Assessing the overall impact of the dairy sector

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1 Introduction

Any discussion on the overall global impact of the dairy sector must include all the important socio-economic and environmental benefits and costs associated with the sector: *people, planet* and *prosperity*. In this respect Fig. 1 and 2, and the following quotations from the United Nations Food and Agricultural Organisation (FAO) and United Nations Environment Programme (UNEP) provide a useful context:

> Sustainable consumption and production in food and agriculture is a consumer-driven, holistic concept that refers to the integrated implementation of sustainable patterns of food consumption and production, respecting the carrying capacities of natural ecosystems. It requires consideration of all the aspects and phases in the life of a product, from production to consumption, and includes such issues as sustainable lifestyles, sustainable diets, food losses and food waste management and recycling, voluntary sustainability standards, and environmentally friendly behaviours and methods that minimize adverse impacts on the environment and do not jeopardize the needs of present and future generations. Sustainability, climate change, biodiversity, water, food and nutrition security, right to food and diets are all closely connected. (FAO, 2016a)

> Billions of people around the world consume milk and dairy products every day. Not only are milk and dairy products a vital source of nutrition for these people, they also present livelihoods opportunities for farmers, processors shopkeepers and other stakeholders in the dairy value chain. (Muehlhoff et al., 2013)

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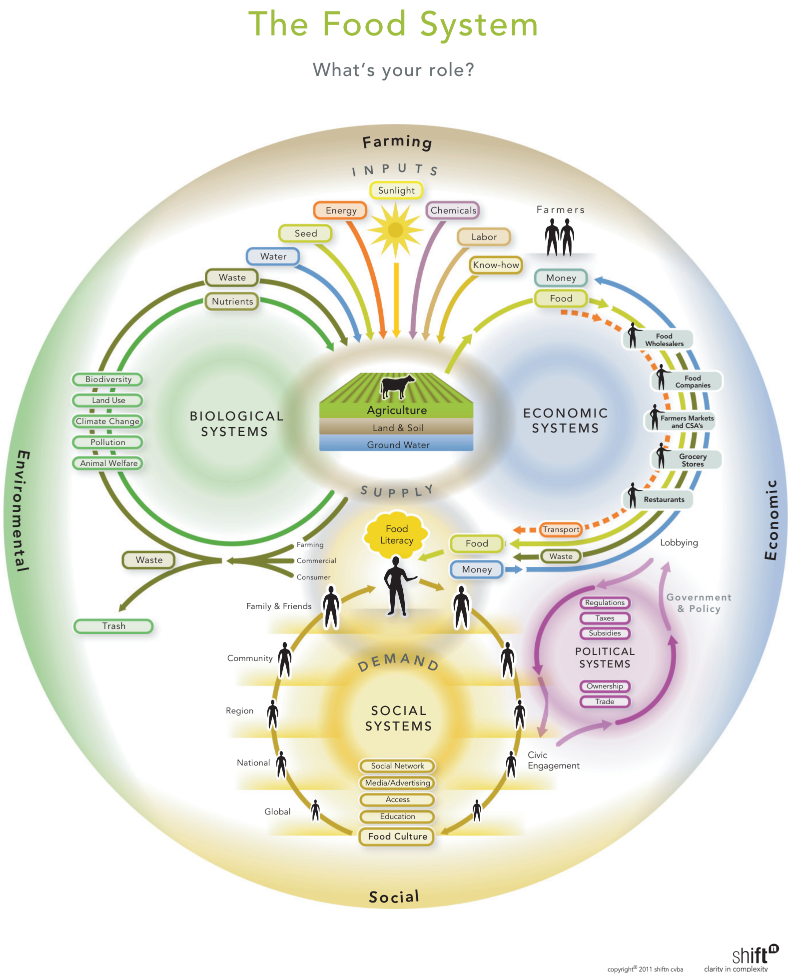

Figure 1 The food system.

Clearly, to determine the overall impact of dairying from the perspective of sustainable consumption and production is an extremely complex undertaking. It is also clear that the dairy sector impacts billions of people.

To provide even further context, analysis undertaken by the International Farm Comparisons Network (IFCN) and published by the FAO has determined that 750–900 million people live on dairy farms (FAO, 2010a). Many of these are smallholder farmers living in developing nations where dairy is indispensable to their livelihoods. Latest estimates are that up to 1 billion people derive a significant proportion of their livelihoods from dairy if you include employment throughout the whole of the dairy chain (Steinfeld et al., 2010; IFCN, 2015; Dugdill et al., 2013). Of the estimated 570 global farm holdings 25% or 150 million keep milking animals (FAO, pers. comm.).

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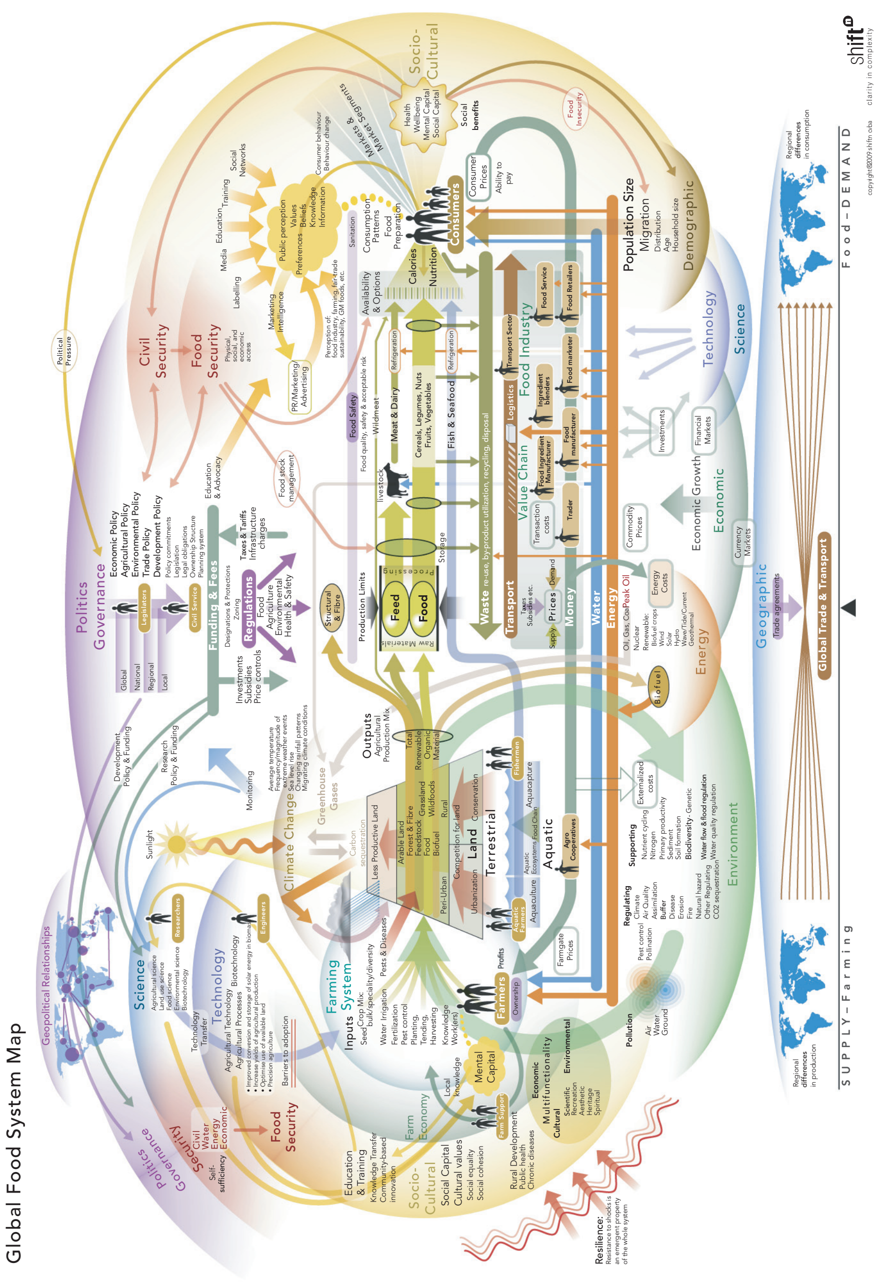

Figure 2 Global food system map.

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Dairy including cow and buffalo milk is the world's number one traded agricultural food by value (FAOSTAT, 2013), and in addition to providing a livelihood for approximately one-seventh of the world's population, provides an important source of nutrition for over six billion people. In addition to providing a wide range of micronutrients, global milk production contributes on an average per capita/per day basis: 134 kcal of energy, 8.3 g of protein and 7.6 g fat; or 5%, 10% and 9% of global food energy, protein and fat (FAO, pers. comm.). Dairy farming utilises 7% of the world's land (FAO, pers. comm.) and significant water and other resources. Dairy also produces waste streams such as effluent and greenhouse gases (GHG).

2 Socio-economic impact of the dairy sector

The enormous global socio-economic impact is often neglected in discussions about the environmental impact of dairy at a local level or when discussing factors such as GHG emissions at the global level. This can result in naive or overly simplistic recommendations that, to 'save the plant', people should reduce or eliminate dairy from diets. As will be covered later in this chapter we still need to do more research to create better knowledge and understanding about what constitutes sustainable food systems and to develop comprehensive models and holistic frameworks to enable and drive progress. Nevertheless, current evidence points to an almost indispensable role for dairy within sustainable and nutritionally secure food systems once all socio-economic and environmental factors are taken into account.

2.1 Dairy's impact on livelihoods

Key facts: The global dairy sector produces approximately 800 billion litres of dairy nutrition and through 240 million jobs, including 150 million farms and smallholdings directly supports the livelihoods of up to 1 billion people.

Dairy makes an important economic contribution to society and is both big business in terms of the intra- and inter-country trade in dairy products, with current global milk production reaching 800 billion litres (FAO Outlook, 2016; FAOSTAT, 2016; IDF, 2015), and small business in the livelihoods it provides to hundreds of millions of smallholders in many developing countries (Steinfeld et al., 2010; IFCN, 2015; Dugdill et al., 2013). It is estimated that 240 million people are employed either directly or indirectly in the dairy sector (FAO, pers. comm, elaborated from FAOSTAT and the World Bank Development Indicators Database). In the previous chapter Trends in dairy farming and milk production: the case of the UK and New Zealand the importance of dairy farming and trade in dairy products in selected developed markets was highlighted. In China 736 dairy enterprises employ over 270 000 people (IBIS World, 2016) and in Australia 6200 dairy farms create full-time employment for 39 000 people (Dairy Australia, 2015). Table 1 provides examples of the millions of dairy farmers and smallholders involved in producing milk in selected African and Asian countries.

The economic contribution of dairy is the lifeblood of dairy farming families and the rural communities in which they live, with most milk being produced in the world by independent family-owned farms or smallholdings rather than by large corporate farming operations. For example, the 45 million cows in India are owned mostly by smallholders and the 5 million cows in New Zealand are mostly owned by family-operated dairy farms.

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Similarly 97% of the 48 500 dairy farms in the United States are family owned and operated (DMI, 2016).

Farmer ownership in the dairy chain often goes beyond the farm. In many countries of the world the cooperative model predominates with farmers collectively owning either milk supply, processing assets, marketing and distribution or all aspects of a vertically integrated 'cow-to-customer' supply chain. Although of the top seven global dairy companies listed in chapter 35, Nestlé and Danone are publically listed and Lactalis is privately held, the next four (Fonterra, FrieslandCampina, Dairy Farmers of America and Arla Foods) are all cooperatives owned and controlled by their farmer suppliers. Similarly, the largest milk company and also the largest food product marketing organisation in India is a cooperative: Gujarat Cooperative Milk Marketing Federation Ltd (GCMMF) popularly known as 'AMUL'. GCMMF procures approximately 15 million litres of milk per day from over 18 500 village milk cooperative societies and approximately 3.4 million mostly smallholder producer members.

In 2015, global milk production reached approximately 800 billion litres (FAOSTAT, 2016; IDF 2015). India, as the largest producer, accounted for over 150 billion litres or approximately 20% of global milk, with most of this being produced by smallholders with two or less cows (Table 1). Over 70 million Indian rural households depend upon dairying, 'which touches the lives of the poorest of the poor' including small and marginal farmers and landless labourers (Sibal, 2016). In addition to the employment and incomes created in milk production, over 70 jobs can be created elsewhere in the dairy chain for every 1000 L of milk produced in India (see Dugdill et al., 2013 and references therein).

In Kenya, where in latest estimates there are nearly 1.7 million dairy farms averaging 3.4 cows per 'farm' (Table 1), every 1000 L of milk produced generates full-time employment for 77 people in milk production (Dugdill et al., 2013) and an average income that is 1.4 times Kenyan per capita GDP (World Bank, 2003). Also, in Kenya, an additional 3–20 jobs are created for every 1000 L in post milk production processing and marketing, with

Table 1 Dairy farmers and smallholders involved in producing milk in selected African and Asian countries

	Milk production cows and buffalo (ECM mill t)	Number of farms (1.000)	Average size of farms (animals per farm)	Milk yield cow and buffalo (ECM t/cows/year)
Africa				
Kenya	4.4	1690	3.4	*
Uganda	1.9	2179	2.5	0.3
Asia				
China	31.6	1852	3.6	5.3
India	157.4	76136	1.6	1.2
Sri Lanka	0.5	221	3.5	0.6

Explanations: ECM = energy corrected milk on 4% fat and 3.3% protein.
Source: IFCN Dairy Report 2015 based on national statistics and estimations. *Data not available. For further information on the number and importance of smallholder milk producers see FAO (2008, 2015), Dugdill et al. (2013) and IFCN Dairy Report (2015).

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the informal market creating more jobs than the formal one. On average these jobs are paid more than three times the Kenyan minimum wage.

Unlike cropping, where farmers often have to manage outgoings over a long period before they get paid, dairy provides year-round income (Dugdill et al., 2013 and references therein). Similarly, dairy unlike some other livestock sectors provides more employment than, for example, rice or wheat production. Dairy can also have higher labour productivity such as in India, where it is 2.5 times that of agriculture in general (Dugdill et al., 2013 and references therein).

Another important socio-economic aspect of the dairy sector is the empowerment of women. In developing and developed countries women play an important role in dairying. For example in developed countries such as New Zealand, women often work as equal partners with their spouses to manage the family farm, having similarly worked in partnership as sharemilkers while building equity towards farm ownership.

In developing countries such as India the role of dairy in empowering women is profound where women not only constitute approximately 70% of the dairying labour force (Sibal, 2016), but have also created thousands of women-only dairy cooperative societies (Dugdill et al., 2013 and references therein). There are over 4.5 million women members and 330 000 women in leadership roles of Indian dairy cooperative societies (NDDB Annual Report, 2014–15; Sibal, 2016). Using empirical evidence from Kenya, Tanzania and Mozambique, Njuki and Sanginga (2013) estimated that dairy cows are directly owned by women in 25% of cattle rearing households.

Smallholder milk production is also the dominant model in many Asian countries, which together with the 'recognition that dairying represents one of the fastest returns for rural dwellers, many of them landless, have prompted many governments in the region to place a priority on dairy development as a means for economic growth' (He Changchui, Assistant Director General and FAO Regional Representative for Asia and the Pacific, FAO, 2008). The importance of dairy development within Asia has also prompted the formation of a new organisation, Dairy Asia, to coordinate a regional strategy for sustainable development of milk production and dairy chains throughout the region (FAO, 2015). The Dairy Asia strategy will follow a holistic approach to sustainability across the different dimensions of people, planet and prosperity (FAO, 2015).

More research, data and knowledge, and from this knowledge better models and frameworks are needed to inform policy and decision makers. However, it is clear that, it will be extremely difficult to sustainably replace the livelihoods provided by dairy with better alternatives once employment and, as will be discussed later in this chapter, provision of nutrition and other options for land use are taken into account.

2.2 Dairy's impact on nutrition

Key facts: most national dietary guidelines recommend 1–3 servings of dairy a day which approximates to 500 ml of milk/person/day. Increasing dairy consumption to match dietary guidelines could save billions of dollars in national health budgets and help maintain healthy body weight, reduce type 2 diabetes, hypertension, cardiovascular disease, osteoporosis, rickets and stunting. Dairy protein is substantially higher in nutritional quality than plant-based proteins. Dairy can be the lowest cost source of dietary calcium, riboflavin and vitamin B12 and is significantly more hydrating than water and many other beverages.

The FAO publication *Milk and Dairy Products in Human Nutrition* (Muehlhoff et al., 2013) provides a comprehensive treatise on the role of milk and dairy products in human

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nutrition and health. The role that milk and dairy products play in diets is also covered by Miller et al. (2007), Miller and Auestad (2013) and by van Hooijdonk and Hettinga (2015). Dairy is included in national dietary recommendations because of the significant contribution to it makes towards meeting the body's needs for a variety of macro and micro nutrients including protein, calcium, magnesium, selenium, riboflavin, vitamins B5 and B12. For example, in the United Kingdom for nutrients for which there is evidence of low intake/status dairy provides the following average contribution to daily requirements: calcium (43%), iodine (38%), vitamin B12 (36%), riboflavin (33%), zinc (17%), vitamin A (14%), potassium (13%) and magnesium (11%), despite average consumption of 200g/day (Buttris and Riley, 2013) being well below that recommended in many national dietary guidelines. Five hundred ml milk also provides approximately 35% of the RDI for protein, noting that dairy protein is also of the highest nutritional quality (Rutherfurd et al., 2015). The contribution to nutrient-poor diets in some developing countries can be even greater (Muehlhoff et al., 2013).

In an analysis of dietary recommendations from 42 countries, Weaver et al. (2013) found that most counties recommend at least one serving and in some countries up to three or more servings of dairy/person/day as part of a balanced diet. Although serving sizes can vary, Weaver et al. (2013) determined that this approximates to the equivalent of 500 ml of milk/person/day.

Dairy consumption can deliver substantial positive health outcomes through improved metabolic health (McGregor and Poppitt, 2013), lower insulin resistance (Nestel et al., 2013), improved muscular skeletal health (Weaver et al., 2013; Miller et al., 2014; Mitchell et al., 2015), by reducing dental caries (Weaver et al., 2013) and the incidence of cardiovascular disease, hypertension and type 2 diabetes (Kliem and Givens, 2011; Miller and Auestad, 2013; Weaver et al., 2013). The possible association of dairy consumption with certain cancers, type 1 diabetes and (for whole-fat dairy products) heart disease all look unlikely, given the findings from recent meta-analysis and the balance of scientific evidence (Kliem and Givens; 2011; Hill et al., 2011; Astrup, 2014; Rice, 2014; Larson et al. 2015). In a systematic review of milk consumption and mortality from all causes, cardiovascular disease and cancer (Larson et al., 2015), no consistent association between milk consumption and all-cause mortality was found. However, Larson et al. (2015) argue that on the basis of a lack of consistent association among existing studies, large prospective studies are warranted to determine relationship between milk consumption and mortality.

Dairy consumption can translate into substantial reductions in national healthcare costs, with a study in the United States concluding that consumption of 3–4 servings of dairy per day could translate into cumulative five-year savings of over US$200 billion (McCarron and Heaney, 2004). A study in Australia using different methodology and underlying assumptions found that 0.9–3.3% of direct healthcare expenditure in the 2010–11 financial year or approximately AUD$2.0 billion could have been saved had Australians previously consumed the recommended quantities of milk and dairy products (Doidge et al., 2012). There is some consistency in the findings of these studies once differences in the size of the US and Australian populations, timeframes and currencies are taken into account.

New benefits from consuming dairy are being discovered. For example, a recent paper on the development of a beverage hydration index (BHI) (Maughan et al., 2016) found that skim and full-fat milk were significantly more hydrating over a 4-hour period than a range of other commercially available beverages including still water (control), sparkling water, cola, diet cola, hot tea, iced tea, coffee, lager, orange juice and a sports drink. Skim milk and full-fat milk had a similar hydrating effect to that of a specialist oral hydration

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solution, with a BHI of approximately 1.5 compared with the other beverages that were not statistically different to the still water control (BHI of 1.0). The superiority of milk as a hydrating drink has been confirmed in a number of studies on hydration following exercise including recent findings published in the *British Journal of Nutrition* (Seery and Jakeman, 2016).

The FAO Expert Consultation 'Dietary protein quality evaluation in human nutrition' has recommended that a new and advanced method the Digestible Indispensable Amino Acid Score (DIAAS) for determining the quality of dietary proteins be adopted by Codex (for review see Leser, 2013). The DIAAS method demonstrates the superior nutritional quality of milk protein when compared with plant-based proteins (Rutherfurd et al., 2015). As milk protein was up to 30% higher in nutritional quality than the quality of the highest scoring plant proteins and over three-fold higher in nutritional quality than the worst scoring plant proteins this has significant consequences for sustainable diets and health. Inaccurate assessment of protein content and quality from different food sources could lead to erroneous conclusions about the relationship between protein production with land and water use or GHG emissions (IDF, 2016).

In less-developed countries, dairy can reduce micronutrient deficiency, malnutrition and stunting or low height-for-age. Stunting can result from poor maternal nutrition, poor diet and infections during the first two years of life (Muehlhoff et al., 2013). The impact of stunting is not only restricted growth but also impaired cognitive development. Current estimates are that 159 million children under the age of five are stunted (UNICEF, WHO and World Bank, 2015). Even modest consumption of milk when compared with most national dietary recommendations has been found to markedly reduce stunting. In a study of over 2000 children in Malaysia the incidence of stunting was halved over a 21-month period through the provision of 250 ml of milk twice per week (Chen, 1989). A number of observational studies have found that milk and other animal-sourced foods are associated with better growth, micronutrient status, cognitive performance and motor function development in children in low income countries (Weaver et al., 2013; Iannotti, 2013).

As the balance of evidence and expert opinion points to the essential role of dairy in diets, how much milk will the world need in the future? The FAO (Alexandratos and Bruinsma, 2012; FAOSTAT, 2013) predicts that demand for milk could grow to approximately 1.1 trillion litres by 2050. A crude approximation of the global milk requirements for the current population of 7.3 billion (UNDESA, 2015) should everyone have access to 500 ml milk, is 1.3 trillion litres of milk/year (7.3 x 0.5 x 360) or 500 billion litres more milk than is produced today. Looking to the future if demand for milk matched current dietary recommendations by 2050 then 9.6 billion people (UNDESA, 2015) will require over 1.7 trillion litres of milk/year or more than double current production, especially as national dietary recommendations for pregnant and lactating women and for certain age groups are often higher than 500 ml/day (Weaver et al., 2013).

2.3 Reasons for low milk consumption

However, even today, consumption of milk falls well short of recommendations in many countries (Miller and Auestad, 2013). In many developing countries access and affordability limit dairy consumption, whereas in many developed countries a myriad of factors influence the choice of the consumer (Fig. 1). In most developed countries consumers have almost endless choices of foods to select from and are also often confused or overwhelmed by inconsistent formal and informal dietary advice. Food choice is further complicated

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by other influences such as habits, culture/values, fashion/fads, family/friends, pleasure/enjoyment/entertainment and knowledge/education/advice. Dairy products have higher income elasticity of demand (Gerosa and Skoet, 2013). At low income levels more is spent on dairy relative to other foods but at higher income levels the elasticity of demand decreases for all food categories including dairy. Put simply we value dairy nutrition when we are poor but may lose sight of that value when we become richer and are ‘spoilt for choice’.

Misperceptions about lactose intolerance, milk allergies and whole-fat dairy products may also be limiting dairy consumption. Perception of milk allergy is far more frequent than confirmed through testing. The incidence of allergies to cow's milk protein is significant at between 2 and 6% and primarily occurs in early childhood, with most individuals outgrowing the allergy by the age of five years (Weaver et al., 2013). Although residual milk protein allergy can be as high as 5–15% in those who developed it in infancy, these individuals represent much less than 1% of the adult population.

By contrast, lactose mal-digestion/mal-absorption is far more common and results from the downregulation of the enzyme lactase that can develop at weaning. It is possible that as high as 70% of the world's population has at least some lactase deficiency, but the frequency can vary considerably among populations (Weaver et al., 2013). For example, in Europe, lactose mal-digestion can vary from as low as 4% in Ireland and Denmark to as high as 56% in Finland and in some Asian countries the rate can reach almost 100% (Weaver et al., 2013). Unlike some forms of milk allergy it is not life-threatening, and although some individuals experience significant discomfort, symptoms can vary considerably with wide variation in individual tolerance (Weaver et al., 2013). The vast majority of subjects can tolerate up to 12 g in a single dose and up to 24 g if consumed throughout the day (Weaver et al., 2013), noting that this is below the amount of lactose that would be consumed in a 250 ml serve or two 250 ml serves of milk, respectively. As such and in contrast to some recent food fashions and fads, most individuals should be able to tolerate the amount of lactose in milk and dairy products consumed to meet dietary recommendations in many countries. In addition, low lactose dairy products including fermented dairy products are available for individuals who genuinely have lactose intolerance and still experience discomfort with even low levels of milk consumption.

There is also the common misperception that consumption of whole-fat dairy products contributes to obesity and CVD. Noting that over 41 million children are overweight and has increased by 10 million over the last two decades (UNICEF, WHO and World Bank, 2015), consumption of dairy products at dietary recommendations of 2–3 servings per day has been shown to help maintain a healthy weight and assist with weight loss during calorie-restricted diets (for reviews see chapter 7 in Miller et al., 2007 and Dougkas et al., 2011; Stonehouse et al., 2016).

The long-held view that dietary fat in general and particularly whole-fat dairy products are associated with CVD does not appear to hold up to scrutiny (Weaver et al., 2013). Although more research is called for, the majority of meta-analysis of available prospective studies show that dairy consumption including whole-fat dairy consumption is not associated with increased risk of CVD (Weaver et al., 2013; Astrup et al., 2016). Nestlé et al. (2012) found that inflammatory and atherogenic biomarkers for CVD were not increased following single high-fat meals containing four different types of full-fat dairy products (butter, cream, yoghurt and cheese). Similarly, Dalmeijer et al. (2013) in a population-based cohort study and Rice (2014) in a review of eighteen observational studies concluded that dairy consumption including full-fat dairy products does not contribute to CVD. Lawrence

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(2013) in a review of the scientific evidence for relationship between dietary fats and health found that several recent studies indicate that saturated fatty acids from dairy can improve rather than be detrimental to health.

In recent years concerns over the ecological footprint of food production systems have started to influence the choice of some consumers and also the choices that are made for consumers by government policies and through choice editing within the food chain, for example by retailers who may limit the stocking or access to foods that do not meet certain criteria. However, as will be discussed later in this chapter caution is advisable at this time given the complexity of the issue, need for more data and knowledge, and the likelihood that premature action will result in unintended consequences.

Attempts have been made to help consumers identify healthy and affordable foods through various government-endorsed and private-labelling schemes. These vary from simple 'traffic light' systems that use of colour codes to often identify the so-called negative nutrients to limit such as fat, sugar and salt, to more holistic indexes such as the nutrition-rich foods (NRF) index (Drewnowski, 2010). Such holistic approaches will be necessary to establish the aggregate nutritional value of foods as a step towards the even more complex task of developing holistic frameworks that include all important socio-economic and ecological elements of sustainable food systems. The NRF index has been used to demonstrate that at least in the United States dairy is an affordable source of nutrients and lowest cost source of dietary calcium, riboflavin and vitamin B12 (Drewnowski, 2010; Miller and Auestad, 2013). The NRF index is an advancement but still suffers from an inability to take account of food matrix effects where individual food components may not elicit the same biological responses following consumption of some foods such as dairy when compared with others. Dietary guidelines should be based on foods rather than nutrients (Astrup, 2014) or better still on diets and lifestyles.

Given the complex way in which a myriad of factors can influence consumer choice (Fig. 1 and 2), changing diets can be difficult to achieve so it is imperative that in doing so that unintended consequences are avoided as further changes to correct for such consequences will be equally difficult to achieve. As discussed by Golan and Kuchler (2016), empirical evidence suggests that labelling of foods and especially under voluntary schemes to achieve specific environmental or social outcomes is rarely so potent as to influence a critical number of consumers to change their consumption choices or critical number of producers to change their production practices. Influences of consumer choice (Fig. 1 and 2) of course influence the demand for dairy and the impacts of this demand on livelihoods, nutrition and the environment. Government policies, regulations, standards and labelling together with the availability, choice/variety, quality, convenience and affordability of dairy provided by food chains and systems are important influences of choice. But in a world where information can travel at the speed of light, finding ways to engage with, educate and inform consumers via social networks and other channels will be just as important.

3 Ecological impact of the dairy sector

Perhaps even more challenging than assessing the impact of dairy on livelihoods and nutrition is the complex problem of assessing the ecological impact of dairy as a result of the significant variation in farming systems used to produce milk and significant variation in the ecologies with which those farming systems interact across different regions of the

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world. Dairy farming can be found from Iceland to India, from Scotland to Saudi Arabia and from China to Chile. In fact, there are very few places inhabited by humans without some form of milk production mostly from cows but also buffaloes, goats, sheep and other species such as camels.

3.1 Dairy's impact on the environment

Key facts: Dairy farming utilises 7% of the world's land, of this 85% or 850 million ha is either pastures or rangeland. Dairy cows consume 2.5 billion tonnes of dry matter or approximately 40% of the global livestock feed intake. Seventy-seven percent of this feed is human-inedible pasture or straws (FAO, pers. comm.). Dairy creates 2.7% of global GHG emissions or 4.0% including meat from dairy animals.

The socio-economic benefits of dairy come at an ecological cost. However, headline statements about the amount of land and water used or GHG produced masks a level of detail that is important to understand and particularly in considerations, debates, policies and actions relating to dietary advice and sustainable food systems.

Dairy farming utilises 1 billion ha or 7% of the world's land to feed the major milking species (cows, buffaloes, goats and sheep) (FAO, pers. comm.). Of the 1 billion ha 85% or 850 million ha is either pastures or rangeland, with 150 million ha of arable land also being used to produce feed for dairy animals (FAO, pers. comm.). Dairy cows consume 2.5 billion tonnes of dry matter or approximately 40% of the global livestock feed intake (FAO, pers. comm.). However, it is important to note that 77% of this feed is human-inedible pasture or straws (FAO, pers. comm.).

Dairy creates 2.7% of total anthropogenic GHG emissions or on average 2.4 kg CO_2 equivalent per kg of milk produced (FAO, 2010b). However, because of very wide variations in dairy farming practices, GHG emissions vary from 1 to 7.5 kg CO_2 equivalent per kg of milk produced (FAO, 2010b). Improvements in the breeding and feeding of dairy cows and management of dairy farms has created phenomenal improvements in milk production. For example, in the United States over the past sixty years milk yield increased more than fourfold while using 90% less land, 65% less water, producing 75% less manure and at 63% less GHG per unit of milk (Capper et al., 2009). Through such improvements, average milk production per cow per year in the United States is now more than ten times the global average (Miller and Auestad, 2013). However, commensurate with these improvements has been a dramatic reduction in the number of dairy farms, for example between 1970 and 2006 dairy farming operations reduced from 648 000 to just 75 000 (USDA, 2016) and has reduced further to approximately 48 500 farms (DMI, 2016). By contrast, the phenomenal increase in milk production within India through Project Flood (NDBB, 2016) from less than 25 billion litres per year in 1970 to approximately 150 billion litres in 2015 has been based on improvements to and retention of smallholder dairying.

It is thus of obvious importance to not only look at the ecological impact of dairy today per unit of production and the socio-economic benefits it provides but the impact it can have in the future through improvements to dairy chains and any trade-offs between socio-economic and ecological factors. For example, it is theoretically possible to produce over one trillion litres of milk and the nutritional benefits this could provide with fewer cows and at average GHG emissions that are 40% lower than today (van Hooijdonk and Hettinga, 2015), but this may also involve a significant reduction in the number smallholders involved

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in dairy production and associated livelihoods. It is also why dairy development initiatives around the world should focus on all three aspects of people, planet and prosperity.

Another important consideration that is often neglected when considering GHG emissions from dairy is that methane represents between 51 and 67% of dairy emissions depending on the species and production system, emissions being higher in grassland-based systems than mixed systems (Gerber et al., 2013). By contrast, carbon dioxide plays a minor role in on-farm emissions, representing on average 5–10% of farm-based emissions. The importance of this point in terms of global warming was highlighted by Oxford University Physicist Raymond Pierrehumbert in a letter to the editor of *The Economist* (20 August 2016):

> When you stated that methane is "25 times as potent" a cause of global warming as carbon dioxide, you perpetuated the myth that there is a single conversion factor that translates the climate effect of methane into what would be caused by an "equivalent" amount of carbon dioxide ("Tunnel vision", 23rd July). The number you quoted is based on a measure called "global warming potential". This measure exaggerates the importance of methane because it fails to properly reflect the importance of the short (12 year) lifetime of methane in the atmosphere compared with carbon dioxide, which continues to transform the climate for centuries.
>
> A simple financial analogy is useful. If you opened a bank account for storing your methane emissions, it would be as if the account paid a negative interest rate of −8.3% annually (a concept which may become all too familiar in the real world of banking before long). The balance in the account represents the warming effect of the methane emitted.
>
> If you deposited $1000-worth of methane today, in 50 years your account would be worth only $16. A big pulse of methane released today would have virtually no effect on the temperature around the time we hope global warming will be peaking. If you were to deposit a steady $100 of methane a year your account would be valued at $1205 in a few decades but would then stop growing. The only way to increase the amount of warming from methane is to increase the annual emissions rate. Not so with carbon dioxide, which acts more like a bank account with a zero interest rate (rather like a real bank account these days). A fixed emission-rate of carbon dioxide accumulates in the atmosphere, leading to warming that grows without bounds over time.
>
> In fact, if warming causes the land ecosystems to start releasing rather than storing carbon, it would be as if your bank account had a positive interest rate. Not a bad thing for a real bank account, but bad news for climate if it is carbon dioxide you are banking.

3.2 Nutritional value versus environmental impact

Just as there are misperceptions about dairy nutrition and health, there are misperceptions that dairy is an inefficient use of natural resources (Miller and Auestad, 2013; van Hooijdonk and Hettinga, 2015). Reports from the World Resources Institute (Ranganathan et al., 2016) and the International Food Policy Research Institute (IFPRI, 2016) propose a framework to shift consumers to more sustainable diets through a reduction in calorie intake, a reduction in protein consumption and a reduction in consumption of animal-based foods. These reports compare land use, freshwater consumption and GHG emissions with calories and protein consumed for the major plant-based and animal-based foods including dairy. Westhoek et al. (2014) in an analysis focused on the European Union proposed that

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replacing 25–50% of animal-derived foods with plant-based foods on a dietary energy basis would reduce GHG emissions by 25–40%, nitrogen emissions by 40%, cropland by 23%, improve the nitrogen efficiency of food from 18% to between 41 and 47%, and reduce saturated fat intake by 40% with a commensurate reduction in CVD.

Similarly, claims that to 'save the planet' the consumption of dairy should be reduced in or in some extreme cases eliminated altogether from diets are made on a regular basis in both print media and social media, but also in quality peer-reviewed scientific journals. Lang and Barling (2012) in an excellent analysis of the complexity and difficulties of integrating nutritional and sustainability policy, the authors highlight meat and dairy as one of four policy hot spots. 'Nutrition advice tends to support their consumption, but environmental concerns suggest more consideration be given to upper limits' (Lang and Barling, 2012). Although the authors call for more analysis and that the fragmented consideration of nutrition in either a life science or biochemical context, a socio-economic context or an environmental context must be integrated, they still conclude that more horticulture, less meat and dairy, more equal distribution, better skilled consumers, less consumption overall in the rich world are likely to be answers to sustainability and food security (Lang and Barling, 2012).

Are such arguments to reduce dairy consumption valid given current knowledge and global considerations of all important socio-economic and ecological factors?

Although there are similarities in some meat production systems with dairy and culled dairy cattle are a source of meat, it is questionable that meat and dairy should be aggregated given the differences in the nutrition they provide (see Table 1 in Buttris and Riley, 2013), differences in their ecological footprints (Ranganathan et al., 2016; IFPRI, 2016), differences in their global impact on livelihoods and the fact that in many developed countries meat consumption is above dietary recommendations (Ranganathan et al., 2016; IFPRI, 2016) whereas milk consumption is below dietary recommendations (Miller and Auestad, 2013).

Claims that reducing milk intake will improve health including CVD do not look valid given the evidence presented earlier in this chapter.

Whereas GHG is a global issue water is in the main a local issue and care is needed when using the term 'water consumption' because the water may not be consumed as such. Is the water used from a water rich or water stressed/deficit location? Is there a significant net usage of water or is it replaced through rainfall and so on? What is the quality of the water that is returned to the environment? This complexity is recognised by the International Standards Organisation in its guidelines for water footprints (ISO, 2014), where 'results from a water footprint inventory may be reported, but shall not be reported as water footprint' and 'Water inputs and water outputs of different resource types, different quality, different form, different location with different environmental condition indicators or different timing shall not be aggregated in the inventory phase', 'Aggregation may be performed at the impact assessment phase'. That is not to say that water use and quality is not an issue for some dairy chains and as such should be a priority for research and improvement initiatives.

Land use is also complicated by topography, local climate and soil characteristics that make some land more suitable and productive for particular agricultural purposes. Teague et al. (2016) make strong arguments that the use of grasslands and pastures for optimised systems of ruminant grazing will significantly reduce rather than increase GHG emissions. Teague et al. (2016) propose that rather than reducing livestock to mitigate climate change, producers should be encouraged to replace unsustainable crop and livestock practices with regenerative management practices. Teague et al. (2016) also argue that applying

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such systems to just 25% of the land used by such producers would result in a greater reduction in GHG than reducing livestock numbers by 50%. An important point given that globally 85% of the land used for dairying is pasture or rangeland and 77% of the feed consumed by dairy animals is from pasture and straws. This creates a solid platform from which to make improvements to dairy farming systems to reduce GHG emission per unit of milk production.

A study on the GHG emissions of self-selected individual diets in France found that dairy contributed less to diet-associated GHG emissions when compared with other animal-origin food groups (Vieux et al., 2012). This study also found that changes to the amounts of different foods consumed would have little impact on GHG emissions without a simultaneous reduction in calorie intake to match energy needs. Vieux et al. (2012) concluded that changing the structure of diets by reducing the consumption of animal-based products is probably not a sufficient approach to significantly reduce GHG emissions. The total quantity of food consumed by each individual explained more of the variance in diet-related GHG emissions than the carbon intensity or energy density of the diet. The need to reduce calorie intake to recommended levels as a means to reduce food-related GHG emissions is one of the recommendations from the World Resources Institute (Ranganathan et al., 2016) and the International Food Policy Research Institute (IFPRI, 2016).

Using a nutrient density to climate impact (NDCI) index, Smedman et al. (2010) compared nutrient density with the associated GHG emissions for a range of beverages including carbonated drinks, orange juice, beer, red wine, mineral water, milk and milk substitutes, for example, soy drink and oat drink. The NDCI index for milk was substantially higher (0.54) than all other beverages, with orange juice being the next best with an NDCI of 0.28. The soy drink had an NDCI less than half that of milk and the oat drink an NDCI index below 0.1. Thus, milk has a superior NDCI and as described previously superior BHI than many other drinks.

Dairy cows are highly efficient in converting human-inedible materials such as grass, straw, silages and various inedible waste streams from human food production into milk (Miller and Auestad, 2013; van Hooijdonk and Hettinga, 2015). For example, for the average cow in the Netherlands only 6% of the diet is human-edible and with 22% of the energy and 27% of the protein from the total diet converted into milk (van Hooijdonk and Hettinga 2015). But more significantly the return on the human-edible fraction of the diet is 357% and 438% on an energy and protein basis, respectively (van Hooijdonk and Hettinga, 2015). Referencing recently completed analysis, 1 kg of animal-sourced protein was found to require 17.7 kg of protein feed for ruminants and 7.4 kg of protein feed for monogastrics (HPLE, 2016). However, when accounting for whether this feed was human-edible or non-human-edible, the human-edible protein required to produce 1 kg of animal-sourced protein was lower for ruminants than for monogastrics (HPLE, 2016).

In predominantly pasture-based systems such as those used in New Zealand and in many developing countries, the return will be even higher given the lower use of human-edible energy and protein in cow's diets.

4 Dairy within sustainable diets

In the introduction the broad and complex scope of what constitutes sustainable production and consumption of food was presented (FAO, 2016a; Fig. 2). The FAO and Biodiversity International have proposed the following definition for sustainable diets:

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> Diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessibly, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources. (Burlingame and Dernini, 2012)

Shenggen Fan, Director General of the International Food Policy Research Institute, in his introduction to the 2016 Global Food Policy Report (IFPRI, 2016) notes that a food system that promotes well-being of people and planet should have six characteristics:

- *Efficient*
- *Inclusive*
- *Climate-smart*
- *Sustainable*
- *Nutrition- and Health-driven*
- *Business-friendly*

No doubt further definitions and elaborations for what constitutes sustainable diets and food systems will be made over the coming years. So how do we combine all important socio-economic and ecological aspects to create frameworks and models that support sustainable food systems? Moreover, how do we do this in a way that is globally relevant and locally applicable, that creates food security, accommodates the needs of developed and developing nations, scale farming and smallholder farming, recognises the diverse social and ecological needs of communities and the planet and can operate efficiently and resiliently within the complexity shown in Fig. 2.

While more research, data and knowledge is needed at local, national and global scales to determine the combined socio-economic and ecological impact of food chains and systems, it is almost certain that dairy will be an important component in sustainable food systems given its broad impact and magnitude of benefits described earlier in this chapter.

5 Global frameworks for sustainable food and dairy production

The need for more research and knowledge relating to sustainable food systems is highlighted by the FAO (FAO, 2016b). Furthermore there needs to be a common understanding of issues, adaptation of knowledge tools to the needs of the various categories of actors within the sustainable food system and information sharing between these actors (Maybeck, 2016). This can be challenging given the different motivations and drivers of these actors such as intergovernmental organisations, national governments, commercial companies and civil society. Nevertheless,

> knowledge, the way it is constructed, organised and shared, is key to any type of transformation of agriculture and food. (Ren Wang Assistant Director General, Agriculture and Consumer Protection Department, FAO, 2016b)

Although new knowledge relevant to nutrition, food security and sustainability will be created over the coming years, we cannot wait for all the answers and must make progress towards the development of a nutritional secure world and sustainable food

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systems. In this respect, progress will be highly iterative and care will be needed to avoid unintended consequences of policies and actions. We must be conscious of trade-offs and confident that actions will indeed take us two steps forward and at worst only one step backwards (2:1) and will not result in the opposite (1:2). We must recognise that although environmental performance is an important aspect of sustainability they are not the same thing nor are food security and sustainability, although they are closely interlinked (FAO, 2016b). Care will be needed in both policy development and action to ensure that outcomes actually *do good* rather than just *feel good*. Simplistic solutions are unlikely to be robust or at least make a significant impact in isolation. For example, buying local could be part of the solution but so could fairer and more open international cross-border trade as it is almost certain that sustainable food systems will need to encompass both. The recent WTO agreement to eliminate export subsidies and in so doing reduce distortions in trade policies should facilitate improved efficiency of value chains, markets and trade systems (IFPRI, 2016). Similarly smallholders are not always the most efficient producers in agricultural systems but given the 1 billion livelihoods, many of them smallholders supported by dairy:

> Any solution which ignores the livelihood issues would be inequitable
> T. Nanda Kumar, Chairman, India National Dairy Development Board (FAO, 2015).

Recognising the complexity of the challenge and the need for common global frameworks to be locally relevant and applicable, the dairy sector has developed a comprehensive Dairy Sustainability Framework (DSF). The DSF is composed of eleven sustainability criteria (Fig. 3) covering socio-economic and ecological aspects of the dairy chain (GDAA-DSF, 2014; 2015/16). The DSF is designed to recognise the variability of global dairy farming systems and chains, and the necessity for prioritisation of sustainability issues at a local level. The DSF provides a common way for the dairy sector to make and measure progress towards more sustainable food systems whilst further work is undertaken to develop models to integrate all socio-economic and ecological impacts. So far the DSF is being used to assist hundreds of dairy organisations to align, connect and progress approximately two hundred sustainability-related initiatives (GDAA-DSF, 2015–16). Participation in the DSF is growing rapidly, with 27% of global milk production already operating under the DSF covering over 30 million cows, 658 000 farms and 3700 processing plants worldwide.

In recognition of the need for more knowledge, the UN Committee on World Food Security (CFS) established a High Level Panel of Experts (HLPE) to report on the role of livestock in sustainable agricultural development (SAD) for food security and nutrition (FSN). The HLPE report (HLPE, 2016) recognises the complexity of the challenges for SAD to create FSN and makes a number of high-level recommendations to address these challenges including the need to fill data gaps and the need for more research and development. The HPLE report also recognises the variation in livestock farming systems and for the purposes of priority areas for intervention (Table 2) categorises them into four systems: smallholder mixed farming, pastoral systems, commercial grazing systems and intensive livestock systems. A number of case studies are included in the report to highlight initiatives and best practices, but falls short of outlining the strengths of the various farming systems and focuses more on areas for improvement. Another weakness in the report is that although it recognises the need for SAD to be incorporated into trade policies, the report puts more focus on progress at a national level without describing how such progress can be globally integrated. The HPLE report sets out an eight-step

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Figure 3 Dairy sustainability framework criteria.

The DSF consists of 11 Sustainability Criteria
To ensure the desired sector alignment is achieved, the industry has developed for each of the Criteria, a strategic intent. The Strategic Intent is designed to guide the sector when designing mitigation initiatives under any of the Criteria by specifying the desired improvement for each.

pathway in order to design national SAD strategies starting with a situation analysis and ending with monitoring and ongoing iterative adjustment; and three interlinked principles: *improve resource efficiency* given the huge opportunity for improvements to be made by the adoption of best practices, *strengthen resilience* to risk and shocks, and *improve social equity/responsibility outcomes*.

The CFS has also established another HLPE to provide scientific and technical information to support the implementation of decisions of the second International Conference on Nutrition (ICN2, 2014) and the Sustainable Development Goals (SDGs, 2016, see Fig. 4).

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Table 2 Priority challenges to attain SAD for FSN in different farming systems

System	Scale and geography	Key health and One-Health challenges	Key social challenges	Key environmental challenges	Key economic challenges
Smallholder mixed farming	Around 600 million persons mainly in south and south-east Asia and Africa Around 30 million small farmers in developed countries	Endemic animal diseases Zoonotic diseases Food-borne diseases Contribution to NCD	*Farm fragmentation* *Lack of rights, entitlements, tenure* Ageing workforce and exodus of young people Rural abandonment	Climate change *Land degradation* Loss of biodiversity	*Low economies of scale* *Exclusion from high-value markets and service* *Low productivity and high yield gaps*
Pastoral	Nearly 200 million pastoralists	Endemic animal diseases Zoonotic diseases	*Marginalisation: lack of rights, entitlements, tenure* *Conflict over land and water* *Inequitable norms and institutions*	*Climate change* *Extreme events (droughts, floods)* *Water scarcity*	*Lack of access to markets and services* Low productivity
Commercial grazing	Hundreds of thousands of farmers in Latin America, parts of the United States, Australia, and southern Africa	Emerging diseases Contribution to NCD	*Displacement of indigenous peoples and local communities* *Vulnerable groups* *Poor work conditions* *Rural abandonment*	*Deforestation;* *contribution to climate change* *Land conversion*	Exposure to world price volatility International market access Low economies of scale
Intensive	Around 2 million intensive dairy farmers in the United States, Brazil, Europe, New Zealand Several million intensive pig, poultry and beef/sheep feedlot farms, mainly in BRICs and high-income countries	*Emerging diseases* *Food-borne diseases* *Contribution to antimicrobial resistance and NCD*	*Poor work conditions* *Poor animal welfare*	*Air, land, water pollution* High water use *Contribution to climate change*	Exposure to world price volatility *Price squeeze from input suppliers, processors and retailers*

From Sustainable agricultural development for food security and nutrition: what roles for livestock? A report by the High Level Panel of Experts on Food Security and Nutrition. July 2016. www.fao.org/cfs/cfs-hlpe.

The HLPE is tasked with considering food chains from ‘farm to fork’ and all sustainability challenges including economic, social and environmental dimensions and how they relate to nutrition. The report from the HLPE is planned to be released in 2017 and will hopefully take us a step further towards integrated thinking if not integrated models for

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Figure 4 Sustainable Development Goals. Source: www.un.org/sustainabledevelopment/sustainable-development-goals.

sustainability and together with the report on the role of livestock in SAD and FSN (HPLE, 2016) provide guidance to existing initiatives such as the DSF, the Global Agenda for Sustainable Livestock partnership (GASL, 2016), Livestock Environment Assessment and Performance partnership (LEAP, 2016) and Dairy Asia.

6 Where to look for further information

For further information see www.dairy.declaration.org and Milk and dairy products in human. FAO, 2013. ISBN 978-92-5-107863-1.

7 Future trends and conclusion

Given the enormous socio-economic impact of dairy and the significant natural capital used to produce it, further work to assess the holistic impact of dairying is an important priority if we are to create sustainable food systems that will feed over nine billion people by 2050. More knowledge is needed to enable the combined (Livelihood impacts) + (Nutritional impacts) + (Ecological impacts) of the dairy sector to be established even at local levels or within different sustainable food systems, noting that there will not be a single 'one-size-fits-all' system that will work across all geographies.

Calls to limit dairy consumption on environmental or nutritional grounds do not look valid given the balance of current knowledge. That is not to say that the dairy sector is perfect and there is scope for significant improvements in the efficiency and effectiveness

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of dairy chains. For example although the global loss and waste of milk and dairy products is estimated to be significantly lower than cereals (30%) or root crops, fruit and vegetables (40–50%), 20% of milk that is produced is not consumed (FAO, 2011). There is a considerable opportunity to increase milk production whilst decreasing resource use and GHG emissions per unit of production, but this will need to be done in ways that recognize the critical role that dairy plays in livelihoods. Growing access to dairy to meet nutritional guidelines and enrich diets will need to be done through a balanced approach involving local dairy development programmes and international cross-border trade of dairy products.

Moving forwards, the SDGs should provide a common high-level context to discuss the relevance and impact of dairy and the DSF a common mechanism for the dairy sector to measure and drive progress towards the SDGs; national and local socio-economic and ecological targets; and the business strategies, social responsibility plans and priorities of individual organisations in the dairy chain.

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