Chapter 13
Reality and Consequence for Livestock Production, Human Nutrition, Health, and Food Security Under the Impact of Climate Change

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Context and Setting

Climate change is a natural phenomenon that is happening globally and affecting all aspect of livelihoods and possibly the very existence of nature as we know it. One current significant example of the effect of climate change is the disturbance of the production, availability, and distribution of food. Until recently, the total world population was approximately seven billion humans, and it is projected to be over nine billion by 2050. In the developing nations, there are many people suffering from famine, illness, and early death caused by restricted intake of nourishing food. Micronutrient deficiency remains a serious problem in Indonesia with approximately 100 million people, or 40% of the population, suffering from one or more micronutrient deficiencies. In rural areas with poor market access, forests and trees may provide an essential source of nutritious food (Ickowitz et al. 2016). Limiting consumption of food containing animal protein will cause retardation of growth rate and inhibit the development of the brain in humans. Over generations, this will contribute to "lost generations." At the same time, in most developed countries, people have excess production of food grain – a large proportion is used as feed for livestock or is utilized to produce biofuel. One of the agricultural pathways toward sustainable food and nutrition security is through local production of nutritious

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food, an activity in which smallholder farmers play a crucial role. As food consumers, all rural and urban people in developing countries count heavily on the efficiency of their local smallholder farmers and herdsmen to satisfy their food needs.

The Agriculture Sectors' Role in Climate Change

Climate change profoundly affects the conditions under which agricultural activities are conducted. In every region of the world, plants, animals, and ecosystems have adapted to prevailing climatic conditions. As those conditions change, they will all be affected in ways that are difficult to predict precisely. We briefly examine the linkages between climate change, agriculture, and food security (Box 13.1) and discuss the biophysical impacts of climate change on the agriculture sector and how they translate into socioeconomic impacts with consequences for food security and nutrition. We comment on, but do not elaborate, the mechanisms and impact of greenhouse gas emissions and removals from the agriculture sectors and how these contribute to climate change. The implication is that the agriculture sectors need to both adapt to climate change by building resilience and contribute (as a sector) to climate change mitigation.

Box 13.1 Summary of Climate Change Impacts on Agriculture

- Increased frequency and intensity of extreme climate events such as heat waves, droughts, and floods, leading to loss of agricultural infrastructure and livelihoods
- Changes in plant, in livestock and fish diseases, and in pest species
- Decrease in fresh water resources, leading to water scarcity in arable areas
- Sea-level rise and coastal flooding, leading to salinization of land and water, and risks to fisheries and aquaculture
- Water and food hygiene and sanitation problems
- Changes in water flows impacting inland fisheries and aquaculture
- Damage to forestry, livestock, fisheries, and aquaculture
- Acidification of the oceans, with extinction of fish species
- Temperature increase and water scarcity affecting plant and animal physiology and productivity
- Beneficial effects on crop production through carbon dioxide "fertilization"
- Detrimental effects of elevated tropospheric ozone on crop yields

(Sources: Adapted from Tirado et al. (2010) and updated using Porter et al. (2014), HLPE (2012), and IPCC (2014). Impact pathways from climate change to food security FAO (2016)

Food Security and Agricultural Developments

According to the World Food Summit (1996), food security is defined as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences. Food security is built on three pillars that are (1) *food availability*, sufficient quantities of food available on a consistent basis; (2) *food access*, having sufficient resources to obtain appropriate foods for a nutritious diet; and (3) *food use*, appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

Accordingly, agriculture is a main sector that must be responsible for fulfilling the supply component of food security. In this context, the providing of food is not only just referring to availability, accessibility, and usability but also very important to maintain the food quality and continuity. Food quality is related to the capacity of food itself to provide adequate and vital nutritional components such as balancing of protein, energy, vitamins, and minerals. One example of food that could fulfill those requirements stems from livestock products such as meat, milk, and eggs. Intensification of livestock production, especially under Indonesian conditions, is an urgent agenda.

Food security is a complex sustainable development issue linked to human health through malnutrition but also to sustainable economic development, environment, and trade (WHO 2012). More than 85% of Indonesians are living in rural areas where agriculture is the main activity for supporting their livelihoods. It is well known that the agriculture sector is an unstable business due to many affecting conditions. One example of current disturbances is coming from climate change. For example, flooding damages the facilities of irrigation and transportation, soil and water body, crop, forages, and livestock. These conditions are a burden to the rural communities and sometimes make them lose hope and engender frustration.

The agriculture sector contributes 20% globally to GHG emission today and will be reduced 15% by 2020 and less than 10% by 2050. The role of livestock by their emissions of methane (see below) and through the deposition of dung and urine (either directly while grazing or through spread of animal manures from intensive livestock-raising facilities like dairy farms, piggeries, or poultry sheds. Agriculture as a source of GHG is not the main issue, although measures to mitigate the impacts are still required. The pressing problem (main issue) is how to protect agriculture and food production systems from climate change. The magnitude and geographic extent of climate change are quite considerable. Figure 13.1 illustrates the potential change in agricultural output worldwide.

As Fig. 13.1 shows, climate change has a more severe effect on the agriculture sector in developing countries compared to that of developed countries. Meaning that climate change seriously affects the agriculture activity and will have consequences to food security. A more detailed conceptual framework of climate change affecting food security and human nutrition and health is illustrated in Fig. 13.2.

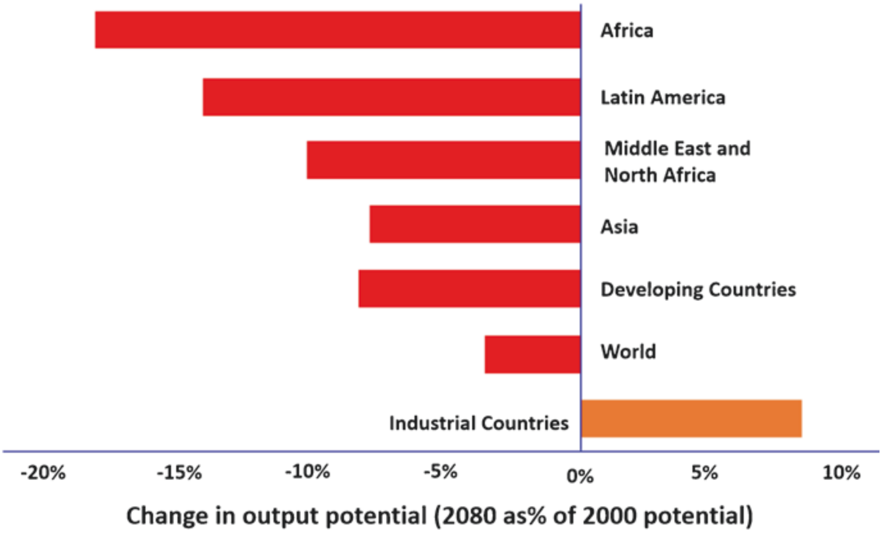

Fig. 13.1 Change in agricultural output potential due to climate change: 2000–2080 (IFAD 2012)

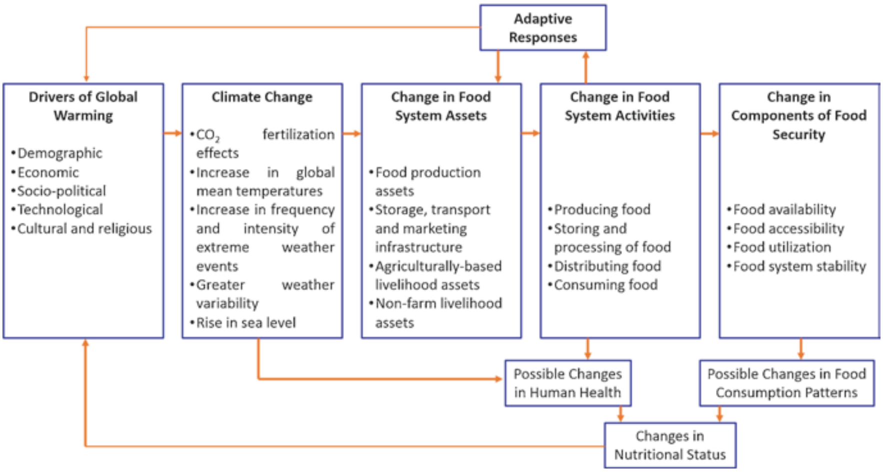

Fig. 13.2 Conceptual framework of impact of climate change in food security (FAO 2007b)

Food System, Agriculture, Human Nutrition, and Health

A food system may be described simply as a process that turns natural and human-made resources and inputs into food (Pinstrup-Andersen 2011). It is essential this concept be understood in relation to relate the agriculture (livestock) production and human nutrition and health (see Figs. 13.3 and 13.4).

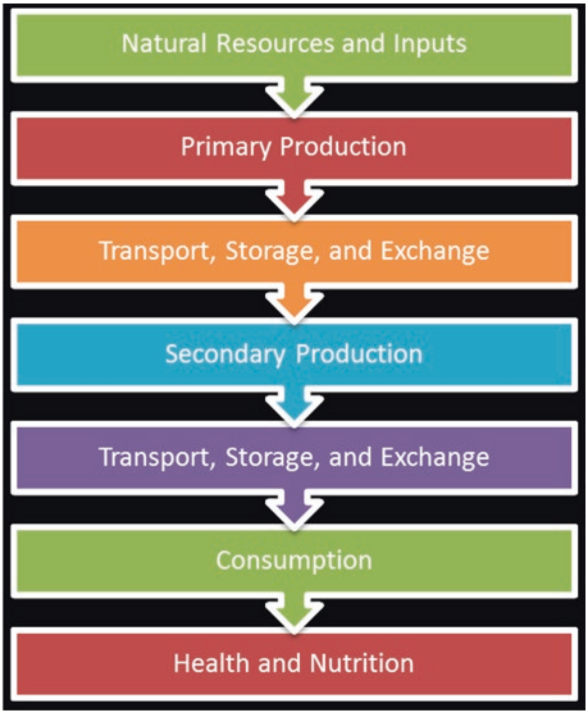

Fig. 13.3 A food system (after Pinstrup-Andersen 2011)

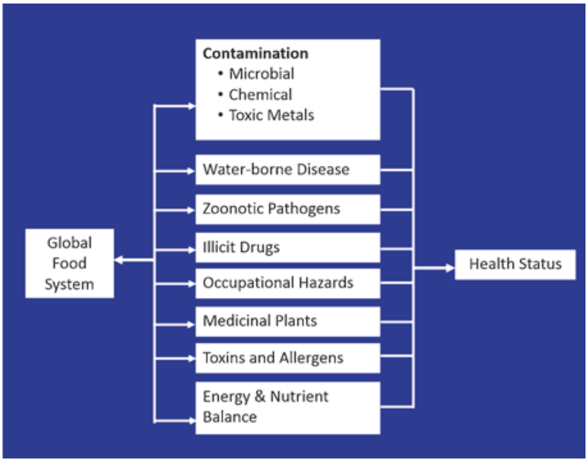

Fig. 13.4 Interaction between food systems and human health (after Pinstrup-Andersen 2011)

As Fig. 13.3 illustrates, agriculture (especially where animal husbandry is at its core) depends upon the availability and balance of natural resources and input interventions to that process. The secondary production (processing, transport, storage, and exchange activities) makes the food available at the time and place desired by consumers. This process must be continued and improved. If the main goal is to improve them, Pinstrup-Andersen (2011) suggested that it is useful to visualize food systems as dynamic behavioral systems that can change in response to change in the behavior of the various decision-makers and agents in the system, such as consumers, producers, market agents, resource owners, nongovernmental organization, and governments.

Food systems operate within biophysical, socioeconomic, political, and demographic environments (Pinstrup-Andersen 2012). In the context of this chapter, more attention is given to the relationship between livestock production, nutrition, and health (Fig. 13.4).

Food systems act as complex social-ecological systems, involving multiple interactions between human and natural components. Nutritional patterns and environment structure are interconnected in a mutual dynamic of changes. The systemic nature of these interactions calls for multidimensional approaches and integrated assessment and simulation tools to guide change. There is an urgent need for a review and conceptual modelling framework that articulates the synergies and trade-offs between dietary diversity, widely recognized as key for healthy diets, and agricultural biodiversity and associated ecosystem functions, crucial resilience factors to climate and global changes is urgently needed. Energy and nutritional deficiencies, infectious diseases, obesity, and chronic diseases may influence food systems by lowering the labor productivity of food systems workers, by reducing the adoption of improved technology and the use of inputs and credit, and by leading to suboptimal use of land, water, and other resources. From the previous explanation, it can be understood that food systems influence critically the human nutrition and health status and, in turn, their productivity.

Climate change affects livestock production in multiple ways, both directly and indirectly (FAO 2016; Steinfeld et al. 2006). The most important impacts are on animal productivity, animal health, and biodiversity, the quality and amount of feed supply, and the carrying capacity of pastures. Increasing variability in rainfall leads to shortages of drinking water, an increased incidence of livestock pests and diseases, and changes in their distribution and transmission (Gray et al. 2009). It also affects the species composition of pastures, pasture yields, and forage quality (Attia-Ismail 2019). For livestock owners, especially in the tropical regions, a major consequence of warming temperatures (as part of climate change) arises from the spread of disease vectors, the survival of larval stages (or eggs and or spores) of parasites, and other pests and diseases. The tsetse fly (*Trypanosoma brucei*) in Africa is an example, and its geographic range has expanded as climatic conditions become more favorable (Squires 2019a). But cattle ticks (*Babesia* spp.), buffalo fly (*Simulium meridionale* and related species), etc. are others. Impacts of climate change on animal health are also documented, especially for vector-borne diseases, with rising temperatures favoring the winter survival of vectors and pathogens. In Europe, global warming is likely to increase sheep tick activity, and the risk of tick-borne diseases, in the autumn and winter months (Gray et al., 2009). Outbreaks of Rift Valley fever in East Africa are associated with increased rainfall and flooding due to El Niño-Southern Oscillation events (Lancelot et al. 2008; Rosenthal and Jessup 2009; Porter et al. 2014).

Higher temperatures cause heat stress in animals, which has a range of negative impacts: reduced feed intake and productivity, lower rates of reproduction, and higher mortality rates. Heat stress also lowers animals' resistance to pathogens, parasites, and vectors' status. Research in India found that a combination of climate-related stresses on sheep – for example, excessive heat and lower nutritional intake – had severe impacts on the animals' biological coping mechanisms (Sejian et al. 2015). The effects of higher temperatures may be reduced in intensive cattle, pig, and poultry production units, through climate control (Thornton et al. 2009), provided that appropriate housing and energy are available. However, projected drier conditions in the extensive rangelands of Southern Africa would increase water scarcity; in Botswana, the costs of pumping water from boreholes increase 23 percent by 2050. In the Near East, declining forage quality, soil erosion, and water scarcity will most likely be exacerbated in the semiarid rangelands (Turral et al. 2011; Mohamed et al. 2019, Emadi 2019). Climate change and climate variability threaten the provision of a range of crucial goods and environmental services, as well as undermine the lifestyles and livelihoods of smallholders across the globe (from the "roof of the world" in the Himalaya-Hindu Kush region (Shang et al. 2019) to the vast areas of Greater Central Asia (including within its boundaries Mongolia, western China, and the five former soviet republics). These nations are (Kazakhstan, Tajikistan, Uzbekistan, Kyrgyzstan, Turkmenistan, and Afghanistan) (Squires and Lu 2018, Squires et al. 2018a) and in the Palaearctic region (Squires et al. 2018) and many other regions in the world.

Climate Change, Food Security, and Livestock Production

Climate change is directly and/or indirectly affecting livestock/animal production. Devendra (2011) distinguished factors which climate change influences the animal production that are heat stress, agroecological zone, water availability, quantity and quality of available feed resources, type of production system, and productivity. Summary of those factors and research and development opportunities is presented in Table 13.1.

According to FAO, the effect of climate change on the production and productivity of the agriculture sectors will translate into mostly negative economic and social impacts, with implications for all dimensions of food security.[1] Climate change can reduce incomes at both the household and national levels. Given the high dependency on agriculture of hundreds of millions of poor and food-insecure rural people, the potential impacts on agricultural incomes – with economy-wide ramifications in low-income countries that are highly dependent on agriculture – are a major concern. By exacerbating poverty, climate change would have severe negative repercus-

[1] The three dimensions of food security (including their dynamics and stability) are A. Availability, production, distribution, and exchange of food; B. Access, affordability, allocation, and preference of food; and C. Utilization, nutritional value, social value, and safety of food.

Table 13.1 Major issues in animal production that will be affected by climate change impacts

Major issues	Potential climate change impacts	Opportunities for R and D
1. Heat stress	– Physiology – Metabolism – Reduced feed intake – Reduced reproduction – Increased mortality – Low productivity – Unsuitable production systems – Reduced multifunctionality	– Adaptation – Feed efficiency – Measures to increase intake – Supplementation
2. Feed resources (forages, crop residues, AIBP, and NCFR)*	– Reduce quantities – Poorer nutrition quality – More fibrous – Decreased palatability – Supplementation	– Use more heat-tolerant plants – Food-feed systems – Use of multipurpose tree legumes – Conservation
3. Land use systems	– Shift to dryland agriculture – Droughts – Water scarcity – Pressure on adaptation	– Heat-tolerant plants and animals – Emphasis on rainfed agriculture – Maximizing feed supply – Increase agronomic practices and use of animal manure to sustain fertility – Conservation practices
4. Animal species and breeds	– Adaptation – Possible reduce in size – Loss of biodiversity – Migratory systems	– Dynamics of nomadic and transhumant systems – Ensuring choice for AEZ – Understanding interactions with the environment – Improving vulnerability and survival of the poor and their animals
5. GHG emissions	– Reduces crop growth and animal productivity – Poor C sequestration – Intensification	– Improved use of grasses, legumes, and agronomic practices – Use of dietary nitrates to reduce CH4
6. Integrated NRM and holistic systems*	– R and D – Advantage of shade in plantations – Increased economic benefits	– Interdisciplinarity – Use of systems perspectives
7. Semiarid and arid AEZs including rangelands	– Reduced feeds – Overstocking – Environmental damage – Improved management – Water use efficiency	– Control of numbers – Landlessness – Use of multipurpose leguminous trees

*AIBP – Agro-Industrial By-products, NCFR – Nonconventional feed resources, NRM – Natural resource management
Source: Devendra (2011)

sions on food security. In a World Bank study, which compared "worst-case" and more optimistic scenarios with a scenario of no climate change (Hallegatte et al. 2016) a scenario with high-impact climate change, rapid population growth and a stagnant economy indicated that an additional 122 million people would be living in extreme poverty by 2030. With the same level of climate change impacts but with universal access to basic services, reduced inequality, and extreme poverty affecting less than 3% of the world's population, the number of additional poor is projected to be just 16 million (Rosenberg and Hallegatte 2015). Under the worst-case scenario, much of the forecast increase in the number of poor occurs in Africa (43 million) and South Asia (62 million). Reduced income in the agricultural sector explains the largest share of increased poverty as a result of climate change. This is because the most severe reductions in food production and increases in food prices occur in Africa and India, which account for a large share of the world's poor. The second most important factor leading to increased poverty is impact on health, followed by the impacts of higher temperatures on labor productivity. Although climate change poses concrete threats to future food security, the likely impacts will differ by region, country, and location and will affect different population groups according to their vulnerability. Future food security trends will also be influenced by overall socioeconomic conditions, which, in turn, have implications for the vulnerability of countries and populations around the world.

When analyzing the possible future impact of climate change on food security, it is important to bear in mind that food and agriculture will be affected by a range of other drivers of change, including growth in population and income (Nardone et al. 2010). Results from IFPRI IMPACT model suggest that, by the year 2050, an additional 40 million more people could be at risk of undernourishment than there would be in the absence of climate change (De Pinto et al. 2016a). Livestock are responsible for 12% of anthropogenic greenhouse gas emissions. Sustainable intensification of livestock production systems might become a key climate mitigation technology. However, livestock production systems vary (Havlik et al. 2014).

Of the sources of specific GHG emissions from agriculture, the most significant contribution at the global level – amounting to 40% in CO_2 equivalent – comes from enteric fermentation[2] in ruminants, which is a major source of methane emissions (Steinfeld et al. 2006). Different species of livestock and various ruminating wildlife have anatomical and other differences that affect methane production (Squires 2019c). Enteric fermentation is the largest source of emissions from agriculture in all regions except Oceania and Eastern and Southeast Asia, with the share fertilizers of total emissions ranging from 58% in Latin America and the Caribbean to 37% in countries in developed regions. As reported by Tubiello and Loujani (2010) in terms of the magnitude of global emissions, this is followed by manure left on pasture (16%), the use of synthetic fertilizers (12%), and rice cultivation (10%).

[2] Enteric fermentation is a digestive process in ruminants, in particular, by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal. Methane, an aggressive greenhouse gas, is a by-product.

Livestock Production and Human Nutrition and Health

It is well known that food produced by livestock/animal such as meat, milk, and egg contains complete and balanced nutrients – energy, essential amino acids, minerals, and vitamins. Consuming much carbohydrate may cause hunger (–) oedema (*kwashiorkor*). Inadequate consumption of Fe can cause anemia. Also, a newborn baby will suffer from calcium (Ca) and phosphorus (P) due to deficiency of Ca and P in mother's milk or limited milk consumption from breast feeding. So, consuming adequate amounts of livestock products (meat, milk, and egg) could overcome the nutritional deficiencies. Also an international issue is that many children under 5 years old in developing countries die because of malnutrition (Fig. 13.5). Malnutrition is unbalance between protein and energy intake. Figure 13.6 illustrates the framework of malnutrition.

Besides providing the better nutrients, livestock production also directly and indirectly influences the human health. For example, disposing manure and urine to the body of water (river or irrigation canals) could contaminate the water and in turn brings waterborne diseases (e.g., malaria, diarrhea). In addition, anthrax is one of the zoonotic diseases that can attack human and animals. Climate change that causes sudden disaster may increase the risk of deteriorating human health. A conceptual

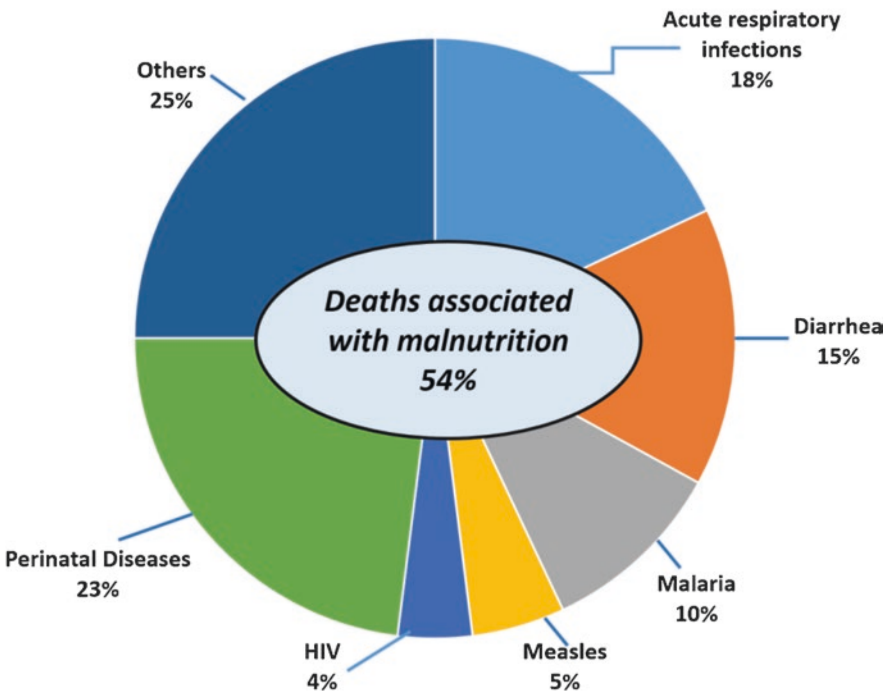

Fig. 13.5 Deaths associated with malnutrition in sub-Saharan Africa (after Watson II and Pinstrup-Andersen 2011)

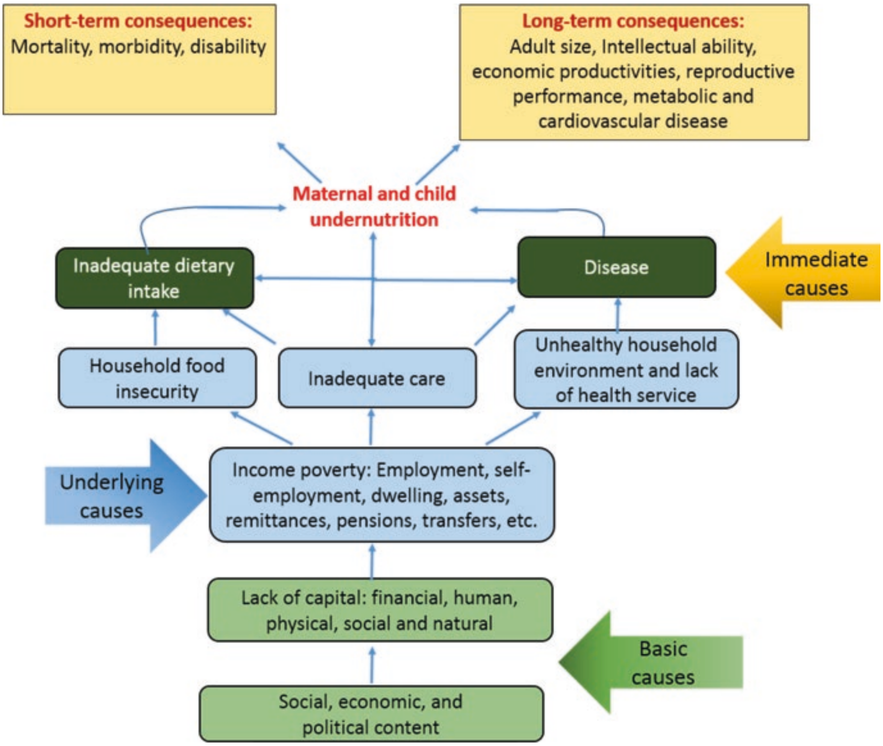

Fig. 13.6 Maternal and child under nutrition framework (Pinstrup-Andersen and Watson II 2011a, b)

framework of the linkage between agriculture (livestock production) and health is depicted in Fig. 13.7. Therefore, appropriate management is also important to be applied to mitigate the disaster from livestock production systems (Gerber et al. 2010). A novel approach to better nutrition based on higher intake of animal protein can be seen in efforts by FAO (and others) to promote use of mini-livestock. These alternative food sources include insects, amphibians, reptiles, and rodents (Squires 2019b).

Summary and Conclusions

Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living. Meanwhile, climate change is a threat to livestock production because of the impact on quality of feed crop and

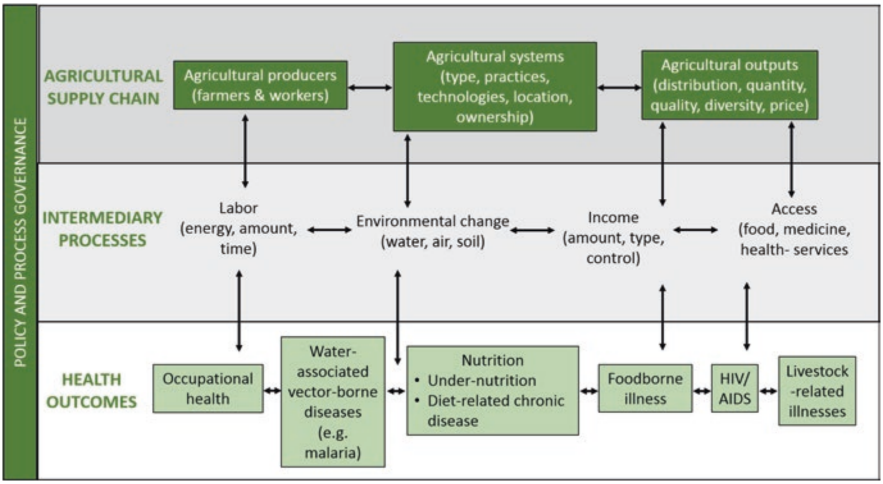

Fig. 13.7 A conceptual framework of the linkage between agriculture (livestock production) and health (after Braun et al. 2011)

forage, water availability, animal and milk production, livestock diseases, animal reproduction, and biodiversity.[3]

Much of agriculture's vulnerability to climate change lies in the fact that its agricultural systems remain largely rainfed and underdeveloped, as the majority of farmers are smallholders with few financial resources, limited access to infrastructure, and disparate access to information. At the same time, these systems are highly reliant on their environment, and farmers are dependent on farming for their livelihoods. Their diversity, context specificity, and the existence of generations of traditional knowledge offer elements of resilience in the face of climate change. Overall, however, the combination of climatic and non-climatic drivers and stressors will exacerbate the vulnerability of agricultural systems to climate change, but the impacts will not be universally felt. Climate change will impact farmers and their agricultural systems in different ways, and adapting to these impacts will need to be context-specific.

The livelihoods of rural communities and their food security are at risk from water-related impacts linked primarily to climate variability. The rural poor, who are the most vulnerable, are likely to be disproportionately affected. Adaptation measures that build upon improved land and water management practices will be fundamental in boosting overall resilience to climate change. And this is not just to maintain food security: the continued integrity of land and water systems is essential for all economic users of water, including livestock owners. Climate change is affecting the food systems and food security. Livestock producers invest significantly in food systems, but intensification of livestock production has led to environmental burdens

[3] Nearly 100 livestock breeds became extinct between 2000 and 2014.17% (1458) of the world's farm animal breeds are at risk of extinction. Genetic erosion is largely due to indiscriminate crossbreeding. Europe, the Caucasus, and North America are the areas with most breeds at risk.

causing groundwater contamination, runoff of contaminated materials, noxious smell, generation of greenhouse gases (particularly methane), and spread of zoonotic diseases. Those burdens are eventually affecting the nutrition and health of human beings. For the future existence of nature and humankind, it is important to consider that efforts for the food production especially livestock production systems must be taken into consideration in the application of adaptable technology, management of mitigation, and those that are environmentally friendly (Fan and Pandya-Lorch 2012).

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