Foresight Project on
Global Food and Farming Futures

WP1: Understanding and improving the relationship between agriculture and health

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Summary

The relationship between agriculture and health is complex, rapidly evolving and increasingly global. The relations are both direct, such as the impact of food consumption and nutrition on health, and indirect, such as the impact of agricultural wage earning on access to food and health care. We identify and discuss three distinct areas that exemplify the scale and importance of agriculture-health interactions. First, the direct effects on human health of current food consumption patterns. Second, the direct consequences to human health of agricultural production practices, and third, the set of wider issues relating to agricultural development and sustainability and their indirect effects on health. In addition, the agricultural-health relationship interacts within increasingly complex, multi-level food systems.

Patterns of food consumption generate poor health in two ways, through under-nutrition which contributes to death and stunting, and through unbalanced, low quality diets which contribute to a range of common chronic non-communicable diseases. Under-nutrition is most severe among the rural poor in low- and middle-income countries, and persists there despite advances in global agricultural production and trade. Rapid increases in the nutrition-related chronic disease burden now affects populations at all stages of economic development. In order to develop effective policies to combat these problems, and to measure their impact, we require data on diets and how they are changing. While there is now global consensus on what constitutes a healthy diet, there is a lack of information on patterns of food consumption that would allow us to determine who is eating healthily. Currently available measures of individual food consumption are insufficient both in terms of reliability and availability. Furthermore, the global food system is not static and data sources currently do not respond to rapidly expanding food systems that are shaped by changing demands for foods caused by, among others, urbanisation and the increasing role of the food industry and supermarkets in the processing and sale of foods. We identify this lack of a primary evidence base as a significant knowledge gap for research and policy development.

Agricultural food chains can reduce health through the spread of toxicants, such as pesticides and aflatoxins, and diseases including food-borne diseases such as...
Campylobacter spp., as well as other zoonotic diseases. This latter category includes avian influenza and SARS, which have the potential to spread independently in human populations and have attracted particular attention due to the potential some have shown to evolve and become pandemic. Historically, agricultural systems respond well to the need to prevent and suppress livestock diseases that affect commercial production, but have responded poorly to animal diseases which pose only public health risk. This has created a need today for better integration of agricultural and health capacity in responding to zoonotic threats. These threats will become more challenging with the lengthening and globalisation of food chains, particularly in low- and middle-income countries where there is a demand for enhanced food safety mechanisms but currently insufficient incentive and regulation.

Food quality and food safety are important to the health of all consumers, while the proportion of the world’s population that are food producers experience additional agriculture-health associations. They are particularly exposed to agricultural health risks, including toxicants and diseases. More importantly, food producers depend on agriculture for their livelihood, and derive from this income with which they purchase health care and access to food. Poor agriculture therefore contributes to poor health, which in turn reduces labour and productivity further, influencing food security.

Throughout this report we show how these three agriculture-health interactions relating to food quality, food safety and health in production systems are all more intense and problematic in low- and middle-income countries. This is where we find persistent under-nutrition as well as the most rapid diet transition, where safety risks from food are greatest and where the potential effects of health on food security, and vice versa, are greatest. If complex agriculture-health associations are not considered, the benefit of agricultural development programmes may be offset by negative health impacts. Conversely, there are distinct co-benefits between sustainable agricultural development and good health.

Global agricultural policy relating to human health has largely been directed at issues of food safety and within this remit has been reasonably successful. It has not effectively addressed the far greater agricultural effect on health, namely its contribution to the quality of human nutrition, through the provision of sufficient
quantities of the right nutrients. This is where future effort in aligning agricultural policy with health priorities needs to be focused; efforts that will need to involve both governments and the private sector. Only by making health one of the drivers of agricultural policy will we be able to feed a human population of nine billion healthily in 2050.

**Keywords:** health, nutrition, agriculture, food consumption, food policy
1. Introduction

Agriculture fundamentally involves a relationship between society, nature and the bodily basis of human development (Friedmann 2005). The concept of ‘healthy’ agriculture, therefore, has several dimensions: a particular agricultural activity may promote the health of a society through providing employment, sustainable food chains or economic growth; the health of the environment by intelligent use of natural resources; or the health of individuals in terms of their physical and mental wellbeing. In this paper, we will focus on the health of individuals, and its relationship with agriculture.

Figure 1 illustrates the complex relationship between agriculture and human health, and serves as an outline for this paper. As a source of food, agriculture can influence health through nutrition, but also by increasing human exposure to diseases and toxicants related to agriculture and food chains. This relationship affects all humans, insofar as we are all consumers. Less directly, and for only a part of the human population, agriculture can provide employment and income, which enables individuals to lead healthier lives. Agriculture may also affect health indirectly through its impact on the environment and ecosystem services, which may affect human health through changes in, for example, the prevalence of certain diseases, access to water, or climate change. Finally, there is a reciprocal process in this relationship, whereby the health of individuals involved in agriculture may affect agriculture itself; an unhealthy agricultural population may provide less labour and resources, with consequences for productivity and implications for all consumers. The arrows linking agriculture and health in this diagram are shorthand for complex food systems, in which agriculture production is generated, processed into foods and distributed through markets. The health effects generated in these food systems extend well beyond the health effects of food production itself, and the increasingly global nature of food systems means that local health effects may have geographically distant agricultural causes.
Figure 1: Interaction between agriculture and health

Large arrows represent direct links, thin arrows are indirect associations.
The relationships illustrated in Figure 1 describe a fundamental, health-improving process, with agriculture producing a healthy human population capable of sustaining the production necessary for health. In reality, the scale of negative health effects arising from this process is very substantial. While global food production has kept up with demands (Dyson, 1996; FAO, 2009), gross inequalities remain in regional and national distribution of, and economic access to, available food (Sen, 1981; Lang, 2010). About one billion people are under-nourished in terms of their consumption of macronutrients, that is, energy and protein, while about two billion are under-nourished in micronutrients, such as iron and iodine (SCN, 2004; World Bank, 2006). Lack of macro- and micronutrients are estimated to be the underlying cause of 35% of all child deaths and 11% of the global disease burden (Black et al., 2008). At the other extreme, excess dietary consumption, or over-nutrition, is increasingly leading to global epidemics of obesity and diabetes resulting in rapidly increasing burdens of disability and death across all world regions (WHO/FAO, 2003; Haslam et al., 2005). Indeed, several nutrition-related chronic diseases such as coronary heart disease and stroke are now among the leading causes of death worldwide, with the burden growing most rapidly in the world’s lowest income countries (WHO, 2008), often leading to a ‘double burden’ of both under- and over-nutrition, placing a huge burden on societies and the existing health systems (FAO, 2006).

Food-borne diseases also have a substantial impact on health. For example in the USA the estimated medical costs, productivity losses and value of premature deaths due to diseases caused by five food-borne pathogens (Campylobacter, non-typhi Salmonella, E. coli O157, E. coli non-O157 STEC and Listeria monocytogenes) in 2000 were $6.9 billion (Henson, 2003). Recent work by the UK Food Standards Agency (FSA) estimated that Campylobacter is the highest priority pathogen in terms of public health impacts in the UK with salmonellas and Listeria monocytogenes also significant (Jones pers. comm.).

Any consideration of the future of agriculture must include strategies for addressing current negative effects, and must ensure that new agricultural innovation and expansion avoids creating new negative effects of agriculture on health. In this study, we begin by describing in more detail the food systems that link agriculture and
health. Then, we consider the specific relationships illustrated in Figure 1 in more detail:

- The effect of agriculture on consumers, through nutrition and through food-borne diseases and contaminants.
- The effect of agriculture on the health of producers, and the reciprocal effect of producer health on agriculture.
- The effect of agriculture on health as it is mediated by environmental processes.

In examining these relationships, we pay particular attention to factors limiting our understanding of agriculture-health links, as these reveal areas for research and evidence-gathering necessary to improve agricultural impacts on health. We also place emphasis on agriculture-health links in low- and middle-income countries. These countries appear to experience particularly serious negative health effects associated with agriculture, and they are also the countries where agricultural change in future is likely to be most rapid and actively driven.

2. The global food system

A food system is often defined as the process involved in feeding a population and includes activities such as food production, processing, packaging, transportation, marketing, consumption, and disposal of food and food-related items. A food system operates within, and interacts with, wider social, political, economic and environmental contexts. The workings of food systems are governed by a combination of: international and national regulations; commercial standards; industry culture, structure and conduct; individual firm strategies and practices; and social norms on the part of farmers, firms, workers and consumers. To reflect this, some writers have preferred the term ‘food regime’ to highlight the importance of expectations, rules and regulation in shaping food systems (Friedmann, 2005).

Over recent decades, national food systems in all countries have undergone fundamental changes in character, resulting in integrated food production and consumption at a global level (Friedmann, 2005; Lang, 2010). This long-run trend
has involved growing urban demand, greater influence of the private sector in shaping food markets, and increasingly vertically coordinated supply chains. Value addition from farmgate through international trade, transport, storage, processing, manufacture and retailing is a major global industry. According to recent estimates, processed food sales of a value exceeding $3 trillion are a major component of global food markets and account for about three-fourths of total world food sales (Gehlhar et al., 2005). The coffee industry illustrates this clearly and its enormous social and environmental significance has attracted substantial attention from analysts, policy-makers and development practitioners in the last 10-15 years (Ponte, 2002; Giovannucci et al., 2005). Large firms not only shape supply chains but significantly influence agricultural production and consumption food patterns through new product development, advertising and promotion, with multiple health consequences. They are repositories of data and information about food purchasing that is both commercially valuable but also of significant public and research interest. The global agri-food industry not only sells agricultural input supplies and foodstuffs but stimulates research and development in basic and applied science. It is also a major employer.

Even the most remote communities today usually engage in exchange of locally produced foods for globally supplied foods, and exchange has grown in scale and complexity as economic development proceeds (North, 1987; North, 1990). Modern food systems, seen as value chains, are becoming longer in terms of both space and time, and more complex in terms of the processing and manufacturing, or value-adding functions.

The chain of processes that link agricultural production, food and health are illustrated in Figure 2. From farm to fork, these value chains have the capacity to make safe food products affordable to consumers while providing satisfactory incomes to producers, labourers and others involved in the chains. But these chains can also operate in ways that have negative health impacts. For example, production and processing systems may generate and amplify food-borne disease risks, while marketing systems may move them quickly around the world. Food manufacturers and retailers can in effect subtract value from the food chain by adversely affecting the healthiness of diets and by exacerbating income distribution inequities among suppliers. While trading in foodstuffs has a history as long as civilisation itself, the
events of recent years illustrate how agri-food markets can be affected by international financial investment and speculation strategies in a way that can threaten food security and health (Piesse et al., 2009).
Figure 2: Complex links between agricultural production and health consequences
The mediating role of markets in linking agricultural production with safe and healthy food consumption is fundamental to the food system as a whole. Consumption in advanced economies of most products is achieved through commercial channels and value chains, ‘managed’ by some of the largest firms in the world: Cargill, Coca Cola, Carrefour (Gibbon, 2001; Bair, 2005). Large firms not only shape supply chains but significantly influence agricultural production and food consumption patterns through new product development, advertising and promotion, with multiple health consequences (Lang, 2010; van der Ploeg, 2010).

2.1 The food chain in low- and middle-income countries

In low- and middle-income countries, local markets are particularly important mediators of economic and physical wellbeing: the agri-food sector accounts for a large part of the economic activity – production, trading and consumption – of poor peoples, with multiplier effects on markets for inputs, financial services, consumer goods and employment. Both the livelihood capitals of producers, intermediaries and consumers, and the array of formal and informal local institutions and organisations influence the efficiency of these market linkages and determine the resulting livelihoods impacts, economic growth and development processes. Within the local rural economy, the pervasive role of staple foods in influencing wellbeing is less widely acknowledged by researchers and policy-makers than the more exotic but limited high value exports markets (Poole et al., 2010), while there remain real – but surmountable – challenges to incorporating smallholder growers of staple foods such as cassava into regional and international markets (Poole, 2010).

Nevertheless, global markets have penetrated into the remotest and poorest regions, and consumer tastes are changing in many low- and middle-income countries with imported products becoming key components of aspirational diets, a process hastened by rapid urbanisation (Friedmann, 2005). Consumption patterns have changed even in rural areas, reflecting not only greater rural landlessness but also important shifts in patterns of production and consumption among rural farmers. Even for apparently land abundant regions, rural landlessness is increasing rapidly (Peters, 2004) and almost all smallholders in lower income countries are at different times both suppliers and purchasers of foodstuffs in response to seasonal variation
in surplus and deficit (Poulton et al., 2006). This reliance on the market has important poverty dimensions; in Madagascar nearly three times as many poor households are net buyers as are net sellers (Minten et al., 2006).

Another phenomenon in low- and middle-income countries is the growth of supermarkets as preferred retail channels for (mainly) urban populations (Reardon et al., 2003) and their possible effects on patterns of food consumption in these countries (Hawkes, 2008). This phenomenon is the result of both supply and demand factors. The combined effect of increased urbanisation and the growth of women in the workforce has resulted in greater demand for convenience shopping and convenience food. Lower prices of processed food have fed into this changing demand. Rising real mean per capita incomes and a rise of middle classes in low- and middle-income countries has increased demand for processed foods and ‘western style shopping’. The expansion of refrigeration has also contributed to the growth in demand for supermarkets, as has the increase in car ownership and improvements in public transport. On the supply side, liberalised economies have attracted foreign investment, and advances in technology and the practice of efficient consumer response (ECR) has enabled supermarkets to coordinate supply (Reardon et al., 2003). Even in historically regulated markets such as India, modern retail systems are developing fast, offering more labelled and branded food products than traditional systems, and sometimes at lower prices (Minten et al., 2010).

Food security has been a prime concern for low- and middle-income countries and the global development agenda. Food security policies at both the national and global level have usually contained a focus on increasing food production (Lang, 2010) together with attempts to improve the distribution of food by improving access. While emergency food relief was a key policy response in the latter half of the 20th century, more recent attempts to improve the access of the poorest have included a range of initiatives to raise their purchasing power, such as cash transfers, food vouchers or public works schemes (DEFRA, 2010). These measures are now often delivered as part of wider social safety nets to deliver assistance in a timely and predictable manner when most needed, and reduce dependence on emergency food handouts.
2.2 Future trends in the food chain

Just as we are seeing rapid changes in markets and consumer preferences in low- and middle-income countries, we are also seeing changes in high-income countries, such as the emergence of box schemes and farmers’ markets, which operate in parallel with services provided by mass retailers (van der Ploeg, 2010). Food systems are thus constantly evolving and diversifying. While markets are more globally integrated, different and changing preferences exist and persist in different countries and regions (Cadilhon et al., 2006; Haddock-Fraser et al., 2009).

Overlaid on this changing global food system is a general trend towards greater local volatility of price and uncertainty of supply. The rise of agricultural sector superpowers, such as some South American countries in grains, sugar cane and other global commodities, has made international markets more competitive. Less regulation and state involvement in the food market has led to greater price volatility. Biofuel production may compete with and limit local production and availability, as may the current global ‘scramble for agricultural land’. Climate change is likely to change geographical patterns of productivity and supply, while increasing the frequency of production crises due to droughts and flooding. The recent food price crisis illustrates how a combination of factors influencing food supply and price may have dramatic effects on access to food. In this case, they included climate-related poor harvests in major producing regions, low food stocks, depreciation of the US dollar, financial speculation, inappropriate energy policies and diversion of agricultural production into biofuels (Toye, 2009; Ghosh, 2010).

Across these trends in food systems, there are two broad messages for the agriculture-health interaction. Firstly, food systems are providing a greater variety of foods to a greater proportion of the world’s population, expanding access to healthy and less healthy diets, and to safe and less safe foods, creating greater local opportunities for positive and negative health effects. Secondly, global food systems have the potential to improve food supply and access to nutritious foods, but their recent behaviour reveals that they can also reduce food security and hence increase risks to nutrition and health. Overall, emerging food systems are powerful drivers of the agriculture-health relationship, capable of rapid positive or negative change in health effects, depending on the behaviour of consumers, producers and regulators.
3. The effects of agriculture on nutrition and health

Foodstuffs produced in agricultural systems are processed through food systems before reaching consumers. What is finally consumed by individuals is influenced by a large number of cultural and traditional patterns and practices as well as individual perceptions of the intrinsic attributes of foods. These food attributes include its nutritional and physical characteristics, its safety in terms of freedom from toxicants and pathogens, and the way in which foods are produced and provided, all of which may be considered elements of food ‘quality’ (Hooker et al., 1996; Caswell, 1998; Poole et al., 2002). From the perspective of feeding a world population, food quality has a particular meaning: the food security definition adopted at the 1996 World Food Summit refers to individuals with access to ‘sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life’. This highlights two attributes, the nutritional value of food, and its safety. We will consider these two attributes in this report, focusing initially on nutrition.

3.1 The components of a healthy diet

It has long been recognised that a balance of nutrients forms the basis of a healthy diet, and ongoing research continues to further our understanding in this area. The primary elements of a diet are the three macronutrients, carbohydrates, protein and fat (Table 1), but the relative contribution of these macronutrients and their constituent sub-types are crucially important in the definition of a healthy diet.

Table 1: The components of a healthy diet and population nutrient intake goals from the WHO Expert Committee

<table>
<thead>
<tr>
<th>Component</th>
<th>Dietary sources</th>
<th>Recommendations ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>Staple crops such as rice, wheat and potatoes as well as simple sugars (see below)</td>
<td>55-75%</td>
</tr>
<tr>
<td>Free sugars ²</td>
<td>Added sugar (often)</td>
<td>&lt; 10%</td>
</tr>
</tbody>
</table>
fructose and sucrose) plus naturally occurring sources such as honey and fruit juices

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Source/Characteristics</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td></td>
<td>15-30%</td>
</tr>
<tr>
<td>Saturated fatty acids</td>
<td>Found in animal fats such as butter</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>n-6 polyunsaturated fatty acids</td>
<td>Seed oils such as corn and sunflower oil</td>
<td>5-8%</td>
</tr>
<tr>
<td>n-3 polyunsaturated fatty acids</td>
<td>Found in canola and soy oil as well as oily fish</td>
<td>1-2%</td>
</tr>
<tr>
<td>Trans fatty acids</td>
<td>Produced during industrial manufacture of partially hydrogenated vegetable oils and found in many fried and baked goods</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Monounsaturated fatty acids</td>
<td>Preponderant in some oils such as olive oil</td>
<td>By difference</td>
</tr>
<tr>
<td>Protein</td>
<td>Animal products including meat and milk Vegetable sources including legumes</td>
<td>10-15%</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>Salt</td>
<td>&lt; 5g per day</td>
</tr>
<tr>
<td>Fruits and vegetables</td>
<td>Fruits are the seed-containing part of the plant whilst vegetables in this context are the remaining edible parts</td>
<td>≥ 400g per day</td>
</tr>
</tbody>
</table>
Total dietary fibre | Wholegrain cereals, fruits and vegetables


1Recommendations refer to population nutrient intake goals defined by WHO Expert Committee (WHO/FAO, 2003)

2Free sugars refers to all ‘simple’ sugars (monosaccharides and disaccharides) added to foods by the manufacturer, cook or consumer, as well as naturally occurring sugars

3Fats are categorised by the absence (saturated) or presence (unsaturated) of double bonds, the number of double bonds (one = monounsaturated, more than one = polyunsaturated) and their position in the carbon chain

4n-6 indicates that the first double bond occurs on the 6th carbon in the fatty acid chain whilst polyunsaturated indicates the presence of more than one double bond

5n-3 indicates that first double bond occurs on the 3rd carbon in the fatty acid chain whilst polyunsaturated indicates the presence of more than one double bond

6A very small proportion of trans fatty acids in the diet are naturally occurring and are found in foods from ruminant animals

7Monounsaturated fat = total fat – (saturated fat + polyunsaturated fat + trans fat)
3.1.1 Carbohydrates

Carbohydrates are the predominant source of energy in the diet, playing a key role in metabolism and the maintenance of homeostasis. The type and balance of carbohydrates in the diet are of great importance to health. For example, the consumption of foods containing large amounts of simple carbohydrates (refined sugars), such as sweetened beverages, can promote weight gain by increasing the energy density of the diet and by their lower satiety value (van Dam et al., 2007). While in contrast, diets rich in complex carbohydrates such as whole-grain cereals, vegetables and nuts contribute to lowering the risk of type 2 diabetes (de Munter et al., 2007; Barclay et al., 2008), cardiovascular disease (Streppel et al., 2005) and certain types of cancers (World Cancer Research Fund/American Institute for Cancer Research, 2007), while also providing a good source of fibre and a range of vitamins and minerals. The most recent FAO/WHO Scientific Update on carbohydrates in human nutrition stated that ‘whole-grain cereals, vegetables, legumes and fruits are the most appropriate sources of dietary carbohydrate’ (Mann et al., 2007).

3.1.2 Fats

Fats are a second major dietary energy source and are essential for growth and development in early life. The fat in our diets is composed mainly of fatty acids, which vary widely in their carbon chain length and the number and position of their double bonds (Table 1). It is increasingly recognised that different structural categories of fats have contrasting impacts on health (Lecerf, 2009). For example, there is strong evidence that the consumption of trans fatty acids (TFAs) increases the risk of cardiovascular disease, with potential adverse effects also on insulin resistance and adiposity (Teegala et al., 2009). In contrast, the omega-3 long-chain polyunsaturated fatty acids (omega-3 LCPs), most commonly found in fish, have been shown to have beneficial effects for cardiovascular health (Scientific Advisory Committee on Nutrition, 2004; Lecerf, 2009). Omega-3 LCPs play a crucial role in brain and retinal development in utero (Uauy et al., 2006), but evidence is inconsistent that additional consumption of these oils in childhood enhances brain function. There is also no evidence that consuming supplemental omega-3 LCPs in later life helps slow cognitive decline (Dangour et al., 2010).
3.1.3 Protein

Dietary intake of protein is vital for normal growth and development and the maintenance of body protein (WHO/FAO/UNU, 2007). Proteins are comprised of amino acids, some of which cannot be synthesised in the body and thus are termed ‘essential’, and the quality of protein in a diet is defined based on its provision of essential amino acids. The digestibility of proteins is also an important factor in defining dietary protein adequacy, with protein sources in typical Western diets having a digestibility of approximately 95%, while proteins from a typical Indian rice-based diet have a digestibility of only 77% (WHO/FAO/UNU, 2007). Beyond the primarily metabolic demand, attention is now focusing on the role of protein intakes in promoting lifelong health and there is emerging evidence that protein quality may have consequences for optimal muscle and bone growth (Millward et al., 2008). The most recent Expert Consultation on protein requirements stated that an intake of 0.83g of high quality protein per kilogram of body weight per day should be sufficient to meet the requirements of most of the adult population, and highlighted that intakes three to four times higher than this may not be risk-free (WHO/FAO/UNU, 2007).

3.1.4 Nutrients as foods

In reality diets are not categorised based purely on their macronutrients content, but instead are composed of different foods providing specific combinations of macro- and micronutrients. One of the most diverse food groups is fruits and vegetables, which play an important role in promoting health. No single known component-nutrient explains the observed beneficial health effects of consuming a high vegetable and fruit diet and their impact is likely due to a combination of being low in energy density, high in fibre and a source of vitamins and minerals as well as to lesser-understood bio-active components such as polyphenols. The protective effect of fruit and vegetable consumption on cardiovascular disease and other chronic disease risk is well recognised (WHO/FAO, 2003), and it has been estimated that 2.6 million deaths per year could be attributed to the inadequate consumption of fruit and vegetables, primarily through their effects on ischaemic heart disease and stroke (Lock et al., 2005).
In some countries and cultures meat and dairy products are an important part of the diet, representing good sources of protein, and a range of minerals such as iron, zinc and calcium, and micronutrients such as vitamin B12. In contexts where dietary intakes are sub-optimal, animal source food products can be an essential source of these important nutrients. However, some meat and dairy products are also a major contributor of saturated fat in the human diet, and high intake of saturated fat is consistently associated with increased risk of heart disease, largely because of the effect on serum cholesterol concentrations (Hu et al., 2001; WHO/FAO, 2003; Jakobsen et al., 2009). High consumption of red (and processed) meat has also been shown to be associated with increased risk of colorectal cancer (World Cancer Research Fund/American Institute for Cancer Research, 2007) and total mortality (Sinha et al., 2009).

3.1.5 Synthesis of expert reports on dietary intake for the prevention of disease

There are evident complexities in defining the relationships between population nutritional intake and health. It is therefore a challenge to provide comprehensive dietary guidelines for population intakes based on the global diversity of primary foodstuffs. Dietary guidelines have been part of public health nutrition policies since the early 20th century. These guidelines, often produced by expert bodies, initially focused on the prevention of specific nutrient inadequacies, but more recently, their focus has changed to the prevention of food and nutrition-related chronic diseases. However, expert reports rarely synthesise evidence into dietary guidelines that encompass nutritional inadequacy, infectious and chronic disease.

This shortcoming was recently addressed in a systematic review of expert panel dietary recommendations for the prevention of nutritional deficiencies, infectious and chronic diseases published between 1990 and 2004 (World Cancer Research Fund/American Institute for Cancer Research, 2007). The review identified 94 expert reports of which only three (two from India and one from South Africa) arose from expert panels in low-income countries. The reviewers identified a broad consensus in dietary recommendations for the prevention of disease (Table 2). Generally, reports recommended diets high in cereals, vegetables, fruits and pulses, and low in red and processed meats. Recommended diets are correspondingly high in dietary
fibre and micronutrients, and low in fats, saturated fatty acids, added sugars and salt (World Cancer Research Fund/American Institute for Cancer Research, 2007).

In 2003, WHO published population nutrient intake goals (WHO/FAO, 2003) which continue to reflect the current evidence and provide a simple definition of the nutritional composition of a ‘healthy diet’ for nine billion people (Table 1). The WHO report did not focus on the micronutrient intake requirements, although this continues to be an active area of research (FAO/WHO, 2002). Currently, the WHO recommends, among others, vitamin A supplementation to children in at-risk areas (de Benoist et al., 2001), salt iodisation to prevent iodine deficiency disorders (WHO, 1994) and either iron fortification or supplementation for the prevention of iron deficiency anaemia (WHO/UNICEF/UNU, 2001).

Table 2: Summary of expert panel dietary recommendations for the prevention of nutritional deficiencies, infectious and chronic diseases

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Recommendations</th>
<th>To prevent or manage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals (grains), roots, tubers, and plantains</td>
<td>Include wholegrain cereals in the diet with a suggested intake of three to six or more servings per day</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td></td>
<td>Foods high in iron should be eaten in combination with foods that enhance rather than inhibit iron absorption: cereals (grains) should be consumed with meals of low iron content, and foods high in ascorbic acid, such as tubers, should be included with meals</td>
<td>Iron deficiency anaemia</td>
</tr>
<tr>
<td>Vegetables, fruits, pulses (legumes), nuts, seeds,</td>
<td>Include 400g (five or more servings)/day of vegetables and fruits, including pulses (legumes)</td>
<td>CVD, CHD, hypertension</td>
</tr>
<tr>
<td>Exposure</td>
<td>Recommendations</td>
<td>To prevent or manage</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>herbs, and spices</td>
<td>Foods high in ascorbic acid, such as orange juice, carrots and cauliflower, should be included with meals</td>
<td>Iron deficiency anaemia</td>
</tr>
<tr>
<td>Meat, fish, and eggs</td>
<td>Red meat consumption should be moderated and lean meat preferred (unspecified amount)</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td></td>
<td>Consume between one to three servings per week of fish, choosing oily fish</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td>Fats and oils</td>
<td>Limit intake of hydrogenated/partially hydrogenated vegetable oils and hard margarines (unspecified amount)</td>
<td>CHD</td>
</tr>
<tr>
<td></td>
<td>Total dietary fat to provide no more than 30-35% of total energy</td>
<td>CVD, CHD, overweight/obesity</td>
</tr>
<tr>
<td></td>
<td>(intake should not be restricted in children under two years)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intake of saturated fat should be no more than 7-10% of energy</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td></td>
<td>Restrict intake of myristic acid (including coconut products)</td>
<td>CHD</td>
</tr>
<tr>
<td></td>
<td>Limit intake of dietary cholesterol to &lt;300 mg/day</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td></td>
<td>(intake &lt;200mg/d for individuals at risk or with pre-existing of CVD)</td>
<td></td>
</tr>
<tr>
<td>Exposure</td>
<td>Recommendations</td>
<td>To prevent or manage</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Salt and sugar</td>
<td>Limit intake of polyunsaturated fatty acids to no more than 10% of energy</td>
<td>CHD</td>
</tr>
<tr>
<td></td>
<td>Limit intake of trans-fatty acids (unspecified amount)</td>
<td>CVD</td>
</tr>
<tr>
<td></td>
<td>Limit intake of sodium to no more than 100 mmol/day</td>
<td>Hypertension</td>
</tr>
<tr>
<td></td>
<td>Limit/reduce consumption of salt and salted foods to no more than 6g of salt/day</td>
<td>CVD, CHD, hypertension, stroke</td>
</tr>
<tr>
<td></td>
<td>Limit the proportion of energy in the diet from sugar (unspecified amount)</td>
<td>CVD, overweight/obesity, dental caries</td>
</tr>
<tr>
<td></td>
<td>Avoid consumption of sugary foods and drinks between meals</td>
<td>Dental caries</td>
</tr>
<tr>
<td>Milk and dairy products</td>
<td>Eat low-fat versions of dairy products in preference to high-fat versions</td>
<td>CVD, CHD</td>
</tr>
<tr>
<td>Water, fruit juices, soft drinks, and hot drinks</td>
<td>Avoid using sugary drinks in baby bottles</td>
<td>Dental disease</td>
</tr>
<tr>
<td>Alcoholic drinks</td>
<td>Limit intake of alcoholic drinks to two drinks for men and one drink for women per day and if drinking, do so only with meals</td>
<td>CVD, CHD, hypertension, stroke</td>
</tr>
<tr>
<td>Food production, processing, preservation, and foods</td>
<td>Limit/reduce intake of refined carbohydrates/grain products and foods</td>
<td>CVD</td>
</tr>
</tbody>
</table>
Exposure | Recommendations | To prevent or manage
---|---|---
Dietary constituents and supplements | Include fibre in the diet (unspecified amount) | CVD
       | Ensure an adequate intake of vitamin D and calcium | Osteoporosis

Source: adapted, with permission, from (World Cancer Research Fund/American Institute for Cancer Research, 2007).


1Synthesis of recommendations from a systematic review of expert reports published since 1991. Recommendations have only been included if they were made in three or more reports.
3.2 Food consumption trends

Evidence from around the world suggests that economic development results in major transitions in population-level dietary, and corresponding disease, patterns. The nutrition-related changes (encompassing both dietary intake and physical activity) have been termed the ‘nutrition transition’ and describe trends moving away from dietary patterns that typify those of hunter-gatherers containing large amounts of fibre and low amounts of sugar and fat, to energy-dense diets composed predominantly of highly processed foodstuffs common to much of the developed world today (Drewnowski et al., 1997; Popkin, 2004; Popkin, 2006). The dietary changes are themselves driven by a variety of culturally-specific factors including the increased production, availability and marketing of processed foods and the complex effects of urbanisation (Popkin, 2006).

Societal change in low- and middle-income countries is accelerating the nutrition transition (Popkin, 2002). Furthermore, as food consumption continues to change in these countries there will be increasing dependency on complex food chains, which implies the direction of these dietary transitions is and will be one way. The consequences for population prevalence of nutrition-related chronic disease are all too evident; the WHO Global Burden of Disease project lists coronary heart disease and stroke within the top ten leading causes of death worldwide with diabetes mellitus also a leading cause of death in high- and middle- and increasingly in low-income countries (WHO, 2008).

3.3 Food processing

The links between agricultural production and nutritional consumption are non-linear and, particularly as countries develop, occur within an increasingly complex food system. The foods we consume have progressed though many stages of processing from post-harvest to industrial manufacturing and our dietary choices are influenced by many different factors from cultural norms to marketing campaigns (Figure 2). Traditionally a means of preserving foods over time, food processing in its industrial form now encompasses a vast array of processes and a multi-billion dollar industry (Friedmann, 2005; van der Ploeg, 2010). While advances in the processing and handling of food can increase the range of food options available to individuals, the consumption of highly processed foods are in general detrimental to health due to
their excess energy-density, sugar, salt and unfavourable fat content (WHO/FAO, 2003; World Cancer Research Fund/American Institute for Cancer Research, 2007).

Food processing also has the potential for health benefits, and fortification of commonly-used foodstuffs represents a strategy for reducing nutritional deficiencies, such as the prevention of iodine deficiency through universal salt iodisation (Zimmermann et al., 2008) or the fortification of flour with folate to prevent neural tube defects (Stevenson et al., 2000). Although this latter policy has not been without controversy (Mason et al., 2008). However, issues with implementation and sustainability can impact on fortification programmes; despite a large global public-private partnership to implement salt iodisation the goal of eradication of iodine deficiency disorders by the year 2000 was not met (Hetzel, 2002).

3.4 Assessing global food availability and individual consumption

Changing patterns of agricultural production, food availability and processing will have profound impacts on individual food consumption and, as a result, on population health. A thorough understanding of these impacts requires a dependable means of measuring food consumption around the world. Currently the most widely used method is a measure of food availability complied by the FAO into data presented as Food Balance Sheets (FBS) for all countries in the world. Although a useful method of assessing trends in production and differences in availability between world regions, there are serious and well-recognised flaws in using FBS to characterise the diet of a population and/or to inform global policy. Availability estimates are a poor proxy for consumption as they do not take into account production outside of the formal sector, manufacturing processes or waste at a retail or household level. In addition the production and trade estimates themselves are subject to a number of errors in calculation (Svedberg, 1999; Rushton et al. In prep). Direct measures of food consumption collected by nationally representative dietary surveys are required to accurately understand diet patterns within and between populations but can be prohibitively costly and lengthy to conduct in most settings. A more thorough critique of three approaches commonly used to assess food consumption at a population level is provided in Appendix I focusing on FBS, household budget surveys and individual diet surveys. In the remainder of this
section we illustrate one of the issues of using FBS food availability data as a proxy for consumption with some original data analysis.

3.4.1 A comparison of individual dietary intake data and FBS food availability data: UK and Mexico

In order to examine the challenges posed in the comparison of individual dietary intake surveys with the more globally available FBS data on food availability, we present an analysis involving national surveys of individual dietary intake and FBS food availability data from two countries; the UK and Mexico. We selected these two national surveys to compare countries at different stages of development from different regions of the world. We were greatly constrained by the need to find comparable dietary intake survey data, and in this regard it is noteworthy that we found no low-income or lower middle-income countries for which national-level dietary intake survey data could be obtained.

The UK National Diet and Nutrition Survey (NDNS) recruited around 2,000 adult individuals from across the UK and collected dietary information using a seven-day weighed record (Henderson et al., 2003). The Mexican Health and Nutrition Survey (MHNS) included 20,000 adults and used a 101-item food frequency questionnaire to record foods eaten over the previous seven days (Ramirez et al., 2009). FBS food availability data from the same year that the surveys were conducted were abstracted for both countries from the FAO website.

For both the UK and Mexico, individual dietary intake of all macronutrients was substantially lower than estimated to be available at a national level from FBS data (Tables 3 and 4). In the UK and Mexico, energy availability was approximately 70% and 83% higher, respectively, than the average adult energy consumption as estimated from dietary intake surveys. These findings mirror those reported from a comparison of four other high-income countries (Canada, Finland, Poland and Spain), which also demonstrated that FBS food availability data overestimated actual food consumption (Serra-Majem et al., 2003). Similarly, FBS data on fruit and vegetable availability in 15 countries (mostly high-income) have been reported to substantially over-estimate actual consumption, although the degree of overestimation varied widely (Pomerleau et al., 2003). It has been suggested that as the food system develops and becomes more complex, the discrepancy between
dietary intake and food availability data increases due to a lack of information at the manufacturing level as well as the variations in waste (FAO, 1983; Dowler et al. 1985; Sekula et al. 1991).
<table>
<thead>
<tr>
<th>Food available for consumption</th>
<th>National Diet and Nutrition Survey</th>
<th>Healthy nutrient goals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All (N: 833)</td>
<td>All (N: 891)</td>
</tr>
<tr>
<td></td>
<td>Male Benefits (N: 110)</td>
<td>Female Benefits (N: 150)</td>
</tr>
<tr>
<td></td>
<td>No benefits (N: 723)</td>
<td>No benefits (N: 740)</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kcal/capita/d</td>
<td>3369</td>
<td>2321.6</td>
</tr>
<tr>
<td></td>
<td>(585.2)</td>
<td>(597.1)</td>
</tr>
<tr>
<td></td>
<td>2113.8</td>
<td>2355.0</td>
</tr>
<tr>
<td></td>
<td>(573.2)</td>
<td>(420.4)</td>
</tr>
<tr>
<td></td>
<td>1640.9</td>
<td>1521.4</td>
</tr>
<tr>
<td></td>
<td>(501.6)</td>
<td>(406.0)</td>
</tr>
<tr>
<td>% animal source</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>425.3</td>
<td>275 (79)</td>
</tr>
<tr>
<td></td>
<td>(79)</td>
<td>(275)</td>
</tr>
<tr>
<td></td>
<td>259 (74)</td>
<td>203 (59)</td>
</tr>
<tr>
<td></td>
<td>(203)</td>
<td>(259)</td>
</tr>
<tr>
<td></td>
<td>277 (79)</td>
<td>193 (70)</td>
</tr>
<tr>
<td></td>
<td>(193)</td>
<td>(277)</td>
</tr>
<tr>
<td></td>
<td>205 (57)</td>
<td>155-75%</td>
</tr>
<tr>
<td>% of calories</td>
<td>50.5</td>
<td>47.7 (6.0)</td>
</tr>
<tr>
<td>calories from free sugars (%)</td>
<td>13.6 (6.7)</td>
<td>13.5 (6.5)</td>
</tr>
<tr>
<td></td>
<td>14.5 (8.0)</td>
<td>11.9 (6.5)</td>
</tr>
<tr>
<td></td>
<td>13.5 (6.5)</td>
<td>13.6 (8.6)</td>
</tr>
<tr>
<td></td>
<td>14.5 (8.0)</td>
<td>11.5 (6.0)</td>
</tr>
<tr>
<td></td>
<td>13.5 (6.5)</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>141.3</td>
<td>86.5 (28.2)</td>
</tr>
<tr>
<td></td>
<td>(28.2)</td>
<td>(86.5)</td>
</tr>
<tr>
<td></td>
<td>81.5 (29.6)</td>
<td>87.2 (27.9)</td>
</tr>
<tr>
<td></td>
<td>(81.5)</td>
<td>(87.2)</td>
</tr>
<tr>
<td></td>
<td>61.4 (21.7)</td>
<td>56.4 (23.6)</td>
</tr>
<tr>
<td></td>
<td>(61.4)</td>
<td>(56.4)</td>
</tr>
<tr>
<td></td>
<td>62.5 (21.2)</td>
<td>35.0 (6.6)</td>
</tr>
<tr>
<td></td>
<td>(62.5)</td>
<td>(35.0)</td>
</tr>
<tr>
<td>% of calories</td>
<td>37.7</td>
<td>35.8 (5.6)</td>
</tr>
<tr>
<td>calories from saturated fat (%)</td>
<td>13.4 (2.9)</td>
<td>13.3 (3.2)</td>
</tr>
<tr>
<td></td>
<td>13.4 (2.9)</td>
<td>13.2 (3.3)</td>
</tr>
<tr>
<td></td>
<td>13.4 (2.9)</td>
<td>13.0 (2.8)</td>
</tr>
<tr>
<td></td>
<td>13.4 (2.9)</td>
<td>13.2 (3.4)</td>
</tr>
<tr>
<td></td>
<td>13.4 (2.9)</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Nutrient</td>
<td>g/capita/d</td>
<td>% of calories</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Protein</td>
<td>99.4</td>
<td>11.8</td>
</tr>
<tr>
<td>Fruit</td>
<td>232.3</td>
<td>16.5 (3.6)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>228.8</td>
<td>15.8</td>
</tr>
</tbody>
</table>

2. National Diet and Nutrition Survey, UK, 2000/01 (Henderson et al., 2003). Values are means (SD) for intake derived from seven day weighed food record
4. Benefits: refers to households in receipt of Working Families Tax Credit at the time of the interview of the receipt of Income Support, or (Income-related) Job Seeker’s Allowance by the respondent or anyone in their household in the 14 days prior to the data of the interview
5. Free sugars defined as non-milk extrinsic sugars such as honey and table sugar
6. Trans fat intake re-estimated as 1% of food energy by the Food Standards Agency in 2007 to take into account new product information
7a. Fruit defined by FBS as: plantains, bananas, orange, lemons and limes, grapefruit and pomelos, tangerines, mandarins, clementines, satsumas, other citrus fruit, melons, watermelons, apples, apricots, avocados, cherries, figs, grapes, mangoes, papaya, peaches, pears, persimmons, pineapples, plums, quinces, blueberries, cranberries, gooseberries, raspberries, strawberries, kiwi, other fruits (fresh), dates, figs (dried), prunes, currants, raisins, other dried fruit
7b. Fruit defined by NDNS as: apples and pears, citrus fruits, bananas, canned fruit in juice, canned fruit in syrup, ‘other fruit’ (including plums, grapes and soft fruits)
8a. Vegetables defined by FBS as: beets, carrots, turnips, rutabagas/swedes, onions (green), onions (dry), artichokes, tomatoes, asparagus, cabbage, cauliflower, celery, kale, lettuce, spinach, beans (green), broad bean (green), chilli peppers, garlic, cucumbers, mushrooms, eggplant, peas (green), pumpkins, squash, gourds, okra, radishes and other vegetables
Vegetables defined by NDNS as: raw carrots, raw tomatoes, ‘other raw’ and salad vegetables, peas, green beans, leafy green vegetables, carrots (not raw), tomatoes (not raw), baked beans, ‘other vegetables’ (including mushrooms, cauliflower, onions and peppers)
Table 4: Nutrient consumption of adults (20-59y) in Mexico

<table>
<thead>
<tr>
<th>Food available for consumption(^1)</th>
<th>Male (N: 5898)</th>
<th>Female (N: 9848)</th>
<th>Rural (N: 6466)</th>
<th>Urban (N: 9280)</th>
<th>Healthy nutrient goals(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy kcal/capita/d</td>
<td>3244</td>
<td>1963 (1475, 2673)</td>
<td>1592 (1178, 2091)</td>
<td>1644 (1189, 2253)</td>
<td>1750 (1296, 2336)</td>
</tr>
<tr>
<td>% animal source</td>
<td>19.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrate g/capita/d</td>
<td>503.6 (218.1, 390.7)</td>
<td>294.1 (179.9, 324.1)</td>
<td>243.2 (194.7, 375.1)</td>
<td>266.9 (193.1, 350.2)</td>
<td>260.5 (187.7, 333.3)</td>
</tr>
<tr>
<td>% of calories</td>
<td>62.1</td>
<td>61.5 (55.5, 67.9)</td>
<td>61.5 (55.2, 67.8)</td>
<td>66.3 (59.9, 72.1)</td>
<td>60.6 (54.5, 66.4)</td>
</tr>
<tr>
<td>Fat g/capita/d</td>
<td>96.0 (38.2, 77.4)</td>
<td>55.0 (30.9, 65.1)</td>
<td>46.2 (26.4, 59.2)</td>
<td>52.1 (36.2, 71.5)</td>
<td></td>
</tr>
<tr>
<td>% of calories</td>
<td>26.6</td>
<td>26.4 (21.0, 31.4)</td>
<td>26.1 (17.2, 27.8)</td>
<td>27.1 (22.2, 32.1)</td>
<td></td>
</tr>
<tr>
<td>calories from saturated fat (%)</td>
<td>7.6 (5.4, 9.9)</td>
<td>7.6 (5.4, 10.2)</td>
<td>6.1 (4.1, 8.8)</td>
<td>7.8 (5.8, 10.3)</td>
<td></td>
</tr>
<tr>
<td>Protein g/capita/d</td>
<td>92.0</td>
<td>57.4 (42.8, 77.7)</td>
<td>49.2 (35.9, 65.1)</td>
<td>47.8 (34.8, 65.5)</td>
<td>53.8 (39.5, 70.5)</td>
</tr>
<tr>
<td>% of calories</td>
<td>11.3</td>
<td>11.8 (10.5, 13.5)</td>
<td>12.0 (10.6, 13.7)</td>
<td>11.3 (10.3, 12.7)</td>
<td>12.1 (10.6, 13.8)</td>
</tr>
<tr>
<td>Fruit (^4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Mexican Health and Nutrition Survey
2. Healthy nutrient goals
3. 55-75%
4. 10-15%
<table>
<thead>
<tr>
<th>g/capita/d</th>
<th>316.4</th>
<th>52.3</th>
<th>75.5</th>
<th>68.9</th>
<th>64.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>&gt;400g</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>167.4</td>
<td>50.2</td>
<td>61.2</td>
<td>53.6</td>
<td>58.1</td>
</tr>
</tbody>
</table>

2. Mexican Health and Nutrition Survey (MHNS), 2005/06 (Barquera et al., 2009). Data are median (inter-quartile range)
4a. Fruit defined by FBS as: plantains, bananas, orange, lemons and limes, grapefruit and pomelos, tangerines, mandarins, clementines, satsumas, other citrus fruit, melons, watermelons, apples, apricots, avocados, cherries, figs, grapes, mangoes, papaya, peaches, pears, persimmons, pineapples, plums, quinces, blueberries, cranberries, gooseberries, raspberries, strawberries, kiwi, other fruits (fresh), dates, figs (dried), prunes, currants, raisins, other dried fruit
4b. Fruit defined by MHNS as: fleshy edible parts from trees or fresh plants containing seeds
5a. Vegetables defined by FBS as: beets, carrots, turnips, rutabagas/swedes, onions (green), onions (dry), artichokes, tomatoes, asparagus, cabbage, cauliflower, celery, kale, lettuce, spinach, beans (green), broad bean (green), chilli peppers, garlic, cucumbers, mushrooms, eggplant, peas (green), pumpkins, squash, gourds, okra, radishes and other vegetables
5b. Vegetables defined by MHMS as: plants having edible parts such as leaves (cabbage, lettuce, spinach), stems (celery etc), sprouts (asparagus etc), flowers (cauliflower, artichoke etc), pods (green beans, etc), roots (carrots, beets etc), bulbs (onions, garlic, etc), fruits culturally considered vegetables in Mexico (such as tomato, cucumber, avocado), green seeds (peas, broad beans) and pulses (beans, lentils, chickpeas and soybeans).
3.4.2 Are individuals eating a ‘healthy’ diet?

Population dietary intake data can be used to assess the adequacy of the diet, to highlight at-risk groups and to assess the effectiveness of interventions aimed at population dietary change. Data from the NDNS suggest that adults in the UK are on average exceeding the recommended intakes of free sugars, total fat and saturated fat (Table 3). These average figures obscure what can be a wide variation in intakes; the range between the lowest and highest 2.5 percentile of percentage energy from fat for men was 24-47% and for women was 22-48% (Henderson et al., 2003). In contrast to the UK, total and saturated fat intakes in Mexico appear to lie within the range recommended as a healthy nutrient intake goal, although again these mean values obscure a range of intakes and some individuals will be consuming over 35% of energy from fat. The intake of fats has been shown to increase as countries progress through the nutrition transition and this difference in intakes may reflect the different transition stages attained by the two countries (Popkin, 2006). In Mexico, the fruit and vegetable intakes are much lower than the 400g intake goal and may point to an area of health promotion that requires emphasis.

A significant shortcoming in the use and interpretation of FBS food availability data is that they provide no information on the variation of availability by sex, socio-economic status, region or age. Comprehensive national dietary intake surveys, such as the NDNS and MHMS, will stratify dietary intakes into sub-groups, thereby providing important insights into the differential burdens of disease risk factors in addition to highlighting at-risk groups.

For example, in the NDNS, low socio-economic status, defined as individuals receiving state benefits, was associated with greater intake of free sugars in both men and women (Table 3). Such wealth-related differences in diet pattern are well-recognised as one of the main causes of social inequalities in health (Robinson et al., 2004; Shelton, 2005). Similarly, data from the MHNS showed that individuals from urban areas reported substantially higher intakes of fat and saturated fat than those in rural areas (Table 4), highlighting one of the commonly observed trends associated with urbanisation, which is in turn one of the key drivers of the nutrition transition (Drewnowski et al., 1997). From this brief synopsis of the nutritional intakes of two countries at different stages of development we can see the wealth of
information that may be derived from national surveys and the usefulness of this information for informing nutrition policy. The comparison also shows that there are important health-related dietary patterns emerging and that these differ between and within countries.

3.4.3 Using FBS estimates when dietary intake surveys are not available: nutrient availability in Bangladesh and Tanzania

Nationally-representative nutritional surveys have not been conducted in the majority of low-income countries (Smith et al., 2006). In South Africa, for example, intake surveys have been carried out for particular regions or for particular population groups (children and pregnant women), but not for the population as a whole. In these settings, FBS food availability data are often used as a proxy for individual dietary intakes despite their important limitations outlined above. FBS data for Bangladesh and Tanzania suggest very low energy availability (Table 5), which for Tanzania does not meet the World Food Programme target level of calorie consumption (2100kcal/d) (WFP, 2007). In addition, only a small proportion of this energy is derived from animal sources, suggesting a diet that may be low in certain key vitamins and minerals that are less available from vegetable sources. The Bangladesh data also reveal a level of fat availability that is below the minimal desirable intake of 15% of energy (FAO/WHO, 1994). However, given the substantial limitations of using FBS food availability data as a proxy measurement of food consumption it seems pertinent to question the validity of the data presented in Table 5.

Only a few studies have investigated the applicability of FBS food availability statistics for assessing dietary consumption in low-income country settings and generally conclude that FBS data may underestimate actual intake (Poleman, 1981; Svedberg, 1999), primarily because people grow, catch and process a large proportion of their diet that do not appear in country-level production statistics. For example, data on the milk production and consumption in Bolivia, Kenya and Nepal indicate that only 13% of milk is produced and traded in formal milk chains (Anderson et al., 2004). It is arguably of greater concern to have accurate measurement of food consumption in low- and middle-income countries where there remains under-nutrition coupled with the increasing transition to high-energy, low-
nutrient diets. These transitions may not occur uniformly across a country or even within a household (FAO, 2006), questioning the usefulness of country-level FBS for providing data that will inform nutrition policy. Nationally-representative nutritional surveys are a more accurate and nuanced method of characterising the diet of a population, and the widespread reliance on FBS food availability data in poorer countries has important implications for the limits of our understanding of diet in these settings, not least because of the paucity of FBS statistics from these regions.

Table 5: Food availability information for Bangladesh and Tanzania

<table>
<thead>
<tr>
<th>Food available for consumption</th>
<th>Bangladesh</th>
<th>Tanzania</th>
<th>Healthy nutrient goals²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kcal/capita/d</td>
<td>2261</td>
<td>2019</td>
<td></td>
</tr>
<tr>
<td>% animal source</td>
<td>3.3</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>454.5</td>
<td>381.1</td>
<td>55-75%</td>
</tr>
<tr>
<td>% of calories</td>
<td>80.4</td>
<td>75.5</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>27.6</td>
<td>33.5</td>
<td>15-30%</td>
</tr>
<tr>
<td>% of calories</td>
<td>11</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>48.7</td>
<td>48.5</td>
<td>10-15%</td>
</tr>
<tr>
<td>% of calories</td>
<td>8.6</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Fruit³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>34.2</td>
<td>77.0</td>
<td>&gt;400g</td>
</tr>
<tr>
<td>Vegetables⁴</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g/capita/d</td>
<td>45.8</td>
<td>76.4</td>
<td></td>
</tr>
</tbody>
</table>

¹Food Balance Sheet information, 2005: FAOSTAT (FAO, 2009)
²Population nutrient intake goals defined by WHO Expert Committee (WHO/FAO, 2003)
³Fruit defined as: plantains, bananas, orange, lemons and limes, grapefruit and pomelos, tangerines, mandarins, clementines, satsumas, other citrus fruit, melons, watermelons, apples, apricots, avocados, cherries, figs, grapes, mangoes, papaya, peaches, pears, persimmons, pineapples, plums, quinces, blueberries, cranberries, gooseberries, raspberries, strawberries, kiwi, other fruits (fresh), dates, figs (dried), prunes, currants, raisins, other dried fruit
Vegetables defined as: beets, carrots, turnips, rutabagas/swedes, onions (green), onions (dry),
artichokes, tomatoes, asparagus, cabbage, cauliflower, celery, kale, lettuce, spinach, beans (green),
broad bean (green), chilli peppers, garlic, cucumbers, mushrooms, eggplant, peas (green), pumpkins,
squash, gourds, okra, radishes and other vegetables

3.4.4 Implications of the knowledge gap

The incomplete nature of the available agricultural production and dietary intake data poses significant limitations on our ability to provide guidance to policy-makers on ensuring food security for all. Projected agricultural production estimates are based on global food availability data and the likely changes in availability in light of historical patterns (FAO, 2009). Thus the FAO estimates that by 2050 the global average daily calorie availability will reach 3,050 kcal per person (FAO, 2009). Whilst this estimate suggests that there should be sufficiency in terms of calorie availability, it does not mean that in 2050 all nine billion inhabitants of the Earth will be able to consume a healthy diet.

Inaccuracies in measuring or estimating food consumption undermine our capacity to know whether we are currently able to feed the world healthily and to assess the impact of projected agricultural trends. It is noteworthy that in the Millennium Development Goals (MDGs), the consumption-related indicator for reducing hunger (MDG 1C) is the proportion of the population below the minimum level of dietary energy consumption (based on food availability data), a statistic undermined by the limitations of FBS with its limited information on the distribution of food consumption, and also a statistic lacking any direct emphasis on dietary quality.

Influencing the future production and processing of food requires a thorough understanding of the impacts of a changing food system on health, which will in turn rely on accurate data from each stage of the food system: from production to consumption. A good understanding of what foodstuffs are being produced, imported and exported in different countries and regions not only allows surveillance of current production for nutritional planning, but provides a means of evaluating policy interventions aimed at improving production for nutritional (and other) goals, or assessing other shocks to the food system, such as the recent global financial crisis.
As countries progress through economic and nutrition transitions, with a greater proportion of the diet becoming processed foods, the food system becomes increasingly complex, and traditional calculations of commodity availability become an even poorer proxy for consumption patterns of nutrients (Dowler et al., 1985). A thorough understanding of the impact of the changing food system on health will therefore require information on the combining, mixing and removing of nutrients during the manufacturing of processed products (FAO, 2004) and/or detailed information on nutritional intakes. Although considered the ‘gold standard’ for monitoring population dietary intake, nationally-representative data on food consumption are only available for a small minority of countries and this situation is unlikely to improve in the short-term due to resource constraints.

In addition, a greater understanding is needed of the anthropological and behavioural imperatives underlying individual and societal food consumption patterns. This is because even given the data on which sound policy can be formulated, the provision of information to consumers about health and welfare risks and benefits of different foods has only a limited effect in changing behaviour, at least in the short to medium term. Witness, for example, the decades taken to influence behaviour, norms and laws on tobacco consumption in the United Kingdom and in other advanced countries. Nutrition communication tends to be focused on educating the consumer to make healthy choices, while insufficient attention has been paid to the pleasure of eating behaviour: ‘epicurism’. To improve the health aspects of consumer behaviour, information should be oriented also towards increasing pleasure and consumer satisfaction as well as educating consumers about harmful attributes (Poole et al., 2007).

3.4.5 Improving production and consumption estimates

We have shown that food availability data cannot be used interchangeably with food consumption data. Moreover, the accuracy of statistics behind food availability data are extremely variable, and it seems unlikely that current institutional incentives to improve the system will be adequate to significantly enhance data collection and analysis. Notwithstanding these concerns, accurate data on food consumption are a vital component of effective planning of public agricultural investments and for the implementation of sound public health nutrition policy. To improve our capacity to
predict the health consequences of changes in agriculture and food systems we propose the following areas for future work:

• Improve FBS measurement, through more refined data collection and analysis to estimate food production.

• More extensive and representative individual dietary intake studies, focused on areas at risk of under-nutrition and those in dietary transition.

• Better information on the mixing and processing of food, its nutritional content and the destination of processed foods.

• Enhanced data on waste at all stages of the food chain.

Such a list of data collection needs is, however, not new. For example, the Partnership in Statistics for Development in the 21st Century (PARIS21) was established in 1999 to facilitate the collection of national statistics in low-income countries (www.paris21.org) but appears to have had little impact on the quality of statistics used to assess food availability in these settings. However, we suggest there are two recent trends that might shift this situation, one in the public and one in the private sector.

In recent years the world has seen dramatic change and improvements in data collection for other aspects of the economies in low- and middle-income countries such as poverty data capture and analysis relating to the MDGs. There are strong arguments that, as the MDGs come to be reviewed towards 2015, there should also be a refinement in data collection and analysis processes to ensure that links between food production, processing and consumption can be placed in a systems framework that not only demonstrates access to food but also to the right balance of key nutrients. This will require substantial resources, but its linkage to globally agreed goals will make such investment more likely. Recent initiatives such as the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture may go some way to filling this current knowledge gap (World Bank, 2010). The use of new information and communication technologies may provide a cost-effective alternative to household surveys – computer based surveys in UK, for example, have proven more effective than traditional questionnaires in encouraging
schoolchildren to report their food consumption patterns (Moore et al., 2008).
Secondly, the conditions are right today for public-private partnership approaches to healthier diets, with potential for greater collection of consumption data by the private sector. Major food manufacturers and retailers are increasingly aware of the significance of food quality, diet and health for social responsibility in relation to consumers, as indeed they are of the significance of agricultural production conditions for social and environmental responsibilities among suppliers. Moreover, through electronic data collection at the point of sale, major manufacturers and retailers are the repositories of at least some of the food production, processing, preference and purchase data for which there are public sector ‘lacunae’. Whilst there remain considerable shortcomings in these data for assessing food consumption (no information on food distribution, waste and so on), they could represent an important untapped resource on patterns of food purchase in the retail sector. In low- and middle-income countries, where there is little public sector investment, these measurements by the rapidly expanding supermarket companies could be a particularly valuable resource (Reardon et al., 2003).

4. The effects of agriculture on food safety

There are a range of food safety issues that relate to how food is produced, processed and packaged. For convenience these are split into chemical or biological residues in food (Figure 3). Chemical residues may be caused by the use of medication at production level to control pests or diseases and in some cases the use of antibiotics and hormones to enhance and stimulate growth. In addition chemical residues may occur due to contamination of food; some examples of this may be deliberate such as melamine in milk, while others are accidental such as dioxins in meat or aflatoxins in maize or nuts. A final source of chemical residue could be through the environment such as animals that produce milk or meat on soils with heavy metal contamination. Biological residues come either from the presence of diseases or pests in the plants or animals that food is derived from or from environmental contamination during processing, with listeria perhaps being the best example.
We will focus here on biological contaminants and particularly diseases affecting human health, which are particularly associated with animal production. We will not cover chemical toxins in the food chain, but would make the following observations in passing. These usually cause local, acute poisoning events, but may occur on a larger scale where contaminated produce is traded globally, as was the case for the contamination of Chinese milk products with melanine in 2008 (Guan et al., 2009). However, chronic poisoning effects are poorly understood and of concern, particularly in low-income countries, where frequent exposure is more likely due to poorer food safety standards. For example, aflatoxins are associated with fungal contaminants in crops and harvested products, and high levels are particularly frequent in tropical crops like maize and groundnuts, and chronic effects include growth retardation (Gong et al., 2003) and immune suppression (Jiang et al., 2005), which would compound the effects of malnutrition in poor communities more likely to encounter low quality foodstuffs.
Animals share a range of diseases with humans, many of which are endemic and cause production losses in agriculture (Bennett, 2003). However, the scale of losses to production is dwarfed by concern for the impact of these diseases on human health and welfare (Shaw, 2009). In the assessment of food-borne disease impacts in high-income countries, the imputed value of premature deaths accounts for a very high proportion of the total cost, in the case of salmonella in the USA around 90% (Henson, 2003). In low- and middle-income countries impact assessment figures reflect the different medical costs and other resource limitations and are in general much lower than those estimates for rich countries ($236 million, or around $176 per case for medical costs in 1996) (Henson, 2003). In general estimates in low- and middle-income countries are scarce and are potentially more difficult to make, as food-borne disease could easily be masked by other sanitary and disease problems in the general society (Gargouri et al., 2009). In an attempt to fill this information gap WHO is running an initiative to estimate food-borne disease burdens in lower income countries (WHO, 2010) and it has been suggested that 'developing countries bear the heaviest burden of food-borne diseases in the world' (Motarjemi et al., 1996). An indication of the food-borne disease burden in various low- and middle-income countries is provided in Table 6.
Table 6: The occurrence of the important food-borne diseases in different regions

<table>
<thead>
<tr>
<th>Disease</th>
<th>Africa</th>
<th>Central &amp; South America</th>
<th>SE Asia</th>
<th>Western Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus cereus</em> gastroenteritis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Botulism</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brucellosis</td>
<td>+/-+</td>
<td>+/-+</td>
<td>+/-+</td>
<td>+/-+</td>
</tr>
<tr>
<td>Campylobacteriosis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Cholera</td>
<td>+/-+</td>
<td>+/-+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em> enteritis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td><em>Escherichia coli</em> disease</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Listeriosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Typhoid and paratyphoid fever</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Salmonellosis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Shigellosis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em> intoxication</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td><em>Vibrio parahaemolyticus</em> enteritis</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><em>Vibrio vulnificus</em> septicaemia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>++</td>
</tr>
</tbody>
</table>

- absent
+ occasional or rare
++ frequent
+++ very frequent
In addition to direct effects on health, there are impacts from food scares and trade restrictions associated with control of animal disease outbreaks, which will affect particularly agricultural producers. In the UK foot and mouth disease outbreak of 2002, the loss of herds and livelihoods had impacts on the mental and emotional health of affected farmers (Thompson et al., 2002). Control of this outbreak involved widespread culling, with associated environmental health concerns, as well as closure of the countryside, with economic losses outside the livestock sector (Thompson et al., 2002). In low- and middle-income countries investments in animal health are struggling to keep pace with the change in livestock sectors (Rushton et al., 2006), and the local economic, and indirect health impacts of large-scale production losses may be more severe.

4.1 The demand for food safety

The current basis for food safety and quality assurance (QA) was laid by scientific advances in the 19th century. Modern concerns were first drawn together in 1961 with the first steps towards an international food code, which subsequently became the responsibility of the joint FAO/WHO Codex Alimentarius Commission (Codex Alimentarius Commission, 2010). Interest in systems for assuring the safety of food products has increased dramatically since the beginning of the 1990s. In advanced economy countries, consumer awareness of the incidence of contaminated food products and the associated health risks has been the principal factor boosting demand for safety as a food quality attribute and changes have resulted mostly from contamination crises. Safety scares have also occurred in the food systems of developing economies, where the effective demand for food safety and QA is less evident. Nonetheless, public awareness of the health, education and economic implications of unsafe food systems in low- and middle-income countries is growing fast.

Poorer societies characterised by food scarcity, lower life expectancy and lower levels of education, are likely to demand less food safety than richer societies. In economic terms, food safety is a ‘luxury’ good rather than a necessity and as income rises, more food safety is demanded (Swinbank, 1993). Besides income and prices, the demand for food safety probably depends also on perceived risk, which is a
function of the level and value of available information and of individual attributes such as age and education. Where incentives and information flows are imperfect, the market alone may fail to provide the level of food safety demanded by society. Quality specifications with the appropriate monitoring and enforcement methods may serve as a mechanism to internalise the health benefits within the food chain. While poorer countries may not implement significant food safety regulation themselves, they are likely to be affected by such regulation in high-income countries. Food safety concerns may prevent exports to high-income countries (e.g. difficulties faced by Kenya in the export of Nile perch in the 1990s to Europe (Jaffee et al., 2005)) or, where exports are permitted, may restrict entry into the value chain to those producers who can meet traceability standards (Jaffee et al., 2004).

4.1.1 The history of food safety in the UK: a case study

Bad food unquestionably was a major contributor to the poor quality of life in the industrial towns of early 19th century Britain (Collins, 1993). Improvements in food quality were not just a matter of scientific achievement, but also of institutional development and improved commerce. The regulatory framework was enhanced from 1860 onwards by establishing public analysis, introducing penalties for adulteration, and formulating clearer descriptions of punishable offences. Changes in business culture also played a part, with the development of ethical approaches such as fixed prices, fair dealing and value for money. By the late 19th century firms traded on their reputation for honesty, integrity and quality, and trade associations developed. The Provision Trade Association, founded in 1887, ‘had regulations covering every aspect of the conduct of the provision trade, from transactions between members to the grading of produce’ (Collins, 1993).

In the late 19th century and early 20th century there were major changes in the structure and organisation of the food industry, accompanied by a fall in real food prices and growth in real incomes. Distributors were increasingly concerned with securing greater control of their suppliers, even to the point of integration with overseas production. Concentration in manufacturing also led to higher standards through the application of improved technology, greater standardisation of products, and the generation of steady profits. Increased competition played a part in
increasing market concentration, not just in manufacturing but also in retailing. Loss of specialisation of food handling trades, and the increased dependence on merchandising forced moves towards assured quality. As incomes rose, distributors competed more on quality, service and freshness than on price. Branding evolved ‘in response to the anarchy of the marketplace with its multiplicity of products of unknown origin and doubtful quality’ (Collins, 1993).

Comparable organisational and institutional changes in the UK food system of today are driven by many of the same factors that were at work 100 or so years ago. Above all, advanced food industries are driven by the need for control of the food chain in order to satisfy consumer demands in respect of product quality – including food safety – and value-for-money.

4.1.2 The challenge of food safety in low- and middle-income countries

Measures leading to improved food QA in low- and middle-income countries are likely to bear some similarity to the British experience outlined above. Efficient, effective and relevant QA mechanisms are likely to involve improved scientific knowledge, accompanied by technical and institutional responses through both regulatory and market mechanisms. Therefore, information and incentives are likely to play a part in QA mechanisms at least as important as policy, especially where the regulatory environment is weak and the ability to obtain redress for injury suffered through legal processes is limited. There may be important lessons to be learnt from situations where lower income country producers are able to adhere to food quality standards in order to accessed high-income country markets (Jaffee et al., 2004).

Uncertainty about the fundamental science of food safety is important, but information problems arise not just because of a lack of information but also from the abuse of information, or dissemination of misinformation, and the existence of asymmetric information between stakeholders and the attendant agency problems. The appropriate approach to QA will depend on the type of hazard or quality imperfection and also the potential technological and institutional solutions. Further evidence of the evolution of technological and institutional approaches comes from Brazil where the level of food safety is associated with the level of socio-economic development (Resende, 1993). Dynamic and modern food control mechanisms that accompanied the municipalisation of food control services in 1988 have been
associated with improved primary health care and a unified health system (Resende, 1993).

4.2 Food safety in the livestock industry

The relationships between the economics of food safety and technological and institutional development are illustrated by the livestock industry. In Britain the prices for meat began to rise in the 1840s, which stimulated an adoption of more intensive livestock production and a modification of housing systems. Around the same time livestock diseases became more problematic as livestock and livestock product movement increased and livestock value chains became longer and more complex (Rushton, 2009). Of greatest note was the importance of economic diseases such as rinderpest, contagious bovine pleuropneumonia and foot and mouth disease. These diseases caused such problems that the State reacted and began to invest in veterinary services, education and research (Fisher, 1998). However the response to diseases that cause less dramatic losses to production, yet have serious impacts on human health, were not addressed in many high-income countries until much later (Fisher, 1998; Waddington, 2002; Shaw, 2009). At international level, concerns on the need to control rinderpest stimulated the creation of the international office of animal health in the 1920s, but this agency has only recently developed a strong interest and role in food-borne and zoonotic disease issues.

These initial investments in animal health and production, mainly associated with high-income countries, were stimulated by large changes in livestock production and their associated value chains. The changes in the livestock sector created new disease problems, and also amplified the impact of contagious diseases. The response over time has been a combined public and private effort to control animal diseases in order to minimise their socio-economic impact. In some cases this has led to the eradication of disease in a number of countries.

The adoption of complex livestock value chains occurred in various world regions in response to the globalisation of livestock and livestock product movement and as a response to technological changes in transport and storage. Animal health systems have also changed to support these new value chains with important consequences for livestock diseases. Towards the end of the 1980s many high-income countries had become recognised as free from the major transboundary diseases and were
beginning to make assessments of how to protect themselves from potential re-entries or re-emergence of disease. On a worldwide level there were also successes that included the control and near eradication of rinderpest and the improved control of other transboundary diseases in low- and middle-income countries with strong livestock export potential.

However, there have been some major setbacks and large areas of the world have not been included in these advances (Rushton et al., 2006). The setbacks include the:

- Occasional introduction of transboundary diseases in developed countries such as foot and mouth disease.
- The emergence of new diseases such as bovine spongiform encephalopathy (BSE) and highly pathogenic avian influenza H5N1.
- The impact of food-borne pathogens such as E.coli O157 and salmonella.

Attention in the agricultural sector in the last 150 years has initially been caught and directed at the high impact, usually economic diseases such as rinderpest in cattle (Fisher, 1998) and blight and rust in crops. Generally there has been a slow response to problems that are spread through agriculture and food chains into the human population. Historically in high-income countries, there has been a tendency towards first satisfying our food quantity needs before asking about quality.
5. The health of producers in agricultural systems

So far we have focused on agricultural effects that impact on the health of consumers, associated with the nutritional properties of food and the spread of infectious diseases and contaminants through food chains. As Figure 1 illustrates, the relationship between agriculture and health is more than this simple linear process linking production and consumer health. There is an additional set of links relating to the fraction of the population who are both consumers and producers of food, particularly farmers and others involved in food systems. For them, food production generates income, which can be invested in improving health, while their own health, as producers, affects the labour and resources that they can put into agricultural production. In thinking about the future of global food and farming, the health of this community deserves special attention, not least because more than 98% of the one billion agricultural workers are in low- and middle-income countries and generally account for the poorest individuals (ILO, 2008). Hawkes and Ruel have created a model for agriculture and health interactions in low- and middle-income countries that specifically identifies producers in the food chain and incorporates the two-way nature of this process (Hawkes et al., 2006) (Figure 4):
Figure 4: Model of agriculture and health interactions in low- and middle-income countries

Reproduced, with permission from (Hawkes et al., 2006)
This model illustrates how agricultural producers experience all of the health risks associated with food chain outputs experienced by the broader consumer community, but also experience particular occupational health risks. Further, if poor health or other factors affects their labour, their capacity to generate food and income from farming may decline, leading to greater health risks. In the following sections we will consider these two health aspects of food production: specific health risks to producers, and the effect of health on agricultural production.

5.1 Health risks to producers and workers

Farmers and farmworkers experience a range of agriculturally-related occupational health risks, including exposure to pesticides, physical injury and increased exposure to particular diseases (ILO, 2000; Cole, 2006). WHO estimated that approximately three million people are poisoned and 220,000 die from pesticide use each year (WHO, 1990) and most of these will be farmers and farmworkers. A more recent World Bank estimate suggests 355,000 die annually, two thirds of them in low- and middle-income countries (World Bank, 2008). Reported poisonings and deaths may be the tip of the iceberg, as much exposure goes unreported and many pesticide effects are chronic and accumulating. Greater effects in lower income countries reflect a number of factors, including limited education on handling of pesticides, application and residues, the persistence there of dangerous pesticides discontinued or banned in high-income countries in addition to high levels of use associated with pest and disease outbreaks. There are also a range of other occupational health risks associated with agriculture including injuries associated with the use of agricultural tools and machinery (Cole, 2006). As well as concerns about pesticide exposure and worker safety, specific concerns are raised about the health impacts of wage employment on farms related to long working hours, lack of access to clean water and sanitation (ILO, 2000).

Farming increases the incidence of certain diseases amongst local farming communities. In the tropics and subtropics particularly, a number of serious vector-borne diseases are associated with water bodies, where vectors breed. These
include mosquito-borne malaria and Japanese encephalitis as well as schistosomiasis transmitted by water-dwelling snails. Agricultural areas tend to be clustered around these water resources and many agricultural projects intensify this association through the creation of dams and irrigation systems resulting in locally high levels of disease prevalence. In Africa, malaria incidence in areas of rice and cotton irrigation has been shown to be higher than in surrounding, non-irrigated areas (Mutero et al., 2006). Schistosomiasis is known to spread with the introduction of irrigation and water development schemes in both Africa and Asia (Xu et al., 2000; Mutero et al., 2006).

A range of zoonotic diseases affect farming households in low- and middle-income countries, due to their proximity with livestock, including trypanosomiasis, rabies and brucellosis (WHO, 2006). These diseases tend to be neglected by national health systems because they are diseases of the very poor. While zoonotic diseases like the influenza virus, H5NI, Nipah virus and Rift Valley Fever are gaining international reputations as potential pandemic threats, it is worth noting that they are also today largely infectious diseases associated with livestock producers.

Water-related and zoonotic diseases come together in the association of farming systems with outbreaks of viral Japanese encephalitis. This disease is transmitted by mosquitoes to humans but amplified in livestock, like pigs, and has become more significant in agricultural intensification schemes in Asia where rice irrigation and pig production has been introduced (Erlanger et al., 2009; van der Hurk et al., 2009).

Most of the health risks associated with agricultural production can be mitigated through investment in education, hygiene and new technologies for pest and disease control and health risks from pesticide use has been dramatically reduced in many agricultural systems through integrated pest management (Waage, 1998). Drivers of such change include governmental and inter-governmental regulatory processes, such as the widespread banning of highly dangerous Class 1 pesticides including many organochlorines and organophosphates. Increasingly, the private sector has the potential to play an important role. As food producers and retailers source and brand foods on the basis of their being from environmentally sustainable production systems, or safe for consumers or fair for producers, they may contribute, directly and indirectly, to the reduction of farmer and farmworker health risks. At the
same time, it is clear that some standards are likely to have wider health impacts than others, with considerable unevenness in the content, coverage and inspection of private standards (Tallontire et al., 2005; Henson et al., 2009).

5.2 The effect of poor health on agriculture production

Where farming is a principal source of income and food for families, poor health may reduce both labour input and its productivity, and hence production and income, with important health consequences. Joffe presents this relationship as a three-step, positive feedback loop (Joffe, 2007). First, *health status affects labour productivity*: poor health may mean periods off work, reducing income, while a death in a family may mean a loss of income altogether. Recent data from China illustrates the direct association between ill-health and loss of productivity, particularly in rural areas (Liu et al., 2008). Poor health in a family also requires time from carers, often women and children. Where it means children are unable to go to school, there are long-term, inter-generational impacts on labour productivity. Second, *labour productivity affects nutrition*: greater labour productivity means more food is produced and can be purchased, allowing greater access to a variety of nutritious foods. Where productivity decreases, access to foods are more limited, and usually restricted to the most inexpensive staples. Finally *nutritional intake affects health status*: insufficient nutritional intake may lead to a reduced capacity for productive work (Martorell et al., 1988), while under-nutrition in pregnancy and infancy impacts on child survival and growth as well as long-term mental and physical development (Grantham-McGregor et al., 2007), which in turn reduces productivity in adulthood (Victora et al., 2008). Putting these three elements together creates a loop in which the trigger of poor health can drive farming populations into a downward spiral of declining productivity and health, creating an inter-generational poverty trap. Conversely, this feedback loop also means that positive interventions at any point can stimulate improvements throughout the process.

Evidence for this relationship between health, productivity and nutrition comes from recent studies of the effects HIV/AIDS on farming communities (Gillespie, 2006; Asenso-Okyere et al., 2010). Studies show that HIV-positive agricultural workers are less productive than healthy workers in the same agricultural systems, while HIV/AIDS-affected households reduce the size of their farmed areas and labour
intensity relative to unaffected households, with consequences for production, income and nutrition. Reduced household income may drive family members to seek employment opportunities elsewhere, which in certain circumstances may itself increase the risks of contracting HIV/AIDS (Gillespie et al., 2005). As such a high proportion of people suffering from HIV/AIDS are farmers, a number of promising programmes have been developed that focus on producing nutritious crops on small plots close to HIV/AIDS-affected homes (Gillespie, 2006). A similar effect of health on productivity is seen with malaria, repeating bouts of which may debilitate adult farmers (Asenso-Okyere et al., 2010). The impact of poor health is also evident for farmworkers. Studies from East and Southern Africa of the impact of HIV/AIDS found that labour-intensive agricultural activities, such as estate-based sugar and tea production, were impacted both in terms of lower productivity, absenteeism and, in some cases, the higher cost of employee health benefits (Fox et al., 2004; UN Populations Division, 2004).

5.3 The impact of agricultural change and development

The productivity-related examples of links between agriculture and health cited above all focus on low- and middle-income countries where agriculture remains the occupation of much of the population, and where many rural farmers are at high health risk from under-nutrition and infectious disease. This means that agricultural change, and growth, in itself can have dramatic health benefits (Lipton et al., 1988). Agricultural development programmes that support new, more productive crop varieties, more efficient and sustainable inputs and production practices and improved market access make a tremendous impact on health by increasing income, creating more employment opportunities, raising wages and generally improving local livelihoods, independent of any targeted health intervention in those communities (Ashley et al., 2001).

The challenge facing agricultural development is to achieve this health benefit without incurring unanticipated, negative health effects in the process. Unfortunately, there are many examples of negative effects in the history of agricultural development and intensification. All of these can be related to a lack of awareness amongst agricultural policy-makers and investors regarding the nature of agriculture-health linkages. A well cited example is that of improved potato production in Carchi,
Peru in the late 1990s (Yanggen et al., 2003; Cole, 2006). The promotion there among smallholder farming communities of new pesticides and application methods for control of crop pests and diseases (a phenomenon typical of agricultural intensification programmes) had positive economic effects. Pest and disease control increased yields and income, more than compensating for the cost of the new technology. However, spraying also had serious health impacts, with many farmers suffering from pesticide poisoning due to poor education in safe pesticide handling. The effects, mostly neurological, affected both physical work and decision-making, and were experienced across households, due to the storage of pesticides in the home. The cost of poisoning, in terms of work-days lost, created negative health impacts that, in economics terms, outweighed the economic gains from pesticide use. Ultimately, an integrated pest management regime proved the most effective approach to achieving the benefits of pest control without the disbenefits of impaired health. A similar situation has been described in rice intensification, where health effects from pesticide use may exceed the benefits of using pesticides to reduce economic losses due to pests (Rola et al., 1993).

These are perhaps extreme examples and the trade-off between agricultural improvement and negative health effects is complex. An analysis of malaria in African rice production revealed a ‘paddies paradox’ (Ijumba et al., 2001). New irrigation schemes for agriculture in areas that previously had little malaria can lead to increases in vectors and disease prevalence. However, in areas where malaria is already present and ‘stable’ in the human population, new irrigation schemes may not have that effect and may even lead to a decline in malaria. This phenomenon appears to be related to both ecological and socio-economic factors. For the latter, increased income to farmers in such irrigation schemes allows them to invest in better prevention and control of malaria, such as the use of bed-nets and medicines. Higher incomes from agricultural development not only make possible more nutritious diets, but better health care generally, including disease prevention and control.

Another example of conflicting agriculture and health development is found in programmes to increase fish production in rural communities (Roos et al., 2006). Many studies have shown that production of small fish in rice producing areas can improve nutrition of poor communities, particularly through higher intake of beneficial
fatty acids, minerals and other micronutrients. While such innovation has been the focus of aquacultural development projects, other projects have focused on increasing commercial production of larger fish for markets. These larger, commercially traded species do not provide the same level of nutritional benefits, nor are they as likely to be locally consumed, and hence the health improvement opportunity comes through increased income from selling fish. The trade-off is complex, but it is likely that local communities do less well, nutritionally, through commercial fish production than through producing smaller fish for local consumption.

A common feature of many agricultural development projects is the commercialisation of agricultural production systems, the effect of which on the poor has been diverse and ‘specific to location, implementation, and policy environment’ (von Braun et al., 1994). A key issue is the degree to which poor people benefit either as farmers or workers in new agricultural activities, or benefit more generally from the spillover effects of local economic growth. In terms of the impact on food security or nutrition, it is evident that agricultural commercialisation had the greatest impacts when it drew in the malnourished poor either as farmers or workers. Detrimental impacts on the intra-household distribution of income have been documented in some cases of agricultural commercialisation; with women being disadvantaged in terms of their control of either farming decisions or agricultural income (von Braun et al., 1994; Gladwin et al., 2001). This is of concern given the evidence from low- and middle-income countries that greater female control of household income generally increases the share spent on food and thus improves the nutritional status of children (Pridmore et al., 2009). The International Labour Organization (ILO) concludes that agricultural commercialisation in low- and middle-income countries is important in producing greater employment opportunities but that greater regulation and better legislation is needed to ensure that these are of decent quality (ILO, 2008).

Agricultural development, which may include intensification and commercialisation of agriculture, has the potential to improve livelihoods of the rural poor, increasing their capacity to pay for nutritious foods and healthcare. However the intensification of agriculture should only be conducted with a thorough understanding of potential
trade-offs with health and consideration of how they can be mitigated, and net human welfare maximised.

6. agriculturally-mediated environmental effects on health

Many of the health effects of agriculture are linked to environmental externalities associated with agriculture itself. For instance, the emergence and spread of zoonotic diseases may arise from conversion of natural forest into agricultural land, enhancing movement of diseases from wildlife to livestock and humans, while pesticide over-use and poisonings may stem from a loss of natural, environmentally based pest control as agricultural systems are made more intensive. More fundamentally, environmentally unsustainable agricultural production, while increasing food supply in the short term, may fail in the long term, affecting livelihoods of the rural poor, nutrition and health through the feedback loops discussed in the previous section.

Few studies of future agricultural development consider health implications. The Agrimonde project (INTRA /CIRAD, 2009), is an ambitious exercise to model to 2050 different future scenarios of food production relative to environmental sustainability. Two complex scenarios are identified, based roughly on ideas from the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005). The first, Agrimonde GO, continues current trends in production and intensification, dealing with environmental issues in a reactive manner. In this scenario, changes in food consumption are driven by economic growth and consumption tracks increasing food availability. Agrimonde 1, by contrast, is directed at environmental sustainability, adopting more extensive and less intensive farming while seeking to conserve natural resources. This scenario assumes there will be behavioural change, decoupling consumption from availability, such that wealthy regions will consume less per capita. In effect, Agrimonde 1 seeks to produce food sustainably, leading to lower levels of production, mitigated by more healthy patterns of food consumption. Both models ‘feed a world of 9b in 2050’ (INTRA /CIRAD, 2009). Agrimonde GO accumulates environmental and health costs, but achieves dietary needs with production to spare. Agrimonde 1 has lower environmental and health costs, but there is little surplus and a strong requirement for increased trade between regions in
order to distribute food to areas where production is below demand (INTRA /CIRAD, 2009).

The Agrimonde model implies that current trends in agricultural growth will contribute to environmental degradation, including loss of biodiversity and increased greenhouse gas emissions, with likely indirect health effects. A number of other studies have examined more directly the effect of changing agricultural practices on reducing the need to extend agricultural land to feed 9b people in 2050, focusing particularly on reduction or change in the production and consumption of meat products, particularly from ruminants (Stehfest et al., 2009; Wirsenius et al., 2010). Changing agriculture in this way will have not only environmental but health effects as well. A recent study by Friel et al. (2009), demonstrates the potential for health co-benefits of climate change mitigation measures in agriculture. The agriculture sector contributes between 10% and 12% of total global greenhouse gas emissions (Smith et al., 2007) and within the sector, livestock production accounts for the vast majority (nearly 80%) of all greenhouse gas emissions (Steinfeld et al., 2006). It has been estimated that rising demand for animal source food products, especially in middle-income transition economies, is likely to drive up the production of livestock by 85% by 2030 from levels in 2000 (World Bank, 2008) and this will further significantly affect sector emissions. A recent analysis investigated the health co-benefits of greenhouse gas mitigation strategies aimed at the livestock sector, using a reduction of 30% in livestock production as an important mitigation strategy (Friel et al., 2009). Models assumed that a reduction in production would result in a commensurate fall in consumption and focused on the impact on ischemic heart disease rates as a consequence of reduced saturated fat consumption. The authors conducted case studies using the UK and Sao Paulo City, Brazil as examples and revealed that a 30% cut in consumption of animal source saturated fat would result in a decrease of about 17% in the number of premature deaths from heart disease among adults in both settings (Friel et al., 2009). This is a good news story, a policy that is good for the environment and good for public health. Furthermore, only one diet and health association, heart disease, was examined and there may also be additional benefits to health associated with decreased consumption of livestock products such as reduced incidence of certain types of cancer. It must be emphasised however that there are important limitations with these sorts of
modelling exercises which can limit their interpretation. For example, the models used data only from the UK and did not take into account different forms of livestock rearing, which contribute differentially to greenhouse gas emissions and to food production (Friel et al., 2009).

While this exercise highlighted important co-benefits of climate change mitigation strategies for health, a more sophisticated understanding of the impact of changing agricultural policies is required to fully understand the implications for health. For example, a recent analysis modelled the impact of adopting the healthy dietary guidelines on saturated fat intake both in terms of direct health benefits but also the impact on agricultural production, trade, the economy and livelihoods (Lock et al., 2010). The analysis reveals the importance of understanding the connections between these various policy areas, highlighting the fact that there are trade-offs involved in every policy decision with areas that will benefit while others lose. To ensure that dietary recommendations are truly sustainable, a range of economic, social, environmental and health objectives will need to be met.

7. Discussion: making health a driver of agricultural policy

While agriculture provides the basis of human nutrition and health, we have shown how the relationship between agricultural change and health improvement is complex and not always positive. For the world’s consumers agriculture, working through food systems, has the potential to contribute to unhealthy diets and the burden of disease. For that important part of our population that produces food, agricultural practices may undermine health, directly or through effects on labour and income. These diverse effects share two distinctive features. Firstly, they are considerably more severe in low- and middle-income countries. Consumers in these countries experience the greatest levels of both under-nutrition and food-related chronic diseases, the ‘double burden’ of food-related disease. They are also likely to be exposed to high levels of food-borne disease. In addition, their agricultural producers suffer high levels of direct and indirect negative health effects resulting from agricultural practices, including pesticide poisoning, vector-borne disease and lack of access to health services due to low income. Because agriculture is an
important occupation in low- and middle-income countries, and an important part of their economies, these effects on producers have considerable national impact, relative to high-income countries.

Secondly, the same processes that contribute to reduced health can contribute to improved health – there are no inherently negative drivers of health in agriculture. As we have seen:

• Healthy diets are achieved through a balance of food intake and particularly the quality of the food consumed. Changing patterns of food consumption can drive improved health as well as reduced health, depending on what and how much is consumed.

• Food systems, particularly modern value chains, have the potential to efficiently remove risks of toxicants and disease, as well as to spread and amplify these.

• The effect of ill health on farmers that drives a reduction in labour, income and access to health care is a negative feedback loop that can be reversed to create compounding, positive health effects. Improved health increases productivity which contributes to further health improvement, even to the extent of overcoming agriculturally-related disease burdens such as malaria.

• Wage employment on farms is also widespread in low- and middle-income countries with workers among the poorest individuals. The imposition of both public and private standards has the potential in certain circumstances to improve working conditions on farms and thus farmworker health. As with farmers, an improvement in health is likely to raise worker productivity.

• Agriculture may contribute to negative population health through its effects on climate change, but it can also contribute to health improvement through changing agricultural practices which generate co-benefits of climate change mitigation and improved diets.

The fact that we can document widespread negative effects of agriculture on health indicates that too many practices are driving this relationship in the wrong direction, rather than the right direction towards improved health effects. We suggest that this misdirection has two causes. Firstly, there is a profound lack of understanding of
agriculture-health relationships, based on a lack of research and evidence. Secondly, in part as a result of this lack of evidence, current agricultural policy is not designed to optimise health benefits. The complex linkages between agriculture and health outlined in this report suggest that there would be clear benefits to placing health as a central driver of agricultural policy change.

7.1 Improving the evidence base

Agricultural development policy has been built on an evidence base derived from agricultural research, with limited attention to the evidence base from health research. This is not surprising: agriculture and health research sectors have developed independently over the past century with little interaction. Their separation is reflected in university departments, government ministries, multinational business clustering and the present sectoral fragmentation of the inter-governmental system, particularly the separation of health and agricultural activities in the WHO and FAO, respectively. As a result of this history, there are today enormous institutional barriers to the inter-sectoral research collaboration necessary to a joined up approach to agriculture and health research.

We have highlighted in this paper some policy consequences of this failure to collect and use health evidence in agricultural development:

• Crop development strategies have focused on quantity (cheap energy production) rather than on producing inexpensive foods that present a healthy balance of macro- and micronutrients.

• Development of animal production systems has been pre-occupied with economic diseases of livestock and has ignored or acted slowly to address zoonotic diseases of human health importance.

Development of agricultural production systems to improve livelihoods, based on intensified irrigation and livestock production have not considered counteracting effects of increasing vector-borne and zoonotic disease. This lack of integration of agricultural and health research has also resulted in parallel development by agricultural and health sectors of different solutions to the same problems. Consider for instance the challenge of improving the quality of diets, particularly in low- and
middle-income countries. Here there has been a range of initiatives from different sectors, including:

- Creating more nutritious varieties of crops through breeding or engineering cereal lines to express higher levels of vitamin A, iron and zinc (www.harvestplus.org), or breeding of animals, and/or modifying their diets, to produce healthier meat products (Stewart et al., 2001; Rymer et al., 2010).

- Adding micronutrients to processed foods, already a successful practice in many countries for delivery of iodine (Zimmermann et al., 2008) and folic acid (Stevenson et al., 2000), and increasingly a feature of the commercial development of processed foods.

- Providing nutritional supplements, a health intervention aimed specifically at populations at particular risk of malnutrition, such as routine vitamin A supplementation during child immunisation programmes (Goodman et al., 2000).

- Campaigns to change consumer behaviour and encourage healthier diets, such as the UK ‘five a day’ programme to promote fruit and vegetable consumption (Department of Health, 2010), or similar price-based initiatives from the food and food retail industry.

- Economic proposals to encourage the production of healthier foods through targeted commodity production, import or export subsidies.

Health interventions which compensate for unhealthy diets through specific medication, for example the use of statins to reduce LDL cholesterol (Delahoy et al., 2009). These different approaches to improved diets provide a rich portfolio of opportunity, particularly as they may have complementary features with respect to reaching different populations. But these research areas are presently being pursued largely in isolation by different agriculture and health research clusters, making it unlikely that they will be integrated in the most productive and efficient way.

Achieving such integration is a challenge that will require not only innovative ways of organising and funding research efforts but fundamentally a means to measure and compare the health benefits of very different kinds of innovations. There have been encouraging, recent developments in this area. For example, the vitamin A-
associated health benefits of uptake of new ‘golden rice’ varieties, genetically modified to express beta carotene, has been calculated in terms of Disability Adjusted Life Years (DALYs) (Stein et al., 2006), which can in turn be used to calculate health-related economic rates of return on agricultural investment. Developing metrics that allow the comparison of health benefits from innovations in agriculture and health will be important to building policies around the best combination of strategies.

Finally, we suggest that a particularly serious consequence of the isolation of agricultural and health research has been under-investment in the collection of satisfactory data to understand agriculture-health interactions. In this paper, we have paid particular attention to highlighting the profound lack of good quality data that relates food production and individual-level food consumption, as a basis for understanding agriculture-health links. Without a commitment to providing an evidence base that measures the relationships between agriculture and health, we do not see a clear incentive for improving on the current use of FBS and similar crude approaches to measuring the relationship between agricultural production and dietary intake.

7.2 Changing agricultural policy

Consider the current alignment of agricultural policy with health priorities. On a global scale, health priorities correspond to the global burden of disease, which WHO has partitioned into a number of components (WHO, 2008). The link between agriculture and these burdens is clear from considering the 10 leading causes of death worldwide. These are, in order of importance: coronary heart disease; stroke and other cerebro-vascular disorders; lower respiratory infections; chronic obstructive pulmonary disease; diarrhoeal disease; HIV/AIDS; tuberculosis; tracheal, bronchus and lung cancers; road traffic accidents; premature and low birth weights. Four of these (heart disease, stroke, diarrhoeal disease and premature and low birth weights) have a direct link to nutrition while some others, such as HIV/AIDS, have complex and important interactions with agriculture, as we have seen. The global burden of disease can alternatively be grouped into disease classes, of which WHO recognises three broad groups (Table 7). Across these groups, the burden differs substantially between high- and low-income regions such as Europe and Africa.
### Table 7: The contribution of agricultural policy to the global burden of disease

<table>
<thead>
<tr>
<th>Disease category</th>
<th>DALYs per 1000 population</th>
<th>Contribution from agricultural activity</th>
<th>Relevant agricultural policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicable, maternal, perinatal, and nutritional conditions</td>
<td>20 Europe 370 Africa</td>
<td>Food insecurity, under-nutrition</td>
<td>Policies to increase food security through agricultural production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infectious diseases in food chain</td>
<td>Food safety regulations</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-communicable disease</td>
<td>160 Europe 100 Africa</td>
<td>Unbalanced diets</td>
<td>Dietary recommendations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pesticides/additives</td>
<td>Food safety regulations</td>
</tr>
<tr>
<td>Group 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injuries</td>
<td>30 Europe 40 Africa</td>
<td>Occupational injury</td>
<td>Work safety regulations</td>
</tr>
</tbody>
</table>

\[^1\text{DALY} = \text{disability adjusted life years for 2004 provided in WHO Global Burden of Disease Report (WHO, 2008)}\]

Different types of agricultural practices influence these disease burdens, as shown, and each of these activities can be associated with the presence or absence of agricultural policies. From this comparison, regions such as Africa suffer health burdens largely related to dietary nutrition. In these poorer regions the greatest DALYs are associated with Class 1 diseases encompassing both under-nutrition and the effects of poor nutrition on susceptibility to communicable disease. It has been estimated that over one-third of child deaths from communicable disease are directly related to under-nutrition (Black et al., 2008). Food-borne diseases are a risk in Africa, but will be a very small part of the DALYs contributed by communicable
diseases, which will come largely from HIV/AIDS, malaria and tuberculosis. Non-communicable diseases also contribute in Africa to many DALYs, reflecting the growing contribution of the dietary transition. In wealthy regions such as Europe, these non-communicable diseases dominate.

Overall, the agriculturally-related diseases contributing most to the global burden of disease are associated with diet and diet quality yet agricultural policies directly relevant to dietary intake are few in both high- and low-income regions. Governments make recommendations about balanced diets, but do not have policies of enforcement. By contrast, agricultural policy is very well developed in the context of food-borne infectious diseases and contaminants. Most governments subscribe to and implement measures developed in the World Trade Organisation (WTO), FAO, WHO and the World Organization for Animal Health (OIE) to protect the safety of food and restrict the movement of contaminated food and diseases in the food chain.

This simple comparison points to a profound mismatch between agriculturally related disease burdens and the targeting of agricultural policy. In particular, the policy focus on food-borne contaminants and diseases is disproportionately large and that on nutritional aspects of non-communicable diseases disproportionately low. The explanation for this would seem simple. These health-related policies and policy gaps are determined not by health concerns but by commercial considerations in the food system. Policies to reduce food-borne diseases and contaminants have been developed to protect agricultural trade and food systems, while policies to improve diets and nutrition have not been developed because they would constrain these same systems. An additional policy driver is the effect of the mass media whose commercial interests often also lead to a lack of analysis and balance in reporting health risks from different sources. The effective communication of sound science is essential for creating a more accurate awareness of agri-food and health risks and challenges.

This policy mismatch prepares us poorly for the future. Consider, for example, one of the most dramatic emerging, health-related trends in agriculture, the ‘livestock revolution’, an increase in meat and dairy production to respond to growing demands of wealthier, urban populations in low- and middle-income countries (Delgado et al., 1999). Much of the recent growth in the livestock protein supply has come from
intensive monogastric systems and to some extent from a growth in milk production. The dramatic increases in livestock production have been celebrated, but this trend has also generated concerns about the contribution of meat and dairy products in the dietary transition and the growth of chronic diseases (Popkin, 2009). Concerns have also been raised in relation to health externalities such as the impact on the livelihoods of traditional farmers (Haan et al., 2001; Hefferman, 2002) and potential negative environment impacts (Steinfeld et al., 2006). There has been concern about growing problems with the control of transboundary animal diseases and more specifically the emergence and resurgence of dangerous zoonotic diseases (Greger, 2007). There are pervasive arguments that recent rises in disease problems are related to changes in livestock production systems and the increase in livestock populations (Leibler et al., 2009), although the capacity to collect data and to analyse these systems continue to be weak. Presently, therefore, the only health-related agricultural policy which has a chance of influencing the livestock revolution and its health effects relates to zoonotic disease risks, which is only a fraction of the health threat.

In recent months we have seen resurgence in interest in agricultural food security and with it a growth of interest among international organisations and bilateral development agencies in reducing hunger and improving nutrition driven by the time-bound targets of the Millennium Development Goals. What we need to see now is a similar effort to drive health issues into policy relating to the other dimension of the double-burden, the negative health effects of the dietary transition. As mentioned above, governments are unlikely to legislate diets, but they could do far more than they do at present to encourage these. However, the greatest opportunity lies in changing policy in the private sector. As we have seen, the private sector elements of the food system have enormous potential and opportunity to:

• Improve our understanding and evidence for the effects of diet on health, through their collection of information on consumer behaviour and tools such as value-chain analysis.

• Influence dietary intake through the processing, distribution and pricing of foods.

• Improve the health and productivity of food producers through influencing the safety and sustainability of the supply of foodstuffs.
All of these capacities enhance public sector opportunities to achieve these same ends, and point to a strategy of public-private sector partnership in developing a policy context that addresses this missing policy gap in agriculture and health alignment.

8. Conclusions

In this paper we have explored the interactions of agriculture and health and highlighted where this inherently positive association has the potential or tendency to turn negative, with agricultural policy and practice generating negative health effects that detract from its overall value to society. These have focused on three areas: nutrition, food-borne diseases and health effects specific to agricultural producers.

Consumers face health risks from malnutrition, which includes both persistent under-nutrition among the poor and the effects of the dietary transition on reducing the healthiness of diets for both poor and less poor consumers. Here we have highlighted the paucity of good data to understand the nature and dimensions of malnutrition, and the need to change agricultural policy to focus more on the generation of food quality than food quantity. This policy change must be undertaken as a public-private partnership, as stakeholders in commercial food systems have a substantial contribution to make in understanding this problem and inducing healthy patterns of food consumption behaviour.

Consumers face health risks through globalised food chains which can amplify and spread diseases and toxicants. While there is a great deal of agricultural policy directed at making food chains safe, which if properly implemented could reduce these risks, international standards for food safety still need development. In addition, there is an underlying lack of attention to human health issues in the design of changing agricultural production systems, particularly for livestock. Without this, human disease risks from production systems will continue to be dealt with reactively.

Finally, agricultural producers face particular health risks, associated with poverty in agricultural systems, malnutrition and disease. This is a complex interaction between
agriculture and health, of particular importance to low- and middle-income countries. Economic growth is a solution, but the nature of that growth will affect equity and the balance of health risks, requiring a careful incorporation of health evidence into development policy.

Climate change will potentially attenuate both agricultural and health improvement, making it all the more important that these sectors integrate their activities. Overall, many of the issues raised require an integration of health and agricultural research questions and tools and will be vitally important in achieving the goal of feeding nine billion people in 2050 in a way that is truly healthy.

Value chain analysis has emerged as an analytical framework to enable firms to look beyond their own boundaries, to examine linkages with other organisations and to identify ways of creating and sustaining better business performance. Adoption and diffusion of the value chain concept has led to an emphasis on a wider range of stakeholders. Value chain approaches have the merit of being inclusive of all stakeholders and potentially useful for intervention where the links in the food supply chain are weakest.

Agri-food policy for a healthy global population must take account of this commercial dimension. Market activity operates within a broader framework of both formal and informal constraints that regulate economic activity. Institutions supporting a pro-poor commercial environment are likely to include both private commercial initiatives and also public policy interventions. Policies on competition, for example, can be locally targeted and help to restrain anti-competitive market structures and conduct, and serve as a framework for sectoral support from the public and donor sectors.

Moreover, there are roles for civil society and advocacy organisations in building markets that meet the challenges of availability and affordability of safe and healthy foodstuffs for all, such as an efficient regulatory environment, business ethics, social and environmental responsibility, competition policies, and consumer education.

The global food and public health systems are intimately linked through a complex and constantly evolving set of multi-directional relations. While the agricultural system produces the foodstuffs needed for life, the many direct and indirect negative effects of agriculture on health are only just beginning to be understood and are rarely included in the global policy debate. There has to date been insufficient
dialogue between the research communities in the agricultural and health sectors, a situation that is not helped by the current paucity of available relevant data. Greater integration of research on agriculture and health is essential to help devise policy to ensure improved health for future generations.
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Conflict of interests

The authors have no conflict of interests to declare.
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**Short title for page headings:** Improving agriculture-health relationships
Appendix

1. Commodities production, Food Balance Sheets and global food availability

The United Nations Food and Agriculture Organization (FAO) compiles national data on food production and on per capita food availability for most countries in the world. These data are available online (http://faostat.fao.org) and are widely used to inform agricultural and food policy. Production data are presented for the top 20 most important food and agricultural commodities produced in a given country in terms of their value and size. Food availability data are presented in food balance sheets (FBS) and provide figures on the estimated availability of over 100 foodstuffs in grams/capita/day. The FBS are constructed using FAO information on food production and net trade. The food available for consumption is then calculated after estimating the amount used for industrial or agricultural purposes (for example, as seed or for animal consumption or biofuels), wastage in the production system and change in national stock levels. It is important to emphasise that measures of food availability are not measures of food consumption, but in the absence of other data, food availability is widely used as a proxy for food consumption.

The calculation of food availability is subject to a range of potential errors, from the initial calculation of production and trade, to the determination from this of what food is available for consumption. The statistics used for food production and net food trade by FAO have been criticised by both academics (Svedberg, 1999) and independent evaluators (CC-IEE 2008). In 2008 an independent evaluation noted that ‘the quantity and quality of data coming from national official sources has been on a steady decline since the early 1980’ (CC-IEE 2008). This lack of good quality data is particularly acute for certain low-income countries where there may be no official statistics; FAO currently fills this gap by providing its own modelled or imputed
estimates of food production, which are used for over 70% of African countries and for over 50% of countries from Asia and the Pacific (CC-IEE 2008).

Figures on animal populations and production parameters provide further illustration of errors inherent in office-based estimates. A recent case study from South America revealed that livestock population figures reported by the FAO differed by 10-50% from the reality on the ground and that very sparse data on livestock production parameters were used to estimate production (Rushton et al. In prep). A striking example from this region is the difference in estimates in Brazilian cattle populations, with the official number being 180 million compared to estimates of 160 million (FNP Consultoria e Comercio 2006). As agricultural production numbers form the basis of FBS estimates of food availability, errors of this magnitude will have important consequences for the accuracy of the resulting food availability data, and any estimates of consumption calculated from these.

At the level of estimating per capita food availability, errors in FBS estimates can result from incomplete or out-of-date country-specific population estimates which are usually based on the resident population and do not take into account tourists, illegal immigrants or refugees. This issue may be particularly pronounced for many sub-Saharan African countries where published population census data are often out of date and are likely to suffer from undercounting and misreporting due to issues of accessibility, risk and the conceptual problems of encompassing highly mobile populations and complex patterns of household formation (Sender et al. 2005).

FBS data provide incomplete information on the level of home-production of foods or on the level of processing different food commodities undergo prior to their availability for consumption. In many low-income countries foods produced at home (which do not reach the market) remain largely unprocessed and are predominant in the household diet. In contrast, as countries undergo the nutrition transition, foods are often highly processed, and FBS data based on the production and trade of agricultural commodities are unable to provide information on the composition of the processed foods actually available for consumption.

Finally, a key source of error in using FBS food availability statistics as a proxy for food consumption is that FBS data do not allow for food waste at the retail and household level. This level of food wastage can be particularly high in urban areas of
developed countries, but will vary greatly both between and within countries. In the UK it has been estimated that one-third of all food purchases (i.e. foods available for consumption at the household level) are thrown away, equating to 6.1 million tonnes of foodstuffs a year (WRAP 2008).

2. Food availability at the household level

Household budget surveys (HBS) generally conducted by National Statistical Offices are available from many countries in the world including an increasing number of low-income countries (Smith et al. 2006). These surveys generally aim to acquire nationally-representative information on household expenditure for a range of commodities, including food, primarily to construct cost-of-living indices. Where HBS include information on the quantities of different types of foods purchased, as well as consumption from own-production, this information equates to the food available at the household level and is therefore frequently used as a proxy estimate of consumption in a similar manner to FBS food availability data. In HBS, dietary data are collected as part of the larger household level survey, which is a strength as they can be related to the socio-economic status of the household and, provided the sample is representative, regional variations can also be investigated. In reality, however, samples are not always representative due to issues such as a lack of accurate sampling frame, poor response rates and a tendency to over-sample urban compared to rural areas and poorer compared with wealthier households.

Other important limitations of using HBS data to assess the composition of the household diet include a lack of information on food consumed outside the home, on waste within the household or on food used for other reasons (such as pet food) or fed to guests. Measuring the consumption of home-produced food may also prove difficult. In addition, the methodologies used may not be directly comparable between countries (Naska et al. 2009). A further important limitation when using the data as a proxy for individual dietary intake is the lack of information on the distribution of food within the household. Intra-household food allocation may be a particular concern in low-income country settings where food consumption is known to vary widely between members of a household, with higher-status household members often consuming considerably more, and better quality, foods than other
members of the family (Gomna et al. 2007; Leroy et al. 2008). A final consideration is that seasonal trends in food consumption are not captured by these surveys unless they are conducted year-round, which has its own consequences in terms of implementation costs.

Few studies have quantitatively assessed the comparability of food availability data derived from FBS and HBS. However, a recent comparison of data from 18 European countries reported a general tendency for HBS-derived values to be lower than those from FBS for the major food groups (Naska et al. 2009). Despite the lower values in HBS, estimates from the two methods of the availability of most food groups, with the exception of meat products, correlated well (Naska et al. 2009). HBS and FBS are thus complementary methods of assessing food availability, and have an important role to play in informing public policy. However, because of their inherent limitations they are not able to provide accurate data on food consumption at the individual level (Serra-Majem et al. 2003); a concept that is explored further in the following sections.

3. Individual dietary surveys of food consumption

Direct estimates of individual food consumption for a population are generally derived from surveys conducted on nationally-representative samples. When conducted properly, individual dietary intake data from population surveys can often be sub-divided by age and sex categories and used to investigate regional and socio-economic variations. There is a surprising paucity of nationally-representative surveys even from high-income country settings. Indeed, in order to estimate the consumption of fruit and vegetables by individuals worldwide, the Global Burden of Disease project was only able to identify nationally-representative dietary intake survey data from 26 countries, and had to rely entirely on FBS food availability data for African countries (Lock et al. 2005). This lack of dietary intake surveys probably arises from the complexities and expense involved in conducting regular high-quality rounds of data collection and analysis, insufficient information on the energy and nutrient composition of local foods and low participant literacy levels in some countries (Ferro-Luzzi 2002).

Collecting individual dietary intake data involves methods such as weighed records, 24-hour recalls and food frequency questionnaires, none of which is error-free.
Weighed food records over seven days are generally viewed as the ‘gold standard’ by nutritionists, although it is recognised that respondents must be highly motivated and literate and that the burden of data collection may impact on their dietary behaviour (Gibson 2005). 24-hour recall methods are commonly used, although must be repeated on several days to more accurately capture habitual dietary intake (Gibson 2005). Food frequency questionnaires require fewer resources, but there exists an ongoing debate around the validity of dietary intake data reported via this method (Bingham et al. 2003; Prentice 2003). Difficulties in comparison and interpretation of individual dietary intake data collected in different countries also arise from the use of diverse study designs, sampling frames, seasonal variation in dietary intake and methods of data collection.
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