

Protein production: planet, profit, plus people?^{1–4}

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ABSTRACT

Food sustainability and food security are increasingly in the spotlight and increasingly intertwined. According to some projections we will need to nearly double food production in the next 4 decades. This article argues that protein production and consumption are pivotal to sustainability, because anthropogenic contributions to the nitrogen cycle are 100–200% compared with a contribution of 1–2% to the carbon cycle by mineral fuel combustion, with biodiversity as the main casualty. Because 1 kg animal protein requires ~6 kg plant protein, its large-scale production by means of factory farming is a major driver of biodiversity loss, climate change, and freshwater depletion. Furthermore, intensive livestock production is associated with antibiotics resistance and increasing incidence of emerging diseases. Therefore, a “reversed” diet transition back to less animal protein could make a difference. Some European countries, such as the United Kingdom, Sweden, and The Netherlands, have published integrated policy reports addressing food security, sustainability, and health combined. The food industry is focusing on food safety and increasingly on sustainability. An important issue is consumer communication, because consumer “framing” is radically different from that of governmental and industrial policy makers. There is no “one size fits all.” A huge range of differences exists between countries and between distinct groups of consumers within countries; getting consumers to change their diets in a more sustainable direction is likely to require much more than gentle nudging. National governments and the United Nations should assume their responsibilities and initiate a global strategy integrating sustainability, food security, nutrition, and equity. To date, the profit pillar of sustainability has taken precedence over planet and people. It is time to redress the balance. *Am J Clin Nutr* 2014;100 (suppl):483S–9S.

INTRODUCTION

Nutrition takes a prominent position among our universal needs, demanding considerable resources along with water, shelter, and energy (1). However, access to food is far from equitable, with the result that presently ~1 billion people are obese and ~1 billion go hungry (2). In a world speeding toward a population of 9 billion, it is increasingly acknowledged that nutrition should not just promote health but sustainability as well (3–7).

World population and average income are at unprecedented levels and will continue to rise. However, increasing food production generates its own feedback inhibition, thus compromising food security, food safety, and food sustainability. From the perspective of food security and nutrient adequacy, there is a bias toward calories and vitamins. From the perspective of food sustainability, there is a bias toward climate change, and so to-

ward carbon and calories. However, nitrogen—or protein for that matter—is an important but often disregarded macronutrient with a pivotal role in biodiversity loss, climate change, and human health risks.

Therefore, the current article argues that food security, food sustainability, and nutrition are increasingly intertwined and should be addressed in an integrated way, by identifying trade-offs and setting priorities. Subsequently, it is argued that a reduction in the consumption of animal products is a prominent option toward more sustainable food production. The role of major stakeholders and policy options will be discussed.

SUSTAINABILITY

“Humanity has the ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.” (8)

This statement by the World Commission on Environment and Development, linking 1) global environmental deterioration, 2) poverty, and 3) rapid population growth, is often used as a definition of sustainability. It links the environment’s ability to meet present and future human needs with theories of social justice—both within and between generations—as a basis for ecologic, economic, and social aspects of sustainability (9).

In this respect, ecology, economy, and society are known as the 3 pillars of sustainability, alternatively referred to as “people, planet, profit.” For a heterogeneous society it is often easier to agree on the ills to be avoided (eg, poverty) than on the ideals to be achieved (eg, the ideal income distribution) (10), so sustainability may be a generally accepted goal with relative consensus on its “ills” (such as production-related impacts) but hardly ever on its “ideals.” For example, an industrial “framing” of sustainability (11, 12) and that of the average consumer may be worlds apart, because the latter primarily associates “sustainability” with attributes such as “natural” and “just” (13). At any rate, sustainability is not a static notion but a moving target,

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which should be understood as a challenge to preserve the adaptability and resilience of the natural (biotic and abiotic) systems that form the basis of economic and social development.

FOOD SUSTAINABILITY

Many definitions of sustainability are known and are generally based on its 3 pillars of ecology, economy, and society. The same holds with respect to food sustainability (14). However, distinct definitions of food sustainability may, or may not, address issues such as human health, equity, and animal welfare, indicating that the issue is fraught with ethical considerations. In fact, it is often unclear whether food sustainability definitions refer to production or consumption. The gap between production and consumption can be 30%, which may be in the form of waste (15) or other uses of food such as pet food. As an illustration of the latter, De Silva and Turchini (16) conservatively estimated that 2.48 million tons of wild-caught fish is used directly by the cat food industry, raising the ethical point that the use of a limited biological resource to feed pets competes with human food purposes.

Because it appropriates major shares of all ice-free land (33%), freshwater (70%), and energy production (20%) (17, 18), food production is one of the main drivers of environmental degradation and resource depletion (19). As global food production and consumption continue to increase, so will the associated environmental impacts. In fact, the environmental impacts of food production include both resource depletion and pollution on all scales from local to global. Prominent examples include impacts on biodiversity (20, 21), climate change (22), and human health (23), clearly showing the range and importance of anthropogenic impacts on the environment via food production.

FOOD SECURITY

“Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The 4 pillars of food security are availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security.” (24)

Defined in this way, food security is shown to have many dimensions. Technology does not seem to be the limiting factor, and producing enough food for 10 billion people seems feasible (25, 26). Rather, socioeconomic aspects such as sex and poverty are likely to constrain access to food (27–29). Another economic aspect is the market exclusion of smallholder producers by current intensification trends (30, 31), which also tend to disrupt beneficial functions of biodiversity (32).

The real challenge is still to come, however. Initially, the FAO projected that by 2050 world food demand will be ~70% higher than in 2005/2007 (33) but later revised this figure to 60% (34). According to other recent analyses, however, a 100–110% increase in global crop supply will be needed from 2005 to 2050 (35). As a consequence of the foreseen increase in demand, world market price projections of the International Food Policy Research Institute showed that world grain prices may increase 30–50% before 2050 (36). However, more recent sources suggested that “Global food prices are predicted to rise by 70–90 percent by 2030” (37).

After the 2008 price increases, Lawrence Haddad, one of the authors of the Foresight report (38), warned in an interview, “The last 3 to 4 years have seen alarming spikes in hunger. The price rises in 2007–8 were actually quite modest in a historical context but it led to 100 million more people going hungry. Bigger price rises could wipe out the development gains of the last 20 years and promote violent conflict and migration” (39). In 2012, after droughts that threatened US corn harvests, similar warnings were voiced by the FAO (40).

In fact, the effects of the seemingly inevitable price increases are not restricted to developing countries (41). Browning et al (42) summarized the impacts in the United Kingdom as follows: “There are over 4 million people in the UK currently living in food poverty” and “The lowest income households tend to be the hardest hit by changes in food affordability. The relative affordability of food—measured by the share of total consumer spending that goes on food and nonalcoholic drink for household supplies—is therefore a key indicator of household food security.”

NUTRITION AND HEALTH

Embedded in the definition of food security is the requirement that food should be nutritious, safe, and healthy. Such is generally addressed at the level of individuals by dietary guidelines (43). However, by their effects on public health and global sustainability, current food production volumes and methods have led to a new situation, as is evident from publications linking nutrition, health, and sustainability. For example, McMichael et al (23) summarized: “Together with persistent widespread undernutrition, overnutrition (and sedentarism) is causing obesity and associated serious health consequences. Worldwide, agricultural activity, especially livestock production, accounts for about a fifth of total greenhouse-gas emissions, thus contributing to climate change and its adverse health consequences, including the threat to food yields in many regions. Particular policy attention should be paid to the health risks posed by the rapid worldwide growth in meat consumption, both by exacerbating climate change and by directly contributing to certain diseases.”

By the same token, the Health Council of The Netherlands concluded that dietary guidelines should take full account of the ecologic perspective. In their 2011 report on this issue, and based on an international workshop, they advocated a diet transition toward fewer animal products, because such a diet will result in a tremendous reduction in the pressure on land, freshwater, and biodiversity resources, with added benefits for human health and animal welfare (7). In Italy, the Barilla Center complemented the existing food pyramid based on nutrition with an environmental pyramid based on sustainability (44), addressing food security in the process (45). Once more, livestock products were shown to have important health and environmental impacts.

In addition, resistant bacteria (eg, methicillin-resistant *Staphylococcus aureus*, extended spectrum β lactamase) result to a large extent from antibiotics used in intensive livestock production (46, 47). When a prophylactic addition to feed was forbidden in the European Union (EU) in 2006, therapeutic antibiotic use in livestock production increased. The amount of antibiotics used in livestock is considerably (~5-fold) higher than is used in human health care. Research by the European Medicines Agency showed that



in the EU antibiotics resistance kills ~25,000 people and costs ~€1.5 billion/y (48). Finally, an endless string of food scares associated with emerging zoonotic diseases (including Bovine Spongiform Encephalopathy, avian influenza, Q fever, enterohemorrhagic *Escherichia coli*) can be linked to livestock products (49). The concept of “One World, One Health” becomes even more powerful when considering that biodiversity was recently shown to have a positive effect in natural ecosystems by reducing disease (50).

INTEGRATED APPROACH

Until a decade ago, addressing food security without compromising sustainability was considered an ever-growing challenge (51, 52), but more recently the message was summarized in a more direct way: “Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years. Growing competition for land, water, and energy, in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment. The effects of climate change are a further threat. But the world can produce more food and can ensure that it is used more efficiently and equitably. A multifaceted and linked global strategy is needed to ensure sustainable and equitable food security” (53). Other authors advocate an integrative approach to nutrition (54). In addition, it is held that the effects of price increases may be cushioned by adopting a more holistic approach toward resources (55). In fact, some European countries, such as the United Kingdom (56), Sweden (4), and The Netherlands (5), have published policy reports addressing the combined issues of food security, sustainability, and health. In an increasingly interlinked world speeding toward 9 billion people an integrated approach is clearly the way to proceed. However, to tackle such a complex issue efficiently, at least some priority setting is required to establish a beachhead.

SETTING PRIORITIES

To quantify sustainability in terms of the carrying capacity of our planet, the groundbreaking article by Rockström et al (57) defined and established boundary values that should not be transgressed for the most important anthropogenic environmental issues (**Table 1**). Subsequent analysis indicates the following: 1) food production is an important driver underlying all of these impacts; 2) the top 3 environmental impacts, ie, bio-

diversity loss, nitrogen cycle disruption, and climate change, are strongly interlinked rather than independent of one another; and 3) protein production is the pin linking these 3 impacts (19). The underlying causes are discussed in detail below.

Dietary protein is nutritionally crucial (58), because it is the primary way to acquire nitrogen, which is an essential element in DNA, RNA, and cell protein. Smil (59) also calculated that before the large-scale application of fertilizers, the world population was capped at ~3 billion people by nitrogen limitation, less than half the present number. The proportion of animal protein in the diet is primarily income dependent (60), but the actual protein source also depends on cultural aspects (61).

Importantly, a large proportion of fertilizer nitrogen is lost to the environment. In 2005, just 17% was consumed by humans in crop, dairy, and meat products, and the global nitrogen use efficiency of crops keeps dropping (21). In parallel, ammonia emissions from manure are increasing. Much of this “reactive nitrogen” is deposited in nitrogen-limited ecosystems via the atmosphere. There it leads to unintended fertilization of ecosystems unable to cope with this nutrient inflow (eg, several types of forest), which makes it one of the leading causes of terrestrial biodiversity loss (62, 63). Pollution from livestock enterprises affects both terrestrial and aquatic ecosystems (64). In addition, fertilizer runoff may lead to algal blooms and dead zones in sensitive coastal ecosystems, with inevitable repercussions on aquatic biodiversity (21). In sum, the nitrogen cycle is strongly linked to both terrestrial and aquatic biodiversity loss.

The tremendous energy input in nitrogen fertilizer alone is responsible for 2% of world energy consumption (63) and for 37% of all energy expenditure in US agriculture (3), thus causing significant climate change (21, 59) and linking the anthropogenic disruption of the nitrogen cycle to the disruption of the carbon cycle (ie, to climate change). In short, nitrogen is crucial to terrestrial and aquatic biodiversity loss, climate change, human health, and many other issues (21, 23, 62, 65). Anthropogenic contributions to the natural carbon cycle represent 1–2% by mineral fuel combustion (18) but are 100–200% to the natural nitrogen cycle. In fact, the current production of fertilizer far exceeds the formation of reactive nitrogen by natural processes, such as lightning (21, 62, 66). Consequently, Rockström et al (57) ranked the impacts of this nitrogen cycle disruption in between those of biodiversity loss and carbon cycle disruption (*see* Table 1). Because nitrogen cycle disruption has strong impacts both on biodiversity and on the carbon cycle, protein production was shown to be the pivotal link between the top 3 environmental issues in the Rockström et al ranking (19).

The environmental impacts of reactive nitrogen on biodiversity, climate change, and human health are well established in the United States (67) and in China (68). In Europe, the associated costs have been estimated at €70–320 billion annually, of which ~75% is related to health damage and air pollution (66). In summary, reducing the losses of reactive nitrogen compounds in the food chain will benefit biodiversity, human health, and a rapidly changing climate, thus “killing several birds with one stone,” and making it stand out as a top priority to achieve sustainability.

REDUCING ANIMAL PROTEIN INTAKE

The conversion of plant protein into animal protein is a metabolic process optimized for animal survival. Turning protein

TABLE 1

Ranking environmental impacts according to the transgression of planetary boundaries established by Rockström et al¹

| Rank | Environmental impact | Current status ² |
|------|--|-----------------------------|
| 1 | Rate of biodiversity loss | >10 |
| 2 | Nitrogen cycle disruption | 3.45 |
| 3 | Climate change (carbon cycle disruption) | 1.1–1.5 |
| 4 | Phosphate cycle disruption | 0.77–0.86 |
| 5 | Ocean acidification | 0.81 |
| 6 | Land-use change | 0.78 |
| 7 | Freshwater use | 0.65 |
| 8 | Stratospheric ozone depletion | 0.50 |

¹Data adapted from reference 57.

²The boundary value for sustainability equals 1.

from feed crops into animal protein for human consumption may be economically feasible, but it is inherently resource-inefficient, which makes intensive livestock production responsible for a disproportionate share of environmental pressure (69–71). On average, 6 kg of plant protein is required to yield 1 kg of meat protein (17, 72). Consequently, only 15% of protein and energy provided by feed crops will be consumed by humans indirectly and 85% of these crops are wasted (and, incidentally, 85% of fertilizer inputs to grow them). In 2000, for example, 942 and 617 million tons of grain were used for food and feed, respectively (36). Of the latter, >500 million tons constitute a tremendous loss of resources. Maybe even more important, this huge amount of potential food is turned into massive emissions of reactive nitrogen (eg, ammonia from manure), which pollutes the terrestrial and aquatic environment and results in biodiversity loss.

Both resource depletion and pollution by livestock production were treated in a comprehensive FAO report (70). Moreover, intensive livestock production was shown to play a crucial role in all 3 of the “planetary boundaries” that have already been overstepped by humanity (ie, biodiversity loss, nitrogen cycle disruption, and carbon cycle disruption) (19). This conclusion was fully confirmed by an exhaustive review of European protein impacts and options for their reduction (65). More recently, Sutton and Dibb (73) estimated that 1) nearly one-third of global biodiversity loss is attributable to livestock production, 2) meat consumption is responsible for nearly half of the UK food greenhouse gas emissions, and 3) the estimated cost to the National Health Service in early deaths related to excessive meat consumption is £1.28 billion.

From the above it is clear that plant protein production causes far less pollution and requires far fewer resources than the production of animal protein. The gain of a “reversed” diet transition (74) back toward a diet with less animal protein (75) is, in fact, amplified by substantial reductions in freshwater, land, and fertilizer requirements (76), with beneficial effects on all of Rockström et al’s (57) environmental impacts (Table 1), without exception (19).

Total protein supply (= production + imports – exports) across the 15 countries of the European Union ranged between 95.8 and 118.9 g/d (77). Correcting for household losses of 25–30% (15, 78), the average European consumption is therefore at least 150% of Dietary Reference Intakes, which are 50–60 g protein/d for adults (79). In the United States, Dietary Reference Intakes are similar (46–56 g/d) (80) to those in the EU. The supply of plant protein is also similar; however, animal protein supply in the United States is considerably higher (ie, 72.3 compared with 61.8 g/d in the EU) (81).

Consequently, on both continents there is ample room for a diet that is less dependent on animal proteins and therefore attractive from a sustainability perspective. In addition, reduced intakes of animal products would benefit human health as well as the ecology (7). European consumers should therefore consider to change their diets by doing the following: 1) eating one-third less protein (the average amount of overconsumption), 2) replacing one-third with plant-derived protein, and 3) replacing the remaining animal protein (primarily meat) with protein from free-ranging animals (82). In agreement with the results of the multidisciplinary Protein Foods, Environment, Technology and Society (PROFETAS) research program (83), these 3 steps

would benefit health, environment, and animal welfare. Similar recommendations could be phrased for the United States.

Of course, a successful diet transition requires local differences to be addressed. For example, the global population has been projected to increase by 50% between 2000 and 2050, and both meat and dairy demand have been projected to double (70). Most of the projected population increase will take place in Africa and India, although meat demand will increase primarily in China and South America and dairy demand in India. Such geographic distinctions should be taken into careful consideration.

STAKEHOLDERS AND POLICY

Reducing consumption in general or that of livestock products in particular is easier said than done. In essence, there is no “problem owner.” Although lip service is paid to “less is more,” the bottom line is that to reduce consumption (or to be told to do so) is in sharp conflict with the desires of the average consumer, industrialist, and politician.

As indicated above, some countries have integrated policies “educating” or “advising” consumers to reduce meat consumption, placing the burden of responsibility on the consumer’s shoulders, but they shy away from more substantive measures. Options include promotion of meat substitutes and the taxation of meat products, for example (84). According to the Royal Society, stakeholder dialogue is a must (85), and a framework to help consumers, producers, and policy makers out of deadlock and into negotiation is available (86). However, in actual practice, little political effort is devoted to this issue. By the same token, the food industry is focusing primarily on food safety and increasingly on sustainability, but there is a lot of “green washing.”

Despite the social status of meat (61), some consumers are prepared to avoid meat (87), although health benefits are a much stronger motivation than environmental concerns (88). Consequently, consumer communication is crucial, because consumer “framing” is fundamentally different from governmental and industrial policy makers (89). There is no “one size fits all.” A huge range of differences exists among countries (77) and among distinct groups of consumers within a country (90, 91). At any rate, getting consumers to change their diets in a more sustainable direction is likely to require much more than gentle nudging. Consumer awareness should be raised with regard to protein overconsumption and the associated environmental and health costs. More important, however, national governments and the UN should shoulder their responsibilities and take the lead, as proposed by the British Food Ethics Council (92).

CONCLUSIONS

Food demand has been projected to double by 2050. Simultaneously, the environmental impacts of food production will have to be reduced strongly and urgently. Taken together, this outlines the daunting task of almost quartering the impacts per ton of food within a period of only 40 y. Because animal protein production appropriates a huge and disproportionate share of natural resources, it presents a perfect target as an option for significant reduction. Reducing animal protein consumption will therefore benefit both food security and food sustainability (89).



Food security, equity, health, climate, and biodiversity may all benefit. In fact, several authors agreed that 1) a diet transition is required and 2) better dietary health and better environmental quality generally go hand in hand (7, 23, 63, 93).

Continuing on the present path is not an option, because, if animal protein consumption is not reduced voluntarily, a transition toward less animal protein is likely to be brought about by rising prices, which will hurt the poor and increase world hunger. In the words of Roberts et al (92): "So there is a problem: business and government both look to consumers to lead the way on sustainable consumption, but consumers do not want to assume this responsibility." According to these authors, the food business, government, and civil society should all take their responsibility, which can and should be done in small steps. In addition, they propose, "We also need a global strategy, prioritized by the G20 and led by the UN, that takes a comprehensive approach that puts sustainability, equity and hunger at the heart of food security" (92). Be that as it may, such global political processes are renowned to be slower than the few decades that remain to us to absorb the anticipated strain on ecology and society.

So far, an important bottleneck has been the sluggishness of World Trade Organization negotiations, or more in general, the fact that stakeholders (including most governments, industry, and consumers) give preference to economic issues over ecologic and social issues. In this globalized world, the pressures of ethical trade-offs (94) are mounting. Under the current conditions of an unprecedented global population size it may be time to rethink issues such as consumer freedom (diet choice) compared with global food security, the use of 2.48 million tons of fish for cat food, and free trade, not by abolishing these pillars of current society but by adapting them to remain within Rockström et al's planetary boundaries. It is evident that all stakeholders should take responsibility without exception (92); however, national governments and the UN should take the lead and initiate a global strategy integrating sustainability, food security, nutrition, and equity. To date, the profit pillar of sustainability has taken precedence over planet and people. It is time to redress the balance.

The author is a member of the Scientific Advisory Committee of the European Natural Soyfoods Association.

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