Food sustainability, food security and the environment

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Abstract *Sustainable development requires a deliberate choice in the direction of societal transition, but the options are narrowed down by the obligation to feed a growing world population. At present sufficient food is produced, but large differences exist in per capita supply. Poverty prevents many people from attaining a sufficient diet, while growing economic welfare pushes meat consumption conversely. To meet the increasing demands for agricultural products, at least two options are apparent: either to expand and intensify agriculture, which already appropriates significant amounts of nature's resources or to change from resource-intensive meat consumption to more vegetarian diets. The latter option is studied by PROFETAS, which focuses on the environmental sustainability, the technological feasibility and the social desirability to partially replace animal proteins with plant protein products. The Western consumption pattern is a suitable candidate for such a transition, which would benefit the environment as well as human health.*

A short history of agriculture

About 12,000 years ago well-organised populations of hunter-gatherers in the Near East and North Africa adopted a more sedentary lifestyle and concentrated on a few main species of plants and animals as a food source. This shift in subsistence is called the Neolithic revolution, and it heralds the first steps towards domestication of plants and animals and the development of modern agriculture. It was the first of several instances in which agriculture developed independently in places all over the world in the same era (Diamond, 1998).

Mannion (1995) reviews different theories on the motivation for this revolution, and these are rooted in two schools of thought. In the "environmentalist" theory as described by the British archaeologist Childe, a warming climate created changes in habitat and species composition, which favoured a shift from hunting and gathering to the domestication of certain plants and animals. In the Near East for example, the development of seasonal changes favoured the growth of annual plants like grasses, and dry summers encouraged the storing of food. The resulting food security, in addition to a more stationary lifestyle, facilitated the increase of human populations. The Russian botanist Vavilov first introduced an alternative "materialist" theory. He assumed that the primary motive for the inception of agriculture was the need to generate a food surplus for a growing human population. However, pathological research of Paleolithic hunter-gatherer skeletons does not show evidence of severe and chronic stress or malnutrition in contrast to Neolithic skeletons (Mannion, 1995). This

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implies that population pressure and the related scarcity of hunted and gathered food was unlikely to be the force driving the transition from hunting and gathering to farming.

As populations grew, farmers devised ingenious methods such as irrigation, terracing, drainage, fallowing, and reclaiming land from the sea to expand the cultivated area. In addition, they managed to increase production efficiency with the development of new technologies such as animal-powered equipment, crop rotation, guano and saltpetre fertilizers, chemical fertilizers, pesticides and plant hybrids (Trewavas, 2002; Evans, 1998; Brown, 1996). In the twentieth century farmers not only managed to increase production in line with record population growth but also decidedly increased the food energy available per capita (Alexandratos, 1999).

Food security

The revolutionary shift in the provision of food from hunting and gathering to agriculture resulted in mankind's dominion of planet Earth. Over the ages, the ever-growing world population consumed ever-larger parts of the global resources and frequently doubts were voiced about the earth's carrying capacity and limits to the human population (Evans, 1998; Smil, 1994). The debate on the attainability of future population growth is still very much alive (Brown, 1996), and an interesting aspect of the debate is the reversal of causality.

In early times, agricultural food surpluses permitted population growth. The resulting increase in the numbers of human beings both enabled and demanded agricultural expansion and intensification. But present and future population growth is related to economic development, and therefore seemingly independent of the capacity of food production: first comes the fact of population growth and afterwards the question of how to feed those people. This situation seems, if not impossible then at least inherently unsustainable, as will be discussed below, and not only from an ecological point of view.

The concept of sustainability

The World Commission on Environment and Development (1987) widely introduced the concept of "sustainable development" with the publication of *Our common future*. This call for sustainability is variously interpreted but there are two dominant approaches to the concept: the wealth approach and the mosaic approach (Smith and McDonald, 1998).

The "mosaic" approach breaks sustainable development into three components: economy, society and ecology. In literature various interpretations are given of the content of these components. The following brief description is based on Carley and Spapens (1998) and Smith and McDonald (1998). Ecological sustainability requires that development is compatible with the maintenance of ecological processes: the throughput of natural resources is reduced to levels dictated by the earth's carrying capacity, the availability and renewable capacity of resources and the resilience of natural systems. Economic sustainability entails economically feasible development in which production and consumption should serve to enhance quality of life rather than degrade it. Social sustainability entails that development is socially acceptable and should cover the need for global equity. All countries should have equal access to the world's resources and equal responsibility for the management of these resources.

The "wealth" approach requires full appreciation of the value of natural and man-made capital and the equal inheritance of stocks of capital over generations. Weak sustainability is the maintaining intact of the sum of human-made and natural capital. Application of this principle to the mosaic approach allows for the substitution of natural capital with human-made capital and for trade-offs among social, ecological and economic objectives. Conversely, strong sustainability requires that neither natural capital nor human-made decline over time (Smith and McDonald, 1998). The operational qualities of weak sustainability are contested. Ecologically, because it fails to recognize that natural capital is often an prerequisite for manufactured capital (Wackernagel and Rees, 1996), and practically, because the principle indirectly requires that natural capital is held constant at some level, at which point it meets the principle of strong sustainability (Costanza and Daly, 1992). It is argued that there is no separation between human society and the natural world and that economy and society are an integrated part of the ecosystem and is therefore subject to the "laws of nature". Acknowledging a hierarchical dependence provides a better chance to achieve sustainability and recognizes that "a minimum level of ecosystem 'infrastructure' is necessary" (Costanza *et al.*, 1997) beyond which no further trade-offs can be made.

Before integration of the different aspects of sustainability, Hediger (2000) invites us to consider the objectives of sustainable development by answering the questions "What should be sustained?" and "What kind of development do we prefer?", as well as the feasibility of the process by answering the questions "What can be sustained?" and "What kind of system can we get?" The first two questions imply a deliberate choice on the preferred direction of change, but only those people whose fundamental needs have been fulfilled can make a free choice and it is the fundamental right of everybody to be free from hunger. This issue, in combination with the projected growth of the world population to nine billion human beings (UN Population Division, 2000, 2050 – medium variant) delineates the direction of development. Consequently, it forces our focus on Hediger's second group of questions of what can best be achieved with regard to the least harmful of trade-offs among environmental and other issues. The next sections briefly consider some questions on the demand side of the food production system analogous to the questions raised by Hediger:

- What kind of system do we have?
- What food do we need?
- What kind of system can we get?

Present food system

At present it is argued that sufficient food is produced to feed the world population (FAO, 2002). From 1960 to 1995 per capita food availability grew from 2,300 kcal to 2,700 kcal per day (Alexandratos, 1999), and which is the lower limit of the range that is considered a safe average food supply: 2,700 kcal – 3,200 kcal (Gilland, 2002). However, large differences in the average supply exist among countries of the developed and developing world. Apart from human and natural disasters, which contribute to local and regional insufficiencies, poverty prevents the acquisition of food for those who are most in need (FAO, 2002). The demand for agricultural produce is mainly determined by purchasing power. On the one hand, 800 million people presently live in absolute poverty and are affected by malnutrition and under-nourishment. These people lack the finances to translate their physical needs into the "real demands" of the world market (FAO, 2002). On the other hand, a general trend can be described of food consumption patterns in relation to income. For animal-derived foods, an S-shaped growth curve is often used (Grigg, 1995). The first part of the curve represents the low-income diets that basically rely on staple foods: cereals, roots and tubers. This group of people consumes roughly 200 kg of grain per person, per year (Brown, 1996). The initial response to a rise in income is to satisfy the demand for food: the consumption of starchy staples increases (Grigg, 1999). Once this need has been satisfied a shift from tubers and coarse grains like barley and millet is made to more expensive cereals like wheat. With a further increase in income (GDP/capita $>$ \$500), the second part of the curve is reached and more luxurious foodstuffs such as fruits, vegetables and animal foods gradually replace part of the staples (Grigg, 1995). The last part of the curve describes the high-income diets (GDP/capita $>$ \$10,000) when saturation of animal products is reached. For this group of people the direct and indirect consumption of grains may be as high as 800 kg per person per year (Brown, 1996). Moreover, affluent diets not only imply a high consumption of animal products, but also of other foodstuffs like oils, beverages and sweets (Gerben-Leenes and Nonhebel, 2002).

Average food requirements

The global demand for food is determined by population growth and minimum physiological requirements. The human body requires food for the provision of energy and nutrients for growth, maintenance and activities. An average food energy availability of 2,900 kcal is considered satisfactory, although physical energy requirements are appreciably lower (Gilland, 2002); Dutch data for example, recommend a daily energy intake of 2,400 kcal for an adult performing low physical activity (Gerben-Leenes and Nonhebel, 2002). In order to comply with nutritional constraints, 55 per cent of the energy must be provided by carbohydrates, 35 per cent by lipids and 10 per cent by proteins (Gerben-Leenes and Nonhebel, 2002). The average energy content of protein is 4 kcal/g (Carpenter, 2000) and 72 g protein is required to provide 10 per cent of a 2,900 kcal food supply. This is comparable to the amount mentioned in Gilland who further assumed that half of all protein intakes should be animal-derived. He estimates that approx. 420 kg cereals/capita yr is necessary to provide both the present and the future population with an average daily supply of 2,900 kcal and 40 g animal proteins (Gilland, 2002). This corresponds to a cereal production of 3,780 million Mt in 2050 to feed nine billion people (UN Population Division, 2000, 2050 – medium variant), which is 1.86 times the global production in the year 2002 (FAO, 2003b).

Future food system

To meet the large increase in cereal demand that is required to feed 9 billion people, two options are open: to expand production area or to intensify production practices. But agriculture already appropriates significant amounts of available natural resources, especially with regard to land. In addition to biodiversity, this is also affecting the N-cycle, the hydrological cycle, and the C-cycle (Helms and Aiking, 2003). Additional pressure will further reduce natural capital and concern is voiced on the sustainability of ecosystem services in general (Tilman *et al.*, 2002), as well as on the feedback of environmental impacts on agricultural production itself, especially with regard to soil degradation, irrigation and climate change (Ruttan, 1999).

White (2000) suggests two options to attain greater equity of food availability, which may also be used to reduce trade-offs between food demand and environment. The first option is to redistribute calories from high-calorie diets to low-calorie diets. The second option is to reduce the environmental impact per calorie food product and the transformation of resource intensive meat-based diets to a more grain-based diet (White, 2000). To elaborate on the latter: vegetarian diets compare favourably to present diets on important environmental issues such as land use (Gerben-Leenes and Nonhebel, 2002; Pimentel and Pimentel, 2003; Slager *et al*., 1994). Furthermore, it is estimated that, on a national scale, about a quarter of the world population consumes an unnecessarily high amount of animal proteins (Gilland, 2002), and as a consequence indirectly devours a high amount of cereals. In theory, a reduction of animal proteins in these diets would reduce this inefficient cereal demand and the resources spared in the production of animal feeds could then be used for the production of food for the growing population or the conservation of natural resources. The western consumption pattern with its abundant food supplies and fairly carnivorous nature is a suitable candidate for the reduction of animal foods, which is the object of study in PROFETAS.

PROFETAS

The PROFETAS research programme (Protein Foods, Environment, Technology and Society) aims to explore the system changes involved with the large-scale transition from animal to plant proteins. The main goal is to provide a set of tools to facilitate the development of policy options (Aiking *et al*., 2000). The choice of this goal is based on the results of an earlier study on sustainable technology development (Weaver *et al*., 2000). In the latter study it was concluded that it is not feasible to predict products or solutions years in advance but that it would be better to develop a set of tools to facilitate future problem solving. Two other conclusions from the same study also heavily influenced PROFETAS programme's development: first, the replacement of meat protein as a component of ready-made meals and snacks is more likely to succeed than trying to mimic whole meat chops; and second, innovations have to be acceptable to consumers primarily.

From the onset it was clear that a major transition rather than a gradual shift from animal to plant foods is not free from barriers, and at least four were identified (Aiking and Vellinga, 2001):

(1) Social forces opposing change are strong – meat has high status and it is the average human's desire to eat high up the food chain given the right financial situation.

(2) Economic forces opposing changes are strong, because vested interests in the meat production chain are powerful.

(3) Technological know-how on the development of novel plant protein foods (NPFs) is insufficient.

(4) For centuries the meat chain has been optimised for the use of all by-products; the large-scale replacement of meat may seriously affect related production

systems and this may potentially offset a large part of the theoretical environmental gain.

All these considerations resulted in a multidisciplinary research programme in which 24 researchers in the field of economy, social sciences, and environment, as well as food technology, consumer sciences and plant sciences study the feasibility of a more vegetarian diet (PROFETAS, 2003). The primary hypothesis is that a substantial shift from animal to plant protein foods is:

- environmentally more sustainable than present trends;
- technologically feasible; and
- socially desirable.

To provide the desired set of tools to facilitate policy options (Aiking *et al.*, 2000), the transition is studied using the partial replacement of pork with novel protein foods based on green peas in the European Union as a test case. Green peas were chosen because of their high protein content (± 23 per cent (Vaughan and Geissler, 1997)), the favourable options to produce the crop in Western Europe and the absence of undesirable compounds such as phyto-estrogens. Pork was selected as a representative of animal protein because of the relatively uncomplicated production chain – pigs supply only a single food item (meat), as opposed to cattle (milk and meat), and chickens (meat and eggs), and because pork production is an interesting example of intensive rearing methods that uses considerable amounts of high quality plant foods such as cereals. Pigs are generally considered the least efficient of feed converters followed by beef cattle, milking cows, broilers and egg laying hens, requiring about 7 kg feed to produce 1 kg meat (Durning and Brough, 1991). On the other hand, pigs consume large amounts of side-products from other food industries such as citrus pulp (CBS and LEI, 1999) that would have to be disposed of otherwise. Furthermore, pork is a popular foodstuff. On average it supplies ± 37 per cent of meat proteins in the European Union, but national differences are substantial ranging from 23 per cent in Greece to 58 per cent in Austria (FAO, 2003a). Dietary differences among nations do not only apply to pork. A culturally defined gradient of plant and total protein consumption clearly separates northern and southern consumers in Europe (Helms *et al.*, 2003). These differences should be addressed because the threshold for the transition to a more vegetarian diet may be significantly lower for Mediterranean diets with their higher consumption of plant proteins than for more northern consumption patterns.

Conclusions

Population growth and the moral obligation to provide sufficient, nutritious and affordable food for everybody will continue to raise the demand for agricultural production. Just providing an average food supply of 2,900 kcal with half of all protein derived from animal products would nearly double the grain demand by the year 2050. Moreover, economic growth in combination with the craving for an excess of animal products by those who can afford it and the inefficient conversion of feed to meat may further raise the demand. A partial solution to reduce the environmental pressure that is due to the present food system can be sought in the voluntary reduction of animal protein consumption and the partial replacement of animal proteins by plant proteins.

The Western diet, which is characterized by an excessive intake of energy as well as of animal products, not only is a good candidate for reducing environmental pressure, but may also benefit from a health perspective. Since the latter is an important issue in Western society, a promising approach to more sustainable consumption would be to stress the fact that both human and environmental health would benefit from a more vegetarian diet.

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