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Alternative pathways to food security and nutrition – water predicaments and human behavior

Jan Lundqvist[a] and Olcay Unver[b]

[a]*Corresponding author. Stockholm International Water Institute, Stockholm, Sweden. E-mail: jan.lundqvist@siwi.org*
[b]*Food and Agriculture Organization of the United Nations, Rome, Italy*

Abstract

Remarkable successes and new challenges to cope with requirements for food and water are analyzed. Trends in demography, food preferences and consumer habits are scrutinized together with their implications for human well-being and natural resources. Making best use of variable and limited water resources presumes proper management and efficient technologies, but also a worthwhile use of goods and services produced, for example, food. Reduction of food losses and waste, and reversing trends in overweight and obesity promise significant water savings. Transformations of food systems in this direction provide opportunities to meet human nutrient and food requirements in a resource-effective manner. In line with the principle of the Sustainable Development Goals, 'no-one should be left behind', governments, producers and consumers must be involved in efforts to ensure food security and nutrition. Naturally, farmers are major actors in food systems. The business community is showing a commitment to contribute to food security and nutrition and to reduce water risks. Consumers are dynamic drivers as well as beneficiaries, victims and culprits in water and food systems and need to internalize resource-use efficiency in their behavior, for example, by reducing food waste and aiming for better nutrition and sustainable diets.

Keywords: Alternative projections; Food and water wastage; Intake *versus* consumption; Nutrition-sensitive water productivity

Scope and purpose

This article outlines alternative pathways for meeting the food and nutrition needs of a burgeoning and generally wealthier world population in a context of increasing water and environmental predicaments. Two game-changing circumstances are addressed: the higher frequency, duration and amplitudes of

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climatic extremes and water-related risks; and growing imbalances in food systems, including losses and waste and a rapid increase in the prevalence of overweight, obesity and micronutrient deficiencies.

Eighty years ago, in 1937, Paul Valéry remarked that 'the future … is no longer quite what it used to be' (*Dictionary of Modern Proverbs*, 2012). We must know the past to understand the present, but projections of the future based on past trends and assumptions that used to be valid may be deceptive. The ongoing debate on how best to achieve the Sustainable Development Goals (SDGs) includes calls for radical changes in water governance, food and energy systems, land use, transport systems, and human behavior. The 17 SDGs and the 169 SDG targets underline the complexity and interdependency of development. For improved food security and nutrition, the main actors in the food system need to be involved: farmers, distributers, processors, traders, and consumers. Given consumers' strong role as drivers in food systems, it is essential that consumer food preferences and habits are addressed with realistic strategies for an increase in people's adoption of healthy diets.

Water resources: scarcity, risks and demography

The landmark UN climate conference in Paris in 2015 moved agriculture from being a part of the problem to the domain of solutions. Over 80 percent of countries listed agriculture as key to their climate-change responses at the 2017 Conference, COP23 of the UN Framework Convention on Climate Change (UNFCCC). This, along with the SDGs, has raised expectations and resolve for accelerated actions on a wide spectrum. For the seventh consecutive year, the Global Risks Report 2018 (WEF, 2017) listed water crises among the top-five global risks both in terms of impact and in terms of likelihood. Extreme weather events, which mean water extremes, are perceived as the top risk both in terms of likelihood and impact. Considering its high dependence on water, the agricultural sector is naturally affected.

More than half the world's population, some four billion people, are exposed to drought for at least one month per year (Mekonnen & Hoekstra, 2016). Kummu *et al*. (2016) and Varis *et al*. (2017) reported a similar magnitude of people exposed to water scarcity. Huge variations characterize availability, usability and access, but basically the size of the water resources is fixed, while demography, economic activities and human aspirations change. Three billion people relied on the same volumes of water in the 1960s as some seven-and-a-half billion do today. In a generation, another two billion people will need and want water for a variety of uses, including food production, while the size of the resource remains basically the same. Projections indicate that the most rapid increase in water demand will be in urban contexts. OECD (2012), for example, estimated that global water demand will increase by 55 percent between 2000 and 2050. Water Resources Group 2030 (2009) predicted that the gap between reliable supply and aggregate demand could be as high as 40 percent in 2030, assuming current levels of water-use efficiency and productivity. For food producers, competition will primarily affect irrigated systems. Growing variation in precipitation pattern affects all types of agriculture.

According to FAO, achieving food security in the decades ahead will require a combination of measures, including a 10 percent increase in water withdrawals for an expansion of irrigation (FAO, 2006, 2011b; Alexandratos & Bruinsma, 2012; Unver *et al.,* 2017). With the big role of irrigated agriculture in food policies and being a major water user, nutritional productivity of water would be natural to include in the planning and performance assessment of irrigation systems. In a review of advice to farmers in irrigation systems, Domenech (2015) found, however, that there is no systematic attempt to promote the use of water for the cultivation of crops that could improve food security and nutrition.

Table 1. Evolution and trends in population, aggregate agricultural production, food supply and estimated average per capita consumptive water use.

Year	World population (billion people)	Global agricultural production (kg per capita per year/kg per capita per day)	Global food supply (kcal per capita per day)	Vegetal source foods (kcal per capita per day)	Animal source foods (kcal per capita per day)	Protein supply; per capita per day (high-income countries/low- and middle-income countries)	Estimated consumptive water use (litres per person per day)
1961	3	1,002/2.75	2,194	1,856	338	82/57	2,280
2011	7.1	1,321/3.62	2,868[a]	2,362	507	100/67	3,209
2050	*9.8*	*1,450/3.97*	*3,000*	*2,410*	*640*	*110/80*	*3,760*
2100	*11*	?	?	?	?	?	?

[a]FAO (2017) estimates that the food supply in terms of kcal per capita per day was 3,350 in high-income countries and 2,750 for low- and middle-income countries.

Notes: Figures in columns 3–7 are derived from Food Balance Sheets and population numbers (column 2) from UN estimates. Column 8 provides estimates by authors. FAO Food Balance Sheets started to be systematically compiled in 1961 (FAO, 2001). The question marks in Table 1 shown for 2100 indicate that the actual values are highly dependent on the pathways taken now towards set targets and visions. Per capita consumptive water use = 0.5 litres per vegetal kcal + 4 litres per animal kcal are crude estimates used in literature (see, for example, Hoekstra, 2012). By using the same figures for consumptive water use for the various years, it is assumed that the water transpiration remains a function of biomass produced. Increasing biomass production implies that relatively more water is transpired. On the other hand, improved water management in terms of, for example, better regulation of water supply over the season means savings, for example, in evaporation during cropping period. In hot-climate regions, evaporation rates are high. Level and changes in water productivity, 'crop per drop', over time and variation between seasons, crops and breeds as well as between local areas are multifaceted and complex and have not been attempted to be incorporated in Table 1.

Trends in food supply – laudable achievements with multiple trade-offs

Globally, food supply (the amount of food available on the market) increased by about 30 percent (on an average per capita basis) between 1961 and 2011 (Table 1), naturally with significant variations between countries. The increase is remarkable given that the world population more than doubled (from about three billion to seven billion people) over the same period. The increase in primary food production is even more impressive because a significant part of production is used for livestock feed and other uses. In addition, a certain quantity of produce is lost on farms and in transport, processing and marketing; such losses can be quite high in both quantity and quality, especially for vulnerable, high-value and nutritious commodities such as fruit, vegetables, fish and meat in countries with inefficient distribution systems.

Currently, about 45 percent of global cereal production is used directly as food, about 35 percent is used for feeding animals, and 20 percent is for 'other uses', including the production of biofuels (FAO, 2011a). The use of large quantities of cereals as animal feed has made it possible to raise large populations of cattle, pigs, chickens and other livestock. Based on information in Food Balance Sheets (see FAO, 2001), the proportion of animal calories in global food supply increased from 18 percent in 1961 to 21 percent in 2011. The per capita supply of protein is now over 100 g per day for high-income countries and over 70 g per day in low- and middle-income countries (FAO, 2017, p. 84), quite a remarkable progress, as will be discussed further below.

The good news is that never before have so many people been exposed to such a varied and tempting supply of food produced by farmers and food industry worldwide; invariably, such foods are available consistently and at a large scale. Global cereal production alone contains more than twice the total amount of energy required to provide a sufficient energy intake for all people on the planet. A majority of the world's population can now afford and enjoy two or more meals a day – the combined result of socio-economic development, the fight against poverty, and the increased availability of food.

The bad news is that significant amounts of the food produced are lost and wasted while also overeating and unbalanced diets have exploded. Together these imbalances have become threats to human well-being and water security, virtually in all parts of the world.

The threat of large-scale starvation, which has been present throughout history, has been significantly reduced despite a rapid increase in the global population. After decades of a steady reduction in the prevalence of undernourishment, recent compilations of data show that the percentage of people being undernourished is increasing. The increase is, however, mainly affecting people in conflict areas (FAO, IFAD, WFP, UNICEF & WHO, 2017), that is, the increase is largely associated with extreme socio-political contexts, and not necessarily due to water scarcity and agricultural practices *per se*.

In general, concerns about the supply side of food systems are shifting from insufficient production and supply to issues likely to affect food production in the medium and long term, such as water risks, global warming and environmental consequences. On the demand side, worries refer to: food losses and waste, and the implications for public health of questionable diets and overeating, that is, food intake in excess of medical recommendations for a healthy and active life. Nutrition and the problem of unbalanced diets are now high on development agendas (see, for example, FAO, 2017; Pinstrup-Andersen, 2018).

Alternative pathways toward food security and nutrition

Calculations of future food requirements are generally based on assumptions of demographic trends and economic growth. Implicitly, it is assumed that increases in food demand, including a new mix of food preferences, will be met through corresponding increases in production. It is surprising that there are no alternative calculations about future food requirements. As a comparison, projections about population growth usually show three alternatives: low, medium, and high variants.

It is, for instance, surprising that Target 3 of SDG 12 is not considered in projections. The target calls on all nations to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030. A number of prominent colleagues are involved in efforts to translate Target 12.3 into action[1]. Aligned with this agenda, initiatives are taken by FAO[2], the G20[3] and the European Union[4]; legislative action in France[5] and Italy[6]; and national versions of Agenda 2030 as expressed in nationally determined contributions to the mitigation of climate change.

A reduction in food losses and waste of 50 percent by 2030 is a commitment with far-reaching positive implications. With a 50 percent reduction of food losses and waste, the need to increase production is

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[1] For example, Champions 12.3, a coalition of 22 executives from government, business, international organizations, research institutions, farmer groups and civil society dedicated to inspiring ambition, mobilizing action, and accelerating progress toward achieving SDG target 12.3 by 2030 (https://champions123.org/about).

[2] www.fao.org/3/a-i4068e.pdf

[3] www.fao.org/platform-food-loss-waste/it

[4] https://ec.europa.eu/food/safety/food_waste/eu_actions_en

[5] www.foodnavigator.com/Policy/France-s-food-waste-ban-One-year-on

[6] www.telegraph.co.uk/news/2016/08/04/italy-adopts-new-law-to-reduce-food-waste

naturally reduced, implementation of SDG Target 12.3 will also help reduce daunting water risks and curb greenhouse gas (GHG) emissions. If, in addition, the high prevalence of overeating is reduced, the positive effects will be even greater. Such transformations provide an opportunity to reduce imbalances and inefficiencies in the food systems in terms of the triple malnutrition: undernourishment (access to too little food); overweight and obesity (excess food intake); and micronutrient deficiencies (unbalanced diets).

More people and more disposable income versus *resource and environmental realities*

The shifts in consumer habits involve a growing preference for animal-based food items but also fruit and vegetables and, generally, fresh produce. Meat-based diets provide high levels of protein but they are also resource-intensive and sources of GHG emissions. It is therefore relevant to consider information as to what levels of meat intake are sound. According to medical literature, an average daily intake as to 0.83 g of high-quality protein per kg of body weight (i.e. 50–60 g for an average adult) is sufficient to meet an adult's requirement for protein (World Health Organization, FAO & UNU, 2007; Hawkesworth *et al*., 2010). McMichael *et al*. (2007) proposed 'a working global average intake of 90 g, of which not more than 50 g comes from red meat' or animal-source foods. However, protein supply has gradually increased in both high-income and low- and middle-income countries (FAO, 2017). According to official statistical information, it is now well above the 'working global average' for intake (Table 1).

Water requirements vary significantly between food items (see, for example, Hoekstra, 2012). For example, the production of 1 ton of red meat requires in the order of 15–20 times more water than the production of 1 ton of wheat or millets. The production of red meat generates in the order of 20 to 28 kg of carbon dioxide per kg, which is 8–10 times the emissions generated in the production of 1 kg of white meat and much more than that generated by the production of an equivalent amount of grains and vegetables. In general, evidence on the environmental impacts of diets supports the premise that what is good for human health is also good for the environment (FAO & Food Climate Research Network, 2016).

Imbalances in food systems

Increases in food production and supply in excess of population growth over extended periods of time have proved Thomas R. Malthus wrong, at least at the global level[7]. Discussions on the ratio between population numbers and food production and supply continue (see, for example, Hopfenberg & Pimentel, 2001; Gilland, 2002; Suweis *et al*., 2015). In contradiction to previous thoughts, there are few who argue that it will not be possible to feed a growing world population. A more valid question concerns how food preferences and food habits develop and how these can best be aligned with resource contexts and farmers' capabilities.

Two major imbalances characterize contemporary food systems.

Malnutrition. In the midst of opulent supply and overeating in increasing parts of the world, an estimated 830 million people are undernourished worldwide (FAO, IFAD, WFP, UNICEF & WHO, 2017). Undernourishment is related to various circumstances: too little food to eat, unbalanced diets, and low absorption of nutrients in the body. Low absorption of food in the body is typically affecting children in

[7] The famous essay of Thomas R. Malthus 'An Essay on the Principle of Population' was first published in 1798 when the world population was around 1 billion.

areas where people rely on poor water supply, where sanitation facilities are lacking and hygiene is poor. Unbalanced diets are typical in areas where the reliance on staples, such as maize, wheat and rice, is high. Generally these cereals have a high content of carbohydrates but low content of other nutrients than that of energy.

A balanced diet should include fruit and vegetables but, primarily due to poverty, the diets of poor people do not include foods of high nutrition value. Also among the poor, obesity is a reality and a sign of unbalanced diets in combination with social habits. After decades of a gradual reduction of undernourishment, an increase is now reported especially in conflict areas (FAO, IFAD, WFP, UNICEF & WHO, 2017).

Generally, water scarcity and poverty are linked. Differences in living conditions cause undernourishment and also food and nutrition insecurity. Some people must spend half or more of their incomes on food, others in wealthier segments of the communities are able to access and enjoy a rich supply using a much smaller fraction of their disposable incomes.

Losses, waste and overeating. Production and supply continue to increase over and above what can, and reasonably should, be eaten. As much as one-third of total production, an average of about 0.5 kg per day per capita worldwide, is estimated to be lost or wasted (FAO, 2012). Admittedly, the estimate is rough and due, partly, to variations in definition. Generally, losses and waste refer to food produced, supplied and bought. More radical views are also presented. It is, for instance, argued that grains used as feed for animals are a part of food waste (www.matvett.no).

Estimates are also difficult to make since losses and waste occur in many segments of the food supply chain. Deficiencies and technical problems in harvesting, transport, and storage are common in poor countries, and their consequences can be particularly severe in hot-climate regions. On the other hand, the discarding of food that is fit for humans to eat can largely be associated with human preferences and behavior that is typical in affluent societies (Lundqvist *et al*., 2015a, 2015b). Aesthetical considerations, for example, the difficulties for farmers to sell fruit and vegetables with imperfections on the skin, are additional complications in the supply/value chain, which further reduce beneficial use of the food produced.

With a growing surplus of food, two kinds of food habit follow: the throwing away of part of food even when it is fit to eat, and overeating. There is a limit to the quantity of food that people can eat and also practical problems in keeping large amounts of food in fridges and other storage. Many food items become unpalatable within days of purchase or storage. From a resource point of view, there is no difference between throwing away food and overeating.

Hence, overeating may be seen as a kind of waste of food (Blair & Sobal, 2006; Lundqvist, 2017). Alexander *et al.* (2017) report that overeating-related food loss is at least as large as consumer food waste. The combined volumes and value of food lost, wasted and overeating are staggering, and much higher than the common figure of about a third of food lost and wasted. They are an illustration of poor resource use efficiency in food systems in rich countries as well as in poor countries.

Food losses, waste and overeating come with a big price tag, although invisible for most people. FAO (2013) estimated that if global food losses and waste were a country, it would be the third-largest GHG emitter after China and the USA. There is also a resource cost: rivers are over-exploited, water tables are lowered, and large tracts of land are devoted to the production of food and other agricultural commodities that ultimately are lost or wasted (see, for example, Liu *et al*., 2013).

Water, food and people in the SDG context

Water concerns are addressed directly in SDG 6, but they also underpin most, if not all, of the 17 SDGs, notably SDG 2 (zero hunger). The overall aim of the SDGs is to end poverty, protect the planet and ensure prosperity for all; no one should be left behind (UN, 2015). In the support text of the Zero Hunger Goal, it is noted that 'A profound change of the global food and agriculture system is needed if we are to nourish today's 795 million hungry and the additional 2 billion people expected by 2050' (http://www.un.org/sustainabledevelopment/hunger/). The text, however, does not mention the two billion people who are overweight, obese or suffering from micronutrient deficiencies. WHO (2016) estimated that nearly two-thirds of the world's population live in countries where overweight and obesity kill more people than underweight. Government ministers and representatives of FAO and WHO clearly identified this as a problem at the Second International Conference on Nutrition (Rome, Italy, 19–21 November 2014), stating, in their Rome Declaration, thats 'overweight and obesity among both children and adults have been increasing rapidly in all regions, with 42 million children under five years of age affected by overweight in 2013 and over 500 million adults affected by obesity in 2010' (FAO & WHO, 2014, p. 10). The Second International Conference on Nutrition recommended action to combat overweight, including, among other things, regulation of the marketing of food and non-alcoholic drinks (FAO & WHO, 2014, p. 11).

How much more food and how much more water?

Looking back at the food, water and people equation a generation or two ago illuminates tremendous changes. At the World Food Summit in 1996, a comprehensive review was undertaken of changes in food (in)security in previous decades. The prevalence of undernourishment was about 35 percent in 1969–71. With a world population of about 3.7 billion in 1970, well over one billion people lived in countries where food supply was below the national average dietary energy supply (DES; referring to the energy contents of food supply) of 2,700 kcal per capita per day. In connection with the launch of the Green Revolution in the 1960s, massive investments were made in irrigation schemes and a package of improved seeds, fertilizers, etc. Since then, production and supply of food have increased significantly as illustrated in Table 1. Reduction in absolute and relative levels of undernourishment is laudable. But a pertinent question can be asked: when do increasing levels of food supply and levels of food intake no longer support the ambition of a 'healthy and active life' for all?

Contemporary discussions on food security and nutrition include a higher DES compared with previous assumptions. If a higher DES is achieved through a corresponding increase in production, an increase in consumptive water use and negative environmental impact are implicit. A higher DES could be achieved through improved water productivity or through a reduction in food losses and waste. Currently, the average DES is around 2,750 kcal for low- and middle-income countries and 3,350 kcal for high-income countries (FAO, 2017). Table 1 shows that the global average food supply (after conversions and losses from field to market) exceeded 2,800 kcal per capita per day in 2011. Projections for 2050 suggest that average global food supply will increase to about 3,000 kcal per capita per day. The norm for DES of around 2,700 kcal per capita per day – formulated 20 years ago – has been reached in low- and middle-income countries and it is much higher than that in high-income countries.

Contrary to the DES and intake levels indicated above, significantly lower figures have been reported for actual food intake, also in rich societies. In the UK, Hawkesworth *et al.* (2010) used data obtained from national diet and nutrition surveys to estimate the average daily food intake for adults (19–64 years) at 1,640 kcal for females, 2,321 kcal for males, about 2,000 kcal on average for females and males. A health and nutrition survey in Mexico in 2005–06 estimated daily food intake at 1,592 kcal for adult females and 1,963 kcal for adult males (Hawkesworth *et al.*, 2010). Smil (2000) reported average daily intake in Canada at less than 2,000 kcal.

Revising calculations of how much more food will be required

A widely circulated estimate of additional future food requirements was made during preparations for the World Food Summit in 2009. The world food crisis in 2007–08, in which food shortages in several countries fueled riots and almost toppled governments (see, for example, Evans, 2009; Berazneva & Lee, 2013), formed a dramatic context for the summit. Official statements, transmitted through press releases and reports, included an estimate that 70 percent more food would be required globally by 2050 (FAO, 2009). However, this estimate was interpreted as a recommendation, probably influenced by perceptions of a contemporary food crisis and threats of future crises, with a lack of food in shops and riots in some parts of the world.

It is seldom mentioned that the base years for the estimate were 2005–07; thus, the increase of 70 percent was to be realized over a period of about 45 years. A revision of the estimate a few years later indicated an increase in production of 60 percent from 2005–07, that is, with the same base years (Alexandratos & Bruinsma, 2012), again seldom recognized.

Another revision has recently been made (FAO, 2017) using updated global population projections (UN, 2015). It suggests that an increase of 48.6 percent in global agricultural production, including food, feed and biofuel, will be required between 2013 and 2050, that is, over a period of about 37 years, to meet growing demand. The projected increase is substantially higher in sub-Saharan Africa and South Asia, however, at 112.4 percent, which is due to demographic and economic prospects. However, there is no discussion of what kind of crops are realistic given the water and agroecological context and how such an increase contributes to rural transformation. A doubling of agricultural production, especially in areas where poverty is endemic and water risks are mounting, will require considerable efforts.

Taking into account the new base year and revised population projections, the new estimate is in line with previous calculations. It involves no consideration of how reductions in food losses and waste represent an opportunity for achieving food security and nutrition without a high increase in production and the projections are not sensitive to nutrition. The lack of alternative projections and the accuracy, to one decimal, of the estimate for changes over such a long period of time are noteworthy.

Beware of differences between food consumption and food intake

Food consumption is one of the most commonly used terms in analyses of food security, often in combination with production (for example, 'sustainable production and consumption'). In the media and public debate, food consumption is invariably understood as what we eat. It is an economic term, however, and it is used in estimates of how much food we buy or otherwise procure. Most of this food is eaten (i.e. 'food intake'), but some of it is thrown away (even if fit for humans to eat), some of it consists of bones, zests and other inedible parts, and some is used for purposes other than food.

A clear terminology is essential for generating reliable, comparable data, which, in turn, is necessary for understanding and monitoring food systems and informing policy making. The absence of such clarity makes it hard to improve knowledge among the public, for example, in understanding how food security and nutrition are related to agricultural production and the extent, trends, causes and implications of food losses and waste. Policies for effective supply chains will be hard to formulate and execute, and SDG 12.3 will be impossible to monitor, in the absence of a stringent terminology linked to reliable statistical information.

The magnitude and implications of food waste and overeating are veiled by the conventional terminology and their incorporation in the general term 'food consumption'. The gap between consumption, that is, what we buy and otherwise procure, and recommended diets increases (cf. Figure 1).

Significant changes in the burdens of triple malnutrition

The continual increase in per capita food supply has played a major role in reducing the prevalence of undernourishment. Parallel with this positive trend, an opposite type of problem has increased significantly. Malnutrition caused by overweight and obesity has increased rapidly in recent decades in both developed and developing countries, with very high rates in Egypt, Mexico and Pacific island states. In China and India, respectively, more than 300 million people are overweight or obese (IFPRI, 2015). Developments in Ghana have led to a tremendous reduction in the incidence of undernourishment but also to a rapid increase in the prevalence of overweight, obesity and micronutrient deficiencies (Figure 2).

Farmers' livelihoods and markets

Farmers make decisions based on economic considerations and self-interest (Pinstrup-Andersen, 2018). Their assessment of what are the 'best' decisions may differ from other actors in food systems. For instance, what are the implications from a reduction of losses and waste of food produced in line with SDG Target 12.3? There seems to be a fear that the income of farmers, and possibly also other actors in the supply chain, may be negatively affected since there would be reduced opportunity to sell what is produced.

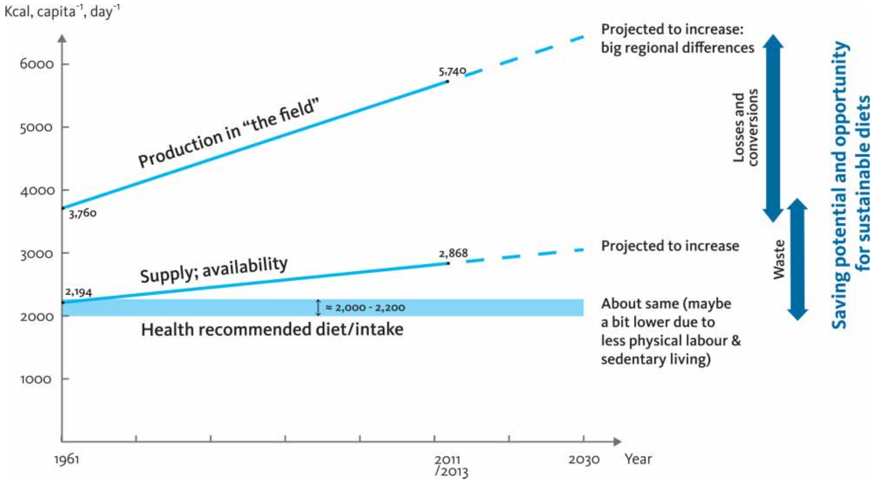

Fig. 1. Trends and gaps in average global food production and supply, and recommended food intake. (*Data sources:* Food Balance Sheets (production and supply), various sources (health recommended intake).)

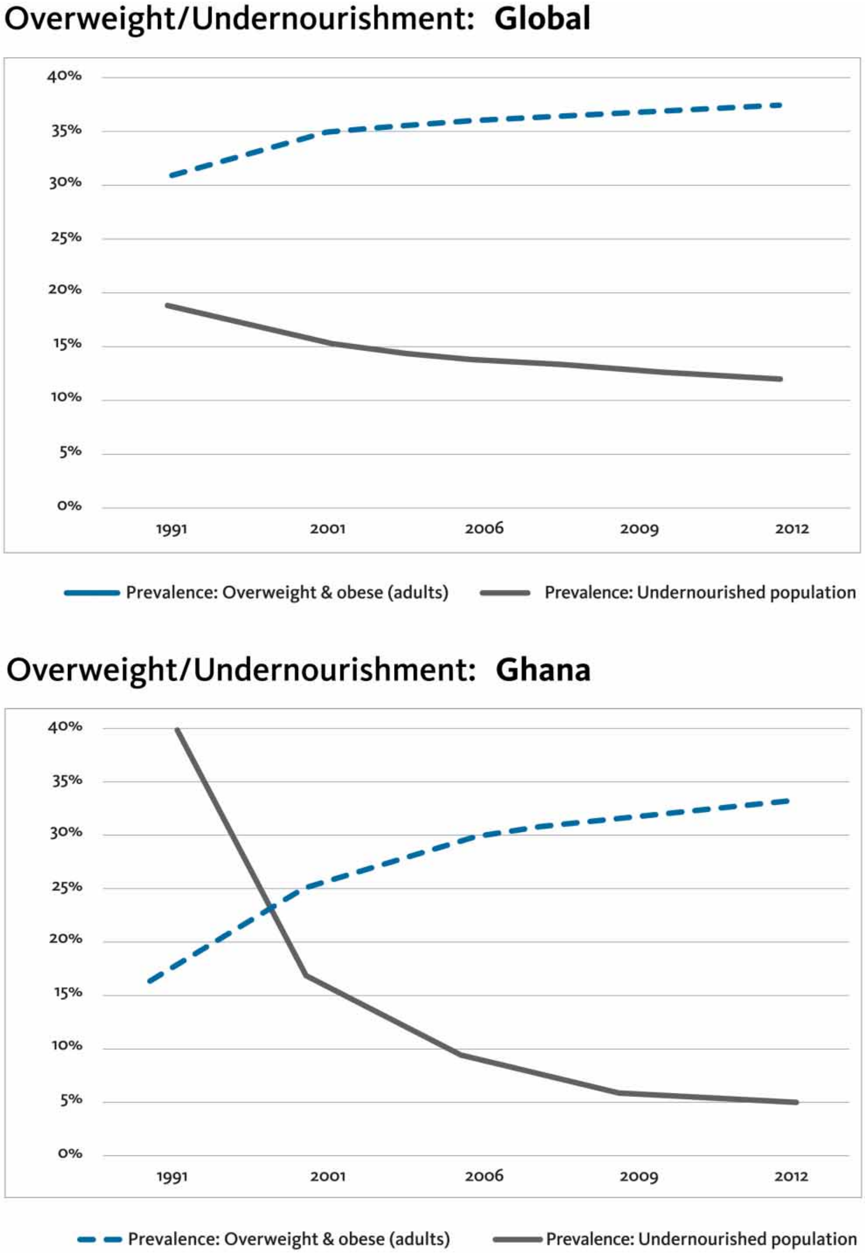

Fig. 2. Percentage of the population that is undernourished and overweight/obese, globally and in Ghana, 1991–2012. (*Sources:* trends of undernourished population: FAO, IFAD & WFP, 2013; trends for obese and underweight population: IHME, 2012.)

A reduction of food losses and waste will not be realized in the short term, however, and there is a continuous increase in overall demand driven by demographic and economic trends (FAO, 2017 p. 136). Equally significant, food losses and waste vary by commodity. A decrease in losses, both in terms of quantity and quality, is particularly important for produce that is vulnerable and sensitive to deficiencies in the transport and storage system, such as fruit, vegetables, milk and other dairy products, and fish. Compared with staples, which are less sensitive to problems in the transport and storage systems, these commodities generally have high nutritional value and, equally importantly, there is growing demand and, thus, income opportunities for farmers in an urbanizing world.

Food losses not only reduce the amount and quality of produce that reaches the market; at the farm level they deprive farmers' families of the possibility to sell produce at various occasions and thus obtain cash and food for the family over the year. With no food left in their store and with little money, hardship for farmers increases towards the end of a season. A lack of proper on-farm storage, or local storage facilities, limits the ability to market the produce over time, with negative consequences for the prices that farmers can obtain.

Finally, it should be recognized that improvements in farmers' income and livelihoods may not be achieved by producing more of the same. A more promising approach is a mix of products for which there is an expanding demand. A crucial precondition is that there are means to bring such produce to market. Today, information about markets is easily accessible through the mobile phones that are common even in rural communities, however, the physical access to remunerative markets is poor.

Policies for water governance and sound food habits

The triple malnutrition and water scarcity and risks are good reasons to review policies for food systems. Instead of policies that stimulate 'more crop per drop' or what Pinstrup-Andersen (2018) calls 'calorie maximization approach', it is now urgent to support an orientation of food systems that produces more nutrition and better economic prospects per drop aligned with sound food habits among consumers.

For farmers, there must be a demand and market for nutrient-dense crops/foods and consumers need to be sensitized about the importance of good food habits. Among the range of interventions that are discussed, two may be mentioned.

One intervention refers to efforts to promote crops for which there is a low demand, for example, millets. There is an interesting initiative currently going on in India where the central government has recommended schools in the entire sub-continent to include millets in the preparation of midday meals. Millets and sorghum are associated with 'poor people's food' and as a result there is no market and the economic prospects for farmers to produce these crops are poor. If a momentum is created, this programme will push the demand for these kinds of crops and provide an opportunity for farmers to improve their livelihoods. The subsidies that are common for wheat, rice and maize could be reallocated to provide incentives for the cultivation and marketing of 'smart' crops, which are important in many respects: from water, environmental and nutritional points of view[8]. Procurement of large quantities of food takes place also in other contexts. Through the P4P (Purchase for Progress) initiative, the World Food Programme buys huge quantities of food for distribution in conflict areas, as food for work, in schools, etc. About 600,000 tons of food are bought from about a million farmers, including a large number of female farmers (http://www1.wfp.org/purchase-for-progress).

Another desirable intervention refers to the possibilities to market high-value crops, such as fruit, vegetables and other nutrient-dense crops. There is a growing demand for these crops but deficiencies in storage and transport are serious obstacles. Targeted investments in better transport and storage – including

[8] ICRISAT is actively involved in efforts to promote millets in India (www.icrisat.org/SmartFood).

cool/cold storage for vegetables, fruit, dairy, meat and fish – will increase the possibility to bring these kinds of vulnerable but valuable produce safely and quickly to growing urban markets. These improvements typically require involvement of both government agencies and the private sector. High-value crops can be successfully cultivated in smallholders' plots and can be relevant particularly for female farmers. Promising cultivation at garden scale with involvement of the private sector is illustrated in Reel Gardening, South Africa (https://play.google.com/store/apps/details?id = io.cordova.ReelGardening&hl = en).

As illustrated in Table 1 and Figures 1 and 2, the world is facing quite different challenges in food systems today and for the future compared with the situation in the recent past. Still, projections about food requirements in the future do not pay attention to trends in per capita food supply or to trends in malnutrition or magnitude of losses and waste of food. Contrary to, for example, population projections, which include three variants, we usually see only one projection of future food requirements and assumptions typically refer to demography and economic trends. It would be relevant, for instance, to include assumptions of different levels of global warming and consequences of an increasing frequency and amplitudes of extreme weather events (McKenzie & Williams, 2015; Lewis *et al.*, 2016). What are the prospects for sustainable intensification (Rockström *et al.*, 2016)? What are the implications for production if the implementation of SDG 12.3 (a call on all nations to halve food waste and reduce food loss by 2030) is successful?

Concluding remarks

Even with massive population growth in the last half-century, the world has been able to increase per capita food production and supply. However, over 2,000 million people are overweight, obese or affected by micronutrient deficiencies, while around 800 million people suffer chronic hunger.

An estimated one-third of the food produced is lost or wasted. If overeating is recognized as a non-desirable use of food, much more than one-third of food produce is wasted, with enormous implications for water, land and energy resources and human well-being.

A nutritional perspective on water productivity is timely and sound. Decisions regarding water, agriculture and food policies need to be better informed about opportunities to use limited water resources for better nutrition. In addition, partnerships involving the main actors in food systems, such as governments, international organizations, the private sector (including farmers), civil society as well as consumers, are crucial for capitalizing on opportunities to reach the targets set in global agendas. A prerequisite for policy formulation and monitoring of its implementation is the availability of reliable and valid data and a stringent terminology.

A continuation of current trends in food habits could have severe consequences at a global scale. What is needed most, but is not made explicit in mainstream reports, is behavioral change that promotes the judicious use of water for the production of foods that are high in nutritional quality. Disincentives are needed for food with high energy density but poor nutritional value, and incentives are required to promote sustainable diets. Sustainable diets are those diets with low environmental impacts that contribute to food and nutrition security and to a healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources (FAO, 2010). It is unsupportable that we maintain the same policies (with a simple focus on production and 'calorie maximization'), conventional thinking and unsustainable practices that have put us in the present predicament. Without a major change in behavior at all levels, from citizens to governments, and in the absence of an integration of nutrition science in water and food policies, the likelihood of meaningful change is remote.

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