutral (having no negative nor positive impact on the supersystem), but this attitude is dangerous, since the subsystem in this case has no eligibility in its supersystem.

1.2.3.Sustainability can only be defined by its absence

Like many scientific theories, sustainability is easiest to test with the help of zero-hypotheses (If this requirement is not fulfilled, is the system still sustainable?). By that method, “sustainability” does not need to be defined in a general way (What is sustainability *per se*?), but any factor can be tested on the general sustainability of the system. This method is used to identify crucial factors for sustainability in this study.

2.STOCK DEPENDENCE: ANNIHILATING SUSTAINABILITY

2.1. Stocks of fossil fuels

2.1.1.The energy slave concept

Most of the activities we take for granted in a modern society require a lot of exosomatic energy (i.e. energy that not emanates from your own body is put into a process). To perform such tasks you need some kind of slave-energy. The Romans had human slaves, but slaves eat food too. When the slave-food energy needed to produce and transport the food for the population of Rome constituted a substantial part of the entire amount of food produced, the empire had no survival capacity any more. Because of the limitation of transport, the support area of the city of Rome was limited to North Africa and the countries around the Mediterranean, regardless of the introduction of energy saving transport methods as sailing-ships and the like. This brought about the end of the Roman empire.

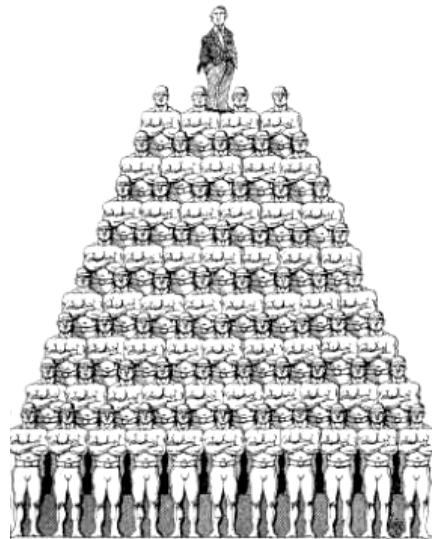


Figure 3. Master and slaves.

In our days, the use of humans as slaves has been abolished. But still, work need to be done, and in a much larger scale than during the Roman Empire. Instead of human slaves, we use mechanical ‘energy slaves’¹, powered by fossil fuels. Beside the advantage of not complaining and making uprisings, they have a further advantage: The do not eat. The food for these slaves is inedible oil, coal or gas, stuff that is extracted from seemingly endless sources.

¹ An ‘energy slave’ is here defined as 1000 kWh of work. This is about the metabolic energy used by one person in a year.

However, the extraction, refining and distribution of fossil fuels still need energy, “eating”, which actually brings about a limitation to the extraction of existing resources. If the mineral can be considered as an energy resource, the sum of the extraction energies must not exceed the energy content of the extracted material. (The rabbit limit: If you live off rabbits, you can not invest more energy in rabbit hunting than the energy content of the rabbits you hunt down. Or, more scientific: To be an energy source, EROI, (*Energy Return On Investment*), can not be lower than 1.)

Globally, every person owns about 8 (7.8) oil-slaves per person. The liquid fuels are the most essential, since nearly all transportation runs on liquid fuels, i.e. oil. Furthermore, however, there are about 11 more slaves of the gas, coal, nuclear and other types². This slave-ownership is however very unevenly distributed throughout the world. The USA, for example has only 4% of the world population, but uses around a quarter of all energy slaves. This gives the US population about 117 slaves per person. Even there, the distribution is very uneven ...

The ‘energy-slave’-ownership is the background of the tremendous success (?) of our current, urbanised society. We can maintain cities far larger than Rome ever was. We can transport foodstuffs for ourselves or our livestock all over the world without even thinking of it. (Just consider the accumulated transport distance of the meal you just ate!) We transport ourselves widely, often hundreds of miles. The food is transformed and distributed in a wayward manner, often using more than ten times the energy contained in it. We have a tremendous success in creating new techniques, and, worst of all, we have become accustomed to this energy use to the extent that we don’t even perceive energy use. We take it for granted, as people in slave-owner cultures often took human slaves for granted.

2.1.2. Energy, cheap or expensive?

If you ask a car-owner in the USA if \$5 per gallon of gasoline is expensive, he would agree totally. If you ask a European car-driver the same question, he would say it is cheap. Energy price is hard to calculate. The price for gasoline at the tank station changes at a nearly daily basis, as does the salary for the person who buys it. Therefore, it is hard to say if the energy is ‘cheap’ or ‘expensive’ if different times or places are compared. One way to reduce this problem is to calculate how long time a certain person has to work in order to get a certain amount of energy.

The result of such a calculation is shown in Figure 4, where the price for gasoline (in SEK/kWh) in Sweden is divided with the salary (in SEK/hour) of a ‘general’ worker in Sweden. Here, it is possible to estimate the availability of energy in the form of gasoline for the worker as the work time needed to buy one kWh (in hr/kWh, or s/kWh). The working time needed to purchase one kWh of gasoline in 1995 has diminished to about 0.1 of the time needed about 1920; i.e., the availability of energy has increased ten times. Whether it can be considered cheaper or not is still a matter of opinion.

² The 1999 world energy use was 382 quadrillion BTU [19]. This corresponds to $1.12 \cdot 10^{11}$ ‘slaves’. Assuming a 6 billion ($6 \cdot 10^9$) population, this gives you 18.65 ‘energy slaves’ per person.

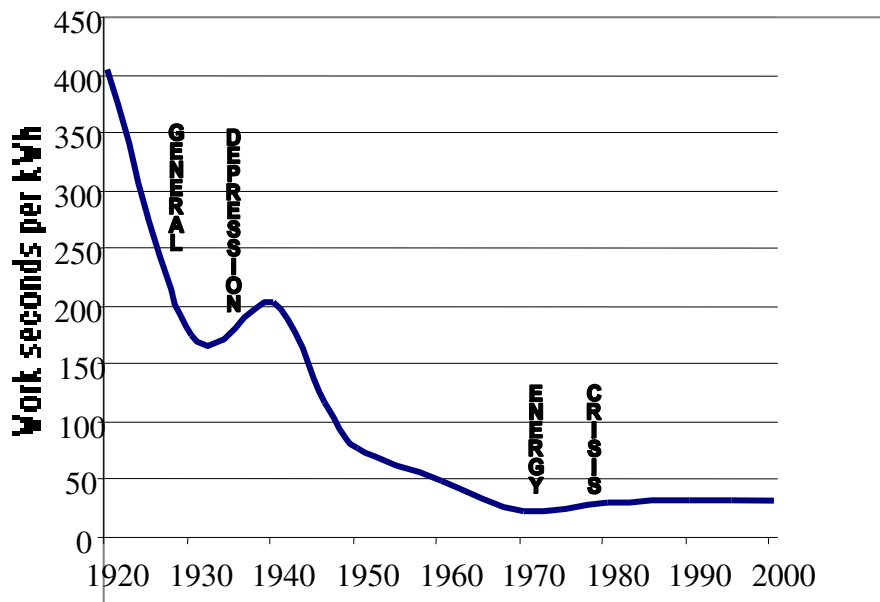


Figure 4. Energy price, calculated as work time per kWh, has diminished about ten times between 1920 and 2000. This also means that the access to energy has increased a tenfold. Note the events ('general depression', 'energy crisis') during energy price increases

The sudden price increase when demand exceeds fuel availability is referred to as a "crunch". Crunches has already occurred [28]. It can be experienced either as an increase in the (numerical) price of energy or as an economic recession. One or both. In both cases, however, the availability of energy decreases.

2.1.3. The Peak

When the extraction of fossil energy is close to its midpoint, even intense extraction efforts will result in a decline in the total extraction ([3]; [4]). The situation, when there is an absolute, unrecoverable, decline in extraction capacity is referred to as "the peak" (Figure). Naturally, the 'peak' will precipitate a 'crunch', but any increase in demand over the extraction capacity will induce a crunch, which might be a transient situation, as opposed to that after the peak.

According to the graph in Figure 5, assuming a rise in demand 1% annually, the peak could be estimated to occur in 2012. In a crunch of this magnitude, it is easy to imagine the decimal point on the gasoline pumps moving one or several steps to the right.

The annual demand increase of 1% assumed in this scenario (conservative, IEA, estimates 1.5% [7]) will result a resource chasm of around 15 billion barrels of oil equivalents per year around 2020. To fill up the demand gap by 2031, about 6,300 new nuclear reactors are needed, and a new annual production of an additional 520, about twice a week. Some observers claim that what we are looking at in this curve, is the end of the world as we know it (Duncan and Youngquist, 1999).

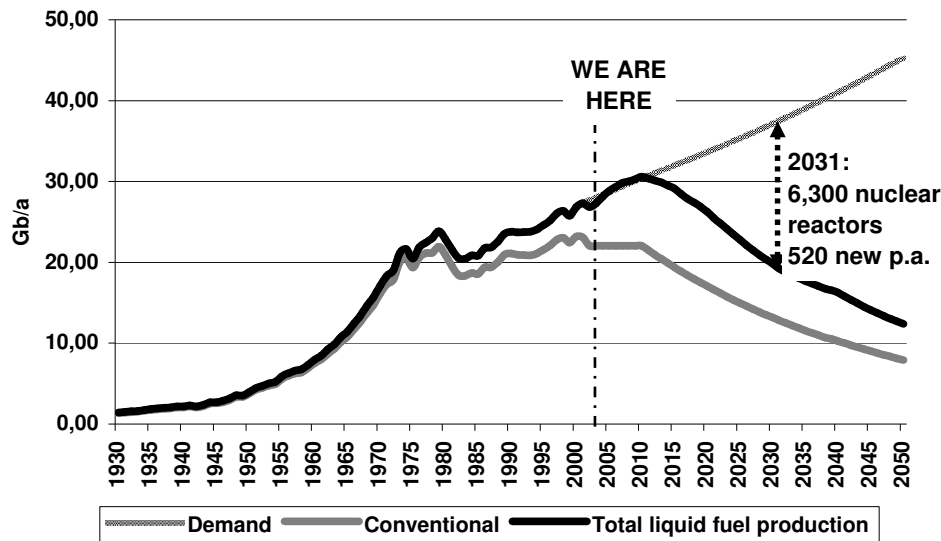


Figure 5. When the extraction of oil not longer can meet the demand around 2012, a sharp increase in price might be expected. The theoretical demand is assumed to increase 1% annually after 2004. Data from C. Campbell 2003. The calculations are made by the author

2.1.4. Food system problems

Since practically all modern activities are based on cheap fossil liquid energy, a sudden price increase (or rather: availability decrease) would affect almost all the way of living as we know it. I will not elaborate this, it is done elsewhere. I will, however go into detail somewhat in another basic sustainability problem; Food supply. All societies are dependent on agricultural production somewhere. Today's agriculture is heavily dependent on fossil fuels.

Half a century ago, it was still common for farms in Western Europe to grow a large part of the feed for their animals and to keep a wide variety. Cows, pigs, horses, geese and chicken could be found on the same farm, together with a variety of crops and refinement procedures. Today, this situation is very rare. The farmers are forced by the increased price for their inputs and the decreased price for their produce to focus on products that can be produced in large quantities to a low unit cost. Rather than managing the land, a farmer now runs a company. State subsidies, together with the entrainment of firms into a new infrastructure, have intensified this specialisation, which has lead to a decrease in diversity, reduced resilience and a decrease in number of production units and support units. In such a situation, the importance of the distribution system increases. Transportation lines are longer, which is a well-known way to increase vulnerability.

In developed countries, the input of fossil fuel energy to agriculture equals, or surpasses, the output of energy in the food supplied for human consumption [17]. This is why industrial agriculture has been described as a black box for converting fossil fuel energy into edible food energy . The implicit assumption underlying this conversion is that fossil fuel and the other necessary inputs will always be so cheap that they will not increase food prices beyond what the public can afford. The auspex for this is discussed above (2.1.2 - 2.1.3). A large-scale system dependent on specialised units and long-distance transportation systems is not only more likely to fail compared to one with

shorter transportation lines and more self-sufficient production units, supplied with solar derived energy, but also, the effects of failure will be more severe. Generally, the development of specialised breeds of animals and plants has increased the energy dependency of farms. The improvement of animals and plants to industrial food production in has itself also led to an increased vulnerability to energy price increases.

Consider a ‘wild’ wheat plant. It has to carry out a substantial amount of work in order to flourish, grow, and maintain itself. What is left over of the collected solar energy is used to produce seeds. In modern agriculture, cultivars have been developed – to be lazy! With the help of fossil fuels, the farmer conducts a lot of the work that wild plant has to do using solar energy. By this, more of the solar energy collected by the ‘improved’ plants is transformed into seeds, although the capacity of the improved plant to collect solar energy has not been increased.

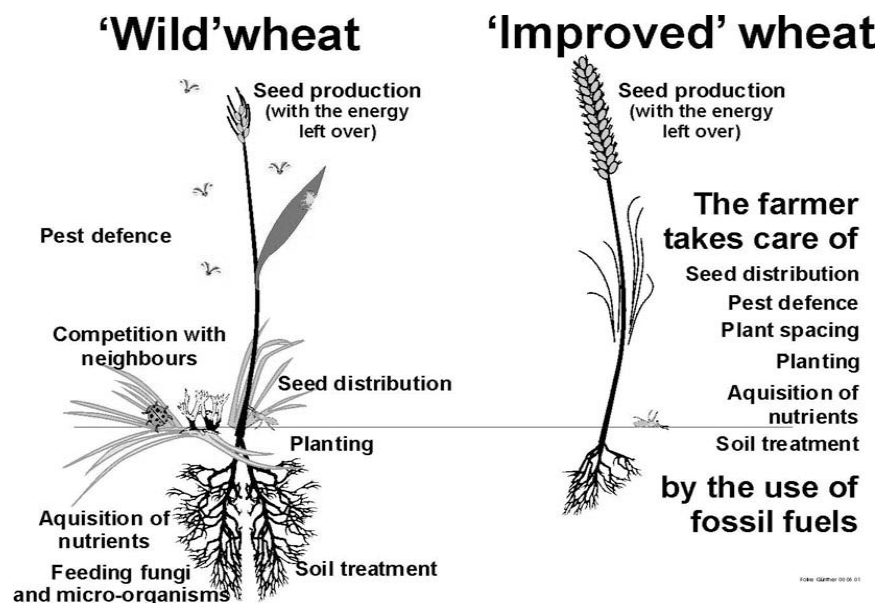


Figure 6. In order to survive and propagate, a wild plant has to carry out a considerable amount of work with solar energy acquired. Only a fraction of this is carried out by the domesticated plant. The rest is made by the farmer, with the use of fossil fuels. This means that the domesticated plant can put much more energy into seed production

The same thing goes for domesticated breeds of animals, not just plants. The tendencies mentioned have increased the agriculture’s dependency of a safe and steady supply of cheap energy and a well-functioning transportation infrastructure.

2.1.5. North Korea (DPRK)

North Korea (DPRK) is an excellent example of the effects of fossil fuel addiction and depletion. Together with Cuba (3.1), it can be considered a full-scale experiment on what happens when an industrialized nation is depleted of the access to cheap energy and imported industrial services. From the 1950s, modernisation of the agriculture in DPRK has been carried out through the promotion of irrigation, electrification, chemicalisation (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 about 1970; and fertilizers and other chemicals

became available in large quantities[8]. 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 resulted in soils highly depleted in natural nutrients. Rotational systems including fallowing or planting with leguminous crops were abandoned, as largely the practice of using organic fertilizers.

Following the collapse of the Soviet Union, DPRK exports to Russia fell by 90%. By 1996, oil imports amounted to only 40 percent of the 1990 level. DPRK then turned China for the bulk of its oil needs. However, China announced that all commerce with DPRK would be settled in hard currency beginning in 1993, which was impossible for DPRK. China also cut its shipments of “friendship grain” from 800,000 tons in 1993 to 300,000 tons in 1994 [2],[31]. On top of the loss of oil and natural gas imports, DPRK suffered a series of natural disasters in the mid-1990s that acted to further weaken an already crippled system. It was estimated that by the end of 1998, 80% of the motorized capacity in the DPRK agricultural sector was inoperable [8]. It is estimated that grain production in the DPRK in 1999 was approximately 40% of what it was ten or more years previously. Former DPRK Korean Workers' Party secretary for international affairs and president of Kim Il Sung University Hwang Jang Yop, who defected to South Korea in February 1997, publicly estimated in March 1999 that the death toll in the DPRK food crisis had exceeded three million people.

DPRK has still not recovered from the shock of oil depletion and losses of its connections with supply-providing countries. However, its government still exists and the crisis prevails, although some international aid efforts have been done.

It is interesting to compare the development of DPRK to that of Cuba (3.1), which was largely in the same situation in the eighties. Although a large part of the population of DPRK lived in urban areas when the crisis was experienced, this part was not mobilized for support of the population with agricultural products by other methods that the conventional, but continued to decrease. (Figure 7)

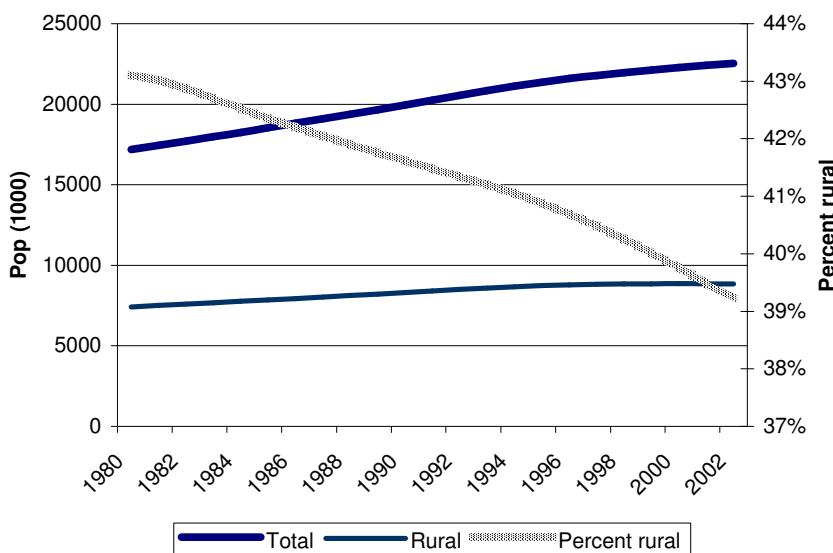


Figure 7. Throughout the crisis, the part of the population living in rural areas of DPRK constantly decreased, as contrasted to that of Cuba (Figure)

2.2. Stocks of non-gaseous nutrients, Phosphorus

2.2.1. Phosphorus is the most crucial nutrient

Of the non-volatile nutrients, phosphorus is the most important due to the difference in concentration in the Earth crust and in biological systems³. Whereas other non-volatile nutrients are more abundant in the crust than in biological systems, phosphorus is both essential in biological systems (DNA, ATP), and is needed in much higher concentration than its existence in the crust. Consequently, phosphorus need to be concentrated from outside the organisms, and a lack of availability is immediately reflected in its vigour.

2.2.1.1. Constant input of phosphorus from storages, a necessity for modern agriculture

The necessity of constant import of nutrients is a well-known fact in agriculture. Import of phosphorus from mining is a part of the agricultural system. However, the extractions of any mineral from mines follow these rules:

Extraction of any mineral is an energy demanding process.

The more of the mineral that is extracted from an ore, the more energy per new amount is needed (the law of diminishing returns).

In the case of phosphorus, this means that the extraction horizon at a certain energy price is limited. At current prices, the extraction horizon can be estimated to about 130 years. At a higher energy price, the economically possible extraction horizon will come closer. Furthermore, when the phosphorus ores will become less workable because of depletion, the yield per effort (YPE) will diminish, i.e. the next lot of extracted phosphorus will need more extraction energy than the previous. The combined effect of this is that the availability of mined phosphorus will not diminish proportionally to the increase of energy prices, but hyper-proportional [15]. Hence, there is an urgent need to find other methods to maintain productivity.

2.2.2. Wastewater management system and nutrient availability

A way to diminish the looming problems of nutrient shortage in agriculture would be a careful recycling of the nutrients used, back to agriculture. However, there are two severe obstacles to this:

2.2.2.1. The MIFSLA attitude

The MIX-First-Separate-Later (MIFSLA) approach to waste water management has led to a system that may be described in the following way (The greyscale of the bars is related to the pollution, the height to the amount):

Clean water is mixed with urine and faeces and becomes a polluting mixture of plant nutrients and pathogens. This mixture is in turn mixed with fairly clean grey water. This mixture is commonly called waste water or sewage.

The resulting mixture is diluted by drainage water (about 200 l/pers/day) in an extensive web of sewage pipes. All this is purified in the waste water plant, i.e. some of the components are solidified and converted to sludge.

The purified mixtures quality is comparable with that of the original grey water, but with double the volume compared to the original waste water. (Figure 8)

³ For a comparison, see <http://www.seafriends.org.nz/oceano/abund.htm>

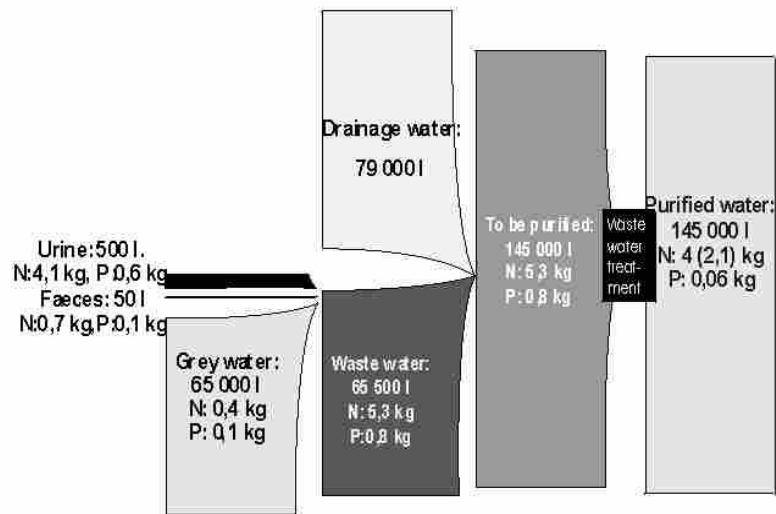


Figure 8. The MIFSLA attitude in waste water treatment. Nutrients are dissolved in large quantities of water, making them extremely expensive to recover

By the repeated mixing, the nutrients in the waste water are exceedingly complicated to recycle. This situation is further aggravated by the HEAP trap (2.2.2.2). The sludge produced by the MIFSLA system is deposited in a limited area around the densely populated areas, out of reach for recycling.

2.2.2.2. *The HEAP trap*

When food (and feed) items are transported over long distances, e.g. from a far-away agriculture to a city, or from a feed producing farm to a farm with animal production, nutrients accompany the substances. In the goal area, the items are broken down by humans or animals into nutrient-rich waste. This waste, either as manure or sludge from wastewater treatment plants is not transported back to the source area, but deposited in the goal area. This gives rise to an accumulation of non-volatile nutrients

When the accumulation has progressed, leakage from the area will occur. Since the accumulation still goes on, the leakage will increase until the leakage equals the imported amount. At this point, the goal area functions as a flow-through zone. Nutrients are inevitably lost [12]. This is referred to as the HEAP effect (Hampered Effluent Accumulation Process) (Figure 9).

The MIFSLA approach and the HEAP effect are detrimental to efforts to recycle phosphorus. Since they are related to the structure of a society, they can not be solved with technical methods (actually, any effort to increase the efficiency of the waste water treatment plants will increase the speed if the HEAP build-up). Instead, system-structural methods must be used to alleviate them.

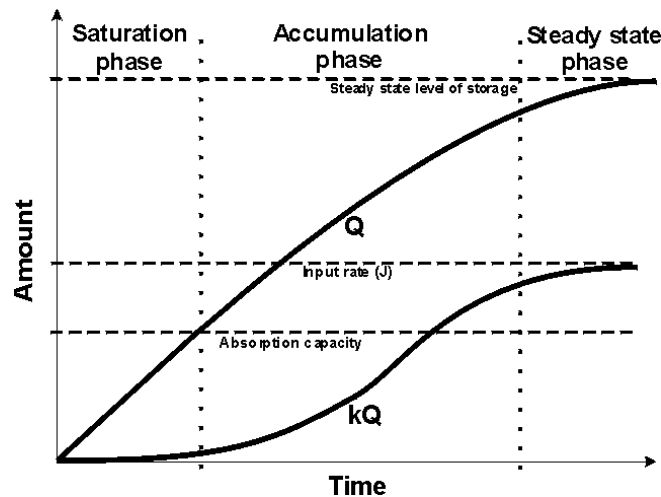


Figure 9. The HEAP trap, a general behaviour for any non-volatile substance imported in an area at a rate J . The substance accumulates in the area in the amount Q . After the accumulation to the absorption capacity of the area, a leakage, kQ will occur. This leakage will increase until it equals the input rate, and no more accumulation will occur.

The system is now converted to a throughput, steady-state, system. This behaviour is typical for nutrients as phosphorus in a city or on a specialized farm. [12]

2.3. The Peak problems are aggravated by s:

2.3.1. Ongoing specialisation of agricultural units

Since 1970, in Sweden, which is not different from the trends in most industrial agricultures throughout the world, the amount of agricultural units have been reduced with 70%, at the same time as the average area has doubled. Simultaneously, the number of support units, as dairies and slaughterhouses have decreased with more than 80%. Such a change is typical for many countries. The reduction of the mesh density of the food system will clearly reduce its redundancy, and consequently its resistance to disturbances, especially in the transport and supply system. These systems are the most prone to be affected by fossil fuel depletion.

2.3.2. Fossil fuel driven agriculture

The increased yields experienced by these methods are not due to increased ability of the crops to obtain more solar energy, but rather that some tasks formerly done by the crops (e.g., extracting nutrients and restraining diseases and herbivores) are done by the farmer using fossil energy, which accounts for the increased grain yield [28].

This strategy is not limited to plant crop production, but can be found in most agricultural and food related activities, as animal husbandry, fish production and fishery. Thus, in order to boost the rate of output, a constant throughput of energy and materials are applied. This makes agriculture highly dependent on different types of industrial support for maintenance, and energy and nutrient requirements. Therefore, in this type of agriculture the industrial energy input often equals or exceeds the output of food energy ([28];[16];[17];[20]).

2.3.3. Decreased population working with agriculture

Due to the increased mechanisation of agriculture (2.3.1), and its economic rationalisation, the amount of people working with agriculture has decreased the last fifty years (Figure 1010), in Europe as in most other parts of the world. The increased distance has, among else, lead to a decreased understanding of agricultural practices by

the general population the agricultural population has become more alienated (“Farmers are scoundrels”) increased price of agricultural products for the consumer due to an increased amount of transportation, middlemen and processing, parallel with a situation where the payment to the producer of the products has decreased.

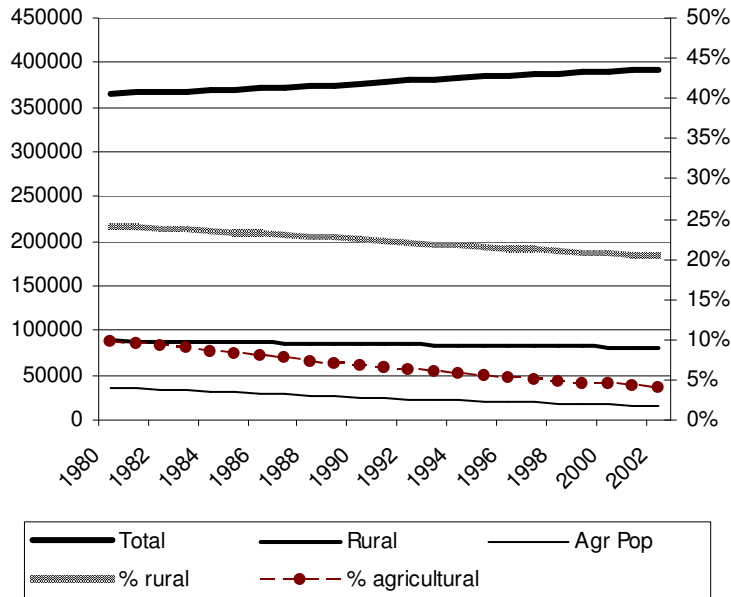


Figure 10. Decrease of the agricultural understanding in the Western Europe population. From 1980-2002, the population increased from 366 millions to 400 millions, but the rural population decreased from 89 millions to 80, and the part of the rural population working in agriculture decreased from 40% to 20% of that. In absolute figures, the agricultural population changed from 36 millions to 16 (4% of total population). (FAO statistics)

2.3.4. Urbanisation

Because of long distance supply systems and the looming energy shortage, the urban, modernized population has become more prone to supply pitfalls than an ‘under-developed’ rural population. Thus, if an increasing part of the population lives in urban areas, the vulnerability of the total population will increase. In Figure 11, one can see the change from less than 30% urban in 1950 to almost 50% today. Currently, 3.18 billion of a world total of 6.45 billion people need to be supplied from elsewhere.

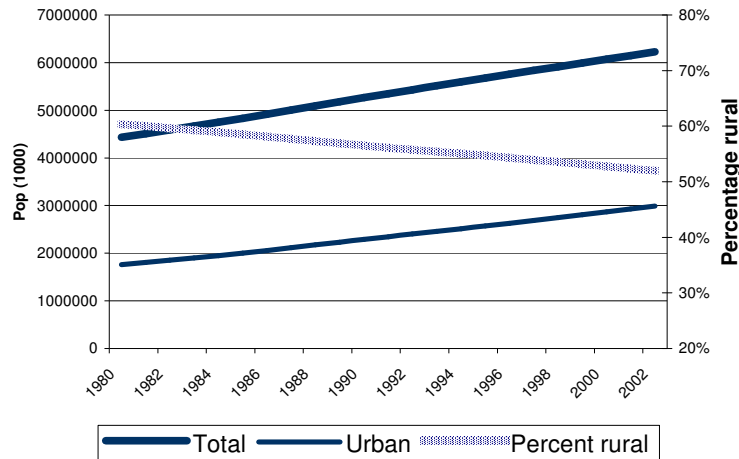


Figure 11. World urban population Since 1950, the world population more than doubled. During this time, the part of the population living in urban areas increased from 30% to 50% (FAO statistics , 2004)

3.RURALISATION

From the previous discussion, it can easily be understood that a mainly urban, locally supported population will be much less vulnerable to failures in energy supply and associated commodities. To emphasize the argument, I will relate to the other part of the ‘full-scale experiment’ related above (2.1.5). DPRK and Cuba were in a very similar situation during the early eighties. They were both using a heavily industrialized, monotonous agriculture, sending their produce very far away, depending on large inputs of fossil fuels and fertilizers. At the fall of the Soviet Union, both were cut off from supply of oil and fertilizers. In Cuba, however a massive change towards organic (low-input) agriculture and a strengthening of the rural areas alleviated the problems considerably.

3.1. The second lesson: Recycle what is not abundant

Devon Tides
New invention saves terrestrial life!
 Lack of phosphorus on land due to losses to sea forces terrestrial ecosystems to develop interactions that re-use valuable minerals.
The regenerative cycle on ecosystem level is invented !
 Award-winning Latimeria says: My friends did everything!
 Page 7

A long time later, about 400 million years ago, Life started to conquer terrestrial areas. A problem was encountered. There was a lack of phosphorus, necessary for all biological process.

To survive, terrestrial ecosystems developed a way to efficiently recycle the available phosphorus by re-charging the used molecules, re-using and collecting them again; the regenerative cycle. This method saved terrestrial life.

Figure 12. Recycling of available phosphorous

3.2. Cuba

In pre-1990, state farms controlled 63% of the arable land. Private land-ownership was restricted and over 160,000 small farmers owned and worked an additional 20% of the

arable land. From the time of the revolution to the 1980s, Cuban agriculture became more mechanized than any other Latin American country. By the end of the 1980s, state-owned sugar plantations covered three times more farmland than did food crops. Because Cuban agriculture was overwhelmingly dedicated to sugar, tobacco and citrus, the country had to import 60% of its food, all from the Soviet bloc. Cuba also imported most of its oil, 48% of its fertilizer, 82% of its pesticides, 36% of its animal feed for livestock, and most of the fuel used to produce sugar.

Although this system of imports and exports had allowed Cuba to modernize and raise the standard of living and the quality of life for all residents, its dependence upon the Soviet Union and the agricultural focus on sugar production placed the country in an extremely vulnerable situation.

The collapse of the Soviet Union brought the loss of oil imports as well as the loss of their major trading partner. And U.S. sanctions kept the country isolated from the rest of the world. Almost overnight, Cuba lost 85% of its trade. Fertilizer, pesticide and animal feed imports were reduced by 80%. Imports of fertilizer dropped from 1.3 million tons per year to 160,000 tons in 2001. Herbicide and pesticide imports dropped from a combined 27,000 tons to 1,900 tons in 2001. Petroleum supplies for agriculture were halved [18] (Figure 13.).

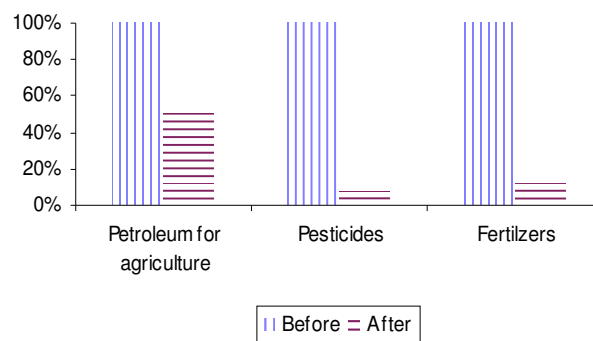


Figure 13. The changes in Cuban agricultural support induced by the collapse of the Soviet Union, in percent

However, there were some very important differences between Cuba and DPRK. For one thing, Cuba has a much warmer climate, with a longer growing season and Cuba has a better ratio of population to arable land.

Furthermore, Cuban scientists had begun exploring alternatives to fossil fuel-based agriculture. Research into ecological agriculture began back in the 1980s. By the time of the crisis, a system of regional research institutes, training centres and extension services was in place to quickly disseminate information to farmers. And finally, the Cuban government had social programs in place to support farmers and the population through the crisis and the transition into ecological agriculture [32]. Today, scientists in Cuba have support all the way to the top of government for doing research on organic and sustainable agriculture.



Figure 14. Intercropping of corn and the nitrogen-fixing *Leucaena sativa*

3.2.1. Some of the actions introduced in Cuba after the forced transition to fuel scarcity

Organic pest control: Some 40 species of plants from 25 families have been identified by Cuban researchers as having potential for control of a variety of pests. Currently the most actively used is neem (*Azadirachta indica*). Over 25 species of insect, mite, and nematode pests are managed with neem.

Biological insect control: Organisms used in controlling insect pests are raised. Fungal species as well as a dozen insect species are used.

Intercropping: Intercropping is of particular interest. Common intercrops are cassava with corn or bush bean, tomato, or cowpea; maize with either peanut, bush bean, sweet potato, and banana with beans, peanut, or a number vegetable crops. There are a large number of vegetable crops grown in polycultures.

Animals for agricultural draft: An adjustable multiple-use plough for use by draft animals is developed. The "multi-plough" can be used for ploughing, harrowing, ridging and tilling, and can be adapted for sowing, covering, hilling, and other operations. Cuba has a half million draft oxen and over a quarter million draft horses. Around 80% of the small, private producers use draft animals. Between 1990 and 1997 the number of animal draft implements in Cuba grew from 160,000 to 375,000, and the number of blacksmith shops grew from 500 to 2,800.



Figure 15. Due to depletion of fossil fuels, draft animals have been common in Cuba

The manure from the animals provides composts for use on crops. Special bags are fastened on the behind of the horses to collect the manure.



Figure 16. Bag for collection of manure from draft horses

Nitrogen-fixing bacteria: The free-living, nitrogen-fixing bacteria *Azotobacter chroococcum*, isolated from Cuban soils, is used extensively in Cuba to provide N to crops.

Urban agriculture: Urban agriculture, in which market garden crops are grown intensively in what the Cubans call *organoponicos*, long cement planting troughs, has grown rapidly and is one of the most remarkable developments of Cuban agriculture. Organoponics provide on the average 215 grams of vegetables per day to Cuban city dwellers. [24]



Figure 17. Organo-ponics outside Havana

Other recycling methods: Vermicomposting and other nutrient recycling methods are widely used.

3.2.2. The Cuban adaptation strategy

Agroecological farming does not work on a large farm. In industrial farming, it is possible to manage thousands of acres without intimate knowledge of the land. A few random observations will provide a single technician with all the input he needs for the application of a particular action to be applied over the entire area. In organic farming, the farmer must be intimately familiar with every patch of soil. By a change into this type of interaction with the land, the addiction to heavy machinery was eased, which in turn made an adaptation to low-energy input possible.

Cuban GNP has grown every year since 1995. There have been solid gains in employment, productivity and exports. Fruit production has returned to its 1989 level

(and even surpassed it in the case of plantains). Vegetables and tubers for domestic consumption have seen a prodigious increase in production. Food intake has climbed to 2,473 calories and 51.6 grams per person, a 33% increase over caloric intake in 1994.

Observers the world over have pronounced the Cuban efforts a success. Without help from either the World Bank or the IMF (and in total contrast to the normal World Bank and IMF reform policy), Cuba has disproved the myth that organic agriculture cannot support a modern nation. Agrarian reform in the 1990s centered on a new system of sustainable agriculture, the development of healthy markets, and the privatization and co-operativisation of the unwieldy state farms [32].

A way to survive the problems of decreased fuel supply and import-export capacity is to increase the self-sufficiency of the population, increase nutrient recycling and to maintain a viable urban population. Cuba has adapted these strategies. The graph in

Figure 8 shows a successful hampering of the decline of the rural population. The part of the population that has moved from large cities to smaller peripheral communities is not reflected in the graph, but that trend is reported by visitors.

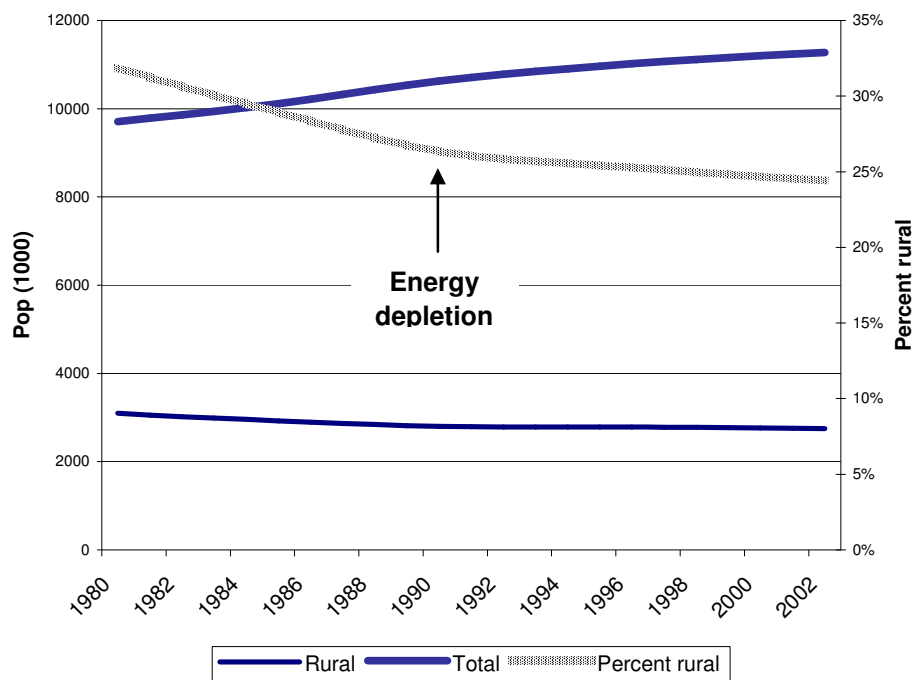


Figure 18. Cuban rural population The decline of the Cuban rural population was hampered by 1990, in connection with the onset of the energy crisis. After this, the population changed towards recycling and self-sufficiency. Compare this curve to that of DPRK (Figure). FAO statistics

3.3. Decreased vulnerability

It seems quite obvious that a successful way to maintain a functioning society in the face of an impending fuel and resource depletion would be to decrease the support line as much as possible. If the supply of water and food for the population can be maintained, as well as nutrients for the agriculture, other problems might be solved too. Otherwise, catastrophe is imminent.

If the depletion problems can be foreseen, which actually was not the case with Cuba and North Korea, a good strategy would be to successively eliminate the liabilities. The

problem, however, is to achieve such a state, since the trend in the pre-peak society points at the opposite direction.

I will suggest some measures that could be taken in order to alleviate the problems of high risk and potential instability of the food supply system. Some benign side effects that can be expected from the alleviation measures will also be pointed out. I will focus on the alleviation of the problems that have arisen as effects of accommodating to cheap fossil energy.

3.3.1. Minimising energy dependence in transportation

The heavy dependence on transportation in current food production system can be ascribed to two or three infrastructure modes:

Fertilisers and other support material for the agriculture are externally produced, often very distantly.

Agricultural sites and end-user of food are often much separated spatially.

Animal fodder is commonly produced very far from where it is needed.

These transportation dependencies could be diminished radically by a closer spatial, and social, integration of agriculture and settlements, together with a re-introduction of a balance between animal husbandry and plant production on individual farms [9]. The discussion in the first part of this paper indicated that today about $10\,000\text{ kWh}\cdot\text{p}^{-1}\cdot\text{yr}^{-1}$ is used for the food system. However, it is possible to imagine a decrease of this figure to $2\,000\text{ kWh}$ through the closer integration of agriculture and settlements, combined with a strategy for local food production. If this were possible for 50% of the Swedish population, the amount of energy saved is about 45 TWh annually, which equals to the electricity production of nine nuclear powered reactors (this is not a fair comparison, since the exergy content of oil and electricity are different, it is only aimed to help the reader grasp the size).

Energy use can of course also be diminished by different intra-farm technological changes to diminish energy investments in agriculture, which is currently of the same order as energy input in food. Increased efficiency of intra-farm energy use can, however, not be expected to lessen the total energy use more than by a small part of the industrial energy subsidies used in agriculture, which is about 18 TWh in Sweden [17].

3.3.2. Increasing nutrient circulation

In modern agriculture, the nutrients lost via export are replaced by new ones, supplied from mineral ores (P, K), or from industrial processes (N). However, this increases the vulnerability of the food system due to the connection with the mining and processing industry and the earlier mentioned problems of materials and YPE (Yield Per Effort).

Natural biological systems, e.g., ecosystems, offset the problem of source deprivation of essential nutrients. They respond in two ways: For elements that have volatile phases (e.g., C, N, O, S and H) supply is by atmospheric transport. For elements that in practice have no volatile phases, repeated cycling solves the problem. Advanced ecosystems are able to nearly eliminate leakage through export of nutrients ([33];[29];[30];[21]). Therefore, in order to augment sustainability, it seems appropriate to imitate the strategies of long-time sustainable self-organising systems. One of the most important of those strategies appears to be 'cyclic charging - discharging process' of simple elements, the regenerative cycle ([10];[13]). In ecosystems, such elements are volatile (N, C, S, O, H) and non-volatile (P, K and trace metals). The limiting ones, such as

nitric oxides and phosphorus, are carefully recycled in such systems ([33];[29],[30];[21]). To attain ecosystem mimicking (ecomimetic) in nutrient management, two changes are needed in current agricultural practice.

- Animal feed is produced on the same farm, or in the vicinity, allowing the manure to be returned to the land where the feed is produced. By this practice, 60-90% of the nutrients, at least the non-volatile ones, can be circulated [9]. Nutrients with volatile phases, e.g. nitrogen, can be conserved by anaerobic storage, effective mixing into the soil or other means.
- Nutrients actually exported as human food, should be returned as uncontaminated as possible, preferably as human urine and (composted) faecal matter. With the use of source-separating toilets, which do not mix urine with faeces, the urine, containing most of the phosphorus and the nitrogen excreted [12], can be easily reclaimed. The faeces can be composted out of reach of flies for six months to a year in order to eliminate pathogens before returning it to the fields (Figure 5).

3.3.3.Integration of agriculture and settlements

Most of the problems pointed out in the first part of this paper can be ascribed to the unintentional separation of agriculture and settlements, that developed as a side-effect of 'the industrial revolution' over the last hundred years. Re-integration of agriculture with settlements would be one way of solving the problems of increased vulnerability and decreased sustainability of the food system. Many of the environmental problems experienced today might also be alleviated by this strategy. Such a restructuring would also increase the ecological qualities of the society.

3.3.4.Alleviating the problems at different scale-levels: 1. Micro-scale – The balanced settlement

It is also necessary to study different hierarchical levels. I will first try to outline an example of how some of the identified problems can be solved on the scale of a single agricultural unit and a simple small settlement (around 200 people).

3.3.4.1. Elimination of dependency for feed and nutrients

Assume an agricultural unit that produces both animal and vegetable products. Suppose further, that all the feed for the animals is produced locally. This will reduce the need for the import of nutrients by 60 - 90 % [9]. However, the export of essential nutrients in food will still amount to at least $3-4 \text{ kg P*ha}^{-1}\text{*yr}^{-1}$. For long-term survival of the system, this amount must be recycled. A human generates about 0.7 kg P/year in urine and faeces. This means that the phosphorus content of the excrement from 5-7 people equals the losses of phosphorus in food from one hectare of a balanced agriculture (Figure 19). From these figures, the area of balanced agriculture needed to support one person is obtained. This area is between 0.23 and 0.15 hectares, which is in agreement with the figure of 0.2 hectare per person calculated from the need of food for a person and the production capacity of an average Swedish farm [11]. A 40-hectare farm may thus be able to support about 200 people for the greater part of their food needs.

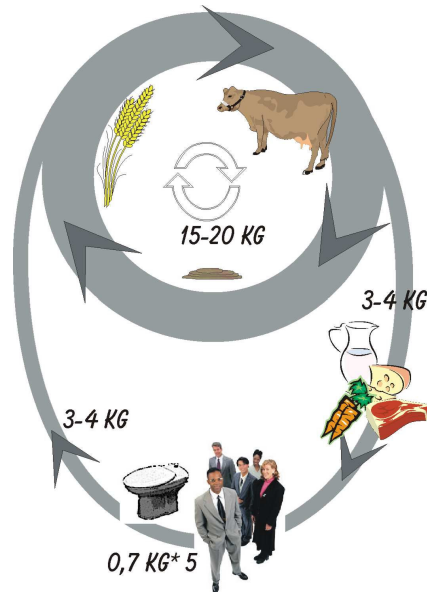


Figure 19. To make up for the phosphorus losses from export, a hectare of balanced agriculture (i.e., one producing food for its animals) need the reclamation of nutrients from 5-7 persons. This implies that one such person needs about 0.2 hectares of the balanced agriculture for the production of food requirements. (Dimension: Phosphorus per hectare)

Thus, to diminish the acute dependence on external support of nutrients, integration is needed between the production of animal fodder and the use of animal manure, and the local settlements with the agriculture as a food producing system. This integration also implies diversification of agriculture because of the diversity of products needed by the population.

3.3.4.2. *Elimination of leakage*

The direct leakage of phosphorus, which in this article is chosen as a 'standard' nutrient from an agricultural unit, is within the range of $0.2 - 0.4 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$. By the opening water courses and re-planting of buffer-strips, a large part of this leakage can be captured ([25],[26]). Examples of reclaiming methods for the nutrients contained in the biomass would be compost, biogas sludge or ash. Such buffer strips also have other functions than the capturing of nutrients. In windy conditions, they also have a wind shielding function, increasing the yield 15 - 30 % within 15 meters from the vegetation strip. Other benefits of such vegetation are the increased occurrence of predators against insect pests and bumble bees for pollination.

3.3.4.3. *Economy*

Another problem already noted above is the low and decreasing income of farmers. The extensive handling and transportation system between the producer and consumer is not only energy intensive, but also appropriates a large part of the price for food paid by the end-user, more than 75% (calculated from Swedish statistics). Furthermore, the income received by the farmer largely covers the cost for financial and material inputs paid by the farmer, which is about 85% calculated from the figures of Augustsson and Johansson [1] (Figure 20).

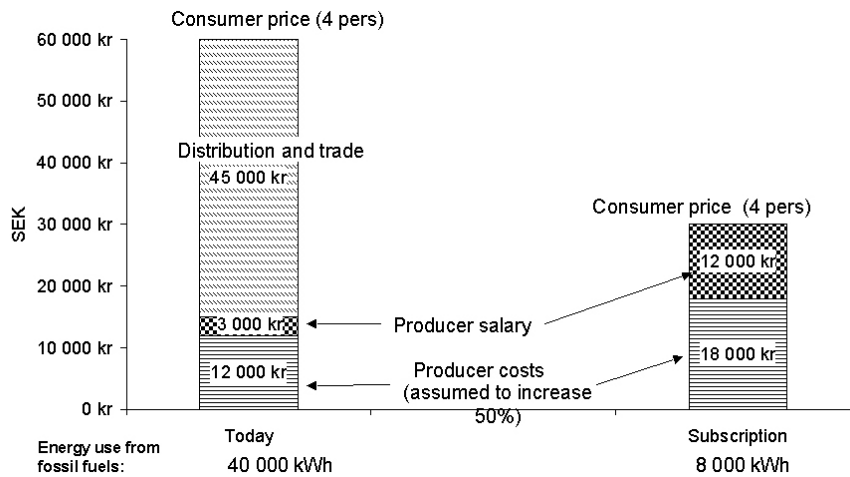


Figure 20. If the farmer accepts a payment equal to half the retail price, a food subscription, would be economically favourable. Not only for the consumers but also for the farmer, even if the production costs will increase with 50%. (Calculations by the author)

With an increased integration of agricultural units and settlements, direct trading between the farmer and the consumer becomes possible. If the farmers were given half the price for food that is paid by the consumer today, this could increase his income five to six times. The consumer could also reduce the cost for the food produced by the farmer by about half. Both figures assume that the product price to the farmer is 25 % of the consumer price, a figure that is somewhat high. Today, the farmer's earnings in Sweden are less than 15 % of his income [1], which represents less than 3.6 % of the market price in the shop. Assuming that the production cost would increase by 30 % because of the increased diversity in agriculture, a fifty-fifty agreement between a farmer and a local settlement would still increase the payment to the farmer from 3.7 % of the shop price to 22 %, or about six times. An increase in income of that magnitude might impose even large changes in agricultural practice.

3.3.5. Alleviating the problems at different scale-levels: 2. Medium scale

The implementation of the solutions proposed above is compatible with intermediate size settlements. Three or four settlements with their associated farms can form groups of 800 - 1,200 persons and an associated agricultural area of 160 - 240 hectares. If areas are also used for the improvement of local ecosystems, 170 - 260 hectares can be expected to support these people. This population size is large enough for the establishment of a common social infrastructure, such as primary schools and small service business. However, it could be argued that this size of settlement is not enough for non-agricultural production, such as cultural needs and service provisions, and that this may generate an increased need for transportation. For the sake of discussion, however, imagine an area where such settlement types cover the land. In such an area, not regarding the incidence of lakes, mountains etc., there would be a population density close to 500 persons/km^2 , which might be enough for a diversity of direct social interactions.

3.3.6. Alleviating the problems at different scale-levels: 3. Large-scale implementation: Ruralisation

Nutrient circulation becomes increasingly expensive with increasing spatial distribution ranges [14]. The energy requirements for distribution of food also tend to increase in quantum leaps when the distribution pathways require extensive packaging and preservation of the products. As pointed out earlier, solving these energy requirements by means of fossil fuels increases the vulnerability of the society above the level needed if only basic provisions are made for human and environmental security. The only solution left, if the goal were this security, would be to maintain basic energy flows from renewable sources, i.e. solar, and reduce the external energy requirements for all sectors to the lowest level possible.

Year 0.



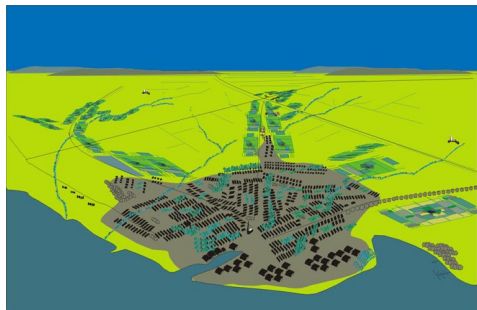
Urban pop. 33,000 Rural pop. 3,000

Year 12.



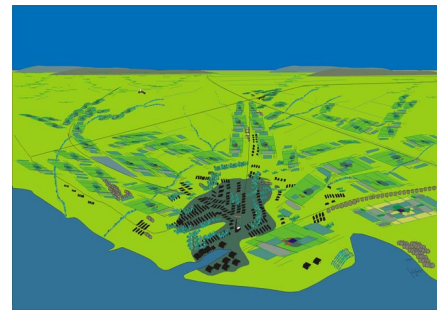
Urban pop. 24,000 Rural pop. 12,000

Year 25.



Urban pop. 12,000 Rural pop. 24,000

Year 50.



Urban pop. 3,000 Rural pop. 33,000

Figure 21. The ruralisation strategy in a hypothetical, medium sized city. Instead of the direct replacement of old houses, balanced settlements are built within the supporting area

The means of providing agriculture with its ‘ultimate’ raw material, phosphorus, would also need change. A system of linear flux of phosphorus through society over a prolonged time is both wasteful and insecure (see MIFSLA and HEAP). To attain nutrient circulation and at the same time as reducing energy support requirements in large societies, a different strategy of societal structure must be chosen: replacing the current trend of increasing agricultural specialisation and urbanisation with one of a closer integration between farms and settlements.

A name for such a strategy is ruralisation, as opposed to urbanisation. This development strategy implies a successive replacement of houses in need of extensive restoration or rebuilding. Instead of building new houses in existing urban areas, small settlements integrated with agriculture, as outlined above, can be created in the hinterland of the urban areas shown in Figure 29.

The benefits of such a system are considerable, contrasted to the inherent problems of the modern industrial settlement-agriculture structure, not only because of its decreased vulnerability, but also for its enhanced social capacity. The ruralisation strategy will imply a gradual increase of the rural population. (Figure).

The experiences of Cuba indicate that this might be a successful strategy.

A gradual, but steady change will after some time have large effects. For example, the town in Figure 29 will experience a 90% change of the population in 50 years with an annual change of only 1.6%.

The effects of this change will be:

- A gradual decrease of the need for food system energy, which is the largest part of the personal energy expenditures. [15]
- A gradual increase in nutrient recycling capacity, which decrease the vulnerability to input disturbances.
- A gradual change in agricultural structure, from industrialization and specialization to emphasis on local demand and resource management.
- A gradual increase in water self-sufficiency by avoiding the MIFSLA attitude (2.2.2.1).

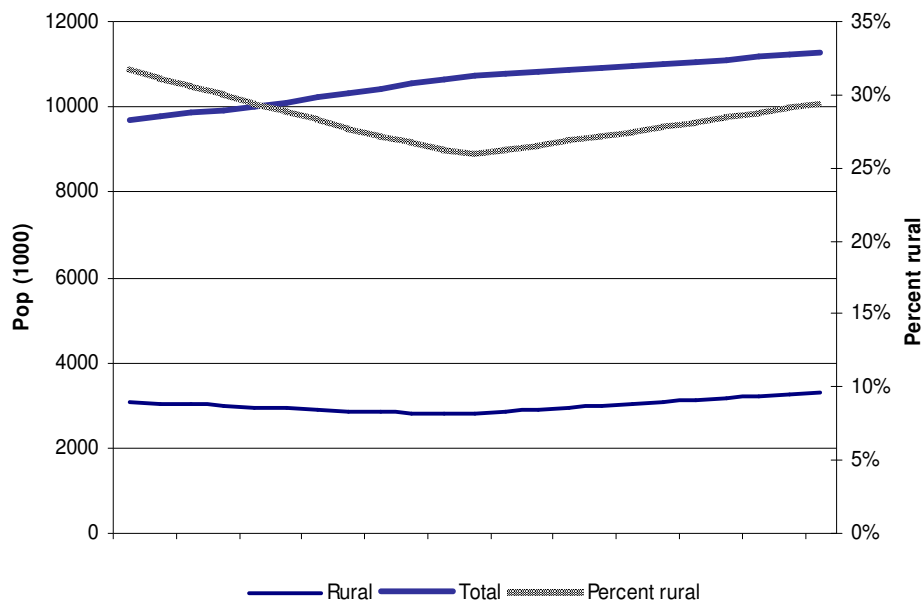


Figure 22. The ruralisation strategy. At a certain time, hopefully before the onset of the energy depletion crisis, the decrease of the rural population is hampered, and the local self-support capacity is increased

3.4. Urban and rural vs. Urban and Rural

Changes in spatial distribution along the urban – rural track will naturally be associated with lifestyle changes shaped by the socio-economical and spatial environment. A person living in a typical urban area naturally adapts to the possibilities and restrictions

of that environment, and the same is true for a person living in a self – sufficient village with all that comes with it. To describe the supposed differences, imagine the lifestyle of an extreme person ('Rural', an old Scandinavian name) living in a ruralised area and compare it to one of a similarly extreme person ('Urban' another old Scandinavian name) living in a urban area. Such lifestyles changes are described in Table 1. The lifestyles of most other persons can be placed somewhere in-between Urban and Rural. The different lifestyles from an extreme urban to an extreme rural depicted in the table can be combined with the spatial pattern of the settlement in a diagram. In such a diagram, it is possible to assess different sustainability capacities in relation to the threats mentioned earlier in this paper. The different grades of sustainability of the combinations are depicted as a greyscale on Figure 23.

Table 1. Comparison of lifestyles of two hypothetical persons 'Urban' and 'Rurik' living in a city respectively in a ruralized area

Parameters	Urban	Rurik
Mobility, daily basis	High	Low
Distance to work	Long (> 30 km)	Short (< 5 km)
Mobility, general	Frequent, short distance (>30 km)	Infrequent, long distance (> 100 km)
Food source	Distant (global)	Local (< 10 km)
Understanding of food system	Low	High
Industrial food processing	High (processed food)	Low (raw material processed at home)
Raw material use	High	Low
Recycling capacity, raw materials	High (part of urban infrastructure)	Low (out of reach of efficient recycling structures)
Recycling capacity, nutrients	Non-existent	High (source separating toilets, composts, balanced agriculture)
Infrastructure dependency	High	Low
Water supply	Grid	Local (well or recycled water)
Water purification	Sewage treatment plant	Source separating toilets, local grey water purification and recycling
Fossil fuel dependency	High	Low
Vulnerability to high energy prices	High	Low
Social service	Formal	Informal
Social interactions	Infrequent	Frequent
Distance to friends	Long	Short
Economic activity (Gross Personal Product)	High	Low
Economic activity (Mode)	International	Mainly local
Settlement density	High <1400 p/km ² , (urban) to moderate 200-1000 p/km ² , (suburban)	Moderate (<1000 p/km ² , vila) to low (> 500 p/km ² including agricultural space)

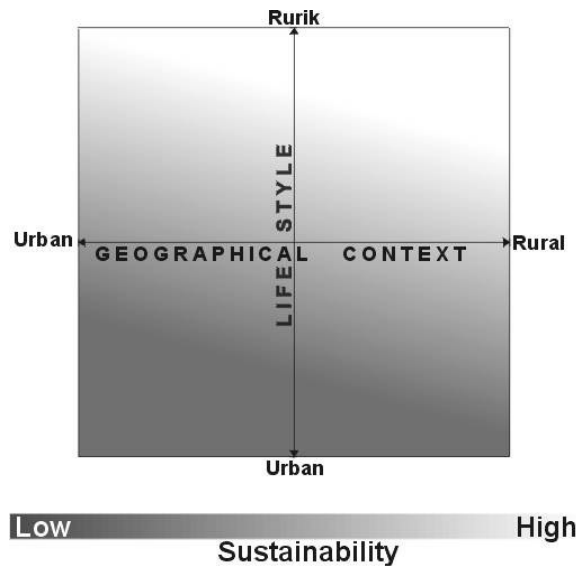


Figure 23. The combination of a geographical context (urban – rural) with a lifestyle context (Urban – Rurik). This combination creates a field, upon which different sustainabilities can be imagined. The different lifestyles are depicted in Table 1

Some combinations of spatial distribution and lifestyles are currently more common than other. In westernized countries, the ‘Urban’ lifestyle is the most common. It is not unusual to find totally urbanised people living in a rural area. Even people living in very sparsely-populated areas (e.g. the Laplanders, or same-people, of North Sweden) are dependent on a supply of gasoline, batteries, spare-parts for machineries and households, transportation facilities, supermarkets, aeroplanes et cetera. Their dependence of the modern industrialised society is similar to that of a person living in an urban area (even if people living in sparsely populated areas often still have a larger capacity to manage without a heavy supply).

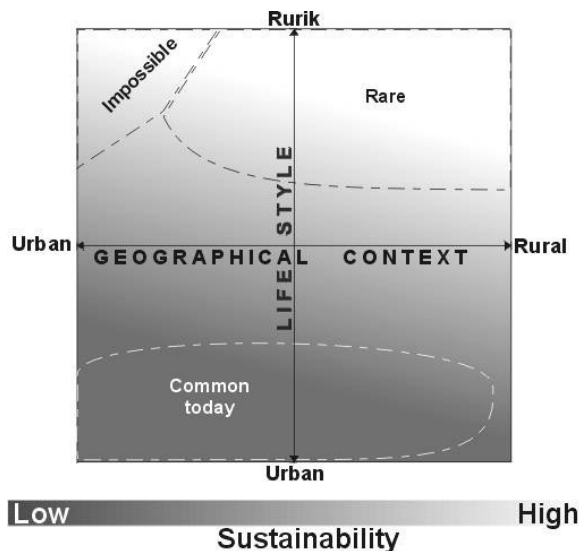


Figure 24. The occurrence of different combinations of lifestyles – distribution patterns. The ‘Rural’ lifestyle is in turn rather rare. Globally, one can only find typical examples of it amid ‘under-developed’ or pastoral tribes. In Sweden, there are a few intentional communities aiming at this lifestyle. In dense urban environments, the ‘Rural’ lifestyle is impossible. (Figure 24)

Ruralisation is often confused with urban sprawl. Urban sprawl is associated with a wide distribution of an urban population, increasing the problems of transportation, food distribution and nutrient recycling. In ruralisation, the new settlements are integrated with local production of food, recycling of nutrients and short transportation lines, thus eliminating some of the main vulnerability problems experienced today. Naturally, these changes will also be associated with large changes in lifestyle (Figure 5).

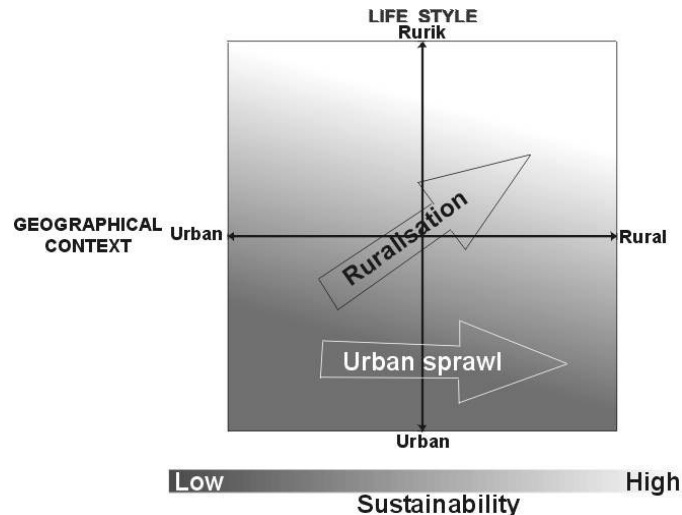


Figure 25. The ruralisation concept contains both a change in life-style and changes in the urban – agricultural landscape, as opposed to *urban sprawl*, which is a mere dispersal of the urban population, without significant lifestyle changes in the sustainability concept. The urban sprawl will even bring about a decrease in sustainability compared to the dense urban settlement

Thus, the ‘ruralisation’ pathway can be described as a movement upwards – rightwards in Figure 5, as opposed to the ‘urban sprawl’ downward – rightward pathway. The differences in sustainability between the end-points are considerable.

4.CONCLUSION

The problems discussed, of energy scarcity due to the oil extraction peak and the depletion of services from ecosystems due to an energy-induced industrialization of the landscape, can not be alleviated by further streamlining along the paradigms currently used.

To solve the combined problem of energy deprivation and ecological degradation, *structural* changes of the society are needed. Such changes could assuage the ominous threats that looms.

Examples of such structural changes are the:

- Shortening of supply lines for food and water
- Increasing the use of solar derived energy
- Re-introduction societal infrastructures that support recycling
- Integration of agriculture, settlements and other social activities
- With a simultaneous change in these directions, accompanied with the structurally induced life-style changes, what is denoted as ‘ruralisation’

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