Acosta, Alejandro (Ed.)

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World livestock : transforming the livestock sector through the Sustainable Development Goals

Food and Agriculture Organization of the United Nations

SUSTAINABLE DEVELOPMENT GOALS

WORLD LIVESTOCK

Transforming the livestock sector through the Sustainable Development Goals

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FOOD AND AGRICULTURE ORGANIZATION OF
THE UNITED NATIONS

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List of Contributors

Editor: A. Acosta
Co-editors: B. Besbes, J. Lubroth, H. Steinfeld and B.G. Tekola
FAO core advisory team: A. Acosta, P. Ankers, R. Baumung, B. Besbes, P. Boettcher, M. Bruni, G. de' Besi, F. Distefano, A. ElIdrissi, J. Lubroth, R. Mattioli, H. Makkar, A. Mottet, J. Pinto, A. Saez, H. Steinfeld and B.G. Tekola
Copy editing: L. Hunt and C. Matthews
Design: C. Caproni, C. Ciarlantini and G. Virgili

CHAPTER CONTRIBUTORS

Chapter 1: A. Acosta, P. Ankers and F. Nicolli
Chapter 2: A. Acosta and P. Boettcher
Chapter 3: R. Mattioli and J. Lubroth
Chapter 4: G. de' Besi and B. Besbes
Chapter 5: F. Distefano
Chapter 6: M. Bruni and P. Calistri
Chapter 7: H. Makkar
Chapter 8: A. Acosta and C. Barrantes
Chapter 9: J. Santos-Rocha, A. Acosta and M. Tibbo
Chapter 10: P. Ankers and A. Acosta
Chapter 11: A. El Idrissi
Chapter 12: A. Mottet
Chapter 13: A. Mottet
Chapter 14: H. Makkar and M. Bruni
Chapter 15: R. Baumung, A. Mottet and F. Teillard
Chapter 16: J. Pinto
Chapter 17: A. Saez and R. Castañeda
Chapter 18: A. Acosta, H. Steinfeld, J. Lubroth, B. Besbes and B.G. Tekola

Foreword

Human progress has been dependent on the products and services of livestock since at least the advent of agriculture, and even the most modern post-industrial societies remain critically reliant on animals for food and nutrition security. As our understanding of economic development advances, so must our recognition of the enduring importance of livestock. Livestock are especially vital to the economies of developing countries, where food insecurity is an endemic concern.

The United Nations 2030 Agenda for Sustainable Development, with its 17 Sustainable Development Goals (SDGs) and 169 targets, has become the universally endorsed framework accepted by all and applicable to all countries. The SDGs build on the success of the 2000–2015 Millennium Development Goals (MDGs) and aim to do even more to end poverty and hunger. They seek to address, in a sustainable manner, the root causes of poverty and the universal need for development. Governments are expected to take ownership and establish national frameworks for their achievement. Implementation and success will depend on the commitment of individual nations to promote sustainable development policies together with inter-sectoral coordination mechanisms, and focused plans and programmes.

Many daunting challenges remain. One in eight people in the world live in extreme poverty; 815 million are undernourished; 1.3 billion tonnes of food are wasted every year; six million children die before their fifth birthday each year; more than 200 million people are unemployed. Moreover, three billion people rely on wood, coal, charcoal or animal waste for cooking and heating; our soils, freshwater, oceans, and forests are being rapidly degraded and biodiversity eroded; and climate change is putting even more pressure on the natural resources we depend on, disrupting national economies and blighting many people's lives. For decades, the livestock debate has focused on how to produce more from less to feed 9.8 billion people by 2050. However, the United Nations 2030 Agenda for Sustainable Development has now added a new and broader dimension to the discussion, it has shifted the focus from fostering sustainable livestock production *per se*, to enhancing the sector's contribution to the achievement of the SDGs.

Along with daunting challenges, the future holds immense opportunities – including for livestock. The sector can play a key role in improving the lives of millions by: providing the world with sufficient and reliable supplies of meat, milk, eggs and dairy products; increasing the direct consumption of animal-source foods; helping to generate income and create employment; and strengthening the assets that rural households use to achieve their livelihood objectives. It can also help improve children's cognitive and physical development as well as school attendance and performance; empower rural women; improve natural resource-use efficiency; broaden access to clean and renewable energy; and support sustainable economic growth. Finally, it can generate fiscal revenue and foreign exchange; create opportunities for value addition and industrialization; stimulate smallholder entrepreneurship, close inequality gaps; promote sustainable consumption and production patterns; increase the resilience of households to climate shocks; and bring together multiple stakeholders to achieve all these goals.

However, before all of this can happen, a number of complex interactions need to be addressed. The scarce availability of productive factors in developing countries may prevent small-scale livestock keepers from benefiting from fast livestock growth; overuse of natural resources to increase short-term production could lower productivity in the long term; although emission intensity from

the livestock sector is declining, a rise in production would lead to higher overall greenhouse gas (GHG) levels. The list continues: competition over land can constrain the availability of natural resources to produce food; emergence and spread of transboundary animal diseases can pose major threats to public health; promoting greater competition with higher levels of market concentration will likely keep many small producers from participating in markets. Overarching all of these issues is the need to curb the negative effects of livestock production on biodiversity and the environment, and to stop the improper use of antimicrobials in stock-raising. Failure to address these interactions could result in positive synergies being precluded and in the predominance of negative trade-offs.

Existing policy instruments can be used either to enhance positive externalities or mitigate negative outcomes. However, the achievement of some of the SDG targets could conflict with the accomplishment of others. It is therefore likely that policymakers will have to trade off gains in one area against losses in the others. To support the transformation needed in the livestock sector to enhance its contribution to the Sustainable Development Goals, this report examines the sector's interaction with each of the Goals, as well as the potential synergies, trade-offs, and complex interlinkages involved. In this regard, this global report is intended to serve as a reference framework that Member States and stakeholders can consult as they move forward to realize livestock's major potential contribution to the 2030 Agenda for Sustainable Development.

José Graziano da Silva
FAO Director-General

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The research and writing team was led by Alejandro Acosta and included: Philippe Ankers, Carlos Barrantes, Roswitha Baumung, Badi Besbes, Paul Boettcher, Mirko Bruni, Paolo Calistri, Rodrigo Castañeda, Giacomo de' Besi, Tito Diaz, Francesca Distefano, Ahmed ElIdrissi, Juan Lubroth, Harinda Makkar, Raffaele Mattioli, Anne Mottet, Francesco Nicolli, Julio Pinto, Ana Saez, Jozimo Santos-Rocha and Markos Tibbo. The initial background paper was prepared by Alejandro Acosta (AGA), David Roland-Holst (University of California, Berkeley), Joachim Otte (Consultant), and Thomas Emmet (University of California, Berkeley).

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Key messages

To better support the transformation needed in the livestock sector and enhance its contribution to the Sustainable Development Goals, the World Livestock (WoLi) report *"Transforming the livestock sector through the sustainable development goals"* examines the sector's interaction with each of the Goals, as well as the potential synergies, trade-offs, and complex interlinkages involved. In this regard, this global report is intended to serve as a reference framework that Member States and stakeholders can consult as they move forward to realize livestock's potentially major contribution to the 2030 Agenda for Sustainable Development. The report shifts the focus of the livestock policy debate from fostering sustainable production *per se* to enhancing the sector's contribution to the achievement of the SDGs. It calls for an integrated livestock sustainable development approach, and highlights the effective translation of the SDGs into specific and targeted national policy action as the major challenge ahead.

Boosting economic growth through the livestock sector's multiplier effects. Livestock systems make a major contribution to national economies worldwide. The value of livestock production accounts for 40 and 20 percent of total agricultural output in developed and developing countries respectively. However, the contribution of livestock to economic growth can be boosted through vertical and horizontal multiplier effects that go beyond production. Indeed, the non-agricultural sector tends to have a higher response to changes in livestock production than agriculture itself. Nevertheless, in developing countries, the livestock sector is highly segmented and the levels of labour productivity differ between processing and production and, within production, between commercial and subsistence farmers. Thus, a simple multiplication of similar opportunities could simply result in an expansion of underemployment. Policies should promote livestock system models that lead to higher labour productivity, facilitate value-addition, and are labour-intensive.

Translating fast livestock growth into faster poverty reduction. Given the sector's expected rapid growth, and the fact that many of the poor rely on livestock for their livelihoods, livestock's contribution to poverty reduction has sometimes been taken for granted. Livestock undoubtedly can play a key role in preventing people from falling into poverty, but the sector's ability to lift them out of it is more debatable. In developing countries, smallholders typically have less than 1 hectare of land, own around 1.3 tropical livestock units, and absorb around one unit of family labour per day. Consequently, the capacity of smallholders to exploit their factor endowments to generate income is limited. Thus, in order to transform rapid livestock growth into poverty reduction, policies should focus on the following: expanding the size of the sector in the economy, increasing its growth rate and the participation of the poor in that growth; the capacity of producers to access factors of production; the ability of workers to link to expanding employment opportunities, and the possibility for consumers to benefit from more competitive prices, safer foods, and quality diets.

Realizing the potential of the livestock sector to end hunger and malnutrition. The livestock sector can contribute in multiple ways to ending hunger and all forms of malnutrition. They include: increasing the direct consumption of nutritious animal-source foods; helping to generate income; supporting the creation of employment; generating fiscal revenue and earning foreign exchange; and providing the world with

sufficient and reliable supplies of meat, milk, eggs and dairy products, and of primary commodities used for clothing, bedding and other household items. However, the sector will have to overcome a new set of interconnected challenges. Increased demand for animal-source foods will add to existing pressure on ecosystems and biodiversity and livestock producers will face greater competition for capital, labour, land, water and energy. Productivity is therefore expected to increase, but at a diminishing rate, while the ongoing transformation of the sector's market structure may hinder small producers and poor consumers from benefiting from economic growth and improvements in productivity. Furthermore, the use of antimicrobial medicines to promote growth and prevent disease in healthy, food-producing animals has exacerbated the emergence and spread of resistant microorganisms. Consequently, the sector can only deliver on expectations if, among other measures, the productivity and income of small-scale food producers is improved, sustainable and resilient food systems are promoted, the diversity of genetic resources is maintained, the proper functioning of food markets is ensured, and the use of antimicrobials is reduced through better access to quality veterinary services and good animal husbandry practices.

Preventing animal diseases to ensure healthy lives. Throughout the world, livestock and derived products are assets to human livelihoods and, through quality nutrition, to human health and well-being. However, animals, including farm animals and their products, also pose risks to human health. More than 70 percent of the infectious diseases that have emerged in humans since the 1940s can be traced to animals. These include Bovine Spongiform Encephalopathy (BSE), Avian Influenza, Severe Acute Respiratory Syndrome (SARS) – Middle East Respiratory Syndrome, and Ebola – some of which may have pandemic potential. Increasing livestock numbers, intensified management, faster animal turnover, confinement of large numbers of animals in small spaces as well as habitat fragmentation through expansion of livestock production, all increase the probability of outbreaks of high-impact animal diseases. Inappropriate use, overuse and abuse of antimicrobials in animal production contributes to an increase in antimicrobial resistance in pathogens causing human infections worldwide. Prevention – through targeted vaccination programmes, improved hygiene, and biosecurity at primary production level – is the best way of both controlling emerging animal diseases and combating antimicrobial resistance. Ensuring collaboration between animal production and health specialists, public health officials, and the commercial sector, including the feed industry, through a "One Health" (One Health, 2018) approach is crucial to achieving an integrated and preventive strategy on livestock-associated human health risks.

Balancing animal-source food intake to increase children's cognitive development, school attendance and performance. Animal-source foods (ASFs) provide high-quality and readily digested protein, are rich in energy and provide readily absorbable and bioavailable micronutrients. These nutrients are more easily obtained from ASFs than from plant-based foods. An inadequate intake of some of the major micronutrients available in ASFs during pregnancy and childhood can lead to health problems that affect growth and educational attainment. Children suffering from undernourishment perform less well at school due not only to basic cognitive insufficiencies in infancy, but also to continuing hunger, which limits their ability to concentrate, or depressed immune systems leading to weaker states of health and absenteeism. Providing adequate amounts of foods of animal origin in the diets of schoolchildren can add much-needed nutritional diversity and sustain and improve cognitive performance, micronutrient status, growth, physical activity, academic achievement, and appropriate response to vaccines while also fending off opportunistic mi-

crobes. Supplying undernourished schoolchildren with milk, meat and eggs through school feeding programmes can therefore be a valuable dietary tool and has also proved to be an incentive to school enrolment and attendance.

Fostering women's participation and decision-making powers in the livestock sector. Throughout the developing world, women and girls in rural and peri-urban areas are deeply involved in livestock systems. However, women, as compared with men, have poorer access to resources such as land and water, credit, markets, assets and technical information. Consequently, women livestock keepers typically face greater economic, social and institutional barriers, and frequently lack the means to fully engage in, sustain and upgrade their farming activities. To enable women to meaningfully operate in, and benefit from, the livestock sector, policies and programmes should work to remove root causes of gender inequalities as well as the obstacles and constraints facing women. Since the leaders of agricultural cooperatives and producer associations who help governments design development plans and policies are predominantly men, in the livestock as in other sectors, women's low representation has an impact on the gender-sensitivity of such plans and policies, and the benefits they offer to women and girls. Thus, fostering women's participation and decision-making powers in the livestock sector can help end gender discrimination in rural areas and ensure women gain equal rights to productive resources, as well as services.

Increasing water-use efficiency in livestock production to address water scarcity. Agriculture withdraws approximately 70 percent of all available freshwater, and livestock production uses roughly 30 percent of that. To meet rising demand for animal products, the livestock sector is currently making growing use of agricultural water, thus increasing competition with other human and crop-agriculture water needs, and raising new and complex health and environmental challenges linked to waste management and water quality. Runoff and nutrient or residue leaks from concentrated sources of livestock waste are a hazard to freshwater sources as well as ocean and coastal environments. If not properly managed, nutrient runoff and excessive concentration of nitrogen and phosphorus can damage surrounding ecosystems, estuaries and coastal fisheries. Manure and slurry pit discharges and outflows from abattoirs and food processing also contribute to contaminating water resources unless adequately treated. Given the very substantial water footprint of livestock production, improving water-use efficiency and policy guidance throughout the production system is key to ensuring access to safe water sources and sanitation.

Turning animal manure into clean, renewable energy. Around 17 percent of the global population lack access to electricity, and 38 percent is without clean cooking facilities. Almost 80 percent of these people live in rural areas. Currently, 80 percent of the world's energy consumption is generated from fossil fuels which are not only finite but produce environmental pollutants. The "Energy Revolution" now replacing polluting coal and oil with clean, renewable sources is likely to figure as one of the most significant conquests of the twenty-first century. Converting livestock manure into biogas could make a major domestic renewable fuel source available to more than a billion people, giving them access to affordable, reliable, and sustainable energy.

Adding value and complexity to livestock products through industrialization. Industrialization is a dynamic instrument of growth, promoting rapid economic and social development. However, in many developing countries processed livestock products contribute to value chains by providing unsophisticated products to downstream actors, representing a very small share of agro-processing and of total exports. Indeed, the six most complex livestock products exported from Africa in 1995–2012 accounted

for less than 15 percent of livestock exports, while the six least-complex products accounted for more than 55 percent. Since not all products have the same impact in terms of economic growth, concentrating on unsophisticated products is keeping the livestock sector in many developing countries from achieving faster economic growth. Economic development is not just about constantly improving the production of the same set of goods but also means acquiring more complex capabilities to diversify production towards more sophisticated products and higher productivity levels. Industrialization offers great opportunities for developing countries to add value and complexity to livestock primary products, allowing the sector to enter the downstream end of global value chains and thus accelerate economic development.

Accompanying openness to trade with infrastructure and financial and institutional development policies to reduce inequalities among nations. The argument that openness to trade contributes to narrowing the development gap between countries is well grounded in conventional economic theory. However, potential gains from trade liberalization will not necessarily affect all countries and groups within society in the same way. There are likely to be significant differences between developed and developing countries, net-exporting and net-importing countries, and, both within and across countries, among small-scale and commercial farmers, and rural non-farm producers and urban consumers. The livestock sector in developing countries often has not been well placed to benefit from trade liberalization. This stems partially from the inflexible structure of production and trade in the sector; lack of financial development and sluggish factor mobility; excessive regulation that prevents resources from flowing; the limited capacity of producers to adjust quickly to market changes; and the low level of compliance with international sanitary measures and food standards. In order to reduce inequality among nations, trade reform needs to be accompanied with appropriate infrastructure, financial and institutional development polices.

Maximizing the benefits while managing the risks of urban livestock. Rapid, global urbanization represents one of the most rapid and profound shifts in the rise of human settlements. Urban agriculture is one aspect of urbanization and takes place in many cities around the world in various forms and contexts. Urban agriculture, as defined by FAO, is "the growing of plants and the raising of animals within and around cities". Urban agriculture, including livestock production, was recognized by the 1996 United Nations Conference on Human Settlements as one of the "desirable practices" for sustainable cities. Livestock production has a variable and controversial, but often essential role to play in and for cities, especially in developing countries. The main benefits of urban livestock production include the generation of income, the creation of jobs, and the delivery of improved food security and nutrition. Urban livestock also present significant risks since, in the absence of proper sanitation and infrastructure, they can pose environmental and public health hazards. In order to make cities more sustainable, specific measures to reduce such risks are required, including improved coordination between health, agriculture, municipal and environmental departments; farmer education on the management of health and environmental risks; and dissemination of information about these hazards to inform legislation and urban planning.

Producing more with less, while balancing consumption, and reducing losses. Livestock supply chains are resource-hungry. They use large amounts of land, water, nutrients and energy and contribute significantly to greenhouse gas (GHG) emissions. As consumption of animal products is expected to increase, the livestock sector needs to produce more with less. Unsustainable production and consumption not only contribute to inefficient use of resources but are also the source of lost economic opportunities,

environmental damage, and poverty and health problems. Adoption of best practices can lead to large gains in natural resource-use efficiency. Rebalancing diets to reach nutritional recommendations can also have significant impact on natural resource use and GHG emissions. Efficiency can further be improved by reducing food waste and losses along supply chains, and targeting different stages of those chains in different regions, depending on priorities. Because improvements are needed along the whole life cycle of products, this goal requires the involvement of various stakeholders, including consumers, policymakers, retailers and industry representatives. However, adapting and enforcing new technologies in local environments, and instituting supporting policies and infrastructure to encourage adoption, will be the greater challenge.

Combating the effects of climate change through improving livestock resource-use efficiency. The relationship between livestock and climate change works two ways. On the one hand, global GHG emissions from livestock supply chains are significant, accounting for 14.5 percent of total anthropogenic emissions. The emissions are mainly from enteric fermentation (CH4), feed and forage production (CO2 and N2O) and manure management (N2O and CH4). On the other hand, climate change affects livestock production, for example though the quality and availability of feed and forage, and the incidence and prevalence of animal diseases and, in some cases, their vectors. Efficiency is key to both reducing emissions and building resilience. A number of mitigation and adaptation options are available to improve natural resource-use efficiency while also increasing soil carbon and recycling nutrients from within food chains. Their implementation requires a transfer of technology and knowledge, together with the right incentives and a conducive regulatory framework. However, measures that go beyond the farm gate are also required, including institutional changes, disaster risk management, and social safety nets.

Reducing the impact of livestock on marine ecosystems by preventing pollution and containing the use of fish products in animal feed. Over three billion people depend on marine and coastal biodiversity for their livelihoods, while broadly the same number obtain almost 20 percent of their usual intake of animal protein from fish. However, the world's ocean fish face serious threats both in terms of loss of biodiversity and declining stocks. The principal source of pressure is overexploitation by fisheries. A substantial part of the global fish catch is turned into fishmeal and fish oil, and used to feed terrestrial animals. Many watercourses suffer from pollution due to effluents from livestock and industry, with profound environmental and human health implications. However, the use of a number of plant-based feeds, together with synthetic amino acids and enzymes, has led to a substantial reduction of fishmeal in the diets of both livestock and aquatic species, thereby contributing to conservation of marine ecosystems. More effective coastal/watershed planning and close collaboration between the livestock, feed and fisheries sectors would help promote sustainability of both land- and marine-based food production systems. A number of new technologies to contain the use of fish products for animal feed, to reduce pollution from livestock waste, and to increase the use of marine plant resources for livestock feed are available. Currently, however, efforts to scale up the new technologies remain in their infancy.

Enhancing the provision of ecosystem services through sustainable grassland management and improvements in feed-use efficiency. Across the globe, natural resources are deteriorating, ecosystems are under stress and biological diversity is being lost. Changes in land use, including deforestation, result in the loss of valuable habitats, water pollution, land degradation, soil erosion and the release of carbon into the atmosphere. Such damage is mainly attributable to the conversion of forests or rangelands to other uses such as agriculture and infrastructure devel-

opment. Land used for grazing and feed production has major environmental impacts: feed links livestock to land use, both directly via grazing, and indirectly via traded feedstuffs. While the livestock sector plays a part in biodiversity reduction, land degradation and deforestation, it also provides invaluable services that protect, restore and promote sustainable use of terrestrial ecosystems, combat desertification, reverse land degradation and halt biodiversity erosion. Whether the environmental effects of the livestock sector are detrimental or positive depends on the livestock production and management system. Livestock production can be crucial in, for example, supporting sustainable rangeland management, preserving wildlife, and enhancing soil fertility and nutrient cycling.

Promoting peace and social stability through livestock. A stable and peaceful environment is the basis for sustainable development. In many communities in developing countries, social and economic well-being is closely linked to the livestock sector. Threats to livestock resources such as droughts, natural disasters and animal diseases, can seriously affect the economic and social balance of local communities. During crises, and particularly during rehabilitation and recovery, livestock are essential in order to restore the supply of animal protein. In terms of public health, animal disease outbreaks can spread quickly and evolve into major health, social and economic crises at regional and sometimes global level. Further, disputes among populations over land and pastures can be sources of conflict, since grazing land is a valuable commodity that is coming increasingly under pressure. Mechanisms such as well-defined property rights, clear legislation, sound livestock policies, confidence in local institutions, and robust infrastructure can enhance the sector's role as a catalyst for social peace and stability.

Building inclusive and effective partnerships in the livestock sector to support the achievement of Agenda 2030. Strong commitment to partnership and cooperation is central to the achievement of the 2030 Agenda for Sustainable Development. The breadth of knowledge, experience and expertise required implies mobilizing a broad range of competences and the participation of multiple stakeholders. Multi-stakeholder processes aim at building a consensus on sustainable solutions and catalyse change through dialogue, consultation and joint analysis. These processes draw on the forces of various public and private stakeholders as well as research and academic institutions, international agencies, non-governmental organizations, and civil society. The livestock sector already counts on a number of multi-stakeholder partnerships at global and regional levels. They play a key role in ensuring sustainable growth in livestock production, meeting rising global demand while addressing related environmental, social and economic challenges. Although the need for multi-stakeholder partnerships to scale up the impact of public–private initiatives is recognized, more understanding is required concerning the legitimacy, inclusiveness, governability, effectiveness and development impact of joint actions.

Translating the key role of livestock in the SDGs into national policies and strategies. The SDGs and targets are aspirational and global. Thus, each country will have to decide how the role of livestock in the SDGs should be incorporated into national planning processes, policies and strategies, and how to set national targets guided by the global level of ambition but taking account of national circumstances. To better support integration of livestock policy and practices with sustainable development strategies, World Livestock presents a Livestock-SDGs Policy Framework as a tool to enhance the impact of livestock policy analysis in accomplishing the 2030 Agenda. The main objectives of this policy framework are: i) to strengthen the capacities of governments and stakeholders to analyse the contribution of the livestock sector to the SDGs, mapping linkages, synergies and trade-offs; ii) to guide the identification of

windows of opportunity for policy change; iii) to support the generation of analytical evidence that assesses the likely impact of policies and programmes; iv) to promote the use of methods and tools to monitor the contribution of the livestock sector to the SDGs; and v) to facilitate high-level policy discussion on emerging livestock and sustainable development issues.

Advancing towards an integrated livestock sustainable development approach. Traditionally livestock sustainability analysis has been conducted using a partial sectorial approach that assesses the effects of the sector's development on one specific dimension of sustainability. In contrast to the Rio "pillars" concept of sustainable development, in the 2030 Agenda, the social, environmental and economic dimensions of sustainable development are intertwined and cut across the entire framework. It is therefore important to avoid considering livestock's contribution to each dimension individually and to eschew the kind of "one-shot" approach that fails to take account of simultaneous contributions, feedback effects, potential collateral impacts, dynamics, synergies and trade-offs between different sustainability dimensions or policy options. WoLi calls for an integrated framework towards sustainability that simultaneously addresses the environmental, social and economic dimensions in a more balanced manner.

Shifting the focus of the debate from fostering sustainable production *per se* to enhancing the livestock sector's contribution to the achievement of the SDGs. For decades, the livestock debate has focused on how to produce more from less to feed 9.8 billion people by 2050. However, the UN 2030 Agenda for Sustainable Development has added a new and broader dimension to the debate. It has shifted the emphasis of the discussion from fostering sustainable production *per se*, to enhancing the contribution of the sector to the achievement of the SDGs.

Executive summary

By signing the 2030 Agenda for Sustainable Development, governments around the world committed to address urgent economic, social and environmental global challenges over the next 12 years. The 2030 Agenda is a road map to end poverty and hunger, protect the planet and ensure prosperity for all. It is fundamental to begin the implementation of this Agenda by creating awareness, understanding each economic sector's potential contribution to its achievement, and building multi-stakeholder consensus on how this could be done. Human progress has been dependent on the products and services of livestock since at least the advent of agriculture, and even the most modern post-industrial societies remain critically reliant on animals for food and nutrition security. As our understanding of economic development advances, so must our recognition of livestock's continual importance.

We are facing a time of immense challenges: one in eight people on earth live in extreme poverty; 815 million people in the world are undernourished; six million children die before their fifth birthday each year; 202 million people are unemployed; our soils, freshwater, oceans, forests and biodiversity are being rapidly degraded; and climate change is putting even more pressure on the resources we all depend on. The livestock sector can play a key role in addressing, directly or indirectly, many of these challenges. While, for decades, the livestock debate has focused on how to increase production in a sustainable manner, the UN 2030 Agenda for Sustainable Development has added a new and broader dimension to the debate. It has shifted the emphasis of the conversation from fostering sustainable production *per se*, to enhancing the sector's contribution to the achievement of the SDGs.

SDG 1. ZERO POVERTY

While extreme poverty rates have declined since 1990, the number of people living in extreme poverty globally remains unacceptably high. According to the most recent estimates, 10.7 percent of the world's population in 2013 were living below the international poverty line of USD 1.90 per person per day. Southern Asia and sub-Saharan Africa are home to the overwhelming majority of people living in extreme poverty. SDG 1 takes a multidimensional approach to ending poverty, with targets emphasizing the eradication of extreme poverty, promoting inclusive economic growth, equal rights to economic resources and property rights, and building resilience at national and regional level to withstand economic, social, and environmental shocks.

Livestock are catalytic in helping rural households achieve their livelihood objectives. First, they enhance human capital by providing access to food, continued good health, and labour for the pursuit of activities. Second, they build social capital, strengthening the cultural diversity and heritage of some ethnic groups and populations. Third, they contribute to the stock of the natural capital that provides the resources and services needed to maintain and improve livelihoods. Fourth, they increase physical capital, providing transport, draught power and alternative energy for households to support and improve their productivity. Fifth, they increase the financial capital of families, provide a mechanism for savings, and serve as liquid assets, or as credit collateral for securing livelihood goals. Sixth, they act as an important resilience and consumption smoothing strategy against external shocks.

SDG 2. HUNGER ERADICATION

Roughly one in nine people suffer from hunger worldwide, with most living in developing countries. Within developing countries, approx-

imately 13 percent of the population is undernourished. With enough food to feed everyone on the planet, continuing hunger and malnutrition call for a major change in global food and agriculture systems. SDG 2 takes a system-wide approach to ending hunger, with an emphasis on achieving food security and improved nutrition, and on promoting sustainable agriculture. SDG 2 targets include ensuring universal access to safe, nutritious and sufficient food all-year round, improving the productivity and incomes of small-scale food producers, promoting sustainable and resilient food production systems, maintaining the diversity of genetic resources for food and agriculture, and ensuring the proper functioning of food markets.

The livestock sector can play a key role in ending hunger, contributing at different levels and from different entry points. At the household level, its principal contribution is increasing the direct consumption of healthy and nutritious animal-source foods (ASFs) and helping to generate income; at rural community level, its contribution is related to the creation of employment opportunities in livestock and food chains, both upstream and downstream. In terms of national economies, an enhanced livestock sector can help reduce ASF prices, generate fiscal revenue, and earn foreign exchange. At the global level, it can supply the world with sufficient and reliable supplies of eggs, meat, milk and dairy products.

In particular, livestock and animal-source foods provide readily digestible protein and essential nutrients and can therefore make critical contributions to ending hunger and improving food security and nutrition. Livestock products contribute to the global human diet with 33 percent of protein intake and 17 percent of calorie intake. ASFs are nutrient-dense, palatable sources of energy and high-quality protein, and also provide a variety of essential micronutrients, some of which – such as vitamin B12, riboflavin, calcium, iron, zinc, and various essential fatty acids – are difficult to obtain in adequate amounts from plant-based foods alone. These characteristics make ASFs important to population groups who are often unable to consume all the food they need, like young children, and pregnant and lactating women.

SDG 3. HEALTHY LIVES

Throughout the world, the human health burden of zoonotic diseases falls heavily on the poor, causing morbidity and mortality, particularly in children, who, even if they survive, will often face higher health care expenses and reduced incomes for the rest of their lives. In terms of human health, major zoonoses are responsible for an estimated 2.5 billion cases of illness and 2.7 million deaths a year. Inappropriate use of antimicrobials in animal production contributes to the spread of drug-resistant pathogens causing human infections across the globe. Today, approximately 700 000 people die of drug-resistant infections every year, but it has been estimated that if no action is taken today, antimicrobial resistance (AMR) could, by 2050, cost ten million lives a year and USD 100 trillion in lost economic output. SDG 3 aims to ensure health and well-being for people of all ages by improving reproductive, maternal and child health; ending the epidemics of major communicable diseases; reducing noncommunicable and environmental diseases; and achieving universal health coverage.

Livestock and derived products are important assets in human livelihoods and nutrition, and consequently in human health and well-being. They provide significant amounts of essential noble, high-biological-value proteins, fatty acids and various minerals and vitamins. Moreover, animals are a source of therapeutic compounds such as antimicrobial peptides. At the same time, however, animals, including farm animals and their products, also present risks to human health. These may be direct, e.g. through the transmission of zoonotic pathogens, which include emerging threats such as Ebola virus and Middle East respiratory syndrome coronavirus (MERS-CoV). As noted, AMR poses another growing peril, as do the residues of medicines, supplements, and contaminants in the environment.

Indirect threats arise too, e.g. in the form of non-communicable diseases, such as cardiovascular illnesses, if animal products are consumed in excess.

SDG 4. QUALITY EDUCATION

The gaps in educational attainment between rich and poor, men and women, rural and urban people, and within and between countries, are still wide. In 2014, there were 263 million children, adolescents and young adults in the world who did not attend school. In low-income countries only 14 percent of students completed upper secondary education. During 2005–2014, some 758 million adults, almost two-thirds of them women, lacked any literacy skills. SDG 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. It focuses on the acquisition of foundational and higher-order skills at all stages of education and development; greater and more equitable access to quality education at all levels, including technical and vocational education and training; and the attainment of the knowledge, skills and values needed to function well and contribute to society.

There are both direct and indirect links between livestock and education. Consumption of ASFs can improve children's cognitive and physical development as well as school attendance and performance. In addition, livestock provides income to poor rural households which they can use to pay for school fees, uniforms and schooling materials. In turn, basic education and agricultural education and training can contribute to more sustainable and efficient livestock systems. However, access to quality and inclusive education, agricultural training and extension and quality diets for poor people is often a challenge, one reason being children's involvement in tending livestock.

SDG 5. GENDER EQUALITY AND WOMEN'S EMPOWERMENT

Gender inequality persists worldwide, depriving women and girls of basic rights and opportunities. Achieving gender equality and the empowerment of women and girls will require more vigorous efforts, including the reform and/or development of national legal frameworks to counter deeply rooted gender-based discrimination that often stems from patriarchal attitudes and related social norms. SDG 5 aims to empower women and girls to reach their full potential in all spheres of their lives, including within the agriculture sector, which also requires eliminating all forms of discrimination and violence against them. It seeks to ensure that they have every opportunity for sexual and reproductive health and reproductive rights; receive due recognition for their unpaid work; have full access to productive resources; and enjoy equal participation with men in political, economic and public life.

Women make up an average of 43 percent of the agricultural labour force in developing countries. Rural women greatly contribute to the development of the small-scale livestock sector – it has been estimated that, globally, rural women represent two-thirds of low-income livestock keepers. However, women's contribution is reduced and constrained by the challenges and inequalities that they experience across the globe, in many spheres of public, private and economic life, as compared with men. Within the agriculture sector, these challenges include poorer access to, and control over, productive resources such as land and water, diminished access to credit, markets and technical information. Livestock keeping and production can make a significant contribution to SDG 5 in achieving gender equality and empowering women and girls, but to enable women to meaningfully operate in, and benefit from, the livestock sector, policies and programmes should work to remove all obstacles and constraints in their way.

SDG 6. SUSTAINABLE MANAGEMENT OF WATER

Water scarcity, poor water quality, and inadequate sanitation already threaten the food security, livelihoods and educational prospects of poor families across the world. Drought afflicts

some of the world's poorest countries, intensifying hunger and malnutrition. Water withdrawals for irrigation and livestock will increase as global population growth and economic development drive up demand for food. SDG 6 aims to find ways to produce more food while using less water – one of the great challenges of our times. Achieving universal and equitable access to safe and affordable drinking water, reducing pollution to improve water quality, eliminating or minimizing dumping and dispersal of hazardous chemicals and biological agents, and encouraging water recycling and reuse are the main strategic targets.

Agriculture uses approximately 70 percent of the available freshwater supply, and roughly 30 percent of global agricultural water goes on livestock production, with one-third of that used for beef cattle. But livestock's direct and indirect usage of freshwater is only one of the central water-related challenges facing animal production: another is waste management and disposal. Runoff and nutrient leaks from concentrated sources of livestock waste are a hazard to freshwater sources as well as ocean and marine environments. Thus, given the large and growing water footprint associated with livestock production, improving water-use efficiency throughout the production system is important in order to achieve SDG 6 and thereby ensure access to safe water sources and sanitation for all.

SDG 7. CLEAN ENERGY

According to the International Energy Agency (IEA), around 17 percent of the global population lacks access to electricity, and 38 percent is without clean cooking facilities. Almost all these people – 80 percent – live in rural areas. Out of the 1.2 billion people without electricity, more than half are in Africa (634 million) followed by developing Asia (512 million), Latin America (22 million) and the Middle East (18 million) (IEA, 2016). Currently, the greater part of the world's energy consumption (approximately 80 percent) is generated from fossil fuels, which are not only a finite resource, but produce environmental pollutants including climate-warming greenhouse gases. SDG 7 seeks to ensure access to affordable, reliable, sustainable and modern energy for all. It highlights the importance of investing in renewable energy sources and of expanding infrastructure to supply sustainable energy services to developing countries.

The "Energy Revolution" now replacing polluting coal and oil with clean, renewable sources is likely to figure as one of the most significant conquests of the twenty-first century. Livestock manure, which can be turned into biogas, has an important role to play in this process, especially in the Global South. For biogas can not only enhance the energy security of developing regions but also help resolve vexing problems such as environmental pollution, bad odour and flies. At a global level, turning animal manure into biogas would also eliminate a leading source of methane, a powerful driver of global warming. In the context of the current environmental debate, solar, wind, geothermal power, animal and biomass energies are considered as clean. Livestock production relies on energy embedded in biomass, which comes mainly from solar energy, although other sources may also contribute.

SDG 8. ECONOMIC GROWTH

Over the past decades, the production and consumption of animal products has become one of the fastest growing sectors in agriculture. This phenomenon, dubbed the "livestock revolution", has been driven by population and income growth, plus rapid urbanization. Continuing expansion is expected, with demand for animal products fuelled by the continued increase in the world's population, forecast to climb from 7.6 billion in 2017 to 8.6 billion in 2030. SDG 8 proposes an integral approach towards more sustainable and inclusive economic growth. To do that, SDG 8 targets higher economic productivity through diversification, technological development, and innovation, and through a focus on high value-added and labour-intensive sectors. The 2030 Agenda also proposes growth-

oriented policies that support productive activities, decent job creation, innovative entrepreneurship, greater access to financial services and the formalization of micro, small and medium-sized enterprises.

Alongside the livestock sector's ability to reach into many different areas of the economy and society, such growth represents a major development opportunity for many countries. Livestock production makes a major contribution to national economies worldwide. In 2014, the value of livestock production in developed countries accounted for 40 percent of total agricultural output, and 20 percent in developing economies. Globally, up to 1.3 billion people are employed in different livestock product value chains. Given the remarkable growth rate predictions, the livestock sector has tremendous potential to create jobs and reduce inequality, directly contributing to SDG 8 in promoting inclusive and sustainable economic growth, employment and decent work for all. Livestock production can boost economic growth in two main ways: through direct contribution to rural livelihoods and agricultural output; and, given the sector's various linkages with other industries, through the multiplier effects of livestock products moving along expenditure and supply chains.

SDG 9. INDUSTRIALIZATION

Although sustainable industrialization is essential for rapid economic and social development, and despite the great opportunities that it holds for developing countries, the latter are still far from achieving the right levels of industrial capacity. Indeed, global average manufacturing value added (MVA) as a share of GDP has been steadily declining in the last few decades from about 21 percent in 1995 to about 15 percent in 2015. According to the United Nations Industrial Development Organization, the share of manufacturing employment in developing countries grew from about 12 percent in 1970 to 14 percent in 2010, i.e. essentially remaining stagnant. SDG 9 focuses renewed attention on the importance of building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation, thus reallocating resources for socially inclusive and environmentally sustainable economic growth.

Animal production offers attractive opportunities for industrialization and an increased share of MVA in the national economy. The animal product processing industry is one of the fastest-growing in emerging nations. This fact, combined with overall development of industrial capacity, infrastructure, research and innovation, and access to finance, offers the livestock sector an excellent opportunity to add value and achieve more inclusive economic growth. However, a significant number of developing countries contribute to livestock global value chains primarily through the provision of primary and unsophisticated products to downstream actors in developed countries. Since not all products have the same impact in terms of economic growth, concentrating on unsophisticated products is substantially keeping those countries from growing faster and improving key development indicators. Hence economic development is not just about constantly improving the production of the same set of goods. It has more to do with acquiring more complex capabilities that help diversify production towards more sophisticated products and higher productivity levels.

SDG 10. REDUCED INEQUALITIES

Economic inequalities are defined by people's economic positions in society, measured in terms of income, purchasing power or wealth. Yet inequalities are also linked to demographic characteristics such as gender, age or ethnicity. Certain individuals and groups have consistently inferior opportunities to those of their fellow citizens merely on account of their birth. SDG 10 calls for reducing inequalities in income, as well as discrimination based on sex, age, disability, race, class, ethnicity, religion and opportunity, and this both within and among countries. SDG 10 is closely correlated to the first of the SDGs (elimination of poverty) and while there

has been progress on poverty reduction over the past decades, the world continues to suffer from substantial inequalities. To reach both SDG 1 and SDG 10, efforts to foster growth need to be complemented by equity-enhancing policies and interventions (World Bank, 2016).

The livestock sector offers substantial opportunities for income generation and job creation, especially in the dairy sector. On the supply side, livestock are a source of food and income for at least half a billion poor people who depend partially or entirely on keeping animals for their livelihood. The proportion of poor women and elderly individuals involved in agriculture, in the broad sense of the term, is increasing. At the same time, the number of young people (15–24) in sub-Saharan Africa looking for jobs will increase by 75 percent in the next 30 years and a thriving livestock sector could play an important part in absorbing them into the labour market. With the right investments and policies – and providing national and regional authorities support a form of livestock development that is inclusive and sensitive to the needs of women and young people – the sector can make a significant contribution to the reduction of inequalities in income, as well as of discrimination based on sex and age.

SDG 11. SUSTAINABLE CITIES

Rapid, global urbanization represents one of the most profound shifts in the rise of human settlements. In 2007, the world's urban population overtook rural population for the first time in history. This trend has continued in the past decade and is expected to spawn more city and urban settlements, transforming the economic and social fabrics of entire countries. By 2050, more than two-thirds of the world's population will live in towns and cities, putting pressure on natural resources, the living environment, and public health. SDG 11 aims to make cities and human settlements inclusive, safe, resilient and sustainable through the realization of various targets, including: promoting participatory and inclusive urban planning and management; strengthening links between urban, peri-urban and rural areas; embracing environmental and climate issues, including air quality and waste management, resource efficiency, mitigation and adaptation to climate change, and resilience to disasters.

Until recently, urban livestock production was often regarded as problematic and was severely restricted by city laws and policies. However, keeping livestock in urban settings is now gaining greater recognition because of the benefits it can offer city dwellers. Livestock production often has an essential role to play in and for cities, especially in developing countries. Its principal benefits include income generation, employment creation and improved urban food security, nutrition and health. It also plays an important role in poverty alleviation and the social inclusion of disadvantaged groups, especially women, and in enhancing the resilience of city dwellers to food or economic crises. Proximity to local markets makes urban livestock production attractive, especially for perishable foodstuffs. However, before the sector can fully contribute to meeting the SDG 11 goals and targets, several issues regarding health and environmental risks must be resolved.

SDG 12. SUSTAINABLE CONSUMPTION AND PRODUCTION

According to some ecological footprint studies, including by the World Wide Fund for Nature (WWF) and the Global Footprint Network (GFN), humans are already using more than one earth's worth of resources and could consume the reserves of three planets by mid-century. Though these studies are controversial, they raise the question of whether there will be enough to sustain 8.6 billion people in 2030. SDG 12 is concerned with sustainable consumption and production and aims to "do more and better with less". The objective is to increase net welfare gains from all economic activities while reducing the amount of resources used, and at the same time lowering environmental degradation and pollution. Because improvements are needed along the whole life cycle of products,

this goal requires the involvement of various stakeholders, including consumers, policymakers, retailers and industry representatives. SDG 12 targets give priority to programming and encourage governments to undertake public procurement policies that support sustainability and help the private sector to integrate sustainable practices in their production cycles.

As a particularly resource-hungry sector, livestock can contribute very significantly here. Yield gaps and large potential for efficiency gains have been identified in all regions and production systems. However, sustainability is required on the demand side too. SDG 12 targets highlight the importance of information, especially to consumers. They stress the need for education and encourage developed countries to take the lead in implementing programmes promoting sustainable consumption. This is critical for livestock in particular as demand for ASF is growing fast in developing countries. Finally, reducing waste and loss, as well as chemical pollution, is also listed as a key SDG 12 target. Significant efforts are needed throughout food supply chains, with the participation of all stakeholders, to reduce the amount of meat, milk and eggs wasted by consumers and the food industry or lost in the production process. This can deliver major sustainability gains.

SDG 13. TAKE URGENT ACTION TO COMBAT CLIMATE CHANGE AND ITS IMPACTS

The UN recognizes that climate change is the single biggest threat to development. 2016 was the third hottest year recorded in a row. The same year, the average CO_2 concentration in the atmosphere surpassed the emblematic threshold of 400 parts per million, a level never before reached in recorded history (more than 650 000 years). The current rate of increase is more than 100 times faster than when the last ice age ended. The already alarming climate change impacts on agriculture, and the implications for food security, are that the burden will disproportionately fall on the poorest and most vulnerable. SDG 13 aims to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters. Its second target is to integrate climate change measures into national policies, strategies and planning, which means increasing countries' ability to adapt to the adverse impacts of climate change but also fostering low emissions development.

Climate change impacts livestock directly (for example through heat stress and increased morbidity and mortality) and indirectly (e.g. through quality and availability of feed and forages, and animal diseases). Smallholder livestock keepers, fisherfolk and pastoralists are among the most vulnerable to climate change. At the same time, the livestock sector contributes significantly to climate change in that direct livestock GHG emissions, from manure and enteric fermentation, represented 2.4 gigatonnes of CO_2 equivalent in 2010, about 21 percent of total emissions from agriculture, forestry and other land uses, or about 5 percent of total anthropogenic GHG emissions. FAO estimates that emissions from livestock supply chains, including feed production, processing and transport as well as energy used on and off farm and post-farm emissions, account for about 14.5 percent of total anthropogenic emissions.

SDG 14. LIFE BELOW WATER

Over three billion people depend on marine and coastal biodiversity for their livelihoods, while broadly the same number obtain almost 20 percent of their average intake of animal protein from fish. In addition, fish provides essential fats such as long-chain omega-3 fatty acids, vitamins A, B and D, and minerals. However, pressure on global fish resources has been increasing steadily in recent decades. In 2013, about 58 percent of marine stocks were fully fished, with no potential for increased production, and 31.4 percent were overfished, with production increases only possible after successful restocking. SDG 14 seeks to promote the conservation and sustainable use of marine and coastal ecosystems; to prevent marine pollution; to increase economic

benefits to small island developing states (SIDS) and least-developed countries (LDCs) from the sustainable use of marine resources.

A significant, but declining, proportion of the world's fish catch is processed into fishmeal (mainly for high-protein feed) and fish oil (as a feed additive in aquaculture, but also for human consumption). Fishmeal and oil can be produced not only from whole fish but also from fish remains or other fish by-products. Overall demand continues to grow making a substantial contribution to the depletion of marine stocks. Pigs and chickens currently use about 27 percent of global fishmeal production. A significant problem is that nutrient runoff and leaching from livestock waste has serious environmental consequences if not properly managed, and can be very detrimental to coastal marine fisheries. Leaching rates vary depending on climatic and soil conditions, and differ significantly between countries or regions within a country.

SDG 15. LIFE ON LAND

Across the globe, natural resources are deteriorating, ecosystems are degraded and biological diversity is being lost. Changes in land use, including deforestation, result in the loss of valuable habitats, less clean water, land degradation, soil erosion and the release of carbon into the atmosphere. Such damage is mainly attributable to the conversion of forest or rangelands to other land uses such as agriculture and infrastructure development. SDG 15 is based on the axiom that healthy ecosystems protect the planet and sustain livelihoods. Focusing largely on biodiversity and land use, SDG 15 aims to enhance the delivery of ecosystem services from all types of environments, with explicit targets on conserving ecosystems and genetic resources, restoring land, halting deforestation and combating desertification.

Livestock production is ubiquitous, with up to 25 percent of the earth's land area covered by rangelands. Livestock populate about 70 percent of that area while 33 percent of croplands are used for fodder production. In recent years, awareness and scrutiny has grown regarding the livestock sector's impact on biodiversity, land use and climate change. However, whether livestock benefits or damages the environment depends not only on the kind of production system used, but also on how it is used. Livestock can provide valuable regulating and supporting ecosystem services through their direct interaction with land, vegetation, soil and habitat. Sustainable grassland management, enhanced provision of ecosystem services through livestock and moderate improvements in feed-use efficiency are key to achieving SDG 15.

SDG 16. PEACE AND JUSTICE

According to the United Nations, many countries still face protracted violence and armed conflict, and far too many people suffer under weak institutions and lack access to justice, information and other fundamental freedoms. By the end of the year 2015, a little over 65 million individuals were displaced worldwide as a result of conflict, generalized violence, or human rights violations whose origins could often be traced to agricultural, livestock and food/economic crises. Most of the displaced people were livestock producers from rural areas. SDG 16 envisages peaceful and inclusive societies based on respect for human rights, the rule of law, good governance at all levels, and transparent, effective and accountable institutions.

Poor governance and the absence of law provide fertile ground for conflicts over land use and management, which jeopardize the livelihoods of pastoralists who depend on readily available rangeland resources and grazing areas. Climatic changes and related loss of resources further exacerbate their insecurity. Civil unrest and humanitarian crises take a harsh toll on the livestock sector as collective insecurity quickly translates into higher livestock mortality, lower productivity and reduced access to local and national markets. Ecosystems and biodiversity, which well-managed livestock help to protect and preserve, are also hard hit under such conditions. Emergencies caused by climate change

variability and natural disasters can cause massive social disruption and sudden migratory movements, including the large-scale displacement of livestock farmers.

SDG 17. PARTNERSHIPS FOR THE GOALS

The adoption of Agenda 2030 for Sustainable Development marked a turning point in the global community's approach to development. The SDGs embrace economic, social and environmental aspects of development and highlight the importance of the linkages between them. The breadth of knowledge, experience and expertise required for SDG implementation also implies mobilizing a broad range of competencies and the participation of non-state actors, such as civil society organizations, producer organizations, the private sector, academia and research institutions. This will be fundamental to the achievement of all SDGs along the three dimensions of sustainable development – economic, social and environmental. SDG 17 calls for multi-stakeholder partnerships between various actors to help provide financial, knowledge and institutional support to spur progress across different sectors. By working together in partnership, all stakeholders can help achieve transformative change.

At present, the livestock sector already counts on a number of multi-stakeholder partnerships at global and regional levels. They play a key role in ensuring sustainable growth in livestock production, meeting rising global demand while addressing related environmental, social and economic challenges. The following are some of the many leading partnerships with recognized work on sustainable livestock development: One Health, Global Agenda for sustainable livestock (GASL), Livestock Environmental Assessment and Performance (LEAP) Partnership, Global Pastoralists Knowledge Hub, Multi-stakeholder Feed Safety Partnership, Tripartite partnership of FAO, World Health Organization (WHO), and World Organisation for Animal Health (OIE), Global Alliance for Livestock Veterinary Medicine (GALVmed), Livestock Global Alliance, Dairy Asia, Partnership for Livestock Development, Poverty Alleviation and Sustainable Economic Growth in Africa (ALIVE), and the Latin American Commission for Sustainable Livestock Development (CODEGALAC).

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1. Livestock and no poverty

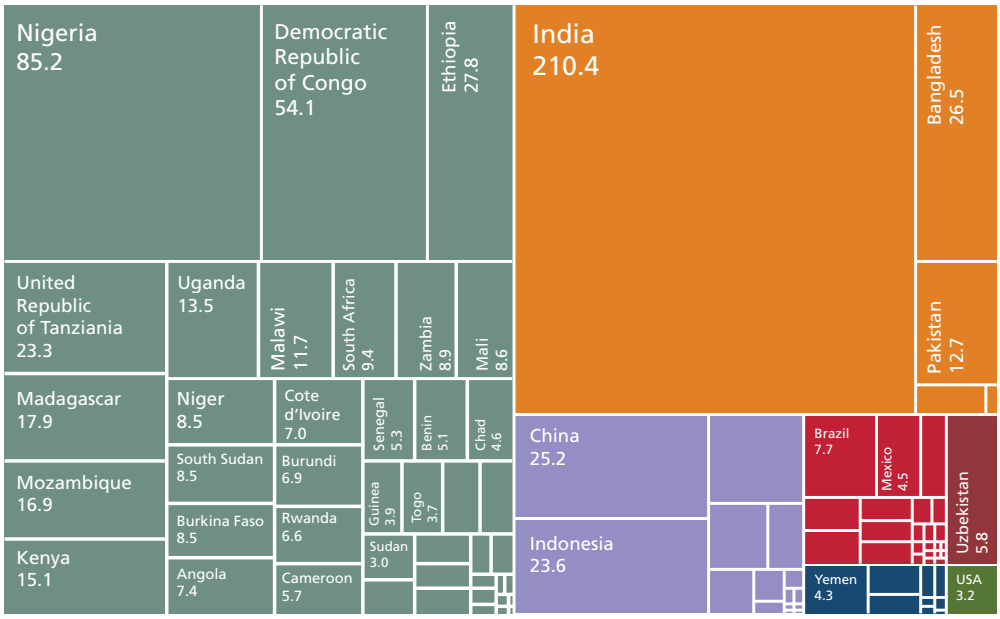
INTRODUCTION

While extreme poverty rates have declined since 1990, the number of people living in those conditions globally remains unacceptable high (Figure 1). According to the most recent estimates, one in five people in developing regions lived below the international poverty line of USD 1.90 per person per day in 2013 (World Bank, 2017). Although poverty rates have declined in all regions in recent decades, progress has been uneven. Falling poverty levels have been largely driven by rapid advances in East Asia and the Pacific and in South Asia, leaving sub-Saharan Africa as the poorest region, and where half of the world's extreme poor live. Moreover, as we struggle to fight poverty, some 200 million people remain unemployed and an additional 600 million new jobs will be needed over the next 15 years to absorb burgeoning working-age populations (World Bank, 2013). Goal 1 of the United Nations' Agenda for Sustainable Development (SDG 1) takes a multidimensional approach to ending poverty in all its forms. SDG 1 targets include eradicating extreme poverty; building resilience among the poor; and creating sound policy frameworks (UN, 2016a).

Livestock are catalytic in helping rural households achieve their livelihood objectives. First, they enhance human capital by providing access to food, continued good health, and labour for the pursuit of activities. Second, they build social capital, strengthening the cultural diversity and heritage of several ethnic groups and populations. Third, they contribute to the stock of the natural capital that provides the resources and services needed to maintain and improve livelihoods. Fourth, they increase physical capital, providing transport, draught power and alternative energy for households to support and improve their productivity. Fifth, they increase the financial capital of families, provide a mechanism for savings, and serve as liquid assets, or as credit collateral, for securing livelihood goals. Sixth, they act as an important buffer against external shocks (Abed and Acosta, 2017).

Given the rapid growth expected for the sector, and the empirical observation that the livelihoods

1 EXTREME POVERTY IN THE WORLD (2013)



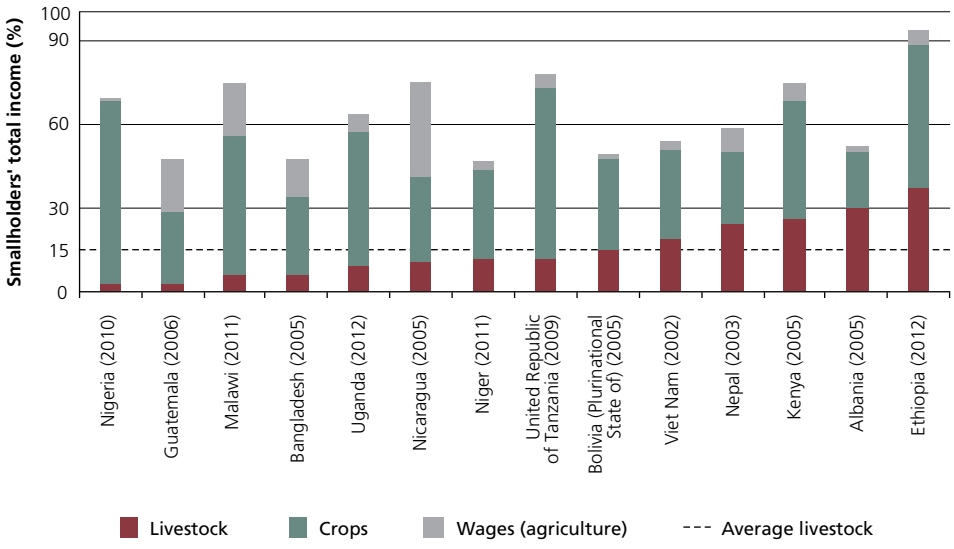
Source: Based on data from the World Bank and the United Nations Population Division, 2018.

of many poor people depend on livestock, the sector's contribution to poverty reduction has been widely anticipated. As noted, livestock play an important role in helping poor households maintain their livelihood levels. However, they may not necessarily be able to capture the benefits from the sector's expected growth. Livestock's effective capacity to transform rapid growth into poverty reduction depends on a combination of microeconomic and macroeconomic factors. The former include the capacity of producers to use their livestock-related assets to generate income; the ability of workers to take up expanding employment opportunities; and the possibility for consumers to benefit from more competitive prices (De Janvry and Sadoulet, 2009). The latter comprise the size of the sector in the economy, its level of growth, and the participation of the poor in that growth (Christiaensen *et al.*, 2011).

THE CATALYTIC ROLE OF LIVESTOCK IN STRENGTHENING HOUSEHOLD LIVELIHOODS

The correlation between livestock growth and poverty reduction is still an understudied topic in economic literature. One issue has to do with data quality and availability. Often the statistical information available in agricultural or household surveys does not allow one to differentiate between various livestock activities in household livelihood strategies. Thus, it is difficult to isolate the specific role played by livestock assets. In the best of cases, when the information is available it is reported, aggregated in the form of Tropical Livestock Units (TLUs), making it extremely complex to assess the effects of the composition of herds and the particular relevance of certain animal species. However, the importance of accounting for the composition of livestock assets has been stressed by some recent publications. Bati (2013) and Ngigi *et al.* (2015), for

2 SHARE OF INCOME-GENERATING ACTIVITIES IN SMALLHOLDERS' TOTAL INCOME



Source: Based on data from FAO Smallholder Farmers' Dataportrait, 2018.

instance, stressed the importance of small ruminants in building resilience to climatic risks and additional shocks, but also noted that shocks affect different livestock groups in different ways. In a study in Madagascar, Feldt (2015) stressed how goats, which primarily feed on grasses, are generally less affected by regional droughts and climatic stress than other livestock. Hence, it is argued, there is increasing importance of goats, small ruminants, and more generally of livestock portfolio diversification as a coping strategy for drought. Nevertheless, a proper test of this hypothesis on an aggregate scale is still missing.

The evidence that growth in the livestock sector leads to poverty reduction is still inconclusive. Pica-Cimarra *et al.* (2015), exploiting household level data, show that livestock are an important asset for all income groups in the 12 countries they analysed, but that there are no strong correlations between household wealth, herd size and livestock species owned. Alary *et al.* (2011), studied the multiple and complex role of livestock in Niger. Their descriptive analysis highlights that the main contribution of livestock to poverty reduction lies in its interaction with other economic activities, since there is no direct correlation between livestock and income. Finally, Ellis and Mdoe (2003), show how, in the United Republic of Tanzania, livestock ownership is concentrated in the top quartile of income distribution, and ownership in lower groups is nearly non-existent.

Acosta *et al.* (2018) point out that, rather than assessing the relationship between livestock and poverty in terms of simple income generation, livestock's contribution should be understood in light of the catalytic role they play in helping poor people achieve their livelihood goals. In order to better capture the relationship between livestock and poverty, the contribution of livestock production to income generation should

not be isolated from other agricultural and non-agricultural sources of income. They all form part of the complex livelihood strategies employed by rural households to build resilience and fight poverty.

As shown in Figure 2, agriculture is the main income source of smallholders in most developing countries. The share of livestock-related activities in smallholders' total income varies from country to country but averages around 15 percent. This share is highest in Ethiopia (37 percent), Albania (28 percent) and Kenya (25 percent), and lowest in Guatemala and Nigeria (both 3 percent). In relative terms, livestock activities constitute the third most important source of income, after crops and non-agricultural employment, and above agricultural employment, transfers and other revenues. Livestock thus play a major role as a source of income diversification in rural households' economic portfolios. The resources generated through livestock activities serve to "hang in" (i.e. to maintain livelihood levels), to "step up" (expand these activities to generate fresh income), or to "step out" (accumulate assets in order to move into different activities) (Dorward *et al.*, 2009).

The relationship between livestock activities, income diversification and poverty reduction is not straightforward, however. For example, if the share of livestock activities increases together with rising incomes, it may be a sign that households are using livestock as a "stepping up" strategy to improve their livelihoods. Alternatively, if livestock activities increase as incomes decrease, it could indicate that households are employing livestock to "hang in" in the face of adverse socio-economic circumstance, or because they cannot diversify their sources of income. Lastly, a decrease in livestock activities as incomes rise could be a sign that households are using livestock as a "stepping out" strategy to accumulate assets to then move into different activities (Dorward *et al.*, 2009; Davis *et al.*, 2010).

LIVESTOCK AS A RESILIENCE STRATEGY

Dealing with climatic shocks and other types of exogenous income-reducing crises can be extremely hard for poor, ill-equipped households. This is especially true for farmers in rural areas lacking adequate financial support or formal and informal safety nets (Banks *et al.*, 2001). Indeed, these difficulties are magnified when shocks hit all members of the same community simultaneously, as in the case of natural disasters and other climatic shocks (Binswanger and Rosenzweig, 1986). For example, a severe drought affecting an entire region may impose severe hardship on entire villages, inhibiting local-based consumption-smoothing mechanisms that could, in normal circumstances, provide some insurance against unexpected consumption reductions.

The role of livestock in building resilience against external shock has been highlighted. Herds can be viewed as a precautionary form of savings as they represent an asset that can be realized whenever needed (Dercon, 2002). This becomes especially relevant in periods with low and poorly distributed rainfall leading to crop failures, and is even more important in the absence of credit facilities (Banks *et al.*, 2001). Under such conditions, farmers owning both crops and livestock can be expected to be more resilient to climatic shocks, or in general more capable of coping with different types of external stresses. This mechanism, however, can be weakened by several factors. First, poorer farmers may need to conserve a positive livestock holding in order to maintain a reproductive herd, at least as long as consumption remains above subsistence level. Second, the insurance function of livestock can be limited by the correlation of income shocks and asset shocks (McPeak, 2017). Third, if, following a crisis, several farmers in the same area decide to sell their livestock to cope with income loss, this will determine a fall in the market price for livestock, and a consequent disincentive to selling additional units (Kazianga and Udry, 2006).

Several studies in sub-Saharan Africa have shown how livestock assets can help cushion sudden drops in income and agricultural production (Kinsey *et al.*, 1998; McPeak, 2004) since they can be accumulated in good years and sold to smooth consumption in bad ones. Similarly, Rosenzweig and Wolpin (1993), using data from India, found that bullocks, which are traditionally used as source of mechanical power, are often also used to smooth consumption in income crises. Nevertheless, the authors note that the short-term benefits of selling livestock come at the price of reduced long-term crop productivity due to the loss of draught power. Seo (2011), shows that an integrated farm owning both crops and livestock is more resilient under global warming than a farm specialized in crops or livestock. Finally, a recent analysis by Hanke and Barkmann (2017) confirms that livestock sales contribute to farmer earnings and that small ruminants play a fundamental role in compensating for food expenditure, thus increasing household resilience.

Contrasting results, however, can be found in studies by Fafchamps *et al.* (1998), Fafchamps and Lund (2003), and Hoogeveen (2002), which have consistently found that livestock sales have a small or insignificant effect, suggesting that such sales do little to smooth consumption in the face of income loss. Similarly, a study by Kazianga and Udry (2006), examines the role of livestock, grain storage and intra-household transfer in smoothing consumption in response to income risks. Their analysis is based on a survey conducted between 1981 and 1985 in Burkina Faso, during a period of severe drought. Overall, they found that livestock did not serve as a buffer stock during the period analysed, while the accumulation and decumulation of grain stocks did help to smooth consumption during the crisis. However, the size of this effect was small.

Figure 3 presents the average regional value of the Standardized Precipitation-Evapotranspiration Index (SPEI) as a proxy for climate shocks in a number of African countries surveyed in different years. This index, recording anomalies in temperature and their effects on drought intensity, makes it clear that we are witnessing an exogenous shock, (Acosta *et al.*, forthcoming). As precipitation decreases (and/or temperature rises) the value of the index becomes negative. Thus, a lower index number means a more severe drought with respect to numbers close to zero. The figures evidence a degree of homogeneity as most of the countries show negative values, highlighting drought as an exogenous shock severely impacting the livelihoods of rural households.

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Merging this data with the FAO Smallholder Farmers' Portrait Database, Acosta *et al.* (forthcoming) were able to test the role of livestock as an ex-ante form of risk management and self-insurance coping strategy against climatic shocks. More specifically, the authors tested the effect of both climate shocks and livestock (measured in TLU), and their interaction on two distinct measures of household welfare: income and consumption. The analysis was carried out exploiting a large cross-sectional dataset, which included over 223 000 households in 19 countries. The authors were thus able to exploit a quintile regression framework, and presented different regression results for different quintiles of both income and consumption distribution, as the relationship between coping strategies and welfare outcomes is expected to be inconstant across income groups (Asfaw, 2018).

When using income as a dependent variable, the same study found that an increase in rainfall and a decrease in temperature are, on average, associated with higher total income levels. This means, in other words, that climatic conditions impact welfare. Also significant is the effect of TLU, confirming a positive association between the number of livestock units and household income. Interestingly, this effect varies with income level, and gets larger and stronger as we move from the first to the last quintile. Finally, the interaction has a positive coefficient, which can be interpreted as confirmation that, on average, livestock partially mitigate the negative impact of the SPEI on total income. This result is particularly evident for poorer households, where the size of the interaction effect is significantly higher with respect to the aggregate effect.

Replicating the analysis in other continents provides some additional insights. In African, European and Central Asian countries, the main evidence is in line with aggregate results. On the contrary, in Latin America, the effect of climate anomalies is very low or insignificant across the different income groups, and the interaction has the inverse result with respect to expectations. According to the authors, the main possible explanation is to be sought in the different composition of livestock in Latin America. In other words, the big ruminants typical of South American countries, being more sensitive to drought, might have a negative impact on income when households face adverse climatic conditions. However, this is just a hypothesis and was not formally tested in the analysis.

When using consumption as a dependent variable, the study found similar but less robust results with respect to the income case. In sum, Acosta *et al.* (forthcoming), find that livestock have a significant contribution to household welfare and resilience in most of the samples considered in the analysis; secondly, climatic crises tend to be regressive, and poorer households are generally more affected; thirdly, country specificity matters.

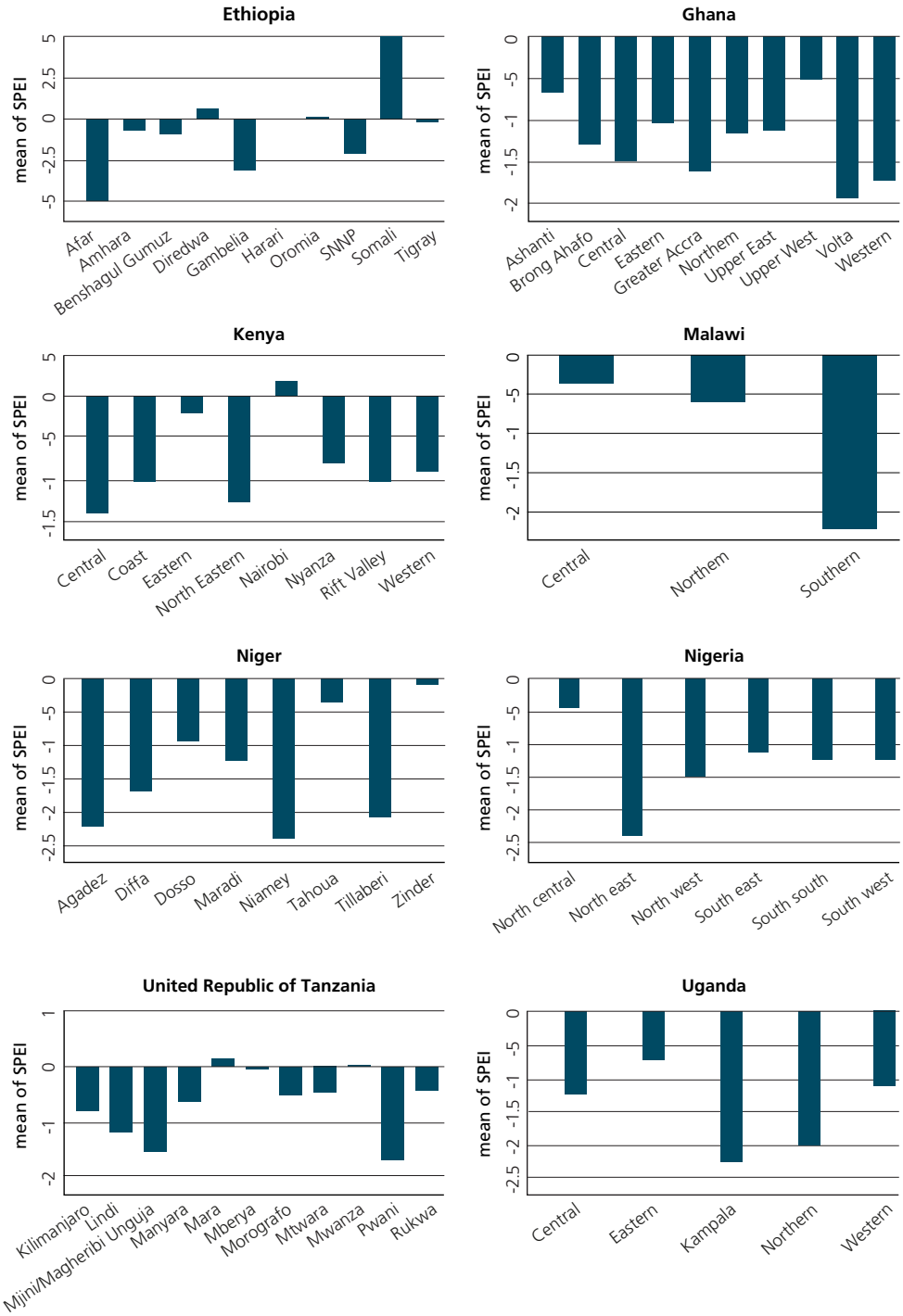
TRANSLATING FAST ECONOMIC GROWTH INTO FASTER POVERTY REDUCTION

Empirical evidence indicates that successful macroeconomic performance is a precondition for fighting poverty (Cervantes-Godoy and Dewbre, 2010). Traditionally, livestock poverty analysis has focused on studying the microeconomic effects of livestock assets on poor household livelihoods, with less attention given to higher-level economic factors that determine the sector's potential contribution to poverty alleviation. This situation has led to a limited understanding of how rapidly evolving livestock market trends and structures influence poor people's capacity to make a decent living from stock raising. Part of the macroeconomic debate on economic growth and poverty reduction bears on the issue of the actual contribution of growth in individual sectors to poverty reduction (Bourguignon, 2003).

Globally, livestock's share of agricultural output is about 40 percent in developed countries, and 20 percent in developing countries. According to the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) (OECD and FAO, 2017), livestock has been one of the fastest-growing agricultural sectors in developing nations. There is little doubt that rapid economic growth contributes to poverty alleviation (Christiaensen *et al.*, 2011; De Janvry and Sadoulet, 2009), indeed, according to Loayza *et al.* (2010) agriculture is acknowledged as the economic sector with the highest impact on poverty reduction. However, the correlation between rapid growth in livestock production and rural poverty reduction is still an understudied topic.

Between 2000–2004 and 2009–2013, the total gross production value of livestock commodities increased substantially in many developing countries. Yet while some of the poverty reduction figures are impressive, the relationship between livestock's economic performance and the level of rural poverty alleviation is less

3 STANDARDIZED PRECIPITATION-EVAPOTRANSPIRATION INDEX (SPEI)



Source: Acosta *et al.*, forthcoming.

TABLE 1
SMALLHOLDER FACTORS OF PRODUCTION

	SMALLHOLDERS *(%)*	AVERAGE FARM SIZE *(Ha)*	LIVESTOCK TROPICAL UNITS *(LTU)*	FAMILY LABOUR *(Person/Day)*
Kenya (2005)	75	0.5	1.6	1.7
Ethiopia (2012)	75	1.0	2.1	1.0
Malawi (2011)	75	0.5	0.6	0.3
Niger (2011)	78	2.6	0.9	0.4
Nigeria (2010)	90	0.6	2.4	0.9
United Republic of Tanzania (2009)	80	0.9	1.4	1.1
Uganda (2012)	75	0.7	0.2	0.7
Bangladesh (2005)	80	0.2	0.7	0.8
Nepal (2003)	81	0.6	1.7	2.5
Guatemala (2006)	84	0.7	1.0	1.0
Albania (2005)	74	0.4	1.4	1.4
Simple mean	**79**	**0.8**	**1.3**	**1.1**

Source: Based on FAO Smallholders Farmers' Data Portrait, 2017.

clear. For example, while in Mali, Ethiopia and Uganda the gross value of livestock production increased by 80, 52, and 50 percent respectively, the rural poverty headcount ratio decreased by 14, 9, and 18 percent. The fact that the sector's impressive growth performance has not matched a corresponding drop in rural poverty suggests that fast livestock growth *per se* may not automatically translate into benefits for the poor. Much depends on the pattern and composition of the growth, on employment and productivity intensity, on the production system profile, and on the market's structure and the level of participation of the poor.

LIVESTOCK GROWTH AND EMPLOYMENT GENERATION

The level of employment, the quality of jobs, and whether or not poor people have access to decent jobs are crucial determinants of poverty reduction (Hull, 2009). Population prospects suggest that the capacity of creating decent employment is, and will continue to be, one of the major challenges in developing countries over the coming decades. Considering that poverty is largely a rural phenomenon in many of those countries, pro-poor strategies will have to pay special attention to job creation in rural areas. The fact that livestock continue to be an important source of livelihoods will need to be reflected in those strategies, and given that related manufacturing activities will also be expanding rapidly, special attention must be given to creating livestock-oriented jobs outside the farm system.

Increased smallholder labour productivity is essential if livestock growth is to reduce poverty though employment generation. As shown in Table 1, while the vast majority of agricultural producers are smallholders (79 percent), the availability of domestic factors of production to increase the level of smallholders' labour productivity is low. In the developing countries analysed, smallholders typically have less than 1 hectare of land, own around 1.3 livestock tropical units (capital), and absorb around one unit of family labour per day. Consequently, the capac-

ity of smallholder production units to generate employment is limited. Thus, growth that only results in a multiplication of livestock subsistence production units, without changes in labour productivity, may not be enough to alleviate poverty.

CONCLUSION

SDG 1 calls for a multidimensional approach to ending poverty. Given the livestock sector's expected rapid growth, and the assumption that many of the poor rely on livestock for their livelihoods, livestock's positive contribution to poverty reduction has sometimes been taken for granted. Livestock can indeed play a catalytic role in strengthening the assets that rural households use to achieve their livelihood objectives, and in increasing the resilience of families to external shocks. Yet the sector's capacity to turn fast sectoral growth into reduced poverty will vary depending on countries and production systems, and on a combination of macroeconomic and microeconomic factors. These include, on the macro side, the size of the livestock sector in the economy, its growth rate, and the participation of the poor in that growth; and on the micro side, on the capacity of producers to use their livestock-related assets to generate income, the ability of workers to link to expanding employment opportunities, and the possibility for consumers to benefit from more competitive prices.

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2. Livestock and zero hunger

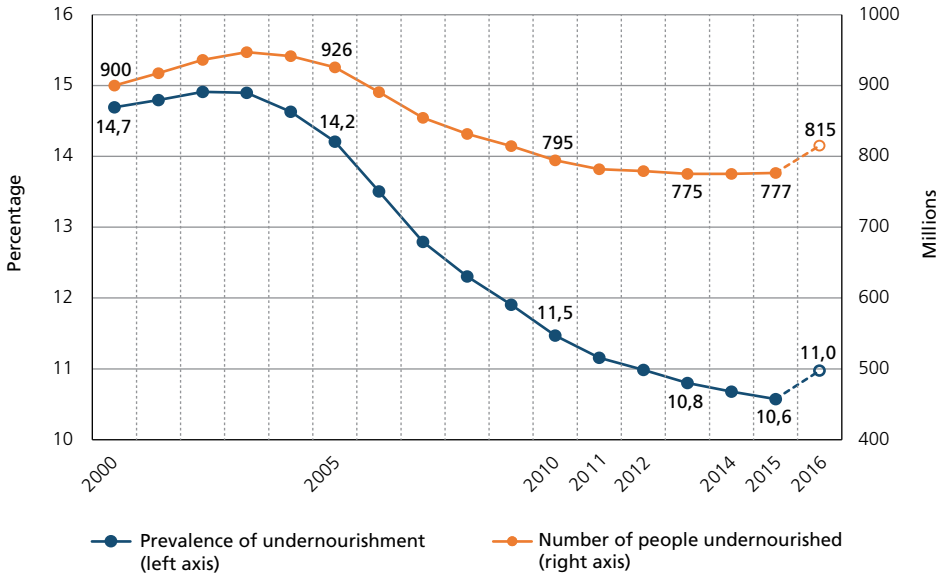
INTRODUCTION

Roughly one in eight people suffer from hunger worldwide, and most of them live in developing countries. Within those countries, approximately 13 percent of the population is undernourished (measured in terms of dietary energy consumption). The persistence of hunger is no longer a matter of food availability. With enough food to feed everyone on the planet, continuing hunger and malnutrition calls for a major change in global food and agriculture systems (UN, 2016a). The United Nations' Millennium Development Goals (MDGs), which preceded the current SDGs, set the target of halving the proportion of people suffering from hunger between 1990 and 2015. During that period, and for the developing regions as a whole, that proportion decreased from 23.3 percent to 12.9 percent. Seventy-two developing countries out of 129, or more than half the countries monitored, reached the MDG hunger target. However, one in eight people in developing countries still fail to obtain sufficient protein and energy from their diets, and even more suffer from some form of micronutrient deficiency (FAO, 2016a).

After a prolonged decline in hunger numbers, the most recent estimates indicate that the number of people in the world suffering hunger increased from 777 million in 2015 to 815 million in 2016. The food security situation has deteriorated above all in parts of sub-Saharan Africa, Southeast Asia and Western Asia, frequently as a result of conflict, drought or floods. However, food security has also declined in more stable settings, especially where economic slowdown has drained foreign exchange and fiscal revenues, affecting food availability in two ways: through reduced import capacity and food access, and through reduced fiscal revenue to protect poor households against rising domestic food prices. The latest hunger figures stand as a warning that the goal of a world without hunger by 2030 is a challenging one. It will require renewed efforts and novel ways of working (FAO, 2017a).

SDG 2 takes a system-wide approach to ending hunger, with an emphasis on achieving food security and improved nutrition, and on promoting

4 PREVALENCE AND NUMBER OF UNDERNOURISHED PEOPLE IN THE WORLD 2000–2016

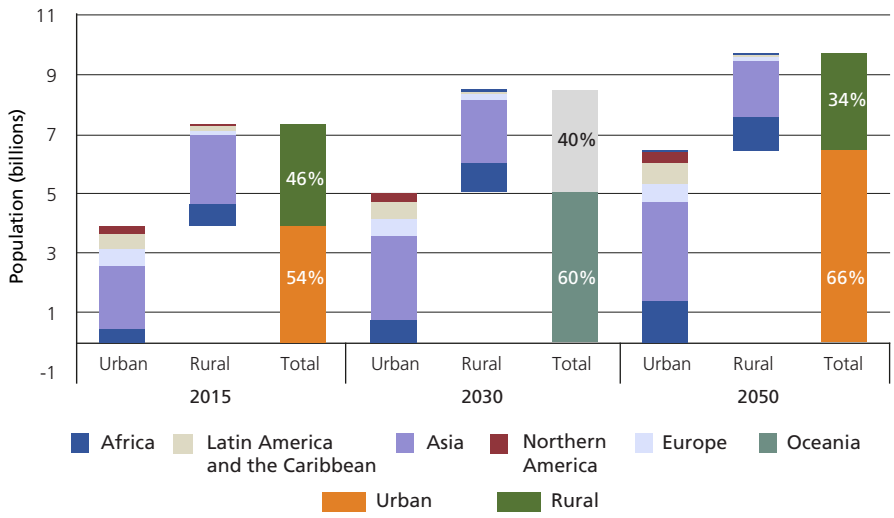


Source: FAO, *The State of Food Security and Nutrition in the World*, 2017.

sustainable agriculture. SDG 2 targets include ensuring universal access to safe, nutritious and sufficient food all year round, improving the productivity and income of small-scale food producers, promoting sustainable and resilient food production systems, maintaining the diversity of genetic resources for food and agriculture, and ensuring the proper functioning of food markets (UN, 2016a). The livestock sector can play a key role in ending hunger, contributing at different levels and from different angles. At the household level, its principal contribution is increasing the direct consumption of healthy and nutritious animal-source foods (ASFs) and helping generate income; at rural community level, its contribution is related to the creation of employment opportunities in livestock and food chains upstream and downstream. In terms of national economies, an enhanced livestock sector can help reduce ASF prices, generate fiscal revenue, and earn foreign exchange. At the global level, it can supply the world with sufficient and reliable supplies of meat, milk and dairy products.

The livestock sector will, however, have to overcome a new set of interconnected challenges if it is to deliver on expectations. Increased demand for ASFs will add to existing pressure on ecosystems. Livestock producers will face greater competition for capital, labour, land, water and energy, and productivity is therefore expected to increase, but at a diminishing rate. The ongoing structural transformation of livestock markets could prevent small producers and poor consumers, particularly in developing countries, from benefiting from economic growth and improvements in productivity. Overarching all these issues is the need to curb the negative effects of livestock production on biodiversity and the environment, to stop the improper use of antimicrobials, and to minimize trade-offs on other SDGs from achieving SDG 2 targets.

5 RURAL AND URBAN POPULATION 2015–2050



Source: Based on data from the Department of Economic and Social Affairs of the United Nations, 2017.

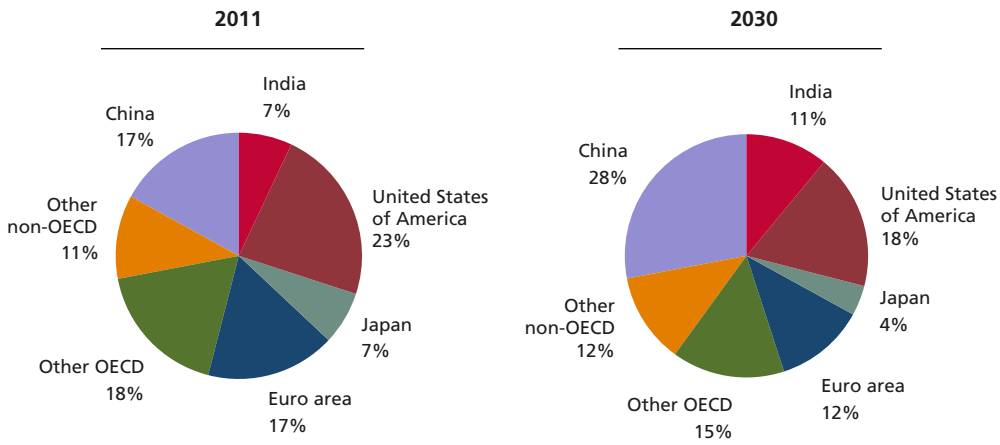
GLOBAL TRENDS IMPACTING THE SECTOR

According to the UN World Population Prospects, 2017 Revision (UN, 2017), the world's population was nearly 7.6 billion in 2017, meaning that the planet has added approximately one billion inhabitants in little more than a decade. Today, children under 15 years of age account for roughly one quarter of the world's inhabitants, people over 60 for just over one eighth, while more than half of all humans on the planet are adults between 15 and 59 years old. By 2030, the world's population is projected to increase again, by slightly more than one billion to 8.6 billion, and to increase further to 9.8 billion in 2050. Of the net 2.2 billion increase expected in the world between 2017 and 2050, 1.3 billion, or more than half, will be in Africa. By 2050, most of the world's people – 54 percent, or 5.2 billion – will live in Asia, 26 percent in Africa (2.5 billion), 8 percent in Latin America and the Caribbean (780 million), 7 percent in Europe (716 million), 4 percent in North America (435 million), and 1 percent in Oceania (57 million).

Over the last six decades, the world has undergone a process of rapid urbanization (UN, 2014). In 1950, more than two people out of three lived in rural settlements. Today, over half of the world's population lives in urban areas. The coming decades will bring further profound changes to the size and spatial distribution of the global population. Continuing urbanization and population growth is projected to pack 1 billion people into towns and cities during the coming 13 years, with 85 percent of the increase taking place in Asia and Africa. Meanwhile, the world's rural population, which has been growing slowly since 1950, will reach its peak in a few years' time. Thus, by 2030 the proportion of the world's population is expected to be 60 percent urban and 40 percent rural.

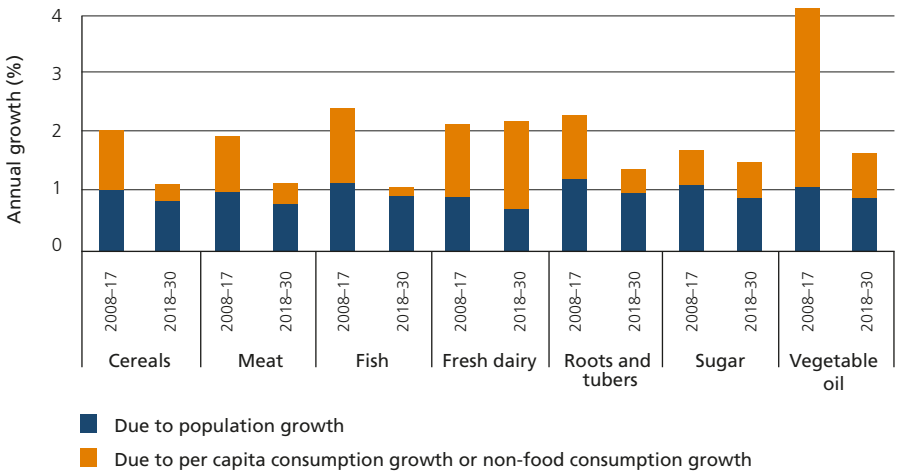
The OECD's long-term global growth prospects (OECD, 2012) indicate that the global economy should grow by 2.8 percent annually over the next decade, but growth in developing economies will be faster and stronger than in developed ones. The coming years will see major changes in countries' share of global GDP

6 CHANGES IN COUNTRY SHARE OF GLOBAL GDP (REAL GDP AT 2005 PPPs)



Source: OECD, 2012.

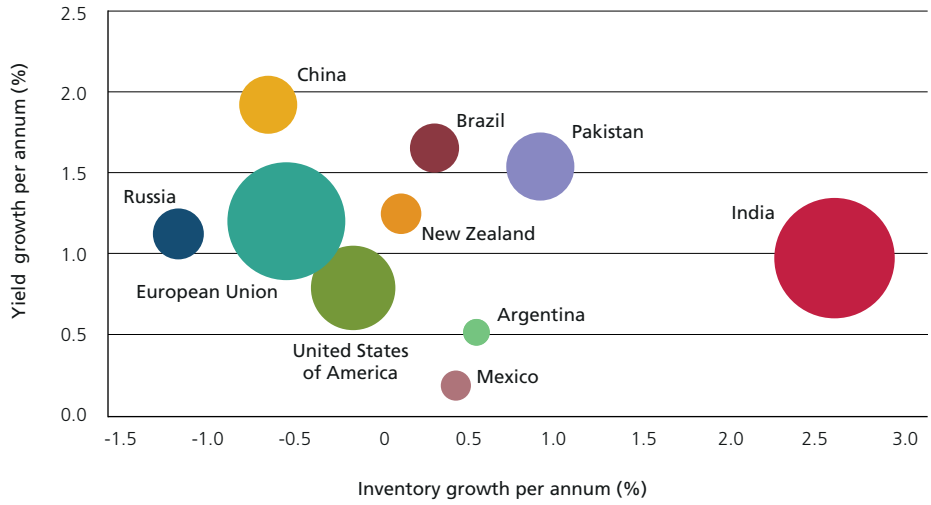
7 GROWTH IN DEMAND FOR KEY COMMODITY GROUPS, 2008–17 AND 2018–30



Source: FAO 2018, Aglink-Cosimo projections.

(Figure 6). For example, OECD countries, which accounted for 65 percent of global economic activity in 2011, will see their share of GDP shrink to 49 percent of world total by 2030. The United States of America, with 23 percent of the global economy in 2011, will see its GDP share drop to 18 percent by 2030. The People's Republic of China, which produced 17 percent of global GDP in 2011, is projected to become the biggest economy in 2030, with 28 percent of world product. India is currently overtaking Japan and will pass the Euro area in about 15 years.

8 GROWTH IN MILK PRODUCTION BETWEEN 2018 AND 2030



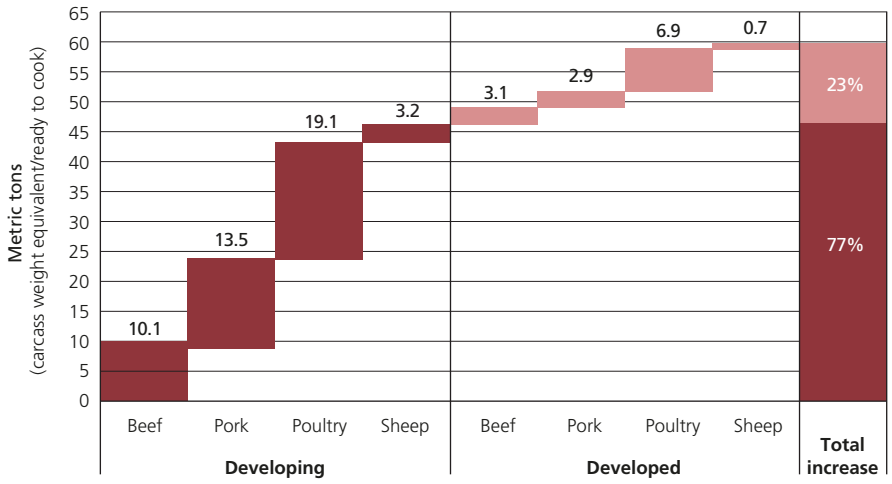
Source: FAO 2018, Aglink-Cosimo projections.

The combination of population, urbanization and income growth is expected to increase global demand for food. However, the rate of increase should slow down as income growth in the People's Republic of China is projected to flat-line, driving down spending on food. This is true for most of the commodities analysed below except for fresh milk, where a further increase in demand growth is expected (Figure 7). Income growth is often assumed to apply across the entire population and influence demand for agricultural products. However, the benefits of economic growth may not be spread evenly, so that consumers at the bottom of the income ladder may not see a corresponding increase in their incomes (OECD and FAO, 2016). This partially explains the fact that while consumption will be mainly driven by population growth during the next decade, per capita demand growth will only play an important role for a few commodities (OECD and FAO, 2017).

According to the FAO Aglink-Cosimo projections, global milk production in 2030 will be 33 percent above the 2015–2017 baseline. Production growth in developing countries will stem from a combined increase in dairy herds of about 1.2 percent per year, and a yield increase of about 1.0 percent per year; while in developed countries growth will mainly come from improved yields (Figure 8). The three largest producers in the baseline period are the European Union (Member Organization) (21 percent), India (20 percent), and the United States of America (12 percent). By 2030, India will have outpaced the European Union (Member Organization) to become the largest milk producer and will, together with Pakistan, account for nearly one-third of world milk production.

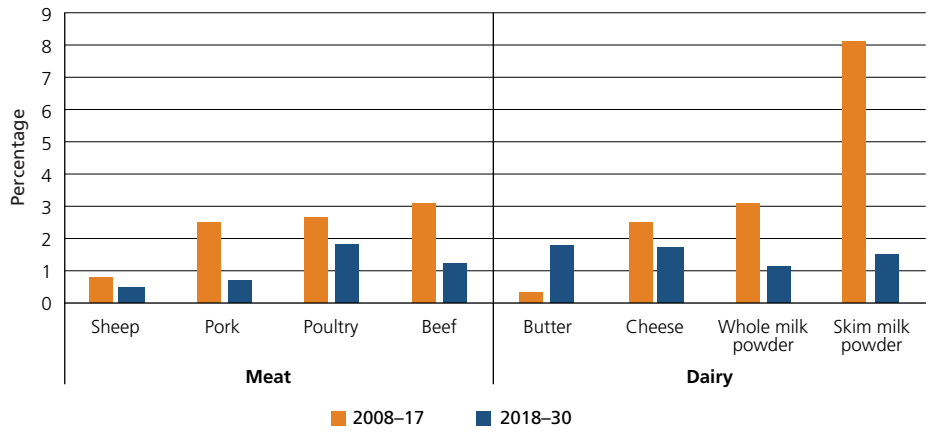
Global meat production is projected to be 19 percent higher in 2030 relative to the 2015–2017 base period. While the largest producers (Brazil, China, the European Union (Member Organization) and the United States of America) will continue to dominate meat production, developing countries are expected to account for almost all of the total increase (Figure 9). The bulk of the additional meat

9 GROWTH IN GLOBAL MEAT PRODUCTION, 2015–17 AND 2030



Source: FAO 2018, Aglink-Cosimo projections.

10 ANNUAL GROWTH IN TRADE VOLUMES, 2008–17 AND 2018–30



Source: FAO 2018, Aglink-Cosimo projections.

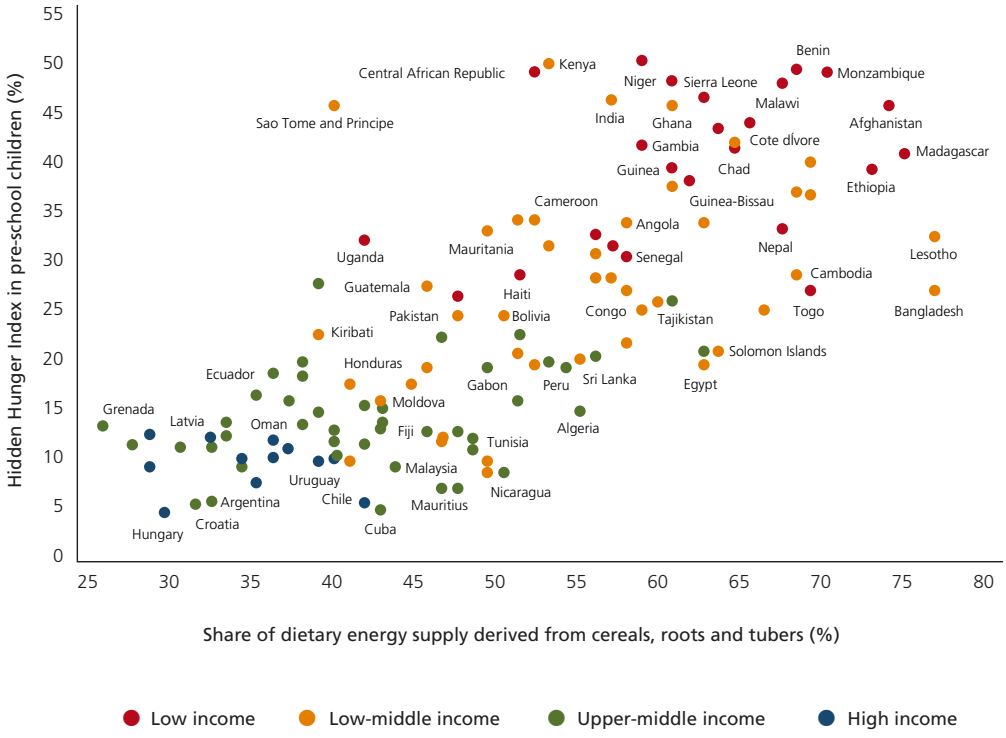
will in fact come from developing countries, where production – notably from Argentina, China, Brazil, India, Mexico and Pakistan – will account for 77 percent of the additional output. Poultry meat will remain the primary driver of growth in global meat production in response to expanding world demand for this affordable source of animal protein. Production will expand rapidly in countries that produce surplus feed grains (OECD and FAO, 2017).

According to FAO Aglink-Cosimo (2018) growth in trade of agricultural commodities is slowing down (Figure 10). Possible reasons include: reduced demand growth; slower growth in global supply chain formation; a slowing of trade reforms; and a maturing trade sector in the People's Republic of China. While the trend to slower growth is evident across most livestock commodities, the change is most pronounced in pig meat and milk powder. Reduced trade growth in the latter reflects changing demand patterns in the People's Republic of China but is also affected by an import ban imposed by the Russian Federation. Despite the slowdown in trade, the relative proportions of different commodities traded will not change drastically. Milk powder remains the most traded agricultural commodity and fresh dairy products will continue to be among the least traded.

LIVESTOCK AND HUNGER ERADICATION: SYNERGIES AND TRADE-OFFS

These global market trends could bring opportunities for the sector to strengthen its contribution to the fight against hunger. However, they present a new set of challenges. Thus, it is likely that policymakers will have to trade gains in one area against loss in others. To better support integration of livestock policy and practices with sustainable development strategies, this section discusses some key synergies and trade-offs.

11 HIDDEN HUNGER INDEX (2009) VS SHARE OF ENERGY INTAKE FROM CEREALS, ROOTS AND TUBERS (2008–2011)



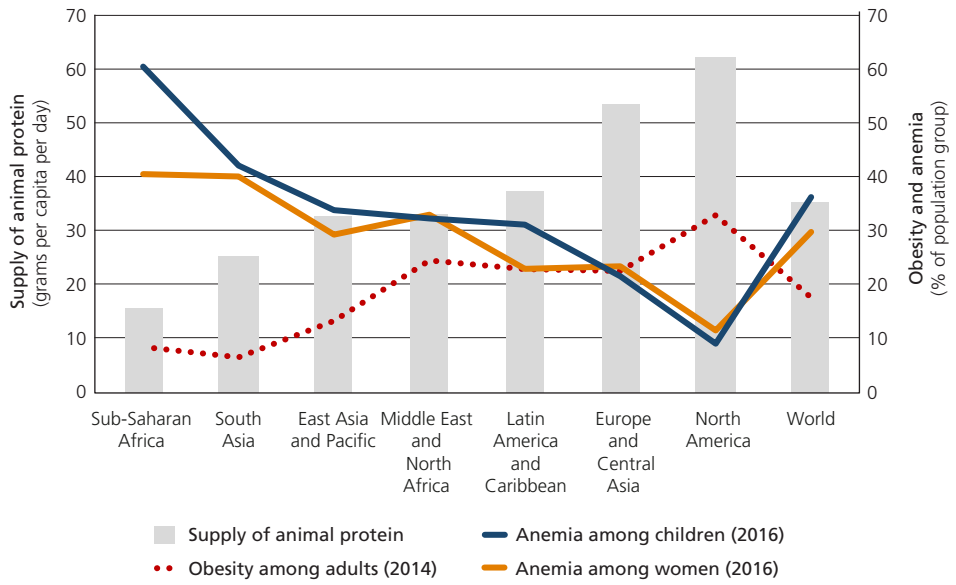
Source: Based on data from FAOSTAT, 2017 and Muthayya *et al.*, 2013.

NUTRITION

Various forms of micronutrient deficiencies affect some two billion people globally, particularly in developing countries. The greatest health burdens of this "hidden hunger" are caused by zinc and vitamin A deficiencies, followed by iron deficiency. Deficiencies in zinc, vitamin A and iron lead to impaired growth, compromised immune functions and, in the case of iron, impaired cognitive development and reduced work capacity. An important factor contributing to these deficiencies is the consumption of mainly plant-based diets that are low in micronutrients (Figure 11). Children have particular difficulty in obtaining adequate energy and nutrients from bulky, plant-based diets.

Livestock and animal-source foods provide readily digestible protein and essential nutrients, and can make critical contributions to ending hunger and improving food security and nutrition. Livestock products contribute to the global human diet with 33 percent of protein intake and 17 percent of calorie intake (Rosegrant *et al.*, 2009). ASFs are nutrient-dense and palatable sources of energy and high-quality protein, and also provide a variety of essential micronutrients, some of which, such as vitamin B12, riboflavin, calcium, iron, zinc, and various essential fatty acids, are difficult to obtain in adequate amounts from plant-based foods alone (Murphy and Allen, 2003). Furthermore, meat increases iron and zinc absorption from fibre- and phytate-rich plant staples (Gibson, 1994). Brown *et al.* (1998) note that only ASFs have the potential to provide enough calcium, iron and zinc for infants. In the case of vitamin B12, all requirements must be met from ASFs, as there is virtually no vitamin B12 in plant-based foods (FAO and EU, 2017). These characteristics make ASFs important for population groups

12 OBESITY AND SUPPLY OF ANIMAL PROTEIN PER REGION



Source: Based on data from WHO and FAO, 2018.

with limited capacity to consume food relative to their needs, like young children and pregnant and lactating women.

Conversely, developed countries and an increasing number of developing nations suffer from adverse health effects, such as overweight and obesity, associated with excessive consumption of red and processed meat and from related chronic diseases (Neumann *et al.*, 2010). Links between disease and overconsumption of ASFs have for years been ascribed to their content of saturated fatty acids. Recent studies, however, have begun to cast doubt on the strength of these links, at least as concerns diets containing moderate levels of animal products (e.g. Fogelholm *et al.*, 2015; Praagman *et al.*, 2016). At the current low levels of consumption of ASFs by the rural poor in developing countries, even small increases in ASF intake provide nutritional benefits that far outweigh any acute or chronic disease risks associated with high consumption of red meat and animal products in high-income countries or high-income households in developing countries (Randolph *et al.*, 2007).

CONSUMPTION SMOOTHING

Livestock composition can be play a particularly significant role in strengthening the consumption-smoothing strategy of small-scale livestock keepers in response to exogenous shocks. The evidence is generally mixed and based on single country case studies. Some analyses have stressed the importance of small ruminants in building resilience to climatic risks and additional shocks, but also note that shocks affect different livestock groups in different ways (Bati, 2013; Ngigi *et al.*, 2015). In a study in Madagascar, Feldt (2015) stresses that goats, which primarily feed on grasses, are generally less affected by regional droughts and climatic stress than livestock. Hence, the increasing importance placed on goats, small ruminants, and more generally livestock portfolio diversification, might be a coping strategy to drought. However, a proper test of this hypothesis on an aggregate scale is still missing.

Contrasting evidence with respect to the above-mentioned aspects can be also found: Fafchamps *et al.* (1998), Fafchamps and Lund, (2003) and Hoogeveen, (2002) have consistently found a small or insignificant effect of livestock, suggesting that livestock sales are unable to smooth consumption in the face of income loss. Similar conclusions are drawn in a study by Kazianga and Udry (2006), which examines the role of livestock, grain storage and intra-household transfers in smoothing consumption in response to income risks. Findings are based on a survey conducted between 1981 and 1985 in Burkina Faso, during a period of severe drought. Overall, the study concludes that livestock did not serve as a buffer during the analysed period, while accumulation and decumulation of grain stocks helped to smooth consumption during crises.

According to the literature, several factors may account for such findings, which conflict with the general view that livestock afford important protection against external shocks. First, poorer farmers may need to hang onto their animals in order to maintain a reproductive herd. Second, the insurance function of livestock can be limited by the combination of income shocks and asset shocks (McPeak, 2004; McPeak, 2017). Third, if several farmers in the same area decide to sell their livestock during a crisis, this will determine a fall in livestock prices and act as a disincentive to further sales (Kazianga and Udry, 2006).

PRODUCTIVITY

During the past 15 years the world has seen a major increase in livestock food products. Between 2000 and 2014, global production of meat and milk respectively increased by 39 percent and 38 percent. Increasing partial productivity through factor substitution is a reasonable goal. For example, if increased productivity per head of livestock is obtained by partial factor substitution (PFP), e.g. by intensified feeding or the use of more capital, the level of PFP might appear to rise while the level of total factor pro-

TABLE 2
HISTORICAL AND PROJECTED GLOBAL AGRICULTURE TFP GROWTH RATES BY SUBSECTOR

	TOTAL FACTOR PRODUCTIVITY (TFP)			
SECTOR	**1991–2000**	**2001–2010**	**2011–2030**	**2021–2030**
Total Agriculture	1.52	1.86	1.45	1.19
Ruminants	1.06	1.13	0.87	0.70
Non-ruminants	2.72	4.64	3.81	3.16
Crops	1.33	1.30	0.97	0.79

Source: Ludena *et al.*, 2007.

ductivity growth remains unchanged (Ludena *et al.*, 2007). However, increasing total factor productivity (TFP), meaning simultaneously increasing the productivity of land, capital, labour, water, and energy would be a major challenge (Abed and Acosta, 2018). Thus, a better understanding of the drivers and measurement of livestock productivity has become a major topic in the policy debate around sustainable livestock development (Acosta and De los Santos, 2018).

In assessing the global level of agriculture productivity growth, Ludena *et al.* (2007), measured and forecast the level of TFP for crops, ruminants, and non-ruminant production systems. The results (Table 2) show that the agricultural TFP rate of growth has increased over the past two decades, rising from 1.52 per annum in the 1990s to 1.86 per year in 2000–2010. The breakdown of agricultural TFP into subsectors reveals, however, that non-ruminant TFP productivity growth (i.e. pigs and poultry) far exceeds that in the other subsectors. This rapid growth stems from important technological changes over this period. In the ruminant sector the same pattern exists, although technology-powered growth has been much slower.

While the past two decades have shown a rapid increase in agricultural productivity growth rates, particularly for livestock, the assumption that similar growth will continue in the future is not supported by present evidence. Indeed, as shown in Table 2, the level of TFP growth rate per annum is projected to fall in all three agricultural subsectors during the coming two decades. Some of the main arguments that support this trend are: i) livestock producers will face greater competition for capital, labour, land, water and energy, ii) developing countries are catching up fast with the production efficiency levels of developed countries; iii) future productivity growth will be constrained by further expansion of technological innovation; and iv) improvements in technical efficiency will soon reach a stable ceiling.

LAND USE

Around two-thirds of the world's 5 billion hectares classified as "agricultural land" are unsuitable for crop production and can only be used for grazing livestock (de Haan *et al.*, 1997). Livestock not only provide a means of using grasslands to support human livelihoods but also convert large amounts of plant materials that are not edible by humans (e.g. straws, stovers, oilseed cakes, brewers' grains) into valuable food (FAO, 2012a). Livestock further contribute indirectly to food availability by increasing crop output through the provision of manure, a valuable source of organic plant nutrients that reduces the need for chemical fertilizers (Sansoucy *et al.*, 1995).

As the livestock sector grows and intensifies, competition over land to produce feed and fodder crops, as opposed to food grains and crops for human consumption, can reduce the amount of

BOX 1

THE FOOD–FEED COMPETITION

Livestock have received considerable attention in recent years amid controversy about how animal feed production competes for land and other resources with production of human food. Livestock consume a third of all cereals produced and use about 33 percent of global arable land. They occupy 2 billion ha of grasslands, of which about 700 million could be used to grow crops. Yet the cereals used to feed livestock make up only 13 percent of their overall diets, with another 1 percent coming from other human-edible crops. Grass and leaves make up 46 percent of livestock diets: 19 percent comes from crop residues; 8 percent from fodder crops; 5 percent from oilseed cakes; 5 percent from other by-products; and 3 percent from other plant sources that are not edible for humans. Of the plant material fed to livestock, 86 percent would be inedible by humans directly but is converted into valuable food for human consumption and contributes greatly to food and nutrition security.

food available for humans. Another controversial issue is the use of food grains as animal feed. Currently, 33 percent of available arable land, is used to grow animal feed (Steinfeld *et al.*, 2006). According to Mottet *et al.* (2017) livestock consume one-third of global cereal crops and producing 1 kg of boneless meat requires an average of 2.8 kg human-edible feed in ruminant systems and 3.2 kg in monogastric systems. However, global figures such as these mask vast differences across species and production systems. While ruminants use more dry matter per kilo of protein produced than pigs or poultry, they require less human-edible protein since they rely more on grass and forages. Pigs and poultry consume less feed to produce the same amount of protein, but a far higher proportion of that feed could be eaten directly by humans.

GENETIC DIVERSITY

Genetic improvement is a particularly powerful tool for increasing productivity and efficiency, but proper management of genetic resources is essential (FAO, 2007). Decisions should be in line with national policy on animal genetic resources. Crossbreeding programmes, particularly with imported breeds, should be complemented with conservation programmes. Within-breed genetic improvement should seek to optimize improvements in productivity with maintenance of genetic variety. Thus, strengthening of national capacity for management of animal genetic resources is a critical need for many countries (FAO, 2007; FAO, 2015a).

Indiscriminate crossbreeding, undertaken with the aim of increasing production, is considered the main threat to breed diversity worldwide (FAO, 2015a). On the intra-breed level, genetic diversity of the Holstein breed has decreased substantially over time (Kim and Kirkpatrick, 2009). Artificial insemination has been an extremely valuable tool for increasing productivity, but a recent genomic study reveals that all of the Holstein bulls (N > 250) available commercially for artificial insemination in the United States of America descend from only two ancestor animals (Yue *et al.*, 2015).

Populations of livestock present in any given area for many years are assumed to be genetically adapted to local conditions, including climate, available feed resources and endemic diseases. Likewise, in situations where livestock interact substantially with natural biodiversity, as in pastoralist production systems, local organisms have adapted to the presence of livestock. Therefore, maintaining the unique biodiversity of a livestock breed is considered important both in terms of efficient and sustainable livestock production

BOX 2

BIODIVERSITY VS PRODUCTIVITY

Maintaining genetic diversity in livestock breeds is crucial in order to raise farm animals in a wide range of environments, to help adapt production systems to climate change, and to provide the basis for diverse products and services. Preserving biodiversity is most likely to run counter to the objective of increased product yield and is often ignored, including where the diversity of livestock themselves is concerned. Genetic diversity must be considered at the species, breed and intra-breed levels. On the species level, cattle are by far the leading milk-producing livestock species in the United States of America, although sheep and goats are also present in the country. On the breed level, in 1944, the distribution of dairy cattle breeds was much more diverse. More than half of the milk (54 percent) was produced by "small" dairy breeds (Ayrshire, Guernsey and Jersey) and 46 percent by large breeds (Holstein, Brown Swiss). By 2007, 90 percent of the milk was produced by a single breed, the Holstein.

BOX 3

THE END OF THE MILK QUOTA IN THE EUROPEAN UNION (MEMBER ORGANIZATION)

The dairy sector of the European Union (Member Organization) (EU) has undergone several major structural changes over the last decades. Since the end of the Cold War, the regulatory intensity of EU dairy production has been reduced substantially. The 1992 MacSharry reform (named after the EU Farm Commissioner at the time) introduced a continuous process of liberalization. The last major event in this process was the abolishment of the quota system on 31 March 2015. The steady reduction of governmental intervention in the EU dairy market resulted in greater market orientation on the one hand, but also in diminishing income security for dairy farmers on the other. EU farmgate milk prices started behaving unpredictably during the world food price crisis in 2007–2008, which was followed by the liberalization steps implemented by the CAP Health Check in 2008 (the so-called 'soft landing'). Whereas price, and thus revenue variations, were kept around 10 percent annually before 2007, year-to-year price fluctuations of up to 65 percent have been occurring since then. Such unprecedented and substantial uncertainty concerning selling prices and farm revenues has challenged the economic viability of many farms, and particularly that of small, specialized dairy holdings.

and for the surrounding ecosystem. For this reason, proper management of local breeds is specifically targeted in the SDG Indicators.

TRADE REFORMS

Trade policies have important implications for food security via income and expenditure. While any trade reform that changes the balance between liberalization and protection of an agricultural good can affect levels of food security, livestock-related reform is especially problematic because of the key role the sector plays in most developing countries. That role can be direct, through livestock's contribution to the availability of food, or indirect since in many countries the sector is not only a key engine of economic development but one of the most heavily distorted agricultural subsectors (FAO, 2003).

The argument that openness to trade contributes to economic growth and that this can, in turn, promote poverty reduction and food security, is well grounded in conventional economic theory. However, potential gains from trade liberalization will not necessarily affect all countries and groups within society in the same way. There are likely to be significant differences between developed and developing countries, net-exporting and net-importing countries, and, both within and across countries, among small-scale and commercial farmers, and rural non-farm producers and urban consumers (Valdés and Foster, 2012).

The livestock sector in developing countries has often not been well placed to benefit from trade liberalization. This stems partially from the inflexible structure of production and trade in the sector; lack of financial development and sluggish factor mobility; excessive regulation that prevents resources from flowing; and the limited capacity of producers to adjust quickly to market changes (FAO, 2003). The nature and magnitude of the effects of trade liberalization depend on a number of factors, including the pace, sequencing and scope of liberalization; the adaptability of the sector to changing economic conditions; the sector's degree of exposure to

TABLE 3

KEY CONCERNS WITH RESPECT TO FOOD MARKETS EFFICIENCY AND TRANSPARENCY

COUNTRIES	FOOD PRICE INCREASE	FOOD PRICE VOLATILITY	PRICE TRANSMISSION ALONG THE CHAIN	DECLINING TERMS OF TRADE FOR FARMERS
Australia			+	+
Belgium		+	+	
Canada	+		+	
Chile			+	+
Czechia	+			
Denmark	+		+	
Estonia			+	+
European Union	+	+	+	
France	+	+		+
Indonesia	+		+	+
Israel	+		+	
Italy	+	+	+	+
Latvia			+	
Lithuania	+			
Netherland			+	+
New Zealand			+	
Poland		+	+	
Portugal			+	+
Slovenia			+	
South Africa	+		+	
Switzerland	+	+	+	
Turkey	+	+	+	+
United Kingdom	+			+

Source: OECD, 2014.

competition from food imports; the presence of favourable initial conditions, and accompanying measures such as adequate regulatory and export capacity; and finally, the time horizon considered (FAO, 2015a).

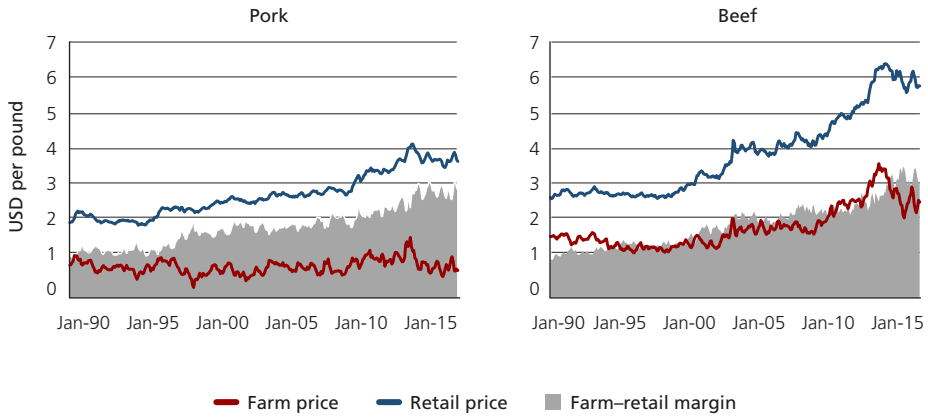
According to FAO (2015a), when trade reforms are implemented in an unstable macroeconomic framework or in a weak institutional setting, they can produce negative effects. If markets are missing or do not function properly, shifts in relative prices will not lead to a shift in production and thus make a positive impact on food security. Similarly, the lack of good physical infrastructure, such as roads, ports, and marketing equipment, can hamper the ability of the sector to benefit from trade reforms. Therefore, while theory may suggest that the liberalization of trade policies results in net benefits to liberalizing countries, it may have some adverse consequences for some nations, and for the poor in particular. However, rather than using this fact to resist trade reform, policymakers should look into complementary policies to attenuate the adverse consequences of liberalization to the greatest extent possible (Winters, 2001).

MARKET PERFORMANCE

Markets are the natural connection between producers and consumers. Enhancing the proper functioning of food commodity markets is therefore key to eradicating hunger (Sexton and Lavoie, 2001). Since the food crises at the end of the last decade, there has been growing global concern about the level of efficiency and transparency of food markets and about how food prices are formed and transmitted along the supply chain. In many OECD countries (Table 3), the issue of market efficiency has indeed been identified as a top priority by stakeholders in government and industry (OECD, 2015).

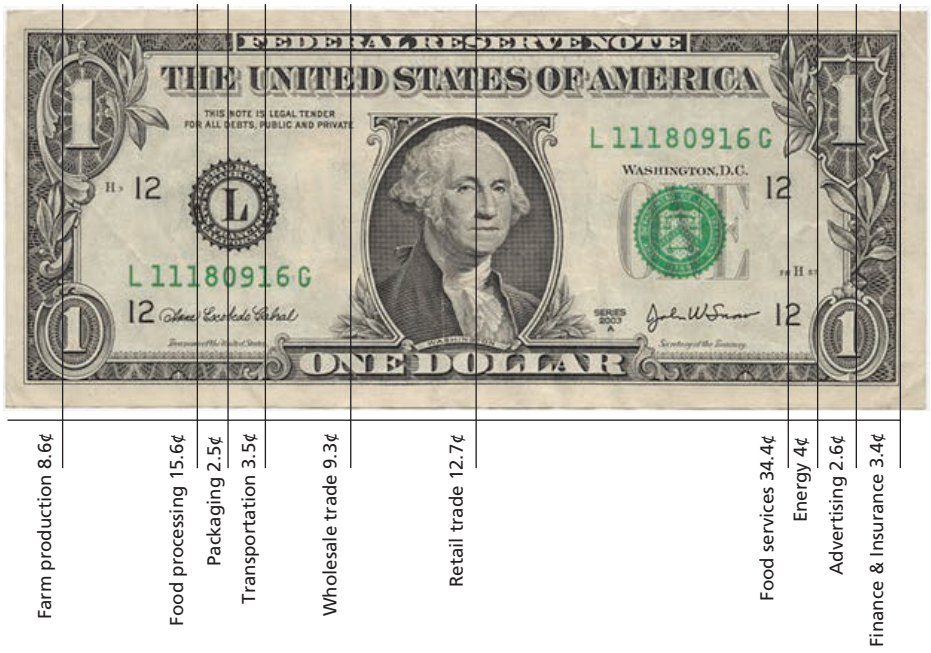
The livestock sector has gone through a profound structural transformation, associated with mergers and consolidations that have led to greater industry concentration, a decrease in the number of producers, and an increase in the scale of operations (Acosta and Valdés, 2014). This phenomenon is occurring both in developing and developed countries. For example, Figure 13, shows the historical evolution of livestock prices at the farm and retail level in the United States of America for pork and beef.

13 LIVESTOCK PRICE SPREAD IN PORK AND BEEF MARKETS IN THE UNITED STATES OF AMERICA



Source: Based on data from USDA–ERS, 2016.

14 FOOD DOLLAR 2015 (UNITED STATES OF AMERICA)



Source: USDA, 2015 Food dollar: Industry Group (Nominal).

Whereas all series are moving in the same direction, retail prices have increased substantially faster than producer prices, with marketing margins also moving up as a result.

This issue has captured special attention from policymakers due to its implications for welfare distribution, hence the need for policy intervention. According to the USDA Economic Research Service (ERS) a breakdown of the "Food Dollar" (Figure 14) reveals that for a dollar spent in 2015 by consumers on domestically produced food, only 8.6 cents went to farmers, 15.6 cents went to processors, 9.3 cents went to wholesalers, 12.7 cents went to retailers, and 34.4 cents went to pay for services provided by the catering industry (ERS and USDA, 2017). In other words, about 91 percent of consumers' annual expenditure on domestically produced food goes to providers of non-agricultural food and services and around 9 percent goes to farmers. As highlighted by Lloyd (2017) "what goes on between the farm and the fork is simply too big to ignore".

As shown, the expansion of livestock markets during the last decade has been accompanied by structural changes associated with mergers and consolidations, leading to increased market concentration (e.g. MacDonald *et al.*, 2000). This phenomenon threatens the livelihoods of small livestock producers who face higher entry barriers to markets and thus risk being marginalized or excluded; and consumers, who face higher prices for AFS products than would be expected from greater market efficiency.

CONCLUSION

Goal 2 seeks to end hunger and all forms of malnutrition. The livestock sector can contribute significantly at different levels and from different angles. At the household level, it can increase the direct consumption of ASFs and help generate income; at the rural community level, it can support the creation of employment opportunities; at the national economy level, it can reduce ASF prices, generate fiscal revenue, and

earn foreign exchange; and at the global level, it can provide the world with sufficient and reliable supplies of meat, milk, eggs and dairy products. The sector must, however, overcome some new, interconnected challenges. Increased demand for livestock products will add to existing pressure on ecosystems; livestock producers will face greater competition for resources so that while productivity should increase, it will likely do so more slowly. Furthermore, the ongoing transformation of the sector's market structure may hinder small producers and poor consumers from benefiting from economic growth and productivity improvements.

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3. Livestock and healthy lives

INTRODUCTION

Throughout the world, livestock and derived products are assets to human livelihood and nutrition, and thereby to human health and well-being, providing essential noble, high-biological-value proteins, fatty acids and various minerals and vitamins. Moreover, animals are a source of therapeutic compounds such as antimicrobial peptides, while porcine and bovine insulin have long been used to treat human diabetes. In addition, farm animals supply traction and transport, raw materials (hides, wool, skin, feathers, etc.), cash and financial security through savings – all essential components in maintaining decent livelihoods and in building resilience to climate changes and associated natural disasters. Additionally, animals in general offer positive psychological, emotional and social benefits to humans (e.g. companionship or the effect of pets on autistic individuals), and are of cultural value not only to their owners and their families but to society as a whole.

However, animals, including farm animals and derived products, also pose risks to human health. Such risks can be direct, e.g. through the transmission of zoonotic pathogens, including emerging viral diseases such as Ebola virus and Middle East respiratory syndrome coronavirus (MERS-CoV); through the development of bacteria resistant to antimicrobials; and through increasing concentrations in the environment of the residues of medicines, supplements and contaminants. Or they can be indirect, like non-communicable diseases such as cardiovascular disorders, which occur if ASFs are consumed in excess. However, although wild and domestic animals have long been a source of diseases for humans, their benefits to mankind in terms of nutrition, health, livelihoods, life expectancy and well-being largely exceed their negative aspects. This chapter addresses how livestock contributes to achieving Sustainable Development Goal (SDG) 3, which aims to: ensure health and well-being for all at all ages by improving reproductive, maternal and child health; end epidemics of major communicable diseases; reduce non-communicable and environmental diseases; achieve universal

health coverage; and ensure access to safe, affordable and effective medicines and vaccines for all (UN, 2016a).

LIVESTOCK AND DISEASES

While there are many noted economic and human health benefits to livestock production, the vast majority of human pathogens have their origins in animals (Jones *et al.*, 2008), which means that animals and animal products potentially present a recurrent and growing risk to human health. It is a risk that can, however be reduced through proper prevention and control measures. For instance, interventions on livestock to reduce gastrointestinal or respiratory illnesses may, it has been suggested, have a direct positive impact on human illness (Thumbi *et al.*, 2015). There is evidence too that mass vaccination of livestock against zoonotic brucellosis – not a new disease – benefits not only human health but the entire agricultural sector as well, contributing to poverty alleviation in the process (Roth *et al.*, 2003).

The risk of zoonotic diseases is overall higher in developing countries. Furthermore, due to the cultural and social division of labour in those countries, the main groups at risk of exposure are women and children, who work closely with livestock. Women are involved with livestock in several ways: they clean cattle sheds, feed animals, and are responsible for milking, processing and dairy sales (FAO, 2013a). And because of their frequent contact with cows and calves during milking, women are often the first to detect sick animals (Tangka *et al.*, 2000). Children are mainly tasked with herding and watering animals, or with egg collection. In Ethiopia, it has been reported that children spend about nine hours a day herding and watering animals (Giglietti and Steven, 1986).

In December 2015, after an eight-year study, the World Health Organization published the first global and regional estimates of the incidence of mortality from, and burden of, foodborne disease in terms of disability-adjusted life years (DALYs) due to 31 food-borne hazards, many of which are zoonotic or transmitted through animal products (Havelaar *et al.*, 2015). It was estimated that more than 600 million people globally – i.e. almost one person in ten – became ill after consuming contaminated food in 2010. Of these people, 420 000 died, with the highest toll in the African region. At a global level, the most frequent causes of foodborne illness were diarrhoeal disease agents,

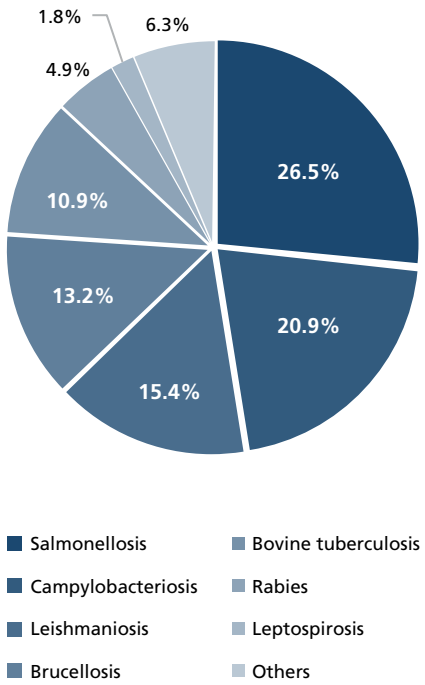
TABLE 4
TEN LEADING CAUSES OF DEATH IN 1850, 1900 AND 2000 IN THE UNITED STATES OF AMERICA

YEAR 1850	YEAR 1900	YEAR 2000
Tuberculosis	Pneumonia	Heart disease
Dysentery / Diarrhoea	Tuberculosis	Cancer
Cholera	Dysentery / Diarrhoea	Stroke
Malaria	Heart disease	Lung disease
Typhoid Fever	Stroke	Accidents
Pneumonia	Liver disease	Diabetes
Diphtheria	Accidents	Pneumonia / Influenza
Scarlet Fever	Cancer	Alzheimer's disease
Meningitis	Normal ageing	Kidney disease
Whooping Cough	Diphtheria	Blood poisoning

Source: https://nonprofitupdate.info/2010/10/21/10-leading-causes-of-death-in-1850-and-2000-2/

particularly *Norovirus* and *Campylobacter* spp. Non-typhoidal *Salmonella* spp. were the major causes of death. In total, 40 percent of the burden was borne by children under five years of age. Diarrhoeal disease agents accounted for 18 million DALYs, or 54 percent of the global burden, of which non-typhoidal *Salmonella* spp. alone was responsible for four million DALYs and *Campylobacter* spp. for more than two million DALYs. It was estimated that the parasite worm *Taenia solium* caused 2.8 million DALYs. This data confirms that the human health burden of food-borne disease is significant throughout the world, and that a large part of this burden is related to animals and/or foods of animal origin. Even though the burden is higher in developing countries, food-borne diseases also have a significant impact in developed countries.

15 HUMAN CASES OF ZOONOSES FROM 2006 TO 2017



Source: Based on data from WAHIS, 2017.

Throughout the world, the human health burden of zoonotic diseases falls heavily on the poor. They cause morbidity and mortality, in particular in children, health care expenses, and reduced income, at times for the remainder of people's lives. A study conducted by ILRI (Grace *et al.*, 2012) found that 56 zoonoses were responsible for an estimated 2.5 billion illnesses and 2.7 million deaths a year. In Kenya, in an area of deep poverty, a high incidence of zoonotic diseases (Felkin *et al.*, 2011) was observed, including Q-Fever, cysticercosis, cryptosporidiosis, but also trypanosomosis (Knobel *et al.*, 2013; Von Wissmann *et al.*, 2011). Due to limitations in health services and surveillance systems in many developing countries, zoonotic diseases tend to be under-diagnosed and under-reported (WHO, 2005). They are not prioritized by national or international health systems, and most fall into the 'neglected tropical disease' (NTD) category.

The challenges posed by NTDs are no longer limited to developing countries. Due to globalization, growing international trade and climate change, the North is also affected (TWN, 2016), particularly as concerns vector-borne diseases. For with global warming, vectors and associated pathogens are moving geographically to previously free areas (Jones *et al.*, 2008), and it is reported that almost half of the world's population is now susceptible to vector-borne pathogens (Tomley and Shirley, 2009). Like zoonoses, these diseases affect mainly women and children in developing countries, who represent the most vulnerable social groups (women because of pregnancy and childbirth, children because their immune systems are not fully developed) (McDonald, 2011). One example was the recent incursion of Zika virus into Latin America and the Caribbean.

Increasing livestock numbers, intensified management, faster animal turnover, confinement of large numbers of animals in small spaces as well as habitat fragmentation through expansion of livestock production all increase the

probability of outbreaks of emerging zoonoses. These include Bovine Spongiform Encephalopathy (BSE), Highly Pathogenic Avian Influenza (H5N1), Severe Acute Respiratory Syndrome (SARS) and MERS, some of which may have pandemic potential (Cohen, 1992; Shea, 2003). A study found that more than 70 percent of the infectious diseases to emerge in humans since the 1940s can be traced back to animals, above all wildlife (Jones *et al.*, 2008) and many of these are food-borne and resistant to antimicrobial medicines. They include SARS and associated coronavirus in bats, civet cats, and other mammals; Ebola virus in wildlife; and rabies and associated viruses (Bennet, 2006; Calisher *et al.*, 2006; FAO, 2013b; Jones *et al.,* 2008; Turmelle and Olival, 2009). A significant proportion of such microorganisms found in livestock and/or wildlife can be transmitted to humans directly, via the environment or through ASFs.

Animals and ASFs can also transmit to humans the residues of medicines, supplements, and contaminants. They can affect health through a single exposure, resulting in acute poisoning, or through long-term exposure, affecting the reproductive and immune systems, (e.g. external hormone residues), or causing non-communicable diseases (NCDs) such as cancer. Overconsumption of ASFs is associated with an increase in the burden of NCDs on humans, particularly of cardiovascular disorders mainly linked to cholesterol and saturated fatty acids levels (Steinfeld, 2013; Wang and Beydoun, 2009) (Table 4) but also of overweight and certain forms of cancer.

On the positive side, income generated by livestock can produce increased household income that can be spent on health (Thumbi *et al.*, 2015). Further, it should be stressed too that farm animals make many positive contributions to human health by, for example, producing medicines such as bovine and porcine insulin used in the treatment of diabetes. Horses produce antisera against snake venom, and cationic antimicrobial peptides (AMPs) with a broad spectrum of activity against Gram-positive and Gram-negative bacteria (Kues and Niemann, 2004). It should also be noted that animals in general have a positive effect on the well-being of humans at psychological and emotional levels, and are culturally important in many communities.

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Human health risks associated with animals and ASFs can be prevented by raising awareness, educating consumers, and promoting hygienic livestock production and food preparation practices. Ensuring collaboration between animal production and health specialists, public health officials and the commercial sector, including the feed industry, through a "One Health" (One Health, 2018) approach is crucial to achieving an integrated and preventive strategy on livestock-associated human health risks, and in so doing, contribute to the achievement of SDG 3.

LIVESTOCK AND ANTIMICROBIAL USE/ANTIMICROBIAL RESISTANCE (AMU/AMR)

Inappropriate use, overuse and abuse of antimicrobials in animal production contributes to the increase in AMR in pathogens causing human infections across the globe (Landers *et al.*, 2012). It has been estimated that, if no action is taken today, by 2050, ten million lives a year and USD 100 trillion of economic output are at risk from drug-resistant infections. Today, approximately

700 000 people die of drug-resistant infections every year. Low- and middle-income countries face the greatest burden from the growth in drug-resistant infections (O'Neill, 2016). FAO has developed an Action Plan on AMR in food, agriculture and the environment (FAO, 2016b) which addresses four major focus areas:

- Improve awareness on AMR and related threats.
- Develop capacity for surveillance and monitoring of AMR and AMU in food and agriculture, including livestock.
- Strengthen governance relating to AMU and AMR in food and agriculture, including livestock.
- Promote good practices in food and livestock–agricultural systems, and the prudent use of antimicrobials.

The FAO Action Plan supports the WHO-led Global Action Plan on AMR (WHO, 2016), and both highlight the necessity of applying a "One Health" (One Health, 2018) approach, with the involvement of public health and veterinary authorities, the food and livestock–agricultural sectors and other concerned partners. Halting the emergence, outbreaks and spread of disease at source, when identified, cannot and should not rely on the use of antimicrobials alone.

Prevention is the best way of combating AMR. Intensive use of antimicrobial agents is recognized as one of the principal causes of AMR (O'Neill, 2016). Against this background, the use of naturally disease-resistant animals (DRAs) has been advocated as a longer-term policy and strategy for reducing antimicrobial usage. This would diminish AMR in farm animals (Woolhouse *et al.*, 2015), as the use of DRAs requires a lower number of treatments than for susceptible animals (Mattioli *et al.*, 1998; Murray and Black, 1985). In addition, as previously mentioned, cationic AMPs, which represent a new class of antibiotics derived from livestock species, have the ability to remain unaffected by classical resistance genes so that, to date, no cases of antimicrobial resistance have been recorded for AMPs (Kues and Niemann, 2004).

LIVESTOCK, WATER, HYGIENE AND ENVIRONMENT

Poor populations face several challenges regarding household hygiene conditions, access to clean water, and access to sanitation facilities. Such problems together create ideal environments for pathogens to be transmitted via foodstuffs, particularly animal source foods. Lack of hygiene facilities might increase significantly the risk of transmission of bacteria and viruses.

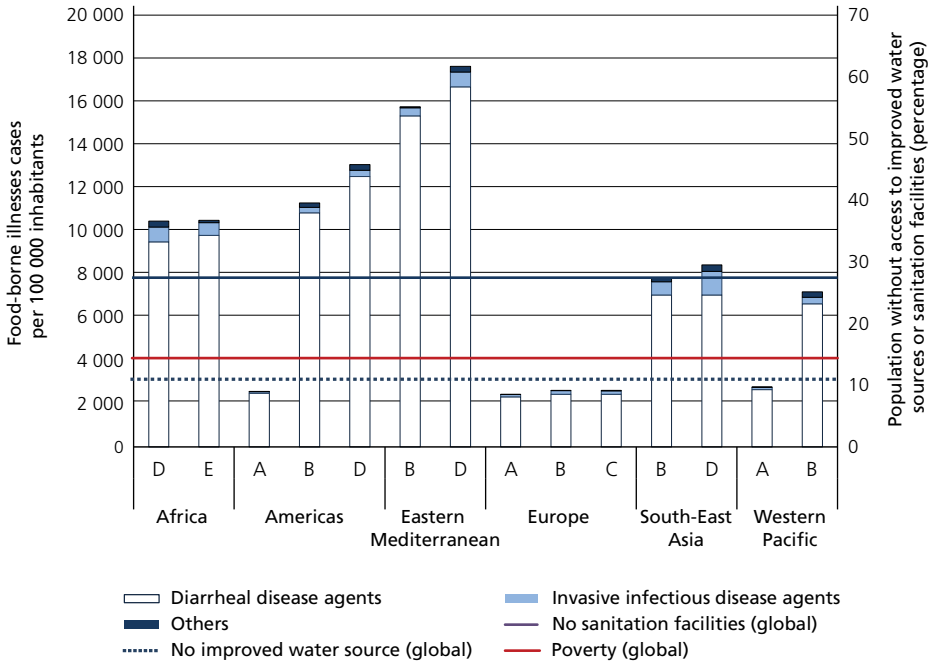
According to WHO, access to hygienic sanitation facilities has risen in the last decades, and the proportion of the population able to use them has risen from 54 percent to 68 percent since 1990. However, 30 percent of the global population still lacks such access, meaning that more than 2 billion people still do not have toilets or improved latrines. As evident from Figure 16, the regions with the largest numbers of food-borne illnesses per 100 000 inhabitants are those with less access to sanitation facilities.

In poor households with low hygienic conditions in low-income countries, diarrhoeal diseases cause about 1.9 million deaths per year, mainly among children, and most are due to food-borne pathogens such as *Salmonella* and *Campylobacter*, transmitted in animal-derived foods (FAO and WHO, 2009). As shown in Figure 16, the regions with most cases of food-borne diseases are also those with less access to improved water sources. A review found that domestic animal husbandry was associated with human diarrheal disease in 20 out of 29 studies (Zambrano *et al.*, 2014), the surmised pathway being faecal-oral pathogen transmission to young children households. Common among poorer families, subclinical environmental enteric dysfunction, the aetiology of which still needs to be established, has recently been found to be a major determinant of child stunting (Crane *et al.*, 2015).

According to Figure 16, food-borne diseases are more recurrent in regions classified as Strata C, D, and E.

Compared to the other regions, Strata C, D and E also concentrate the largest proportion of the population living in extreme poverty. As

16 FOOD-BORNE ILLNESSES LINKED TO HYGIENE CONDITIONS



Note: The subregions are defined according to child and adult mortality, as defined by Ezzati *et al.* (2002). Stratum A: very low child and adult mortality, Stratum B: low child mortality and very low adult mortality, Stratum C: low child mortality and high adult mortality, Stratum D: high child and adult mortality, and Stratum E: high child mortality and very high adult mortality.
Source: Based on data from WHO, WHO/UNICEF Joint Monitoring Programme (JMP), and the World Bank, 2018.

shown in the graph, the poverty rate in these regions surpasses significantly the global average, meaning that food-borne illnesses are a problem that primarily affects poor populations.

Living in proximity to livestock, especially in settings lacking basic sanitation facilities, can prompt the transmission of disease from animals to humans. Children, who commonly share the task of taking care of household livestock, are at greater risk of exposure, and children under the age of five have the highest risk of severe illness from zoonoses once contracted (FAO, 2013b; Marquis *et al.*, 1990). Therefore, accessibility to clean water, good hygienic practices and a healthy environment are all positive factors contributing to limit the onset and spread of infectious diseases.

LIVESTOCK AND NUTRITION

Meat and meat products together with dairy and eggs and their products are a valuable source of noble, high-biological-value proteins, fat and various physiological, functional compounds, e.g. micro/trace elements and vitamins (Wyness, 2013; Zhang *et al.*, 2010). These are of great importance in everyday human diets and in ensuring balanced growth, including cognitive and physical development (Randolph *et al.*, 2007).

Consumption of animal-source food (ASF) provides diet nutrients essential for balanced growth and cognitive outcomes in school-aged children (Neumann *et al.*, 2003). Studies conducted in Ecuador (Iannotti *et al.*, 2017) and in Kenya (Mosites *et al.*, 2016) have demonstrated that promoting children's consumption of

BOX 4

CHILD GROWTH AND CONSUMPTION OF ANIMAL-SOURCE FOOD

Consumption of animal-source food (ASF) provides diet nutrients essential for balanced growth and cognitive outcomes in school-aged children (Neumann *et al.*, 2003). Studies conducted in Ecuador (Iannotti *et al.*, 2017) and in Kenya (Mosites *et al.*, 2016) have demonstrated that promoting children's consumption of milk and eggs improves their nutrition, linear growth rates and height gains. The Kenya study also suggests that frequency of consumption of ASF is associated with livestock ownership and healthy household farm animals. Therefore, actions aimed at controlling diseases in animals positively impact not only on livestock productivity but also on ASF consumption patterns.

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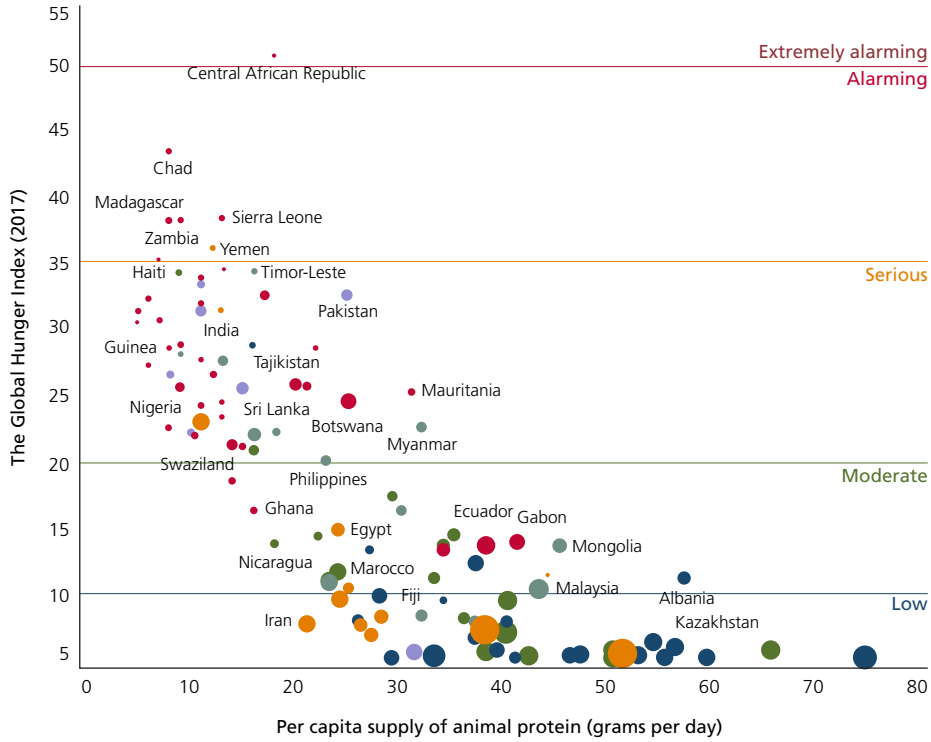
Responding to concerns about the possible health risks of consuming meat and meat products and, at the same time, aiming to increase the beneficial effects of dairy products, meat and eggs in human diets, some livestock production systems are modifying their processes so as to improve both the quality and nutritional traits of meat (Pighin *et al.*, 2016). Techniques designed to produce pigs with a more balanced ratio of unsaturated to saturated fat acids in their meat have, for instance, been developed in Japan (Kues and Niemann, 2004).

A major global objective of this SDG is improving child and maternal health. In developing countries, 2.3 million child deaths (41 percent of the total child death rate) are ascribed to malnutrition (Schroeder and Brown, 1994). According to WHO, every day about 830 women die from preventable causes related to pregnancy and childbirth and 99 percent of all maternal deaths occur in developing countries (WHO, 2016). The relationship between livestock and child and maternal health is complex, with multiple channels enabling both positive and negative impacts (e.g. Mosites *et al.*, 2015). Provided health measures are in place to prevent the transmission of pathogens from animals to humans, livestock ownership is positively linked with human nutrition and health, particularly in low-income settings (Randolph *et al.*, 2007).

Consumption of ASFs can improve child nutrition, immune competence, i.e. increased resistance to and recovery from infectious diseases (e.g., Begum, 1994; Yigrem *et al.*, 2015), increased cognitive development and reduce stunting in children (Jin and Iannotti, 2014; Murhpy and Allen, 2003). Animal foods provide high energy and quality diets, micronutrients and improved nutrition for pregnant and breastfeeding women (Grosse, 1998). Small amounts of ASF in early childhood have been shown to have remarkable impacts on physical and cognitive development, hugely enhancing human capital (Neumann *et al.*, 2002).

The 2017 Global Hunger Index (GHI), developed by IFPRI, captures the multidimensional nature of hunger by considering four indicators – undernourishment, child wasting, child stunting, and child mortality. Countries with large GHI scores, such Chad, Central African Republic, Liberia, Madagascar, Sierra Leone, Sudan, and Zambia, suffer from extremely alarming or alarming levels of hunger. However, as countries increase their capacity to supply the

17 RELATIONSHIP BETWEEN CONSUMPTION OF ANIMAL-SOURCE FOOD AND NUTRITION



Source: Based on data from IFPRI, FAO and the World Bank, 2018.

population with larger amounts of animal protein, their GHI score tends to decrease, reflecting an improvement in nutrition, particularly in children (Figure 17).

CONCLUSION

Goal 3 aims to ensure health and well-being for all at all ages. While the benefits derived from livestock are well recognized, if not managed properly, livestock and their products can be sources of communicable and non-communicable human diseases. Many of the microorganisms harboured by livestock can be transmitted to humans. Overconsumption of ASF leads to an increase in the non-communicable human disease burden. Inappropriate use of antimicrobials in livestock production contributes to rising antimicrobial resistance in animal and human infections across the globe, and contamination of soil or surface waters through manure and other waste. Considering the magnitude of the linkages and the complexity of the relationships between human health, animal health, nutrition and the environment, multidisciplinary and interdisciplinary action is required. The "One Health" (One Health, 2018) concept and approach is considered pivotal in designing and promoting policies, strategies and actions for the livestock sector to ensure healthy lives and production efficiency.

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4. Livestock and quality education

INTRODUCTION

The United Nations have recognized education as a fundamental human right (UN, 1948). Although significant progress has been made over the last 15 years to achieve universal primary education – partly driven by the Millennium Development Goals (MDGs) and Education-for-All frameworks – for many people, education remains an unrealised right. The gaps in education attainment between rich and poor, men and women, rural and urban people, and within and between countries, are still wide. In 2014, there were 263 million children, adolescents and young people in the world who did not attend school. The completion rate of upper secondary education in low-income countries was only 14 percent. From 2005–2014, some 758 million adults, almost two-thirds of them women, lacked any literacy skills (UNESCO, 2016).

Sustainable Development Goal 4 aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". It has a wider scope than MDG 2's "achieve universal primary education" as it aims to ensure education at all levels and access to lifelong learning opportunities. Specifically, it focuses on the acquisition of foundational and higher-order skills at all stages of education and development; greater and more equitable access to quality education at all levels, as well as technical and vocational education and training; and the knowledge, skills and values needed to function well and contribute to society (UN, 2016b). As a first step towards achieving SDG 4, the global education community adopted the Education 2030 Framework for Action in Paris in November 2015 (UNESCO, 2015).

There are both direct and indirect links between livestock and education. Consumption of animal-source foods (ASFs), such as meat, milk and eggs, can improve children's cognitive and physical development as well as school attendance and performance (Neumann *et al.*, 2002; Ruel, 2003; Fratkin *et al.*, 2004; Moore *et al.*, 2008; Dror and Allen, 2011; Hulett *et al.*,

2014). In addition, livestock provides income to poor rural households which they can use to pay for school fees, uniforms and schooling materials (Leroy and Frongillo, 2007; FAO, 2009a). Furthermore, basic education and agricultural education and training can contribute to more sustainable and efficient livestock systems. However, access to quality and inclusive education, agricultural training and extension and quality diets for poor people is often a challenge, also because of children's involvement in livestock-related activities. This limits the capacity of poor, small-scale livestock producers to develop profitable and efficient businesses and to adopt innovations, which in turn makes it harder for them to escape poverty, food insecurity and child labour.

The links between livestock and education are key to sustainable livestock development and to poverty reduction. If the efficiency of livestock production systems is improved (e.g. through improved livestock practices and management), the children of poor, livestock-dependent households can be freed from child labour and gain better access to education. Inclusive and participatory livestock research and extension programmes have a crucial role to play in supporting this process through relevant information and knowledge. This chapter provides evidence of how ASFs can contribute to children's health and cognitive development. It describes the extent to which children are involved in livestock production and how this reduces their attendance at school and access to opportunities. Moreover, the chapter describes the importance of livestock-derived income in allowing poor households to afford basic education. Livestock research, extension and training are presented as opportunities to improve livestock productivity and income. When successful, these activities can contribute to both reducing child labour in the livestock sector and to increasing the nutritional status of poor people.

ANIMAL-SOURCE FOODS FOR IMPROVED NUTRITION AND EDUCATION ATTAINMENT

Good nutrition is the foundation for human health and well-being, physical and cognitive development, and economic productivity (FAO, 2013c). Indeed, adequate nutrition is increasingly recognized as a determining factor in poverty reduction and economic and social development (FAO, 2013d). Nutritional intake during childhood and pregnancy is particularly important, as it affects child growth, health and educational performance as well as economic status and protection from both infectious and non-communicable diseases during adulthood (Neumann *et al.*, 2003; Victora, 2008). However, undernutrition remains a problem in many developing countries, with over 800 million hungry people in the world (FAO *et al.*, 2017). Micronutrient deficiencies affect close to two billion people, increasing the risks of blindness, mental retardation and early death. Africa and Asia are the regions most affected by nutritional deficiencies. Over one-third of African and Asian women suffer from anaemia and almost one out of every four children under five is stunted (FAO *et al.*, 2017). At the same time, around two billion people in the world are overweight or obese, with global obesity almost tripled since 1975 (FAO, 2012b; WHO, 2017).

ASFs provide high-quality and readily digested protein, are rich in energy and provide readily absorbable and bioavailable micronutrients (Neumann *et al.*, 2012b). These nutrients are more easily obtained from ASFs than from plant-based foods (Murphy and Allen 2003; Dewey and Adu-Afarwal 2008; Allen 2014). Although essential minerals such as iron and zinc are also present in cereal staples, they have lower mineral bioavailability due to their form and the presence of inhibitors of absorption such as phytates (FAO, 2009a). ASFs are richer than plant foods in certain micronutrients, particularly vitamin A, vitamin B12, riboflavin, calcium, iron and zinc but this varies depending on the foods. Overall, red meat has a higher content of zinc and iron than other meats, such as poul-

TABLE 5
MAJOR MICRONUTRIENTS (PER 100 G) CONTAINED IN SELECTED ANIMAL-SOURCE FOODS[a]

ANIMAL-SOURCE FOOD (ASF)	IRON *(mg)*	ZINC *(mg)*	VITAMIN B_{12} *(µg)*	VITAMIN A[b] *(µg RAE[c])*	CALCIUM *(mg)*
Meat					
Beef, medium fat, cooked	0.32	2.05	1.87	15	8
Goat meat (moderately fat)	2.3	4.0	1.13	0	11
Liver, beef	10	4.9	52.7	1500	8
Mutton	2	2.9	2.2	10	10
Pork	1.8	4.4	5.5	2	11
Poultry	1.1	4.0	0.10	85	10
Milk whole, unfortified	0.01	0.18	0.39	55	119
Hen eggs, cooked	3.2	0.9 (raw)	2.0 (raw)	500	61

Notes: (a) Nutrient contents are approximate and based on different sources; (b) Vitamin A content varies with cooking method; (c) RAE (retinol activity equivalent).
Source: Adapted from Neumann *et al.*, 2013.

try. Milk and eggs are particularly important sources of preformed vitamin A, while milk is a source of calcium and phosphorus. Vitamin B12 is mostly provided by meat and milk (Watanabe, 2007; Neumann *et al.*, 2013). Table 5 details the main micronutrients contained in some ASFs.

Today, poor people in many developing countries (especially young children and their mothers in rural households not owning livestock) are not consuming enough ASF (Murphy and Allen, 2003; IFPRI, 2004; Azzarri *et al.*, 2014; Jin and Iannotti, 2014; Mosites, 2015), while other people, particularly in developed countries, are consuming too much (PAHO, 2006). The inadequate intake of some of the major micronutrients available in ASFs during pregnancy and childhood can lead to health problems that affect growth and educational attainment. Moderated inadequacies in consumption of such nutrients can lead to problems such as anaemia, reduced work capacity, night blindness and poor growth. Long-term low intake of these nutrients can lead to more severe problems including: rickets, impaired cognitive performance, blindness, neuromuscular deficits, psychiatric disorders and eventually death (Murphy and Allen 2003). On the other hand, excessive consumption of ASFs can increase the risk of obesity (especially in children) and of heart disease and other non-communicable diseases (McMichael *et al.*, 2007; Voortman *et al.*, 2016).

THE CONTRIBUTION OF ASFS TO CHILDREN'S GROWTH AND EDUCATIONAL ATTAINMENT

Despite improvements in recent decades, high prevalence of stunting continues to be a big problem, especially in Africa and South Asia. In 2016, 155 million children under five years of age, or around 23 percent of all children in the world, were stunted (low height-for-age) (UNICEF, WHO and World Bank, 2017). Stunting is the cumulative result of various factors such as poor maternal nutrition, poor diet, and infections during the first two years of life (FAO, 2013c). It causes permanent impairment of cognitive and physical development and increased child morbidity (Hoppe *et al.*, 2006). Adults who were stunted as children generally earn less and are more likely to have received a lower education (Victora *et al.*, 2008; Dewey and Begum, 2011). Several studies have demonstrated the beneficial role of ASFs in the diets of pregnant women and infants and in reducing the incidence of stunting

BOX 5

SCHOOL MILK PROGRAMMES FOR IMPROVED COGNITIVE AND PHYSICAL DEVELOPMENT OF UNDERNOURISHED CHILDREN

Although excessive consumption of ASFs can lead to increased risks of obesity in children and of heart disease and other non-communicable diseases (Koletzko *et al.*, 2016), adequate access to safe and quality ASFs can improve the nutritional status of undernourished individuals. Among ASFs, milk is considered to play a key role in promoting children's growth and development (Dror and Allen, 2011). It is an important source of energy, lipids and high-quality proteins, and contains nutrients critical for growth and development, such as calcium, vitamin A, riboflavin and vitamin B12 (Hoppe *et al.*, 2008). A study carried out by Lien do *et al.* (2009) in a northern delta province of Viet Nam, has shown that primary school children strongly benefited from a school milk programme. Benefits included a ten percent reduction in underweight and stunting, improved micronutrients status, better learning indicators (including better short-term memory scores) and a general improvement in well-being. A Malaysian study conducted by Chen (1989) on more than 2 000 children aged six to nine years also showed that a school milk programme resulted in a reduction of underweight from 15 to 9 percent, in stunting from 16 to 8 percent, and in wasting (low weight-for-height), from 3 to 2 percent, two years from the start of the programme.

Source: Adapted from FAO, 2016a.

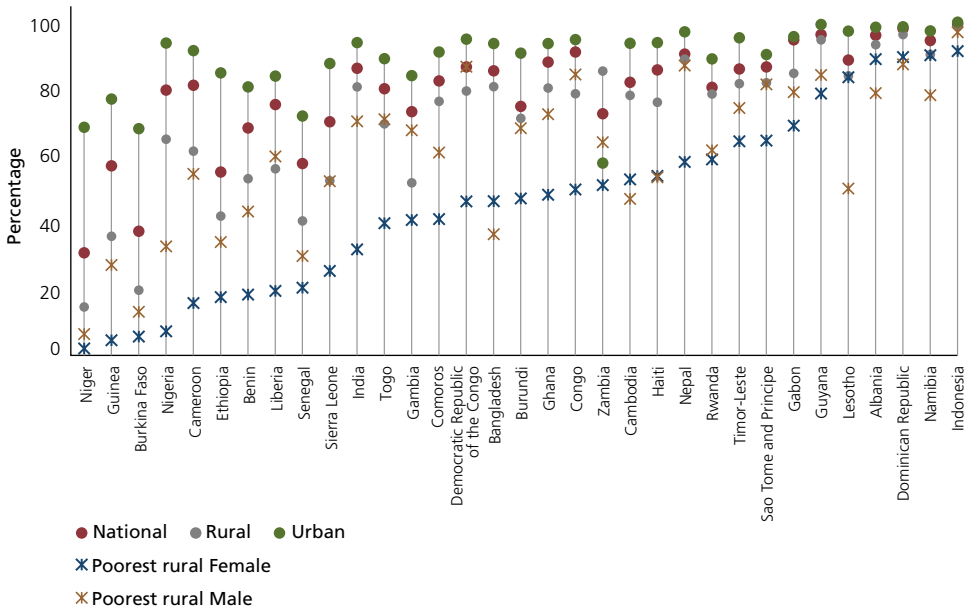
(Allen *et al.*, 1992; Neuman *et al.*, 1992; Kirksey *et al.*, 1992). For instance, findings from a cross-sectional study conducted through the Global Network for Women's and Children's Health Research in Guatemala, Democratic Republic of Congo, Zambia, and Pakistan suggest that eating meat offers protection against stunting (Krebs *et al.*, 2011).

Children suffering from undernourishment can perform less well at school due not only to the damage to their basic cognitive capacity in infancy, but also to continuing hunger, which limits their ability to concentrate. Evidence suggests that the inclusion of adequate amounts of foods of animal origin in the diets of schoolchildren can add much-needed diversity and sustains and improves cognitive performance, micronutrient status, growth, physical activity and academic achievement (Black, 2003; Murphy *et al.*, 2003; Grillenberger *et al.*, 2006; Neumann, 2007; Gewa *et al.*, 2009; FAO, 2013c; Iannotti *et al.*, 2013; FAO, 2016c). Mayurasakorn *et al.* (2010) conclude in a study on the nutritional status of children at primary schools that the consumption of at least three eggs per week can effectively correct protein malnutrition among primary school students. Providing milk, meat and eggs to undernourished schoolchildren through school feeding programmes can therefore be a valuable tool for improving their diets. It has also proved to be an incentive for school enrolment and attendance (Adelman *et al.*, 2008; Omwami *et al.*, 2011; Kristjansson *et al.*, 2016). A cost-benefit analysis carried out by Glewwe *et al.* (2001) concluded that one dollar invested in an early childhood nutrition programme in the Philippines could return at least three dollars in terms of academic achievement.

ACCESS TO BASIC EDUCATION FOR LIVESTOCK-DEPENDENT HOUSEHOLDS: CHALLENGES AND OPPORTUNITIES

Access to basic education can help farmers to adopt and apply innovations and improve agricultural productivity (Lockheed *et al.*, 1980;

18 YOUTH LITERACY RATE BY LOCATION, GENDER AND WEALTH IN SELECTED COUNTRIES



Source: Adapted from data from UNESCO, 2017.

Phillips, 1994; Weir, 1999; FAO and UNESCO-IIEP, 2003; Asadullah and Rahman, 2009; Reimers and Klasen, 2013). However, in rural areas of developing countries, where most small-scale livestock producers are based, children (especially girls) have lower access to quality education and opportunities to acquire skills than children living in urban areas. This is reflected in the fact that many rural areas have low levels of literacy, especially among poor women (Figure 18).

Education in rural areas is often characterized by low availability and quality of schools and infrastructure (especially in remote areas and beyond primary level), low quality and higher turnover rate of teachers, and limited pedagogical materials (IFAD, 2011; ILO, 2016; ILO, 2017). Moreover, curricula are often built on the needs of urban children and do not include agricultural topics, thus reducing parents' interest in enrolling their children in school (IFAD, 2011). Often, school calendars are not in line with agricultural seasons, making it difficult to combine education with rural work (FAO, 2013a). Other barriers keeping poor children in rural areas from attending school are tuition fees and the opportunity cost of schooling. In some countries, school fees can represent 5 to 10 percent of a family's income – and up to 30 percent for the poorest households (UNICEF, 2002). In pastoralist contexts, mobility and nomadism can present an additional barrier to education (Box 6).

LIVESTOCK INCOME TO PAY FOR EDUCATION

Livestock provide high-quality food and cash to poor and disadvantaged households (especially to women) in times of need, serving as an asset, a form of savings and a safety net (FAO, 2009a). Such households often sell or barter poultry, sheep, goats, cattle and their products to pay for

BOX 6

EDUCATION FOR PASTORALISTS

Pastoralist communities often face difficulties sending their children to conventional schools. Formal day schools are bound to specific locations and thus exclude a mobile, often nomadic lifestyle. Moreover, most school curricula are of very little relevance to pastoralists. Children sent to formal day schools miss out on the opportunity to learn pastoralism from their families and later usually opt for different occupations. Today, while some children go to conventional schools, in many cases boarding schools, others move with the family. Various alternative schooling models have been developed to try to bridge traditional and formal education. Mobile schools following migrating pastoralists in a tent or a bus are successfully being run in Iran (Islamic Republic of) and, to a lesser extent, in Eastern Africa. Open-distance learning via radio is a promising way of reaching a large number of people at modest cost: teachers and students do not have to be in the same place and information can be provided flexibly.

Sources: Scott-Villiers *et al.*, 2006; Krätli and Dyer, 2009; Dyer, 2010, 2015.

schooling (i.e. school fees, uniforms and textbooks) and other family needs, such as food, medical bills and clothes (Alders and Pym, 2009; Gabanakgosi *et al.*, 2013; Thomas *et al.*, 2014). In Namibia, almost 40 percent of respondents in a regional survey declared that they were selling cattle to pay school fees while 60 percent were selling their animals to cover other household needs (Thomas *et al.*, 2014).

The percentage of livestock revenue spent on school fees can be significant. For instance, a study from Chenyambuga *et al.* (2014) reports that over 25 percent of the income from dairy goat production (i.e. sales of goat milk and live animals) in two villages in the United Republic of Tanzania went on school fees. Kosgey *et al.* (2008) found that households in selected districts in the central and western parts of Kenya spent over 30 percent of livestock income on school fees. In some areas, the need to pay for school fees at the beginning of the school year can influence livestock prices in local markets. The sudden increase in livestock available for sale on the market causes prices to drop (Barrett *et al.*, 2003; Moreki *et al.*, 2010; Maass *et al.*, 2012).

CHILD LABOUR IN THE LIVESTOCK SECTOR

Almost 100 million children work in agriculture (including livestock), which accounts for nearly 60 percent of all child labourers aged 5–17 (ILO, 2013a). Worldwide, the issue is predominantly one of rural poverty. Work done by children in the livestock sector typically includes: herding, feeding, cleaning (animals and sheds), collecting fodder and water, and helping with processing. Many of these activities are likely to be hazardous and/or to interfere with children's education. Herding activities are particularly difficult to combine with school, because they take up most of the day (FAO, 2015a). A study on pastoral child labour and education carried out by ILO in 2013, analysed the lives of children in cattle camps in South Sudan and the risks and hazards (e.g. injuries from cattle or wildlife, zoonoses) linked with labour and life in camps. The study found that many parents did not value formal education for their children (especially girls) but placed importance on the learning experiences acquired through working with livestock. However, these traditional views were found to be changing, with tribes starting

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to consider education important for political participation and representation, as well as in marketing (ILO, 2013b). Changing attitudes towards formal education are being seen in an increasing number of pastoral communities throughout the world and, if adequately supported through quality education programmes, represent an opportunity for increasing school enrolment in livestock-dependent communities (FAO, 2013a).

RESEARCH AND EXTENSION FOR A MORE SUSTAINABLE AND EFFICIENT LIVESTOCK SECTOR

Increased demand for meat, milk and eggs during the past decades has mostly been met through major technological innovations and structural changes in the livestock sector. Technological change has mostly been achieved by private research and development efforts aimed at increasing the productivity of commercial producers (especially in poultry, pork production and dairy), in contrast with publicly funded research focused on developing solutions for small-scale producers. As a result, benefits and productivity improvements for the latter have been limited and in many developing countries livestock numbers have increased significantly more than yields (FAO, 2009a). With world population expected to reach 9.8 billion in 2050, demand for foods of animal origin is projected to continue increasing (Alexandratos and Bruinsma, 2012; UN, 2017). This presents significant opportunities for poverty reduction, food security gains and improved human nutrition but rising demand has to be met without increasing risks to the environment and public health. To this end, research advances can play a key role in increasing livestock productivity and efficiency (e.g. by improving animal health, feeding and breeding) and in supporting the sustainable and equitable development of the livestock sector, including through improved resource-use efficiency (FAO, 2009a).

According to a large body of evidence analysed by Alston *et al.* (2000), agricultural productivity improvements are closely linked with public investments in agricultural research and development (Pardey *et al.*, 2006). Nin *et al.* (2007) describe the contribution that research and development (R&D) can make to the development of the livestock sector. Compared to research in crops, livestock research is often slower, costlier and more complex as animals are more expensive than crops and seeds, and more time is needed to observe the impact of new practices or technologies. Results can also be more uncertain. The authors also report how, in several developing countries, research has not adequately promoted livestock development, due to problems such as poor research planning, environment and organisation. In many instances, this can be associated with the fact that livestock research is not considered a priority (particularly when comparing investments in research on livestock to those on crops) and is seen as sufficient to serve current development needs. A study by Townsend and Thirtle (2001) based on data from South Africa analysed the rates of return of research on livestock through a methodology that made it possible to differentiate between animal health and animal production research. Return on livestock R&D was found to be high and research to be as produc-

BOX 7

LIVESTOCK FARMER FIELD SCHOOLS: IMPROVING THE LIVELIHOODS OF SMALL-SCALE LIVESTOCK PRODUCERS THROUGH A PARTICIPATORY AND HANDS-ON LEARNING APPROACH

Farmer Field Schools (FFSs) are more than an extension approach, they are a form of adult education. Over the past two decades, Livestock FFSs have been established by FAO and other development stakeholders to a wide range of environments and livestock production systems, including pastoralism and agro-pastoralism, dairying, poultry production, integrated rice–duck systems, rabbit production, pig production, beekeeping, beef production, camel production and small ruminant production. In Livestock FFSs, groups of 15 to 25 livestock producers engage in hands-on, participatory learning over a season/production cycle. In these "schools without walls", small-scale producers meet regularly (generally once a week) to test, validate and adapt good agricultural and marketing practices that help them achieve sustainable food production and improved livelihoods. FFS groups learn by comparing local practices with new ideas through trial, observation, critical analysis and discussion. In the process, group members acquire technical skills, strengthen group cohesion, and design strategies for increased income through better understanding of value chains while also defining opportunities for business and enterprise development. Moreover, groups develop community action plans, establish new linkages with service providers and private sector actors to strengthen their enterprises and improve their livelihoods. Today, the FFS approach is used for livestock development throughout the developing regions and is attracting growing interest from governments, NGOs, the private sector and other stakeholders.

Sources: FAO, 2016d, 2018.

tive for livestock as for crops, when considering the potential losses from animal diseases that the research helped avoid. The study concluded that in South Africa the rate of return was over 35 percent for animal health research and 27 percent for research aimed at improving livestock production and productivity.

Despite existing links between agricultural R&D and agricultural productivity and poverty reduction, investment in R&D in many low-income countries has stalled or declined. For example, the share of sub-Saharan Africa in global expenditure on public agricultural research declined from 10 percent in 1960 to 6 percent in 2009 (UNESCO, 2016). Foreign assistance to agricultural R&D is also very low and volatile, resulting in challenges for planning and implementation. A comprehensive analysis of OECD data carried out by FAO in 2015 concluded that only 7 percent of Official Development Assistance going to agriculture, forestry and fishing was allocated to research and as little as 2 percent to extension (FAO, 2015b).

Today, there is an acute shortage of agricultural specialists and professionals in several developing countries, particularly in sub-Saharan Africa and Asia. In addition, a generation gap threatens future agricultural research as a large share of PhD-qualified agricultural researchers are reaching retirement age (Dobermann and Nelson, 2013). In countries like Namibia, Guinea and Mali, over 80 percent of agricultural researchers with PhDs are over 50 (IFPRI, 2017). By contrast, middle-income countries such as China, India and Brazil, have grown in importance both as agricultural producers and as producers of agricultural research (IAASTD, 2009; Alston and Pardey, 2014). In this context,

it should be noted that the sum of their investments in public agricultural research accounts for 31 percent of world total (UNESCO, 2016).

EXTENSION AND TRAINING

Extension is traditionally seen as providing a service that "extends" research-based knowledge to producers. This approach is very much focused on increasing production, improving yields, training farmers, and transferring technology. But the perceived lack of success of public agricultural extension systems in many countries has resulted in the development of several new approaches. Many countries have introduced agricultural advisory systems that help farmers to form groups to deal with marketing issues and to partner with other service providers and stakeholders (Davis, 2008; FAO, 2008, 2010a). Experience has shown that effective advisory services must be tailored to the specific needs and demands of a wide range of different producers (e.g. pastoralists, fisherfolk, forest farmers) in different contexts and environments (FAO 2016c). To this end, participatory approaches such as farmer field schools (FFSs) (Box 7) have been developed to better respond to the needs of different environments and households, thereby increasing the impact and relevance of advisory services and of research innovations (FAO, 2014a).

Today, extension or rural advisory services are no longer provided exclusively by the public sector but are also offered by private-sector firms (including agri-input and agro-processing companies and cooperatives) and civil society organizations, including producer organizations (FAO and KIT, 2016). However, poor farmers and marginal livestock producers, particularly women, are often excluded from extension and other services (IFAD, 2011). A sample of household survey data from nine countries showed that smaller farms are always the least likely to have access to extension information (FAO, 2014a). Over the years, efforts have been made to increase rural women's and men's access to extension information. The innovative radio-based training approach implemented in Kenya, for instance, was designed to reach the many small-scale dairy producers, especially women and young people, living in remote areas who had no access to extension. The approach proved to be useful and penetrative, and brought a number of significant immediate returns, such as a reduction of milk rejection by a cooperative from 30 to 8 percent and increased demand for extension services from 59 to 68 percent. The number of dairy producers seeking information about livestock prices increased from 28 to 35 percent (Njuguna *et al.*, 2014).

CONCLUSION

Goal 4 promotes inclusive and equitable quality education at all levels. Consumption of ASFs improves children's cognitive and physical development as well as school attendance and performance. In addition, livestock provide income to poor households to pay for schooling. School feeding programmes that include ASF products can help provide proper nutrition to undernourished children. However, among traditional livestock-raising communities, sending children to school conflicts with pastoral lifestyles. Other issues are related to gaps in livestock R&D and to the fact that small-scale livestock producers are often challenged in obtaining agricultural training and advisory services, limiting their capacity to manage their livestock more efficiently. Participatory, hands-on approaches, such as Livestock Farmer Field Schools, can successfully develop livestock producers' critical analysis, decision-making and communication skills. Strengthening the nexus between livestock production, nutrition, education, and health requires inclusive inter-sectoral approaches tailored to the specific needs and demands of livestock producers.

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5. Livestock development and gender equality

INTRODUCTION

The livestock sector provides livelihoods for the majority of rural communities worldwide. Globally, about 600 million of the world's poorest households keep livestock as an essential source of income (Thornton *et al.*, 2006). Livestock performs multiple functions in this setting, providing food, fertilizer, cash income and fuel, as well as promoting savings and social functions (ILRI, 2007). However, several studies show that the livestock sector is underperforming. The reasons include climate change, rural–urban migration, scarce investments, and gender inequalities. Women, compared with men, have poorer access to, and control over, natural and other resources such as land and water, credit, markets, assets and technical information. Consequently, women livestock keepers typically need to overcome greater economic and institutional barriers, and frequently lack the means necessary to fully engage in, sustain and upgrade their farming activities. Increasing and upgrading livestock production/management, processing and marketing with a focus on gender equality and women's empowerment can play a significant role in helping achieve the various targets and indicators set by SDG 5.

In the developing world, some 290 million women and girls rely on livestock to generate income (FAO, 2011a, 2013a). Some can slightly increase their revenues by producing and processing livestock products such as cheese and yoghurt, which have a higher value, can be kept longer, and provide nutritious food. Another source of extra income is wool and other animal fibres, which also require processing. In Mexico's Chiapas mountains, for example, sheep rearing is mainly the responsibility of women, providing 36 percent of household income through wool processing and sales (FAO, 2012c). Furthermore, livestock ownership greatly contributes to rural women's economic empowerment, providing a source of cash for immediate household needs. Nonetheless, the constraints that such women

must work under limit their productivity and reduce their ability to fully contribute to their families' food and nutrition security and to the growth of the livestock sector as a whole. Indeed, there is mounting evidence that gender inequalities impose high costs on societies worldwide, hindering the productive potential of economies and their overall development. That is both a challenge and an opportunity. At household level, women with greater control over livestock assets have been shown to contribute to better food security for all family members and to the nutrition and education of their children (World Bank, 2001; Quisumbing, 2003). At global level, removing or significantly reducing the barriers faced by women livestock farmers is one effective way to spur livestock growth and improve the well-being of rural communities.

In developing countries, livestock usually represent a consistent portion of national GDP and contribute substantially to rural incomes. For example, in rural Africa the World Bank estimates that, on average, livestock-related activities generate almost a quarter of rural incomes (World Bank, 2013). Livestock provide income and employment not only to farmers and pastoralists but also, along value chains, to contract herders, animal handlers, traders and market operators (FAO, 2011c). Livestock also contribute to better nutrition for all household members, particularly children. As noted in the previous chapter, millions of children suffer from stunted growth, cognitive impairment, weakened immunity and disease because of micronutrient deficiencies. Livestock-keeping can maximize the availability of a variety of nutritious, animal-source foods (ASFs), facilitating the intake of protein, iron and micronutrients (Stevens *et al.*, 2015).

Although many rural women make a living out of livestock and related activities, traditional gender roles greatly affect their opportunities both to fully engage in, and profit from, the sector, and to move up from subsistence to commercial livestock production, and from informal

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to formal markets, which typically represent more profitable outlets. Women frequently lack the means to acquire either the necessary knowledge and technical skills, or the credit facilities and land to successfully operate in the sector. Customary gender norms and power dynamics limit their ability to enter high-value markets and fully profit from livestock production. Power relations can also constrain income-earning opportunities for women who, in many regions, have to consult their husbands before selling or slaughtering animals (e.g., Dolan, 2002; van Hoeve and van Koppen, 2005). Furthermore, the industrialization and formalization of important livestock value chains can often represent a threat to women livestock keepers, who find themselves marginalized due to stricter regulations and standards, as well as working hours that clash with their roles as mothers and income-earners.

Developing programmes, policies and extension services tailored to local conditions and targeting rural women livestock keepers can help achieve several SDG 5 targets such as ending discrimination against women and girls; recognizing and valuing unpaid care and domestic work; ensuring women's participation in decision-making in political, economic and public life;

and promoting equal rights for women to productive and natural resources, as well as services. Acquiring access to, and control over, livestock gives women the chance to gain employment and additional income and to achieve their full potential. Currently, growing global demand for animal protein represents a real opportunity for poor rural women working with livestock, offering considerable benefits not only for the women themselves and for their households, but also for the agricultural sector as a whole and the global economy.

However, a review of evidence on the importance of livestock for women (ILRI, 2010) also argues that despite women's great contribution to livestock production and management in developing countries, more research is still needed on their role and the potential benefits of livestock-related interventions at individual, household and community levels. To this end, it is imperative to elicit stronger political will, and facilitate better targeted agricultural aid and gender-sensitive programme and policy actions, in order to bring about economic and social transformation in rural communities, and make them more equitable, efficient and productive. The following sections provide an analysis and some of the evidence available on the important linkages between livestock farming, gender equality and women's empowerment. They also consider recent data and successful practices which, following international implementation, have proved capable of fostering sustainable livestock productivity on the one hand, and gender equality and women's empowerment on the other.

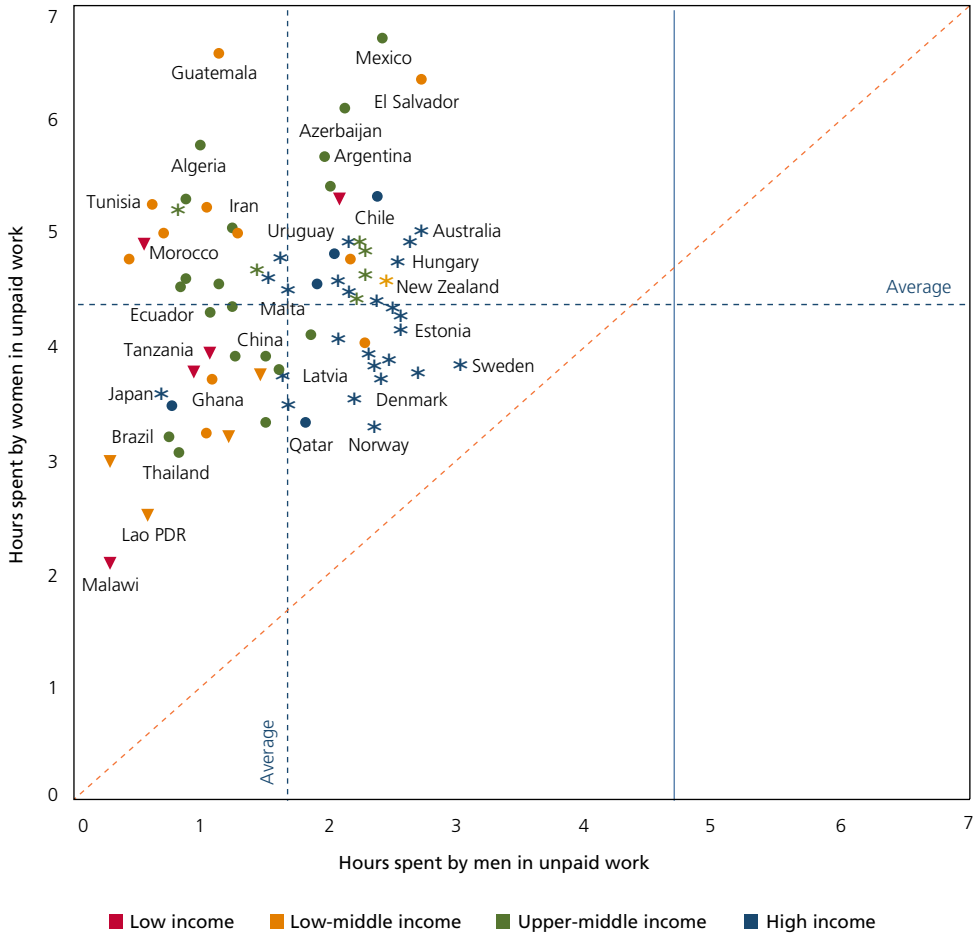
REDUCED WORK BURDEN AND INCREASED LIVESTOCK PRODUCTIVITY

On average, women make up 43 percent of the agricultural labour force in developing countries (FAO, 2011a; Fan *et al.*, 2015). Within the livestock sector, they usually look after livestock on a day-to-day basis, which generally involves arduous, time-consuming, and energy-intensive work. In Africa, this includes cleaning sheds, harvesting fodder, fetching water for the animals, milking them, making butter and cheese, and caring for any pregnant or sick livestock (FAO, 2015c). Men and boys, on the other hand, are usually in charge of grazing, and of taking animals for veterinary treatment when the need arises (Yisehak, 2008). Similar patterns can be identified in Latin America and Southeast Asia, where the workload of rural women tends to be just as heavy (GALVmed, 2011a, 2011b; CGIAR, 2017).

Labour force statistics often underestimate the amount of time that women devote to livestock. For women are less likely than men to define their activities as work or to report themselves as engaged in livestock management – while working, on average, longer hours than men. As a result, most of the livestock work carried out by women is not reported, recorded, or considered in formal labour statistics (FAO, 2011c). In addition to livestock-keeping and production, women also perform a number of unpaid jobs essential to rural households. These are tasks traditionally assigned to women such as processing food crops, fetching water and firewood, cooking family meals and caring for the elderly, children and the sick. Men are instead usually involved in commercially oriented farming, both in the cropping as well as livestock sectors, and tend to spend little or no time caring for the home and the children (FAO, 2013a).

National time–use surveys produced in 2014 by the Rwanda National Institute of Statistics confirm that women have a longer work week than men (49 hours, compared with 41), and that of those working hours, 21 are spent on domestic work as compared to men's seven. This heavy and unrecognized workload is one of the main factors limiting women's ability to improve their livestock production and productivity. Yet as men migrate to cities in search of more lucrative employment, women's involvement in livestock is projected to increase and intensify (Deere, 2005; Upadhyay, 2005; Johnson *et al.*, 2013). Time–use surveys carried out at broader

19 NUMBER OF HOURS SPENT BY WOMEN AND MEN IN UNPAID WORK



Source: Based on data from the United Nations Statistics Division, 2018.

scale reveal similar findings. Graph 1 shows the proportion of time spent per day by women and men on unpaid and paid work in selected countries. Data are based on surveys conducted between 2000 and 2014 by UNSTAT, the United Nations Statistics Division, in 59 countries – 30 from developing and 29 from developed regions.

The graph highlights how consistently, across both developing and developed regions, women tend to devote more time than men to unpaid work. This clearly has a major impact on women's capacity to upgrade from subsistence to commercial livestock production, and to achieve their full potential within the sector. Women's workload can also be negatively influenced by changes in livestock production systems. For example, moving from extensive to intensive livestock production can often increase the amount of time women spend collecting and carrying water. If women's heavy workload is reduced, they are far more likely to engage in other productive tasks benefiting household food and nutrition security overall welfare. They are also more likely to participate in decision-making

processes and bodies and take advantage of development opportunities through technical and vocational training.

A number of approaches have been developed worldwide to redress these inequalities. Labour-saving technologies, practices and services, for example, can greatly ease the work burden of women. They include technologies for efficient water use and collection, such as planting vegetable crops, integrating fodder production close to home and watering with household waste water (Bishop-Sambrook *et al.*, 2004). The development and distribution of tools specifically designed to be simpler and less physically demanding for women can ease women's work load too. Training female extension agents can make it easier to share knowledge on improved livestock systems and technologies as well as surmount social norms that often make it unacceptable for women to interact with male extension staff.

WOMEN'S PARTICIPATION AND DECISION-MAKING POWER IN THE LIVESTOCK SECTOR

Women's limited leadership opportunities and participation in decision-making, including in cooperatives and producer associations, largely keeps them from increasing their livestock production and productivity. They usually lag behind both in terms of group membership and of executive positions within them. Since the leaders of agricultural cooperatives and producer associations working with government in designing development plans and policies are predominantly men, in the livestock as in other sectors, women's low representation has an impact on the gender-sensitivity of such plans and policies, and the benefits they offer to women and girls (GIZ, 2013). Moreover, when the membership and leadership of farm cooperatives is male-dominated, women are unlikely to take an interest in the activities of such groupings. Thus, the potential for increased production offered by the establishment of cooperatives can never be fully achieved.

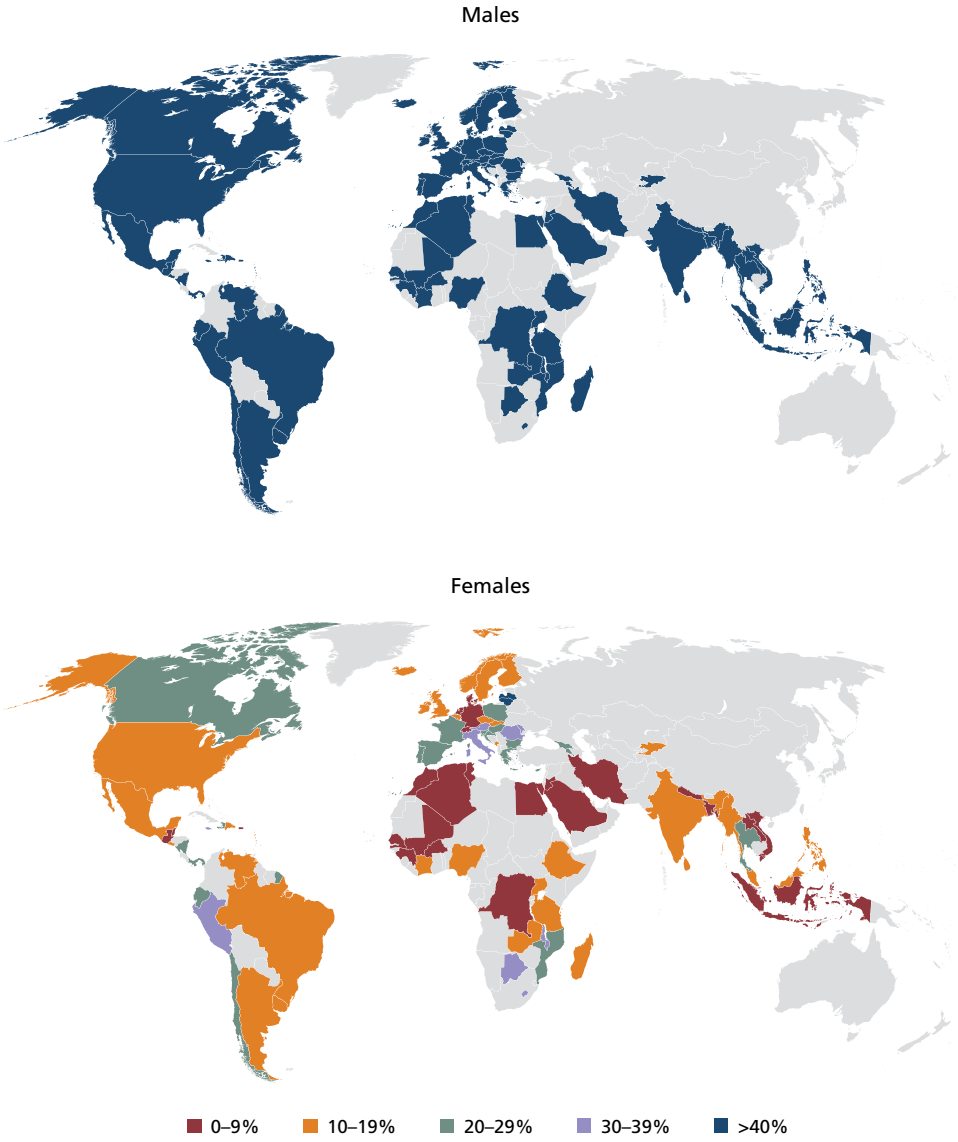
According to the International Labour Organisation (ILO), there are strong links between women's involvement in cooperatives and poverty reduction. After becoming involved in cooperative associations, women report they perform new and more productive labour activities and earn higher incomes, which greatly contribute to better food security in households. Active participation in cooperatives has also been shown to increase women's decision-making at household level and to improve their participation in, and contribution to, community management and development (ILO, 2014).

A number of successful programmes worldwide have highlighted the benefits deriving from women's participation in leadership and decision-making in agricultural cooperatives and producer associations. India's National Dairy Development Board (NDDB), established to modernize and improve milk production in the country, offers one example of the negative effects of gender imbalance within cooperatives and producer associations. Since membership was heavily dominated by men, improvements in national dairy production and productivity expected from the NDDB remained far below expectations. Given the disappointing performance, in 1995 the Board launched the Women's Dairy Cooperative Leadership Programme and the Women's Thrift Groups (WTG). Training was given on various aspects of animal hygiene and health, as well as on leadership, orientation, responsibilities and rights of membership, etc. These initiatives led to higher profits and a more productive and successful dairy sector in India (Torres, 2001).

THE IMPORTANCE OF NATURAL RESOURCES FOR IMPROVED LIVESTOCK PRODUCTION

Women's limited access to natural resources, particularly land, means they typically face greater challenges than men in overcoming economic and technical obstacles to running or upgrading their livestock activities. Land access and control remains one of the main obstacles

20 GLOBAL DISTRIBUTION OF AGRICULTURAL HOLDERS DISAGGREGATED BY SEX



Source: FAO Gender and Land Rights Database, 2018.

to women's full participation and success in the sector. The ability to claim one's rights and seek redress is governed above all by the laws guaranteeing those rights and detailing how to claim protection. While in many countries there has been progress in the last two decades in formulating and adopting more gender-equitable legislative and regulatory frameworks, explicit discrimination against women continues in others. As a result, widespread inequalities persist,

particularly in the field of land rights, with discriminatory legal provisions still in place with respect to access, ownership, and control of land, houses, and business premises.

Although land is not a prerequisite for keeping livestock (if feed can be purchased), grazing land is key to livestock production in many areas (Deere and Doss, 2006). Gender disparity in land ownership can therefore be a significant barrier for women livestock keepers, hindering their ability to increase production and discouraging them from making long-term plans and investments in livestock production. Without land, women also lack collateral for loans and access to regular financial services (Quisumbing *et al.*, 2015; FAO, 2011).

When women only have access to, rather than control over, land, this limits the decisions and options available to them on how the land should be used. Studies on household dynamics in assets distribution and use have shown that it is not only the total amount of household assets that determines development outcomes, but also and foremost who in the household controls the assets. In this regard, an important element is also represented by the quality of land that is assigned to women, which very often is far from the house, consists of impoverished soils and is less productive. As livestock are often a means for rural women to diversify their income, access to, and control over, quality land can often greatly reduce women's vulnerability and positively affect their production levels. When women do control assets such as land, a number of positive outcomes ensue. Interventions aimed at increasing women's control over assets have resulted in improved household food security, child nutrition and education, as well as the well-being of women themselves (World Bank 2001; Quisumbing 2003). In Bangladesh, for example, a higher share of women's assets is directly associated with better health outcomes for girls. Research from IFPRI estimates that equalizing women's status in terms of access and control over assets could lower child malnutrition in South Asia by 13 percent (13.4 million children) and in sub-Saharan Africa by 3 percent (1.7 million children) (Smith *et al.*, 2003).

Securing women's control over natural resources, particularly land, could do much to lift women out of poverty by allowing them to operate successfully in the livestock sector. Policymakers need to pursue full enforcement of existing regulation on land rights, as well as policy coherence within and across land policy frameworks, statutory as well as customary. Coherence between laws could, however, often prove a challenge, especially when informal civil and family legislation sets limits on the capacity of women to perform legally binding acts. Such limitations often bar women from signing land contracts, which usually runs counter to national law and international agreements. Data show that women with strong property rights have children who are three times less likely to be severely undernourished and that they sometimes earn almost four times more than women without secured property rights (Landesa, 2015; Allendorf, 2007; Doss, 2006). The evidence is that strengthening the rights of women to land strongly benefits them, their families and their communities.

GENDER IN INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) BENEFITS LIVESTOCK PRODUCTION AND PRODUCTIVITY

Women's limited access to technologies, and ICT in particular, is an obstacle to their achieving higher livestock production. It stands in the way of adopting improved animal husbandry practices and accessing credit opportunities or more profitable markets. The technology gap is one reason why women are typically far less productive and efficient than men in the livestock sector and livestock markets, with negative consequences on household food and nutrition security (FAO, 2012a).

Information technology opens the door to technical information, including, importantly, information on animal health and veterinary care as well as market information and prices. A

study carried out by FAO and the International Livestock Research Institute (ILRI) in 2016 in selected dairy production sites in the United Republic of Tanzania highlighted how animal diseases undermine food security in many ways, particularly as a result of economic damages due to loss of output, income and investment. The study found that although women are very active in animal husbandry, they are only marginally involved in animal health management, and their knowledge of veterinary science is mainly based on traditional animal health practices – with consequent impacts on the food security of their households.

Mobile phones are being used successfully to increase access to financial services by the rural poor, particularly women. This has great significance because lack of adequate finance represents a major barrier keeping women from taking advantage of livestock market opportunities. Their ability to obtain credit is often determined by context-specific legal rights, social norms, family responsibilities and access to, and control over, other resources. However, if such barriers are removed, research conducted in Ethiopia, Ghana and Bangladesh has shown that women with access to credit choose to invest in livestock, leveraging credit to expand from poultry-rearing to keeping goats and dairy cattle (Rubin *et al.*, 2010; Todd, 1998).

Technical information obtained via mobile phones often results in increased livestock productivity for women. This includes data on correct feeding, safe husbandry practices and animal health and reproductive care – all of which translate into higher productivity, reduced veterinary expenses and lower animal mortality.

The use of mobile technology for the delivery of animal health services has also been shown to improve women's access to veterinary knowledge and information as well as care delivery, resulting in improved livestock productivity. Poor awareness of animal health in subsistence-oriented production systems, combined with a poor communication and transport infrastructure, often translate into ill-functioning private and public animal health services, calling for the establishment of alternative forms of animal health services.

The NGO Farm Africa's Kenya Dairy Goat and Capacity Building Project has tested the use of mobile phones to deliver animal care and health services and information. Results show that mobiles play a key role in fighting livestock disease outbreaks and contribute to increased attendance and participation in animal health providers' meetings, which can be convened or cancelled at short notice. Furthermore, use of mobiles reduces the transaction costs to women livestock keepers since diagnoses can now be made over the phone at little or no cost. The project also uses mobile phones to place orders for veterinary drugs, thus saving both time and expense (ILRI, 2010).

CONCLUSION

Goal 5 seeks to empower women and girls to reach their full potential. Throughout the developing world, women and girls in rural areas are deeply involved in livestock production. However, women livestock farmers typically face greater challenges than men, including economic, social and institutional barriers. To enable women to meaningfully operate in, and benefit from, the livestock sector, policies and programmes should work to remove root causes of gender inequalities as well as the obstacles and constraints facing women. Doing so could make livestock a pathway out of poverty for millions of rural women and girls. Key areas for policy intervention include developing gender-responsive extension services and participatory training programmes for rural women; providing them with improved access to land and productive assets, as well as to markets, credit and insurance; and fostering their access to labour-saving technologies. Finally, there is a need to collect, document and disseminate those successful approaches and good practices that have clearly had a positive effect on women's economic empowerment and have been shown to increase gender equality in the livestock sector.

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6. Livestock and sustainable management of water

INTRODUCTION

Water scarcity, poor water quality and inadequate sanitation already threaten food security, livelihoods and educational prospects of poor families across the world. Climate change is exacerbating water scarcity in some regions while other regions will have increased or even excess water flows. Events such as droughts and floods are also expected to multiply in both frequency and intensity in some locations, deepening hunger and malnutrition in some of the world's poorest countries. Water withdrawals for irrigation and livestock will increase as global population growth and economic development drive up demand for food. There is a need to almost double food production in developing countries by 2050. How to grow – and raise – more food using less water is one of the great challenges of our times. Achieving universal and equitable access to safe and affordable drinking water, reducing pollution to conserve water quality, eliminating or minimizing dumping and dispersal of hazardous chemicals and biological agents, and encouraging water recycling and reuse are the main strategic targets of SDG 6.

Agriculture uses approximately 70 percent of the available freshwater supply, and roughly 30 percent of global agricultural water goes on livestock production (Ran *et al.*, 2016), with one-third of that supporting beef cattle (Mekonnen and Hoekstra, 2012). To meet rising demand for animal products, the livestock sector is intensifying its water use, and in so doing is increasing competition with other users and environmental services (Naylor *et al.*, 2005; McMichael *et al.*, 2007; Sutton *et al.*, 2011). Besides water scarcity, one of the central water-related challenges facing the livestock sector is waste management and disposal given that faeces and urine can be hazardous to the environment. Improved management of waste from slaughtering, tanning and food processing is another imperative.

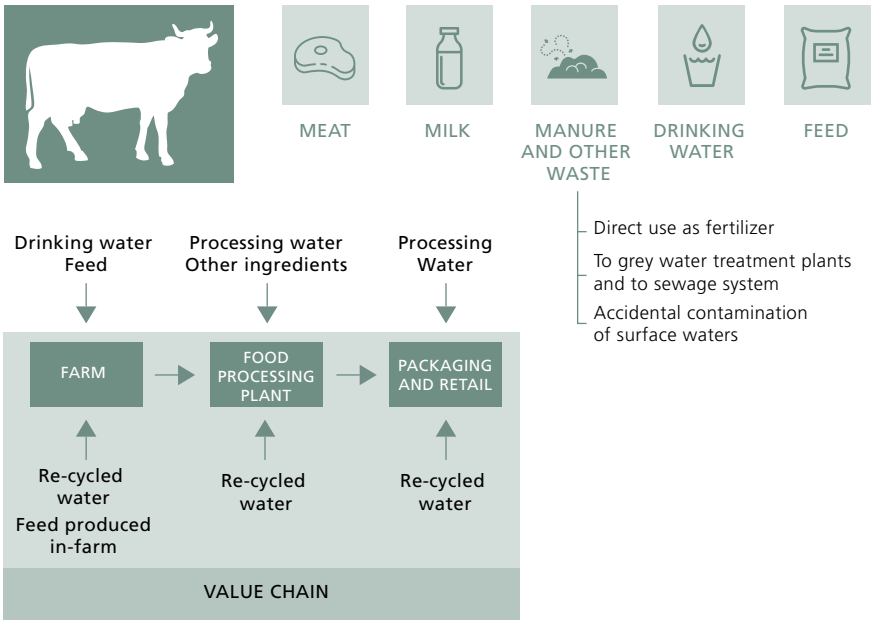
Many studies analysing the impact of livestock production on the sustainable management of water resources have extensively used the water

footprint methodology developed by the Water Footprint Network (WFN). Although the methodology was developed for water resource management, it has many applications in the context of environmental assessments linked to sustainable diets. Currently, however, water footprint assessments relying on the competing life cycle assessment (LCA) framework are gaining increasing currency. In order to bring some clarity and order to the methodologies for footprint assessment, the FAO-based Livestock Environmental Assessment and Performance (LEAP) Partnership is seeking to achieve an overall consensus with multiple stakeholders and the mainstream scientific community.

ACCOUNTING FOR LIVESTOCK WATER DEMAND

The water footprint has been used as an indicator of water consumption for both direct and indirect water usage at consumer and producer level. It aims to measure the total volume of freshwater used to produce the goods and services consumed or utilized by individuals, communities and businesses. Water use is understood as the amount of water consumed and/or polluted per unit of time. The water footprint is geographically explicit, showing not only the water volumes used and polluted, but also the areas involved (Hoekstra, 2008). Given the very substantial water footprint of livestock production, improving water-use efficiency and policy guidance throughout the production system is an important element in achieving SDG 6 and ensuring access to safe water sources and sanitation. In addition to universal water access, SDG 6 targets emphasize substantially increasing water-use efficiency across all sectors to address water scarcity. Furthermore, a more efficient use of water resources through livestock production value chains would have an impact also in the achievement of other SDGs, such as SDG 2, "End hunger, achieve food security and improved nutrition, and promote sustainable

21 WATER FOOTPRINT



Source: FAO, 2018.

agriculture", SDG 12, "Ensure sustainable consumption and production patterns", and SDG 15, "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss".

A mainstream practice for water footprint assessment relies on the methodology developed by the WFN. The total water footprint of an individual or community has three components: the blue, green and grey water footprints:

- The blue water footprint is the volume of freshwater consumed from global blue water resources (surface and ground water that lies beneath the surface) to produce the goods and services consumed by individuals or communities.
- The green water footprint is the volume of water evaporated, transpired or incorporated by plants (i.e. consumed during the production process) from global green water resources (rainwater stored in the root zone of the soil).
- The grey water footprint is the volume of freshwater required to assimilate a given load of pollutants, taking account of natural background concentrations and existing environmental water quality standards.

In a WFN-based assessment, the total water footprint is the sum of blue, green and grey water flows. In addition, unsustainable blue water withdrawals are often reported.

Analysis of livestock's impact on the sustainable management of water resources has relied extensively on the blue water footprint. While water is used at all stages of livestock production, from animal drinking water to dairy and meat processing, it is feed production that requires the greatest quantities. Along the value chain the water footprint has two components: the internal water footprint, which is the consumption of water internally produced by recycling other systems for reuse in food production; and the external water footprint, which is defined as the consumption of the volume of water resources produced externally and acquired by the value chain. A virtual water budget can be calculated considering the external and internal water use and the water contents of products and waste.

As evident from Table 6, the total water footprint can vary greatly according to the animal species, the food product, and the type of farming system involved. For example, the water footprint for meat increases from 4 300 l/kg for chicken to 5 500 l/kg for goat meat, with pig meat requiring 6 000 l/kg, sheep meat 10 400 l/kg and beef 15 400 l/kg. In terms of the combined footprint of blue and grey waters, industrial production systems use more water than farms with grazing animals (Mekonnen and Hoekstra, 2012).

Currently, water footprint assessment relying on the life cycle assessment (LCA) framework is gaining wider currency. In comparison with the WFN methodology, the LCA framework can lead to very different results. In 2014, the Geneva-based International Organization for Standardization (ISO) issued a new standard, ISO 14046, seeking to establish a harmonized framework for the quantification and reporting of water footprints based on LCA with a set of new principles, requirements and guidelines. The approach could help in assessing the magnitude of water-related environmental impacts and identify ways of reducing them. Yet whereas ISO 14046 sets the general framework, no particular assessment method or indicators are recommended, and gaps in recommendations could also lead to inconsistent applications.

BIOLOGICAL AND CHEMICAL WATER HAZARDS FROM LIVESTOCK

Besides livestock's direct and indirect usage of freshwater, one of the central water-related challenges facing the animal production sector is waste management and disposal. Manure, urine and wastewaters used during farming may contain organic compounds such as macro-nutrients, drug residues, hormones, pathogens (i.e. bacteria and viruses) and inorganic substances, like heavy metals and other elements used as feed additives.

TABLE 6

WATER FOOTPRINT VALUES REPORTED FOR SELECTED FOOD PRODUCTS

ANIMAL PRODUCTS	FARMING SYSTEM	WEIGHTED GLOBAL AVERAGE (LITRES/KILOGRAM)			
		GREEN	BLUE	GREY	TOTAL
Beef	Grazing	21 121	465	243	21 829
	Mixed	14 803	508	401	15 712
	Industrial	8 849	683	712	10 244
	Weighted average	14 414	550	451	15 415
Sheep meat	Grazing	15 870	421	20	16 311
	Mixed Industrial	7 784	484	67	8 335
	Industrial	4 607	800	216	5 623
	Weighted average	9 813	522	76	10 411
Goat meat	Grazing	9 277	285	-	9 562
	Mixed	4 691	313	4	5 008
	Industrial	2 431	413	18	2 862
	Weighted average	5 185	330	6	5 521
Pig meat	Grazing	7 660	431	632	8 723
	Mixed Industrial	5 210	435	582	6 227
	Industrial	4 050	487	687	5 224
	Weighted average	4 907	459	622	5 988
Chicken meat	Grazing	7 919	734	718	9 371
	Mixed	4 065	348	574	4 987
	Industrial	2 337	210	325	2 872
	Weighted average	3 545	313	467	4 325
Eggs	Grazing	6 781	418	446	7 645
	Mixed Industrial	3 006	312	545	3 863
	Industrial	2 298	205	369	2 872
	Weighted average	2 592	244	429	3 265
Milk	Grazing	1 087	56	49	1 192
	Mixed	790	90	76	956
	Industrial	1 027	98	82	1 207
	Weighted average	863	86	72	1 021

Source: Mekonnen and Hoekstra, 2012.

Runoff and nutrient leaks from concentrated sources of livestock waste are a hazard to freshwater sources as well as ocean and marine environments (Mekonnen and Hoekstra, 2012). If not properly managed, nutrient runoff and excessive concentration of nitrogen and phosphorus can damage surrounding ecosystems and coastal fisheries. Manure and slurry pit waste discharges and outflows from animal slaughtering and food processing also contribute to contaminating water resources unless adequately treated. Animal waste can dump hazardous biological and chemical residues into the environment as well.

Several waterborne zoonoses circulate through drinking and recreational waters contaminated with animal waste, especially faecal material and manure. Rivers and streams carry faecal waste and pathogens, some of which have developed resistance to antimicrobial drugs – a serious threat to global public health. The bacteria are then released into lakes and other surface water bodies used for recreation, into commercial shellfish farms and into drinking-water sources.

Poultry, pigs, sheep, cattle and other domesticated animals generate around 85 percent of the world's animal faecal waste, proportionally a far greater amount than that contributed by humans. These animals' faecal production rate and potential dispersal into the environment can be as high as 2.62×10^{13} kg/year (Dufour *et al.*, 2012). Very often as a result, approximately four billion cases of diarrhoea occur each year, leading to nearly two million human deaths. Intestinal nematodes and other parasites like *Giardia* infect more than a billion people worldwide. The percentage of illnesses caused by zoonotic or water borne pathogens is difficult to determine due to lack of data, although it is generally accepted that zoonotic pathogens are responsible for 75 percent of emerging infectious diseases (Cotruvo *et al.*, 2004). Whilst a large number of zoonotic pathogens can affect humans, five are known to cause illness very frequently: *Cryptosporidium*, *Giardia*, *Campylobacter*, *Salmonella* and *E. coli* O157 (Dufour *et al.*, 2012), all which may also originate in livestock.

Pathogens released into the environment can contaminate and colonize fruit and vegetables through irrigation waters. For example, the occurrence of *Salmonella* and outbreaks due to *Salmonella typhimurium*, which may survive for extended periods in manure and manure-treated soils (Himathongkham *et al.*, 1999), have been associated with the consumption of fresh lettuce (Horby *et al.*, 2003).

Many chemical contaminants may be present in livestock waste, including micronutrients (Jongbloed and Lenis, 1998), veterinary pharmaceuticals (Boxall *et al.*, 2003; Campagnolo *et al.*, 2002; Meyer 2004), heavy metals, especially zinc and copper (Barker and Zublena, 1995) and naturally excreted hormones (Hanselman *et al.*, 2003; Raman *et al.*, 2004). Animal waste is also rich in organic and biochemical oxygen-demanding materials (BODs). For example, treated human sewage contains 20–60 mg BOD/litre, raw sewage contains 300–400 mg, and swine waste slurry contains 20 000–30 000 mg (Webb and Archer 1994).

All these chemical substances can harm marine and aquatic ecosystems and threaten public health directly and indirectly. Excessive phosphorus levels can contribute to algal blooms and cyanobacterial growth in surface waters used for recreation or as sources of drinking water (Burkholder *et al.*, 2007). Toxin-producing phytoplankton and bacterioplankton are ingested by filter-feeding shellfish, zooplankton and herbivorous fish, and the toxins may accumulate in the tissues of these animals and their predators. They can act as vectors for human intoxication either directly, as in the case of shellfish, or indirectly, via the food web (Munday and Reeve, 2013).

Antimicrobials are excreted by animals as parent compounds or metabolites. For example, about 25 percent of the oral dose of tetracycline is excreted in faeces and about 50–60 percent as the parent compound or as an active metabolite in urine (Tasho and Cho, 2016). Antimicrobials can also be bio-accumulated in plants (Tasho and Cho, 2016), representing an additional potential vehicle of exposure for animals and humans.

WATER CONTAMINATION PATHWAYS

Water contamination by pathogens and active chemical substances deriving from animal waste affect animal and public health in various ways. Contaminants from animal waste can enter the environment through leakage from poorly constructed manure storage and lagoons, or during heavy rains causing overflow of lagoons or runoff from recent applications of waste to farm

fields. Or they can precipitate as dry or wet atmospheric deposits (Aneja *et al.*, 2003).

Rainfall has been proven to play a role in *Salmonella* dispersal and contamination of vegetables in the field, especially during concentrated downpours (Cito *et al.*, 2016). As far as chemical contaminants are concerned, soil properties and climatic conditions can affect their transport. For example, sandy, well-drained soils are most likely to transport micronutrients to underlying groundwater (Mueller *et al.*, 1995). Nutrients can also readily move through soils under wet conditions (McGechan *et al.*, 2005).

The possible persistence of veterinary antibiotics in the environment depends largely on soil type, temperature, animal excreta, pH and UV light. Low temperatures, for example, reduce the degradation rate of antibiotics (Tasho and Cho, 2016). In addition, changes in grey water and sewage sanitation and treatment methods may contribute to contamination of water resources. Natural disasters like earthquakes may also play a part, e.g. by damaging pipelines in urban sanitary sewer systems (Cito *et al.*, 2016).

MITIGATION OPTIONS

Mitigation options to improve water-use efficiency can be broken down into three main strategies: reduced water use, reduced depletion, and improved replenishment of water resources (Steinfeld *et al.*, 2006). Reducing water use includes upgrading irrigation technology to improve efficiency, and shifting towards mixed crop–livestock systems, which use less water while increasing productivity (Thornton, 2010; Herrero *et al.*, 2010). Land management practices can also influence water use: overgrazing, for instance, can affect water filtration and retention capacity in grasslands, and significantly compromise the water cycle. As noted, one of the central water challenges facing the livestock sector is waste management and disposal.

Many technical solutions are in place in industrialized production systems to improve manure collection, storage, and processing methods, utilising physical and chemical processes. The major problem is applying and adapting such technologies to local conditions in developing countries. One solution that has proved successful in reducing nutrient pollution and conserving marine resources is the Integrated System of Phytodepuration (ISP). ISP was tested on different production systems, with a mean efficiency value of over 85 percent in removing Chemical Oxygen Demanding substances (Petroselli *et al.*, 2016).

As for the growing threat of antimicrobial resistant pathogens circulating in water, a first step would be to cut back on the use of antimicrobials by making quality vaccines and diagnostic assays (point-of-care) more readily available and affordable, while also improving biosecurity and hygiene on farms and at markets. In fact, a key element in reducing antimicrobials in livestock production is ensuring the health and welfare of animals and effective disease prevention is the best way of keeping animals healthy. What is needed now is to introduce an integrated approach for reducing the use of antimicrobials with livestock as an essential part of national animal health strategies. Implemented through specific action plans and supported by harmonized surveillance systems, such an approach would also produce valuable data on AMR in livestock and their food products. This would also provide vital information for a continuous evaluation of the effectiveness of the measures taken. All actors in the sector, including farmers, private veterinarians and food operators, must be made aware of the urgent need to reduce the use of antimicrobials and to become actively involved in this process (EMA and EFSA, 2017).

The World Health Assembly has urged all Member States to develop, by 2017, national action plans on antimicrobial resistance that are aligned with the objectives of the World Health Organization's (WHO) 2015 global action plan. A manual has been developed by WHO, in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE), to assist countries in preparing or refining their

national action plans. Better sanitation, together with greater food and water safety, must be core components of infectious disease prevention.

CONCLUSION

SDG 6 concerns the quality and sustainability of water resources. Agriculture uses approximately 70 percent of the world's available freshwater, and roughly 30 percent of global agricultural water is used to produce livestock. Total water footprints vary greatly, depending on the animal farming system, but intensified animal production appears to go hand in hand with an increased water footprint. Thus, when selecting a farming system, careful consideration should be given not only to economic and productive aspects but to the water resources required and their sustainable use. A holistic approach to water management should be adopted, leading to fully integrated wastewater management that pays close attention to antimicrobials and other residues, *inter alia*. Management strategies should be site-specific, and take account of social, cultural, environmental and economic conditions in the targeted areas, with water governance a key issue in decision-making.

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7. Livestock and clean energy

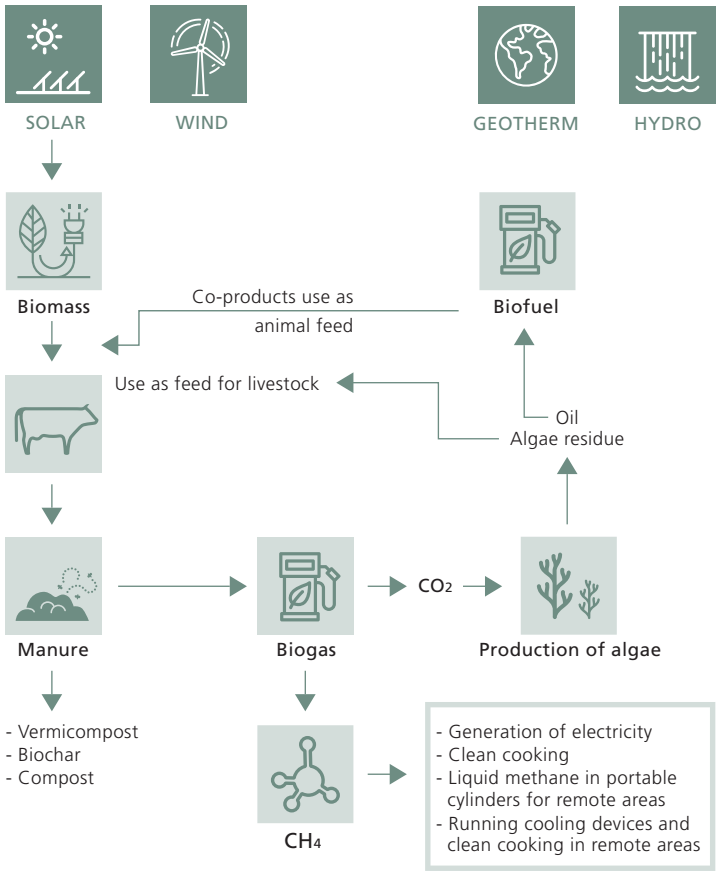
INTRODUCTION

Sustainable Development Goal 7 seeks to ensure access to affordable, reliable, sustainable and modern energy for all. It highlights the importance of investing in renewable forms of energy and expanding infrastructure to supply sustainable energy services to developing countries, where many people still live without electricity. According to the International Energy Agency (IEA), around 17 percent of the global population lacks access to electricity, and 38 percent is without clean cooking facilities. Almost all of these people – 80 percent – live in rural areas. Out of 1.2 billion people without electricity, more than half are in Africa (634 million) followed by developing Asia (512 million), Latin America (22 million) and the Middle East (18 million) (IEA, 2016).

Currently, the greater part of the world's energy consumption (approximately 80 percent) is generated from fossil fuels which are not only finite but produce environmental pollutants, including climate-warming greenhouse gases. Low-carbon energy sources, such as solar or those obtained from biomass, are not only renewable but have a much lower environmental impact than conventional fuels. Renewable energy is a fast-developing sector that creates jobs and boosts local economies. At country level, renewables, especially if locally produced, offer developing nations the chance to break away from foreign oil supplies, which drain their reserves of foreign currency and put their economies in thrall to outside forces. Renewable bioenergy offers the prospect of greater, more sustainable economic growth stemming from its wider availability at increasingly lower costs.

The "Energy Revolution" now replacing polluting coal and oil with clean, renewable sources is likely to figure as one of the most significant conquests of the twenty-first century. Livestock, whose manure can be turned into biogas, has an important role to play in this process, especially in developing countries. For biogas not only enhances their energy security but also helps resolve vexing problems such as environmental pollution, bad odour and flies. At global level, turning animal manure into biogas would also

22 CLEAN ENERGY–LIVESTOCK NEXUS



Source: FAO, 2018.

eliminate a leading source of methane, a powerful driver of global warming. In the context of the current environmental debate, solar, wind, geothermal power, animal and biomass energies are considered as clean. Indeed livestock production relies on energy embedded in biomass, which comes mainly from solar energy, while other sources may also contribute (Figure 22).

BIOGAS AND ENERGY GENERATION

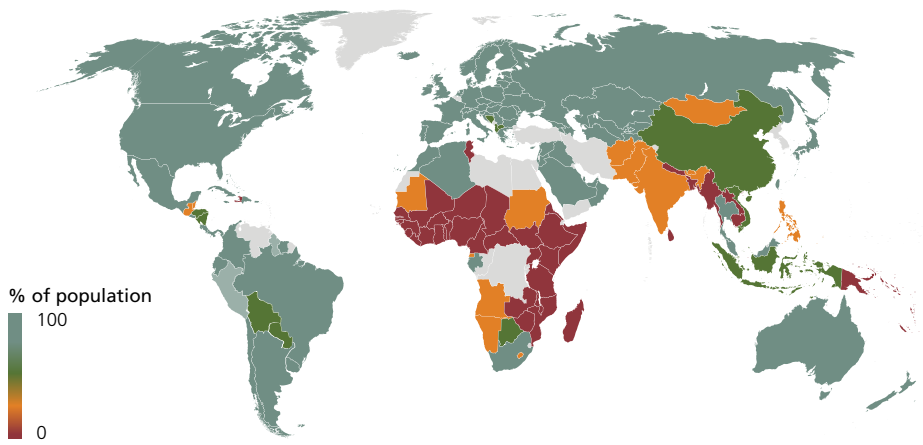
Converting livestock manure into biogas could make a major domestic renewable fuel source available to more than a billion people, giving them access to affordable, reliable, and sustainable energy in line with SDG 7. Especially in sub-Saharan Africa and Southern Asia, rural villages and remote areas often lack direct connections to national electricity grids, locking them in poverty and underdevelopment. Yet India and the People's Republic of China, the two leading Asian countries using biogas technology, have shown there is a way out of this energy trap. Between 2003 and 2013, the People's Republic of China built 42 million small household biogas plants that provide light, heating and power and run on chicken and cattle manure, as well as a number of much larger biogas power stations with a daily capacity of 18 000–60 000 kWh

(Chen *et al.*, 2012). India had installed some 3.4 million family-size biogas reactors in various isolated parts of the country by the end of 2002 and in 2015, the number of family-size biogas plants in India was reported to be four million with an overall potential for eight million more (Kapdi *et al.*, 2005).

In 2013, biogas production in Europe, Asia, the Americas and Oceania was respectively 0.57, 0.4, 0.28 and 0.02 exajoules (Statista, 2017) where one exajoule is roughly equivalent to 174 million barrels of oil. In Europe, which leads the field in biogas installations, the United Kingdom, Italy, Poland, France and Czechia in particular are expected to expand production. In 2006, global installed capacity of electricity generation through anaerobic digestion was 20 000 MW (Demirbas and Balat, 2006). Besides the People's Republic of China and India, many developing countries in Asia and in Africa, are using biogas to expand household electricity production (Sorathiya *et al.*, 2014). Electric lighting makes it possible for children to study at home in the evening and improves their performance at school (Mengistu *et al.*, 2015). The synergy here is with SDG 4 on ensuring inclusive and quality education for all. Livestock production is increasing in developing countries and will continue to do so in the near future, therefore plentiful supplies of livestock manure will be available as feedstock to run a new generation of digesters for biogas production.

Decentralized bioenergy technology provides a cost-effective and sustainable alternative to grid electricity. The abundance of livestock manure in regions with low electrification rates is thus a major opportunity for generating energy for homes and communities. For farmers, it could also provide a valuable source of income from selling manure and other agricultural by-products such as feed crop residues (Mohammed *et al.*, 2013). Biogas conversion could assist countries in meeting renewable portfolio standard (RPS) requirements (which call on them to produce more energy from renewables), while simultaneously reducing pollution and greenhouse gas emissions (in synergy with SDG 13 on climate change) (Cuéllar and Webber, 2008).

23 PROPORTION OF POPULATION WITH ACCESS TO CLEAN FUELS AND TECHNOLOGIES FOR COOKING



Source: Adapted from WHO, 2018.

Excessive diversion of manure towards bioenergy production however could adversely affect soil health and crop productivity (trade-off with SDG 15 aimed at sustaining life on land).

BIOGAS AND CLEAN COOKING

A high proportion of the population still lacks access to clean fuels and technologies for cooking (Figure 23). Using biogas for cooking would not only reduce land degradation from biomass collection for cooking (Wei *et al.*, 2004) but would also save women the long hours they now spend gathering fuelwood thereby freeing them to engage in more productive tasks. In India, for instance, women spend more than one hour every day on average collecting fuelwood (Bloomfield, 2015). Likewise, women farmers lose considerable time in fuelwood collection in sub-Saharan Countries (World Bank, 2014).

Seen from another perspective, the provision of clean energy removes a highly lethal health threat to women and children, who inhale much of the smoke from traditional, wood-burning cooking fires (synergy with SDG 3) (Kang *et al.*, 2009; Li *et al.*, 2012; Xiao *et al.*, 2015). According to the World Health Organization's (WHO) Global Health Observatory (GHO) household air pollution caused 4.3 million deaths and 7.7 percent of global mortality in 2012. Use of biogas and other clean-energy options reduce exposure to the most health-damaging air pollutants (e.g. particulate matter) by as much as 90 percent (MacCarty *et al.*, 2010). Another important advantage of using clean energy for household purposes is that it helps reduce land degradation from biomass collection for cooking (synergy with SDG 15 on protecting ecosystems) (Wei *et al.*, 2004).

BIOGAS COOLING AND FOOD WASTE

Approximately 30 to 50 percent of milk is wasted in rural areas due to lack of refrigeration. In many remote areas in developing countries, biogas-run refrigerators and chilling appliances can help preserve multi-nutrient and vitamin levels in animal-source foods (ASFs) and fruit and vegetables; increase their shelf-life; and reduce food waste, enhancing both nutrition and food security (synergy with SDG 2 on ending hunger, and SDG 3). Introduction of biogas-powered cooling appliances is expected to trigger a cascade effect, encouraging further development of innovative biogas-based technologies for homes and industries while at the same time creating new jobs (SDGs 8 and 9).

BIOGAS IN PORTABLE DEVICES

Technology now exists for purifying and bottling biogas. Pure biogas stored in portable cylinders as compressed gas can be used anytime, anywhere (see Table 7), making biogas an easily marketable source of energy. Bottled gas reduces distribution costs because transporting biogas through pipes is very expensive. Biogas bottling plants at villages in the Indian states of Punjab and Maharashtra have successfully produced biogas containing 98 percent methane, compressed at 150 Bar, in cylinder form (Sorathiya *et al.*, 2014). In this way, biogas can be used not only for cooking but also for running

TABLE 7
POTENTIAL OF NEWER BIOGAS PURIFICATION AND BOTTLING TECHNOLOGY

COUNTRY	PLANT CAPACITY (m^3)	PURE BIOGAS PRODUCED (kg/day)	NO. OF GAS CYLINDERS FILLED	USE OF GAS	SAVINGS
Pakistan	60	21.6	4 cylinders of 3.5 kg	To run engines	Diesel worth $147/day
India	600	231	27 cylinders of 8 kg	Cooking	Light Petroleum Gas worth $240/day

Source: Adapted from Sorathiya *et al.*, 2014.

cooling devices in remote areas. In addition to decreasing food waste, such appliances are also important in terms of both individual and public health as they allow human and animal vaccines to be preserved at low temperature (SDG 3). However, any compromises in safety norms during transportation and use of portable compressed gas could be detrimental (trade-off with SDG 3).

Purified methane biogas stored in cylinders has also been used to run auto rickshaws and diesel engines. This kind of methane is used to cook the lunches supplied in a school feeding scheme for 18 000 pupils in India. As an extra bonus, biogas generation produces slurry that can be used as organic fertilizer. A 600 m3 plant in Punjab makes about USD 111/day from selling the slurry to local farmers (synergy with SDGs 2 and 3). Other advantages of purified biogas are illustrated in Table 7. The initial cost of setting up plants is considerable and needs government subsidies and loans that can, however, be recovered in 4–5 years.

OTHER VALUE-ADDED PRODUCTS FROM BIOGAS AND MANURE

Processing animal manure into biogas produces additional valuable by-products, such as quality fertilizer through anaerobic digestion, and 'biochar' through pyrolysis, both of which offset the use of synthetic fertilizers and enhance soil fertility and carbon sequestration (Holm-Nielsen *et al.*, 2009; Schouten *et al.*, 2012) (synergy with SDG 15). Vermicompost (compost using various worm species) converts Nitrogen, Phosphorus, Potassium and Calcium present in the manure into forms that are more soluble and available to plants. Vermicompost also contains biologically active substances such as plant growth regulators. The worms could also serve as a source of protein in animal feed. The integration of composting and vermicomposting requires less time to complete a cycle and also results in a superior product with more stability and homogeneity – hence high crop yields (Sorathiya *et al.*, 2014). However, use of manure as vermicompost decreases manure availability for clean-energy generation (trade-off with SDG 7). After sanitization, manure can be used for rearing insects for use as animal feed (synergy with SDG 2 on hunger).

The carbon dioxide obtained from anaerobic digestion and thermo-chemical conversion of livestock manure can further be used for production of algal biomass. Algae can utilize carbon dioxide ten times more efficiently than terrestrial plants and have high generation rates. Some algae accumulate large quantities of intracellular oil and are a most promising non-crop-based feedstock for biofuel production (Miao and Wu, 2006). Furthermore, residue left after extracting oil makes a good feed for fish and livestock (Oilgae, 2016) (synergy with SDG 2). As livestock production systems grow and intensify, controlling pollution from farms will be an increasingly important issue. Biogas production is extremely relevant here as, in addition to being a source of fuel, it offers a valuable waste management solution.

BIOFUEL AND LIVESTOCK FEED

Biofuels like bioethanol are renewable sources of energy. Approximately 6 percent of global grain production is used for biofuel production. A co-product of the world's harvest is some 48 million tonnes of protein- and energy-rich distillers' grains (FAO, 2012d). The grains can be added to the diets of ruminants as well as poultry, pigs and aquatic species (Makkar, 2014). In the last 15 years or so, distillers' grains have replaced soymeal and maize in the diets of beef cattle and swine (FAO, 2012d), suggesting they are helping reduce food–feed competition and, by extension, contributing to some reduction in land used to grow soybeans for feed. In addition, mixing distillers' grains with solubles in the diets of ruminants decreases enteric methane emissions, and although the amount of nitrogen released in manure could rise (Benchaar *et al.*, 2013; Hünerberg *et al.*, 2013), good manure management would reduce this trade-off. Besides mitigating environmental problems

involved in their safe disposal, feeding biofuel co-products to animals saves grain nutrients for consumption in the human food chain.

A number of other biofuel co-products such as glycerol, fatty acid distillate, cakes and meals from oilseed plants such as rape, soya, camellia, non-toxic jatropha and pongamia, among others, can also be used to feed livestock, as can by-products from algae used in making biodiesel (FAO, 2012d). In most developing countries, ruminants' diets are based on crop residues and other poor-quality roughage – from 55 to 60 percent of the diet (Mottet *et al.*, 2017). This results in high emissions of greenhouse gas per unit of animal product (e.g. 4–9 kg CO_2 eq./kg milk) (Opio *et al.*, 2013). Supplementing feed with biofuel co-products that are rich in protein and energy, and do not compete with human food, decreases enteric methane to around 2 kg CO_2 eq./kg milk by optimization of the rumen (Makkar, 2017). However, use of grains or edible oils for biofuel generation would increase food–fuel competition (trade-off with SDG 2). In the future, oil extraction from unconventional sources for clean energy generation is likely to increase, and prudent use of the co-products of this process can be made in the livestock feed industry. The synergies between the biofuel and livestock sectors not only help achieve SDG 7 on providing clean energy but can also promote SDG 2 and SDG 13 (climate action) by respectively improving food security and protecting the environment.

ANIMAL POWER – ONE OF THE OLDEST FORMS OF BIOENERGY

Animal traction is particularly important for food security in smallholder farming systems. Since ancient times, humans have used animals such as cattle, buffaloes, horses and elephants to carry out different types of work. Even today, in alternative to mechanization, animals assist directly with crop production, helping to plough, plant, and weed. Animal power figures not only in food production, however, but also in distribution and rural trade (they are used on-farm, in marketing, as mounts and as pack animals). They save household members, especially women and children, time and effort by carrying water and fuelwood, while animal power can also be used for heavier-duty tasks such as water-lifting, milling, logging, land excavation and road construction. Many different types of animals are employed and in particular cattle, buffaloes, horses, mules, donkeys and camels. For instance, in India, two-thirds of the

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cultivated area is ploughed using animal energy and 14 million carts haul up to 15 percent of the country's total freight. According to a 2007 census, some 60 million cattle and buffaloes worked in agriculture a decade ago, saving fossil fuel worth approximately USD 1 billion, annually (Natarajan *et al.*, 2016).

Using animals for labour-intensive road construction can be highly cost-effective, and animal power can also be profitably harnessed in forestry and for specific operations on estates and large-scale farms. In mixed farming systems, the use of animal power encourages crop–livestock integration and sustainable farming practices. While producing their own manure, draught animals also transport the manure of other livestock to the fields to enhance the structure and fertility of the soil. Animal-powered transport can yield particular social and economic benefits too: farmers with carts or pack animals have wider contacts with traders, resulting in improved market access and higher production and profits.

It may be argued that this source of energy is far from modern and that the animals produce greenhouse gases but the use of all types of bioenergy is associated with some amount of GHG emissions. Although largely ignored in current discussions on clean energy generation, animal traction is still widespread in many developing countries. It remains relevant and useful because it is suited to the needs of farmers with small land holdings on hilly terrain, where farm machinery is impractical. Urban-based planners and politicians often forget the importance of animal power to rural people when addressing the issues of modernization, industrialization and urbanization.

Recent examples of animal power marginalization include subsidies to tractors and imported equipment, and exclusion of animal-powered transport. Governments should, however, provide a suitable policy environment that supports the maintenance or development of animal draught services. Legislation and development processes should not isolate animal-power users or support services, either directly or indirectly, and animal traction needs to be portrayed as a renewable technology that is relevant to the modern world. Future potential for animal energy to complement other power sources should be assessed.

CONCLUSION

Goal 7 encourages wider access to energy, and greater use of renewables. The livestock sector, increasingly, is contributing to the provision of clean, renewable energy by converting manure into biogas. Animal draught power is also used extensively in smallholder settings, and its increased use in future can help achieve renewable energy targets. Livestock are further able to exploit the reserves of energy contained in plant biomass that is not edible by humans. New institutions and technologies will be needed, however, to greatly expand manure-based biogas generation. The use of clean energy to substitute fossil fuels in feed production must also be increased.

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8. Economic growth and employment

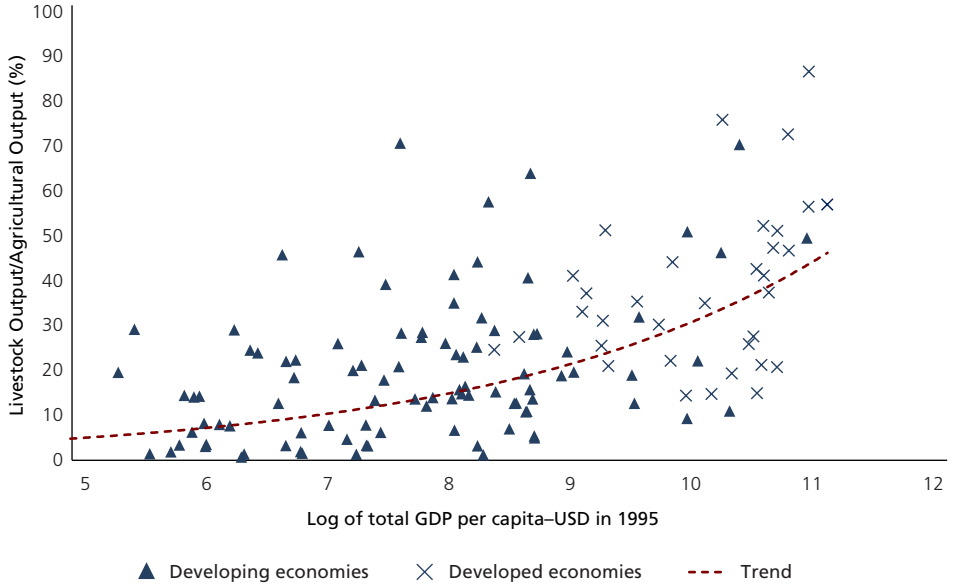
INTRODUCTION

Over the past decades, production and consumption of livestock products has increased substantially, with the sector becoming one of the fastest-growing in agriculture. Driving this "livestock revolution" was a combination of population growth, rising incomes and rapid urbanization (Delgado *et al.*, 1999). Continuing expansion of the sector is expected, with demand for livestock products fuelled by the one billion increase in world population projected by 2030 and by a further decline in poverty, giving consumers greater access to animal protein (OECD, 2017). SDG 8 proposes an integral approach towards more sustainable, sustained and inclusive economic growth (UN, 2016a).

Livestock production makes a major contribution to the global economy, employing at least 1.3 billion people worldwide and providing livelihoods for 600 million poor smallholder farmers in developing countries (Thornton *et al.*, 2006). Livestock's share of total agricultural output is nearly 40 percent in developed countries and 20 percent in developing ones. The vigorous growth of the sector, and its ability to reach into many different areas of the economy and society, presents a major opportunity for many countries on their path towards economic development.

Vertical and horizontal multiplier effects from the livestock sector can boost economic growth in two main ways: by contributing directly to rural livelihoods and agricultural output; and through the sector's various productive linkages with other industries. However, the sector in developing countries is highly segmented, exhibiting sharply different levels of labour productivity between processing and production, and, within production, between commercial and subsistence farmers. Thus, a simple multiplication of similar opportunities could just result in an expansion of underemployment. Livestock economic growth models should therefore put particular emphasis on increasing labour productivity and focus on high-value-added and labour-intensive activities.

24 SIZE OF THE LIVESTOCK SECTOR ACCORDING TO THE LEVEL OF ECONOMIC DEVELOPMENT



Note: The graph includes the 10-year average values from 132 countries, covering the period from 2005 to 2014.
Source: Based on data from FAOSTAT, 2017.

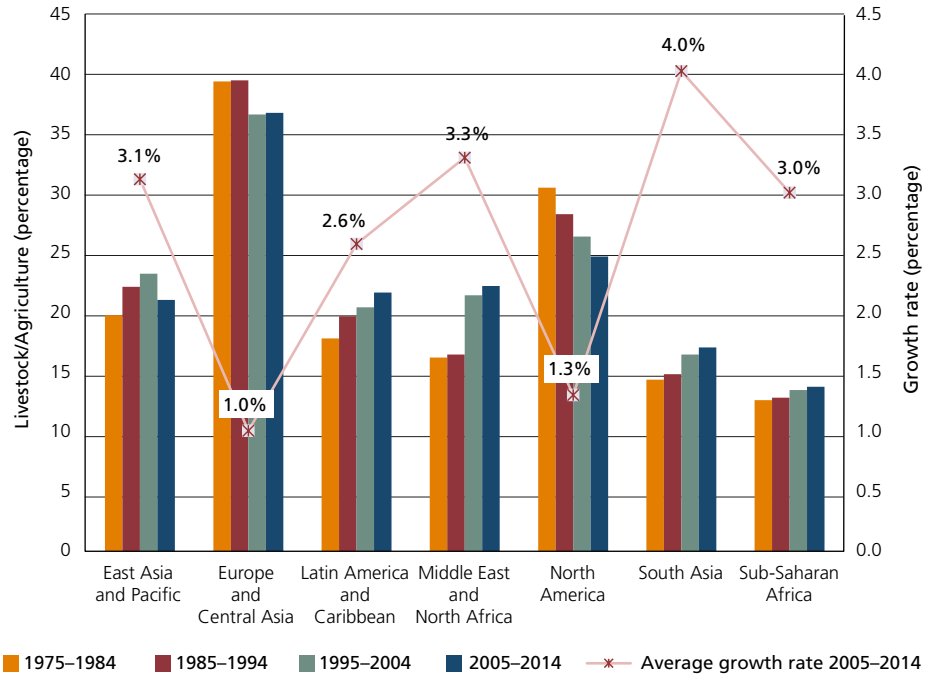
CONTRIBUTION OF LIVESTOCK TO THE ECONOMY

Although the share of agriculture in national GDP tends to decrease as countries move up the development ladder (Valdés and Foster, 2010), the contribution of livestock to agricultural output tends to increase as agriculture modernizes and markets become more specialized. This phenomenon is illustrated in Figure 24, which shows a positive correlation between the size of the livestock sector within agriculture as a whole and national per capita income. The share of livestock production in developed countries (nearly 40 percent of agricultural output) is twice as large as in developing economies (about 20 percent).

As indicated in Figure 25, livestock production in developed economies contributes a substantially bigger share of total agricultural output than in developing economies. For instance, in North America, and Europe and Central Asia, it accounts for 25 percent and 37 percent of agricultural production respectively. This contrasts with much lower shares, ranging between 14 percent and 22 percent, in the other regions – Latin America and the Caribbean (LAC), the Near East and North Africa (NENA), South Asia (SA), and sub-Saharan Africa (SSA). It should be noted, however, that the sector has grown faster in developing regions – between 2.6 percent and 4 percent per annum – than in developed regions, where it has averaged 1 percent per annum in Europe and Central Asia and 1.3 percent in North America.

The growth of the livestock sector can produce complex vertical and horizontal multiplier effects that reach well beyond the agricultural sector. Acosta and Barrantes (2018), using panel data information from 69 countries covering the period 1970–2014, estimated the response of the agricultural and non-agricultural sectors to changes in the value of livestock production. Their results show that the non-agricultural sector tends to respond more elastically to changes

25 LIVESTOCK SECTOR EVOLUTION SHARE WITH RESPECT TO TOTAL AGRICULTURAL OUTPUT AND AVERAGE GROWTH RATES PER REGION



Note: The graph includes the 10-year average values from 131 countries, covering the period from 1975 to 2014. For the first two periods (1975–1984) and (1985–1994), countries belonging to the Commonwealth of Independent States and Georgia were not included.
Source: Based on data from FAOSTAT, 2017.

TABLE 8

ELASTICITY OF AGRICULTURAL AND NON-AGRICULTURAL OUTPUT WITH RESPECT TO LIVESTOCK GROWTH

ECONOMY CLASSIFICATION	AGRICULTURE OUTPUT	NON-AGRICULTURE OUTPUT
High income	0.43	1.02
Upper middle income	0.60	0.90
Lower middle income	0.64	0.76
Low income	0.71	0.73

Source: Acosta and Barrantes, 2018.

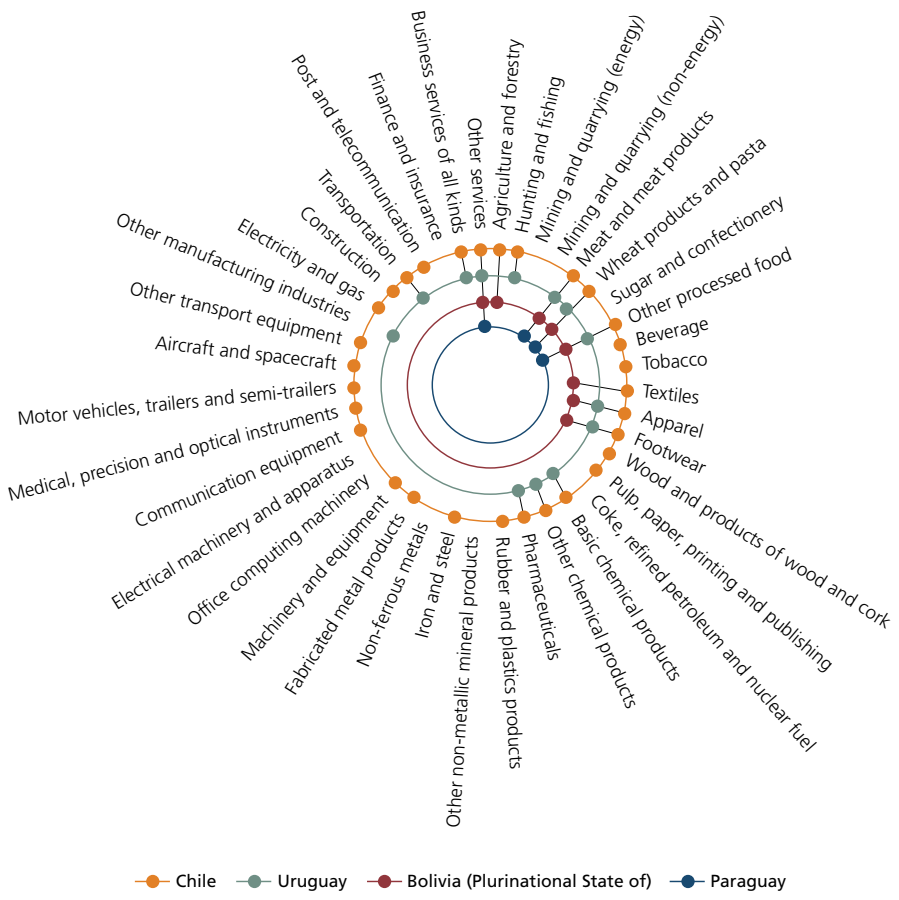
in livestock production. For example, in lower middle-income economies, an increase of 1 percent in livestock production tends to expand the non-agricultural sector by 0.76 percent in contrast to the agricultural sector's 0.64 percent.

It is interesting to note that these elasticities differ depending on the level of countries' economic development. As the level increases, the response of the agricultural sector to livestock expansion decreases, while the response of the

non-agricultural sector rises. In high-income economies, an increase of 1 percent in livestock production tends to expand the non-agricultural sector by 1.02 percent, in comparison with 0.73 in low-income countries. On the other hand, in high-income economies an increase of 1 percent in livestock production triggers an increase of 0.43 percent in agricultural production, in comparison with 0.71 in low-income countries.

These dynamics can be explained by the number of forward and backward linkages of the sector with other industries through various production and consumption channels. In high-income economies, the sector requires greater quantities of high-value-added industrial products, including fossil fuels, pharmaceutical products, rubber and plastic, machinery, infrastructure, electricity and gas, transport, and financial and insurance services. In addition, it provides inputs to other industries such textiles and agrochemicals, products for the agro-food industry, and pharmaceuticals. Thus, in larger and more

26 FORWARD LINKAGES OF THE MEAT AND DAIRY INDUSTRY TO OTHER INDUSTRIES



Note: The space marked with blue represents a technical coefficient higher than 0.0001 in the intermediate demand section of the Input–Output Matrix of technical coefficients.
Source: Based on data from the Economic Commission for Latin America and the Caribbean (CEPAL), 2017.

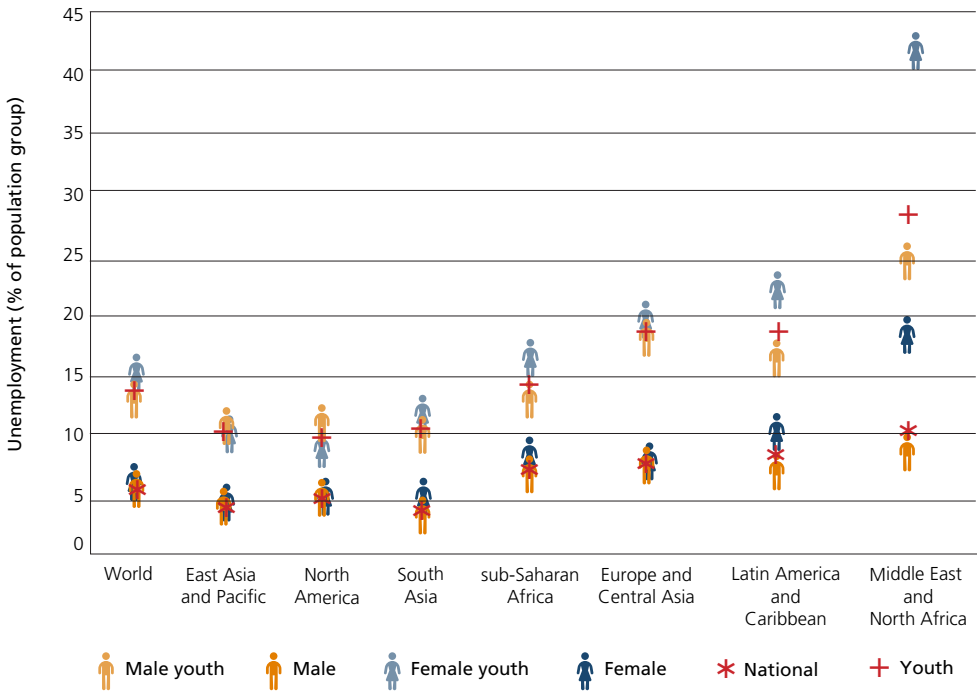
complex supply chains interconnected with industries in other economic areas, each link of the supply chain generates a larger portion of value added, promoting higher overall economic growth through the various multipliers.

This phenomenon is clearly evident in Figure 26, which compares the linkages of the meat and dairy industry in higher- and lower-income countries. Economies with high income levels – Chile and Uruguay – present more productive linkages than economies with lower incomes such as Bolivia (Plurinational State of) and Paraguay. For example, the Chilean and Uruguayan meat and dairy industries provide inputs to 30 and 13 other industries respectively; whereas in Bolivia (Plurinational State of) the sector links up with eight industries, and in Paraguay with only four. Clearly, energizing the livestock sector in Chile and Uruguay would leverage greater growth in the overall economy than in the latter two countries, given the number of multipliers present and acting along more complex value chains.

POPULATION GROWTH AND EMPLOYMENT GENERATION

In 2013, the poorest region in the world was sub-Saharan Africa, with 35 percent of the population living on less than USD 2 a day, followed by South Asia (17.5 percent), Latin America and the Caribbean (5.3 percent) and East Asia and the Pacific (4.5 percent), for a total of 800 million poor. These regions face not only widespread poverty, but also high unemployment rates. As shown in Figure 27, unemployment amounts to 6 percent of the total labour force

27 UNEMPLOYMENT RATE BY GENDER AND AGE GROUPS IN 2017



Note: The values are expressed as percentage of the corresponding category's total labour force.
Source: Based on data from ILO, 2018.

globally, but is much higher in several economic regions, particularly in SSA, Europe and Central Asia (ECA), LAC and NENA. Especially worrisome is youth unemployment, which is twice that of the overall unemployment rate in every region. Further, a clear gap between males and females exists in both adult and youth populations, with females suffering the largest exclusion from the labour market.

Given the population prospects, the capacity to create remunerative jobs is, and will continue to be in coming decades, one of the major challenges in combating poverty in developing countries. The world's population is set to increase by more than one billion in the next 15 years, reaching 8.5 billion by 2030. By 2050, SSA, SA, and NENA will have increased their populations by 1.9 billion, accounting for nearly 86 percent of the total projected world population growth. These regions also have the largest shares of youth and child populations – averaging 25 percent and 16 percent respectively – which highlights the crucial need to promote youth employment there.

With growing demand fuelled by income and population growth, particularly in urban areas, increasing livestock production in developing or emerging regions represents a major opportunity for stimulating local economies and rural livelihoods. Considering the many vertical multiplier effects at work, a growing livestock sector can dynamize employment in the agricultural sector as a whole since it requires increasing quantities of labour and capital along the supply chains, including transport, slaughterhouses, hygiene, and feed production. The development of larger supply chains and productive linkages with other industries can also help stimulate labour markets in other sectors of the economy.

However, the livestock sector in developing countries is characterized by being highly segmented between processing and production, and, within production, between commercial and subsistence farmers. Thus, the level of productivity in domestic factors of production, including labour, may differ between segments. Indeed, productivity tends to be higher among commercial producers, who are often better endowed with capital, land, technology and access to marketing infrastructure, and lower among subsistence farmers. Economic intuition

TABLE 9
WORLD POPULATION PROSPECTS

	2017				2050			
REGION	**POPULATION** *(Billion)*	**RURAL**	**CHILD** *(0-14 years)*	**YOUTH** *(15-24 years)*	**POPULATION** *(Billion)*	**RURAL**	**CHILD** *(0-14 years)*	**YOUTH** *(15-24 years)*
EAP	2.3	42%	20%	13%	2.4	27%	16%	11%
China	1.4	42%	18%	12%	1.3	24%	14%	10%
ECA	0.9	29%	18%	12%	0.9	21%	16%	11%
LAC	0.6	20%	25%	17%	0.8	14%	17%	12%
MENA	0.4	35%	30%	17%	0.7	26%	22%	14%
SA	1.8	66%	29%	19%	2.3	49%	20%	14%
India	1.3	66%	28%	18%	1.7	50%	19%	14%
SSA	1.1	61%	43%	20%	2.2	45%	33%	19%
World	7.5	45%	26%	16%	9.7	34%	21%	14%

Note: EAP refers to East Asia and the Pacific, ECA to Europe and Central Asia, LAC to Latin America and the Caribbean, NENA to Near East and North Africa, SA to South Asia, and SSA to sub-Saharan Africa.
Source: Adapted from the World Bank, 2017.

would predict that growth in demand for livestock products would trigger a rise in output supply and inputs demand across all segments. However, since livestock jobs in the subsistence segment are marked by low wages and poor conditions, a simple multiplication of similar opportunities might just result in an expansion of underemployment.

CONCLUSION

Goal 8 promotes sustainable economic growth and full and productive employment. The value of livestock production accounts for nearly 40 percent of total agricultural output in developed countries and for 20 percent in developing countries. Yet the contribution of livestock to overall economic growth through numerous vertical and horizontal multiplier effects goes well beyond simple production. In developing countries, however, the livestock sector is highly segmented and the level of labour productivity differs widely between processing and production processes, and also between commercial and subsistence farmers. Thus, simply multiplying the same kind of opportunities might just result in an expansion of underemployment. Livestock economic growth models should therefore put special emphasis on increasing labour productivity and focus on high value-added and labour-intensive activities.

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9. Livestock and industrialization: turning challenges into opportunities

INTRODUCTION

Industrialization is a dynamic instrument of growth, promoting rapid economic and social development (Upadhyaya, 2013) as it shifts labour and other resources from labour-intensive and less productive activities towards more capital- and technology-intensive ones. It offers great opportunities for developing countries to enter the downstream end of global value chains and in so doing to accelerate economic growth (UNIDO, 2016). The role of industrialization is particularly important in developing and emerging economies, where the share of services is relatively smaller than in developed countries. Caselli (2005) and Restuccia *et al.* (2008) argue that differences in living standards between countries primarily stem from two factors. First, developing countries employ a much larger share of their labour force in agriculture compared to the other sectors; and second, agriculture in developing countries is less productive than in developed ones. When countries' workforce is mainly involved in primary agriculture, which, sadly, is the least-productive part of the economy, it has adverse impacts on economic growth and development (Herrendorf *et al.*, 2013; Caselli, 2005; Restuccia *et al.*, 2008).

SDG 9 brings renewed attention to the importance of building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation, thus reallocating resources for achieving socially inclusive and environmentally sustainable economic growth. Given the dynamics of the global economic landscape and the need to tackle issues of inequality, sustainable and inclusive industrialization is a central target of SDG 9. Achieving the goal depends on investing in research and innovation as well as developing resilient infrastructure. Industry is an important job creator in most economies, accounting for more than

470 million jobs worldwide at the end of the last decade (SDG, 2016). Nevertheless, according to the United Nations Industrial Development Organization (UNIDO, 2016), the share of manufacturing employment in developing countries grew from about 12 percent in 1970 to 14 percent in 2010, i.e. essentially remaining stagnant.

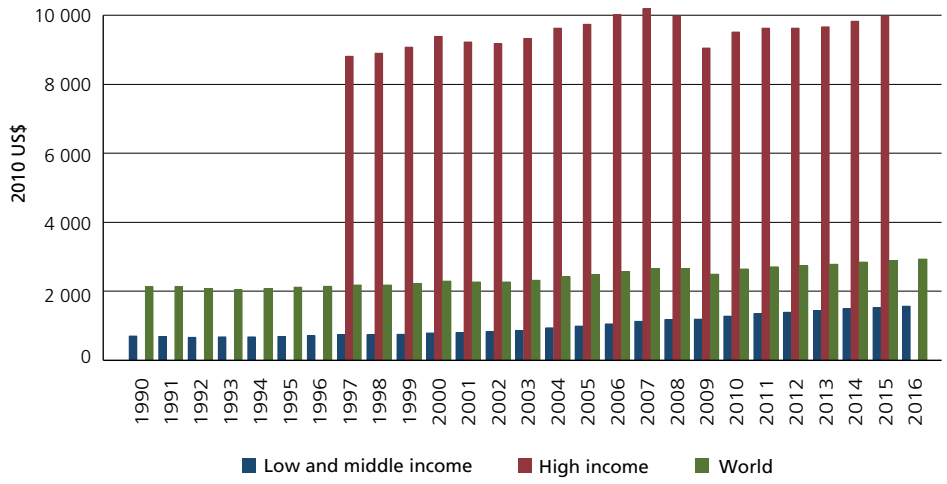
Linkages between the livestock sector and industrialization work both ways. On the one hand, the fast-growing sector offers attractive opportunities for industrialization and an increased share in the national economy. The animal product processing industry is one of the fastest growing in emerging economies, with a rate of 3 percent per annum forecast for the coming decades (FAO, 2017b). On the other hand, the overall development of industrial capacity, infrastructure, research and innovation, and access to finance, offers the livestock sector an excellent opportunity to add value to increasingly limited and deteriorating land and water resources, and achieve more inclusive economic growth. This chapter elaborates on the role that sustainable and inclusive industrialization can play in livestock development, and also underscores the opportunities offered by the sector for countries to industrialize not only faster but also sustainably, a central goal of SDG 9.

GLOBAL TRENDS IN INDUSTRIALIZATION

Although sustainable industrialization is essential for rapid economic and social development (Upadhyaya, 2013), and despite the great opportunities that industrialization holds for developing countries, the latter are still far from achieving the right levels of industrial capacity. Indeed, global average manufacturing value added (MVA) as a share of GDP has been steadily declining in the last few decades from about 21 percent in 1995 to about 15 percent in 2015 (World Bank, 2017), which is due in part to a substantial increase in services.

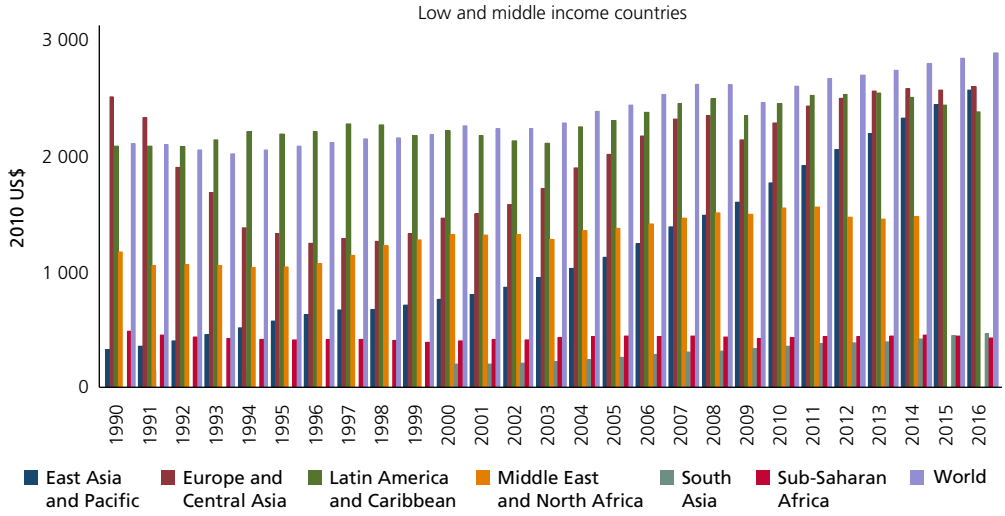
This is not necessarily an indication of deindustrialization, however, nor of a recoil in countries' levels of development. Total MVA has exhibited high growth rates for the last few decades in countries at all income levels (low, middle, and high) and MVA per capita has expanded

28 INDUSTRY VALUE ADDED PER CAPITA (BY INCOME)



Source: Based on data from the World Development Indicators, World Bank 2017.

29 INDUSTRY VALUE ADDED PER CAPITA (BY REGIONS)



Source: Based on data from the World Development Indicators, World Bank 2017.

in most regions[1]. In the same period, the global per capita industry value added (IVA) also grew from about USD 2 000 in 1990 to about USD 2 900 in 2016, with levels varying substantially between low- and high-income economies. In 2015, high-income countries had an average IVA per capita of about USD 10 000 while the average for low- and middle-income countries was less than USD 3 000 (Figure 28).

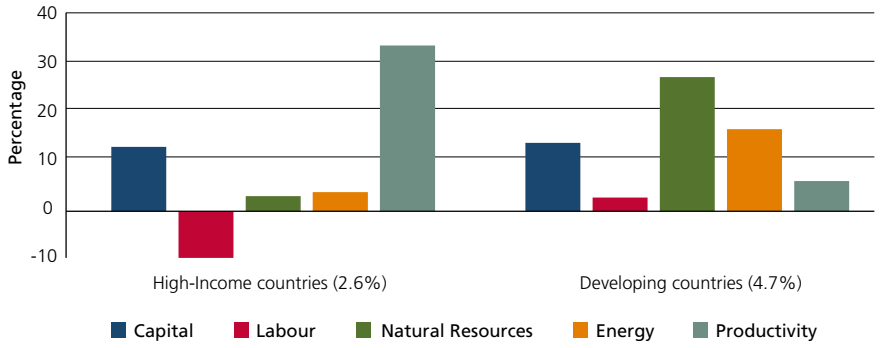
The growth rates of IVA per capita were also very different across regions. While East Asia and the Pacific (EAP) multiplied its IVA per capita more than seven times since the beginning of the nineties, South Asia (SA) only doubled it, and sub-Saharan Africa (SSA) remained virtually stagnant. Poor infrastructure, limited adoption of labour-saving technologies, weak logistics and trade facilitation, limited regional integration, and weak enabling structures are key gaps which help explain the differences in the levels of industrialization between regions.

[1] According to UNIDO (2016), MVA per capita is considered a good metric for countries' levels of industrial development. Yet, since manufacturing is the largest part of industry, and processing of agricultural and livestock products is largely excluded from it, we use both manufacturing (MVA) and industry value added (IVA) per capita to analyze trends in countries' levels of industrialization.

DRIVERS OF INDUSTRIALIZATION IN DEVELOPED AND DEVELOPING ECONOMIES

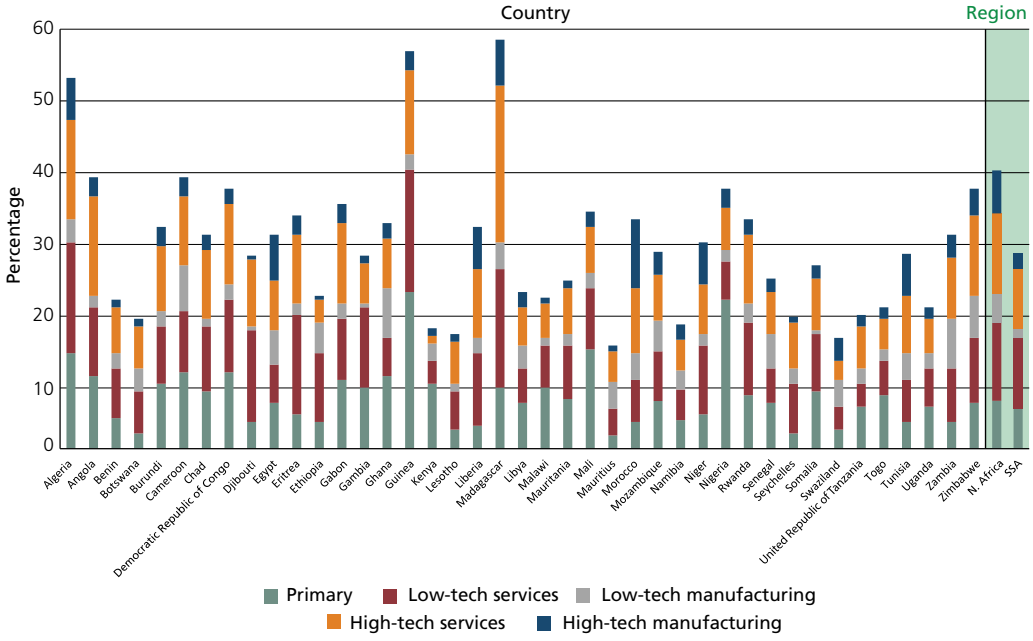
The role of industrialization is particularly important in stimulating growth in developing and emerging economies, where the share of services is relatively smaller than in developed countries, although MVA growth has outpaced GDP growth in the past 20 years. In 2014, the share of MVA growth was 25 percent higher than that of GDP (UNIDO Statistical Database, 2017). A major reason why developing regions, in particular SSA and North Africa have remained stagnant in terms of IVA per capita while experiencing high levels of total IVA growth, has to do with the way industry drives economic growth in developing parts of the world. Output growth in those regions is primarily generated through higher investment and the use of natural resources and energy; whereas high-income countries have been expanding output growth through increased productivity, achieved through resource-saving technologies, without putting further pressure on inputs (Figure 30).

30 FACTORS CONTRIBUTING TO MANUFACTURING GROWTH (1995–2007)



Source: Adapted from UNIDO, 2017.

31 PARTICIPATION OF AFRICAN COUNTRIES IN DOWNSTREAM GLOBAL VALUE CHAIN ACTIVITIES



Source: Adapted from Foster-McGregor *et al.*, 2015.

These differences are also reflected in the way different countries are connected to global markets. Foster-McGregor *et al.* (2015) suggest that a significant number of countries in SSA, for example, are closely connected to global value chains (GVCs) – more than any other developing region and even more than some rich countries such as the United States of America. However, most of this engagement involves upstream value chain activities, with African firms

primarily supplying low value added inputs and unsophisticated manufactured goods to downstream firms overseas. This is a particularly critical issue for livestock in African countries. The sector has so far not been able to do much more than supply relatively unsophisticated products with limited value added.

As shown in Figure 31, more than 65 percent of SSA's participation in GVCs consists in the provision of primary inputs and low-tech services and manufactures. The situation in North Africa is slightly different because of the presence of oil-producing countries, more than 56 percent of the subregion's contribution to GVCs is still in the form of upstream activities – and the figure climbs to over 70 percent in Sahelian countries such as Mauritania. Downstream operators, who are mostly located in the developed world, have more opportunities for upgrading and innovation, and are more capable of capturing larger shares of the value of finished products.

SHARE OF LIVESTOCK IN AGRO-PROCESSING VALUE

According to the Social Account Matrix (SAM), from a sample of developing countries, processed livestock products represent a very small share of the gross value of agro-processing and of total exports (see Table 10). In fact, for all sampled countries, processed crop products contribute strikingly more to agro-processing and total exports than processed livestock products. Processed crops represent about 21 percent of agro-processing gross output in South Africa, 19 percent in Egypt, and 12 percent in Tunisia, while livestock processed products account for 0.2, 0.8 and 1.3 percent respectively. Some of these differences seem to reflect crops' dominant share of agricultural production in these countries, although the level of export intensification also indicates that only a very small share of the total supply of processed livestock products is actually exported. Processed livestock products sold as exports accounted for a minor share of local livestock production in South Africa (2009), United Republic of Tanzania (2009) and Tunisia (2012) – amounting to 1.9, 0.1 and 2 percent respectively.

There has been substantial improvement in the SSA and MENA regions since the 1990s in terms of the composition of livestock exports. In both cases the share of exported processed livestock products increased from 25 and 37 percent in 1990–1999 to about 45 and 70 percent in 2010–2014 respectively. However, in SSA the value of processed livestock products as a share of total agricultural exports dropped from 1.6 percent in 1990–1999 to less than 1 percent 2010–2014 (FAO, 2017b). This contrasts with the general trend in other regions such as North America, South Asia, and, remarkably, MENA, where greater exports of processed livestock products also account for a greater share of total agricultural exports.

The fact that African countries already participate in GVCs gives them an advantage because they do not have to build up a whole network of market connections from scratch, nor create an entire industry capable of competing in the international marketplace. But since the continent has been primarily involved in upstream production, where opportunities for upgrading and innovation are limited, entering downstream value chains will require not only the adoption of pertinent public policies but also a series of initiatives from the private sector aimed at incentivizing investments, promoting technical training, acquiring new connections, and developing new business and technical skills.

LIVESTOCK INDUSTRIALIZATION: OPPORTUNITIES AND CHALLENGES

As previously indicated, a significant number of developing countries, contribute to GVCs primarily through the provision of primary and unsophisticated products to downstream actors in developed countries. This is in part because those countries have not acquired, or at least exploited, the capabilities required to engage in more sophisticated activities. For example, limited compliance with food safety requirements

TABLE 10

KEY SOCIAL ACCOUNT MATRIX INDICATORS FROM DEVELOPING COUNTRIES

COUNTRY	PRODUCT	SHARE IN AGRICULTURE GROSS OUTPUT *(%)*	SHARE IN AGRO-PROCESSING GROSS OUTPUT *(%)*	SHARE IN TOTAL IMPORTS *(%)*	SHARE IN TOTAL EXPORTS *(%)*	IMPORT PENETRATION *(% total demand)*	EXPORT INTENSIFICATION *(% total supply)*	SHARE OF HOUSEHOLD CONSUMPTION *(%)*
South Africa (2009)	Crop processed	11.7	21.5	8.3	5.4	9.6	5.8	22.5
	Livestock processed	n.a	0.2	1.5	0.3	9.1	1.9	5.2
United Republic of Tanzania (2009)	Crop processed	0.8	3.9	21.3	7.9	33.4	8.1	33.2
	Livestock processed	0.0	0.0	0.1	0.0	0.8	0.1	6.1
Egypt (2010)	Crop processed	2.7	19.1	14.6	12.0	15.4	12.2	20.0
	Livestock processed	0.0	0.8	1.2	2.2	11.5	16.1	2.8
Tunisia (2012)	Crop processed	9.8	11.6	4.5	6.3	15.4	18.4	14.6
	Livestock processed	0.0	1.3	0.5	0.3	4.2	2.0	6.0
Bolivia (Plurinational State of) (2012)	Crop processed	3.3	15.0	11.2	11.4	13.9	17.7	22.2
	Livestock processed	0.0	2.1	0.6	0.2	2.7	1.3	12.2

Source: Calculation based on SAMs developed by IFPRI, 2017.

TABLE 11

SHARE OF IMPORTS AND EXPORTS AND COMPLEXITY INDEX OF LIVESTOCK PRODUCTS (1995–2012)

PRODUCT	PCI	IMPORT SHARE (%)	EXPORT SHARE (%)
Meat, edible meat offal, salted, dried; flours, meals	0.424	0.16	0.14
Cheese and curd	0.171	3.32	6.33
Meat, edible meat offal, prepared, and preserved	0.103	1.45	0.99
Manufactures of leather, saddlery & harness	0.075	0.50	1.05
Butter and other fats and oils derived from milk	0.022	3.17	0.32
Milk, cream and milk products (excluding butter, cheese)	-0.128	25.48	5.29
Edible products and preparations	-0.142	22.92	14.70
Fur skins, tanned or dressed	-0.148	0.02	0.23
Other meat and edible meat offal	-0.271	10.84	5.45
Bird eggs, egg yolks; egg albumin	-0.289	0.91	0.74
Fur skins, raw	-0.434	0.03	0.20
Margarine and shortening	-0.498	2.60	2.39
Meat of bovine animals, fresh, chilled or frozen	-0.570	7.23	5.58
Animal oils and fats	-0.753	1.71	1.41
Live animals	-0.772	4.70	14.51
Animal or veg. oils & fats, processed	-0.787	4.85	2.73
Leather	-0.841	6.80	20.79
Wool and other animal hair (incl. wool tops)	-0.899	0.71	7.24
Crude animal materials	-1.054	1.96	3.21
Hides and skins (except fur skins), raw	-1.173	0.65	6.71
Average livestock PCI	**-0.3982**		

Source: Adapted from Yaméogo *et al.*, 2014.

is a major challenge which has affected the ability of major African livestock-producing countries to export processed livestock products. According to Hidalgo and Hausmann (2009), since not all products have the same impact in terms of economic growth, concentrating on unsophisticated products is substantially keeping those countries from achieving faster economic growth and improving key development indicators. Specializing in some products rather than others can determine the speed of a country's growth (Hausmann *et al.*, 2007).

The technological sophistication of a product can be defined in terms of the level of technical capabilities involved in its production.[2] Similarly, the technological sophistication of an economy can be gauged by the types of products it makes. According to Hidalgo *et al.* (2007), products are interlinked according to the types of capabilities required in their production and less-developed countries produce and export goods with a lower number of interindustrial connections (i.e. less complex goods). Hence economic development is not just about constantly improving the production of the same set of goods but has more to do with acquiring more complex capabilities that help diversify production towards more sophisticated products and higher

[2] It is helpful to think of capabilities as set of tangible inputs such as roads, bridges, transportation systems, collecting centres and infrastructure, or as intangibles such as skills, knowledge, institutions, regulations and services.

productivity levels (Felipe *et al.*, 2012). Hausmann *et al.* (2011) argue that wealthier economies tend to be more complex and have more diverse stores of knowledge.

The livestock sector's level of complexity is relatively low in developing countries. For example, in Africa, which has a sizeable livestock population and where livestock raising is an important economic activity in almost every country, locally-made livestock products have a low level of complexity, and the most complex products are usually imported. According to Yaméogo *et al.* (2014), the product complexity index (PCI) is very low, and sometimes negative, for most livestock products in Africa.[3] As indicated in Table 11, the six most complex livestock products exported from Africa in 1995–2012 accounted for less than 15 percent of livestock exports, while the six least-complex products accounted for more than 55 percent. Conversely, the nine most complex products accounted for virtually 70 percent of all livestock imports in the same period, and this goes a long way to explaining the region's livestock trade deficit. Despite its great livestock potential, Africa is a net importer of livestock products, including large amounts of processed goods. From 1995 to 2012, African countries generated about USD 51 billion through the export of livestock products, while imports cost the continent more than USD 140 billion – almost three times as much (Yaméogo *et al.*, 2014).

Livestock seem to be a fast track for countries to achieve their SDG 9 industrialization goals. According to Mayberry *et al.* (2017), returns on investment in livestock in Africa and South Asia could be maximized through improved nutrition, genetics and health care, together with improved access to credit, extension and technical capacities. Introducing social and cultural transformations, including attitudes to risk, would also be beneficial. Furthermore, livestock also offer attractive opportunities for adding value internally, accessing untapped higher-value domestic outlets (import substitution) and international markets, increasing foreign revenue, and reducing import dependence. This chapter argues that livestock have a relatively higher potential for adding value to the economy than crops and fisheries/aquaculture. As shown in Table 12, globally, the PCI for primary and processed livestock products is respectively -0.31 and -0.21 – substantially higher than -1.51 and -0.72 for crops, and -1.21 and -1.36 for fisheries.

TABLE 12
PRODUCT COMPLEXITY INDEX IN AGRICULTURE SUBSECTORS (2015)

TYPE OF PRODUCT	PRIMARY	PROCESSED
Crops	-1.51	-0.72
Livestock	-0.31	-0.21
Fisheries/aquaculture	-1.21	-1.36

Note: the CPI average is 0.098 for non-agriculture products.
Source: Based on data from Observatory of Economic Complexity - MIT, 2017.

Hidalgo and Hausmann (2009) argue that since developing countries still earn less than they could do, simply on the basis of their existing capabilities, they should be able to grow faster than countries that can only expand their economies by accumulating new capabilities. In fact, Freitas and Paiva (2016) suggest that one of the quickest ways to grow economically is by adding products to the national export portfolio that are more sophisticated but also use the same types of capabilities as products already being made locally. The PCI for livestock primary products is clearly lower than for processed products. However, the gap between the two is not enormous, indicating that further engagement in livestock processing does not require huge efforts to acquire new capabilities. Value chain players should therefore be helped to produce more sophisticated products by using existing capabilities and acquiring new ones only when necessary.

[3] Hidalgo and Hausmann (2009) developed a technique which uses economic data to measure the complexity of products and countries. Important features include: (a) it captures the complexity of the set of capabilities available in a country; (b) it strongly correlates with the levels of income per capita; (c) it predicts future growth; and (d) it depicts the complexity of a country's future exports. This approach suggests that the level of development of a country is associated with the level of complexity of its economy.

CONCLUSION

Goal 9 focuses on infrastructure development, industrialization and innovation. Livestock offer some of the best opportunities for adding value, given the fact that ASF products exhibit higher levels of complexity than crops. Accordingly, they have greater potential to increase the value of exports, promote economic growth, and improve livelihoods. At the same time, however, the sector is characterized by rapid market concentration, largely due to major gaps in infrastructure, technology and innovation, which limits the field to a relatively few actors with higher investment capacity. Policies that encourage economically and environmentally sustainable agro-industrialization, shifting more workers towards more productive and profitable activities, and integrating small-scale producers in the growth of value chains, are likely to yield higher social and economic returns. They can also attract further investments focusing on infrastructure development and innovation.

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10. Reduced inequalities

INTRODUCTION

Economic inequalities are defined by people's economic positions in society, measured in terms of income, purchasing power or wealth and are also linked to demographic characteristics, such as gender, age or ethnicity. Certain individuals and groups have opportunities consistently inferior to those of their fellow citizens merely on account of their birth. Sustainable Development Goal 10 calls for reducing inequalities in income, as well as those based on sex, age, disability, race, class, ethnicity, religion and opportunity, and this both within and among countries (UN, 2016c). SDG 10 is closely correlated to the first of the SDGs (elimination of poverty) and while there has been progress on poverty reduction over the past decades, the world continues to suffer from substantial inequalities. To reach both SDG 1 and SDG 10, efforts to foster growth need to be complemented by equity-enhancing policies and interventions (World Bank, 2016).

Global demand for livestock products is booming as a result of population growth, increased purchasing power and changes in diets. The livestock sector has become and will continue to be one of the fastest-growing in agriculture for the next decades. As such, it offers substantial opportunities for income generation and job creation, especially in the dairy sector.

On the supply side, livestock are a source of food and income for 600 million poor smallholders whose livelihoods depend partially or entirely on keeping animals. The proportion of poor women and elderly individuals involved in agriculture, in the broad sense of the term, is increasing. At the same time, the number of young people aged between 15–24 in sub-Saharan Africa looking for jobs will increase by 75 percent in the next 30 years and a thriving livestock sector could play an important part in absorbing these newcomers into the labour market.

With the right investments and policies, and providing national and regional authorities support a form of livestock development that is inclusive and sensitive to the needs of women and young people, the sector can make a significant contribution to the reduction of inequalities in

income, as well as of discrimination based on sex and age. Greater opportunities for rural households to become involved in livestock production, processing, and marketing will lead to reduced inequality as livestock husbandry and livestock value chains are potent catalysts for smallholder income growth with relatively low investment and input costs.

The future development of a livestock sector that contributes to SDG 10 requires reaching beyond policies and investments specific to livestock. It calls for spending on infrastructure to link lagging regions; implementing rural development policies that are both youth and gender sensitive; improving access to services – including financial services – for all; framing adequate social protection programmes, including pension schemes; enacting migration policies that take into account the needs of people moving with their animals; and enabling free trade and the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) for trade in livestock and livestock products from least developed and low-income countries.

However, unless the consequences of expanded and intensified livestock production on rural households in developing countries are considered, the overall impact on small-scale farmers will be negative. Competition for fertile land to produce livestock feed and the privatization of good rangeland could well force smallholders and vulnerable communities into less productive, less connected areas, increasing their social, economic and political exclusion. Empowerment of producer organizations by giving them legal recognition and providing them with capacity development is essential if small-scale producers are to have a voice in the political debate around rural development and the use of land.

INCOME GROWTH

Achieving SDG 10 will require per capita income in the bottom 40 percent of the population to grow at a higher rate than the national average. Because of its rapid expansion, especially in the developing world, and because animal husbandry takes place largely in rural areas – where three-quarters of the world's poor live – livestock offer substantial opportunities for income growth among the bottom 40 percent of the population in both low-income and some middle-income countries. This, coupled with measures to reduce income discrepancies across sectors, makes livestock highly relevant to achieving SDG 10.

With demand continuing to rise, the livestock sector's fast growth is expected to last into the next decades. In South and East Asia, the sector will contribute about 40 percent to the expansion of the agricultural economy, which, in turn, is expected to grow more than 20 percent over the next ten years. Intensive pork and poultry production will account for most of the extra meat production. This will offer limited opportunities for poorer livestock keepers, although some jobs should become available in processing and marketing. In the dairy sector, however, small-scale milk producers and sellers stand to benefit from the 20 percent increase in milk yields expected by 2025 and from the fact that more milk will be produced for fresh consumption. However, for those benefits to materialize, inclusive rural development policies need to be put in place.

In Africa, beef consumption will continue to grow strongly, by 2.6 percent per annum to 2025. Although much smaller in absolute terms, consumption of lamb and mutton has nonetheless expanded impressively over the past decade, with demand for sheep and goat meat mostly met by small-scale local producers. Dairy milk production has enormous potential for economic development and food security in rural areas of Africa. In southern and eastern Africa especially, commercialization of the sector has already shown dairy's potential to reduce poverty by providing people with a regular income. Growth in milk production, reaching 37 percent over the past decade, was made possible largely due to the contribution of a vibrant smallholder

farming sector. Growth in demand for dairy products is projected to accelerate to 2.6 percent per annum in Africa between 2017 and 2025 (OECD and FAO, 2016).

On the supply side, and focusing on poor producers, Robinson *et al.* (2011) estimated that the total number of poor people whose livelihoods depended entirely or partially on livestock production was more than half a billion in 2010 (calculated in terms of countries' rural poverty lines). There are also many poor farmers who, while not owning livestock, make their living by supplying inputs and services to the livestock sector, and selling livestock products such as milk. Some 70 percent of poor livestock keepers live in South Asia (India, Pakistan and Bangladesh) and sub-Saharan Africa (particularly Nigeria, Ethiopia, Uganda, Burundi, Rwanda, Malawi, Kenya, South Africa and Niger), and it can be assumed that their earnings place them in the bottom 40 percent in their respective countries.

The number of pastoralists living in arid and semi-arid lands is unknown, as is the proportion of pastoralists living within the bottom 40 percent. Livestock are the main income earners for families in drylands – areas that are often affected by human-induced crises, climate change and increasingly frequent and intense natural disasters. All this exposes livestock keepers in arid and semi-arid areas to a greater risk of falling into poverty. Investment in the development of arid and semi-arid areas is therefore a priority if SDG 10 is to be achieved.

That said, the majority of poor livestock farmers are sedentary and operate in mixed crop–livestock production systems. These are irrigated plots in parts of South Asia, and rainfed holdings in parts of India and in most of sub-Saharan Africa. Over one billion poor people farm this way and 600 million of them depend partially or entirely on livestock for their livelihood (based on the national and the international USD 1.25 per day poverty lines used in 2010). At the time, Robinson *et al.* (2011), estimated that this number would double if a USD 2 per day poverty line were used.

The efficiency gap in livestock production within these mixed crop–livestock systems is known to be large but can be filled by existing technologies and good animal husbandry practices. Improvements can be made in feeding and housing practices, herd or flock management, and disease control strategies. There is therefore great potential for increasing productivity and incomes in both South Asia and sub-Saharan Africa in a sector involving hundreds of millions of people. Filling the efficiency gap will significantly contribute to reaching SDG 10.

It should, however, be noted that, for many poor, livestock-owning households, farm animals are not their main source of income. Pica-Ciamarra *et al.* (2015) found that the direct contribution of livestock to the incomes of rural animal owners in 12 developing countries was 12 percent, ranging between 2 percent and 24 percent. Nonetheless, besides money earned from selling animals or animal products, livestock provide many other goods and services that contribute to families' livelihoods and welfare, and help reduce inequalities between the bottom 40 percent and the rest of the population. Such goods and services include animal-source food (ASF) for household consumption, manure, draught power and transport. Livestock's role as a form of savings and insurance also advances equity where social protection and financial services are either insufficient or unavailable.

A diversified approach is therefore required to fully exploit the potential for inequality reduction which the fast-growing livestock sector offers livestock owners. This approach should include:

- A range of animal production and health interventions, with appropriate targeting. These should facilitate access to feed and pasture throughout the year, reduce losses due to diseases and ensure that livestock products from extensive or semi-intensive production systems meet consumer requirements in terms of quality, safety, quantity and regularity of supply.

- A set of policies and investments that go beyond animal production and health and support a fully inclusive, gender-sensitive rural development process is also necessary. Investments in new or improved rural roads facilitate access to markets, for example, and have a direct impact on both poverty and the reduction of economic inequality. Improved access to rural financial services or cash transfers and social protection programmes creates opportunities for poor livestock keepers to integrate into markets. Weak or unequal property rights also remain an important constraint preventing smallholders from expanding production. Institutional reforms can be very effective in stimulating smallholder entrepreneurship and closing inequality gaps. As noted, a special emphasis on the economic development of arid and semi-arid lands is required as pastoralists are particularly affected by climate change.

Indeed, it must be stressed that in the absence of such measures, the livestock sector's current rapid growth will clearly contribute to heightening, rather than reducing, inequalities by 2030. Intensive livestock production requires increasingly large quantities of both soy and cereals as feed. By 2050, somewhere between 3 and 3.5 billion tonnes of cereals (wheat, coarse grains and rice) will be needed every year to feed the planet, and a third of that will go to feeding livestock (currently, 900 million tonnes of cereals are used as feed annually). While cereal prices are expected to remain close to what they are today in the medium term, the growth in demand for cereals could trigger an increase in food prices in the long term, leading to the kind of crisis last seen in 2007–2008. The bottom 40 percent would be proportionally more affected.

Increased world demand for feed concentrates involves an expansion of soy and cereals production areas. Accordingly, the number of large-scale land acquisitions by foreign entities has accelerated since 2000, mainly in Africa. These acquisitions are usually in fertile regions, with good water access and developed infrastructure. Such areas have traditionally been farmed by smallholder families (Pesche *et al.*, 2016) and large-scale land acquisitions usually result in their displacement and increased inequalities. The future expansion of intensive livestock production must therefore integrate all three pillars of sustainability – economic, environmental and social – including social equity.

ANIMAL-SOURCE FOODS, PRICE INFLATION AND INEQUALITY

The level of income distribution in a country is traditionally assumed to shift from relative equality to inequality and back to greater equality as

BOX 8

ERADICATING LIVESTOCK DISEASES

Policies and programmes aimed at eradicating livestock diseases or focusing on an area-wide approach for the elimination of parasites or disease vectors deserve special mention here. Past initiatives such as the Global Programme for the Eradication of Rinderpest or the Eradication of the Tsetse fly in Zanzibar, and current programmes like the Global Strategy for the Control and Eradication of the Peste des Petits Ruminants, have the advantage of benefiting all producers, including the poorest members of communities. Providing the diseases targeted are endemic in areas where small-scale producers are active, their elimination reduces inequalities by reducing losses for everyone, including the poorest producers who could not otherwise have afforded to treat their livestock.

countries develop. Inequality will rise as some people move away from economic activities which yield a low marginal product into more productive ones. At some point, the marginal product of all economic activities converges and income differences narrow (IMF, 1998).

There is extensive literature noting a strong relationship between inflation and income inequality (Albanesi, 2007). The rise in food prices has been identified as one of the major driving forces behind inflation. This effect tends to be larger in developing countries where households spend a larger proportion of their income in food.

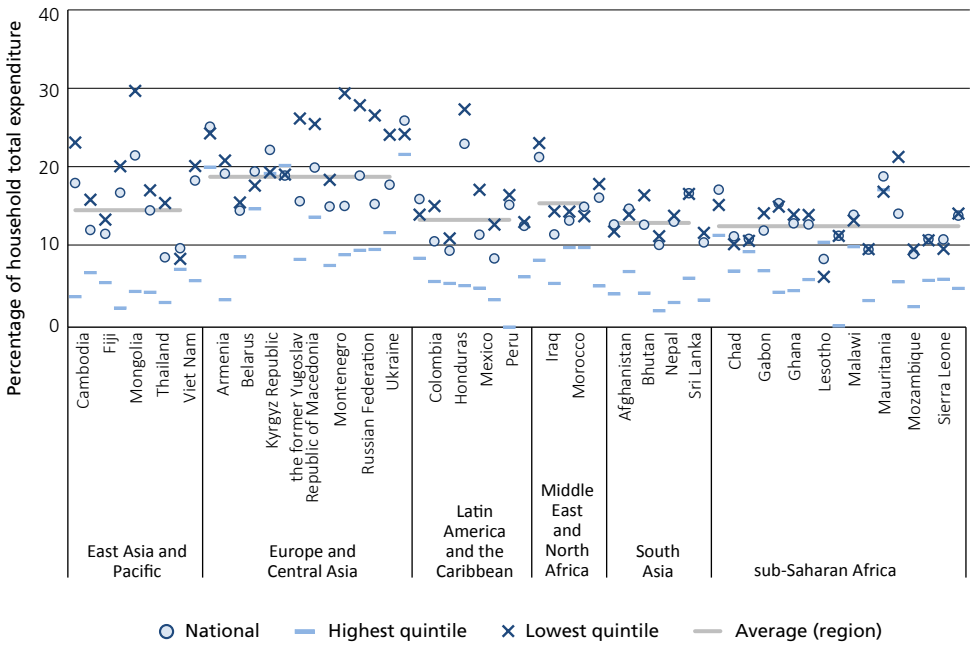
In developing regions such as sub-Saharan Africa and the Middle East and North Africa, the cost of animal-source foods accounts for nearly one-third of the food basket. The percentage of income spent on ASFs tends to be higher for poorer households. While the richest households spend around ten percent of their income on ASF products, the poorest spend about 20 percent. Thus, policy measures aimed at controlling food price inflation should pay particular attention to the behaviour of ASF prices.

PROMOTING THE SOCIAL, ECONOMIC AND POLITICAL INCLUSION OF ALL

Empowerment and social, economic and political inclusion of all are pivotal in SDG 10. The reduction of the proportion of people living below 50 percent of median income, by age and sex, and of persons with disabilities, serves as an indicator of success for this target. Measuring progress requires the collection and analysis of age- and gender-disaggregated data that is currently not broadly available for the livestock sector.

One tends to think about age inequalities in terms of opportunities for the young but the welfare of the older members of the community is a growing concern in many ageing societies. For example, the age of smallholders involved

32 PERCENTAGE OF HOUSEHOLD EXPENDITURE ON ANIMAL-SOURCE FOODS



Source: Based on data from the World Bank, 2018.

in agriculture is increasing in many of the Near Eastern and North African countries, including, evidently, a good number of livestock-owning households. The phenomenon results partly from the absence of inclusive government-funded pension schemes, especially in rural areas. People reaching retirement age go back to the land to produce food and go on making a living. The rapid growth in demand for livestock products, especially milk, chicken and eggs, gives elderly smallholders a chance to improve their livelihoods by selling their surplus production.

The development of government-funded pension mechanisms, where and when possible, would be a more efficient way to reduce age inequalities. For it would not only benefit the elderly but also facilitate the generational transfer of holdings and land tenure to the children of an ageing generation of farm heads and to rural landless youths willing to invest in agriculture.

In sub-Saharan Africa, the 15–24 age population is expected to grow from less than 200 million in 2017 to over 350 million in 2050. Trends in structural transformation in sub-Saharan Africa show that opportunities for wage jobs in industry or services will remain limited. For the next two decades, it is expected that agriculture will offer three-quarters of new work opportunities, mainly through self-employment. The growing demand for ASF on the continent offers a chance to create new jobs for young people, providing the African livestock sector can propose products that are competitive in terms of quality and price compared to imports.

Within rural environments, livestock keeping has historical, cultural and traditional roots, and the involvement of young children is very common. As defined by the UN Convention on the Rights of the Child and the International Labour Organization, some of the work children do in the livestock sector, such as herding, interferes with their education and must be categorized as child labour. But there is currently little statistical information on child labour in the livestock sector indicating a strong need for further age- and sex-disaggregated data collection (FAO, 2013a).

Gender equity is a recurrent topic in the narrative surrounding the livestock sector in developing countries. Programmes supporting livestock development are considered privileged entry points for addressing equality between sexes as livestock ownership is usually open to both men and women. And while access to land is often restricted to men in low- income countries, both men and women are involved in the management of livestock (Bravo-Baumann, 2000). In reality, however, livestock's ability to foster the social and economic inclusion of women is variable.

In considering gender equity, poultry is often regarded as a good place to start because chickens, which are a dependable source of income and food in poor households, are often owned by women. Chickens or eggs can be sold at short notice, which helps cover day-to-day expenses, and women usually keep the income. Sheep and goats, however, may not contribute as much to reducing gender inequalities. For example, a recent study on employment creation in the small-ruminant subsector in Ethiopia found that although joint ownership, usually between spouses, was the most common form of ownership, men have the ultimate decision on the use of animals, in particular marketing. Furthermore, men held an almost complete monopoly on trade in markets, where women were generally not welcome, especially as sellers (Mueller *et al.*, 2017). Investment programmes in support of small-scale livestock producers therefore require both in-depth understanding of the role of women in the households targeted and an assessment of the impact of interventions on the income and social status of both men and women. Again, disaggregated data and approaches that help change the economic role of women in households are necessary.

SDG 10 will have to be achieved within the context of the feminization of agriculture as men move out of farming in search of better employment opportunities and women are left to work on the farm. Nonetheless, in most countries in sub-Saharan Africa, (Slavchevska *et*

al., 2016), the share of women working in agriculture has not changed significantly in the last few decades. The fact that women represent well over 50 percent of the agricultural workforce does however indicate a feminized sector. In Africa, a quarter of all households are headed by women and one person in five lives in such a household. But detecting the changing roles of women within agriculture, and more specifically within the livestock sector, will require the collection of relevant data.

Persons with physical disabilities will find it difficult to rear livestock due to the nature of the work. The sector's growth does not offer many opportunities for the greater inclusion of physically challenged persons.

SAFE AND RESPONSIBLE MOBILITY OF PEOPLE

Achieving SDG 10 requires a change in the way migration is perceived and dealt with in many countries. It is essential that countries move towards more orderly, safe, regular and responsible population movements through well-managed migration policies.

In 2015, some 247 million people lived in a country not of their birth. About half of all migrants globally moved from a developing to a developed country, but migration to the former, although a smaller share of the global total, was still very significant. Some 79.6 million people, or almost one-third of the world's migrants, moved from one developing country to another. For example, in 2015 nearly 33 million Africans were living outside their home country, but more than one out of two migrated within Africa. Sub-Saharan Africans lead intra-African migration (nearly 75 percent), often moving to neighbouring countries (Côte d'Ivoire, South Africa, Nigeria, Kenya and Ethiopia are the top five receiving countries) (McKinsey Global Institute, 2016). Again, 740 million people were internal, within-country migrants travelling either on a temporary or a permanent basis in search of better work. This kind of economic migration does not usually involve livestock moving across borders (with the exception of the regular seasonal movements of pastoralists) and is not directly relevant to the discussion on livestock and SDG 10.

An estimated additional 65 million people are

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currently forcibly displaced because of war or insecurity. The six countries that have produced two-thirds of the world's cross-border refugees in the recent past all have, or had, vibrant livestock sectors with important roles in the rural economy: Syrian Arab Republic, Afghanistan, South Sudan, the Federal Republic of Somalia, Sudan and the Democratic Republic of the Congo. These countries are either in acute or protracted crisis. It should be noted that refugees and asylum-seekers differ from voluntary migrants in fundamental ways. Many may have suddenly been forced to abandon their homes. Livestock owners may have lost all or part of their assets and, in some cases, may be fleeing to neighbouring countries with their animals.

Well-managed migration policies, especially regarding countries receiving refugees who are forcibly displaced, require measures addressing the movement of animals as well as people. Control and management on the use of grazing grounds within host countries is a high priority to avoid conflicts between displaced populations and host communities. Measures to control animal diseases are required to protect both migrants' livestock assets, fundamental for starting a new life, and the herds of hosting communities. Because many migrants have skills in livestock husbandry, policies that facilitate their insertion in the local livestock sector will contribute to a better integration in host communities. Moreover, investing in the livestock sector in refugees' countries of origin will act as an engine of stabilization and recovery for people living in fragile contexts, offering new opportunities to both would-be migrants and returnees.

This snapshot of the correlations between livestock and migration would not be complete without a discussion of the impact of remittances. Migrant transfers to developing countries reached USD 431.6 billion in 2015 (United Nations, 2016c). Of these, 40 percent were sent to rural areas and invested in agricultural activities and in livestock in particular. For livestock not only generate income but also represent productive and moveable assets in times of conflict and insecurity. Facilitating and reducing the costs of money transfers to the families of migrants in their countries of origin would contribute to a reduction in inequalities, to stabilization and to the increased resilience of communities dependent on livestock.

TRADE AGREEMENTS

Facilitating exports from developing countries will reduce inequalities among nations. The proportion of tariff lines with zero tariff applied to imports from least developed (LDCs) and developing countries, is used as indicator of success for Target 10.a of SDG 10 (by 2030, progressively achieve and sustain income growth of the bottom 40 percent of the population at a rate higher than the national average).

Developing countries, in particular LDCs, do benefit from special and differential treatment (SDT) in accordance with WTO agreements. SDT gives special rights to developing countries and gives developed countries the possibility of treating them more favourably than other WTO Members. This is the case with the Generalized System of Preferences (GSP), for example. Under the GSP regime, developed countries offer non-reciprocal preferential treatment (such as zero or low duties on imports) to products originating in developing countries. In this regard, the Secretary-General of the United Nations, in his report "Progress towards the Sustainable Development Goals" (United Nations, 2016c), explains that major developed country markets already offer duty-free market access to LDCs on most of their tariff lines. Even when they do not, as in the case of some agricultural products, the average applied tariff rate is often close to zero. Almost all agricultural products from the LDCs (98 percent), including livestock products, are exempt from duties by developed countries (versus 74 percent of products from developing countries).

Regional free trade agreements also offer opportunities for small-scale livestock producers and contribute to evening out the playing field among countries. The possibility of exporting

live animals, duty free, from pastoral and agro-pastoral areas of West Africa, across borders to the large urban coastal centres is a good example of a booming trade benefiting small-scale producers. Regional free trade agreements are efficient in reducing inequalities only if cooperation between customs and other concerned authorities is successful and if the movement of animals is not hampered by illegal and informal levies along the road. This common practice should be curbed to reap the full benefit of negotiated free trade agreements for greater equity.

Among existing non-tariff barriers to trade, sanitary and phytosanitary measures are often mentioned as potentially having distortionary and restrictive effects in the livestock sector, and therefore as creating inequalities among countries. Problems have arisen in respect of meat and meat products and, less frequently, with dairy products. However, sanitary standards and their application reflect a justified desire by governments to control and eliminate any domestic risk to human and animal health and to respond to consumer demand for perfectly safe food. The WTO SPS Agreement forbids the application of regulations that arbitrarily or unjustifiably discriminate between countries. With trade in livestock products growing, raising SPS standards will open up new trading opportunities for some developing countries. However, it is the domestic benefits of higher SPS standards (in terms of improved food safety, public health and animal health) that will have most impact on the livelihoods of the poor, especially children, by reducing their exposure to diseases.

CONCLUSION

Goal 10 calls for reducing inequalities in income. Institutional reforms in the livestock sector can be very effective at stimulating smallholder entrepreneurship and closing inequality gaps. Livestock rearing is a potent catalyst for smallholder income growth, involving relatively low investment, input, and labour costs. However, weak or discriminatory property rights remain an important constraint on the capacity of smallholders to expand sustainably. Enabling livestock to contribute effectively thus means going beyond policies and investments specific to the sector. It requires, among other things, spending on infrastructure to link lagging regions; improving access to services, including financial services for all; framing effective social protection programmes, including pension schemes; adopting migration policies that take into account the needs of people moving with their animals; and implementing free trade agreements for trade in livestock and livestock products from least-developed and developing countries.

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11. Livestock and sustainable cities

INTRODUCTION

Rapid, global urbanization represents one of the most rapid and profound shifts in the rise of human settlements. In 2007, world urban population overtook rural population for the first time in history (UN, 2014). This trend has continued over the past decade and is expected to spawn more cities and urban settlements, transforming the economic and social fabrics of entire countries. By 2050, more than two-thirds of the world's population will live in towns and cities, exerting pressure on natural resources, the living environment, and public health (UN 2014). Spurring the rapid growth of cities of all sizes around the world, urbanization is largely the result of increasing rural-to-urban migration caused by lack of employment and basic services in rural areas, and by employment opportunities in cities. Other contributing factors include extreme events such as conflicts and natural disasters – including events driven by climate change such as desertification and prolonged droughts. Moreover, while migration is a key driver in rapid urbanization, there is growing evidence that self-sustained urban growth and rural transformation are now major contributors to urbanization, particularly in Africa (African Development Bank Group, 2012).

Today's unprecedented urban growth appears irreversible, affecting both developing and developed countries. In addressing urbanization, the United Nations Agenda goes beyond the purely demographic dimension and addresses the main challenges and opportunities shaping twenty-first century cities, including how they affect and contribute to sustainable development and achieving the 2030 goals and targets. Sustainable Development Goal 11 (SDG 11) is to "make cities and human settlements inclusive, safe, resilient and sustainable" through the realization of ten targets, including: access to safe and affordable housing, basic services and the upgrading of slums (Target 11.1); and investment in safe and sustainable public transportation (Target 11.2). SDG 11 also promotes participatory and inclusive urban planning and

management (Target 11.3); protecting the urban poor and people in vulnerable situations (Target 11.5); and strengthening links between urban, peri-urban and rural areas (Target 11.a). In addition, SDG 11 embraces environmental and climate issues, including air quality and waste management (Target 11.6); resource efficiency, mitigation and adaptation to climate change, and resilience to disasters (Target 11.b).

Urban agriculture is one aspect of urbanization and takes place in many cities around the world in various forms and contexts (Lee-Smith, 2012; Orsini *et al.*, 2013). While exact data on the number of people involved in urban agriculture are limited, in 1996 the United Nations Development Programme estimated the figure at 800 million and it has likely risen substantially since. According to Karanja and Njenga (2011), roughly, 15–20 percent of the world's food is grown in urban areas and some 25–30 percent of urban dwellers worldwide are involved in the agro-food sector (Orsini *et al.*, 2013). Urban agriculture offers many advantages, from reducing poverty and improving household security, to supporting social interaction and cooperation, and improving public health. However, many challenges must be addressed if urban agriculture is to become sustainable (Smit *et al.*, 2001; De Bon *et al.*, 2010).

Livestock raising has often been part of urban agriculture, with its own challenges and opportunities. Until recently, urban livestock production was often regarded as problematic and was severely restricted by city laws and policies (McClintock *et al.*, 2014). However, keeping livestock in urban settings is now gaining greater recognition because of the benefits it can offer city dwellers (FAO, 2001, Dubbeling *et al.*, 2010). Urban livestock production has evolved to support the household food security and the economic needs of urban populations, especially in low-income countries. Before the sector can fully contribute to meeting the SDG 11 goals and targets, a number of issues regarding health and environmental risks must be resolved (FAO, 2001; Guendel, 2002; Grace *et al.*, 2015).

This chapter addresses livestock keeping in urban and peri-urban settings (respectively within and around cities) as a form of urban agriculture and presents its dynamics as an integral part of urban life, while also highlighting the pros and cons of urban livestock, particularly in developing countries. This synthesis aims to analyse how sustainable urban and peri-urban livestock production can influence urban policies and plans and contribute to achieving SDG 11 targets and the sustainable development agenda. For present purposes, "urban" production refers to small areas inside cities such as vacant plots, gardens, rooftops and backyards used for growing crops and raising animals for own consumption or sale in neighbourhood markets. "Peri-urban" production refers to facilities close to towns which operate intensive semi- or fully commercial farms to grow crops and raise animals for milk and eggs (Iaquinta and Drescher, 2000).

URBANIZATION AND SUSTAINABLE DEVELOPMENT

Especially in developing countries, growing population and rapidly increasing urbanization challenge the objectives of ending hunger, achieving food security, improving nutrition and attaining sustainable development. Rapid growth has crowded cities, forcing many urban inhabitants into slums and increasing poverty levels (Karanja and Njenga, 2011). Poor urban households spend as much as 60–85 percent of their income on food (Mougeot, 2005; Redwood, 2008). In Africa in particular, urbanization has resulted in a proliferation of slums, increased urban poverty and rising inequality.

The degree of urbanization varies significantly across regions. Currently, Africa and Asia remain predominantly rural, with respectively 60 and 52 percent of their populations living in the countryside. However, these two continents are urbanizing faster than the other regions and are projected to become 56 and 64 percent urban respectively by 2050 (UN, 2014). All over the developing world, urban and peri-urban conglomerations are now facing not only higher poverty

levels, but also serious problems with housing, employment, education, health, clean water and transportation, to name but a few. Such constraints, however, are likely to slow rural–urban migration rates in the coming decades.

The New Urban Agenda, agreed upon by countries at the Habitat III conference in Quito, Ecuador (October 2016), recognizes that making progress on the diverse challenges posed by urbanization is key to achieving sustainable development and eradicating hunger. National and city governments struggle to accommodate urban growth in many parts of the world. Creating sustainable and resilient cities and finding ways of providing food, shelter and basic services to their residents are among the many challenges they face. This is why SDG 11 encourages the development and implementation of more integrated development strategies and solutions within cities.

Cross-cutting linkages with other goals are required for the coherent implementation and monitoring of this and other SDGs in urban areas. Closely related SDGs include: SDG 1 on ending poverty, SDG 2 (food security), SDG 3 (health), SDG 4 (education), SDG 5 (gender equality), SDG 6 (water and sanitation), SDG 8 (decent work and economic growth), SDG 9 (resilient infrastructure), and SDG 13 (climate change action). The implementation of SDG 11 and other SDGs requires every country to judiciously prioritize and adapt the various goals and targets in accordance with local challenges, capacities and available resources.

LIVESTOCK AND URBAN AGRICULTURE

Urban agriculture, as defined by FAO, is "the growing of plants and the raising of animals within and around cities" to provide fresh food, generate employment, recycle waste, and strengthen cities' resilience to climate change. Urban agriculture, including livestock production, was recognized by the 1996 United Nations Conference on Human Settlements as one of the "desirable practices" for sustainable cities (HABITAT II, 1996). It was subsequently also adopted by the World Food Summit (2002) and the UN High Level Task Force on the Global Food Crisis (2008) as a strategy for alleviating urban food insecurity and building cities more resilient to crises (FAO, 2010b). Urban agriculture is widespread both in the developed and developing world (Foodtank, 2016, Smit *et al.*, 2001) but has long been neglected by city planners and policymakers. During the last two decades, however, interest in food production in and around cities has increased as urban populations have soared. Awareness has grown too of urban agriculture's important role in food security, nutrition and the creation of jobs and household incomes, especially in developing countries (Zezza and Tasciotti 2010; De Zeeuw *et al.*, 2011).

Urban, and especially peri-urban, agriculture contributes a significant share of the food consumed in cities, especially fresh and perishable foodstuffs (Mougeot, 2005; FAO, 2011d). While urban farming is still informal in many cities, it has evolved with the urbanization process, particularly in Africa (Lee-Smith, 2012). Household surveys in 15 countries in Africa, Asia, Eastern Europe and Latin America have shown that between 11 and 70 percent of households earn their living from urban agriculture, with an average of over 30 percent (Table 13) (Zezza and Tasciotti, 2010). According to Orsini *et al.* (2013) the proportion of African urban populations involved in agriculture was estimated at about 50 percent in Accra, 80 percent in Brazzaville, 45 percent in Lusaka, 37 percent in Maputo, 36 percent in Ouagadougou, 35 percent in Yaoundé and about 29 percent in Kenyan cities.

An integral part of urban agriculture, livestock raising in and around cities has been practiced for many years and in many parts of the world (FAO, 2001; Thys, 2006; McClintock *et al.*, 2014; Grace *et al.*, 2015). Nonetheless, it has attracted less attention than crop and vegetable cultivation, and precise data about the sector is often lacking (Schiere and den Dikken, 2003). The current scale of urban livestock farming is therefore difficult to assess, although the

TABLE 13
PARTICIPATION OF HOUSEHOLDS IN URBAN AGRICULTURE

COUNTRY AND YEAR	TOTAL PARTICIPATION IN CROP ACTIVITIES (%)	TOTAL PARTICIPATION IN LIVESTOCK ACTIVITIES (%)	TOTAL PARTICIPATION IN AGRICULTURAL ACTIVITIES (%)
Africa			
Ghana 1998	38	14	41
Madagascar 2001	30	13	33
Malawi 2004	45	14	46
Nigeria 2004	29	12	32
Asia			
Bangladesh 2000	26	14	30
Indonesia 2000	10	3	11
Nepal 2003	52	36	57
Pakistan 2001	4	13	14
Viet Nam 1998	65	35	69
Eastern Europe			
Albania 2005	18	10	19
Bulgaria 2001	23	13	27
Latin America			
Ecuador 1995	17	28	35
Nicaragua 2000	65	29	68
Guatemala 2001	25	31	42
Panama 2003	31	12	34
Mean	**33**	**18**	**34**

Source: Adapted from A. Zezza, L. Tasciotti, 2010.

limited, often qualitative evidence available suggests that urban and peri-urban livestock production is currently an important reality for many developing country households. The sector is growing extremely fast too, and according to Taguchi and Makkar (2015), peri-urban farmers are providing about 34 percent of global meat production and nearly 70 percent of egg output. Growth is driven by a set of socio-economic and cultural factors, including improved diets among urban populations, with increased consumption of animal products. Also contributing to the sector's expansion is the availability of high-quality feed such as by-products of the food processing industry, and growing demand for perishable commodities produced as near as possible to the point of consumption. The production of fresh and perishable foods represents a comparative advantage for urban and peri-urban livestock producers, especially in places where rural infrastructure is poor, or where farm-to-market systems are inadequate.

Animals reared in an urban setting are normally cattle for milk, small ruminants and pigs for meat and poultry for eggs and meat. Other animal species include camels and buffalo, as well as non-conventional species such as rabbits and guinea pigs (FAO, 2001). Urban livestock are usually kept in small numbers by families to satisfy their own needs and as a source of extra income. However, specialized, medium- and large-scale, market-oriented producers, especially

for dairy and poultry, can also be found, particularly in peri-urban districts. Related activities may include food processing such as making yoghurt and cheese, both at household level and on a commercial basis.

Pastoral settlements in and around cities are another form of urban livestock production. In some cities, efforts are being made to zone areas for pastoralists and introduce strategies aimed at making their livelihoods more sustainable (Aberra, 2003; Moritz, 2008; Taguchi and Makkar, 2015; Triboi, 2017). Beekeeping is also practiced in urban areas, where it represents a growing activity, probably related to the decline of honeybee and wild bee populations in Europe and North America, but also to the rise of local food movements.

Urban and peri-urban livestock production involves a wide range of actors including producers, suppliers of resources, inputs and services, transporters and processors, retailers and consumers, promoters and managers, and urban planners and municipal authorities. However, the leading actor is the producer. As in urban agriculture generally, different social groups keep urban livestock for a variety of reasons. While some producers are from the middle or rich classes, most urban farmers belong to vulnerable groups such as female-headed households, children, retired people, widows and those with limited formal education. For such groups, involvement in urban livestock keeping represents a form of social security (Guendel, 2002): they grow food largely for their own consumption and income (Thys *et al.*, 2005).

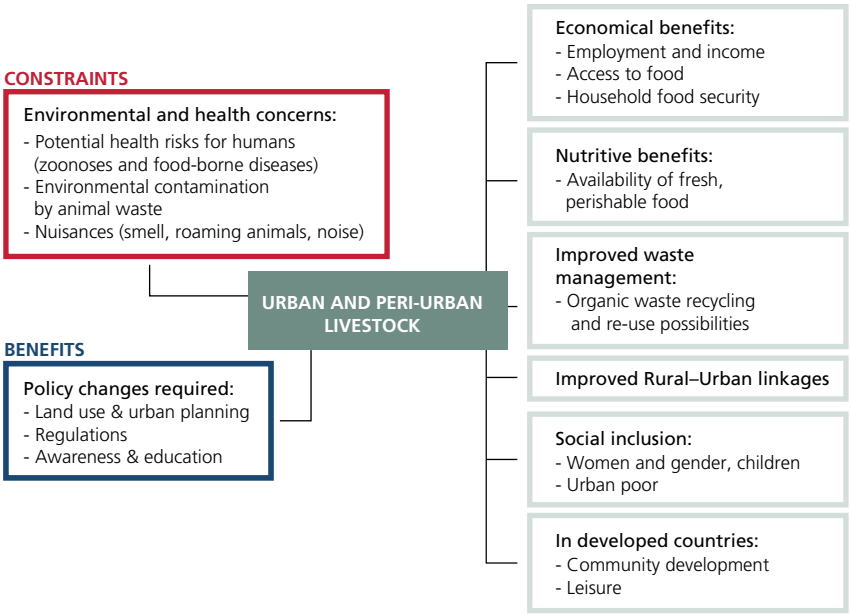
BENEFITS AND CHALLENGES OF URBAN LIVESTOCK PRODUCTION

Livestock production, although sometimes controversial, often has an essential role to play in and for cities, especially in developing countries. Its principal benefits (Figure 33) include income generation, employment creation and improved urban food security, nutrition and health (Thys, 2006; Lee-Smith, 2012). It also plays an important role in poverty alleviation and the social inclusion of disadvantaged groups, especially women, and in enhancing the resilience of city dwellers in food or economic crises (Resource Centres on Urban Agriculture and Food Security (RUAF) Foundation). Proximity to local markets makes urban livestock production attractive, especially for perishable foodstuffs.

Data from various cities around the world clearly show that urban and peri-urban livestock production contributes significantly to urban food systems. For instance, in Hanoi, 50 percent of pork and poultry as well as 40 percent of eggs come from urban and peri-urban areas (Phuong Anh *et al.*, 2004). In Shanghai, 100 percent of milk, 90 percent of eggs and 50 percent of pork and poultry meat are produced in or around the city (Yi-Zhang and Zhangen, 2000). In Kumasi (Ghana), 95 percent of chickens and eggs are produced locally, as are more than 95 percent of fresh milk and 15 percent of meat (Moustier and Danso, 2006). In Dakar, the urban poultry production amounts to 65 percent of national demand (Mbaye and Moustier, 1999). In Dar es Salam and Addis Ababa, the shares of urban demand for milk met by urban and peri-urban producers are respectively 60 percent (Jacobi *et al.*, 2000) and 70 percent (Tegegne *et al.*, 2000). In Mexico City, pork production provides 10–40 percent of household earnings and urban milk production can represent up to 100 percent of household income (Torres-Lima *et al.*, 2000).

The benefits of urban agriculture, including livestock, on the health and nutritional status of the urban poor are well-documented. For instance, a study in Kampala showed that urban farming families are nutritionally better off than non-farming households and that their children are healthier (Maxwell, 1995). According to Corbould (2013) similar findings have been reported from Zimbabwe, Kenya, Uganda and Haiti. Beyond economic benefits, livestock in urban settings also play an important role in waste management since they often feed on organic waste matter (Taguchi and Makkar, 2015). Chickens keep the backyard clean and create value from leftover food, while pigs use household

33 BENEFITS (BLUE) AND CONSTRAINTS (RED) OF URBAN LIVESTOCK PRODUCTION



Source: FAO, 2018.

and market waste products, as well as the by-products of commercial and industrial enterprises. Converting organic household waste is important in developing countries where 50 percent of urban waste is still organic, compared to 14 percent in developed countries (Thys, 2006).

At the same time, urban livestock also present significant risks since, in the absence of proper sanitation and infrastructure, they can be a source of environmental pollution and associated health hazards (Figure 33). Keeping livestock without proper sewage may favour mosquitoes that transmit malaria and major viral diseases, such as yellow fever and dengue, or proliferation of flies that spread pathogens. Food-borne diseases represent another threat, one often made worse by the lack of product safety controls – food produced by urban and peri-urban farmers is either consumed directly by the farmers and their families or sold through informal channels. Other public health problems include zoonotic avian and swine influenzas, rabies as well as tuberculosis or brucellosis, the latter transmittable to humans through close contact with animals or consumption of unprocessed dairy products. Other health risks include diseases that can spread when hygiene is poor or meat is insufficiently cooked, or they may be carried by rodents, like Hantavirus or leptospirosis (FAO, 2001). Nonetheless, studies of zoonoses in urban environments in Nigeria and Kenya suggest that the risk posed by raising, processing, marketing and/or consuming livestock in cities in developing countries is lower than generally thought (ILRI, 2012). While the zoonotic risk might not be huge, the environmental risks remain important and that is why cities increasingly ban rearing livestock in urban areas.

Environmental pollution is an important concern since waterways may be contaminated by manure effluents. This risk is particularly high in poor, densely populated areas lacking basic public services, such as slums, where people who raise livestock usually dispose of animal waste into drains, open sewers and dump sites.

In developing countries, manure is usually applied to farmers' fields or sold to crop producers, but in some cases, it is dumped in the open as garbage. When that happens, large amounts of nutrients such as nitrogen, phosphorus and potassium make their way into water courses together with antimicrobials and heavy metals like copper and zinc, with evident health risks (Taguchi and Makkar, 2015). Other environmental concerns include bad odour, dust, noise and the danger of roaming animals.

URBAN LIVESTOCK AND SUSTAINABLE DEVELOPMENT

Effective implementation of policies and strategies promoting livestock production in urban and peri-urban spaces can make a vital contribution to the achievement of several SDG 11 targets and to the development of sustainable and resilient cities and communities. Table 14 summarizes the SDG 11 targets most relevant to urban livestock production and how they can help achieve the goal. Achieving SDG 11 targets

TABLE 14
CONTRIBUTION OF URBAN LIVESTOCK PRODUCTION TO ACHIEVING SDG 11 TARGETS

SGD 11 TARGETS	CONTRIBUTION OF URBAN LIVESTOCK PRODUCTION TO ACHIEVING TARGETS	KEY AREAS OF NEED IN IMPROVING URBAN LIVESTOCK PRODUCTION AND ACHIEVING PROGRESS ON SDG 11
11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services, and upgrade slums	Improved living conditions and standards through generation of income and employment for urban farmers and the urban poor as well as contribution of urban livestock to household food and nutrition security	• Identify which activities should cease and which ones accelerated and properly managed • Systematically collect and share all kinds of urban data (including on urban agriculture and livestock production) to understand how key indicators for the city are responding • Build appropriate capacity and skills across stakeholder groups • Provide proper education and training to urban farmers on good practices • Ensure processes for multi-stakeholder engagement in all stages of urban development; build consensus, inclusion, resilience and sustainability • Share understanding of related risks to inform government legislation on land zoning and building codes of practice • Enforce existing regulations, which would contribute to improvements in animal health, welfare, and product safety
11.3 By 2030, enhance inclusive and sustainable urbanization and capacities for participatory, integrated and sustainable human settlement planning and management in all countries	Contribution to the development of sustainable and resilient cities that are socially inclusive through appropriate strategies for poverty alleviation and social integration of poor city dwellers	
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality, municipal and other waste management	Contribution to the development of cities that are environmentally healthy through reuse of organic waste as animal feed	
11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	Complementing rural agriculture and increasing the efficiency of the urban food supply through provision of non-market fresh and nutritious food	
11.b By 2030, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters	Use of proper manure management practices would further enhance the income of farmers and resource-use efficiency	

can be measured by factors and determinants for promoting cities and communities that are food secure and productive (Target 11.1), socially inclusive (Target 11.3), environmentally healthy (Target 11.6), working in harmony with rural areas (Target 11.a) and promoting resource-use efficiency (Target 11.b).

FOOD SECURE AND PRODUCTIVE CITIES (TARGET 11.1)

Rearing livestock in cities can fit different livelihood strategies, as demonstrated in several studies and surveys in Africa (Guendel, 2002; Thys *et al.*, 2005; Thys, 2006). Livestock production by poor urban dwellers provides them with convertible assets for important expenditures ranging from school fees and health to clothing and housing, thus contributing to SDG target 11.1 on improving basic services and upgrading slums.

SOCIALLY INCLUSIVE CITIES (TARGET 11.3)

While urbanization is moving the global economy forward, rising inequality and exclusion within cities can disrupt development progress. In that context, efforts should be made to create cities that are more inclusive and ensure that the urban poor benefit from urbanization. Encouraging urban livestock production could work towards the greater social integration of poor city dwellers, including women, who account for 65 percent of urban farmers (Orsini *et al.*, 2013). According to the RUAF Foundation, several municipalities and NGOs have initiated urban agriculture projects involving disadvantaged and economically vulnerable groups with the aim of bringing them into the urban network, building their communities and improving their livelihoods.

ENVIRONMENTALLY HEALTHY CITIES (TARGET 11.6)

For most cities, waste disposal has become a serious problem. Urban livestock producers can help by exploring opportunities for reusing organic waste as animal feed. Examples of such initiatives are reported from the municipalities of Nonthaburi, near Bangkok (Thailand), Johannesburg (South Africa), Hubli-Dharwad (India) and Accra (Ghana) where municipal authorities and/or urban farmers are engaged in collecting organic waste to feed to animals (Taguchi and Makkar, 2015; Nahman *et al.*, 2012; Deelstra and Girardet, 2000). However, apart from limited local initiatives, the role of animals in the large-scale disposal of waste from agro-industry in cities has been neglected by policymakers and city planners. This should be explored through comprehensive analysis of the ecological aspects of urban livestock. Livestock production must be integrated into urban ecologies because it can turn urban waste into a productive resource.

WORKING IN HARMONY WITH RURAL AREAS (TARGET 11.A)

As cities expand, the boundaries between urban, peri-urban and rural activities tend to merge, presenting opportunities for beneficial linkages. Urban and peri-urban livestock production could play an important role here by complementing rural agriculture and increasing the efficiency of the urban food supply. Strengthening these linkages with the involvement of all stakeholders may create the necessary enabling environment for extended trade networks and therefore benefit both smallholder farmers and the urban poor, while also helping support regional development.

These targets cannot be achieved without managing the risks and concerns that are closely associated with urban livestock activities. This will require finding a middle ground in balancing the benefits and challenges of urban livestock, using more evidence-based and relevant policies. A transition to sustainable urban livestock production is needed to reduce any negative effects on public health and the environment. Rather than restricting or banning urban livestock production on health and environmental grounds, cities should instead design a series of accompanying measures to reduce such risks. These may include improved coordination between

health, agriculture and environmental departments, educating farmers on the management of health and environmental hazards, and sharing understanding of risks and concerns to inform government legislation and urban planning policies. Moreover, all stakeholders, in particular urban farmers, the urban poor, and their representatives, should be involved in the analysis of the situation, in the definition of priorities and in action planning and implementation. Such a consultative process would create an enabling policy environment to facilitate inclusive and sustainable planning and development (RUAF, Foundation).

CONCLUSION

Goal 11 aims to make cities sustainable. Today's urbanization represents one of the most rapid and profound shifts in the history of human settlements. Livestock production has a variable and controversial, but often essential role to play in and for cities, especially in developing countries. The main benefits of urban livestock production include the generation of income, the creation of jobs, and the delivery of improved food security and nutrition. However, urban livestock also present significant risks since, in the absence of proper sanitation and infrastructure, they can pose environmental and public health hazards. In order to make cities more sustainable, specific measures to reduce such risks are required, including improved coordination between health, agriculture, municipal and environmental departments; farmer education on the management of health and environmental risks; and dissemination of information about these hazards to inform legislation and urban planning.

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12. Sustainable consumption and production

INTRODUCTION

According to ecological footprint studies by the World Wide Wildlife Fund (WWF) and the Global Footprint Network's (GFN's), humans are already using the resources of more than one Earth and could consume the reserves of three planets by mid-century. Though these studies are controversial, they raise the question of whether we shall have enough resources to sustain 9.8 billion people in 2050. Livestock production is particularly demanding: the sector uses large amounts of land, water and nutrients. Alexandratos and Bruisma (2012) estimate that global consumption of animal products will increase by 70 percent between 2005 and mid-century. Most of the growth will take place in developing countries, where consumption of animal-source food is low or modest. In many countries, many people still eat far too little to even meet their basic nutritional needs. In a business-as-usual scenario, the consumption levels expected in 2050 would mean further expansion of agriculture into natural habitats and continued depletion of natural resources.

SDG 12 is concerned with sustainable consumption and production and aims to "do more and better with less". The objective is to increase net welfare gains from all economic activities while reducing the amount of resources used, and at the same time lowering environmental degradation and pollution. Because improvements are needed along the whole life cycle of products, this goal requires the involvement of various stakeholders, including consumers, policymakers, retailers and industry representatives. SDG 12 targets give priority to programming and encourage governments to undertake public procurement policies that support sustainability and help the private sector to integrate sustainable practices in their production cycles.

A key SDG 12 target is improving efficiency in natural resource use. As a particularly resource-hungry sector, livestock can contribute very significantly here. Yield gaps and large potential for efficiency gains have been identified in all regions and production systems (see for example

Gerber *et al.*, 2013). However, sustainability is required on the demand side too. SDG 12 targets highlight the importance of information, especially to consumers. They stress the need for education and encourage developed countries to take the lead in implementing programmes promoting sustainable consumption. This is critical for livestock as demand for animal-source food is growing fast in developing countries. Finally, reducing waste and loss, as well as chemical pollution, is also listed as a key SDG 12 target. Significant efforts are needed throughout food supply chains, with the participation of all actors, to reduce the amount of meat, milk and eggs wasted by consumers and the food industry or lost in the production process. This can deliver major sustainability gains.

LIVESTOCK AND NATURAL RESOURCES

Livestock are the biggest users of land. Some 26 percent of the world's land area, or about 3.5 billion ha, consists of permanent meadows and pastures, and these are largely devoted to grazing livestock. Also, 33 percent of global cropland, or half a billion ha, is dedicated to fodder and feed production. The expansion of pastures and croplands to feed livestock is a major driver of land-use change and deforestation. Yet, while in some places overgrazing can cause land degradation, in others it is undergrazing that brings about biodiversity loss, ecosystem degradation and reduced grassland productivity. The point is that while livestock can damage the environment in various ways, they also provide a series of valuable ecosystem services. When properly managed, grazing can contribute to preventing soil erosion and bush fires and to improving biodiversity and water quality. These interactions are further explored in the chapter dedicated to "Life on Land".

Livestock also use huge amounts of water. Some of it goes on watering and servicing animals but large amounts also serve to irrigate feed crops and forage, and to process animal products in dairy plants, slaughterhouses, etc. While livestock can make a positive contribution to water quality, for example by maintaining year-round soil cover in grazing areas and offering protection against erosion, they also deplete water resources through the discharge of nutrients and organic matter in streams and groundwater. Few global estimates are available on livestock's use of water because of the complexity of the issue, and different approaches and methodologies exist. Water use can be classified in three different categories: direct withdrawals from surface or groundwater, also known as "blue water"; rainfall or soil moisture, also called "green water"; and the amount of freshwater needed to assimilate pollutants, or "grey water". In their global assessment considering all three water types, Mekonnen and Hoekstra (2012) estimate the global livestock water footprint at 2 422 Gm^3/year, of which more than 87 percent corresponds to rainfall and soil moisture (green water). Almost the entire footprint (98 percent) is due to livestock feed and forage. Livestock account for 29 percent of the water footprint of global agricultural production (8 360 Gm^3/year). However, the authors recognize that their results are significantly affected by their use of simplified feed rations.

As part of the carbon cycle, livestock are both a sink and a source of energy. While fossil fuel energy is required to produce feed and is also needed for milking and processing animal products, animal manure can be recycled – into biogas, through anaerobic digestion for example – and can thus provide an alternative to fossil fuels or fuelwood in livestock operations both large and small. The sector contributes an estimated 14.5 percent of global GHG emissions (Gerber *et al.*, 2013). Nearly 40 percent of total livestock emissions come from enteric fermentation but the greater part, almost 50 percent, is due to feed production, including: manure application and deposition (16 percent); field work (13 percent); fertilizer application (8 percent); and land-use change for soybean, palm oil and pasture expansion (9 percent). Emissions from manure management (before application) account for less

than 10 percent of the total and emissions from processing and transport of animal products represent about 3 percent.

With one-third of total arable land dedicated to feed production, livestock use a significant share of the almost 200 million tonnes of nitrogen, phosphate and potash fertilizers applied annually (respectively 109, 47 and 38 million tonnes) (FAO, 2017b). Through manure, livestock return some of these nutrients to soils and contribute to fertility and crop productivity. In general terms, between 55 and 95 percent of the nitrogen, and about 70 percent of the phosphorus ingested by livestock, are excreted as urine or faeces (Menzi *et al.*, 2010). Bouwman *et al.* (2013) estimated that total nutrients from livestock manure exceed nutrients from synthetic fertilizers at global level.

IMPROVING LIVESTOCK EFFICIENCY IN NATURAL RESOURCE USE

To produce more with less means that livestock production needs to become more efficient in its use of natural resources. Historically, agricultural research and development has focused on improving productivity, or the efficiency with which conventional inputs like land, labour and capital are transformed into marketable outputs. This process, which is motivated at the producer level by profit maximization, has led to significant productivity improvements over the past half a century. Ludena *et al.* (2007) estimate that between 1981 and 2000, total factor productivity (TFP) increased globally at an annual rate of 1.1 percent for ruminants and 2.7 percent for non-ruminants, as compared to 0.5 percent for crops.

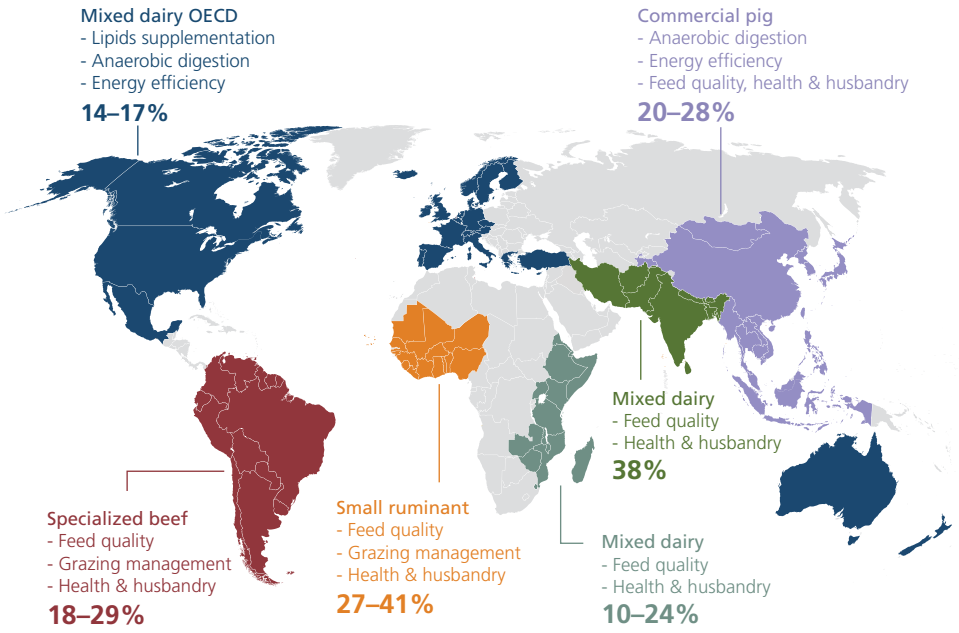
Natural resource efficiency can, in many cases, be enhanced by conventional productivity improvements. For example, in the past four decades the introduction of advanced genetics, feeding systems, animal health controls and other technologies has enabled industrialized countries to reduce their overall land requirements for livestock by 20 percent while at the same time doubling total meat production. Productivity gains can also dramatically reduce GHG emission intensity in ruminant-based systems (Gerber *et al.*, 2013). There is thus the potential to substantially improve natural resource use efficiency by the transfer of technology and knowledge from the world's most efficient production systems to its least performing ones. By so doing, the sector may reap a "double dividend" of improving not only producer profits but also environmental outcomes.

In a recent review, Gerber *et al.* (2015) established a list of desirable interventions, considering the diversity of production systems, and looking at land and water, nutrients, GHG emissions and biodiversity. Modest improvements in feed conversion ratios – the amount of feed needed to produce 1 kg of meat, milk or eggs – could limit or even offset the expansion of land needed to meet projected demand growth. Mottet *et al.* (2017) showed that the area needed to produce human-edible livestock feed (cereals, pulses, soybeans and cassava) would shrink by 8 percent between 2010 and 2025 if feed conversion ratios improved by 5–15 percent, and this despite a projected 21 percent increase in the demand for meat.

Wider adoption of existing best practices and technologies in feeding, health and husbandry, and manure management – as well as greater use of currently underutilized technologies such as biogas generators and energy-saving devices – could help the global livestock sector cut its GHG emissions by as much as 30 percent (Gerber *et al.*, 2013; Mottet *et al.*, 2016). Figure 34 summarizes the options identified by these authors in six regions and production systems to improve efficiency. In five out of the six cases, options resulted in higher productivity and reduced GHG emissions.

To mitigate the impact of livestock on water resources, special attention should be paid to feed composition, feed water requirements and feed origin. Systems using more crop residues, waste and roughage have the lowest water footprint (Mekonnen and Hoekstra, 2012). Improving nutrient management at farm level can also generate large efficiency gains. Improving feeding

34 SUMMARY OF MITIGATION OPTIONS AND POTENTIAL FOR GREENHOUSE GAS EMISSION REDUCTION IN % OF BASELINE EMISSIONS IN SIX REGIONAL CASE STUDIES



Source: FAO, 2018.

systems, manure management and application, as well as animal housing can contribute to improving nitrogen-use efficiency (Oenema, 2006; Gerber *et al.*, 2014).

Adoption of best practices require adequate policies, i.e. better advocacy, research and development (including extension services), but also regulations and incentives. For example, the Nitrates Directive of the European Union (Member Organization), introduced in 1991, aims to prevent nitrates from agricultural sources polluting ground and surface waters and to promote the use of good farming practices. For livestock farmers, it has involved manure storage capacity and application calendars, but since the Directive came into force, nitrogen-use efficiency has significantly improved in the European Union (Member Organization). The amount of agricultural nitrogen used in Western Europe per USD of livestock products dropped from 78 to 73 kg between 2002 and 2014 – a six percent improvement (FAO, 2017b).

Maintaining animal genetic diversity is also critical to optimizing livestock's use of natural resources in various environments and enhances the role farmed animals can play in adapting to fast-evolving disease and climate threats. The implementation of the Global Plan of Action for Animal Genetic Resources, adopted at FAO in 2007, is improving the sustainable use, development and conservation of the world's livestock diversity. However, efforts still need to be made to strengthen the management of these resources.

Payments for environmental services (PES) are also useful policy tools to improve efficiency in natural resource use. However, a review of 50 PES schemes in grazing land (Asian Development Bank, 2014) concluded that in many developing countries with market imperfections and land tenure issues, conditional payments

for environmental services may be less relevant than more general investments in production systems and livelihoods. In addition, analysis of payments for carbon sequestration services projects in developing countries suggests that what really determines the financial viability of such schemes is the profitability of the livestock production system itself, not the value of the environmental services compensated.

Improved productivity does not ensure improved natural resource efficiency, however. A study of OECD agriculture has shown that while most countries have simultaneously improved their TFP and nutrient-use efficiency between 1990 and 2003, some countries (Australia, United States of America, Canada, Portugal) have increased TFP but reduced their nutrient-use efficiency over the same period (Coelli *et al.*, 2009). Consequently, there may be situations where improvements in natural resource-use efficiency will reduce farm profitability, which could be compensated with adequate policies and should be carefully assessed.

The concept of efficiency also has limitations. Gains must be at least as fast as demand growth if the overall impact on resources is to be reduced. For example, Gerber *et al.* (2013) estimate that bridging the efficiency gap could result in a 30 percent abatement of GHG in livestock emissions. Yet a 30 percent improvement in emissions intensity accompanied by a 70 percent rise in demand would actually result in an overall increase of emissions. Furthermore, systems and regions that have already achieved high levels of efficiency have limited potential for improvement. Additional gains attainable through technological advances can still reduce the pressure on natural resources significantly but their cost may be prohibitive when compared to low-efficiency systems. Therefore, adoption of the new technologies may be limited if no adequate support is provided.

A further issue is that gains in efficiency increase profitability and can lead to the expansion of production and, with it, to additional pressure on natural resources. Therefore, ways must be found to protect agro-ecosystems, including grasslands and water courses, and avoid further expansion and deforestation. Environmental services provided by livestock can be promoted through specific payments while water pollution can be avoided through better manure management. Finally, efficiency has also to be thought of in global terms: while it can make sense to produce a maximum of meat, milk and eggs where the environmental cost per kilo is minimum and the economic return maximum, a regionalization of production based on comparative efficiency advantages would threaten food sovereignty and potentially food security.

BALANCING DIETS FOR SUSTAINABLE CONSUMPTION

As noted, demand for animal products will increase by 70 percent between 2005 and 2050 (Alexandratos and Bruisma, 2012). According to FAO's estimates, in countries where food consumption is currently rising, diets will generally feature more livestock products, vegetable oils and sugar. These three food groups together now provide 29 percent of total calories (kcal) supplied in developing countries – 20 percent more than three decades ago. This share is expected to rise to 35 percent in 2030, having stabilized at around 48 percent in industrialized countries.

According to FAO and the Food Climate Research Network (FCRN), (2016), healthy diets have the following features in common: diversity of food, energy balance between intake and expenditure; inclusion of minimally processed tubers and whole grains along with legumes, fruit and vegetables; and meat, if eaten, in moderate quantities. They also include dairy products in moderation, unsalted seeds and nuts, small quantities of fish and aquatic products, and very limited intake of processed foods. Appropriate amounts of meat and other animal-source foods in the diet have high nutritional returns (Bender, 1992; see also Chapters 2 and 3). But overconsumption of meat and other products of animal origin can be harmful, leading to high rates of

cardiovascular disease, diabetes, and some cancers. The consumption of meat and saturated fat in many high-income countries, for instance, far exceeds nutritional needs and has negative health impacts (Walker *et al.*, 2005; McMichael *et al.*, 2007).

A growing number of studies argue that reducing the share of animal-source food in regions with affluent diets could bring substantial environmental and health benefits (Eshel *et al.*, 2006; Erb *et al.*, 2009; Stehfest *et al.*, 2009; Tukker *et al.*, 2011; Tilman and Clark, 2014; Van Dooren *et al.*, 2014; Hallström *et al.*, 2015). These studies usually rely on a Life Cycle Approach (LCA) that considers all the different steps in production, processing and retailing. They also generally focus on two dimensions of environmental sustainability, namely GHG emissions and land use, and limit their analysis of nutritional impact to energy or protein. Such studies usually conclude that the global adoption of affluent "Western-type" diets with high levels of animal products would result in an expansion of arable land (e.g. 20 percent, according to Erb *et al.*, 2010). They argue that diets with lower intakes of animal products offer higher benefits and lower environmental impact. For example, van Dooren *et al.* (2014) show that the average Dutch diet, rich in animal products, has the lowest health score among six diets, including vegetarian and Mediterranean, as well as the highest impact in terms of GHG emissions and land use.

Most of these assessments recognize limitations in their methodology. First of all, they either compare existing diets, making it difficult to transfer results to other world regions. Or they base their calculations only on kcal or protein at best, ignoring micronutrients such as calcium, iron, zinc and vitamin B12, which are difficult to source from an exclusively plant-based diet. In addition, such studies usually rely on rough estimates of animal feed rations and feed conversion ratios, usually neglecting the fact that animals consume large amounts of crop residues and by-products and that a large part of meat and milk production does not rely on cereals. Simplification of this kind can skew land-use change results.

There is little doubt, however, that developing sustainable consumption patterns requires balancing the nutritional and other benefits of animal products with the harmful health and environmental effects of overconsumption. Bearing in mind the very large diversity of diets at global level, rebalancing to reach nutritional targets could also contribute to raising overall efficiency in food systems (Tilman and Clark, 2014).

REDUCING WASTE AND LOSS

FAO has estimated that every year roughly one-third of the food produced for human consumption is lost or wasted (FAO, 2011e). This represents a major dissipation of land, water, energy and other inputs, as well as millions of tonnes of greenhouse gases emitted unnecessarily. Significantly, much more food is wasted per capita in industrialized than in developing countries. For every kilo of meat produced at global level, about 200 grams are lost or wasted. For every litre of milk (or dairy equivalent), between 100 ml and 250 ml are squandered, depending on the region (FAO, 2011e).

In low-income countries, food loss occurs throughout food value chains, and stems from managerial and technical limitations in harvesting, storage, transportation, processing, packaging and marketing (FAO High Level Panel of Experts, 2014). The heaviest losses are in small and medium-scale agricultural and fisheries production and processing. Social and cultural conditions – such as the different roles that men and women play at various stages in the value chain – are frequently an underlying cause of food loss. The difficulties that women face in obtaining access to, and benefits from, income-generating activities affect their productivity, which exacerbates food loss. Pests and diseases, through their impact on animals but also on their feeds, are also a significant source of food loss. Animal diseases can also result in milk, meat or eggs being discarded.

In middle- and high-income countries, consumer waste accounts for approximately half of total meat loss and waste. Food waste is mainly a question of consumer behaviour but as reported by Halloran *et al.* (2014), "beyond the direct reason for food waste, several actors within the food supply chain contribute indirectly to food waste by influencing consumer behaviour, for example through packaging sizes, sale promotions or discounts". Policies and regulations also contribute to food waste and loss. For example, agricultural subsidies may encourage the production of surplus food crops, which reduces both prices and the attention paid – along the value chain and by consumers – to food loss and waste.

Moreover, food safety and quality standards may remove food that is still safe for human consumption from the supply chain. Though most regulations are put in place to ensure consumer safety, it has been shown that "best before" dates usually have no real sanitary justification. Aesthetic defects, for example imperfections in the shape or colour of vegetables, generate significant amounts of waste with no health benefits for anyone (Gustavsson *et al.*, 2011). At consumer level, inadequate planning of purchases and failure to use food before its expiry date also leads to waste.

Reducing food loss and waste could contribute to improving overall efficiency in livestock supply chains and to reducing GHG emissions. It could also help enhance access to food and improve the resilience of food systems to climate change but action on food waste requires an effort from all actors along the supply chains, from producers to consumers. For example, governments, in partnership with the private sector, can build or improve infrastructure and conservation facilities for the transport, processing and storage of agricultural produce. They can also bring about change through appropriate regulations and improved consumer awareness. Building on the example of Denmark, Halloran *et al.* (2014), conclude that the first step is for all actors to adopt a food system approach, with all initiatives, research, and interventions planned accordingly. In developing countries, farmer organizations have a critical role to play while investments in infrastructure, transportation, food industries, and packaging are also required (FAO, 2011d).

CONCLUSION

Goal 12 aims to promote sustainable consumption and production. Livestock supply chains are resource-hungry – they use huge amounts of land, water, nutrients and energy, and contribute significantly to GHG emissions. Unsustainable production and consumption not only contribute to inefficient use of resources, but also entail lost economic opportunities, environmental damage, and poverty and health problems. There are many opportunities and existing technologies for increasing the sustainability of the livestock sector through gains in efficiency. Improvements in animal health, feeding, reproduction practices, manure management and grazing management can contribute to closing yield gaps in all production systems and regions. Reducing waste and loss at all stages of the supply chains can spur significant progress. However, adapting and enforcing new technologies in local environments, and instituting supporting policies and infrastructure to encourage adoption, will pose a significant challenge.

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13. Climate change and its impacts

INTRODUCTION

The United Nations recognize that climate change is the single biggest threat to development. 2016 was the hottest year ever recorded, and the third of three record-breaking years. In 2016, the average CO_2 concentration in the atmosphere surpassed the emblematic threshold of 400 parts per million, a level never before reached in recorded history (more than 650 000 years). CO_2 is increasing more than 100 times faster than when the last ice age ended. Climate change impacts on agriculture and implications for food security are already alarming and its widespread, unprecedented effects disproportionately burden the poorest and most vulnerable.

SDG 13 aims to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters. Its second target is to integrate climate change measures into national policies, strategies and planning, which means not only increasing countries' ability to adapt to the adverse impacts of climate change but also fostering low-emissions development. SDG 13 also includes objectives on awareness raising, education and capacity development regarding climate change. Climate change impacts livestock directly (for example through heat stress and increased morbidity and mortality) and indirectly (for example through quality and availability of feed and forages, and animal diseases). Smallholder livestock keepers, fisherfolk and pastoralists are among the most vulnerable to climate change. However, a wide range of adaptation options are available, including water management, breeding animal and forage species for resistance to drought, heat and harsh environments, providing cooling or shading and implementing on- and off-farm diversification. Other institutional options may also be considered such as income stabilization programmes or insurance schemes.

At the same time, the livestock sector contributes significantly to climate change. According to the Intergovernmental Panel on Climate Change (IPCC, 2014), direct livestock greenhouse gas (GHG) emissions, from

manure and enteric fermentation, represented 2.4 gigatonnes of CO_2 equivalent (CO_2eq) in 2010, about 21 percent of total emissions from agriculture, forestry and other land uses, or about 5 percent of total anthropogenic GHG emissions. Using a Tier 2 methodology (IPCC, 2006) and life cycle assessment approach, FAO estimates that including indirect emissions (such as feed production, processing and transport as well as energy used on and off farm) results in emissions from livestock supply chains to reach 14.5 percent of total anthropogenic emissions (Gerber *et al.*, 2013). Nevertheless, the adoption of existing best practices and technologies in animal feeding, health and husbandry, plus improved manure management, could make the global livestock sector more resilient and cut its GHG emissions by as much as 30 percent. Moreover, carbon sequestration in the biomass and soils of pastures could significantly offset emissions from livestock.

CLIMATE CHANGE AFFECTS LIVESTOCK PRODUCTION IN MULTIPLE WAYS

Climate change affects livestock production in multiple ways, both directly and indirectly, e.g. through the increase of CO_2 concentration in the atmosphere, variations in precipitation and temperature swings. The most significant impacts are felt in animal productivity, forage and feed crop yields, animal health, and biodiversity, as summarized in Figure 35.

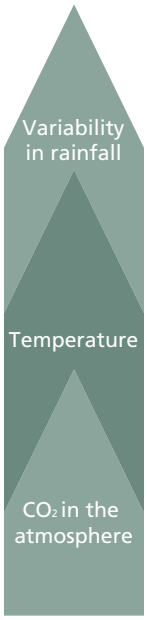
Impacts of climate change on animals are quantified to some extent. For example, the May 2015 heatwave with temperatures above 40°C killed more than 17 million birds in India (Reuters, 2015). According to an industry survey, dairy cows in the hotter, southern European countries suffered heat stress for more than half of the day, resulting in estimated milk loss of up to 5.5 kg/cow/day (Lallemand Animal Nutrition, in FeedInfo, 2015). In Italy, Crescio *et al.* (2010) reported that high temperatures and air humidity could lead to a 60 percent increase in cattle mortality. In various countries of sub-Saharan Africa, 20–60 percent of herds were lost during serious drought events in the past 2–3 decades. In South Africa, Niang *et al.* (2014) reported that dairy yields may decrease between 10 and 25 percent under certain climate change scenarios. Another case study reported by the same authors estimated a 23 percent rise in the cost of supplying water to animals from boreholes in Botswana.

Impacts of climate change on animal health are also documented, especially for vector-borne diseases since rising temperatures increase the survival of vectors and pathogens over the winter. Diseases such as West Nile virus and schistosomiasis are projected to expand into new areas, as are bluetongue or Lyme. Outbreaks of Rift Valley fever in East Africa are also associated with increased rainfall and flooding due to El Niño-Southern Oscillation events (Lancelot *et al.*, 2008; Rosenthal, 2009; Porter *et al.*, 2014).

Impacts on feed crops and forages, and grasslands to a lesser extent, have also been quantified, despite uncertainties resulting from complex interactions between climatic factors (mainly temperatures) and CO_2 concentrations. Increased temperatures and reduced precipitations have direct negative impacts on yields, and records during drought events can reveal major drops in forage production, such as the 60 percent deficit of green fodder experienced during the summer of 2003 in France. Climate change can also affect fodder quality through shifts from C3 to C4 plants and increased shrub cover, increases in lignification as well as plant secondary metabolites such as tannins, alkaloids and saponins, and in plant tissues at higher temperatures (Wilson *et al.*, 1991). Increases in mould infestation and contamination of feed resources resulting from increased variability in precipitations could also impact feed and food safety.

More assessments are required of livestock production under climate constraints to support policies aiming to improve the sector's resilience (IPCC, 2014). In particular, modelling and quantifying aggregated impacts on livestock production systems still need to overcome a

35 CLIMATE CHANGE IMPACT ON LIVESTOCK



	Animals	Forages and feed crops	Labour force and capital
Variability in rainfall	Shortages of drinking and servicing water Diseases - Increased pathogens parasites and vectors - Changed distribution and transmission - New diseases	Decreased yields Decreased forage quality Changes in pasture composition (species, communities) Changes in production systems (e.g. from mixed crop–livestock to rangelands)	Altered human health and resource allocation to livestock Decreased productivity Migration Conflict for resources
Temperature	Heat stress - Decreased feed intake and livestock yiels - Decreased conception rates - Altered metabolism and increased mortality Diseases - Increased pathogens, parasites and vectors - Decreased resistance of livestock - New diseases Domestic biodiversity loss	Decreased yields Decreased forage quality Changes in pasture composition	
CO_2 in the atmosphere		Partial stomata closure and reduced transpiration Change in pasture composition	

A range of climate change adaption solutions exist for livestock production

Animals	Forages and feed crops	Labour force and capital
Water management (e.g. boreholes) Breed for resistance to drought, heat and harsh environments Shifts in species, breeds and/or production systems (e.g. small ruminants, poultry) Disease control and animal health Cooling (indoor systems) or provide shade (e.g. trees)	Irrigation Purchase feed Breed feed crops and forage resistance to drought and heat Changes in cropping calendar Agroforestry Increase mobility for resources	On and off farm diversification Insurance Reconversion (in the context of national/ regional production zoning) Insitutional changes (e.g. trade conflict resolution, income stabilisation programs)

Source: Adapted from Thornton *et al.*, 2009; IUCN, 2010; Niang *et al.*, 2014.

number of challenges (Thornton *et al.*, 2015). First, regional climate scenarios are becoming more available but are still associated with significant uncertainties, which limit our capacity to model livestock productivity under climate change. In extensive grazing and pastoral systems, impacts on rangeland primary productivity, grass species mix and carrying capacity are still mostly unknown. In addition, most models do not take management into account, which results in considerable habitat buffering. Second, animal diseases are affected by climate change, but future distribution patterns should be modelled to understand their impact on scenarios and projections. Finally, the impact on groundwater availability is also an area where more assessments are needed, especially in grazing systems.

36 CLIMATE CHANGE ADAPTATION OPTIONS IN THE LIVESTOCK SECTOR

Animals	Forages and feed crops	Labour force and capital
Water management (e.g. boreholes) Breed for resistance to drought, heat and harsh environments Shifts in species, breeds and/or production systems (e.g. small ruminants, poultry) Disease control and animal health Cooling (indoor systems) or provide shade (e.g. trees)	Irrigation Purchase feed Breed feed crops and forage resistance to drought and heat Changes in cropping calendar Agroforestry Increase mobility for resources	On and off farm diversification Insurance Reconversion (in the context of national/ regional production zoning) Insitutional changes (e.g. trade conflict resolution, income stabilisation programs)

Source: Adapted from Thornton *et al.*, 2009; IUCN, 2010; Niang *et al.*, 2014.

Livestock vulnerability to climate shocks depends above all on the level of their exposure: on the duration, frequency and severity of the shocks; and on the location of stock and of relevant assets such as feedstock, housing, water points, etc. Much also depends on livestock sensitivity: their species or breed, the housing or feeding system used, their health status (e.g. vaccination frequency), and their importance to the household in terms of food security and livelihoods (ICEM, 2013). In addition, a number of other factors contribute to increasing livestock vulnerability to climate change, especially in semi-arid and arid regions. These include rangeland degradation, fragmentation of grazing areas, changes in land tenure, conflicts and insecure access to land, and finally markets (e.g. availability of crop residues and by-products for feed, animal products).

SUPPORTING ADAPTATION IN THE LIVESTOCK SECTOR

Livestock's adaptive capacity depends on the production system used, including choice of species and breeds, the availability/adaptability of alternative feed resources, the accessibility of animals (health/extension services), the type/efficiency of response to outbreaks (surveillance, compensation schemes, etc.) and the household income level (ICEM, 2013). A range of adaptation options are available for livestock production (Figure 36) at different scales: animals, feeding/housing systems, production systems, and institutions. They also differ between small-scale livestock production with low market integration and large-scale production with high integration.

In particular, breeding livestock but also resistant feed crops and forages are key components to building resilience to climate change. Many livestock breeds are already well adapted to high temperatures and harsh environments, but the wider dissemination of such breeds and their incorporation into breeding programmes is restricted by the limited extent to which they have been characterized and improved in structured breeding programmes (Madalena, 2008), and also by trade constraints (Gollin *et al.*, 2008). Adaptation traits are more difficult to study and to record than production traits, have lower heritability, higher levels of non-additive genetic variation and phenotypic variance, and are more susceptible to genotype-by-environment interaction (Frankham, 2009).

The speed of climate change may outstrip the ability of breeds to adapt genetically, or that of their keepers to adjust their management strategies. In places, this may break the link of adaptation between local livestock and their production environments. If such effects occur, adapting production systems and animal genetic resources management will be a major challenge and may increase the need for moving better-suited species and breeds into new areas. It will be critical to ensure that plans to introduce new breeds take into account climatic and other agro-ecological and socio-economic conditions and their predicted future trends. Breeds introduced to new geographical areas should have a range of advantageous traits as introducing breeds considering only one trait has not been successful (Blackburn and Gollin, 2008).

Furthermore, access to inputs and livestock services relevant to climate change adaptation needs to be improved. As regards animal genetic diversity, this requires better characterization of breeds, production environments and associated knowledge; the compilation of more complete breed inventories; improved mechanisms to monitor and respond to threats to genetic diversity; genetic improvement programmes targeting adaptive traits in high-output and performance traits in locally adapted breeds; more effective *in situ* and *ex situ* conservation measures; increased support for developing countries in their management of animal genetic resources; and wider access to genetic resources and associated knowledge.

While irrigating feed crops and grasslands and purchasing feed are immediate farm-level coping mechanisms for short-term adaptation, long-term options exist such as breeding feed crops and forages for water-use efficiency, resistance to drought, salinity and waterlogging. More systemic adaptation such as grassland restoration or diversification in composition, agroforestry with fodder trees and legume shrubs to provide alternative feed resources, shade and water retention, plus animal and feed mobility are also longer-term solutions. In grazing production systems, these long-term strategies address the variability of already scarce feed resources while also providing other types of environmental services, such as mitigation of GHG emissions and biodiversity conservation. They are particularly relevant and should be supported by public policies.

Diversification, both on-farm in mixed crop–livestock systems through increased varieties, species and breeds or processing products, and off-farm by finding sources of income or jobs outside agriculture, is an important element of climate change adaptation (Thornton and Herrero, 2014). Diversifying is, however, very context-dependent, operates at farm level and requires overcoming constraints such as access to information and initial investment costs. Household income diversification is not restricted to developing economies (Kurukulasuriya and Rosenthal, 2013) but can be observed in countries like Canada and Ireland. It requires enabling policies, including training, information dissemination, and support services.

Impact assessments are a prerequisite to the development of adequate policy response to climate change in the long term. IPCC's fourth and fifth assessments reports have stressed the need for impact-assessment frameworks that could be used to estimate the costs and benefits of adaptation options. Such frameworks should pay specific attention to forages and feed resources, which are critical to better assess adaptation needs in livestock. Developments in satellite imagery could also contribute to this effort through the monitoring of soil moisture, the leaf area index, and through infra-red imaging of droughts or tracking pastures and water points for seasonal adjustments in stocking density and mobility. They represent important potential components of early warning systems. Finally, better information is needed on adaptive responses, not only to climate stress but also to associated stresses such as nutrition and diseases.

Livestock can also be a tool for adaptation to climate change. Traditionally, livestock keepers have been capable of adapting to livelihood threats and, in some situations, livestock keeping

is itself an adaptation strategy, in particular in pastoral communities where livestock have always been the main asset in surmounting harsh climatic conditions (IUCN, 2010; Scoones, 1996; Ashley and Carney, 1999). Livestock can be used as a diversification strategy and to manage risk in the event of crop failure (Jones and Thornton, 2009).

In the drylands of sub-Saharan Africa, de Haan *et al.* (2016) have shown that shocks brought about by climate-driven variability on biomass can be buffered by livestock production through animal movement, adjustments in feed baskets, health interventions and animal offtake for market. Mottet *et al.* (2016) have confirmed these observations in Zambia, showing that households with livestock had higher incomes and lower income variation in dry years than households without. In Zambia, using panel data, Arslan *et al.* (2017) demonstrated that diversification, including through livestock, can play an important role in lessening food insecurity and vulnerability in the face of increasingly frequent and intense extreme weather events.

LIVESTOCK MAKE A SIGNIFICANT CONTRIBUTION TO CLIMATE CHANGE

FAO estimates that emissions from livestock supply chains amounted to about 8.0 gigatonnes of CO_2 equivalent in 2010 (GLEAM 2.0, 2017). Direct emissions, including enteric methane and emissions from manure management, accounted for 4.2 gigatonnes of CO_2eq. In addition, emissions from animal feed and forage production account for 3.3 gigatonnes of CO_2eq (41 percent of the total). Emissions from energy used on farm and in the supply chains as well as emissions from processing and transport of animal products account for 4.7 percent of the total (Figure 37). Using the latest estimate of total anthropogenic emissions available from IPCC, Gerber *et al.* (2013) estimated that livestock are responsible for 14.5 percent of global emissions. Beef and cow milk are the two commodities with the highest total emissions, accounting for 3.0 and 1.6 gigatonnes CO_2eq, respectively. They are followed by chicken meat and eggs with 0.83 gigatonnes, pig meat (0.82 gigatonnes), buffalo meat and milk (0.7 gigatonnes) and small ruminant meat and milk (0.5 gigatonnes). Remaining emissions are allocated to other poultry and to non-edible products.

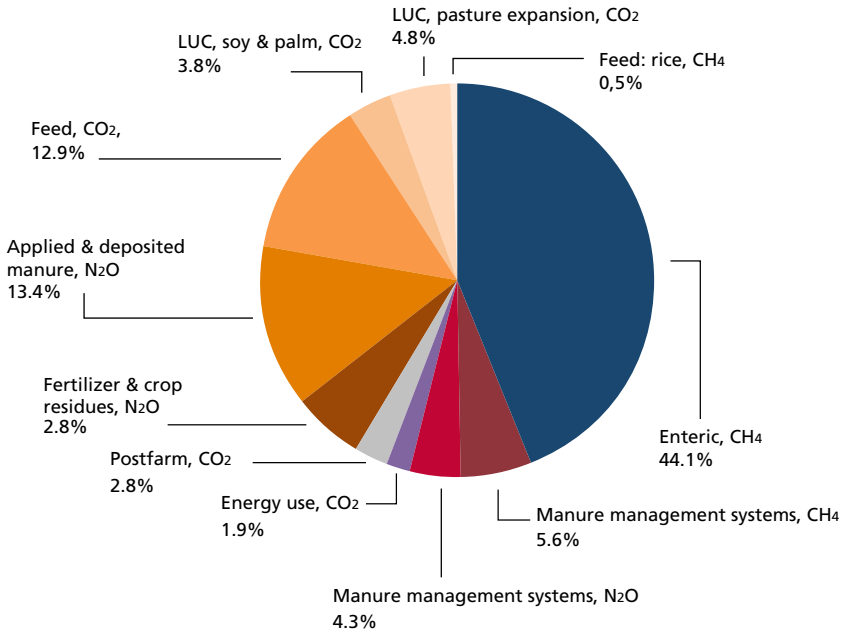
A way to compare the performance of different commodities is to express the emissions in terms of protein produced. By doing so, buffalo meat is the commodity with highest emission intensity, with an average of 404 kg CO_2eq per kg of protein, followed by beef, with an average of 295 kg CO_2eq per kg of protein. The emission intensity of meat and milk from small ruminants and milk from buffalo are 201, 148 and 140 kg CO_2eq per kg of protein, respectively. Cow milk, chicken meat, eggs and pork have lower emission intensities, all below 100 kg CO_2eq per kg of protein. Emission intensities vary greatly among producers, especially in ruminant products (Figure 37). This reflects different agro-ecological conditions, farming practices and supply chain management. It is within this gap between high and low emission intensities that opportunities for mitigation can be found.

Latin America and the Caribbean have the highest level of emissions, with 1.9 gigatonnes CO_2eq, mainly from beef production. East and Southeast Asia, with over 1.6 gigatonnes CO_2eq, is the second-highest emitting region, followed by South Asia with 1.5 gigatonnes CO_2eq. North America and Western Europe emit about the same levels (around 0.6 gigatonnes CO_2eq), while emissions from the Near East and North Africa are similar, but with less than half of the protein. Sub-Saharan Africa presents comparable emissions – about 0.4 gigatonnes CO_2eq, while Eastern Europe, Oceania and the Russian Federation share much lower emission levels (between 0.1 and 0.2 gigatonnes).

EFFICIENCY IS KEY TO REDUCING EMISSIONS AND BUILDING RESILIENCE

Emissions from the livestock sector could already be brought down significantly simply by making wider use of existing best practices and

37 GREENHOUSE GAS EMISSIONS FROM LIVESTOCK SUPPLY CHAINS IN 2010



Source: GLEAM 2.0, 2017.

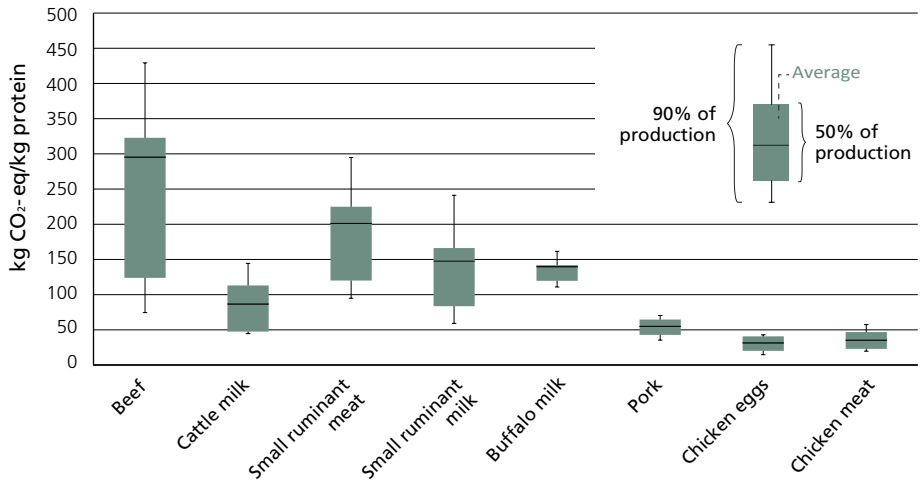
technologies. In effect, a 30–35 percent reduction in GHG emissions would be possible if producers in any given system, region or climatic zone adopted the technologies and practices currently used by their least-emission-intensive peers (measured per unit of animal product). Substantial emission reductions can be achieved across all species, systems and regions.

There is a very large body of evidence on how livestock can contribute to mitigating GHG emissions, from carbon sequestration in grasslands, which cover 25 percent of the earth's land area, to non-CO_2 emissions, including enteric methane, nitrous oxide from feed production and methane and nitrous oxide from manure management and application on grasslands and field crops (Hristov *et al.*, 2012). Packages of mitigation techniques can bring large environmental benefits (Gerber *et al.*, 2013; Mottet *et al.*, 2016) and feasible technical interventions in livestock production systems could reduce livestock's impact by between 14 and 41 percent.

Possible interventions to reduce emissions are mainly based on technologies and practices that improve production efficiency at animal and herd level. They include better feeding practices, animal husbandry and health management. Manure management practices that ensure the recovery and recycling of nutrients and energy contained in manure, and energy savings and recycling along supply chains, are further mitigation options. Such interventions, by helping to reduce emissions and increase production, would make a substantial contribution to food security. Through a more efficient use of natural resources, they also make systems more resilient to shocks.

Their implementation requires transfer of technology and knowledge, together with the right incentives and a conducive regulatory

38 GLOBAL EMISSION INTENSITY BY COMMODITY AND VARIABILITY



Source: FAO, 2018.

framework. The global context has changed and has become more favourable for livestock to contribute to mitigating climate change and its impacts. First, soil carbon and enteric methane have recently entered into the climate policy and funding conversation, with projects such as the 4/1000 Initiative and the Global Methane Initiative. No less than 92 countries have included livestock in their Intended Nationally Determined Contributions (INDCs) (FAO, 2016e). While based on complex biophysical and ecological processes, benefits from improved feed quality and well-functioning grazing are better understood and recognized worldwide. The public at large is also more concerned about the environment and demand for ecosystem services is growing too, including climate change mitigation. Finally, policymakers increasingly recognize the multiple opportunities presented by livestock in terms of economic growth, social benefits and environmental services.

CONCLUSION

Goal 13 calls for urgent action to combat climate change and its impacts. The relationship between livestock and climate change works two ways. On the one hand, livestock make a significant contribution to climate change. In 2010, direct livestock greenhouse gas emissions amounted to 2.4 gigatonnes of CO_2 equivalent, about 41 percent of total emissions from agriculture, forestry and other land uses, and 8 percent of total anthropogenic GHG emissions. On the other hand, climate change affects livestock production, for example though the quality and availability of feed and forage, and the incidence and prevalence of animal diseases. A number of technical mitigation and adaptation options are available to improve natural resource-use efficiency. However, measures that go beyond the farm gate are also required, including institutional changes, disaster risk management, and social safety nets.

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14. Livestock and life below water

INTRODUCTION

Over three billion people depend on marine and coastal biodiversity for their livelihoods, while broadly the same number obtain almost 20 percent of their usual intake of animal protein from fish. In addition, fish provides essential fats such as long-chain omega-3 fatty acids, vitamins A, B and D, and minerals. Small quantities of fish can have significant benefits for individuals consuming plant-based diets (FAO, 2016e). However, the world's ocean fish face serious threats both in terms of biodiversity and food security. The principal source of pressure is overexploitation by fisheries, which has affected the size and viability of fish populations, the genetics of target species, and the food chains and ecosystems to which they belong. A substantial part of the global fish catch is turned into fishmeal and fish oil, and used to feed animals, which in turn leave their own footprint on the health of aquatic and marine ecosystems. Many watercourses suffer from pollution due to effluents from livestock and industry, with profound environmental and human health implications.

Sustainable Development Goal 14 seeks to promote the conservation and sustainable use of marine and coastal ecosystems; to prevent marine pollution; to increase economic benefits to small island developing states (SIDS) and least-developed countries (LDCs) from the sustainable use of marine resources. Some progress has already been made because, over the last decades, the use of fishmeal in livestock diets has decreased substantially. This is largely because plant-based products and synthetic amino acids (e.g. lysine and methionine), as well as enzymes (e.g. phytase and non-starch polysaccharide-degrading enzymes), have become available as feed additives. Recent developments such as the use of seaweed and algal by-products as animal feed are expected to further decrease the use of fishmeal. Seaweed as a source of bioactive compounds for promoting animal health and production, and for decreasing enteric methane, can also be used to enhance the sustainability of livestock production systems. Increasing de-

mand for seaweed for livestock feed and/or oil production could spur the development of a seaweed aquaculture industry.

However, overexploitation could affect marine biodiversity. Nutrient runoff and leaching from livestock waste has serious detrimental effects on coastal marine fisheries. Improvement in waste management on livestock farms can be a cost-effective way of reducing river-based nutrient loads, which often end up in marine systems and contribute to coastal eutrophication. Likewise, decrease in enteric methane and manure-based methane from the livestock sector would contribute to mitigation of ocean acidification driven by global warming, which can adversely affect marine biodiversity and ocean-based food chains. The discussion below revolves around enhancing the sustainability of marine systems by containing the use of fish products in animal feed, reducing the pollutants produced by the livestock sector, and using some marine plant resources for livestock feed.

LIVESTOCK AND MARINE LIFE DEPLETION

Pressure on global fish resources has been increasing steadily in recent decades. In 2013, about 58 percent of marine stocks were fully fished, with no potential for increased production, and 31.4 percent were overfished, with production increases only possible after successful restocking. Furthermore, the ten most productive species accounted for almost a third of the world's marine capture fisheries catch – clear evidence of unsustainable fishing (FAO, 2016e). A significant, but declining, proportion of the world fish catch is processed into fishmeal (mainly for high-protein feed) and fish oil (as a feed additive in aquaculture, but also for human consumption). Fishmeal and oil can be produced not only from whole fish but also from fish remains or other fish by-products: nonetheless overall demand keeps growing and making a substantial contribution to the depletion of marine stocks. Pigs and chickens currently use about 27 percent of global fishmeal output (FAO, 2014b), and while that share is dropping, this is due to the rapid growth of aquaculture and of its share. Identification and use of alternative feed resources for livestock and farmed fish can therefore do much to prevent further depletion of marine stocks.

Some progress is already being made. For example, Norwegian farmed salmon currently eat 50 percent less fishmeal than two decades ago because the use of plant proteins in their feed has increased (Miladinovic, 2015). Fishmeal in the diets of other fish species such as carp, tilapia, trout, eel and shrimp has also decreased (Tacon and Metian, 2008; Tacon and Metian, 2015) and its use in the poultry and pig sectors has dropped substantially too (FAO, 2006a). Supplementation with various synthetic amino acids, in particular lysine and methionine, and enzymes such as phytase and non-starch, polysaccharide-degrading enzyme cocktails, enhances the use of plant-based feeds in the diets of many animal species. Alternative feed resources such as seaweed and other algal by-products, insect meal, biofuel co-products, protein isolates, protein hydrolysates, and waste food can also replace fishmeal in the diets of aquatic species and livestock, and are receiving growing attention (Makkar, 2014; Makkar *et al.*, 2014; Tran *et al.*, 2015).

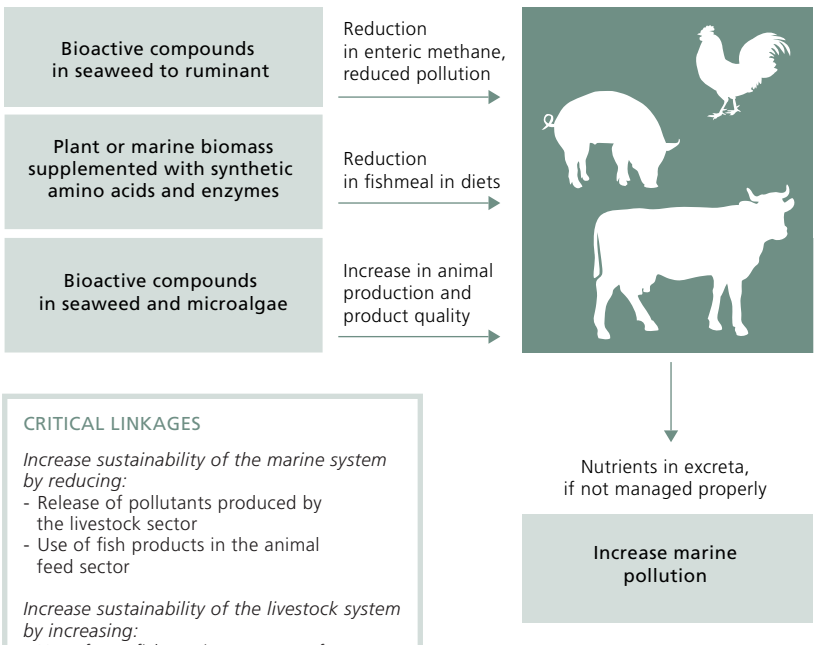
Integrated fish farming produces fish in combination with other agricultural/livestock operations such as cropping and animal husbandry. These systems interconnect in such a way that the by-products/wastes from one sub-system become valuable inputs for another. This optimizes a farm's utilization of land and water resources, maximizes and diversifies output, and minimizes financial and labour costs (Sasikala *et al.*, 2013). Such systems are more sustainable than isolated fish, crop or livestock systems. Farming fish in this way is expected to reduce pressure on ocean fisheries. Alternative feed and systems can do much to enhance the sustainable development and use of marine resources, and to make livestock production more sustainable too.

LIVESTOCK AND MARINE POLLUTION

Nutrient runoff and leaching from livestock waste has serious environmental consequences if not properly managed and can be detrimental to coastal marine fisheries (IAASTD, 2009). Leaching rates vary depending on climatic and soil conditions, which can differ significantly between countries or regions within a country (de Vries and de Boer, 2010). Best management practices to reduce coastal eutrophication must, therefore, be context-specific, taking land and land-use data into consideration. In regions with high livestock density, improving waste management (SDG 7) can be a cost-effective way of reducing river-based nitrogen loads, which often end up in marine systems and contribute to coastal eutrophication (Arheimer *et al.*, 2004).

The biggest task is applying and adapting existing technologies to local conditions in developing countries in order to reduce nutrient pollution and conserve marine resources. One way of doing so is to use the Integrated System of Phytodepuration (ISP) for agroindustrial wastewater. ISP performance was tested on various production systems and returned a mean efficiency value of well over 85 percent in removing Chemical Oxygen-Demanding (COD) substances from marine systems (Petroselli *et al.*, 2016). One of the plants used in ISP is *Phragmites australis*, or common reed, an invasive species from Europe. A significant drawback is that introduction of invasive alien species can pose a major threat to biodiversity (in the United States of America, *Phragmites* is costing the economy

39 MARINE ECOSYSTEM–LIVESTOCK NEXUS



Source: FAO, 2018.

more than USD 120 billion annually) (Pimentel *et al.*, 2005). *Phragmites* can however be controlled by adopting a simple, affordable countermeasure – livestock grazing. Experimental field tests have shown that rotational goat grazing (where goats are given no choice but to graze *Phragmites*) can reduce common reed cover by 80 percent, and that cows and horses also relish this plant (Silliman *et al.*, 2014).

Grazing by large domestic herbivores, such as cows, horses, sheep, and goats, is not only effective in suppressing dominant plants (Esselink *et al.*, 2000), but also has reciprocal positive effects for humans by generating valuable goods, including meat, milk, leather, and wool to support local economies. Employing both mitigation systems (*Phragmites* against COD in marine systems, and *Phragmite* as animal feed) while guarding against excessive spread of this species can help abate pollutants and at the same time increase livestock production, a win-win combination. Likewise, aquatic plants such as duckweed and azolla, which can also be used to reduce COD in polluted water, not only make good animal and fish feed but can serve as a feedstock for biofuel as well (FAO, 2012c, 2014; Muradov *et al.*, 2014; Makkar *et al.*, 2016).

More needs to be done, however, to reduce aquatic pollution, including, importantly, measures to prevent increasing nutrient runoff to water courses from livestock production. Producing feed requires large amounts of natural resources, but also great quantities of fertilizers, pesticides, weedkillers and other chemicals. (FAO, 2016g). If applied excessively and not managed properly, they run off into watercourses and water bodies, and eventually end up polluting seas and oceans. Increased efficiency in feed production, with a corresponding decrease in the use of chemicals and fertilizers, can therefore substantially mitigate damage to marine ecosystems.

Another problem with feed production is that it generates methane, which, together with enteric methane from animals, accounts for almost 85 percent of total methane from the livestock sector (Gerber *et al.*, 2013). Being a powerful greenhouse gas (GHG), methane contributes to global warming and increased ocean acidity, with dire effects on marine life. For further discussion of reducing pollutants from the livestock sector, readers are directed to the chapter on climate change and its impact. With its holistic approach, FAO's Blue Growth Initiative (FAO, 2016f) enhances collaboration among different production sectors, including fisheries and livestock, and aims for more effective coastal and watershed planning. Supporting the initiative will also help reduce the adverse impact of livestock on fisheries.

LIVESTOCK AND MARINE RESOURCES

Farming seaweed can make an important contribution to helping the fisheries and livestock sectors develop sustainably. Some seaweeds are good sources of protein and bioactive compounds, including prebiotics, for increasing production in a sustainable manner. Seaweed is also a source of various minerals that can be added to the feed of aquatic species and livestock, increasing their productivity and saving finite, land-based mineral resources (Makkar *et al.*, 2016). Algae for bio-oil production can be grown in seawater too. The oil can be processed into biofuel (helping promote SDG 7) while any algal residues can be reused as a source of protein in fish and livestock feeds, reducing fishmeal use, and with it, overexploitation of seas and oceans (Oilgae, 2016). So far, fish oil has been used the diets of farmed fish, especially salmon, to increase omega-3 fatty acids in fish muscle (considered beneficial to human health). Now, albeit slowly, fish oil is being replaced by oil from algae, algae-like microorganisms and plants rich in omega-3, which serve the same function (Lenihan-Geels *et al.*, 2013; Ji *et al.*, 2015). Moreover, feeding seaweed and macroalgal products to ruminants effectively reduces enteric methane emissions from rumen fermentation (Li *et al.*, 2016), mitigating environmental pollution (synergy with SDG 13) from cattle and other grazing animals. Finally, increased demand

for seaweed and/or oil for livestock feed could encourage the development of seaweed aquaculture industries in least-developed countries and small island developing states. Overexploitation of seaweed could however affect marine biodiversity (trade-off with SDG 15).

CONCLUSION

Goal 14 promotes the sustainable use of marine and coastal ecosystems. The world's ocean fish are seriously endangered. The main threat is overexploitation by fisheries, affecting the size and viability of wild fish populations, the genetics of target species, and their food webs and ecosystems. A significant, but declining, proportion of world fisheries production is processed into fishmeal (mainly for high-protein feed) and fish oil (as a feed additive in aquaculture, for human and livestock consumption, or as medicinal products). They can be obtained from whole fish, fish remains or other fish by-products. In 2012, about 35 percent of world fishmeal production originated from fish residues. More effective coastal/watershed planning and close collaboration between different sectors – livestock, feed production and aquaculture – would help increase the sustainability of both land- and marine-based food systems. However, technologies to translate them into large-scale applications are in a nascent stage.

15. Livestock and life on land

INTRODUCTION

SDG 15 is based on the axiom that healthy ecosystems protect the planet and sustain livelihoods. Terrestrial and inland freshwater ecosystems, especially forests, wetlands, mountains and drylands, make vital contributions to biodiversity and provide countless environmental goods and services. They contribute to decent livelihoods while at the same time providing clean air and water, conserving biodiversity and mitigating climate change. However, across the globe natural resources are deteriorating, ecosystems are under stress and biological diversity is being lost. The main reason for the loss of natural ecosystems is land-use change: for example, between 1990 and 2015, the world's forest area diminished from 31.7 percent of total land mass to 30.7 percent. The loss was mainly attributable to the conversion of forests to other land uses, such as agriculture and infrastructure (UN, 2016d).

Focusing largely on biodiversity and land use, SDG 15 aims to enhance the delivery of ecosystem services from all types of environments, with explicit targets on conserving ecosystems and genetic resources, restoring land, halting deforestation and combating desertification. SDG 15's focus on halting biodiversity loss comes at a critical time, since many species of amphibians, birds and mammals are heading towards extinction. The Millennium Ecosystem Assessment (2005) recognizes five main direct drivers of biodiversity loss: habitat change, climate change, pollution, overexploitation and invasive species. According to the Convention on Biological Diversity (CBD, 2014), 70 percent of the projected loss of terrestrial biodiversity is linked to agriculture. While loss of forest habitats in some regions, for example the Amazon, has significantly slowed, deforestation in many other tropical areas is still increasing, and habitats of all types, including grasslands, wetlands and river systems, continue to be fragmented and degraded. Unsustainable practices in agriculture, aquaculture and forestry are driving persisting environmental degradation and biodiversity loss (CBD, 2014).

Livestock production is ubiquitous, with up to 25 percent of the earth's land area covered by rangelands (rangelands include natural

grasslands, savannahs, shrublands, some desert lands, alpine terrains, marshes and meadows). Livestock populate about 70 percent of that area (Mottet *et al.*, 2017), while 33 percent of croplands are used for fodder production. In recent years, awareness and scrutiny has grown regarding the livestock sector's impact on biodiversity, land use and climate change. However, whether livestock benefits or damages the environment depends not only on the kind of production system used, but also on how it is used.

Despite their many synergies, natural ecosystems and agricultural production systems are often regarded as mutually exclusive. But this view not only overlooks the ecosystem services provided by livestock and other agricultural systems: it also fails to consider that agricultural biodiversity contributes to general biodiversity. Few appreciate that many "natural" ecosystems have co-evolved with farming and livestock (Biggane and McCracken, 1996; Benton *et al.*, 2002; FAO, 2014c; DeVries *et al.*, 2002). When considering the role of livestock in the management of terrestrial ecosystems, all environmental factors and trade-offs must be taken into account. One recent study in Uruguay, for example, concluded that intensive livestock systems do more environmental damage than extensive systems, but only after comparing them in terms of carbon balance, soil erosion and nutrients and energy use (Modernel *et al.*, 2012). Dikshit and Birthal (2013) quantified the beneficial contribution of livestock to mixed farming systems in India. In a 2014 study, FAO highlighted the interconnected nature of supporting, regulating and habitat ecosystems services.

This chapter provides evidence of both the positive and negative impacts from livestock on deforestation, desertification, land degradation, and ultimately biodiversity depending on how land is used and what kind of livestock system is implemented. It also describes how, beyond influencing biodiversity, livestock are in fact an integral part of biodiversity and provide valuable ecosystem services. The last section offers examples of synergies between land use, ecosystem services and biodiversity, followed by conclusions.

LIVESTOCK AND ECOSYSTEM SERVICES

SDG 15 is directly linked to the regulating and supporting ecosystem services provided by livestock through their direct interaction with land, vegetation, soil and habitat. Ecosystem services are defined by the Millennium Ecosystem Assessment as the benefits humans obtain from ecosystems. They include provisioning services such as food and nutrition, skins and fibre, water, and various raw materials; regulating services that buffer the impact of climate, disease and waste, and maintain water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, weed control and nutrient cycling. Other classifications separate habitat services from supporting services to emphasize the role of landscapes, including agricultural landscapes, in providing habitats for biodiversity and wildlife (FAO, 2014c).

Most regulating and supporting services arise from the direct interaction of animals with their environment, and are therefore related to land management practices, especially in grazing systems. Herbivores can, for example, influence competition between plant species and help determine the structure of the grass sward due to their selective grazing behaviour, nutrient redistribution (dung and manure), treading and seed distribution (Wrage *et al.*, 2011). Among the ecosystem services provided by livestock, FAO (2014c) highlighted their importance, as shown by the following list of key functions: waste recycling and weed control; biological control and animal/human disease regulation; maintenance of soil structure and fertility (nutrient cycling and distribution, organic matter, etc.); prevention of land degradation and erosion; climate regulation; management of water flow and quality; moderation of extreme events (shrub control and maintenance of fire breaks, prevention of landslides and avalanches);

pollination and seed dispersal; and habitat services (facilitating the life cycles of animals and plants, preventing succession to less-valuable ecological states through encroachment of undesirable species, and conserving wildlife and protected areas found in co-evolved landscapes).

The study (FAO, 2014c) reported that livestock grazing is frequently used in protected areas to improve ecosystem services delivery. It suggested that the goals of livestock production and nature conservation are not necessarily antagonistic. As an integral part of agroecosystems, livestock are, as noted, providers of ecosystem services; but as part of human activity they are also clearly consumers of services such as natural biomass production, water resources and soil structure and fertility. The balance between provision and consumption varies greatly, depending on the production system. Another type of trade-off often exists between the provisioning services and other categories: for instance, intensive systems tend to yield more food, at the expense of regulating and supporting services, when inputs of synthetic nutrients and pest control agents are increased. Regarding the cultural services provided by livestock, the FAO study suggests a positive relationship between cultural diversity, landscape heterogeneity and biodiversity.

LIVESTOCK AND BIODIVERSITY

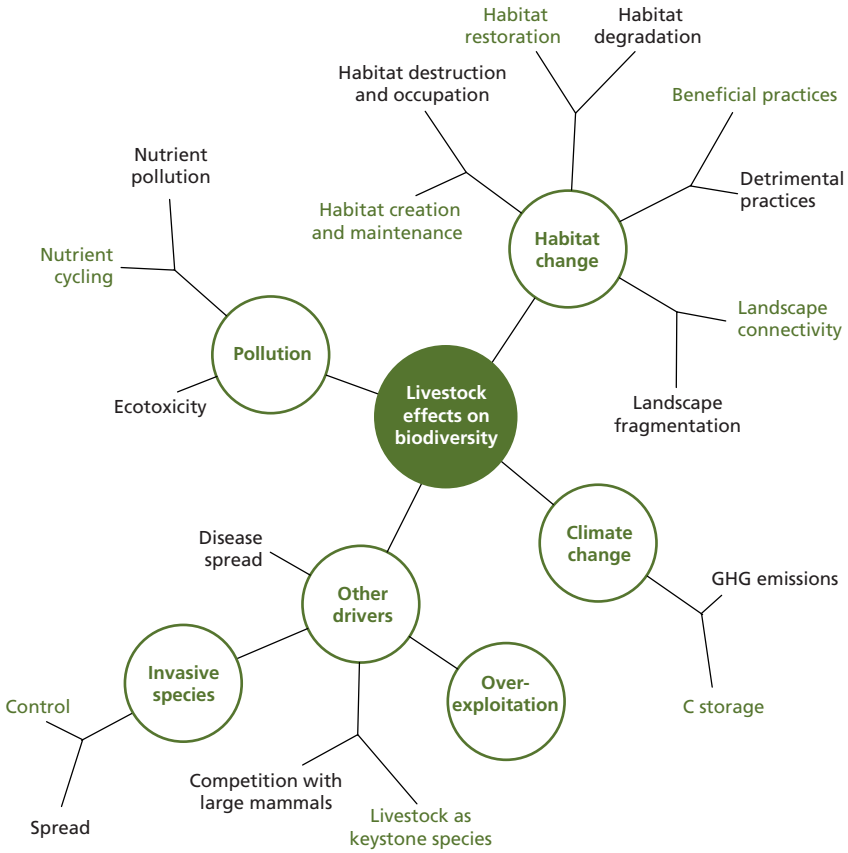
In 2014, the Secretariat of the Convention on Biological Diversity (SCBD) evaluated progress at mid-term towards meeting the objectives of the 2010–2020 Strategic Plan for Biodiversity. The SCBD's main finding was that, based on current socio-economic trends, pressure on ecosystems will continue to increase, with a consequent decline in biodiversity. The Secretariat therefore called for additional action to keep the Plan on course, noting the importance of restoring ecosystem services in agricultural landscapes. The livestock sector clearly has an important role to play here.

The complex relationship between livestock and biodiversity is shown in Figure 40. This chapter focuses on habitat change, while the aspect of livestock's contribution to climate is discussed in more detail under SDG 13, and livestock and pollution is addressed under various other SDGs. Livestock's impact on biodiversity, due to its intrinsic complexity and the lack of agreed metrics, has received less attention in environmental assessments of the livestock sector than other criteria, such as greenhouse gas emissions. Nevertheless, livestock have considerable effects (both positive and negative) on wild species and their habitats and it is therefore important to expand efforts to monitor their impact (FAO, 2016h).

Principles for the assessment of livestock impacts on biodiversity, the title of FAO's aforementioned study, illustrates the ways in which livestock influence wild biodiversity and shows that pressure and benefits are often two sides of the same coin. On the one hand, pristine habitats can be destroyed, as in the conversion of primary forest to pastures or feed crops (e.g. soybean) in the Brazilian Amazon (although it should be noted that livestock are not the only driver of deforestation (FAO, 2006b) and that reduction in forest cover has been diminishing significantly since 2004) (UN, 2016d). On the other hand, in some places with a long history of livestock grazing, a unique biodiversity has specifically adapted to habitats that host grazing animals. This may be related to herbivory being a factor shaping biodiversity in many ecosystems (Frank, 2005), with livestock, when under proper management, taking over the role of wild herbivores (Bond and Parr, 2010). A case study on plant diversity in traditional livestock systems in the Irish Aran Islands showed that moderately grazed areas are more species-rich than under- or overgrazed areas (FAO, 2016h).

Livestock pressure on biodiversity is not only exerted in terrestrial habitats. Aquatic biodiversity is also impacted since most of the water used by agriculture is linked to livestock production (Mekonnen and Hoekstra, 2012), and nutrient loading from fertilization or manure affects water quality (Sutton *et al.*, 2013). Lastly, livestock

40 PRINCIPLES FOR THE ASSESSMENT OF LIVESTOCK IMPACTS ON BIODIVERSITY



Source: Livestock Environmental Assessment and Performance (LEAP) Partnership. FAO, 2016h.

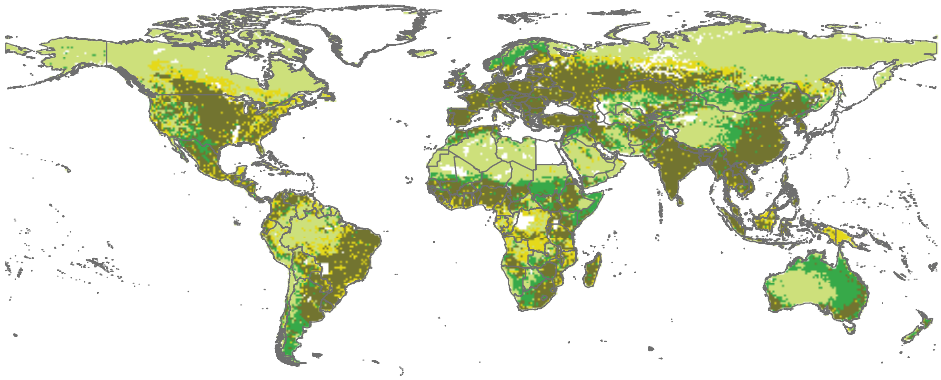
make a significant contribution to anthropogenic GHG emissions responsible for climate change – an increasingly important driver of biodiversity loss, second only to land-use change (Alkemade *et al.*, 2013; Leadley *et al.*, 2010).

LIVESTOCK AND LAND USE

This section provides a broad overview on how the livestock sector, as a major user of land resources, contributes not only to deforestation and desertification, but also to land restoration. Livestock have been one of the major drivers of global habitat change in recent decades. A recent study of deforestation drivers in seven South American countries (De Sy *et al.*, 2015) highlighted the relationship between deforestation and pasture expansion for cattle ranching. More than 70 percent of deforestation in those countries in 1990–2005 was driven by increased demand for pasture. More than 80 percent of deforestation in Brazil during that period was associated with conversion to pasture land.

Generally speaking, extensive production systems require more land to produce one unit of a product like milk or meat. However, livestock's impact is not restricted to the land area they use directly. Their indirect impact – via the land used to produce feed crops – is also a major factor affecting sustainable use of terrestrial ecosystems, with profound implications

41 GLOBAL GRASSLANDS SUITABLE AND UNSUITABLE FOR CROP PRODUCTION AND SHARE OF LAND USE



Source: Mottet *et al.*, 2017.

for forest management, desertification control and the fight against land degradation. Already, one-third of the world's cropland is being used to grow animal feed, and any additional conversion of other ecosystems, such as forests, to produce more fodder will clearly have major consequences on ecosystem services. And while a fully-housed, intensive livestock farm can minimize its environmental impact by adopting full nutrient capture and water and waste recycling, it is still likely to drive changes in ecosystem services on the land where its feed is sourced and produced.

It should be noted, however, that feeding ruminants in general requires less land than industrially-raised monogastrics. Industrial pig and chicken systems primarily use grains and processed agri-food by-products whereas in ruminant livestock systems globally, less than 5 percent of the total feed basket comes from crops (Mottet *et al.*, 2017). In ruminant livestock systems 89 percent of animal feed supply comes from fibrous feeds, including grass and crop residues, and 96 percent is inedible by humans (Mottet *et al.*, 2017). This has major implications for the long-running "food versus feed" debate (on whether humans are misusing natural plant resources by feeding them to livestock). Mottet *et al.* (2017) also go on show that 57 percent of the land used for feed production (including grass, crop residues and other forages) is not suitable for food production. The map in figure 41 gives an overview of grasslands suited and unsuited to crop production, revealing that, in huge areas of the world, rangeland-based livestock production systems are the only option. The message here is that there is less competition than is generally believed between land use for food crops and land for feed crops.

Land use for animal feed production can have a positive influence on the carbon balance, if the soil acts as a carbon sink instead of being a source of emissions (e.g. through deforestation). This is rarely the case in cropland, although conservation agriculture allows for better soil cover and thus promotes natural carbon capture.

TABLE 15

EXAMPLES OF POSITIVE AND NEGATIVE IMPACT OF PRACTICES RELATED TO LIVESTOCK MANAGEMENT ON BIODIVERSITY, PROVISIONING AND REGULATING ECOSYSTEM SERVICES, AND LAND RESTORATION

MANAGEMENT PRACTICE	BIODIVERSITY	PROVISIONING ECOSYSTEM SERVICES	REGULATING & SUPPORTING ECOSYSTEM SERVICES	LAND RESTORATION
Use of diverse, locally adapted breeds	++ Livestock diversity is an integral part of biodiversity	++ Livestock diversity promotes food security, decreases vulnerability to diseases & climatic variations ++ In low-input systems, locally adapted breeds often produce higher yields than breeds selected for high performance and are more resistant to diseases -- Lower yields under high-input systems than breeds selected for high performance under optimal conditions	++ Habitat provisioning, nutrient cycling and primary productivity	++ Breeds adapted to harsh environments provide services through trampling, grazing and browsing, as well as urine and dung + Transportation of seeds across landscapes through animals' coats and dung
Mixed crop–livestock production systems	++ Heterogeneous landscapes provide a diversity of habitats and resources -- Potential habitat conversion from grassland to cropland	++ Provision of both animal and vegetal food products, animal traction, fibre, skins and economic assets	++ Crop–livestock integration; recycling of crop residues, by-products and household wastes; nutrients from manure; pollination; integrated pest management	++ Contribute to maintaining vegetation cover
Improved grazing management by adapting grazing pressure spatially and in time (e.g. rotational grazing, mobility, etc.)	++ Livestock can be the only way to maintain biodiversity-rich grassland habitats in ecoregions where wild herbivores are no longer present ++ Moderately grazed pastures can have the highest plant diversity compared to abandoned or under-grazed pastures	++ Grazing improves grassland vegetation productivity and biomass ++ In most rangelands and mountains where soil and climate do not allow crops to grow, grazing is the only way to produce food for humans	++ Carbon sequestration, shrub encroachment control, bushfire control, erosion prevention, soil fertility, water quality	++ Light or rotational grazing can help restore degraded pastures (underused or overgrazed)
Improved manure management (e.g. storage, anaerobic digestion)	+ Limit nutrient runoff and impact on aquatic species (eutrophication and hypoxic conditions)	++ Provision of energy through anaerobic digestion for household use or electricity generation	++ Improved soil fertility and nutrient cycles	+ Contribute to land fertilization and restored vegetation biomass

(Cont.)

TABLE 15 (CONT.)

MANAGEMENT PRACTICE	BIODIVERSITY	PROVISIONING ECOSYSTEM SERVICES	REGULATING & SUPPORTING ECOSYSTEM SERVICES	LAND RESTORATION
Intensification through feed supplementation, improved animal health, animal genetics, fertility and herd management	+ Land spared through productivity gains – improved efficiency in natural resource use can spare natural habitats for biodiversity -- Loss of animal genetic diversity due to use of fewer, but more specialized breeds	++ Increased delivery of animal products ++ increased productivity	-- A trade-off is usually observed between high levels of productivity (provision of food) and the other categories of ecosystem services ++ reduced GHG emissions and contribution to climate change	- Higher stocking rates leading to overgrazing if grazing poorly managed
Silvopastoralism (association of grazing and trees)	++ Richer landscapes and species diversity ++ Silvopastoralism can act as a buffer and prevent deforestation	++ Increased productivity	+ Improved nutrient cycles + Carbon sequestration ++ Improved resilience to climate and economic shocks	++ Less erosion and resulting degradation
Shift from ruminants to monogastrics	++ land spared -- loss of biodiversity-rich grassland habitats maintained by ruminants due to land–use change -- abandonment of grazing in biodiversity-rich grassland habitats would naturally turn them into forests in the absence of maintenance by ruminants	++ Higher productivity per unit of land -- Loss of productive land: rangelands grazed by ruminants are unsuitable for feed crop production for monogastrics	-- Loss of regulating and supporting services associated with grasslands -- Loss of grassland and traditional agricultural landscapes ++ Possible services associated with the ecosystems replacing grasslands (e.g. forests) if properly managed	-- Shrub encroachment if not well-managed ++ Forest and landscape restoration if properly managed

Note: + = positive effect, ++ = strong positive effect, - = negative effect, -- = strong negative effect.

Permanent, well-managed grassland, however, has the highest potential to function as a carbon sink. Besides its vital role in the carbon cycle, the way the land is used can also have wide environmental impacts in terms of soil quality, water, microclimate, and vegetation (FAO, 2016g; Henderson *et al.*, 2015).

Lands that have poor potential for crop production, such as drylands, mountains or high-latitude areas, usually rely on grazing animals for many key ecosystem functions such as seed dispersal, nutrient cycling, preclusion of plant competition and mitigation of climate change impacts, in addition to associated provisioning services (FAO, 2013d; 2014). In these areas, abandonment of grazing can have grave consequences on biodiversity (see Case Studies 4, 6 and 11 described in FAO, 2016h).

However, the ability of many rangelands to provide ecosystem services benefiting humanity is threatened in many countries due to land degradation. The processes involved in the degradation

of rangelands are still poorly understood (FAO, 2016h). Nevertheless, in combination with pedoclimatic factors, livestock, through overgrazing (Asner *et al.*, 2004), can contribute to land damage in the absence of proper management (FAO, 2014c).

Improved management of the world's rangelands could in fact not only halt but also reverse degradation. It could, in addition, sequester 12–20 billion metrics tonnes of carbon over a 50-year period (assuming two-thirds of the historic loss can be re-sequestered) (Lal, 2003; Henderson *et al.*, 2015). Land-use and management strategies to sequester soil organic carbon include afforestation with suitable tree species, soil management on cropland for fodder production (such as applying manure or vegetative mulches), and pasture management on rangelands.

Pasture management practices vary by location and region but may include controlled grazing at an ecologically sustainable stocking rate, sowing legumes and other improved grazing species, prescribed burning, agroforestry, and erosion management (Abel and Blaikie, 1989; Schuman *et al.*, 2002). In addition to promoting carbon sequestration, these various strategies contribute to grassland restoration, improve nutrient cycling, and, to varying degrees, facilitate water infiltration as well as greater resilience to extreme weather conditions. Regarding the total amount of land used by livestock, Mottet *et al.* (2017) put the figure at 2.5 billion ha and conclude that even modest improvements in feed-use efficiency can reduce further expansion.

BUILDING SYNERGIES

Land use, deforestation, desertification, biodiversity and ecosystem services are all interlinked, but the relationship is not always straightforward. For example, whether increased biodiversity results in more ecosystem services depends largely on the specific type of service involved and on the specific biodiversity facet (CBD, 2014). While plant species richness might lead to higher vegetation biomass productivity in natural grasslands (Grace *et al.*, 2007), grassland improvement through fertilization does reduce biodiversity but can improve forage yields, livestock productivity and thus food supply.

The ability to produce strong synergies between the different components of SDG 15 is a key specificity of the livestock sector. Through improved grazing management in particular, livestock has the potential to deliver benefits at multiple levels: land restoration, animal genetic resource preservation, biodiversity conservation and ecosystem services provision. Striking a balance between under- and overgrazing is crucial for the healthy functioning of grassland ecosystems. Measures helping reverse land degradation include the adjustment of the timing, intensity and spatial distribution of grazing (e.g. rotation, fencing), nutrient management, and grassland productivity improvements such as light fertilization and legume introduction (IPCC, 2007; Soussana *et al.*, 2010).

The restoration of degraded rangelands makes it possible to sequester high quantities of carbon (FAO, 2009b, 2013b). Moreover, proper grazing management and land restoration also enhance other ecosystem services such as the maintenance of soil structure and fertility, and water retention. In addition, grazing is key for vegetation biomass productivity as it fosters regrowth, removes dead material and helps prevent fires. While under- and overgrazing can lead to desertification and shrub encroachment, and lower biodiversity levels, sound grazing management has a direct effect on vegetation species richness through improved fertility, selective control of dominant species and contribution to seed dispersal (FAO, 2016i).

Diverse and productive vegetation in grasslands also provides a high-quality habitat and resources for a wide range of species. Improved grazing management can also aim at maintaining biodiversity beyond grassland ecosystems. Specifically, different types of buffers can be used to help control deforestation (e.g. silvopastoralism acts as a buffer between pastures and forests) and to avoid nutrient and ecotoxic substances that damage biodiversity spilling over

into neighbouring natural terrestrial and aquatic habitats.

Most local breeds of ruminants are found in extensive grazing systems. Combining the use of locally adapted breeds with improved grazing management could be a win-win solution for animal genetic resources, biodiversity and ecosystem services. Agricultural biodiversity and well-adapted livestock are essential components in this respect, particularly in harsh environments where crop farming is difficult or impossible. Diverse livestock breeds adapted to different environments form an integral part of agrobiodiversity. However, the adaptation of specific species and breeds to particular environmental challenges needs to be better understood (FAO, 2015a). Synergies within SDG 15 could lead to other synergies and benefits across SDGs given, for example, that improved grazing management can also lead to higher productivity (SDG 2) and to climate change mitigation (SDG 13).

CONCLUSION

Goal 15 focuses on reducing degraded natural habitats and fighting biodiversity loss. Across the globe, natural resources are deteriorating, ecosystems are under stress and biological diversity is depleted. While the livestock sector plays a part in biodiversity reduction, land degradation and deforestation, it also provides invaluable services that protect, restore and promote sustainable use of terrestrial ecosystems, combat desertification, reverse land degradation and halt biodiversity erosion. It is, however, critical to put negative livestock contributions into geographic, socio-economic and animal husbandry systems context. In arid and semi-arid areas (e.g. the Sahel in Africa), livestock rearing can be a most efficient and viable option to valorize scarce natural resources. When livestock have detrimental effects, it is generally because of the way they are managed, usually for short-term gain, with no concern for sustainability. Livestock production can be instrumental in, for example, supporting sustainable rangeland management, preserving wildlife, and enhancing soil fertility and nutrient cycling. Promoting the services livestock provide on behalf of ecosystems, in combination with moderate improvements in feed-use efficiency, are key to achieving this goal.

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16. Livestock, peace and social stability

INTRODUCTION

Peaceful and safe communities provide a secure environment for sustainable livestock production, making animal protein more widely available for communities. It follows that the global and sustainable development of the livestock sector cannot be achieved without broad progress in good governance, which fosters security, justice and peace. Lack of sound governance tends to produce a spiral of social unrest followed by higher food prices, lessened food security and, in the worst cases, full-blown conflict and famine – and this in a sector already highly exposed to a variety of stresses, including climate change, natural disasters, and livestock diseases.

Poor governance and absence of law provide fertile ground for conflict over land use and management, which jeopardize the livelihoods of pastoralists who depend on readily available rangeland resources and grazing areas. Climatic changes and related resource loss further exacerbate their insecurity. Civil unrest and humanitarian crises take a harsh toll on the livestock sector as collective insecurity quickly translates into higher livestock mortality, lower productivity and reduced access to local and national markets. Ecosystems and biodiversity, which well-managed livestock help protect and preserve, are hit hard under such conditions too.

According to the United Nations, many countries still face protracted violence and armed conflict, and far too many people suffer under weak institutions and lack access to justice, information and other fundamental freedoms. There is much to be done to achieve SDG 16's vision of peaceful and inclusive societies based on human rights, the rule of law, and good governance and institutions. This chapter describes how the livestock sector can help communities and countries get there, emphasizing the interconnections and dynamics between governance, peace, livestock development, climate and ecosystems and social stability in rural and urban areas.

LIVESTOCK, CLIMATE AND SOCIAL STABILITY

In rural communities, social and economic well-being heavily depends on livestock production, which employs almost 1.3 billion rural people globally. Any threat to livestock resources such as droughts, natural disasters, or animal diseases, can seriously affect the economic and social balance of local communities mainly in rural areas. It is well established that increased competition for scarce resources is often followed by strife. With advancing climate change, extreme weather events such as floods, droughts and hurricanes are increasing in frequency and intensity. One of the sectors most exposed to natural disasters is that of free-grazing livestock, which are central to the livelihoods of the poor mainly because that is where they keep their savings. When animals start to die off in a prolonged drought, it may spell the end for their owners too. With their savings gone and no money to pay for food, pastoralist families – who account for two out of three rural households in developing countries – face hunger and then starvation. Drought, it will be recalled, triggered the famine that devastated the Federal Republic of Somalia in 2011 and set the scene for the continuing civil war in the Syrian Arab Republic.

Emergencies caused by climate change variability and natural disasters can cause massive social disruption, with sudden migration including the large-scale displacement of livestock farmers. By the end of the year 2015, 65.3 million individuals were displaced worldwide as a result of conflict, generalized violence, or human rights violations whose origins could often be traced to agricultural, livestock and food/economic crises. More than half (54 percent) of all refugees worldwide were from three countries: the Syrian Arab Republic (4.9 million), Afghanistan (2.7 million), and the Federal Republic of Somalia (1.1 million). The majority of the displaced people were livestock producers from rural areas.

Conversely, livestock can be seen as providing food and livelihood security for displaced people. Unlike land assets, livestock are mobile and can be transported along with populations on the move. Indeed, livestock represent one of the most valuable assets of displaced people and they go to great lengths to make sure they can take their animals with them. For example, donkeys are important for transport, and the milk and meat of small ruminants are a valued source of protein and micronutrients. Climate change, with higher temperatures and longer hot seasons, is also driving the spread of animal diseases in many areas. The relationship between livestock disease and social instability may appear indirect, but significant disease outbreaks have a major impact on security in a number of developing countries. (Lubroth *et al.*, 2017). Animal diseases, especially

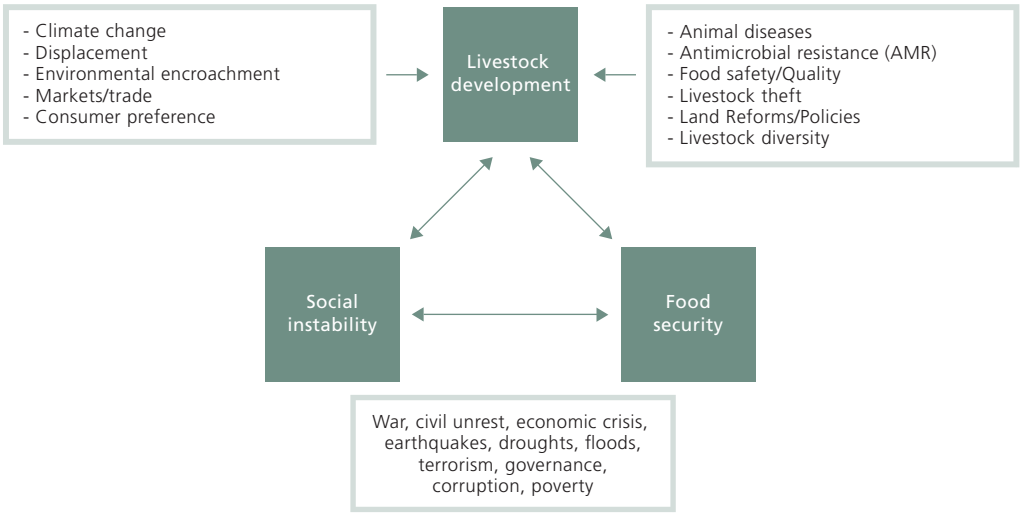
BOX 9

ANIMAL DISEASE VACCINATION CAMPAIGNS WITH PEACE-BUILDING COMPONENT

Vaccination campaigns are used as an entry point to bring together and promote dialogue among conflicting farming and pastoralist communities. All have a common interest in keeping their animals healthy. The fear of losing livestock to disease is seen as greater than that of conflict. While discussing the vaccination campaign, the groups also talk about issues of potential conflict and possible solutions. Such peace-building components were included in FAO livestock health programmes in South Sudan and the Central African Republic.

Source: FAO, 2017c

42 LIVESTOCK DEVELOPMENT, FOOD SECURITY AND SOCIAL INSTABILITY



Source: FAO, 2018.

zoonoses, which make people sick too, can trigger full-blown food and economic crises – with violence a short step away.

Rinderpest, the highly lethal livestock disease, caused food insecurity and social instability in large areas of Africa for two decades during the 1970s and 1980s. In the past two decades, Peste des Petits Ruminants (PPR) has spread rapidly, mostly in Africa, Asia and the Middle East, which are home to some 80 percent of the world's 2.1 billion small ruminants. Sheep and goats are critical assets for poor rural households, providing protein, milk, fertilizer, wool and fibre, as well as often representing essential social capital and access to financial credit. PPR causes more than USD 2 billion in losses each year. Beyond the economic loss, sick animals add to the food insecurity and nutritional challenges faced by the more than 300 million vulnerable households who raise sheep and goats in the regions affected by PPR. Ensuring animal health is a key element in maintaining food security among vulnerable populations. It has been found, for instance, that healthy goats produce 60 percent more meat and milk than unhealthy ones.

Animal diseases, including zoonoses involving humans, can spread quickly and, if not dealt with immediately, can develop into major social and economic regional or global crises, seriously affecting animal and human health, and food security. Examples of such high-impact epidemics are H5N1 Highly Pathogenic avian influenza in Asia and Africa; Ebola in West Africa; Lumpy skin disease in the Middle East and Europe; Rift valley fever in West and Eastern Africa; and PPR in Africa and Central Asia. Animal health programmes can include peacebuilding components that promote dialogue between groups.

Unless resolved promptly, animal diseases can lead to escalating social instability or precipitate major regional or global crises, with serious effects on animal and human health, the economy and food security. There is evidence that poor and politically marginalized communities, especially in rural areas, are disproportionately affected by recurrent animal health

BOX 10

LIVESTOCK, PASTORALISTS AND PEACE

Cross-border pastoralist communities including the Turkana and Pokot in Kenya, the Toposa in Sudan and the Karamajong in Uganda have been involved in many intertribal conflicts over the years. The conflicts erupted because of growing competition over scarce resources, and social, economic and political marginalization stemming from unfavourable government policies. This was compounded by several consecutive years of drought in the region, leading to widespread reduced livelihoods. The conflict was marked by cattle raiding, banditry and growing violence fuelled in part by the proliferation of small arms. Several measures have been taken to resolve these conflicts, including setting up community institutions for resource management and conflict mediation, and many disarmament campaigns. Young people and women were enlisted for conflict resolution through youth peace caravans and women's peace crusades respectively.

FAO has been strengthening the capacity of pastoral communities most vulnerable to drought by setting up Pastoralist Field Schools (PFS) as a way to not only help reduce and prevent inter-community conflicts, but also to promote a learning environment where community members exchange information, best practices, and learn about grassroots ways of coping with drought risks and related challenges (FAO, 2016j). Livestock corridors with water points are being introduced in areas of Africa and, with the support of farmer field schools, can help reduce conflicts between agriculture farmers and pastoralists over scarce land and water resources.

emergencies. Trust and confidence in government and institutions, and robust institutions and infrastructure quickly breakdown at times of civil unrest.

LIVESTOCK AND LAND

Land rights issues can also be potentially explosive in marginalized communities, especially in wide swathes of Africa where pastoralists are entirely dependent on rangeland resources and grazing areas for their livestock. Land conflict resolution, involving complex issues of land tenure and rights, and access to water, is key to averting conflicts. In the Democratic Republic of the Congo, for example, land disputes represent 80 percent of all conflicts in the violence-riven eastern part of the country, with most clashes involving livestock farmers and pastoralists. Farmer–herder conflicts are on the rise across the Sahel due to growing populations of both animals and pastoralists.

Changes in land use from rural to urban can create major problems for livestock farmers. Urban pressure can influence the development of the livestock farming sector in urban areas and can encourage a more efficient use of livestock (reduced herd sizes), and are more productive, maintaining close contact with markets. This can facilitate social integration and closer contact with stakeholders along value chains as well as consumers, while also promoting employment in other urban sectors. Much depends on appropriate land-use planning and on policies being in place to facilitate the integration and adaptation of livestock farming in urban settings. Urban livestock offer a number of benefits, supporting the social resilience of local communities, providing communities with fresh products, especially in times of crisis, and linking urban dwellers with nature.

Together with natural disasters and land rights, resource scarcity and chronic inequality have

been identified as determinants of conflicts in rural areas (Pica-Ciamarra *et al.*, 2007). During a protracted humanitarian crisis, and in particular during the post-crisis recovery phase, the agriculture/ livestock sector has a key role to play in rebuilding social and economic networks, including livestock value chains, market access, and food systems, and in restoring the supply of animal protein. Resolution of land rights issues in post-conflict situations, where local populations often have to cope with an influx of large numbers of refugees, is key to maintaining peace on a sustainable, long-term basis.

LIVESTOCK AND PEACE

Livestock development contributes to peace by providing economic and therefore socio-cultural stability to communities in rural areas, and also by facilitating ecosystem balance, economic development and reducing displacement. It can thus be considered a mitigating factor for conflicts and displacement. The Global Hunger Index 2016, published by the International Food Policy Research Institute (IFPRI), notes that the countries with the highest levels of food insecurity are also those most affected by conflicts. Conflicts are known to chiefly affect rural areas, and particularly women and children.

Attacks on farming communities and the destruction of crops, livestock and markets undermine rural livelihoods and displace people from their homes (FAO, 2016j), especially during civil conflicts, which have tripled in recent years. As a result, conflicts are major drivers of food insecurity and malnutrition, both acute and chronic: countries enduring conflicts or protracted crises have almost three times as many undernourished people as other developing countries. In February 2017, the United Nations formally declared a state of famine in parts of South Sudan, where war and economic collapse had left some 100 000 people starving and a further one million on the brink of famine. Also at risk of famine were the Federal Republic of Somalia, Yemen and parts of northeast Nigeria – all conflict areas.

Globally, 108 million people in 2016 were reported to be facing crisis-level food insecurity or worse. This represented a 35 percent increase compared to 2015, when the figure was almost 80 million. In 2016, prior to the official famine declaration, FAO reported that the ongoing conflict in South Sudan particularly affected cattle, sheep, and goats, which underpin the local economy since 80 percent of the population depend on livestock for a living. It is estimated that the sector has lost some USD 2 billion in potential GDP due to the hostilities, with losses exacerbated by widespread theft and the disruption of veterinary and extension services. Symptomatic of a lack of security and government authority, theft is a major threat to livestock assets worldwide but is a particular problem in conflict situations.

The link between livestock, food security, hunger, poverty, social instability, crisis and conflict is clear, as is livestock's role in maintaining peace, social and economic stability and a nutritious supply of food. Livestock are a key asset for survival in conflicts or war. A prosperous livestock sector can, with the right policies, promote economic development and food security in communities where proper diets maintain people healthy and guarantee the availability of labour. But livestock also contribute to building social capital by providing inclusion, relationships of trust, and empowerment to members of communities. Importantly, farm animals contribute to natural capital, as a source of soil nutrients, genetic resources, biodiversity and ecosystem services – all essential services in maintaining decent livelihoods. Peace begins on the farm, for a solid agricultural and livestock sector provides the basic guarantees of social stability and an assured food supply.

LIVESTOCK AND GOVERNANCE

Promoting a safe, natural and social environment for livestock development and reducing competition for natural resources (by making more resources available and accessible) contribute to social stability and peace in rural areas. Doing so requires good governance based on responsive, accountable and capable local, regional and

national institutions. Conversely, lack of governance and strong institutional arrangements, corruption, and non-delivery of services for the livestock sector are all potential sources of conflict; they also continue to exact a high toll on livelihoods once conflict has broken out. An important conflict mitigation strategy is to improve the governance of commonly accessed and managed resources by reviving and strengthening customary institutions. The role of community elders is crucial in mitigation, and several organizations have set up councils of elders to promote peace. Collaboration between such community institutions and public officials is key to sustaining peace.

While lack of good governance, infrastructure and regulations leads to a decline in societies, livestock are a major component of the economy even in countries affected by instability or crisis, accounting for more than 40 percent of agricultural GDP. In other words, in these and other conflict-torn nations, animal production provides some remaining measure of social and economic security by offering access to food to residents in towns and villages, and ensuring that the population balance remains sustainable between rural and urban areas.

Despite six years of crisis in the Syrian Arab Republic, for example, the agriculture sector still accounts for an estimated 26 percent of GDP and provides a critical safety net for the 6.7 million Syrians, including those internally displaced, who remain in rural areas (FAO, 2017d). In this context, livestock played a major role in the Syrian economy before the crisis, contributing 40 percent of total agricultural production and absorbing 20 percent of rural employment, while generating approximately USD 450 million per annum in exports. The Syrian Arab Republic has, however, seen its herds and flocks shrink significantly since the beginning of the war. Today, there are 30 percent fewer cattle, 40 percent fewer sheep and goats, and a staggering 60 percent less poultry – traditionally the most affordable source of animal protein in the country. Exports have been dramatically reduced.

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Between 2012 and 2013 only USD 4.1 million in meat products and USD 13.8 million in milk products were exported (FAO STAT, 2016).

Damage to the Syrian livestock sector is estimated at some USD 5.5 billion in the past six years. The loss of animals, which either die from extreme hardship and animal diseases, or are killed or stolen, is particularly high in conflict areas (FAO, 2017d). How the absence of government authority inevitably translates into strife is exemplified in the eastern part of the Democratic Republic of the Congo, where land disputes represent 80 percent of all the conflicts waged there in the past two decades (FAO, 2016j). However, with the re-establishment of proper governance, the solution to land issues is relatively simple – to plan land use in a way that reflects the views of livestock herders and to establish joint land-use agreements that recognize and protect group land rights and prevent conflict over resources. The main contesting parties – for example, land administration and customary authorities, farmers, private actors and armed groups – are invited to help identify underlying causes around natural resource access using a Participatory Negoti-

ated Territorial Development (PNTD) approach (FAO, 2016j). Rural areas with those arrangements and agreements can be used as models to promote agriculture and livestock development and sustainability.

Improved governance of livestock and animal health systems is an effective way to attract private and public investments in livestock development, thus providing an additional defence against insecurity and instability. There is now a clearer understanding of the benefits, not only to countries in crisis but to the international community at large, of applying livestock policies and programmes at national level that promote and safeguard sustainable livestock production, and, along with it, public health and food safety. Improving land and property rights and food security, and reducing inequality through the livestock sector is a firm basis for economic and social development. Support to agriculture and livestock-based livelihoods can effectively contribute to peacebuilding and post-conflict recovery and rehabilitation in rural crisis areas. People stay in rural areas when they feel safe to do so, or when the right conditions are created for the return of refugees, migrants and displaced people. Rehabilitation of agricultural production, particularly in livestock communities, and strengthening household food security is clearly a priority objective in post-conflict development in order to enable populations to live in peace once more under functioning institutions. (FAO, 2016j).

CONCLUSION

Goal 16 envisages peaceful and inclusive societies. A stable and peaceful environment is the basis for sustainable development. In many communities in developing countries, social and economic well-being is closely linked to the livestock sector. During crises, and particularly in post-crisis situations, livestock are essential in order to restore the supply of animal protein. In terms of public health, animal disease outbreaks can spread quickly and evolve into major health, social and economic crises at regional or global level. Disputes among populations over land and pastures can be sources of conflict, since grazing land is a valuable commodity that is increasingly coming under pressure. Mechanisms such as well-defined property rights, clear legislation, sound livestock policies, confidence in local institutions, and robust infrastructure can enhance the sector's role as a catalyst for social peace and stability.

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17. Partnerships in support of SDG implementation

INTRODUCTION

The adoption of the Sustainable Development Goals (SDGs) marks a turning point in the global community's approach to development. The SDGs embrace economic, social and environmental aspects of development and highlight the importance of the linkages between them. SDG 17 calls for multi-stakeholder partnerships between various actors to help provide financial, knowledge sharing and institutional support to spur progress across different sectors. By working together in partnership, all stakeholders can help achieve transformative change.

Strong commitment to global partnership and cooperation is central to the implementation and achievement of Goal 17. Key stakeholders are needed to ensure access to finance and investments, markets, technology, knowledge sharing and capacity development as well as policy support for better decision-making. Leveraging partnerships to identify different areas of development that are closely interconnected is imperative.

The breadth of knowledge, experience and expertise required for SDG implementation also implies mobilizing a broad range of competences and the participation of non-state actors, such as civil society organizations, producer organizations, the private sector, academia and research institutions. This will be fundamental to the achievement of all SDGs along the three dimensions of sustainable development – economic, social and environmental. This chapter therefore focuses on the challenges associated with strengthening the livestock sector in the context of a collective, coordinated effort including an unprecedented range of public and private actors in both policy formulation and implementation.

As a major user of natural resources such as feed, land and water, the livestock sector must, in order to develop sustainably, make itself environmentally sound, socially responsible and economically viable. This will require the deployment of multi-stakeholder actions aimed at building stronger knowledge-based policies and

also involve the sharing of knowledge (including local knowledge), technology and expertise, and financial resources.

THE NEED FOR A HOLISTIC APPROACH

Following the 2002 Monterrey and the 2015 Addis Ababa Conferences on financing for development, it was broadly agreed that Overseas Development Assistance (ODA) from traditional bilateral and multilateral donors is not sufficient to tackle the social, environmental and economic development challenges facing the world – and the developing world in particular. There is now broad consensus in the United Nations and Member States that financing development through multiple sources and establishing partnerships with non-state actors are both essential in order to achieve the SDGs. All stakeholders are urged to continue learning, innovating, transforming, and sharing knowledge as they work together, pooling financial resources, experiences and expertise.

In other words, a holistic approach is needed to ensure that the livestock sector develops sustainably and contributes effectively to eradicating hunger, malnutrition and rural poverty. Mobilizing the technical, human and financial resources to that end will require North-South, South-South and Triangular Cooperation (TC) to provide improved access to science, technology and innovation. Knowledge sharing, capacity-building and the strengthening of technical expertise are also central pillars, as is the promotion of a universal, rules-based, non-discriminatory and equitable multilateral trading system.

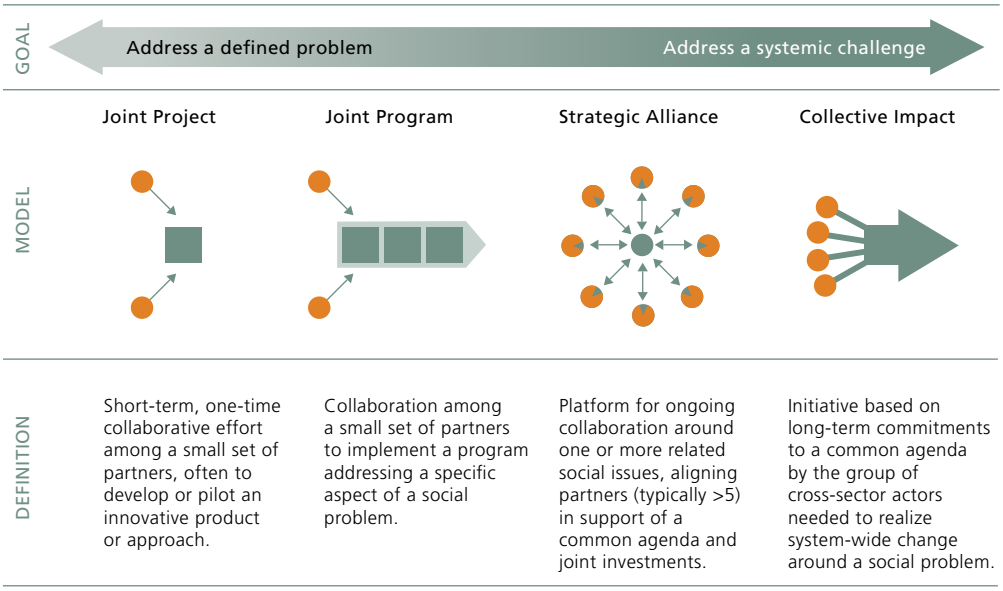
Provisions should also be made for adequate institutional support. While respecting each country's autonomy in responding to local challenges, partnerships among different key actors can address global and regional challenges and contribute to better policy coordination and coherence at local level. The livestock sector's central role is underlined by the High-Level Panel of Experts (HLPE) of the Committee on World Food Security (CFS) in its 2016 report, *Sustainable agricultural development of food security and nutrition: what roles for livestock?* The report indicates that livestock, as part of the sustainable development of agriculture, are essential for poverty reduction and achieving food security and nutrition.

LEVERAGING INSTRUMENTS FOR SDG IMPLEMENTATION

As mentioned, with multidimensional and interconnected global goals and an increasingly diverse range of actors at all levels, the 2030 Agenda emphasizes that the "means of implementation" of the proposed global partnership go beyond finance and relate both to systemic issues and context-specific measures. While the Monterrey Consensus focused on domestic resources and private-sector flows, as well as financial and technical cooperation as engines of development, the Addis Ababa Action Agenda (AAAA) envisages a wider range of levers including science, technology, trade, innovation and capacity-building. With the SDGs, all countries and actors are called on to undertake sustainable public and private measures that impact other countries and the global commons – notably global corporate and civil society networks.

As noted, many of the AAAA action areas are reflected in SDG 17, e.g. the emphasis on South-South (SSC) and Triangular Cooperation (TC), as well as Public-Private Partnerships (PPPs). There is a growing international consensus that SSC and TC are effective in achieving food security, catalysing agricultural development and reducing poverty. Good practices and solutions are often to be found in policies, institutions and programmes in the South, and can be replicated. For instance, some producer organizations and small and medium enterprises have recently helped small producers to raise productivity, access funding and markets and increase their incomes. FAO plays an active role as a facilitator of SSC initiatives in the context of the 2030 Agenda. Leveraging SSC/triangular

43 A BASIC TYPOLOGY OF MULTI-STAKEHOLDER PARTNERSHIPS



Source: Adapted from Hazlewood, 2015.

cooperation for the deployment of expertise helps disseminate development solutions, technologies, capacities, and best practices while also providing hands-on training, including in the livestock sector.

The 2030 Agenda also highlights the role of the private sector in development cooperation, particularly as regards ending hunger and malnutrition. Goal 17 recognizes the private sector as a critical stakeholder and PPPs as key instruments in promoting economic development and improved livelihoods. Some of the leading global commitments for the mobilization of the private sector are the Busan Partnership for Effective Development Cooperation (2011) and the AAAA. Both emphasize the need for more active engagement and contributions from the corporate sector. They also stress the importance of identifying the complementary roles that the corporate sector can play. It should be mentioned, however, that the private sector's engagement comes with risks as well as opportunities because it affects the way development has been delivered so far. This may also apply to PPPs, although they have the advantage of directing much-needed resources to the public sector, while also allowing governments to share the risks associated with investing in agriculture.

Public-Private Partnerships have the potential to improve agricultural productivity and drive sustainable growth in the sector.[4] As the 2030 Agenda urges all stakeholders to continue to learn, innovate, transform, and share knowledge when working together, FAO supports countries in implementing inclusive and cross-cutting policies. The Organization is well placed to foster coherence across a number of issues and areas, including the livestock sector, and encourages bottom-up decision-making based on countries' needs and experiences.

[4] Examples of agri-PPP successes can be found in FAO's Review of international experiences of agri-PPP (2016). The publication includes 70 case studies from 15 developing countries, drawing appropriate lessons and providing advice on the establishment and operational aspects of PPPs to ensure maximum impact.

Multi-stakeholder Processes (MSPs) aim at building a consensus on sustainable solutions and catalyse change through dialogue, consultation and joint analysis. These processes draw on the forces of various public and private stakeholders as well as research and academic institutions, international agencies, non-governmental organizations (NGOs) and civil society. Although the need for global multi-stakeholder partnerships to scale up the impact of public-private initiatives is recognized, more understanding is required concerning the legitimacy, effectiveness and development impact of joint actions.

In a discussion of the issue, Hazlewood (2015) provides a basic typology of multi-stakeholder partnerships where actors from governments, civil society and business as well as United Nations organizations are leveraging not only financial resources but their knowledge assets, in-kind to co-create specific solutions. For instance, scalability of MSPs requires a more integrated and comprehensive approach than a single sector with cross-sector expertise, where the roles of actors as well as their knowledge are of significant importance to SDG implementation. Therefore, the establishment of a governance structure tailor-made to the partnership's purpose and the representativeness of its stakeholders are basic prerequisites. The operational aspects regarding the traceability of the defined actions and the accountability of impact are also indispensable components of a well-functioning governance structure.

The fast-changing livestock sector is central to food systems development and has profound effects on the environment, land use and feed crop production. Livestock production is therefore to be considered in the context of a wide range of farming systems and their distinct challenges. The HLPE's recommendations are worth mentioning in this connection. They identify the need for a conceptual framework and a typology of livestock farming systems in order to establish the pathways and responses to address their sustainable challenges and provide a set of action-oriented recommendations.

FAO hosts, is engaged in and/or convenes a number of these kind of partnerships, which contribute to specific thematic areas and challenges of sustainable development. FAO's work on partnerships is founded on a basic principle: the need for coordinated and effective support to governments in addressing the challenges and opportunities that can advance decisions, commitments and cooperation by different actors in sustainable nutrition, food security and inclusive agricultural growth. As detailed in the SDG implementation, partnerships with the private sector clearly have a role in SDG implementation. The FAO Strategy for partnerships with the private sector (FAO, 2013e). supports country priorities by mobilizing contributions and support from the private sector. The Strategy foresees the role of private actors not only as a source of financial contributions but also to actively promote development. FAO is concerned, however, that the participation of the private sector should be in keeping with responsible investment practices, sustainable trade and innovative and inclusive business models.

In actively promoting partnerships with the private sector, one of FAO's basic tenets is that private stakeholders should conduct responsible investments in agriculture and food systems[5] (RAI principles) in order to contribute to food security and nutrition. These principles apply to all types and sizes of agricultural investment including fisheries, forests and livestock. In addition, FAO also upholds international standards such as the OECD-FAO Guidance for Responsible Agricultural Supply Chains[6]. This comprises recommended standards, a framework for risk-based due diligence, a description of major risks and the measures to mitigate them, and a guide for engaging with indigenous peoples. FAO has also published a Technical Guide for Investors[7] which was developed in consultation with stakeholders to promote responsible investment in agriculture.

[5] http://www.fao.org/cfs/cfs-home/activities/rai/en/
[6] OECD-FAO Guidance for Responsible Agricultural Supply Chains
[7] Technical Guide for Investors

Every company along the value chain, large and small, has the potential to make a significant contribution towards shared and sustainable economic, social and environmental development. FAO, however, highlights the need to evolve from short-term, company-led, ad-hoc partnerships to transformative and systematic alliances ensuring long-term commitment. In this context, the private sector is required to move beyond purely Corporate Social Responsibility (CSR) and make changes in its core business strategies. Allowing a meaningful engagement of stakeholders from civil society in SDG implementation requires putting principles into practice. FAO's Strategy for partnerships with civil society organizations, (FAO, 2013f) such as producer organizations (MBOs), NGOs and social movements, facilitates the establishment of transparent and participatory processes at global, regional and national levels. The Strategy places due emphasis on the participation of civil society in the design and implementation of public policies and regulatory frameworks. Supporting and helping strengthen producer organizations, including the services they provide to their members, is key to ensuring they can contribute to priority thematic areas (e.g. international regulatory frameworks, climate change, and nutrition).

The adoption of the SDGs has created fresh opportunities to increase partnerships with academia and the research community. Through such partnerships, participants can access and promote the latest proven knowledge, tools and information for the enhanced delivery of programmes. They may also help raise awareness among students and teaching staff about the key role they have in contributing to sustainable food and agriculture production for the overall achievement of the 2030 Agenda. The success of the new development agenda through the 17 SDGs, will require policy coherence at all levels to ensure that all initiatives work to support inclusive development for poverty reduction and food security. In the livestock sector, FAO is well placed to foster coherence across areas through bottom-up decision-making based on country needs and experiences.

LIVESTOCK PARTNERSHIPS IN ACTION

The livestock sector benefits from a number of multi-stakeholder partnerships with recognized work at global and regional levels on sustainable livestock development.

GLOBAL AGENDA FOR SUSTAINABLE LIVESTOCK (GASL)

The Agenda addresses sustainable livestock and covers aspects related to livelihoods, economic and social impacts, public health, animal health and welfare, environmental impacts, land use and tenure as well as biodiversity. This global partnership depends on the active engagement of governments as well as NGOs, social movements and community-based organizations, the private sector, donors, academia and research institutions, and intergovernmental and multilateral organizations together with foundations. The Agenda fosters knowledge and coordination mechanisms through Focus Area Groups and Knowledge Networks. GASL has developed a 2016-2018 Action Plan on "Facilitating dialogue, generating evidence and adopting good practices in support of the UN 2030 Agenda for Sustainable Development".

LIVESTOCK ENVIRONMENTAL ASSESSMENT AND PERFORMANCE (LEAP) PARTNERSHIP

LEAP is a multi-stakeholder initiative committed to improving the environmental performance of livestock supply chains while ensuring their economic and social viability. In order to help shape evidence-based policies and business strategies, LEAP has developed a comprehensive guidance and a harmonized methodology for assessing the environmental performance of livestock supply chains. LEAP involves stakeholders across the livestock sector including private actors, governments, academia, and civil society.

GLOBAL PASTORALISTS KNOWLEDGE HUB

The objective of the hub is to fill knowledge gaps on pastoralism and bring attention to the

challenges faced by pastoral communities. It serves both as a repository of technical excellence on pastoralism and pastoral livelihoods, and as a neutral forum for exchange and alliance building among pastoralists and stakeholders. It involves research institutions, international organizations, CSOs, and regional organizations.

MULTI-STAKEHOLDER FEED SAFETY PARTNERSHIP

The partnership aims to improve the safety of feed, thus enhancing food safety, animal health and welfare, and food security. It involves intergovernmental organizations, governments, academia, farmers, producers, the private sector, and civil society.

TRIPARTITE PARTNERSHIP OF FAO, WORLD HEALTH ORGANIZATION (WHO), AND WORLD ORGANISATION FOR ANIMAL HEALTH (OIE)

The objective of the partnership between the three institutions sharing responsibilities and coordinating global health activities is to address health risks at the animal–human–ecosystems interface. Other partners include international actors, regional and national governments, NGOs, private sector, and academics.

GLOBAL ALLIANCE FOR LIVESTOCK VETERINARY MEDICINE (GALVMED)

GALVmed is a non-profit global alliance aiming to protect livestock and human lives and livelihoods by making livestock vaccines, diagnostics, and medicines accessible and affordable in developing countries. It involves agricultural NGOs, health and development agencies, pharmaceutical companies, investors and donors, transnational authorities, governments, regulatory authorities, civil society organizations, research institutes and universities.

LIVESTOCK GLOBAL ALLIANCE

The Livestock Global Alliance is a coalition of international organizations with a global mandate. Its overall objective is to ensure access to clear, science-based information enabling the public – from consumers to policymakers – to better understand the livestock sector and its global public-good dimension. It includes international organizations.

ONE HEALTH

One Health is a global network aimed at improving health and well-being through the prevention of risks and the mitigation of crises that originate at the interface between humans, animals and their environment. It embodies a holistic vision of the challenges that affect human and animal health, food security, poverty and the environment where diseases flourish. Many health problems stem from diseases circulating in animals, transmitted by food or carried by vectors.

DAIRY ASIA

Dairy Asia is a multi-stakeholder initiative in the Asian dairy sector aimed at jointly working towards the common vision of "a socially and environmentally responsible Asian Dairy Sector that enhances rural livelihoods, improves nutrition, and contributes to economic prosperity". It involves governments, national and regional dairy agencies, civil society, the private sector, research/academia, and producers.

PARTNERSHIP FOR LIVESTOCK DEVELOPMENT, POVERTY ALLEVIATION AND SUSTAINABLE ECONOMIC GROWTH IN AFRICA (ALIVE)

ALIVE seeks to ensure the African livestock sector features on the development agendas of national, regional and international policymakers. It emphasizes the sector's crucial impact in terms of poverty alleviation and sustainable economic growth, and its overall contribution to achieving SDGs. ALIVE supports actions in the livestock sector undertaken by the New Partnership for Africa's Development (NEPAD), notably through the Comprehensive Africa Agriculture Development Programme (CAADP). Its core functions are to improve decision-making; raise awareness and access to

knowledge; facilitate better policy-making; and support evidence-based advocacy for investment in livestock development. ALIVE develops policy notes, toolkits in related areas such as dairy production and drought management, and undertakes assessments of programmes. FAO provides technical assistance.

COMMISSION ON LIVESTOCK DEVELOPMENT FOR LATIN AMERICA AND THE CARIBBEAN (CODEGALAC)

CODEGALAC is the FAO technical advisory forum on sustainable livestock production for the Latin American and Caribbean Regional Conference. The Commission was established in 1986 by the FAO Council at the request of its Member States. The Commission brings together representatives from governments to exchange experiences in policies and programmes for sustainable livestock development. Its objective is to support the preparation of policy frameworks for the livestock sector as well as the design and formulation of technical cooperation programmes and strategies. Main topics of discussion involve regulatory and technical issues associated with animal health, sustainable livestock production, climate change, family livestock farming and the sector's development trends.

Many 'bilateral' partnerships between development agencies, civil society organizations, the private sector, academia and research institutions and UN agencies have activities directed at aligning

BOX 11

AN EXAMPLE OF BILATERAL PARTNERSHIPS

Texas A&M University and FAO committed to promoting quality in feed analysis laboratories worldwide to advance knowledge and the use of enabling technology in the livestock sector. Systems that ensure repeatable and defensible analytical results are critical to the safety and quality of regulated products. In the global marketplace, the integrity of sample testing is essential for fair trade and the protection of consumer health. To strengthen quality laboratory systems in developing countries, FAO, Texas A&M University, and the Office of the Texas State Chemist developed Laboratory Quality Systems, an online training (E-course) offered for both professional and graduate credit. The course has been offered since 2013, and it provides laboratory professionals with the breadth of knowledge needed to obtain laboratory data and results that are reliable, interpretable, repeatable, and defensible. Course topics include chain of custody, method development, information management, laboratory accreditation, and international laboratory standards. Improving quality control is critical for sustainable development of the livestock sector. Now celebrating its third year, the partnership offered a course in 2015 which benefited 25 participants from laboratories from 17 countries. This targeted capacity-building initiative is considered of great relevance and practical use as participants are immediately able to use the concepts and skills learned into the daily operations of their laboratories. The course's dual focus on laboratory quality systems knowledge and the practical skills needed to apply this knowledge is especially useful for laboratory personnel who are in the initial stage of developing a laboratory quality system or implementing an ISO system. This mechanism helps build capacity to generate quality data on the chemical constituents and nutritional value of feed and feed ingredients efficiently and at low cost. The FAO Regional Offices in Africa and Asia (respectively in Ghana and Bangkok) actively sponsor candidates from the regions.

methods and practices as well as enhancing knowledge and capacities. By combining integrated and results-driven approaches with various actors, these partnerships highlight the critical importance of targeted commitments to adequately resourced fields of expertise. One example is FAO's partnership with Texas A&M University.

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CHALLENGES

A significant role in SDG implementation is played by data acquisition, monitoring, accountability and capacity-building. Documenting progress and developing evidence-based analysis is also crucial for decision-makers to enhance the effectiveness of policies and ensure the success of the 2030 Agenda. There is a clear challenge in bringing the role of the private sector up to its full potential while ensuring that the interventions of private entities are in line with national priorities. The same applies to civil society organizations, which are key actors in the design and implementation of public policies and regulatory frameworks. A noteworthy challenge to the transformation needed for SDG implementation is the need to leverage knowledge from academia and the research community.

Below are some issues of key interest which may be taken into consideration when examining partnerships in the context of SDG implementation.

PPPs can be an innovative means to finding the increased financing and other "means of implementation" called for in Goal 17. Since large-scale investments are needed, PPPs can offer opportunities for the public and the private sectors to work together in the provision of public goods. New knowledge and technical innovation could be a mechanism for sharing risks. PPPs could bring together a broad range of actors from business, government, smallholder farmers and civil society who have the potential to improve productivity and drive inclusive, sustainable growth in food and agriculture.

Such multi-stakeholder partnerships support governments and other development partners in the design of good policies, programmes and legal frameworks. They can enable collective and coherent action in support of the livestock sector,

BOX 12

KEY ASPECTS TO CONSIDER WHEN EXAMINING PARTNERSHIPS

- Partnerships with private sector entities, civil society and producer organizations, academia and research institutions provide additional means for strengthening and enhancing the effectiveness of government strategies and policies.
- Partnerships with private sector entities need to address responsible investments, sustainable trade and innovative and inclusive business models. Local needs and transparency must be considered in selecting private partners when the allocation of land and/or the granting of land-use rights/concessions, or the use of natural resources and other assets, are at issue. When introducing new knowledge and technological innovations as well as when addressing policy coherence, the contribution of the private sector should include a transparent mechanism for sharing information and risks, and jointly responding to local challenges.
- Partnerships with civil society organizations contribute to the establishment of transparent and participatory processes at all levels, from local to national, especially concerning the design and implementation of public policies and regulatory frameworks. Supporting producer organizations is key to SDG implementation.
- Partnerships with academia and research bodies generate knowledge, and, most importantly, evidence-based analysis in support of decision-making. They can facilitate access to the latest available knowledge, tools and information for the enhanced delivery of programmes, and increase policy coherence. They also help raise awareness among students and teachers, thus contributing to a transformative agenda in SDG implementation.

as previously illustrated. The leveraging of instruments such as South-South cooperation and triangular cooperation can be strategic for sharing best practices, scaling up and replicating experiences. Addressing the specificity of local needs is essential for effective South-South cooperation. All available instruments, approaches and initiatives in support of SDG implementation face the challenge of acting in an integrated manner recognizing SDG interlinkages.

CONCLUSION

Goal 17 focuses on revitalizing partnerships and bringing together governments, the private sector and civil society to achieve universally sustainable development. At global and regional levels, the livestock sector features several multi-stakeholder partnerships that: a) serve to maintain sustainable growth to meet rising global demand for ASF; and b) simultaneously address key environmental, social and economic challenges. Despite the widely known benefits of multi-stakeholder partnerships, a major factor in their effectiveness is the establishment of governance structures appropriate to their mission and composition, and able to address any potential asymmetries of power and conflicts of interest.

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18. Livestock and SDGs: interactions and policy framework

INTRODUCTION

In January 2016, the United Nations officially launched the 2030 Agenda for Sustainable Development, with its 17 Sustainable Development Goals and 169 targets. The SDGs build on the success of the 2000–2015 Millennium Development Goals (MDGs) and aim to do even more to end poverty and hunger. They seek to address, in a sustainable manner, the root causes of poverty and the universal need for development. The SDGs cover the three dimensions of sustainable development: economic growth, social inclusion and environmental protection. Governments are expected to take ownership and establish national frameworks for their achievement. Implementation and success will depend on the commitment of individual nations to promote sustainable development policies together with inter-sectoral coordination mechanisms and focused plans and programmes.

Many daunting challenges remain. One in eight people live in extreme poverty; 795 million are undernourished; 1.3 billion tonnes of food are wasted every year; six million children die before their fifth birthday; some 200 million people are unemployed, including 75 million young women and men; three billion people rely on air-polluting wood, coal, charcoal or animal waste for cooking and heating; the earth's soils, freshwater, oceans, forests and biodiversity are being rapidly degraded; and climate change is placing growing pressure on vital resources, disrupting lives and national economies (UN, 2016a).

This is also a time of immense opportunities – including for livestock. The sector can play a key role in resolving many present challenges by: providing the world with adequate and reliable supplies of safe, healthy and nutritious food; creating employment opportunities upstream and downstream in the food chain; strengthening families' financial, physical, and

social assets; and generating fiscal revenue and foreign exchange. In order to fulfil its potential, the sector will have to face a new set of intersecting challenges. Increased demand for livestock products will, for example, add pressure on ecosystems, biodiversity and the environment; livestock producers will encounter greater competition for capital, labour, land, water and energy; intensified production could prompt the emergence and spread of infectious diseases and, with increased use of antibiotics, heighten the threat to global public health posed by antimicrobial-resistant pathogens.

A wide range of policy instruments are available to strengthen the positive effects or mitigate the negative outcomes of interventions. Nonetheless, the achievement of some of these targets could conflict with accomplishing others. Indeed, all parties concerned will likely soon realize that trade-offs and gains in one area may determine losses in others. To better support integration of livestock policies and practices with sustainable development strategies, this chapter synthetizes the key linkages involved, examines some interactions and suggests how livestock can actively help achieve sustainability goals.

Global trends indicate that between 2017 and 2030, world population will increase by one billion (UN, 2017). Most people – 60 percent of the world's population – will live in towns and cities (UN, 2014), while the global economy will grow at 2.8 percent per annum (OECD, 2012). The combination of population growth, urbanization and rising incomes is expected to increase global demand for animal-source food (ASF) (OECD and FAO, 2017). All this could result in an enhanced contribution to the SDGs by the livestock sector.

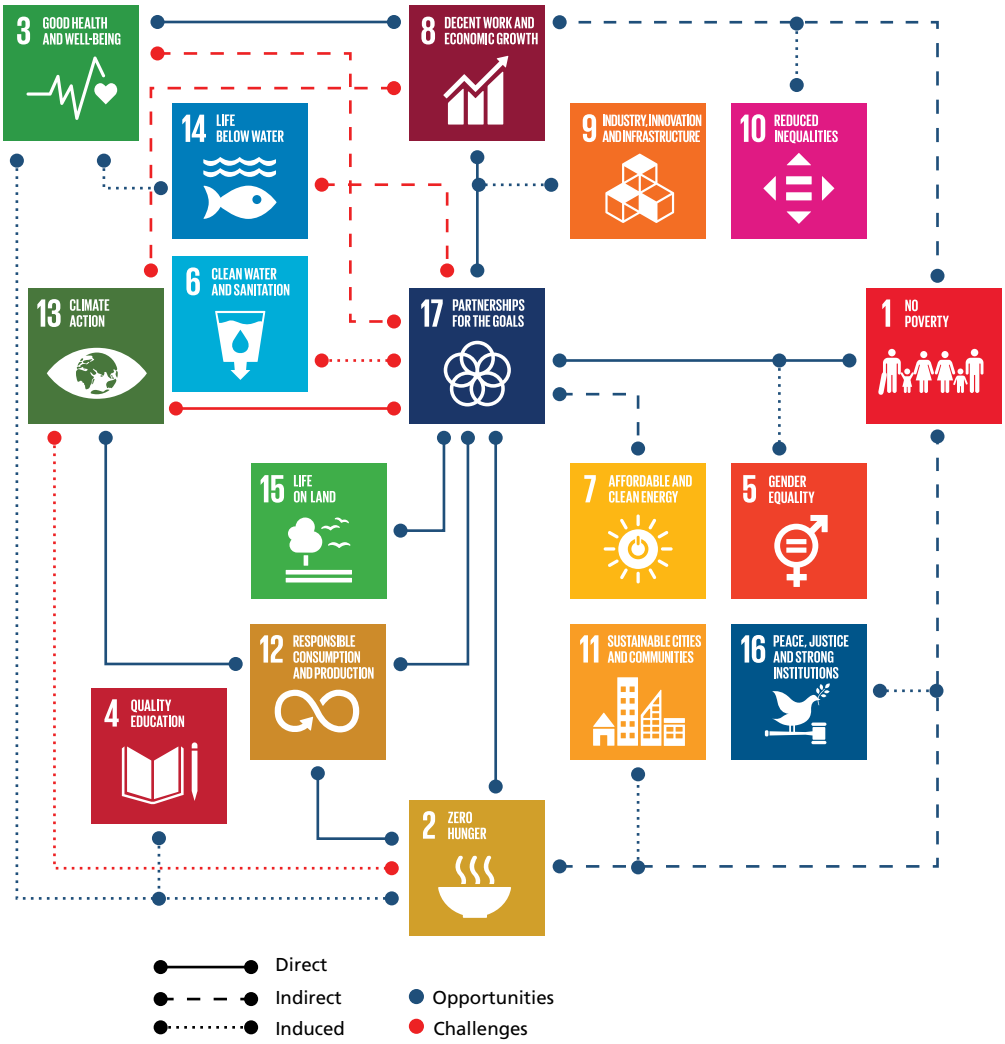
While livestock production relates directly or indirectly to each of the SDGs, linkages with some goals and targets are stronger than with others. These relationships are often defined by a two-way linkage in which, on the one hand, the development of the sector helps achieve some targets; while, on the other, the achievement of a target creates the right conditions for a more sustainable development of the sector (see Figure 44). This section reviews the key linkages between livestock and development, as reflected in the 2030 Agenda, and highlights some key policy messages.

KEY MESSAGES

Goal 1 calls for a multidimensional approach to ending poverty. Given the livestock sector's expected rapid growth, and the assumption that many of the poor rely on livestock for their livelihoods, livestock's contribution to poverty reduction has sometimes been taken for granted. Livestock can indeed play a catalytic role in strengthening the assets used by rural households to achieve their livelihood objectives, and in increasing the resilience of families to cope with shocks. However, the sector's capacity to turn fast sectoral growth into reduced poverty will vary depending on countries, production systems, and on a combination of macroeconomic and microeconomic factors. These include, on the macro side, the size of the livestock sector in the economy, its growth rate, and the participation of the poor in that growth. On the micro side, these include the capacity of producers to use their livestock-related assets to generate income, the ability of workers to link to expanding employment opportunities; and the possibility for consumers to benefit from more competitive prices.

Goal 2 seeks to end hunger and all forms of malnutrition. The livestock sector can contribute significantly at different levels and from different angles. At the household level, it can increase the direct consumption of ASFs and help generate income; at the rural community level, it can support the creation of employment opportunities; at the national economy level, it can reduce ASF prices, generate fiscal revenue, and earn foreign exchange; and at the global level, it can provide the world with sufficient and reliable supplies of meat, milk, eggs and dairy products. The sector must, however, overcome some new, interconnected

44 LIVESTOCK–SDGs INTERACTIONS COMPLEXITY



challenges. Increased demand for livestock products will add to existing pressure on ecosystems; livestock producers will face greater competition for resources so that, while productivity should increase, it will likely do so more slowly; and the ongoing transformation of the sector's market structure may hinder small producers and poor consumers from benefiting from economic growth and productivity improvements.

Goal 3 aims to ensure health and well-being for all at all ages. While the benefits provided by livestock are well-recognized, animals can, if not managed properly, transmit communicable and non-communicable human illnesses and diseases. Many microorganisms harboured by livestock are harmful to humans. Overconsumption of ASF leads to the spread of non-communicable human diseases. Inappropriate use of antimicrobials in

livestock production contributes to increased drug resistance in pathogens, often causing untreatable animal and human infections across the globe. Manure and other animal waste products widely contaminate soil and surface waters. Considering the magnitude of the linkages and the complexity of the relationship between human health, animal health, nutrition and the environment, multidisciplinary and interdisciplinary action is required. The "One Health" (One Health, 2018) concept and approach is considered central in designing and promoting policies, strategies and actions for the livestock sector to help keep people healthy and production efficient.

Goal 4 promotes inclusive and equitable quality education at all levels. Consumption of ASF improves children's cognitive and physical development as well as school attendance and performance. In addition, livestock provide income to poor households that can be used to pay for schooling. School feeding programmes that include ASF products can help provide proper nutrition to undernourished children. However, among traditional livestock-raising communities, sending children to school conflicts with child labour and pastoral lifestyles. Other issues are related to gaps in livestock research and development and to the fact that small-scale livestock producers are often challenged in obtaining agricultural training and advisory services, which limits their capacities to manage their livestock more efficiently. Participatory, hands-on approaches, such as Livestock Farmer Field Schools, can successfully develop livestock producers' critical analysis, decision-making and communication skills. Strengthening the nexus between livestock production, nutrition, education, and health requires inclusive inter-sectoral approaches tailored to the specific needs and demands of livestock producers.

Goal 5 seeks to empower women and girls to reach their full potential. Throughout the developing world, women and girls in rural areas are deeply involved in livestock production. However, women livestock farmers typically face greater challenges than men, including economic, social and institutional barriers. To enable women to meaningfully operate in, and benefit from, the livestock sector, policies and programmes should work to remove all obstacles and constraints in their way. In so doing, livestock could serve as a pathway out of poverty for millions of rural women and girls. Key areas for policy intervention include developing gender-responsive extension services and participatory training programmes for rural women; and providing them with improved access to land and productive assets, as well as to markets, credit and insurance.

Goal 6 concerns the quality and sustainability of water resources. Agriculture uses approximately 70 percent of the world's available freshwater, and roughly 30 percent of global agricultural water is used to produce livestock. Total water footprints vary greatly, depending on the animal farming system, but intensified animal production appears to go hand in hand with an increased water footprint. Thus, when selecting a farming system, careful consideration should be given not only to economic and productive aspects but to the water resources required and their sustainability. A holistic approach to water management should be adopted, leading to fully integrated wastewater management that pays close attention to antimicrobials and other residues, *inter alia*. Management strategies should be site-specific, and take account of social, cultural, environmental and economic conditions in the targeted areas, with water governance a key issue in decision-making.

Goal 7 encourages wider access to energy, and greater use of renewables. The livestock sector is increasingly contributing to the provision of clean, renewable energy by converting manure into biogas. Animal draught power is also used extensively in smallholder settings, and its increased use in the future can help achieve renewable energy targets. Livestock are further

able to exploit the reserves of energy contained in plant biomass that are not edible by humans. New institutions and technologies will be needed, however, to greatly expand manure-based biogas generation. The use of clean energy to substitute fossil fuels in feed production must also be increased.

Goal 8 promotes sustainable economic growth and full and productive employment. The value of livestock production accounts for almost 40 percent of agricultural output in developed countries and for 20 percent in developing ones. However, the contribution of livestock to overall economic growth through numerous vertical and horizontal multiplier effects goes well beyond simple production. In developing countries, the livestock sector is highly segmented and the level of labour productivity differs widely between processing and production, and also between commercial and subsistence farmers. Thus, simply multiplying the same kind of opportunities could just result in underemployment. Livestock economic growth models should therefore put special emphasis on increasing labour productivity and focus on high-value-added and labour-intensive activities.

Goal 9 focuses on infrastructure development, industrialization and innovation. Livestock offer some of the best opportunities for adding value, given the fact that ASF products exhibit higher levels of complexity than crops. Accordingly, they have greater potential to increase the value of exports, promote economic growth, and improve livelihoods. At the same time, however, the sector is characterized by rapid market concentration, largely due to major gaps in infrastructure, technology and innovation, which limit the field to a relatively few actors with higher investment capacity. Policies that encourage economically and environmentally sustainable industrialization, shifting more workers towards more productive and profitable activities, and integrating small-scale producers in the growth of value chains, are likely to yield higher social and economic returns. They can also attract further investments focusing on infrastructure development and innovation.

Goal 10 calls for reducing inequalities in income. Institutional reforms in the livestock sector can be very effective at stimulating smallholder entrepreneurship and closing inequality gaps. Livestock rearing is a potent catalyst for smallholder income growth, with relatively low investment, input, and labour costs. However, weak or discriminatory property rights remain an important constraint on the capacity of smallholders to expand sustainably. Enabling livestock to contribute effectively thus means going beyond policies and investments specific to the sector. It requires, among other things, spending on infrastructure to link lagging regions; improving access to services, including financial services for all; framing effective social protection programmes, including pension schemes; adopting migration policies that take into account the needs of people moving with their animals; and implementing free trade agreements for trade in livestock and livestock products from least-developed and developing countries.

Goal 11 aims to make cities sustainable. Today's urbanization represents one of the most rapid and profound shifts in the history of human settlements. Livestock production has a variable and controversial, but often essential role to play in and for cities, especially in developing countries. The main benefits of urban livestock production include the generation of income, the creation of jobs, and the delivery of improved food security and nutrition. Yet urban livestock also present significant risks since, in the absence of proper sanitation and infrastructure, they can pose environmental and public health hazards. In order to make cities more sustainable, specific measures to reduce such risks are required, including improved coordination between health, agriculture, municipal and en-

vironmental departments; farmer's education on the management of health and environmental risks; and dissemination of information about these hazards to inform legislation and urban planning.

Goal 12 aims to promote sustainable consumption and production. Livestock supply chains are resource-hungry – they use huge amounts of land, water, nutrients and energy, and contribute significantly to greenhouse gas (GHG) emissions. Unsustainable production and consumption not only contribute to inefficient use of resources, but also entail lost economic opportunities, environmental damage, health problems and poverty. There are many opportunities and existing technologies for increasing the sustainability of the livestock sector through gains in efficiency. Improvements in animal health, feeding, reproduction practices, manure and grazing management can contribute to closing the yield gaps that exists in all production systems and regions. Reducing waste and loss at all stages of the supply chains can spur significant progress. However, adapting and enforcing new technologies in local environments, and instituting supporting policies and infrastructure to encourage adoption, will be the greater challenge.

Goal 13 calls for urgent action to combat climate change and its impacts. The relationship between livestock and climate change works two ways. On the one hand, livestock make a significant contribution to climate change. In 2010, direct livestock greenhouse gas emissions amounted to 2.4 gigatonnes of CO_2 equivalent, about 21 percent of total emissions from agriculture, forestry and other land uses, and 5 percent of total anthropogenic GHG emissions. On the other hand, climate change affects livestock production, for example through the quality and availability of feed and forage, and the incidence and prevalence of animal diseases. A number of technical mitigation and adaptation options are available to improve natural resource-use

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efficiency. However, measures that go beyond the farm gate are also required, including institutional changes, disaster risk management, and social safety nets.

Goal 14 promotes the sustainable use of marine and coastal ecosystems. The world's ocean fish are seriously endangered. The main threat is overexploitation by fisheries, affecting the size and viability of wild fish populations, the genetics of target species, and their food webs and ecosystems. A significant, but declining, proportion of world fisheries production is processed into fishmeal (mainly for high-protein feed) and fish oil (as feed additives in aquaculture, for human and livestock consumption, or as a medicinal products). They can be obtained from whole fish, fish remains or other fish by-products. In 2012, about 35 percent of world fishmeal production was obtained from fish residues. More effective coastal/watershed planning and close collaboration between different sectors – livestock, feed production and aquaculture – would help increase the sustainability of both land- and marine-based food systems.

Goal 15 focuses on reducing degraded natural habitats and fighting biodiversity loss. Across the globe, natural resources are deteriorating, ecosystems are being stressed and biological di-

versity depleted. While the livestock sector plays a part in biodiversity reduction, land degradation and deforestation, it also provides invaluable services that protect, restore and promote the sustainable use of terrestrial ecosystems, combat desertification, reverse land degradation and halt biodiversity erosion. When livestock have detrimental effects, it is generally because of the way they are managed, usually for short-term gains, with no concern for sustainability. Livestock production can be instrumental in, for example, supporting sustainable rangeland management, preserving wildlife, and enhancing soil fertility and nutrient cycling. Promoting the services livestock provide on behalf of ecosystems, in combination with moderate improvements in feed-use efficiency, are key to achieving this goal.

Goal 16 envisages peaceful and inclusive societies. A stable and peaceful environment is the basis for sustainable development. In many communities in developing countries, social and economic well-being is closely linked to the livestock sector. During crises, and particularly in post-crisis situations, livestock are essential in order to restore the supply of animal protein. In terms of public health, animal disease outbreaks can spread quickly and evolve into major health, social and economic crises at regional or global level. Furthermore, disputes among populations over lands and pastures can be sources of conflict, since grazing land is a valuable commodity that is increasingly coming under pressure. Mechanisms such as well-defined property rights, clear legislation, sound livestock policies, confidence in local institutions, and robust infrastructure can enhance the sector's role as a catalyst for social peace and stability.

Goal 17 focuses on revitalizing partnerships and bringing together governments, the private sector and civil society to achieve universally sustainable development. At global and regional levels, the livestock sector features several multi-stakeholder partnerships that: a) serve to maintain sustainable growth to meet rising global demand for ASF; and b) simultaneously address key environmental, social and economic challenges. Despite the widely known benefits of multi-stakeholder partnerships, a major factor in their effectiveness is the establishment of governance structures not only appropriate to their mission and composition but also able to address any potential asymmetries of power and conflicts of interest.

INTERACTIONS, SYNERGIES AND TRADE-OFFS

The 2030 Agenda is considered an integrated agenda and defined as an "indivisible whole". The social, environmental and economic pillars of sustainable development are all interlinked within, but also cut across, the Agenda. Indeed, while each goal has a clear starting point in one of the pillars, most goals are in effect, embedded in all three dimensions (OECD, 2015). Traditionally, however, livestock sustainability analysis has used a partial, sectoral approach that gauges the effects of development of the sector on a single dimension of sustainability.

One pitfall in this approach is that it fails to take account of simultaneous contributions, feedback effects, dynamics, synergies and trade-offs between different policy goals and targets. This is particularly important because of the complex, non-linear interactions at play in the SDGs, where the achievement of one target can have positive, neutral or negative effects on one or several others. The analysis presented below is not intended as exhaustive or address each of the SDGs, but to use one goal (SDG2) as an example of the potential synergies and trade-offs between targets.

There are significant positive and mutually supportive interactions in Goal 2, which aims to end hunger and all forms of malnutrition by 2030. They include: developing sustainable food production systems; increasing the productivity of livestock to meet the growing demand for ASFs; ensuring equal access to land, financial services, and opportunities to increase

BOX 13

FOOD VS FEED

Around 0.5 million hectares of available arable land are used for the production of animal feed (Steinfeld *et al.*, 2006). According to Mottet *et al.*, (2017), producing 1 kg of boneless meat in ruminant systems requires an average of 2.8 kg of grains that humans too can eat, and 3.2 kg in monogastric systems. However, livestock also graze on grasslands and convert large amounts of residues from processing crops that are not edible by humans (e.g. straws, stovers, oilseed cakes, brewers' grains) into valuable food for human populations (FAO, 2012a). For example, in India, dairy cattle and buffalo, which are almost exclusively fed on crop residues and by-products, produce enough milk to cover the caloric needs of some 115 million people and the protein requirements of about 230 million people. (Herrero *et al.*, 2010).

productivity; maintaining genetic diversity in livestock breeds to adapt to climate change and enhance biodiversity; investing in infrastructure, research, extension, and technology to increase productive capacity; ensuring the presence of transparent and efficient markets to improve producers' livelihoods and keep consumer prices competitive.

Together with the many positive synergies, there are probably as many goals and targets where conflicts and trade-offs arise. For example: increasing the contribution of livestock to economic growth could constrain the availability of land to produce staple foods. As the livestock sector expands, competition increases for land on which to grow feed and fodder rather than crops for humans; using more land for feed could drive food prices up, jeopardizing the food and nutrition security of poor households. Around 33 percent of available arable land is already used to produce animal feed (Steinfeld *et al.*, 2006), while livestock also consume one-third of world cereal production (Mottet *et al.*, 2017). However, around two-thirds of the global 5 billion hectares classified as agricultural land are in effect unsuitable for crop production and can only be used by grazing livestock (Haan *et al.*, 1997).

Increasing productivity, if not managed well, can diminish the genetic diversity of farmed animals. Biodiversity, often ignored in livestock production, must be considered across species and breeds and within breeds. Indiscriminate crossbreeding, intended to increase production, is considered the main cause of livestock diversity loss worldwide (FAO, 2015a). At the breed level, the distribution of dairy cattle breeds was much more varied in 1994: in the United States of America more than half of the milk (54 percent) was produced by "small" dairy breeds (Ayrshire, Guernsey and Jersey) and 46 percent by large breeds (Holstein, Brown Swiss). By 2007, however, some 90 percent of all milk in the United States of America was produced by a single cattle breed, Holstein.

Increased productivity can also affect the resilience of vulnerable rural households. In many developing countries, livestock and their associated production systems provide services that go well beyond the supply of meat, milk, and eggs. They support crop production, maintain landscapes, provide transport, preserve wealth, and play important ceremonial and cultural roles. Such systems evidence large productivity gaps as compared with industrialized regions because having to produce multiple outputs decreases the capacity to optimize any single output. Thus, although increasing productivity might be a necessary condition for ending hunger, raising productivity in any given setting could diminish the resilience of local households to climate

BOX 14

PRODUCTIVITY VS BIODIVERSITY

Within breeds, the genetic diversity of Holstein cattle has decreased substantially over time (Kim and Kirkpatrick, 2009). Artificial insemination is extremely effective at increasing productivity, but a recent genomic study has revealed that all of the Holstein bulls (N > 250) available commercially for artificial insemination in the United States of America descend from only two ancestors (Yue *et al.*, 2015). Genetic "improvement" is a powerful tool, but care should be taken to manage genetic resources properly, with due consideration given to local context (climate, feed, culture, etc.). Decisions should be consistent with national policy on animal genetic resources. Crossbreeding programmes, particularly with imported breeds, should be accompanied by conservation efforts. In-breed genetic improvements should seek to balance improvements in productivity with maintenance of genetic variability. Strengthening national capacity for the management of animal genetic resources is a critical need in many countries (FAO, 2007, 2015a).

BOX 15

PASTORALISM AND THE MULTIDIMENSIONAL ROLE OF LIVESTOCK SYSTEMS

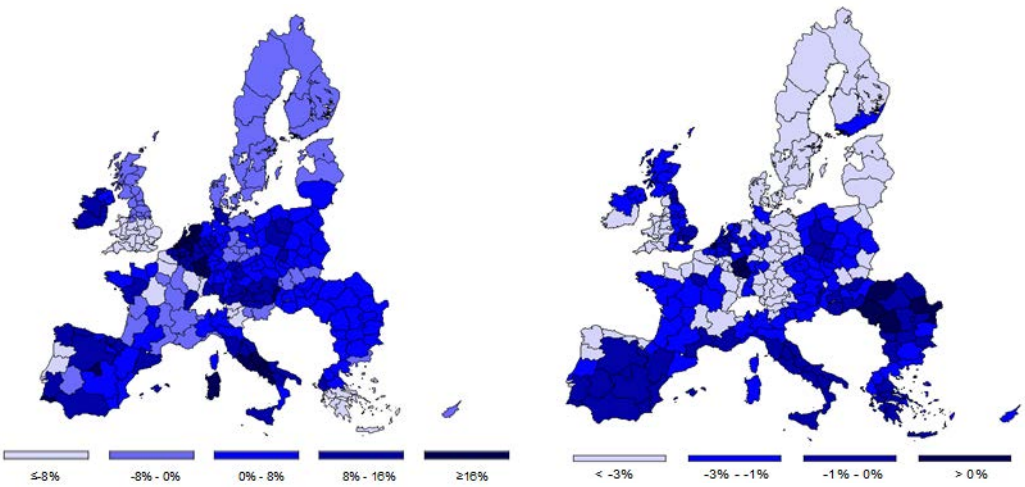
Pastoralism provides multiple benefits in the world's drylands, highlands, wetlands, shrublands and other fragile ecosystems. It helps produce not only meat, milk, skins and animal fibres, but also manure and animal power in support of agricultural activities. Pastoralism also provides important ecosystem services that contribute to improving rangelands and the general environment. Animals on the move help maintain biodiversity and soil fertility, sequester carbon, regulate waters, disperse seeds, and prevent fires. The cultural practices of pastoralists encompass valuable indigenous knowledge and regulate land use in a sustainable and inclusive manner. Cultural services that maintain landscapes also provide recreational value for tourists and society at large. Mobility serves as a way of connecting different regions and countries, linking isolated communities and providing them with news, information and knowledge.

change, extreme weather, drought, flooding and other disasters, and reduce their capacity to progressively improve land and soil quality.

Correcting and preventing trade distortions in world agricultural markets, including through the elimination of all forms of agricultural export subsidies and similar measures, is one of the SDG 2 targets. The argument that openness to trade contributes to economic growth and that this can, in turn, benefit poverty reduction and food security, is well grounded in conventional economic theory. However, potential gains from trade liberalization are not necessarily reflected in all countries and socio-economic groups. Specifically, there are likely to be significant differences between developed and developing countries.

Growing globalization, regional integration, and trade mean that the pursuit of goals in one region or country can interact with the

45 CHANGES BY 2020 IN MILK PRODUCTION AND AGRICULTURAL INCOME



Source: Adapted from Witzke *et al.*, 2009.

goals in another (UN, 2016d). For example, it is projected that by 2020 the abolition of milk quotas in the European Union (Member Organization) will lead to a 4 percent increase in milk output, and a 10 percent decrease in milk prices. However, the effects will be felt differently from one region to another, as shown in Figure 45. While production and agricultural income increase in some regions, they will decrease in others. Total agricultural income would decline due to lower average milk prices, but the dairy industry of the European Union (Member Organization) would benefit since prices of dairy products are expected to decline less than raw milk prices. If a full transmission of lower raw milk prices is assumed, the main beneficiaries of the end of the milk quotas would be consumer (Witzke *et al.*, 2009).

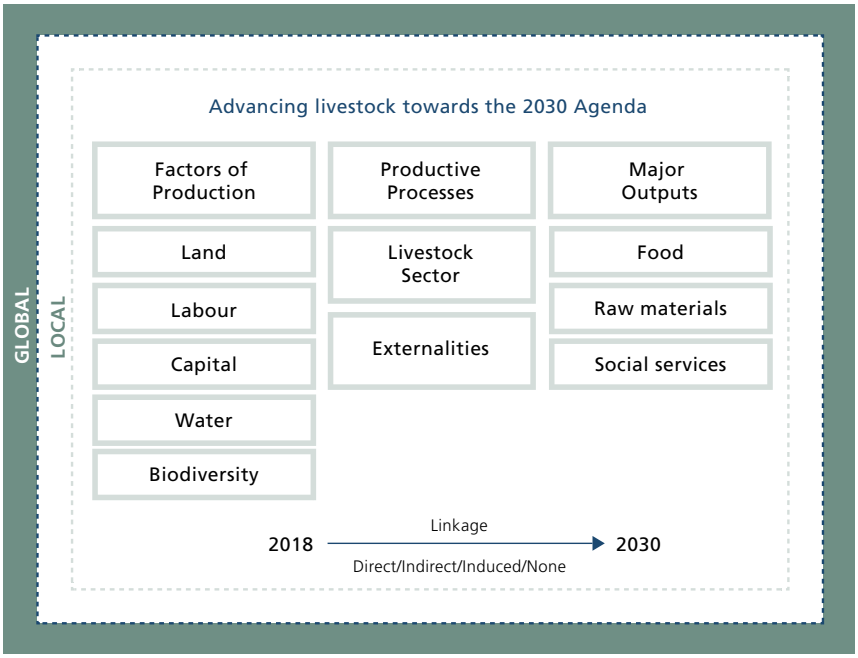
Clearly, the linkages between livestock development and the SDGs are complex. In the sustainable development policy arena, discussions about coherence and interlinkages in the 2030 Agenda have generally focused on the existence of trade-offs and synergies; however, in the livestock policy debate this is an area were conceptual and scientific underpinning is still weak. To address this gap, the next section explores the development of a "Livestock–SDGs

46 LIVESTOCK–SDGS POLICY FRAMEWORK

1. Identifying key linkages
2. Mapping synergies and trade-offs
3. Generating analytical evidence
4. Mapping the policy landscape
5. Analysing the policy framework
6. Considering the political economy

Source: Based on FAO, 2017 and Nilsson *et al.*, 2016.

47 STRUCTURE AND BOUNDARIES OF LIVESTOCK PRODUCTION SYSTEMS



Source: FAO, 2018.

Policy Framework" which aims to support policymakers, stakeholders and investors in identifying ways to enhance the contribution of the livestock sector to the achievement of the 2030 Agenda in a coherent manner.

TOWARDS A LIVESTOCK–SDGS POLICY FRAMEWORK

In the global livestock policy arena, recent discussions have revolved around the potential contribution of the sector to the 2030 Agenda for Sustainable Development. However, at present, there is no comprehensive policy framework to assess and more effectively support the integration of issues relating to livestock and sustainability into national policy processes. To better support integration of livestock policy and practices with sustainable development strategies around the world, this chapter suggests a Livestock–SDGs Policy Framework (see Figure 46) as a tool to enhance the impact of livestock policy analysis in accomplishing the 2030 Agenda.

The main objectives of this policy framework are: i) guide the identification of windows of opportunity for policy change, providing empirical evidence on the ability of the sector to make effective contributions to the SDGs; ii) strengthen the capacities of governments and stakeholders to analyse the contribution of the livestock sector to the SDGs, mapping linkages, synergies and trade-offs; iii) support the generation of analytical evidence that assesses the contribution of the livestock sector to the SDGs, and the likely impact of policies and programmes; iv) promote the use of methods and tools to monitor the contribution of the livestock sector to the SDGs, supporting the uptake of information

from various sources; v) facilitate high-level policy discussion on livestock and sustainable development emerging issues.

The policy framework has six major components, each closely related to the others. The purpose of this framework is to establish a logical and rational process that links issues and evidence with feasible policy initiatives. The framework is based on FAO's 2017 Policy Guidance Note on "strengthening livestock policies for better food security and nutrition" and the "Draft framework for understanding SDG Interactions" (Nilsson *et al.*, 2016).

IDENTIFYING KEY LINKAGES

The first step in the Livestock–SDGs policy framework is to identify key linkages. The aim is to assess how and why the livestock sector can contribute to the SDGs. An adequate definition of the structure and boundaries of the system is critical because, without a clear structure, the analysis would end up trying to cover everything and fail to analyse individual aspects properly.

To facilitate the analytical process, Figure 47 (see previous page) presents a conceptual framework based on an input–output model, a time

TABLE 16
CRITERIA FOR LIVESTOCK–SDG TARGETS LINKAGES

SCALE	LINKAGE	DESCRIPTION
3	Direct	The development of the sector can directly enable or constrain the achievement of a target, e.g. increase the agricultural productivity of small-scale food producers
2	Indirect	The development of the sector sets a condition that enables or constrains the achievement of a target, e.g. ensure access by all people to safe, nutritious and sufficient food all year round
1	Induced	Pursuit of the target enables or constrains the contribution of the sector to other targets, e.g. increase investment in infrastructure, research and extension, and technology development to enhance productivity
0	None	A neutral relationship where the development of the sector does not interact significantly with the respective target, e.g. provide legal identity for all, including birth registration

TABLE 17
LIVESTOCK–SDG TARGETS INTERACTION SCORING

SCORE	INTERACTION	DESCRIPTION
3	Indivisible	The strongest form of positive interaction in which one target is inextricably linked to the achievement of another
2	Reinforcing	One objective directly creates conditions that lead to the achievement of another
1	Enabling	An interaction where the pursuit of one target enables the achievement of another
0	Consistent	A neutral relationship where the achievement of one target does not significantly affect another
-1	Constraining	A mild form of negative interaction where the pursuit of one target sets a condition or places a constraint on the achievement of another
-2	Counteracting	An interaction where the pursuit of one target counteracts with the achievement of another
-3	Cancelling	The most negative interaction, where progress in one target makes it impossible to achieve another target and can lead to a deterioration of the second

Source: Adapted from Nilsson *et al.*, 2016.

frame, a spatial dimension, with linkages divided into four categories. The system interacts with the SDGs through input requirements, the production and distribution processes it generates, and the outputs it creates. These inputs, processes, and outputs, can affect the SDGs locally or globally, directly or indirectly. Linkages may be induced or altogether absent. It is important to note that this figure does not intend to be a precise representation of the production system.

The structure and boundaries of the system should support the identification of key linkages. However, prioritization of linkages is important, otherwise the process will be too vague to be effective. It is not easy to define and agree on criteria that give priority to one linkage over another, since this ultimately depends on the point of entry and perspective of the relevant actor. Nevertheless, the analytical process will have to confront this aspect. To help policymakers and stakeholders to prioritize linkages we use an ordinal scale to rank the level of importance of the linkages from 3 to 0 depending on how strong the linkage is. These linkages can be either positive or negative.

With the aim of starting to unpack the complex interlinkages between the livestock sector and the SDGs, this section explores some of the synergies and trade-offs within and between the 2030 Agenda goals and targets in relation to livestock. Building from the work developed by Nilsson *et al.* (2016) to clarify SDG interactions, the framework presented here uses a seven-point scale indicating the type of interaction with other targets, and the extent to which the relationship is positive or negative.

It should be noted that the position of a given interaction on the scale is rarely absolute or generic. The position and characterization or the interaction depends on the context in which the interaction occurs.

GENERATING AND COMPILING ANALYTICAL EVIDENCE

Policies and investments based on rigorous evidence lead to better outcomes. Analytical evidence should aim to quantify the sector's current and potential contribution to specific targets, including possible synergies and trade-offs supporting the establishment of a baseline. This evidence should help to answer the following questions.

- What is the potential for increasing/reducing the contribution of the livestock sector to a specific target?
- What would be the direct and indirect implications of affecting the contribution of the livestock sector?
- What would be the potential positive and negative externalities of inducing that policy change?

Acosta *et al.* (2017) provide a set of tentative indicators to assess the sector's contribution to some of the SDGs targets. However, one of the major challenges will be to identify and access relevant official information.

Some of this information derives from different sources, including existing official reports, national databases (such as agricultural censuses or living-standard measure surveys) or global databases (such as the FAO smallholder farmers' data portrait, FAO's Global Livestock Environmental Assessment Model (GLEAM) or the Domestic Animal Diversity Information System (DAD-IS)). It will be important, however, to compile and link the different sources of information in a systematic manner that allows for monitoring and reporting. Table 18, for example, presents information related to the percentage of income from on-farm livestock activities in selected countries.

MAPPING THE POLICY LANDSCAPE

Once the linkages, together with livestock's contribution to achieving the SDG targets, and the various potential synergies and trade-offs have been clarified, the next step is to identify, collect and analyse the main policy measures that affect, or could affect, how much the sector effectively contributes. A first step in mapping the policy landscape is to collate the policy documents that can affect the sector's contribution to the SDGs

TABLE 18
PERCENTAGE OF INCOME FROM LIVESTOCK-RELATED ON-FARM ACTIVITIES

COUNTRY	LIVESTOCK (%)	CROPS (%)	AGRI-WAGE (%)	NON-AGRI (%)	TRANSFERS (%)	OTHER
Kenya	24.9	39.5	5.7	19.9	7.2	2.8
Ethiopia	35.3	47.7	5.2	8.8	3.2	0.2
Malawi	6.0	46.0	18.0	17.0	9.0	3.7
Niger	11.0	30.0	3.0	45.3	10.4	0.1
Nigeria	3.0	61.0	0.9	33.0	0.6	0.8
United Republic of Tanzania	11.0	58.0	4.0	23.0	3.0	1.0
Uganda	9.0	45.0	6.0	37.0	1.3	1.1
Bangladesh	6.0	26.0	13.0	35.0	7.2	12.8
Nepal	23.0	24.0	8.4	28.6	14.0	2.0
Viet Nam	18.0	30.0	2.8	25.2	9.6	15.0
Bolivia (Plurinational State of)	14.0	31.0	1.0	47.0	6.0	0.7
Guatemala	3.0	24.0	18.0	40.0	14.0	0.7
Nicaragua	10.0	29.0	31.0	22.0	7.0	1.0
Albania	28.0	19.0	2.0	27.0	23.0	0.5

Source: FAO Smallholder Farmers' Dataportrait, 2017.

positively or negatively, both in the short and long term. This policy framework analysis should help answer the following questions:

- Which are the main macroeconomic and sectoral policies affecting the sector?
- Which are the main agricultural policies?
- Which are the existing livestock policies, strategies and action plans?

A number of countries have developed specific Livestock Development Strategies (LDSs) to guide the sector's development. However, a wide range of policy measures exist, both in and outside the sector, that can also affect its level of sustainability and its contribution to the SDGs. These include macroeconomic policies (trade, fiscal, monetary), agricultural sector policies (land, credit, infrastructure), and livestock-specific policies (animal health, breeding and breed conservation, animal welfare). Countries also have a range of production system or value chain-specific strategies and action plans, instruments often aimed at increasing productivity, production, or access to markets. In addition to national polices and strategies, countries have specific sets of norms and regulations, such as on the control of animal diseases.

ANALYSING THE POLICY FRAMEWORK

The aim of this section is to identify and analyse the impact of specific policy measures on the contribution of the livestock sector to achieving specific SDG targets, and to provide policy recommendations to enhance livestock's role. It also reviews synergies and trade-offs between different objectives of livestock policies and strategies and the achievement of SDGs targets. A major aspect of the policy framework analysis is the identification of options for policy change/reform leading to improvements in the existing policy framework and enhancement of the sector's contribution to SDG targets. Policy

BOX 16

ANALYSING THE LIVESTOCK, FOOD SECURITY AND NUTRITION POLICY FRAMEWORK

Many livestock policies and strategies open with a broad statement identifying the enhancement of food security and nutrition as the main goal of the proposed measures. However, food security and nutrition are usually understood in these strategic documents as food availability, with limited, if any, consideration given to access, utilization and stability. Furthermore, the general perspective is often one of striving to meet food demand and reduce import dependency and foreign exchange expenditure, rather than satisfying basic nutritional needs. Consequently, increasing production, productivity, and sector competitiveness are set as the major policy goals, theoretically leading to higher producer incomes and improved rural and urban food security and nutrition. Central to this vision is the transformation of smallholder subsistence farmers into market-oriented producers, predominantly through technology transfer. However, the proposed policies/strategies are often blind to the context in which smallholder farmers operate and their consequent capacity and willingness to adopt technologies that might increase output on the one hand, but would increase production costs and risks on the other. Following this paradigm, the main areas of public investment tend to be extension and training, research, maintenance of agro and natural biodiversity, plant pest/animal disease control, marketing support and, in some cases, input provision and agriculture-specific infrastructure (FAO and EU, 2017).

framework analysis should help to answer the following questions:

- What would be the contribution of the sector to a specific target if a particular measure were modified?
- Which policy measure change is needed and why?
- What would be the impact of the change on other policy objectives and across SDG targets?

A livestock policy framework seeking to enhance the sector's contribution to the SDGs should view that contribution in broad terms and acknowledge that no single policy or strategy is likely to guide the development of the sector, but that a set of conditions needs to be in place. Specific policy measures may have to be sharpened or relaxed occasionally in order to realize a desired, positive effect. Box 16 presents issues concerning the rationale of livestock food security and nutrition polices/strategies often found in policy frameworks.

CONSIDERING THE POLITICAL ECONOMY

Policy change is a complex process, especially in sectors like livestock, which frequently feature a wide range of competing objectives and a variety of producers. The process of aligning the livestock sector towards the SDGs involves looking for the best ways to influence the policy agenda. While policy analysis can yield various technically viable options for livestock policy adjustment, these may be politically unfeasible. It is therefore important to understand the political economy behind public policies and decision-making. This section should help to answer the following questions:

- Who are the stakeholders in the livestock sector, what stakes do they have and how far can they influence policy-making?
- What is the feasibility of reforms in the context of the national political economy; who stands to benefit and who stands to lose?
- What are the strategic options for promoting policy change?

A prerequisite for the success of any policy reform is consistency with the government's political objectives and alignment with overall national policy. As policy change redistributes resources within society, some groups tend to benefit more than others, while others may actually lose. The likely consequences, whether intended or not, of proposed changes in policy affecting various sectors of society should be understood beforehand. They will determine who is likely to support the policy change, who may oppose it, and who may remain indifferent. Reich (1995) has proposed a framework including the following five dimensions to be considered if the reform is to succeed: i) the consequence of policy reform efforts, i.e. who benefits and who loses; ii) stakeholders' objectives (and how the proposed policy change would affect them); iii) likely support or opposition from key players; iv) the relationship of players in the policy framework; and v) the construction of strategies for change.

CONCLUSION

We are facing a time of immense challenges: one in eight people in the world live in extreme poverty; 815 million people are undernourished; 1.3 billion tonnes of food is wasted every year; six million children die before their fifth birthday each year; 202 million people are unemployed; three billion people rely on wood, coal, charcoal or animal waste for cooking and heating; our soils, freshwater, oceans, forests are being rapidly degraded, biodiversity eroded; and climate change is putting even more pressure on resources we depend on, disrupting national economies and blighting many people's lives. For decades, the livestock debate has focused on how to increase production in a sustainable manner. The UN 2030 Agenda for Sustainable Development has added a new and broader dimension to the debate. It has shifted the emphasis of the conversation from fostering sustainable production *per se*, to enhancing the contribution of the sector to the achievement of the Sustainable Development Goals (SDGs).

The livestock sector can contribute directly or indirectly to each of the SDGs: strengthening the assets that rural households use to achieve their livelihood objectives; increasing the direct consumption of animal-source foods; helping to generate income; supporting the creation of employment opportunities; providing the world with sufficient and reliable supplies of meat, milk, eggs and dairy products; improving children's cognitive and physical development as well as school attendance and performance; empowering rural women; improving natural resources-use efficiency; broadening access to clean and renewable energy; supporting sustainable economic growth; generating fiscal revenue and earning foreign exchange; offering opportunities for value addition and industrialization; stimulating smallholder entrepreneurship and closing inequality gaps; promoting sustainable consumption and production patterns; increasing the resilience of households to cope with climate shocks; and bringing together multiple stakeholders to achieve all these goals.

However, a number of complex interactions also need to be addressed. These include low levels of factor endowments in developing countries might prevent poor livestock keepers from benefiting from the sector's fast economic growth; increasing short-term production through the overuse of resources can result in lowered productivity in the long term; although emission intensity is declining, a rise in production will lead to higher overall GHG emissions; competition over land for the production of feed can constrain the availability of resources to produce food; emergence or spread of transboundary animal diseases can threaten public health and upset trade; promoting a more competitive sector with higher levels of market concentration will likely hamper the capacity of small-producers to participate in markets. Overarching all these issues is the need to curb the negative effects of livestock production on biodiversity and the environment and to halt the improper use of antimicrobials in animal health. Failure to address these interactions could result

in positive synergies being precluded and in the predominance of negative trade-offs.

In other words, enhancing livestock's contribution to the SDGs will require a profound transformation of the sector. This will involve, *inter alia*, looking beyond policies and investments specific to livestock. It will require the formulation of strategies to remove the barriers keeping poor livestock farmers from access to productive assets and rural services; to allow ASF prices to better reflect negative externalities; to strengthen livestock organizations, with emphasis on small-scale producers together with their associations and cooperatives. It means that efforts to increase productivity must focus on small producers; and that extension services must be more gender-responsive. Equally important is the institutionalisation of planning in routine disease prevention, including generalized adoption of One Health (One Health, 2018) approaches. Essential too are trade reform, investment in infrastructure, better access to financial resources, technology innovation and institutional development, while livestock markets must be made more transparent and efficient.

A major challenge will be to translate the role of livestock in the SDGs into national policies and strategies. The SDGs and targets are aspirational and global. Thus, each country will have to decide how the role of livestock in the SDGs should be incorporated into national planning processes, policies and strategies, and how to set national targets guided not only by the global level of ambition but taking into account national contexts. To better support integration of livestock policy and practices with sustainable development strategies, World Livestock presents a Livestock–SDGs Policy Framework as a tool to enhance the impact of livestock policy analysis in accomplishing the 2030 Agenda. The main objectives of this policy framework are to: i) strengthen the capacities of governments and stakeholders to analyse the contribution of the livestock sector to the SDGs, mapping linkages, synergies and trade-offs; ii) guide the identification of windows of opportunity for policy change; iii) support the generation of analytical evidence that assesses the likely impact of policies and programmes; iv) promote the use of methods and tools to monitor the contribution of the livestock sector to the SDGs; and v) facilitate high-level policy discussion on emerging livestock and sustainable development issues.

References

Abed, R. & Acosta, A. 2018. Assessing Livestock Total Factor Productivity: A Malmquist Index Approach". *African Journal of Agricultural and Resource Economics.*

Abel, N. O. J. & Blaikie, P. M. 1989. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. *Land Degradation & Developmen*t, 1(2): 101-123.

Aberra, E. 2003. *Pastoral Livelihoods in Urban and Peri-urban Spaces of Ethiopia: The Case of Yabello, Borana Zone.* International Conference on African Development Archives. Paper 82.

Acosta, A. & Barrantes, C. forthcoming. *The vertical and horizontal economic effects of livestock growth.* Animal Production and Health Division. FAO Working Papers. Rome.

Acosta, A., Nicolli, F. & Panagiotis, T. forthcoming. *The catalytic contribution of livestock to rural households' livelihood strategies: A dynamic cross sectional model.* FAO Working Papers. Rome.

Acosta, A. & De los Santos, L. forthcoming. What is driving TFP change? A persistent and transient efficiency analysis of livestock production systems. *Global Food Security*.

Adelman, S.W., Gilligan, D.O. & Lehrer, K. 2008. *How effective are food for education programs? A critical assessment of the evidence from developing countries.* International food policy research Institute (IFPRI), Washington D.C.

African Development Bank Group. 2012. *Urbanization in Africa.* Accessed 6 February 2018. www.afdb.org/en/blogs/afdb-championing-inclusive-growth-across-africa/post/urbanization-in-africa-10143/

Alary, V., Corniaux, C. & Gautier, D. 2011. Livestock's Contribution to Poverty Alleviation: How to Measure It? *World Development*, 39(9): 1638–1648.

Albanesi, S. 2007. Inflation and inequality. *Journal of Monetary Economics,* Elsevier, vol. 54(4): 1088–1114.

Alders, R.G. & Pym, R.A.E. 2009. Village poultry: still important to millions, eight thousand years after domestication. *World's Poultry Science Journal*, 65(2): 181–190.

Allendorf, K. 2007. Do women's land rights promote empowerment and child health in Nepal? *World Development*, Vol. 35(11): pp. 1975–1988.

Alexandratos, N. & Bruinsma, J. 2012. *World agriculture towards 2030/2050: the 2012 revision.* ESA Working Paper No. 12-03. FAO. Rome.

Ali, J. 2007. Livestock sector development and implications for rural poverty alleviation in India. *Livestock Research for Rural Development*, 19(2): 1–15.

Alkemade, R., Reid, R. S., van den Berg, M., de Leeuw, J. & Jeuken, M. 2013. *Assessing the impacts of livestock production on biodiversity in rangeland ecosystems.* Proceedings of the National Academy of Sciences, 110(52): 20900–20905.

Allen, L.H. 2014. Micronutrient research, programs, and policy: From meta-analyses to metabolomics. *Advances in Nutrition*, 14 (5.3): 344S–351S.

Allen, L.H., Backstrand, J., Chavez, A. & Pelto, G.H. 1992. *People cannot live by tortillas alone: the results of the Mexico nutrition CRSP*. Storrs, CT, USA, University of Connecticut Department of Nutritional Sciences.

Alston, J.M. & Pardey, P.G. 2014. Agriculture in the global economy. *Journal of economic perspectives,* 28(1):121–146.

Alston, J.M., Chan-Kang, M.C., Marra, M.C., Pardey, P.G. & Wyatt T.J. 2000. *A meta-analysis of the rates of return to agricultural R&D: Ex pede herculem?* Research Report no. 113, International Food Policy Research Institute. Washington D.C.

Aneja, V.P., Nelson, D.R., Roelle, P.A. & Walker, J.T. 2003. Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *Journal of Geophysical Research*, 108 (D4): ACH12-1-12-11.

Arheimer, B., Andersson, L., Larsson, M., Lindstrom, G., Olsson, J. & Pers, B.C. 2004. Modelling diffuse nutrient flow in eutrophication control scenarios. *Water Science and Technology*, 49: 37–45.

Arslan, A., Cavatassi, R., Alfani, F., Mccarthy, N., Lipper, L. & Kokwe, M. 2017. Diversification Under Climate Variability as Part of a CSA Strategy in Rural Zambia. *The Journal of Development Studies*, 1–24.

Asadullah, M. N. & Rahman, S. 2009. Farm productivity and efficiency in rural Bangladesh: the role of education revisited. *Applied Economics*, 41(1): 17–33.

Asfaw, S., Pallante, G. & Palma, A. (2018). Diversification Strategies and Adaptation Deficit: Evidence from Rural Communities in Niger. *World Development,* 101: 219–234.

Ashley, C. & Carney, D. 1999. *Sustainable livelihoods: lessons from early experience*. London, Department for International Development.

Asner, G.P., Elmore, A.J., Olander, L.P., Martin, R.E. & Harris, A.T. 2004. Grazing Systems, Ecosystem Responses, and Global Change. *Annual Review of Environment and Resources*, 29: 261–299.

Ayoade, J.A., Ibrahim, H.I. & Ibrahim, H.Y. 2009. Analysis of women involvement in livestock production in Lafia area of Nasarawa State, Nigeria. *Livestock Research for Rural Development*, 21:220. (also available at www.lrrd.org/lrrd21/12/ayoa21220.htm)

Azzarri, C., Cross, E., Haile, B. & Zezza, A. 2014. *Does livestock ownership affect animal source foods consumption and child nutritional status? Evidence from rural Uganda*. Policy Research Working Paper No. 7111. World Bank Group, Washington, D.C.

Banks, J., Blundell, R. & Brugiavini, A. 2001. Risk pooling, precautionary saving and consumption growth. *Review of Economic Studies*, 68(4): 757–779.

Barker, J.C. & Zublena, J.P. 1995. *Livestock Manure Nutrient Assessment in North Carolina.* Final Report. Raleigh, NC. North Carolina Agricultural Extension Service, North Carolina State University.

Barrett, C.B., Chabari, F., Bailey, D., Coppock, D.L. & Little, P.D. 2003. Livestock Pricing in the Northern Kenyan Rangelands. *Journal of African Economics*, 12 (2): 127–155.

Bati, B.M. 2013. *Climate change, cattle herd vulnerability and food insecurity: Adaptation through livestock diversification in the Borana pastoral system of Ethiopia* (Doctoral Dissertation). Germany: University of Hohenheim (also available at https://fsc.uni-hohenheim.de/ fileadmin/einrichtungen/fsc/FSC_Scholars/dissertation/Bekele_Thesis_121213_4114.pdf).

Behnke, R. & Osman, H.M. 2012. *The Contribution of Livestock to the Sudanese Economy*. IGAD LPI Working Paper No. 01 – 12. Addis Ababa, Ethiopia: IGAD Livestock Policy Initiative.

Benchaar, C., Hassanat, F., Gervais, R., Chouinard, P.Y., Julien, C., Petit, H.V. & Massé, D.I. 2013. Effects of increasing amounts of corn dried distillers' grains with solubles in dairy cow diets on methane production, ruminal fermentation, digestion, N balance, and milk production. *Journal of Dairy Science,* 96(4):2413–27.

Bender, A.E. 1992. Meat and meat products in human nutrition in developing countries. Food and Nutrition Paper 53. Rome. FAO.

Bennet, M. 2006. Bats and human emerging diseases. *Epidemiology and Infection,* 134(5): 905–907.

Benton, T.G., Bryant, D.M., Cole, L. & Crick, H.Q.P. 2002. Linking agricultural practice to insect and bird populations: a historical study over three decades. *Journal of Applied Ecology*, 39: 673–687.

Bezanson, K.A. & Isenman, P. 2012. *Governance of New Global Partnerships: Challenges, Weaknesses, and Lessons*. CGD Policy Paper 014. Washington D.C.: Center for Global Development.

Bignal, E. & McCracken, D. 1996. Low-intensity farming systems in the conservation of the countryside. *Journal of Applied Ecology*, 33: 413–424.

Bilal, S. & van Seters, J. 2015. Combining forces for more sustainable global value chains: A European perspective. *GREAT Insights Magazine*, 4.6.

Binswanger, H. & Rosenzweig, M. 1986. Behavioral and material determinants of production relations in agriculture. *Journal of Development Studies*, 22: 503–39.

Bishop-Sambrook, C., Kienzle, J., Mariki, W., Owenya, M. & Ribeiro, F. 2004. *Conservation agriculture as a labour saving practice for vulnerable households: a study of the suitability of reduced tillage and cover crops for households under labour stress in Babati and Karatu Districts, Northern Tanzania*. Rome, IFAD and FAO (also available at http://s3.amazonaws.com/zanran_storage/www.fao.org/ContentPages/4388880.pdf).

Black, M. M. 2003. Micronutrient deficiencies and cognitive functioning. *The Journal of nutrition*, 133(11): 3927S–3931S.

Blackburn, H. & Gollin, D. 2008. Animal genetic resource trade flows: the utilization of newly imported breeds and the gene flow of imported animals in the United States of America. *Livestock Science*, 120, 240–7.

Bloomfield, E. 2015. *Gender and Livelihoods Impacts of Clean Cookstoves in South Asia*. Washington D.C., USA: Global Alliance for Clean Cookstoves.

Bond, W. J. & Parr, C. L. 2010. Beyond the forest edge: Ecology, diversity and conservation of the grassy biomes. *Biological Conservation*, 143: 2395–2404.

Bourguignon, F & Chakravarty, S. 2003. The Measurement of Multidimensional Poverty. *Journal of Economic Inequality*; Apr 2003; 1.

Bouwman, L., Goldewijk, K. K., Van Der Hoek, K. W., Beusen, A. H., Van Vuuren, D. P., Willems, J. *et al.* 2013. *Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900–2050 period. Proceedings of the National Academy of Sciences*, 110(52): 20882–20887.

Boxall, A.B.A., Kolpin, D.W., Halling-Sorenson, B. & Tolls, J. 2003. Are veterinary medicines causing environmental risks? *Environmental Science and Technology*, 37:286A–294A.

Bravo-Baumann, H. 2000. *Capitalisation of Experiences on Livestock Projects and Gender*. Working Document. Bern. Swiss Agency for Development and Cooperation.

Brown, K.H., Dewey, K.G. & Allen, L.H. 1998. *Complementary Feeding of Young Children in Developing Countries: A Review of Current Scientific Knowledge.* WHO/NUT 98:1 World Health Organization, Geneva.

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P.S. & Wichman, M. 2007. Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. *Environmental Health Perspectives*, Vol. 115, No. 2: 308–312.

Byiers, B. & Rosengren, A. 2013. *Common or Conflicting Interests? Reflections on the Private Sector (for) Development Agenda*. ECDPM Discussion Paper, No. 131.

Calisher, C.H., Childs, J.E., Field, H.E., Holmes, K.V. & Schounts, T. 2006. Bats: important reservoir hosts of emerging viruses. *Clinical Microbiology Reviews*, 19(3): 531–545.

Campagnolo, E.R., Johnson, K.R., Karpati, A., Rubin, C.S., Kolpin, D.W., Meyer, M.T., *et al.* 2002. Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations. *Science of the Total Environment*, 299: 89–95.

Caselli, F. 2005. Accounting for Cross-Country Income Differences. In Philippe Aghion and Steven Durlauf, eds., *Handbook of Economic Growth*, Vol. 1A, pp. 679–742. Amsterdam and New York, North Holland Publishing Co.

CBD, Secretariat of the Convention on Biological Diversity. 2014. *How Sectors can contribute to sustainable use and conservation of biodiversity*. CBD Technical Series No. 79, PBL report number 01448, PBL Netherlands Environmental Assessment Agency, The Hague. (also available at https://sustainabledevelopment.un.org/content/documents/1981cbd-ts-79-en.pdf).

CDC. 1999. *MMWR – Morbidity and Mortality Weekly Report* July 30, 1999, 48(29): 621–629 (also available from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm4829a1.htm).

Cervantes-Godoy, D. & Dewbre, J. 2010. Economic Importance of Agriculture for Poverty Reduction. *OECD Food, Agriculture and Fisheries Papers*, No 23. Paris, OECD Publishing.

CGIAR. 2017. *Gender [im]balance in productive and reproductive labor among livestock producers in* Colombia: I*mplications for climate change responses.* Info Note. (also available at https://cgspace.cgiar.org/rest/bitstreams/91190/retrieve).

Chang'a, J.S., Mdegela, R.H., Ryoba, R., Løken, T. & Reksen, O. 2010. *Calf health and management in smallholder dairy farms in Tanzania.* Tropical Animal Health and Production. (also available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2964499/).

Chaoliu Li., Shichang Kang, Pengfei Chen, Qianggong Zhang, Junming Guo, Jue Mi, Puchi Basang, Quzhen Luosang & Kirk R. Smith. 2012. Personal PM2.5 and indoor CO in nomadic tents using open and chimney biomass stoves on the Tibetan Plateau. *Atmospheric Environment*, Vol. 59, November 2012, pp. 207–213.

Chaudry, I., Nosheen, F. & Lodhi, M. 2012. Women's Empowerment in Pakistan with Special Reference to Islamic Viewpoint: An Empirical Study. *Pakistan Journal of Social Sciences* (PJSS) Vol. 32, No. 1 (2012): pp.171–183. (also available at www.bzu.edu.pk/PJSS/Vol32No12012/Final_PJSS-32-1-13.pdf).

Chen, R., Li, R., Deitz, L., Yan Liu, Y., Stevenson, R.J. & Liao, W. 2012. Freshwater algal cultivation with animal waste for nutrient removal and biomass production. *Biomass Bioenergy* 39:128–138.

Chen, S.T. 1989. Impact of a school milk programme on the nutritional status of school children. Asia *Pacific Journal of Public Health*, Vol. 3: 19–25.

Chenyambuga, S. W., Jackson, M., Ndemanisho, E. E. & Komwihangilo, D. M. 2014. Profitability and contribution of small-scale dairy goat production to income of smallholder farmers in Babati and Kongwa districts, United Republic of Tanzania. *Livestock Research for Rural Development*, 26–27.

Christiaensen, L., Demery, L. & Kuhl, J. 2011. The (evolving) role of agriculture in poverty reduction—An empirical perspective. *Journal of development economics*, 96(2): 239–254.

CIRAD & NEPAD. (Centre de coopération internationale en recherche agronomique pour le développement/New Partenership for Africa's Development). 2016. Pesche, D., Losch, B. Imbernon, J., eds. *A New Emerging Rural World. An Overview of Rural Change in Africa*. Atlas for the NEPAD Rural Futures Programme, Second Edition. Montpellier, CIRAD, NEPAD Agency, 76 pp.

Cito. F., Baldinelli, F., Calistri, P., Di Giannatale, E., Scavia, G., Orsini, M., Iannetti, S., Sacchini, L., Mangone, I., Candeloro, L., Conte, A., Ippoliti, C., Morelli, D., Migliorati, G., Barile, N.B., Marfoglia, C., Salucci, S., Cammà, C., Marcacci, M., Ancora, M., Dionisi, A.M., Owczartek, S. & Luzzi, I. 2016. On behalf of the outbreak investigation group. Outbreak of unusual Salmonella enterica serovar Typhimurium monophasic variant 1,4 [5],12:i:-, Italy, June 2013 to September 2014. *Euro Surveillance.* 2016;21(15):pii=30194. DOI: http://dx.doi.org/10.2807/1560-7917.ES.2016.21.15.30194.

Cervantes-Godoy, D. and J. Dewbre. 2010. *Economic ... of the Netherlands as part of the 2009–2010 Program of Work of the Committee for Agriculture* (COAG).

Cervantes-Godoy, D. and J. Dewbre. 2010. Economic Importance of Agriculture for Poverty Reduction. *OECD Food, Agriculture and Fisheries Working Papers*, No. 23, OECD Publishing. doi: 10.1787/5kmmv9s20944-en

Coelli, T. 2009. *Measurement of agricultural total factor productivity growth incorporating environmental factors: a nutrients balance approach.* Working Paper WP03/2009, School of Economics, University of Queensland.

Corbould, C. 2013. *Feeding the Cities: Is Urban Agriculture the Future of Food Security?* Future Direction International, November. (also available at www.futuredirections.org.au/publication/feeding-the-cities-is-urban-agriculture-the-future-of-food-security/

Costales, A, Gerber, P. & Steinfeld, H. *2006. Underneath the Livestock Revolution.* Livestock Report 2006: 15–27.

Cotruvo, J.A., Dufour A., Rees, G., Bartram, J., Carr, R., Cliver, D.O., Craun, G.F., Fayer R. & Gannon V.P.J. 2004. *Waterborne Zoonoses, Identification, Causes, and Control.* Published on behalf of the World Health Organization by IWA Publishing, Alliance House, 12 Caxton Street, London.

Crescio, M. I., Forastiere, F., Maurella, C., Ingravalle, F. & Ru, G. 2010. Heat-related mortality in dairy cattle: A case crossover study. *Preventive Veterinary Medicine*, 97(3): 191–197.

Cuellar, A. & Webber, M. 2008. Cow power: the energy and emissions benefits of converting manure to biogas. Environmental Research Letters, 3 (3). (also available at: http://iopscience.iop.org/article/10.1088/1748-9326/3/3/034002/meta).

Davis, K. 2008. Extension in sub-Saharan Africa: Overview and assessment of past and current models and future prospects. *Journal of International Agricultural and Extension Education*, 15(3): 15–28.

De Bon, H., Parrot, L. & Moustier, P. 2010. Sustainable urban agriculture in developing countries. A review. *Agronomy for Sustainable Development*, 30:21–32.

De Haan C., Cervigni R., Mottet A., Conchedda G., Gerber P., Msangi S., Lesnoff M., Ham F., Fillol E. & Nigussie K. 2016. In de Haan, C., ed. *Prospects for livestock-based livelihoods in Africa's drylands*. Washington D.C.: World Bank Group, p. 79–122.

De Haan, C., Dubern, P.E., Garancher, B. & Quintero, C. 2016. *Pastoralism development in the Sahel: a road to stability?* World Bank Group. Washington, D.C. (also available at http://documents.worldbank.org/curated/en/586291468193771160/Pastoralism-development-in-the-Sahel-a-road-to-stability).

De Haan, C., Steinfeld, H., Blackburn, H. D. *et al.* 1997. *Livestock and the environment: Finding a balance*. Brussels. European Commission Directorate-General for Development, World Bank.

De Janvry, A. & Sadoulet, E. 2009. *Agricultural growth and poverty reduction: Additiona*l evidence. The World Bank Research Observer. (also available at https://openknowledge.worldbank.org/bitstream/handle/10986/4432/wbro_25_1_1.pdf;sequence=1).

De Sy, V.,Herol, M., Achard, F., Beuchle, R., Clevers, JGPW., Lindquist, E., Verchot, L. 2015. Land use patterns and related carbon losses following deforestation in South America. *Environmental Research Letters*, 10, 124004.

De Vries, M. & de Boer I.J.M. 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. *Livestock Science*,128: 1–11.

Wallis DeVries, M.F., Poschlod, P. & Willems, J.H. 2002. Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna. *Biological Conservation*, 104: 265–273.

De Zeeuw, H., Van Veenhuizen, R. & Dubbeling, M. 2011. Foresight project on global food and farming futures. The role of urban agriculture in building resilient cities in developing countries. *Journal of Agricultural Science*, 149: 9–16.

Deelstra, T. & Girardet, H. 2000. Urban Agriculture and Sustainable Cities. In N. Bakker *et al*. eds. *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*, pp. 43–66. Feldafing, Germany. DSE/ZEL.

Deere, C.D. 2005. *The feminization of agriculture? Economic restructuring in rural Latin America.* United Nations Research Institute for Social Development (UNRISD), Occasional Paper 1. Geneva, Switzerland, UNRISD

Deere C.D., Doss, C. 2006. The gender asset gap: what do we know and why does it matter? Feminist Economics, 12 (also available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.465.4520&rep=rep1&type=pdf).

Deka, H.K. *et al.* 2012. *Making Modern Poultry Markets Work for the Poor. South Asia pro-poor livestock policy Programme.* FAO & NDDB. (also available at http://teca.fao.org/read/7678).

Delgado, C.L. *et al.* 1999. *Livestock to 2020: the Next Food Revolution.* Food, Agriculture and the Environment Discussion Paper No. 28. FAO. Rome.

Delgado, C.L. *2005.* Rising demand for meat and milk in developing countries: implications for grasslands–based livestock production. In McGilloway, D.A., ed. *Grassland: a global resource. Proceedings of the twentieth International Grassland Congress*, Dublin, Ireland, 26-30 June 2005. Wageningen, The Netherlands. Wageningen Academic Publishers.

Demirbas, M.F. & Balat, M. 2006. Recent advances on the production and utilization trends of biofuels: A global perspective. *Energy Conversion and Management* 47: 2371–2381.

Dercon, S. 1998. Wealth, risk and activity choice: cattle in western United Republic of Tanzania, *Journal of Development Economics*, 55: 1–42.

Dewey, K. G. & Adu-Afarwuah, S. 2008. Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Maternal & child nutrition*, 4(s1): 24–85.

Dewey, K. G. & Begum, K. 2011. Long-term consequences of stunting in early life. *Maternal & child nutrition*, 7(s3): 5–18.

Dikshit, A.K. & Birthal, P.S. 2013. Positive environmental externalities of livestock in mixed farming systems of India. *Agricultural Economics Research Review*, 26(1): 21–30.

Dobermann, A. & Nelson, R. 2013. *Opportunities and solutions for sustainable food production*. Background paper for the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda. Prepared by the co-chairs of the Sustainable Development Solutions Network Thematic Group on Sustainable Agriculture and Food Production. (also available at: http://unsdsn.org/wp-content/uploads/2014/02/130112-HLP-TG7-Solutions-for-sustainable-food-production.pdf).

Dolan, C. 2002. *Gender and diverse livelihoods in* Uganda. LADDER Working Paper No. 10. (available at http://www.uea.ac.uk/dev/odg/ladder/).

Dorward, A., Anderson, S., Nava, Y., Pattison, J., Paz, R., Rushton, J. & Sanchez Vera, E. 2005. *A Guide to Indicators and Methods for Assessing the Contribution of Livestock Keeping to the Livelihoods of the poor.* Department of Agricultural Sciences, Imperial College London. (also available at www.eldis.org/vfile/upload/1/document/0812/ADorwardReport.doc).

Dorward, A., Anderson, S., Bernal, Y.N., Vera, E. S., Rushton, J., Pattison, J. & Paz, R. 2009. Hanging in, stepping up and stepping out: livelihood aspirations and strategies of the poor. *Development in Practice*, 19(2): 240–247.

Dror, D.K. & Allen, L.H. 2011. The importance of milk and other animal-source foods for children in low-income countries. *Food and nutrition bulletin*, *32*(3): 227–243.

Dubbeling, M. de Zeeuw, H. & van Veenhuizen, R. 2010. *Cities, Poverty and Food: Multi-Stakeholder Policy and Planning in Urban Agriculture.* RUAF Foundation, Practical Action Publishing.

Dufour, A., Bartram, J., Bos, R. & Gannon V., eds. 2012. *Animal Waste, Water Quality and Human Health*. Published on behalf of the World Health Organization by IWA Publishing, Alliance House, 12 Caxton Street, London.

Dyer, C. 2010. Including pastoralists in Education for All. *Commonwealth education partnerships*, 11: 63–65.

Dyer, C. 2015. *Evolution in approaches to educating children from mobile and nomadic communities.* Background paper prepared for the Education for All Global Monitoring Report 2015. Education for All 2000–2015: achievements and challenges.

Economic Research Service (ERS), U.S. Department of Agriculture (USDA). 2017. Food Dollar Series. (also available at https://www.ers.usda.gov/data-products/food-dollar-series/).

Ellis, F & Mdoe, N. 2003. Livelihoods and Rural Poverty Reduction in United Republic of Tanzania. *World Development*, 31(8): 1367–1384.

ECDC (European Centre for Disease Prevention and Control), EFSA BIOHAZ Panel (European Food Safety Authority Panel on Biological Hazards) and CVMP (EMA Committee for Medicinal Products for Veterinary Use). 2017. ECDC, EFSA and EMA Joint Scientific Opinion on a list of outcome indicators as regards surveillance of antimicrobial resistance and antimicrobial consumption in humans and food-producing animals*. EFSA Journal,* 2017;15(10): 5017, 70 pp. https://doi.org/10.2903/j.efsa.2017.5017.

Esselink, P., Fresco, L.F.M. & Dijkema, K.S. 2002. Vegetation change in a man-made salt marsh affected by a reduction in both grazing and drainage. *Applied Vegetation Science*, 2002;5:17–32.

European Commission 2012. Agri-environmental indicator — Gross nitrogen balance. (also available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_gross_nitrogen_balance).

Fafchamps, M. & Lund, S. 2003. Risk-sharing networks in rural Philippines. *Journal of Development Economics* 71 (2): 261–287.

Fafchamps, M., Udry, C. & Czukas, K. 1998. Drought and saving in West Africa: Are livestock a buffer stock? *Journal of Development Economics*, 55(2): 273–305.

Fan, S., Brzeska, J. & Olofinbiyi, T. 2015. The business imperative: Helping small family farmers to move up or move out. In 2014–2015 *Global Food Policy Report*. (also available at http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129075).

FAO & EU. 2017. *Strengthening sector policies for better food security and nutrition results*. Policy guide note 2. Rome.

FAO & FCRN (Food Climate Research Network). 2016. *Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessmen*t. Rome and Oxford.

FAO & ILRI 1995. Livestock development strategies for low-income countries. In Wilson, T. R, Ehui, S. & Mack, S. (eds.) *Proceedings of the joint FAO/ILRI roundtable*, Addis Ababa, 25 Feb–2 March, 1995.

FAO & ILRI. 2008. *Dairy development for the resource poor. Part 1: a comparison of dairy policies and development in South Asia and East Africa*, by Staal, S. J., Pratt, A. N. & Jabbar, M. A. PPLPI Working Paper No. 44–1.

FAO & KIT. 2016. *Towards inclusive Pluralistic Service Systems, Insights for innovative thinking*. Rome. (also available at www.fao.org/3/a-i6104e.pdf).

FAO & UNESCO–IIEP. 2003. *Education for rural development: Towards new policy responses.* Rome, FAO.

FAO & WHO. 2009. Salmonella and Campylobacter in chicken meet. Meeting report. *Microbiological Risk Assessment Series* No. 19, Rome, 56 pp.

FAO, IFAD, UNICEF, WFP & WHO. 2017. *The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security*. FAO. Rome.

FAO. 2001. *Livestock keeping in urban areas.* FAO Animal Production and Health Division Papers, No. 151. Rome, Italy. (also available at www.fao.org/docrep/004/y0500e/y0500e00.htm#toc).

FAO. 2003. *Trade reforms and food security: Conceptualizing the linkages*. Commodity Policy and Projection Service. Rome.

FAO. 2004. The role of livestock in economic development and poverty reduction, by Upton, M. *Pro-Poor Livestock Policy Initiative Working Paper (PPLPI)*, 10: 1–57.

FAO. 2006a. *State of world aquaculture 2006*. FAO Fisheries Technical Paper. No. 500. Rome, FAO. 134 pp.

FAO. 2006b. *Livestock's Long Shadow: Environmental Issues and Options.* Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & de Haan, C., eds. Rome, Italy.

FAO. 2007. *The Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration*. Rome. (also available at http://www.fao.org/3/a-a1404e.pdf).

FAO. 2008. *Global review of good agricultural extension and advisory service practices*. Rome, Italy.

FAO. 2009a. *The state of food and agriculture. Livestock in the balance*. Rome. (also available at http://www.fao.org/docrep/012/i0680e/i0680e.pdf).

FAO. 2009b. *Grassland carbon sequestration: management, policy and economics*. Proceedings of the Workshop on the role of grassland carbon sequestration in the mitigation of climate change. Rome, Italy.

FAO. 2010a. *Mobilizing the potential of rural and agricultural extension*. Rome. (also available at http://www.fao.org/docrep/012/i1444e/i1444e00.htm).

FAO. 2010b. *Food for the cities.* (also available at ftp://ftp.fao.org/docrep/fao/012/ak824e/ak824e00.pdf

FAO. 2011a. *The state of food and agriculture: Women in Agriculture. Closing the gender gap for development*. Rome: FAO. (also available at http://www.fao.org/docrep/013/i2050e/i2050e.pdf).

FAO. 2011b. *World Livestock 2011*. (also available at http://www.fao.org/docrep/014/i2373e/i2373e.pdfwww.fao.org/docrep/014/i2373e/i2373e.pdf).

FAO. 2011c. *The role of women in agriculture*. Rome. (also available at www.fao.org/docrep/013/am307e/am307e00.pdf).

FAO. 2011d. *The place of Urban and peri-urban agriculture (UPA) in national food security programmes.* (also available at www.fao.org/docrep/014/i2177e/i2177e00.pdfwww.fao.org/docrep/014/i2177e/i2177e00.pdf).

FAO. 2011e. *Global food losses and food waste – Extent, causes and prevention*. Rome.

FAO. 2012a. *Pro-Poor Livestock Policy Initiative – Livestock sector development for poverty reduction: an economic and policy perspective – Livestock's many virtues*. (also available at www.fao.org/docrep/015/i2744e/i2744e00.pdf).

FAO. 2012b. *Sustainable nutrition security. Restoring the bridge between agriculture and health*. Rome.

FAO. 2012c. *Invisible Guardians: Women manage livestock diversity*. (also available at www.fao.org/docrep/016/i3018e/i3018e00.pdf).

FAO. 2012d. *Biofuel Co-products as livestock feed-opportunities and challenges.* Makkar, H.P.S. ed. Rome, Italy. (also available at www.fao.org/docrep/016/i3009e/i3009e.pdf).

FAO. 2013a. *Understanding and Integrating Gender Issues into Livestock Projects and Programmes. A checklist for practitioners.* FAO, Rome, Italy, 44 pp. (also available at www.fao.org/3/a-i3216e.pdf).

FAO. 2013b. *World of Livestock 2013: Changing Diseases Landscapes.* FAO, Rome, 111 pp. (also available at www.fao.org/docrep/019/i3440e/i3440e.pdf).

FAO. 2013c. *The state of food and agriculture. Food systems for better nutrition.* Rome.

FAO. 2013d. *Milk and dairy products in human nutrition.* Rome.

FAO. 2013e. *FAO Strategy for partnerships with the private sector*. (also available at www.fao.org/docrep/018/i3444e/i3444e.pdf).

FAO. 2013f. FAO Strategy for partnerships with civil society organizations. (also available at www.fao.org/3/a-i3443e.pdf).

FAO. 2014a. *The state of food and agriculture. Innovation in family farming.* Rome.

FAO. 2014b. *Statistical yearbook 2014 and Market competition between farmed and wild fish*. Rome, Italy.

FAO. 2014c. *Ecosystem services provided by livestock species and breeds, with special consideration to the contributions of small-scale livestock keepers and pastoralists*. Commission on Genetic Resources for Food and Agriculture. Background Study Paper No. 66. Rome (also available at www.fao.org/3/aat598e.pdf/).

FAO. 2015a. *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture*. Rome.

FAO. 2015b. *Handbook for monitoring and evaluation of child labour in agriculture. Measuring the impacts of agricultural and food security programmes on child labour in family-based agriculture.* Rome.

FAO. 2015c. *Running out of time: the reduction of women's work burden in agricultural production*. (also available at www.fao.org/3/a-i4741e.pdf).

FAO. 2016a. *The State of Food Security and Nutrition in the World: Climate Change, Agriculture and Food Security*. Rome.

FAO. 2016b. *The FAO Action Plan on Antimicrobial Resistance 2016–2020.* Rome. (also available at www.fao.org/3/a-i5996e.pdf).

FAO. 2016c. *Asia and the Pacific regional overview of food insecurity. Investing in a Zero Hunger Generation.* FAO Regional Office for Asia and the Pacific. Bangkok, Thailand.

FAO. 2016d. *Farmer field school guidance document – Planning for quality programmes*. Rome.

FAO. 2016e. *The agriculture sectors in the Intended Nationally Determined Contributions.* Analysis, by Strohmaier, R., Rioux, J., Seggel, A., Meybeck, A., Bernoux, M., Salvatore, M., Miranda, J. and Agostini, A. Environment and Natural Resources Management Working Paper No. 62. Rome.

FAO. 2016f. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all.* Rome. 200 pp.

FAO. 2016g. *Environmental performance of animal feeds supply chains: Guidelines for assessment*. Rome.

FAO. 2016h. *Principles for the assessment of livestock impacts on biodiversity*. Livestock Environmental Assessment and Performance (LEAP) Partnership. FAO, Rome, Italy. (also available at www.fao.org/partnerships/leap/publications/en/).

FAO. 2016i. A review of indicators and methods to assess biodiversity – Application to livestock production at global scale. In Teillard, F., Anton, A., Dumont, B., Finn, J.A., Henry, B., Souza, D.M., Manzano P., Milà i Canals, L., Phelps, C., Said, M., Vijn, S., eds. *Livestock Environmental Assessment and Performance (LEAP) Partnership*. Rome, Italy.

FAO. 2016j. *Food security, Nutrition and Peace*. Proceedings of the Security Council Meeting, New York, 29 March 2016. Rome. (also available at www.fao.org/3/a-i5678e.pdf).

FAO. 2017a. *The future of food and agriculture – Trends and challenges*. Rome. (also available at http://www.fao.org/3/a-i6583e.pdf).

FAO. 2017b. FAOSTAT statistics database. [online] Rome. [Cited 15 May 2018] www.faostat.fao.org

FAO. 2017c. *Livestock and the Sustainable Development Goals. Global Agenda for Sustainable Livestock*. Policy Paper, Livestock Information, Sector Analysis and Policy Branch. Rome.

FAO. 2017d. *Counting the cost: Agriculture in Syria after six years of crisis*. Rome. (also available at www.fao.org/fileadmin/user_upload/emergencies/docs/FAO_SYRIADamageandLossReport.pdf).

FAO. 2018b. *Farmer field schools for small-scale livestock producers. A guide for decision makers on improving livelihoods*. Rome.

FAO. 2018a. *Shaping the future of livestock.* The 10th Global Forum for Food and Agriculture (GFFA). Berlin, 18–20 January 2018.

Feldt, T. 2015. *Interrelatedness of grazing livestock with vegetation parameters and farmers' livelihoods in the Mahafaly region, southwestern Madagascar* (Doctoral Dissertation). Witzenhausen, Germany: University of Kassel.

Felipe, J., Kumar, U., Abdon, A. & Bacate, M. 2012. Product complexity and economic development. *Structural Change and Economic Dynamics*, 23(1): 36–68.

Fikin, D.R., Olack, B., Bigogo, G.M., Audi, A., Cosmas, L., Aura, B. *et al.* 2011. The Burden of Common Infectious Disease Syndromes at the Clinic and Household Level from Population-Based Surveillance in Rural and Urban Kenya. (Ed J.G. Beeson). *PLOS One*, Jan. 18: 6(1): e16085.

Fogelholm M, Kanerva N, Männistö S. (2015) Association between red and processed meat consumption and chronic diseases: the confounding role of other dietary factors. *European Journal of Clinical Nutrition*, 69(9):1060-1065.

Foodtank. 2016. *Urban Agriculture. Twelve Organizations Promoting Urban Agriculture around the World*. (also available at https://foodtank.com/news/2016/12/twelve-organizations-promoting-urban-agriculture-around-world/).

Forni, C., Chen, J. L. & Caiola, M.G. 2001. Evaluation of the fern Azolla for growth, nitrogen and phosphorus removal from wastewater. *Water Resources*, 35(6):1592–8.

Foster-McGregor, N., Kaulich, F. & Stehrer R. 2015. *Global Value Chains in Africa*. Working paper. UNIDO/UNU-MERIT. Netherlands.

Frankham, R. 2009. Genetic architecture of reproductive fitness and its consequences. In J. Van der Werf, H.U. Graser, R. Frankham & C. Gondro, eds. *Adaptation and Fitness in Animal Populations: Evolutionary and Breeding Perspectives on Genetic Resource Management*, pp. 15–40. New York, Springer.

Fratkin, E., Roth, E.A. & Nathan, M. A. 2004. Pastoral sedentarization and its effects on children's diet, health, and growth among Rendille of Northern Kenya. *Human Ecology*, *32*(5): 531–559.

Freeman, C. & Wisheart, M. 2015. *Advancing the Debate: Cross-sector partnerships, business and the post-2015 development agenda*. The Post-2015 Agenda Policy Paper. World Vision International.

Freitas, E. E. & Paiva, E. A. 2016. Diversificação e sofisticação das exportações: uma aplicação do product space aos dados do Brasil. *Revista Econômica do Nordeste*, 46(3): 79–98.

Gabanakgosi, K., Moreki, J. C., Tsopito, C. M. & Nsoso, S. J. 2013. Impact of Family Chickens on the Livelihoods of People Living with HIV and AIDS in Four Villages of Botswana. *Journal of World's Poultry Research*, 3(2): 43–53.

Galie', A., Distefano F., Kangogo D., Mattioli R., Wieland B. & Beltenweck I. 2016. [online]. *Gendered Perspective on Smallholder Cattle Production and Health in Three Sites in Tanzania.* [Cited 15 May 2018]. www.agrigender.net/

GALVmed. 2011a. *The gender and social dimension to livestock keeping in Africa: implications for animal health interventions*. (also available at https://assets.publishing.service.gov.uk/media/57a08ac940f0b6497400078e/GALVmed-African-Gender-Report.pdf).

GALVmed. 2011b.*The Gender and Social Dimensions to livestock keeping in South Asia: Implication for animal health interventions*. (also available at https://assets.publishing.service.gov.uk/media/57a08aea40f0b652dd0009a0/GALVmed-South-Asian-Gender-Report.pdf).

Gerber, P. J., Mottet, A., Opio, C. I., Falcucci, A. & Teillard, F. 2015. Environmental impacts of beef production: Review of challenges and perspectives for durability. *Meat scienc*e, 109, 2–12.

Gerber, P., Chilonda, P., Franceschini, G. & Menzi, H. *2005.* Geographical Determinants and Environmental Implications of Livestock Production Intensification in Asia. *Bioresource Technology 96(2): 263–76.*

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. *Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities.* FAO. Rome. (also available at http://www.fao.org/3/a-i3437e.pdf).

Gewa, C. A., Weiss, R. E., Bwibo, N. O., Whaley, S., Sigman, M., Murphy, S. P. *et al.* 2009. Dietary micronutrients are associated with higher cognitive function gains among primary school children in rural Kenya. *British Journal of Nutrition*, *101*(9): 1378–1387.

Gibson, R. S. 1994. Content and bioaccessibility of trace elements in vegetarian diets. *American Journal of Clinical Nutrition* 59 (Suppl.): 1223S–1232S.

Giglietti, R. & Steven, R. 1986. *Labour requirements in livestock enterprises among ILCA sample farmers in Debre Berhan area.* Highlands Program, Addis Ababa, Ethiopia, 44 pp.

GIZ. 2013. *Gender and Livestock Production*. (also available at https://www.giz.de/fachexpertise/downloads/giz2012-en-gender-and-livestock-production.pdf).

GLEAM 2.0. 2017. FAO [online]. Rome. [Cited 15 May 2018]. http://www.fao.org/gleam/en/

Glewwe, P., Jacoby, H.G. & King, E.M. 2001. Early childhood nutrition and academic achievement: a longitudinal analysis. *Journal of public economics*, *81*(3): 345–368.

Global Agenda for Sustainable Livestock (GASL). 2015. *Facilitating dialogue, generating evidence and adopting good practices: In support of the UN 2030 Agenda for Sustainable Development*. Action Plan 2016–2018.

Gollin, D., Van Dusen, E. & Blackburn, H. 2008. Animal genetic resource trade flows: economic assessment. *Livestock Science*, 120, 248–55.

Grace, D. 2012. *The lethal gifts of livestock*. Presentation at International Livestock Research Institute (ILRI). "Livestock Live talk" seminar. ILRI, Nairobi, Kenya, New Blog, 4 November.

Grace, D., Lindahl, J., Correa, M. & Kakkar, M. 2015. Urban livestock keeping. In *Cities and Agriculture – Developing Resilient Urban Food Systems*. RUAF Foundation, pp. 255–284. (also available at www.ruaf.org/urban-livestock-keeping).

Grace, D., Mutua, F., Ochungo, P., Kruska, R., Jones, K., Brierley, L., Lapar, L., Said, M., Herrero, M., Phuc, P.D., Thao, N.B., Akuku, I. & Ogutu, F. 2012. *Mapping of poverty and likely zoonoses hotspots. Zoonoses Project 4.* Report to Department for International Development, UK, 119 pp. (also available at https://assets.publishing.service.gov.uk/media/57a08a63ed915d622c0006fd/ZooMapDFIDreport18June2012FINALsm.pdf).

Grace, J.B., Anderson, T.M., Smith, M.D., Seabloom, E., Andelman, S.J., Meche, G., Weiher, E., Allain, L.K., Jutila, H., Sankaran, M., Knops, J.S., Ritchie, M. & Willig, M.R. 2007. *Does Species Diversity Limit Productivity in Natural Grassland Communities?* University of Nebraska Faculty Publications in the Biological Sciences. Paper 28: digitalcommons.unl.edu/bioscifacpub/28

Grillenberger, M., Neumann, C.G., Murphy, S. P., Bwibo, N.O., Weiss, R.E., Jiang, L. *et al.* 2006. Intake of micronutrients high in animal-source foods is associated with better growth in rural Kenyan school children. *British Journal of Nutrition*, *95*(2): 379–390.

Große-Puppendahl, S., Byiers, B. & Bilal, S. 2016. *Beyond aid in private sector engagement: A mapping of the opportunities and challenges of development and commercially-oriented public support to private sector engagement*. Discussion Paper, nº 187. Maastricht: ECDPM.

Grosse, S.D. 1998. *Farm animals, consumption of animal products, and children's nutritional status in developing countries*. Paper presented at the Symposium on Human Nutrition and Livestock, 14 Oct. 1998, Heifer, Project International, Little Rock, Arkansas, USA, 16 pp.

Guendel, S. 2002. Peri-urban and urban livestock keeping in East Africa. A cooping strategy for the poor? DFID - Livestock Production Programme.

HABITAT II. 1996. *Second United Nations Conference on Human Settlements*. Istanbul, 3–14 June 1996. (also available at http://www.un.org/en/events/pastevents/UNCHS_1996.shtml).

Hagar, G.S.A. 2015. *Assessment of Socio-Economic Impacts on Rural Development Programs on Livestock Sector in Blue Nile and Sennar States, Sudan* (Doctoral dissertation). repository.sustech.edu/handle/123456789/12588

Halloran, A., Clement, J., Kornum, N., Bucatariu, C. & Magid, J. 2014. Addressing food waste reduction in Denmark. *Food Policy*, 49, 294–301.

Hänke, H. & Barkmann, J. 2017. Insurance Function of Livestock: Farmer's Coping Capacity with Regional Droughts in South-Western Madagascar. *World Development*, 96, 264–275.

Hanselman, T.A., Graetz, D.A., Wilkie, A.C. 2003. Manure-borne estrogens as potential environmental contaminants: a review. *Environmental Science and Technology,* 37:5471–5478.

Hausmann, R., Jason, H. & Dani R. 2007. What You Export Matters. *Journal of Economic Growth*, 12(1): 1–25.

Hausmann, R. *et al.* 2011. *The atlas of economic complexity - mapping paths to prosperity*. Hollis: Puritan Press, 2011. 364 p.

Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T. & Lake, R.J. 2010. World Health Organization global estimates and regional comparisons of the burden of food-borne disease in 2010. *PLOS Med* 2015;12:e1001923.

Hazlewood, P. 2015. *Global Multi-stakeholder Partnerships: Scaling up public–private collective impact for the SDGs*. Background Paper 4. Independent Research Forum. (also available at https://sustainabledevelopment.un.org/content/documents/1738Global%20Multistakeholder.pdf).

Herrendorf, B., Rogerson, R. & Valentinyi, Á. 2014. Growth and Structural Transformation. *Handbook of Economic Growth*, *2*, 855–941. DOI: 10.1016/B978-0-444-53540-5.00006-9.

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Freeman, H.A., Bossio, D., Dixon, J., *et al.* 2010. Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems. Science. Vol. 327(5967):pp. 822–5. doi: 10.1126/science.1183725.

Hidalgo, C. A. & Hausmann, R. 2009. *The building blocks of economic complexity*. Proceedings of the national academy of sciences, 106(26): 10570–10575.

HLPE (High Level Panel of Experts on Food Security and Nutrition). 2016. *Sustainable agricultural development for food security and nutrition: what roles for livestock? Report for the Committee on World Food Security (CFS).* HLPE Report 10. Rome. (also available at www.fao.org/3/a-i5795e.pdf).

Himathongkham, S, Bahari, S, Riemann, H. & Cliver, D. 1999. Survival of Escherichia coli O157:H7 and Salmonella typhimurium in cow manure and cow manure slurry. *FEMS Microbiology Letters*,178(2):251–7.

Hoekstra A.Y. 2008. The water footprint of food. In J. Förare (Ed.), *Water for food* (pp. 49–61). Stockholm: The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas). (also available at http://waterfootprint.org/media/downloads/Hoekstra-2008-Waterfootprint-Food.pdf).

Holm-Nielsen, J.B., Al Seadi, T. & Oleskowicz-Popiel, P. 2009. The future of anaerobic digestion and biogas utilization. *Bioresource Technology*, 100, 5478–5484.

Hoogeveen, H. 2002. Evidence on informal insurance in Rural Zimbabwe. *Journal of African Economics*, 11(2): 249–278. dx. doi. org/10.1093/jae/11.2.249.

Hoppe, C., Andersen, G.S. Jacobsen, S., Mølgaard, C., Friis, H., Sangild, P.T., Michaelsen, K.F. 2008. The use of whey or skimmed milk powder in fortified blended foods for vulnerable groups. *Journal of Nutrition*. Vol. 138(1): 145S–161S.

Hoppe, C., Mølgaard, C. & Michaelsen, K. F. 2006. Cow's milk and linear growth in industrialized and developing countries. *Annual Review of Nutrition*, *26*, 131–173.

Horby, P.W., O'Brien, S.J., Adak, G.K., Graham, C., Hawker, J.I., Hunter, P., *et al.* 2003. A national outbreak of multi-resistant Salmonella enterica serovar Typhimurium definitive phage type (DT) 104 associated with consumption of lettuce. *Epidemiology & Infection*,130(2):169–78.

Hristov, A. N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T. *et al.* 2013. *Mitigation of greenhouse gas emissions in livestock production: A review of technical options for non-CO_2 emissions*. FAO Animal Production and Health Paper No, 177, 1–206.

Hulett, J. L., Weiss, R. E., Bwibo, N. O., Galal, O. M., Drorbaugh, N. & Neumann, C. G. 2014. Animal-source foods have a positive impact on the primary school test scores of Kenyan schoolchildren in a cluster-randomised, controlled feeding intervention trial. *British Journal of Nutrition*, *111*(5): 875–886.

Hull, K. 2009. Understanding the relationship between economic growth, employment and poverty reduction. In *Promoting pro-poor growth: Employment*, pp. 69–94. Paris, OECD Publishing.

Hünerberg, M., McGinn, S.M., Beauchemin, K.A., Okine, E.K., Harstad, O.M. & McAllister, T.A. 2013. Effect of dried distillers' grains plus solubles on enteric methane emissions and nitrogen excretion from growing beef cattle. *Journal of Animal Science*,91:2846–2857 doi:10.2527/jas2012-5564.

IAASTD. 2009. *International assessment of agricultural knowledge, science and technology for development. Global report*. IAASTD, Washington D.C.

Iannotti, L., Muehlhoff, E. & Mcmahon, D. 2013. Review of milk and dairy programmes affecting nutrition. *Journal of Development Effectiveness*, *5*(1): 82–115.

Iaquinta, D.L. & Drescher, A.W. 2000. Defining the Peri-Urban: Rural–Urban Linkages and Institutional Connections, Land Reform, Land Settlement and Cooperatives, 2:8–26.

ICEM (International Centre for Environmental Management). 2013. *USAID Mekong ARCC climate change impact and adaptation on livestock.* Prepared for the United States Agency for International Development by ICEM.

IEA (International Energy Agency). 2016. [online].Electricity Access Database. In *World Energy Outlook. 2016.* [Cited 15 May 2018]. www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/

IFAD. 2011. *Rural poverty report 2011. New realities, new challenges: new opportunities for tomorrow's generation*. Rome.

IFPRI. 2004. *The changing face of malnutrition*. In Presentation at the IFPRI Forum. Washington D.C.

IFPRI. 2016. *The global hunger index*. [online]. [Cited 15 May 2018]. http://www.globalhungerindex.org/

IFPRI. 2017. *Agricultural Science and Technology Indicators (ASTI)*. (also available at https://www.asti.cgiar.org/data).

IGU (International Gas Union). 2015. *Biogas – from refuse to energy*. Fornebu, Norway. (also available at: www.igu.org/sites/default/files/node-page-field_file/IGU%20Biogas%20Report%202015.pdf).

Ihle, R., Dries, L., Jongeneel, R., Venus, T. & Wesseler J. 2017. *The EU Cattle Sector: Challenges and Opportunities – Milk and Meat*. Study for the European Parliament AGRI Committee. Brussels. (also available at: www.europarl.europa.eu/RegData/etudes/STUD/2017/585911/IPOL_STU(2017)585911_EN.pdf).

ILO & Asian Development Bank. 2011. *Women and labour markets in Asia – Rebalancing for Gender Equality.* (also available at www.adb.org/sites/default/files/publication/28620/women-labor-markets.pdf).

ILO. 2013a. *Marking progress against child labour: Global estimates and trends 2000–2012*. Geneva.

ILO. 2013b. *Child labour and education in pastoralist communities in South Sudan*. International Labour Office, Governance and Tripartism Department; ILO International Programme on the Elimination of Child Labour (IPEC). Geneva.

ILO. 2014. *Empower rural women – end poverty and hunger: the potential of African cooperatives*. (also available at www.ilo.org/public/english/employment/ent/coop/africa/download/coopafrica_leaflet_iwd2012.pdf).

ILO. 2016. *Rural teachers in Africa: A report for ILO*. Working paper no. 312. Prepared by the Centre for International Teacher Education. Geneva.

ILO. 2017. *Education and child labour in agriculture*. [online]. [Cited 15 May 2018].ilo.org/ipec/areas/Agriculture/WCMS_172347/lang-en/index.htm

ILRI. 2007. *Markets that work – Making a living from livestock*. (also available at https://cgspace.cgiar.org/handle/10568/567).

ILRI. 2010a. *Livestock and Women's Livelihoods: A Review of the Recent Evidence*. (also available at https://cgspace.cgiar.org/bitstream/handle/10568/3017/Discussion_Paper20.pdf).

ILRI. 2010b. *The FARM-Africa dairy goat improvement project in Kenya: A case study*. (also available at agtr.ilri.cgiar.org/agtrweb/index.php?option=com_content&view=article&id=202&Itemid=239).

ILRI. 2012. Livestock in the city: New study of 'farm animals' raised in African cities yields surprising results. *ILRI news*. Available at https://www.ilri.org/ilrinews/index.php/archives/9563

IMF. 1998. Income Inequality: Does Inflation Matter? (also available at https://www.imf.org/external/pubs/ft/wp/wp9807.pdf).

Inter-African Bureau for Animal Resources (AU–IBAR). 2003. *Pastoral Women as Peacemakers*. Nairobi, Kenya. (also available at sites.tufts.edu/capeipst/files/2011/03/AU-IBAR-Pastoral-Women-as-Peacemakers.pdf).

International Food Policy Research Institute (IFPRI). 2016. *Global Hunger Index*. Washington, D.C. (also available at ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/130709/filename/130920.pdf).

IPCC. 2006. *2006 IPCC guidelines for national greenhouse gas inventories*. [online]. [Cited 15 May 2018]. https://www.ipcc-nggip.iges.or.jp/

IPCC. 2007. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer, eds. Cambridge, UK, and New York, USA, Cambridge University Press.

IPCC. 2014. Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IUCN. 2010. B*uilding climate change resilience for African livestock in sub-Saharan Africa*. World Initiative for Sustainable Pastoralism (WISP): a program of IUCN Eastern and Southern Africa Regional Office, Nairobi, March 2010.

Jacobi, P., Amend, J. & Kiango, S. 2000. Urban agriculture in Dar es Salaam: Providing for an indispensable part of the diet. In N. Bakker *et al.* eds. *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*, pp. 257–83. Feldafing, Germany. DSE/ZEL.

Jarvis, Lovell S. 1986. *Livestock Development in Latin America.* Washington, D.C. The World Bank.

Ji, X.J., Ren, L.J. & Huang, H. 2015. Omega-3 Biotechnology: A Green and Sustainable Process for Omega-3 Fatty Acids Production. Front. *Bioengineering and Biotechnology*, 3: 158.

Jin, M. & Iannotti, L.L. 2014. Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science & Medicine,* 105: 16–21.

Johnson, N., J. Njuki, E. Waithanji, M. Nhambeto, M. Rogers, and E. Hutchinson. 2013. *The gendered impacts of agricultural asset transfer projects: Lessons from the Manica Smallholder Dairy Development Program.* CGIAR system-wide program on Collective Action and Property Rights (CAPRi) Working Paper No. 115. Washington, DC: International Food Policy Research Institute.

Jones K.E., Patel, NG., Levy, MA., Storeygard, A., Balk, D., Gittleman, J.L. & Daszak, P. 2008. Global trends in emerging infectious diseases. *Nature*, 451: 990–993, 21 Feb. 2008.

Jones, P.G. and Thornton, P.K. 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy*, 12(4): 427–437.

Jongbloed, A.W. and Lenis, N.P. 1998. Environmental concerns about animal manure. *Journal of Animal Science,* 76: 2641–2648.

Jungcurt, S. 2016. *CFS Adopts Recommendations on Livestock, Smallholders and 2030 Agenda*. IISD. http://sdg.iisd.org/news/cfs-adopts-recommendations-on-livestock-smallholders-and-2030-agenda/

Kapdi, S.S., Vijay, V.K., Rajesh, S.K. & Prasad R. 2005. Biogas scrubbing, compression and storage: perspective and prospectus in Indian context. *Renew Energy* 30: 1195–2002.

Karanja, N. & Njenga, M. 2011. Feeding the Cities. In *The Worldwatch Institute report, 2011. Innovations that nourish the planet*. (also available at groupedebruges.eu/sites/default/files/publications/downloads/stateoftheworld2011.pdf).

Kazianga, H. & Udry, C. 2006. Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics*, 79(2): 413–446.

Kim ES & Kirkpatrick BW. 2009. Linkage disequilibrium in the North American Holstein population. *Animal Genetics*, 40(3):279-88.

Kinsey, B., Burger, K. & Gunning, J. 1998. Coping with drought in Zimbabwe: survey evidence on responses of rural households to risk, *World Development*, 26, 89–110

Kirksey, A., Harrison, G. G., Galal, O.M., McCabe, G. A., Wachs, T.D. & Rahmanifar, A. 1992. *The human cost of moderate malnutrition in an Egyptian village.* Final Report Phase II: Nutrition CRSP. Lafayette, LA, USA, Purdue University.

Knobel D.L., Maina, A.N., Cutler, S.J., Ogola, E., Feikin, D.R., Junghae, M., *et al.* 2013. *Coziella burnetii* in humans, domestic ruminants, and ticks in rural western Kenya. *The American Journal of Tropical Medicine and Hygene,* Mar. 88(3): 513-518. Doi: 10.4269/ajtmh.12-0169. Pmid23382156.

Knoll, A., Große-Puppendahl, S. & Mackie, J. 2015. *Universality and Differentiation in the Post–2015 Development Agenda*. Discussion Paper, No. 173, 2015. Maastricht: ECDPM. (also available at www.ecdpm.org/dp173).

Koletzko, B., Demmelmair, H., Grote, V., Prell, C. & Weber, M. 2016. High protein intake in young children and increased weight gain and obesity risk. *The American journal of clinical nutrition*, 103(2): 303–304.

Kosgey, I. S., Rowlands, G. J., Van Arendonk, J. A. M. & Baker, R. L. 2008. Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research*, 77(1): 11–24.

Krätli, S. & Dyer, C. 2009. *Mobile pastoralists and education: Strategic options*. Education for Nomads Working Paper 1. International Institute for Environment and Development (IIED). London.

Krebs, N. F., Mazariegos, M., Tshefu, A., Bose, C., Sami, N., Chomba, E. *et al.* 2011. Meat consumption is associated with less stunting among toddlers in four diverse low-income settings. *Food and nutrition bulletin*, *32*(3): 185–191.

Kristjanson, P., Waters-Bayer, A., Johnson, N., Tipilda, A., Njuki, J., Baltenweck, I., Grace, D. & MacMillan, S. 2010. *Livestock and Women's Livelihoods: A Review of the Recent Evidence*. Discussion Paper No. 20, International Livestock Research Institute (ILRI).

Kristjansson, E. A., Gelli, A., Welch, V., Greenhalgh, T., Liberato, S., Francis, D. & Espejo, F. 2016. Costs, and cost-outcome of school feeding programmes and feeding programmes for young children. Evidence and recommendations. *International Journal of Educational Development*, 48, 79–83.

Kues, W.A. and Niemann, H. 2004. The contribution of farm animals to human health. *Trends in Biotechnology*, 22(6): 286–294.

Kurukulasuriya, P. & Rosenthal, S. 2013. *Climate change and agriculture: a review of impacts and adaptations*. Environment Department Papers No. 91. Climate Change Series. Washington, D.C., World Bank (also available at documents.worldbank.org/curated/en/2013/06/17911216/climatechange-agriculture-review-impacts-adaptations).

Laca, E.A., and Demment, M.W. 2018. Livestock Production Systems. In Hudson, R., ed., *Management of Agricultural, Forestry, Fisheries and Rural Enterprise*, Oxford, United Kingdom. Eolss Publishers Co. Ltd.

Lal, R. 2003. Carbon Sequestration in Dryland Ecosystems. *Environmental Management* 33(4): 528–44.

Lallemand Animal Nutrition in FeedInfo. 2015. [online]. Lallemand animal nutrition warns of heat stress in cows all over Europe. [Cited 15 May 2018]. http://www.feedinfo.com/console/PageViewer.aspx?page=5050311&str=lallemand).

Lancelot, R., De La Rocque, S. & Chevalier, V. 2008. B*luetongue and Rift Valley fever in livestock: a climate change perspective with a special reference to Europe, the Middle-East and Africa*. Montpellier, France. EDEN Consortium. (also available at https://agritrop.cirad.fr/559553/1/document_559553.pdf).

Landesa. 2015. *Women's land rights*. (also available at www.landesa.org/resources/womens-land-rights-and-the-sustainable-development-goals/).

Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarres, J.F., Proenca, V., Scharlemann, J.P.W. *et al.* 2010. *Biodiversity scenarios: projections of 21st century change in biodiversity and associated ecosystem services*. Technical Report for the Global Diversity Outlook 3. Technical Series no. 50. Montreal, Canada. Secretariat of the Convention on Biological Diversity.

Lee-Smith, D. 2012. Cities feeding people: an update on urban agriculture in equatorial Africa. *Environment and Urbanization*, 22: 483–499.

Lenihan-Geels, G., Bishop, K. S. & Ferguson, L. R. 2013. Alternative sources of omega-3 fats: can we find a sustainable substitute for fish? *Nutrients*, 5: 1301–1315.

Leroy, J. L. & Frongillo, E. A. 2007. Can interventions to promote animal production ameliorate undernutrition? *the Journal of Nutrition*, *137*(10): 2311–2316.

Li, X., Norman, H.C., Kinley, R.D., Laurence, M., Wilmot, M., Bender, H., de Nys, R. & Tomkins, N. 2016. Asparagopsis taxiformis decreases enteric methane production from sheep. *Animal Production Science*. http://dx.doi.org/10.1071/AN15883

Lien do, T.K., Nhung, B. T., Khan, N. C., Nga, N. T., Hung, N.T., Kiers, J., Shigeru, Y. & te Biesebeke, R. 2009. Impact of milk consumption on performance and health of primary school children in rural Vietnam. *Asia Pacific journal of clinical nutrition*, 18(3): 326–334.

Lloyd, T. 2017. Forty Years of PT Research in the Food Industry: Insights, Challenges and Prospects. *Journal of Agricultural Economics*, 68(1): 3–21.

Loayza, N. V. & Raddatz, C. 2010. The composition of growth matters for poverty alleviation. *Journal of development economics*, 93(1): 137–151.

Lockheed, M.E., Jamison, D.T. & Lau, L.J. 1980. Farmer education and farm efficiency. *Economic Development and Cultural Change*, 29: 37–76. University of Chicago.

Lubroth, J., El Iddrissi, A., Hasibra, M., Black, P. & Burgeon, D. 2017. Linking Animal Diseases and Social Instability. *OIE Scientific and technical Review*.

Ludena, C. E., Hertel, T. W., Preckel, P. V., Foster, K. & Nin, A. 2007. Productivity growth and convergence in crop, ruminant, and non-ruminant production: measurement and forecasts. *Agricultural Economics*, 37(1): 1–17.

Maass, B.L., Musale, D.K., Chiuri, W.L., Gassner, A. & Peters, M. 2012. Challenges and opportunities for smallholder livestock production in post-conflict South Kivu, eastern DR Congo. *Tropical animal health and production*, 44(6): 1221–1232.

MacCarty, N., Still D. & Ogle, D. 2010. Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance. *Energy for Sustainable Development,* 2010 14(3): 161–71.

MacMillan, S. 2016, February 29. *Livestock and the Sustainable Development Goals*. ILRI News. https://news.ilri.org/2016/02/29/livestock-and-the-sustainable-development-goals/

Madalena, F. E. 2008. How sustainable are the breeding programs of the global main stream dairy breeds? The Latin-American situation. *Total health*, 138(85): 62.

Makkar, H.P.S. Tran, G., Heuzé, G. & Ankers, P. 2014. State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology*, 197: 1–33.

Makkar, H.P.S., Tran, G., Heuzé, G., Giger-Reverdin, S., Lessire, M., Lebas, M. & Ankers, P. 2016 Seaweeds for livestock diets: A review. *Animal Feed Science and Technology*, 212: 1–17.

Makkar, H.P.S. 2014. *Biofuel co-products as livestock feed – Opportunities and challenges.* Technical Summary. FAO, Rome, Italy. (also available at: www.fao.org/docrep/019/i3650e/i3650e.pdf).

Makkar, H.P.S. 2017. Review: Feed demand landscape and implications of food-not-feed strategy for food security and climate change. [online]. *Journal of Animal Science.* [Cited 15 May 2018]. https://doi.org/10.1017/S175173111700324X

Marzin, J., Bonnet, P., Bessaoud, O. & Ton-Nu, C. 2016. *Study on small-scale family farming in the Near East and North Africa region – Synthesis*. FAO, CIRAD, CIHEAM

Mattioli, R.C., Jaitner, J., Clifford, D.J. & Pandey, V.S. 1998. Trypanosome infections and tick infestation: susceptibility in N'Dama, Gobra and N'Dama x Gobra crossbred cattle exposed to natural challenge and maintained under high and low surveillance of trypanosome infections. *Acta Tropica*, 71: 57–71.

Maxwell, D. 1995. Alternative food security strategy, A household analysis of urban agriculture in Kampala. *World Development*, 23: 1669.

Mayberry, D., Ash, A., Prestwidge, D., Godde, C. M., Henderson, B., Duncan, A., Blummel, M., Reddy Y. R. & Herrero, M. 2017. Yield gap analyses to estimate attainable bovine milk yields and evaluate options to increase production in Ethiopia and India. *Agricultural Systems*, 155: 43–51. (also available at http://doi.org/10.1016/j.agsy.2017.04.007).

Mayurasakorn, K., Sitphahul, P. & Hongto, P. O. 2010. Supplement of three eggs a week improves protein malnutrition in Thai children from rural areas. *The FASEB Journal*, *24* (1 Supplement): 94–8.

Mbaye, A. & Moustier, P. 1999. Market-oriented urban agricultural production in Dakar. In *N. Bakker et al. eds Growing cities, Growing food. Urban Agriculture on the Policy Agenda,* pp. 235–256. Feldafing, Germany, DSE/ZEL.

McClintock, N., Pallana, E. & Wooten, H. 2014. Urban livestock ownership, management, and regulation in the United States: An exploratory survey and research agenda. *Land Use Policy*, 38: 426–440

McDonald, M.C. 2011. Neglected tropical and zoonotic diseases and their impact on women's and children's health. In *The Causes and Impacts of Neglected and Zoonotic Diseases: Opportunities for Integrated Intervention Strategies*. Washington D.C. National Academic Press (also available at https://www.ncbi.nlm.nih.gov/books/NBK62515/).

McGechan, M.B., Lewis, D.R. & Hooda, P.S. 2005. Modelling through soil transport of phosphorous to surface waters from livestock agriculture at the field and catchment scale. *Science of the Total Environment*, 344: 185–199.

McKinsey Global Institute. 2016. [online] *People on the move*: Global migration's impact and opportunity. [Cited 15 May 2018]. https://www.mckinsey.com/featured-insights/employment-and-growth/people-on-the-move

McMichael, A. J., Powles, J. W., Butler, C. D. & Uauy, R. 2007. Food, livestock production, energy, climate change, and health. *The Lancet*, 370(9594): 1253–1263.

McPeak, B.J. 2004. Contrasting income shocks with asset shocks: Livestock sales in northern Kenya. *Oxford Economic Papers*, 56(2): 263–284.

McPeak, B.J. 2017. Applying the concept of resilience to pastoralist household data. *Pastoralism*, 7 (1):14.

Mekonnen, M. M. & Hoekstra, A. Y. 2011. National water footprint accounts: the green, blue and grey water footprint of production and consumption. In *Value of Water Report 50*. Delft, Netherlands, Unesco–IHE Institute for Water Education.

Mekonnen, M.M. & Hoekstra, A.Y. 2012. A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, 15(3): 401–415.

Mengistu, M.G., Simane, B., Eshete, G. & Workneh, T.S. 2015. A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia. *Renewable and Sustainable Energy Reviews*, 48: 306–316.

Menzi, H., Oenema, O., Burton, C., Shipin, O., Gerber, P., Robinson, T. & Franceschini, G. 2010. Impacts of intensive livestock production and manure management on the environment. In *Steinfeld, H., Mooney, A., Schneider, F. & Neville, L.E. eds. Livestock in a changing landscape*, Volume 1: 139–163. Washington D.C. The Island Press.

Meyer, MT. 2004. Use and Environmental Occurrence of Veterinary Pharmaceuticals in the United States. In *Pharmaceuticals in the Environment: Sources, Fate, Effects, and Risks*. Kummerer, K. ed.. New York. Springer-Verlag,155–163.

Miao, X and Wu, Q. 2006 Biodiesel production from heterotrophic microalgal oil. *Bioresource Technology*, 97: 841–846.

Miladinovic, D. 2015. How to process novel fish feed protein sources. Feed Technology: AllAboutFeed, pp 4–5, May 2015.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. [online]. [Cited 15 May 2018]. https://www.millenniumassessment.org/en/index.html

Ministry of Agriculture (MoA) and Ministry of Trade (MoT) of the Federal Democratic Republic of Ethiopia, the USAID-funded Agriculture Knowledge, Learning, Documentation and Policy Project and the Livestock Marketing Development Projects. 2014. *Public-Private Partnerships for Livestock Service Facilities: Lessons from Djibouti and Somaliland for the Mille Quarantine Center*.

Modernel, P., Astigarraga, L. & Picasso, V. 2012. Global vs local environmental impacts of grazing and confined beef production systems. *Environmental Research Letters*, 8 (3): 035052. Doi: 10.1088/1748-9326/8/3/035052.

Mohammed, H.A.H. 2013. *Analysis of Livestock Markets and Products for Pastoralists Depending on Natural Rangelands*. (Doctoral dissertation). Available at http://repository.sustech.edu/handle/123456789/4844

Moore, L. L., Bradlee, M. L., Gao, D. & Singer, M. R. 2008. Effects of average childhood dairy intake on adolescent bone health. *The Journal of Pediatrics*, 153(5): 667–673.

Moreki, J. C., Dikeme, R. & Poroga, B. 2010. The role of village poultry in food security and HIV/AIDS mitigation in Chobe District of Botswana. *Livestock Research for Rural Development*, 22(3): 1–7.

Moritz, M. 2008. Competing Paradigms in Pastoral Development? A Perspective from the Far North of Cameroon. World Development, 36: 2243–2254

Mosites, E.M., Rabinowitz, P.M., Thumbi, S.T., Montgomery, J.M., Palmer, G.H., May, S., Rowhani, A., Neuhouser, M.L. & Walson, J. 2015. The Relationship between Livestock Ownership and Child Stunting in Three Countries in Eastern Africa Using National Survey Data. *PLOS One* (also available at http://dx.doi.org/10.1371/journal.pone.0136686).

Mottet, A., de Haan, C., Falcucci, A., Tempio, G., Opio, C. & Gerber, P. 2017. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security,* 14: 1–8. (also available at www.sciencedirect.com/science/article/pii/S2211912416300013).

Mottet, A., Henderson, B., Opio, C., Falcucci, A., Tempio, G., Silvestri, S. & Gerber, P. J. 2016a. Climate change mitigation and productivity gains in livestock supply chains: insights from regional case studies. *Regional Environmental Change*, 1–13.

Mottet, A., Teillard, F., Falcucci, A. & Gerber, P. 2016b. Achieving mitigation through adaptation: climate smart livestock solutions in Southern Africa. In 6th *International Greenhouse Gas and Animal Agriculture (GGAA2016) Conference*, Melbourne, Australia, February 14–18, 2016.

Mougeot, L.J.A. 2005. Urban agriculture and the millennium development goals. In Mougeot L.J.A., ed. *Agropolis:the social, political and environmental dimensions of urban agricu*lture. London, Earthscan. www.earthscan.co.uk

Moustier, P. & Danso, G. 2006. Local economic development and marketing of urban produced food. In van Veenhuizen R., ed. *Cities farming for the future. Urban agriculture for sustainable cities*. RUAF Foundation, IDRC and IIRR, pp. 171–206

Mueller, B., Acero, F. & Estruch, E. 2017. *Creating employment potential in small-ruminant value chains in the Ethiopian Highlands*. FAO Animal Production and Health Working Paper No. 16, Rome, FAO.

Mueller, D.K., Hamilton, P.A., Helsel, D.R., Hitt, K.J. & Ruddy, B.C. 1995. *Nutrients in groundwater and surface water of the United States—an analysis of data through 1992*. US Geological Survey Water Resources Investor Report, 95–4031.

Munday, R. and Reeve, J. 2013. Risk Assessment of Shellfish Toxins. *Toxins*, 5: 2109–2137; doi:10.3390/toxins5112109

Muradov, N., Taha, M., Miranda, A.F., Kadali, K., Gujar, A., Rochfort, S., Stevenson, T., Ball, A.S. & Mouradov, A. 2014. Dual application of duckweed and azolla plants for wastewater treatment and renewable fuels and petrochemicals production. *Biotechnology for Biofuels*, 7: 30.

Murphy, S. P. & Allen, L. H. 2003. Nutritional importance of animal source foods. *The Journal of nutrition*, 133(11): 3932S–3935S.

Murphy, S. P., Gewa, C., Liang, L. J., Grillenberger, M., Bwibo, N. O. & Neumann, C. G. 2003. School snacks containing animal source foods improve dietary quality for children in rural Kenya. *The Journal of Nutrition*, *133*(11): 3950S–3956S.

Murphy, S.P. & Allen, L.H. 1996. *A greater intake of animal products could improve the micronutrient status and development of children in East Africa*. Paper presented at East Africa Livestock Assessment Workshop, Entebbe, Uganda.

Murray, M. & Black, S.J. 1985. African trypanosomosis in cattle: working with nature's solution. *Veterinary Parasitology*, 18: 167–182.

Muthayya, S., Rah, J.H., Sugimoto, J.D., Roos, F.F., Kraemer, K, *et al.* (2013) The Global Hidden Hunger Indices and Maps: An Advocacy Tool for Action. *PLOS ONE* 8(6): e67860. [Cited 15 May 2018]. https://doi.org/10.1371/journal.pone.0067860

Nahman, A., de Lange, W., Oelofse, S. & Godfrey, L. 2012. The costs of household food waste in South Africa. *Waste Management*, 32: 2147–2153

Natarajan, A. Chander, M. & Bharathy, N. 2016. Relevance of draught cattle power and its future prospects in India: A review. *Agricultural Reviews*, 37 (1): 49–54.

Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., Alder, J. & Mooney, H. 2005. Agriculture. Losing the links between livestock and land. *Science.* 310(5754): 1621–2.

Neumann, C.G., Bwibo, N.O., Murphy, S.P., Sigman, M., Whaley, S., Allen, L.H. *et al.* 2003. Animal source foods improve dietary quality, micronutrient status, growth and cognitive function in Kenyan school children: background, study design and baseline findings. *The Journal of Nutrition*, *133*(11): 3941S–3949S.

Neumann, C.G., Murphy, S.P., Gewa, C., Grillenberger, M. & Bwibo, N.O. 2007. Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *The Journal of Nutrition*, 137(4): 1119–1123.

Neumann, C., Bwibo, N. O. & Sigman, M. 1992. *Functional implications of malnutrition: Kenya project final report*. Human nutrition collaborative research support programme. Los Angeles, Calif, USA: University of California, Los Angeles, School of Public Health.

Neumann, C., Harris, D. M. & Rogers, L. M. 2002. Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutrition Research*, 22(1): 193–220.

Neumann, C.G., Bwibo, N.O. Gewa, C.A. & Drorbaugh, N. 2013. Animal source foods as a food-based approach to improve diet and nutrition outcomes. In B. Thompson and L. Amoroso (Eds.), *Food based approaches. Improving diets and nutrition* (pp. 157–172). Rome, FAO.

Neumann, C.G., Demment, M.W., Maretzki, A., Drorbaugh, N. & Galvin, K.A. 2010. The livestock revolution and animal source food consumption: benefits, risks and challenges in urban and rural settings of developing countries. In Steinfeld, H., Mooney, H.A., Schneider, F. & Neville, L.E., eds. *Livestock in a changing landscape*. SCOPE.

Ngigi, M. W., Muller, U. & Birner, R. 2015. *The role of livestock portfolios and group-based approaches for building resilience in the face of accelerating climate change: An asset-based panel data analysis from rural Kenya*. Bonn, Germany: Center for Development Research. (also available at http://ssrn.com/abstract=2676574).

Niang I, OC Ruppel MA, Abdrabo A, Essel C, Lennard, Padgham J & Urquhart P. (2014) Africa. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199–1265

Nilsson, M., Griggs, D., Visbeck, M. & Ringler, C. 2016. *A Draft Framework for Understanding SDG Integrations*. Paris. International Council for Science (ICSU).

Nin, A., Ehui, S. & Benin, S. 2007. Livestock productivity in developing countries: an assessment. *Handbook of Agricultural Economics*, 3: 2461–2532.

Njuguna, J. K., Mwongela, M., Allport, R. & Irura, D. 2014. Innovative radio-based extension for agriculture and livestock producers in Kenya. Proceedings of the 1st International Research Conference "Enhancing innovation for sustainable development in the 21st Century and beyond" 29–31 Oct 2014 Chuka University, Kenya.

Nolte, S., Koppenaal, E. C., Esselink, P., Dijkema, K. S., Schuerch, M., De Groot, A. V., *et al.* 2013. Measuring sedimentation in tidal marshes: a review on methods and their applicability in biogeomorphological studies. *Journal of Coastal Conservation*, 17(3): 301–325.

O'Hare, B., Makuta, I., Chiwaula, L. & Bar-Zeev, N. 2013. Income and child mortality in developing countries: a systematic review and meta-analysis. *Journal of the Royal Society of Medicine*, 106(10): 408–414.

O'Neill, J. 2016. *Review on Antimicrobial Resistance. Tackling drug-resistant infections globally: Final report and recommendations.* Report to UK Government, May, 2016, London, UK (also available at http://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf).

OECD & FAO. 2012. *Guidance for Responsible Agricultural Supply Chains. Recommendation of the Council on principles for Public Governance of Public–Private Partnerships*.

OECD & FAO. 2013. *Agricultural Outlook 2013–2022.* Paris. OECD Publishing, (also available at https://www.oecd.org/tad/agricultural-policies/OECD–FAO_Outlook_2013–2022.pdf).

OECD & FAO. 2015. *OECD–FAO Agricultural Outlook 2015.* Paris. OECD Publishing. (also available at www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2015_agr_outlook-2015-en).

OECD & FAO. 2016. *OECD–FAO Agricultural Outlook 2016–2025*. Paris. OECD Publishing. (also available at http://dx.doi.org/10.1787/agr_outlook-2016-en).

OECD & FAO. 2017. *Agricultural Outlook 2017–2026.* Paris. OECD Publishing. http://www.oecd-ilibrary.org/agriculture-and-food/oecd-fao-agricultural-outlook-2017-2026_agr_outlook-2017-en).

OECD–FAO Aglink-Cosimo. 2017. [online]. [Cited 15 May 2018]. http://www.agri-outlook.org/about/

OECD. 2011. *Determinants of productivity growth and competitiveness. Fostering Productivity and Competitiveness in Agriculture*. Paris. OECD Publishing.

OECD. 2012. Looking to 2060: Long-term global growth prospects. *OECD Economic Policy Papers* No 03. Paris. OECD Publishing.

OECD. 2014. *Competition issues in the food chain industry.* DAF/COMP (2014)16. Paris. OECD Publishing.

OECD. 2015. *Policy Coherence for Sustainable Development*. Paris. OECD Publishing.

Oenema, O. 2006. Nitrogen budgets and losses in livestock systems. In *International Congress Series*. Vol. 1293: pp. 262–271). Amsterdam, Netherlands, Elsevier.

Oilgae. 2016. *Comprehensive Report on Attractive Algae Product Opportunities*. (also available at www.oilgae.com/ref/report/Comprehensive_Report_on_Attractive_Algae_Product_Opportunities_review.pdf).

Omwami, E. M., Neumann, C. & Bwibo, N. O. 2011. Effects of a school feeding intervention on school attendance rates among elementary schoolchildren in rural Kenya. *Nutrition*, 27(2): 188–193.

One Health. 2018. [online]. [Cited 15 May 2018]. http://www.onehealthglobal.net/contact-us/

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B.& Steinfeld, H. 2013. *Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment.* FAO. Rome. (also available at www.fao.org/docrep/018/i3461e/i3461e.pdf).

Orsini, F., Kahane, R., Nono-Womdim, R. & Gianquinto, G. 2013. Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development*, 33: 695–720.

Pachauri, R. K., Meyer, L., Plattner, G. K. & Stocker, T. 2015. IPCC, 2014: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, IPCC.

PAHO (Pan American Health Organization). 2006. Assessing the economic impact of obesity and associated chronic diseases: Latin America and the Caribbean. Fact Sheet, April 2006. Washington, D.C.

Pardey, P.G., Beintema, N., Dehmer, S. & Stanley, W. 2006. *Agricultural research. A growing global divide?* Washington D.C. IFPRI.

Peterson, K., Mahmud, A., Bhavaraju, N. & Mihaly, A. 2014. *The Promise of Partnerships: A Dialogue between INGOs and Donors*. FSG Consulting.

Petroselli, A, Giannotti, M. Marras, T. & Allegrini, E. 2016. Integrated system of phytodepuration and water reclamation: a comparative evaluation of four municipal wastewater treatment plants. Int. J. Phytoremediation. 2016 Dec 15:0.

Phillips, J. M. 1994. Farmer education and farmer efficiency: A meta-analysis. *Economic development and cultural change*, 43(1): 149–165.

Phuong Anh, M.T., Ali, M. &Thu Ha, T.T. 2004. *Urban and Peri-urban Agriculture in Hanoi: Opportunities and Constraints for Safe and Sustainable Food Production*. Technical Bulletin No. 32, AVRDC – The World Vegetable Center, CIRAD, SUSPER.

Pica-Ciamarra, U., Otte, J. & Chilonda, P. 2007. Livestock policies, land and rural conflicts in sub-Saharan Africa. *Land Reform, Land Settlement and Cooperatives*, 1: 19–33.

Pica-Ciamarra, U., Tasciotti, L., Otte, J. & Zezza, A. 2015. Livestock in the Household Economy: Cross-Country Evidence from Microeconomic Data. *Development Policy Review*, 33(1): 61–81.

Pica, G., Pica-Ciamarra, U.& Otte, J. 2008. *The livestock sector in the World Development Report 2008: Re-assessing the policy priorities*. FAO-Pro-Poor Livestock Policy Initiative (PPLPI) Research Report 08-07. Rome, FAO.

Pighin, D., Pazos, A., Chamorro, V., Paschetta, F., Cunzolo, S., Godoy, F., Messina, V., Pordomingo, A. & Grigioni, G. 2016. A contribution of Beef to Human Health: A review of the Role of the Animal Production Systems. *The Scientific World Journal*, Vol. 2016. Article ID 8681491, 10 p. (also available at http://dx.doi.org/10.1155/2016/8681491).

Pimentel, D., Zuniga, R. & Morrison, D. 2005. Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States. Ecological Economics, 52, 273–288.

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B. & Travasso, M.I. 2014. *Food security* and *food production systems*. In Climate Change *2014*: Impacts, Adaptation, and Vulnerability. Part *A*: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. pp. 485–533. Cambridge University Press.

Praagman, J., Beulens, J.W., Alssema, M., Zock, P.L., Wanders, A.J., Sluijs, I. & van der Schouw, Y.T. (2016) The association between dietary saturated fatty acids and ischemic heart disease depends on the type and source of fatty acid in the European Prospective Investigation into Cancer and Nutrition-Netherlands cohort. *American Journal of Clinical Nutrition,* 103(2):356-65.

Pradère, J.P. 2014. Links between livestock production, the environment and sustainable development. *Scientific and Technical Review,* 33(3). World Organisation for Animal Health.

Quisumbing, A.R. ed. 2003. *Household Decisions, Gender, and Development: A Synthesis of Recent Research*. (also available at http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129647).

Quisumbing, A.R., *et al.* 2015. *Gender, assets, and market-oriented agriculture: learning from high-value crop and livestock projects in Africa and Asia*. (available at https://link.springer.com/article/10.1007/s10460-015-9587-x).

Radhakrishnan, S., Saravana Bhavan, P., Seenivasan, C., Shanthi, R. & Muralisankar, T. 2014. Replacement of fishmeal with Spirulina platensis, Chlorella vulgaris and Azolla pinnata on non-enzymatic and enzymatic antioxidant activities of Macrobrachium rosenbergii. *Journal of Basic & Applied Zoology* 67(2): 25–33.

Raman, D.R., Williams, E.L., Layton, A.C., Burns, R.T., Easter, J.P. & Daugherty, A.S., *et al.* 2004. Estrogen content of dairy and swine wastes. *Environmental Science and Technology*, 38: 3567–3573.

Ran, Y., Lannerstad, M., Herrero, M., Van Middelaar, C. E. & De Boer, I. J. M. 2016. Assessing water resource use in livestock production: A review of methods. *Livestock Science*, 187: 68–79.

Randolph, T., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J.L., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J. & Ruel, M. 2007. Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science*, 85: 2788–2800.

Redwood, M. 2008. Agriculture in urban planning: generating livelihoods and food security. Ottawa, IDRC.

Reimers, M. & Klasen, S. 2013. Revisiting the role of education for agricultural productivity. *American Journal of Agricultural Economics*, 95(1): 131–152.

Restuccia, D., Dennis T. Y. & Xiaodong, Z. 2008. Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis. *Journal of Monetary Economics*, (55): 234–50.

Reuters. 2015. *Indian chicken prices surge to record as heatwave kills millions of birds*. [online]. press article 1.6.2015. [Cited 15 May 2018]. www.reuters.com/article/india-heatwave-chicken-idUSL3N0YM0B920150601

Robinson, T.P., Yhornton, P.K., Franceschini, G., Kruska, R.L., Chiozza, F., Notenbaert, A., Cecchi, G., Herrero, M., Epprecht, M., Fritz, S., You, L., Conchedda, G. & See, L. 2011. *Global livestock production systems*. Rome, Food and Agriculture Organization of the United Nations (FAO) and International Livestock Research Institute (ILRI), 152 pp. Rome.

Rosegrant, M. W. and Cline, S. A. 2003. Global food security: challenges and policies. *Science*, 302 (5652): 1917–1919.

Rosegrant, M. W., Fernandez, M., Sinha, A., Alder, J., Ahammad, H., de Fraiture, C, Eickhour, B., Fonseca, J., Huang, J. et al. 2009. Looking into the future for agriculture and AKST. In McIntyre, B. D., Herren, H. R., Wakhungu, J., Watson, R. T. eds., *International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD): Agriculture at a Crossroads, global report*. Washington, D.C., USA: Island Press. pp.307–376.

Rosenthal, J. 2009. Climate change and the geographic distribution of infectious diseases. *EcoHealth*, 6(4): 489–495.

Rosenzweig, M. & Wolpin, K. 1993. Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: investments in bullocks in India, *Journal of Political Economy*, (101): 223-44.

Roth, F., Zinsstag, J., Orkhon, D., Chimed-Ochir, G., Hutton, G., Cosivi, O., Carrin, G. & Otte, J. 2003. Human health benefits from livestock vaccination for brucellosis: case study. *Bulletin of the World Health Organisation*, 81(12): 867–876.

RUAF Foundation. *Urban agriculture: what and why?* [online]. [Cited 15 May 2018]. www.ruaf.org/urban-agriculture-what-and-why

Rubin, D., Tezera, S.& Caldwell, L. 2010. *A Calf, a House, a Business of One's Own: Microcredit, Asset Accumulation, and Economic Empowerment in GL CRSP Projects in Ethiopia and Ghana*. (also available at www.culturalpractice.com/wp-content/downloads/3-2010-19.pdf).

Ruel, M. 2003. Milk Intake Is Associated with Better Growth in Latin America: Evidence from the Demographic and Health Surveys. *FASEB 17.*

Sansoucy, R. 1995. Livestock – a driving force for food security and sustainable development. *World Animal Review*. No.84/85 pp.5–17 ref.16. FAO. Rome.

Sansoucy, R., Jabbar, Mohammad A., Ehui, Simeon K. & Fitzhugh, H. 1995. Keynote paper: *The contribution of livestock to food security and sustainable development*. Research Report 182946. International Livestock Research Institute.

Sasikala, V., Tiwari, R. & Saravanan, M. 2013. A Review on Integrated Farming Systems. *Journal of International Academic Research for Multidisciplinary*, 3(7): 319–328.

Scherf B.D. and Pilling D., eds. Agriculture. In *FAO Commission on Genetic Resources for Food and Agriculture Assessments*, Rome, Italy (available at www.fao.org/3/a-i4787e/index.html).

Schiere, H & den Dikken, G. 2003. Urban livestock. Urban farming and animal production, a synthesis. In *Annotated Bibliography on Urban Agriculture*. Sida and ETC-Urban Agriculture Programme pp. 324–351. Leusden, the Netherlands, ETC.

Schouten, S., van Groenigen, J.W., Oenema, O. & Cayuela. M.L. 2012. Bioenergy from cattle manure? Implications of anaerobic digestion and subsequent pyrolysis for carbon and nitrogen dynamics in soil. *Global Change Biology Bioenergy*, 4: 751–760. doi:10.1111 /j.1757-1707.2012.01163.

Schroder, D.G. and Brown, K.H. 1994. Nutritional status as a predictor of child survival: Summarizing the association and quantifying its global impact. *Bulletin of the World Health Organisation*, 72: 569–579.

Schuman, G. E., Janzen, H. H. & Herrick, J. E. 2002. Soil carbon dynamics and potential carbon sequestration by rangelands. *Environmental pollution*, 116(3): 391–396.

Scoones, I. 1996. *Hazards and opportunities: farming livelihoods in dryland Africa. Lessons from Zimbabwe*. London, Zed Books. pp 267.

Scott-Villiers, P., Wilson, S., Kabala, N., Kullu, M., Ndung'u, D. & Scott-Villiers, A. 2006. *A Study of Education and Resilience in Kenya's Arid and Semi-Arid Lands*. UNICEF Eastern and Southern Africa Regional Office (ESARO).

Seo, S.N. (2011). Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture: Reply. *Food Policy*, 36(3): 450–451.

Sexton, R.J. & Lavoie, N. 2001. Food processing and distribution: an industrial organization approach. *Handbook of agricultural economics*, 1: 863–932.

Shichang Kang, Chaoliu Li, Feiyue Wang, Qianggong Zhang & Zhiyuan Cong. 2009. Total suspended particulate matter and toxic elements indoors during cooking with yak dung. *Atmospheric Environment*, Vol. 43, Issue 27, September 2009, Pages 4243–4246. doi.org/10.1016/j.atmosenv.2009.06.015.

Silliman, B.R., Mozdzer, T., Angelini, C., Brundage, J.E., Esselink, P., Bakker, J.P., Gedan, K.B., van de Koppel, J. & Baldwin, A.H. 2014. Livestock as a potential biological control agent for an invasive wetland plant. In Yoccoz N, ed. *PeerJ*, 2014;2:e567. (also available at https://peerj.com/articles/567/).

Slavchevska, V.,Kaaria, S. & Taivalmaa, S. 2016. *Feminization of Agriculture in the Context of Rural Transformations: What is the Evidence?* World Bank, Washington, D.C.

Smit, J., Nasr, J. & Ratta, A. 2001. Problems Related to Urban Agriculture. In *Urban Agriculture Food, Jobs and Sustainable Cities*. 2001 Edition. The Urban Agriculture Network, Inc. (also available at www.jacsmit.com/book/Chap02.pdf).

Smith, Lisa C., Ramakrishnan, U., Ndaiye, A., Haddad, L.J. & Martorell, R. 2003. "*The Importance of Women's Status for Child Nutrition in Developing Countries*". (also available at www.ifpri.org/publication/importance-womens-status-child-nutrition-developing-countries). IFPRI.

Sorathiya, L.M., Fulsoundar, A.B., Tyagi, K. K., Patel, M.D. & Singh, R.R. 2014. Eco-friendly and modern methods of livestock waste recycling for enhancing farm profitability. *International Journal of Recycling of Organic Waste in Agriculture* 3:50 (DOI 10.1007/s40093-014-0050-6).

Soussana, J.F., Tallec, T. & Blanfort, V. 2010. Mitigating the greenhouse gas balance of ruminant production systems through carbon sequestration in grasslands. *Animal : an international journal of animal bioscience*, 4, 334–50.

Statista. 2017. *Production of biogas worldwide in 2013, by region (in exajoules)*. (also available at https://www.statista.com/statistics/481828/biogas-production-worldwide-by-region/).

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & De Haan, C. 2006. *Livestock's long shadow. Environmental Issues and Options*, FAO, Rome. 390pp.

Steinfeld, H., Mooney, H.A., Schneider, F. & Neville, L.E., eds. 2013. *Livestock in a changing landscape, Volume 1: Drivers, consequences, and responses*. Washington D.C., Island Press.

Steinfeld, H, *et al.* 2006. *Livestock's Long Shadow: Environmental Issues and Options.* FAO. Rome. 377 pp. (also available at www.globalmethane.org/expo_china07/docs/post-expo/ag_gerber.pdf).

Stevens, G.A., Bennett, J.E., Hennocq, Q. *et al.* 2015. Trends and mortality effects of vitamin A deficiency in children in 13 low-income and middle-income countries between 1991 and 2013: a pooled analysis of population-based surveys. *Lancet Global Health*.

Sutton, M.A., Bleeker, A., Howard, C.M., Bekunda, M., Grizzetti, B., De Vries, W. *et al.* 2013. *Our nutrient world: the challenge to produce more food and energy with less pollution*. NERC/Centre for Ecology & Hydrology.

Sutton, P.M., Rittmann, B.E., Schraa, O.J., Banaszak, J.E. & Togna, A.P. 2011. Wastewater as a resource: a unique approach to achieving energy sustainability. *Water Science Technology,* 63(9):2004–9.

Tacon, A.G.J. & Metian, M. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects**.** *Aquaculture,* 285: 146–158.

Tacon, A.G.J. & Metian, M. 2015. Feed Matters: Satisfying the Feed Demand of Aquaculture. Reviews. *Fisheries Science & Aquaculture,* 23 (1): 1–10.

Taguchi, M. & Makkar, H. 2015. Issues and options for crop–livestock integration in peri-urban settings. Agriculture for Development, No.26, pp.35–38. (also available at www.researchgate.net/publication/286385924).

Tangka, F.K., Jabbar, M.A. & Shapiro, B.I. 2000. *Gender roles and child nutrition in livestock production systems in developing countries: A critical review.* Socio-economics and Policy Research Working Paper *27*. ILRI (International Livestock Research Institute), Nairobi, Kenya, 64 pp.

Tasho, R.P. & Cho, J.Y. 2016. Veterinary antibiotics in animal waste, its distribution in soil and uptake by plants: A review. *Science of the Total Environment,* 563–564, 366–376.

Tegegne, A., Tadesse, M., Yami, A. & Mekasha, Y. 2000. Market-oriented urban and peri-urban dairy systems. *Urban Agriculture Magazine*, 2: 23–4.

Thomas, B., Togarepi, C. & Simasiku, A. 2014. Analysis of the determinants of the sustainability of cattle marketing systems in Zambezi Region of north-eastern communal area of Namibia. *International Journal of Livestock Production*, *5*(7): 129–136.

Thornton, P. K. 2010. Livestock Production: Recent Trends, Future Prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences 365(1554): 2853–67.* (also available at rstb.royalsocietypublishing.org/cgi/doi/10.1098/rstb.2010.0134).

Thornton, P.K. & Herrero, M. 2014. Climate change adaptation in mixed crop–livestock systems in developing countries. *Global Food Security*, 3(2): 99–107.

Thornton, P.K., Jones, P.G., Owiyo, T.M., Kruska, R.L., Herrero, M., Kristjanson, P. U. *et al.* 2006. *Mapping climate vulnerability and poverty in Africa.* 200pp. Nairobi, Kenya. ILRI. (also available at https://cgspace.cgiar.org/handle/10568/2307).

Thumbi, S.M., Njenga, M.K., Marsh, T.L., Noh, S., Otiang, E., Munyua, P., Ochieng, L., Ogola, E., Joder, J., Audi, A., Montgomery, J.M., Bigogo, G., Breiman, R.F., Palmer, G.H. & McElwain, T.F. 2015. Linking Human Health and Livestock Health: A "One Health" Platform for integrated Analysis of Human Health, Livestock Health, and Economic Welfare in Livestock Dependent Communities. *PLOS One*, Mar. 2015 (also available at http://dx.doi.org/10.1371/jou-pone.0120761).

Thys, E. 2006. Role of Urban and Peri-urban Livestock Production. In *Poverty Alleviation and Food Security in Africa*. Mémoire in-8°, Nouvelle Série, Tome 26, fasc. 1. Bruxelles, Academie Royale des sciences d'outre-mer.

Thys, E., Oueadraog, M., Speybroec, N. & Geerts, S. 2005. Socio-Economic Determinants of Urban Household Livestock Keeping in Semi-Arid Western Africa. *Journal of Arid Environments*, 63: 475–496.

Tilman, D. & Clark, M. 2014. Global diets link environmental sustainability and human health. *Nature*, 515: 518–522.

Todd, H. 1998. Women climbing out of poverty through credit; or what do cows have to do with it? *Livestock Research for Rural Development* (also available at www.fao.org/ag/aga/AGAP/frg/lrrd/lrrd10/3/todd103.htm).

Tomley, F.M. and Shirley, M.W. 2009. Livestock infectious diseases and zoonoses. Philosophical Transactions of the Royal Society B: *Biological Science*, Sep 27, 364(1530): 2637–2642.

Torres-Lima, P., Rodriques Sanchez, L. M. & Garcia Uriza, B. I. 2000. Mexico City: The integration of urban agriculture to contain urban sprawl. In N. Bakker *et al.* eds. *Growing cities, Growing food. Urban agriculture on the policy agenda,* pp. 363–390. Feldafing, Germany.

Torres, M.M. *et al.* 2001. A case study on the National Dairy Development Board of India. http://siteresources.worldbank.org/INTEMPOWERMENT/Resources/14655_Natl-Dairy-web.pdf).

Townsend, R. and Thirtle, C. 2001. Is livestock research unproductive? Separating health maintenance from improvement research. *Agricultural Economics*, 25(2-3): 177–189.

Tran, G., Heuzé, V. & Makkar, H.P.S. 2015. Insects in fish diets. *Animal Frontiers*, 2015, 5: 37–44.

Triboi, R.M. 2017. *Urban pastoralism as environmental tool for sustainable urbanism in Romania and Eastern Europe.* Procedia Environmental Sciences International Conference – Green Urbanism, GU. (also available at https://www.ierek.com/wp-content/uploads/2016/08/procediaES_conferenceaGU_Triboi.pdf).

Turmelle, A.S. and Olival, K.J. 2009. Correlates of viral richness in bats (order Chiroptera). *EcoHealth*, 6(4): 522–539.

TWN (Third World Network). 2016. *Access to medicines fundamental to achieving right to health*. TWN Info Service on UN Sustainable Development (also available at www.twn.my/title2/unsd/2016/unsd160701.htm).

Udo, H.M.J. and Steenstra, F. 2010. *Intensification of smallholder livestock production: is it sustainable?* The 5th International Seminar on Tropical Animal Production Community Empowerment and Tropical Animal Industry, Yogyakarta, Indonesia.

UN, Economic and Social Council. 2016. Report of the Secretary-General – *Progress towards the Sustainable Development Goals*. (also available at www.un.org/ga/search/view_doc.asp?symbol=E/2016/75&Lang=E).

UN. 1948. *Universal Declaration of Human Rights*. UN, New York.

UN. 2008. International Standard Industrial Classification of All Economic Activities Rev. 4. Department of Economic and Social Affairs. New York, USA.

UN. 2014. *World Urbanization prospects. The 2014 Revision*. (also available at https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf).

UN. 2016a. *Transforming our World: The 2030 Agenda for Sustainable Development*. New York. A/RES/70/1.

UN. 2016b. *The Sustainable Development Goals Report 2016*. United Nations, New York.

UN. 2016c. Report of the Secretary-General, *"Progress towards the Sustainable Development Goals"*, E/2016/75.

UN. 2016d. *Sustainable Development Goal. Build resilient infrastructure, promote sustainable industrialization and foster innovation*. (also available at www.un.org/sustainabledevelopment/infrastructure-industrialization/).

UN. 2017. Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. ESA/PWP/248

UNDP. UNDP support to the Implementation of Sustainable Development Goal 16. January 2016. New York. (also available at www.undp.org/content/dam/norway/undp-ogc/documents/16_peace_Jan15_digital.pdf).

UNESCO. 2015. *Education 2030 Incheon Declaration and Framework for Action*. UNESCO, Paris.

UNESCO. 2016. *Education for people and planet: creating sustainable futures for all. Global Education Monitoring Report*. UNESCO, Paris.

UNICEF. 2002. *Case studies on girls' education*. UNICEF, New York.

UNICEF/WHO/World Bank. 2017. *Joint Child Malnutrition Estimates*. [online]. [Cited 15 May 2018].https://data.unicef.org/topic/nutrition/malnutrition/#

UNIDO. 2015. *Industrial Development Report 2016: The Role of Technology and Innovation in Inclusive and Sustainable Industrial Development*. Vienna, Austria.

UNIDO. 2017. MVA Manufacturing Value Added Database. Vienna. [online]. [Cited 15 May 2018]. http://stat.unido.org.

United Nations, Department of Economic and Social Affairs, Population Division, 2015. *World Population Prospects: The 2015 Revision. Key Findings and Advance Tables*. Working Paper No. ESA/P/WP.241. (also available at www.un.org/esa/ffd/wp-content/uploads/2015/08/AAAA_Outcome.pdf

UNSTAT. 2016**.** SDG Goal 5. https://unstats.un.org/sdgs/report/2016/goal-05/

Upadhyay, B. 2005. *Women and natural resource management: Illustrations from India and Nepal* (available at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1477-8947.2005.00132.x).

Upadhyaya, S. 2013. *Country grouping in UNIDO statistics*. United Nations Industrial Development Organization (UNIDO) working paper 1/2013.

Upton, M. 2004. *The Role of Livestock in Economic Development and Poverty Reduction.* PPLPI Working Paper No.10. FAO. Rome. (also available at http://ageconsearch.umn.edu/bitstream/23783/1/wp040010.pdf

Valdés, A. & Foster, W. 2010. Reflections on the Role of Agriculture in Pro-Poor Growth. *World Development*, 38(10): 1362–1374.

Valdés, A. & William, F. 2010. Reflections on the Role of Agriculture in Pro-Poor Growth, *World Development*, 38(10): 1362–1374.

Van Dooren, C., Marinussen, M., Blonkb, H., Aiking, H. & Vellinga, P. 2014. Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. *Food Policy*, 44: 36–46.

Van Hoeve, E, Van Koppen, B. 2005. *Beyond fetching water for livestock: A gendered sustainable livelihood framework to assess livestock-water productivity.* (available at https://www.researchgate.net/publication/255621693_Beyond_fetching_water_for_livestock_A_gendered_sustainable_livelihood_framework_to_assess_livestock-water_productivity).

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L. & Sachdev, H. S. Maternal & Child Undernutrition Study Group. 2008. Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet*, *371*(9609): 340–357.

Von Wissmann, B., Machila, N., Picozzi, K., Fèvre, E.M., deC.Bronvoort, B.M., Handel, I.G. *et al.* 2011. Factors associated with acquisition of human infective and animal infective trypanosomes infections in domestic livestock in Western Kenya. (2011). *PLOS Neglected Tropical Diseases,* Jan. (1): e941. Doi: 10.1371/journal.pntd.0000941. pmid:21311575.

Voortman, T., Braun, K. V. E., Kiefte-de Jong, J. C., Jaddoe, V. W., Franco, O. H. & van den Hooven, E. H. 2016. Protein intake in early childhood and body composition at the age of 6 years: the Generation R Study. *International Journal of Obesity*, 40(6): 1018–1026.

Walker, P., Rhubart-Berg, P., McKenzie, S., Kelling, K. & Lawrence, R. S. 2005. Public health implications of meat production and consumption. *Public health nutrition*, 8(04): 348–356.

Wallis DeVries, M.F., Poschlod, P. & Willems, J.H. 2002. Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna. *Biological Conservation*, 104: 265–273.

Watanabe, F. 2007. Vitamin B12 sources and bioavailability. *Experimental Biology and Medicine*, 232(10): 1266–1274.

Webb, J. and Archer, J.R. 1994. Pollution of soils and watercourses by wastes from livestock production systems. In *Pollution in Livestock Production Systems*. Dewi, I.A., Axford, R.F.E., Marai, I.F.M. & Omed, H.M., eds. Oxfordshire, UK. CABI Publishing, 189–204.

Wei, H-G, Yang, P., Wang, Y, and Xie, Z. 2004. Use of rural energy resources and eco-environmental degradation in Tibet. *Journal of Environmental Sciences* 16(6): 1046–50.

Weir, S. 1999. The effects of education on farmer productivity in rural Ethiopia. *The Centre for the Study of African Economies Working Paper Series*, 91.

WHO. 2014. Global Health Observatory (GHO) Data. *Mortality from household air pollution*. (also available at www.who.int/gho/phe/indoor_air_pollution/burden_text/en/).

WHO. 2015. *Maternal mortality*. Fact sheet, Updated November 2016 www.who.int/mediacentre/factsheets/fs348/en/

WHO. 2016. *Antimicrobial resistance – Global action plan on antimicrobial resistance*. ISBN: 078241509763.

WHO. 2017. *Obesity and overweight – Fact sheet*. [online]. [Cited 15 May 2018]. www.who.int/mediacentre/factsheets/fs311/en/

Wilson, J., Deinum, B. & Engels, F. 1991. Temperature effects on anatomy and digestibility of leaf and stem of tropical and temperate forage species. Netherlands Journal of Agricultural Science, 39: 31–48.

Winters, L.A. 2001. Trade policies for poverty alleviation in developing countries. In B.Hoekman, P. English & A. Mattoo, eds. *Trade policy, economic development and multilateral negotiations: a sourcebook.* Washington, DC, The World Bank.

Witzke, P., Kempen, M., Pérez, I., Jansson, T., Skokai, P., Helming, J., Heckelei, D., Moro, A., Tonini, A. & Fellman, T. 2009. *Regional economic analysis of milk quota reform in the EU*. IPTS Report. Luxembourg, European Commission.

Woolhouse, M., Ward, M., van Bunnik, B. & Farrar, J. 2015. Antimicrobial resistance in humans, livestock and the wider environment. *Philosophical Transactions of the Royal Society B* DOI:10.1098/rstb.2014.0083): 15 pp.

World Bank. 2001. *Engendering development: through gender equality in rights, resources, and voice* (also available at siteresources.worldbank.org/PGLP/Resources/Engendering_Development.pdf).

World Bank. 2013. *The Role of Livestock Data in Rural Africa: The Tanzanian Case Study.* www.fao.org/resources/infographics/infographics-details/en/c/201887/

World Bank. 2014. *Clean and Improved Cooking in Sub-Saharan Africa – a landscape report*. Washington, D.C., USA. (also available at http:// documents.worldbank.org/curated/en/164241468178757464/pdf/98664-REVISED-WP-P146621-PUBLIC-Box1393185B.pdf).

World Bank. 2016. *Poverty and Shared Prosperity 2016: Taking on Inequality*. Washington, D.C., World Bank.

World Bank. 2017. *World Development Indicators.* Washington, D.C., World Bank. https://data.worldbank.org/products/wdi

World Resources Institute. 2005. Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis.* Washington, D.C.

Wrage, N., Strodthoff, J., Cahill, H.M., Isselstein, J. & Kaisers, M. 2011. Phytodiversity of temperate permanent grasslands: Ecosystem services for agriculture and livestock management for diversity conservation. *Biodiversity Conservation*, 20: 3317–3339.

Wyness, L. 2013. Nutritional aspects of red meat in the diet. In J.D. Wood and C. Rowlings, eds. *Nutritional and Climate Change: Major Issue Confronting the Meat Industry*. Nottingham University Press, pp. 1–22.

Xiao, Q., Saikawa, E., Yokelson, R.J., Chen P., Li, V. & Kang, S. 2015. Indoor air pollution from burning yak dung as a household fuel in Tibet. *Atmospheric Environment*, Vol. 102, February 2015, pp. 406–412. doi.org/10.1016/j.atmosenv.2014.11.060.

Yaméogo, N.D., Nabassaga, T. & Ncube, M. 2014. Diversification and sophistication of livestock products: The case of African countries. *Food Policy*, 49: 398–407.

Yi-Zhang, C. & Zhangen, Z. (2000). Shanghai: trends towards specialised and capital intensive urban agriculture. In N. Bakker *et al.* (eds), *Growing cities, growing food, urban agriculture on the policy Agenda*, pp. 467–475. Feldafing, Germany, DSE/ZEL.

Yisehak, K. 2008. Gender responsibility in smallholder mixed crop–livestock production systems of Jimma zone, South West Ethiopia. *Livestock Research for Rural Development*. 20:11. [online]. [Cited 15 May 2018]. http://www.lrrd.org/lrrd20/1/yise20011.htm

Yue, X.P., Dechow, C., Liu, W.S. 2015. A limited number of Y chromosome lineages is present in North American Holsteins. *Journal of Dairy Science*, 98(4): 2738-4.

Zezza A. & Tasciotti L. 2010. Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy*, 35: 265–273.

Zhang, W., Ziao, S. Samaraweera, H., Lee, E.J.& Ahn, D.U. 2010. Improving functional value of meat products. *Meat Science*, 86(1): 15–31.

For decades, the livestock debate has focused on how to increase production in a sustainable manner. However, the UN 2030 Agenda for Sustainable Development has shifted the emphasis from fostering sustainable production *per se*, to enhancing the contribution of the sector to the achievement of the Sustainable Development Goals (SDGs). This publication examines the sector's interaction with each of these Goals, as well as the potential synergies, trade-offs, and complex interlinkages. This global report is intended to serve as a reference framework that Member States and stakeholders can use as they engage in the transformation process of the livestock sector towards sustainability. It calls for an integrated approach towards livestock sustainable development, highlights the effective adaptation of the SDGs into specific and targeted national policy action as the major challenge ahead, and flags the steps in the implementation road map.

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