Chapter 1

ECO-AGRI-FOOD SYSTEMS

Photo: ©Shutterstock

What are 'eco-agri-food systems', and are they working?

Food is the ultimate source of energy and nutrients for every human, and is the basis for agricultural production around the world. Agricultural production systems link human diets to inputs used in agricultural production, to the diverse types and quantities of food (and feed), fuel and fibres produced, to the types of management and land use systems that produce them, to how they are processed, stored and transported to consumers, to how they are regulated and where they ultimately end up. From start to finish, these systems can be envisioned as intertwined threads that tie the health of the environment to the health of people[1].

The 'eco-agri-food systems' complex is a collective term for the fabric woven from these many system threads, encompassing the vast and interacting complex of ecosystems, agricultural lands, pastures, fisheries, labour, infrastructure, technology, policies, culture, traditions, and institutions (including markets) that are variously involved in growing, processing, distributing and consuming food.

Having set out what the eco-agri-food systems complex is, how can we determine whether or not it is functioning well?

The primary purpose of the eco-agri-food systems complex can be broken down into three broad objectives: (I) to ensure food security for all; (II) to improve social, economic and cultural well-being and secure over a billion livelihoods; and (III) to not compromise our ability to satisfy the needs of future generations[2]. We comment on each objective in turn.

Food security for all as a human right

One common metric for food security[3] is to consider the physical availability of food, which is related to levels of food production and supply, stock levels and net trade. Box 1.1 highlights the success of food production systems in meeting this objective.

Box 1.1 Food systems are producing more than enough calories to feed the world today[4]

- Since 1970, the amount of food available for every person for direct consumption has increased from 2370 to 2770 kcal/person/day.
- In aggregate, there is sufficient food available for everyone to be fed, and nearly everyone to be well-fed.
- However, owing to problems of access and distribution, some 2.3 billion people in developing countries live with under 2,500 kcal/day (500 million of which live with less than 2,000 kcal/day), while 1.9 billion in developed countries are consuming more than 3,000 kcal/day.

However, food security should also look beyond the supply side, and consider dimensions of economic and physical access to food, food utilization, and their stability over time[5]. These considerations reveal a very different reality of food security in the world (see Box 1.2), illustrating that food security is not simply a matter of producing enough calories per capita, but is much more deeply rooted in our social, economic and political systems.

Box 1.2 Is food security being achieved?

- Globally, an estimated two billion people are experiencing micronutrient malnutrition[6], and 794 million people are calorie-deficient[7].
- In contrast, global levels of obesity have more than doubled since 1980. Recent estimates show that over 1.9 billion adults are overweight, 600 million of which are obese[8].
- Vitamin A deficiency – the greatest preventable cause of needless childhood blindness and increased risk of premature childhood mortality from infectious diseases – still affects 250 million preschool children and a substantial proportion of pregnant women in lower-income countries[9].

Food security also depends on what proportion of the food that is produced is actually consumed (see Box 1.3).

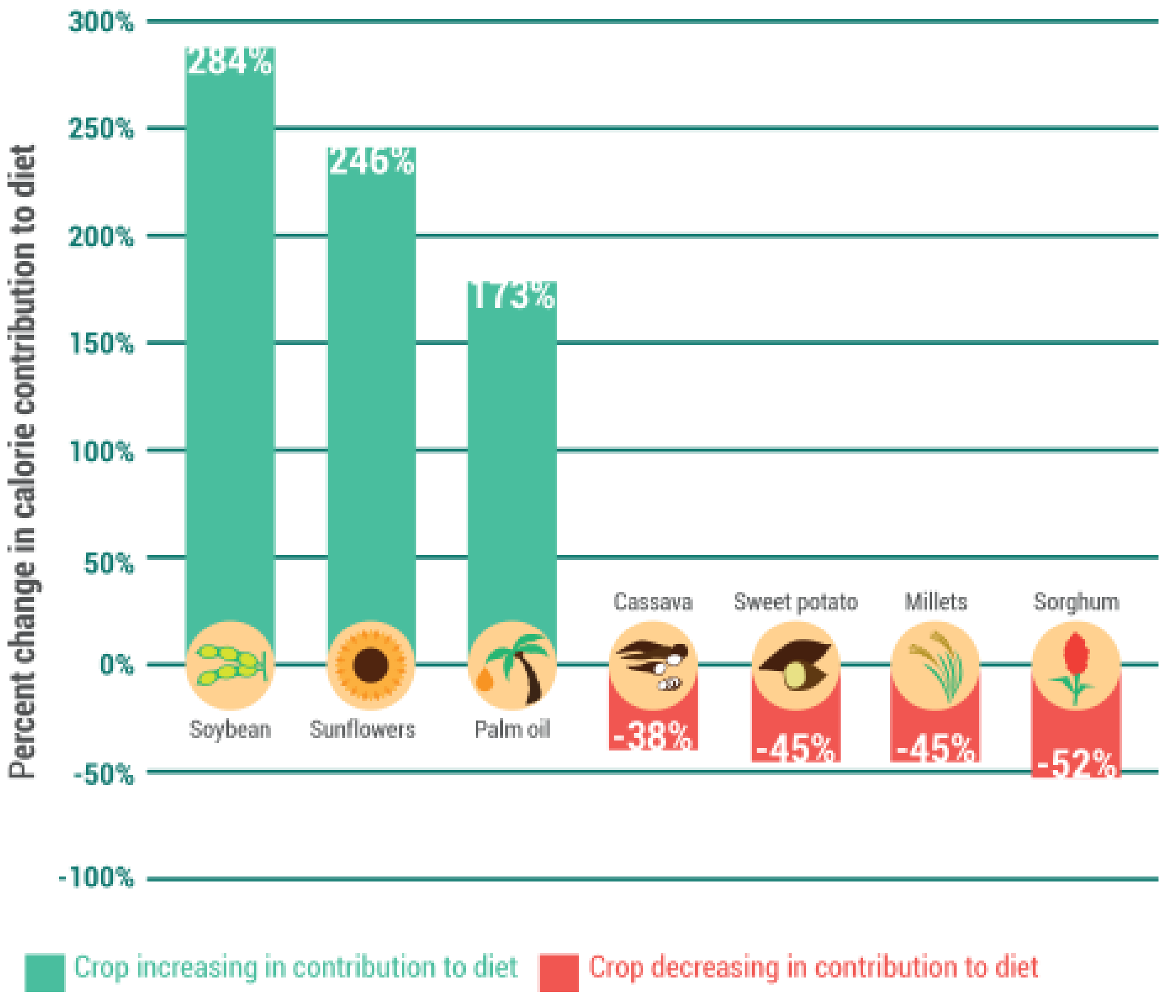
Box 1.3 One-third of all food produced never reaches a plate

- Approximately one-third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes — gets lost or wasted[10].
- An FAO report claims that, if food waste were a country, it would be the third largest emitter in the world in terms of GHG emissions (3.3 billion tonnes)[11].

It is increasingly recognized that a food system must also nourish - that is, provide a healthy, nutritional and well-balanced diet - and not simply supply minimum levels of energy. In an increasingly globalized world, in which a rising share of the population is becoming urban and middle class, and per capita income and consumption levels are rising, consumer demand for 'higher valued foods' (such as meat, dairy, processed food and food consumed away from home)[12] is increasing worldwide, with disastrous consequences for human health (see 'Physical health considerations' below).

Figure 1.1 illustrates another important global trend in the growing contribution of a few major oil crops to diets, and the falling share of regionally important staples. This is a trend that is impacting health in rapidly developing countries more quickly than projected[13], given that these local food crops are often more nutritious and better adapted to grow in local conditions[14].

Figure 1.1 Average change in the calories from crops in national diets worldwide, 1961-2009



Source: Khoury, C.K. et al. (2014) 'Increasing homogeneity in global food supplies and the implications for food security', *Proceedings of the National Academy of Sciences,* 111(11): 4001-4006.

In summary, there is a significant risk that the current food system may soon be unable to provide both adequate and nutritious food to the global population.

Improving well-being and livelihoods

Measuring human well-being has long been discussed and debated[15,16], and that is not the intention of this chapter. However, for the sake of simplicity, it is possible to divide well-being into socio-economic (employment, income), cultural and physical health considerations.

Socioeconomic dimensions

The agricultural sector employs over one billion people worldwide, representing one in three of all economically active workers[17]. In most low- and middle-income countries, agriculture remains the largest employer of the poor and is a major source of livelihoods through wage labour and production for household consumption and markets[18].

Family and smallholder farms are the predominant form of agriculture in the food production sector, but the vast majority of them are small (see Box 1.4) and poor. Indeed, agriculture and rural poverty are closely linked. While the rural poor are more likely than other rural households to rely on agriculture, output per worker is valued much lower in agriculture than in other sectors, resulting in low incomes for people who depend on agriculture for their livelihoods[19].

Box 1.4 The large world of small farms

- Family farms, i.e. those that are managed and operated by a family and predominantly reliant on family labour, make up more than 90 per cent of the world's farms[20].
- Family farms also occupy approximately 70 to 80 per cent of farmland, and are estimated to produce about 80 per cent of the world's food[21].
- In lower-income countries, an estimated 84 per cent of farms (or 475 million farms) are 'smallholder farms', i.e. smaller than two hectares[22].
- An estimated 2.5 billion people are involved in full- or part-time smallholder agriculture, while over one billion people living in rural poverty are dependent on agriculture for their livelihoods[23].

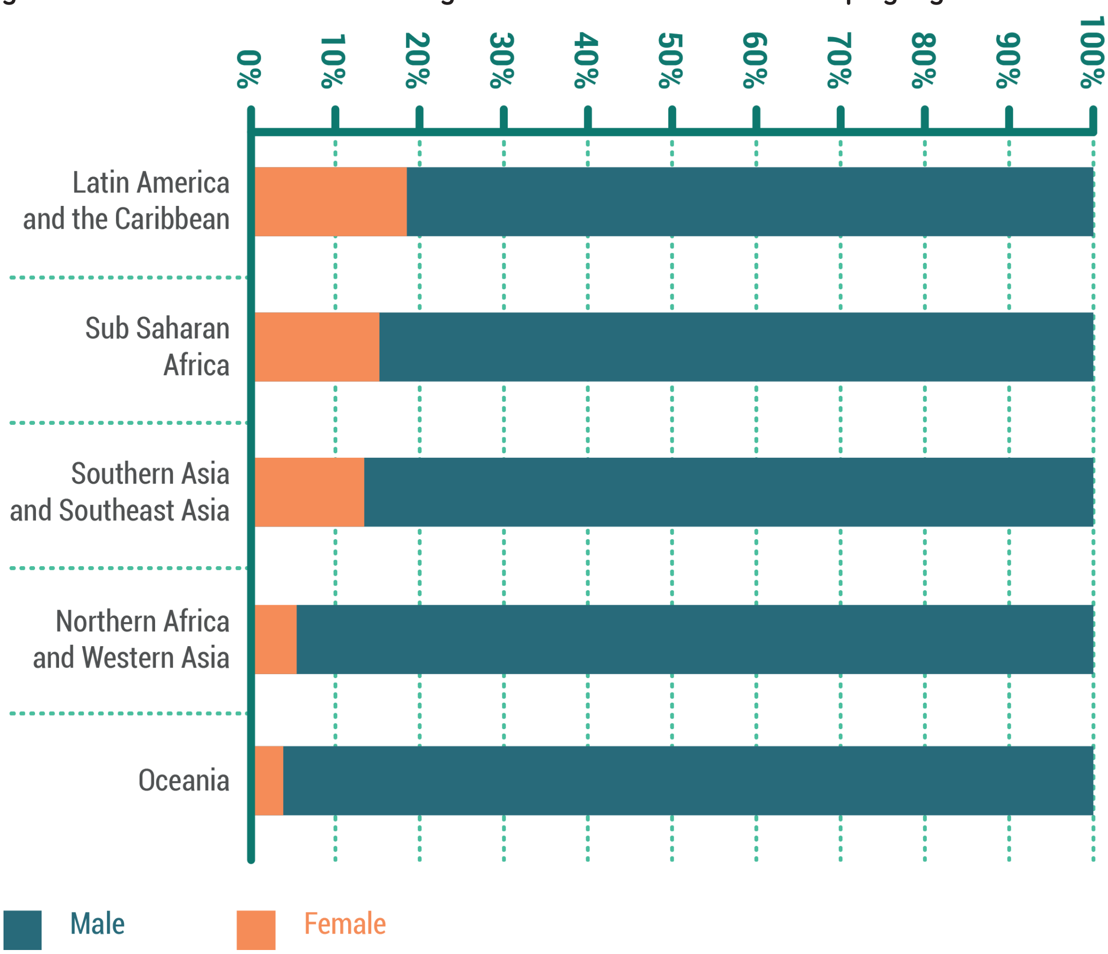
The role of women in agriculture, particularly in developing countries, is also one that deserves more positive attention, particularly with regard to the social and economic opportunities for closing the gender gap. Women comprise on average 43 per cent of farm labour in the developing world[24], whilst owning a tiny fraction of farms. Women also regularly face discrimination in rights and access to resources and support for farms.

These inequities are among the major gender-relative negatives (see Box 1.5) characterizing the role and fortunes of women in agriculture today, despite their central role in household welfare around the world. Indeed, empowering women in agricultural households has been demonstrated to not only improve farm productivity, but also produce wider benefits in improved health, nutrition and education outcomes[25].

Box 1.5 Women represent 43 per cent of farm labour in the developing world

- On average, women comprise 43 per cent of the agricultural labour force in developing countries; this figure ranges from around 20 per cent in Latin America to 50 per cent in parts of Africa and Asia, and exceeds 60 per cent in certain countries[26].
- Although largely restricted to growing food crops and rearing poultry and livestock, women are responsible for 60 to 80 per cent of food production in developing countries[27].
- However, women only represent between five and 30 per cent of all agricultural holders in main developing regions (see Figure 1.2).
- If women had the same access to productive resources as men, FAO estimates that they could increase yields on their farms by 20 to 30 per cent, raising total agricultural output in developing countries by 2.5 to 4 per cent[28].
- Closing the 'gender gap' in terms of access to agricultural inputs alone could lift 100 to 150 million people out of hunger[29].

Figure 1.2 Share of male and female agricultural holders in main developing regions



Source: FAO (2011), *The State of Food and Agriculture: women in agriculture - closing the gender gap for development*, Rome.

Cultural dimensions

Agriculture and food are an integral part of our heritage and cultural landscapes, and key to cultural identity. The underpin community values, festivity, social cohesion and tourism; agricultural landscapes are a location and source of recreation and mental/physical health, providing at times spiritual experience and a reinvigorating sense of place.

FAO estimates that about 500 million hectares around the world are dedicated to agricultural heritage systems that still maintain their unique traditions with a combination of social, cultural, ecological and economic services that benefit humanity[30].

Physical health considerations

Both agricultural production and consumption are directly linked to human health impacts.

While malnutrition and obesity have been mentioned, there is more to be said on the public health (as opposed to food security) dimension. For example, malnutrition is the cause of death for 3.1 million infants and young children every year, largely due to their high nutritional requirements for growth and development. This statistic accounts for 45 per cent of all deaths among children under the age of five, while malnutrition also leads to stunted growth among a further 165 million[31].

Overweight conditions and obesity, on the other hand, are major risk factors for cardiovascular diseases (mainly heart disease and stroke), which were the leading cause of death in 2012, as well as diabetes and some cancers[32]. As illustrated in Figure 1.3, it is projected that, by 2030, the global economic impact of obesity will be US$2 trillion in health costs (2.8 per cent of GDP), equivalent to that of smoking, war and terrorism[33].

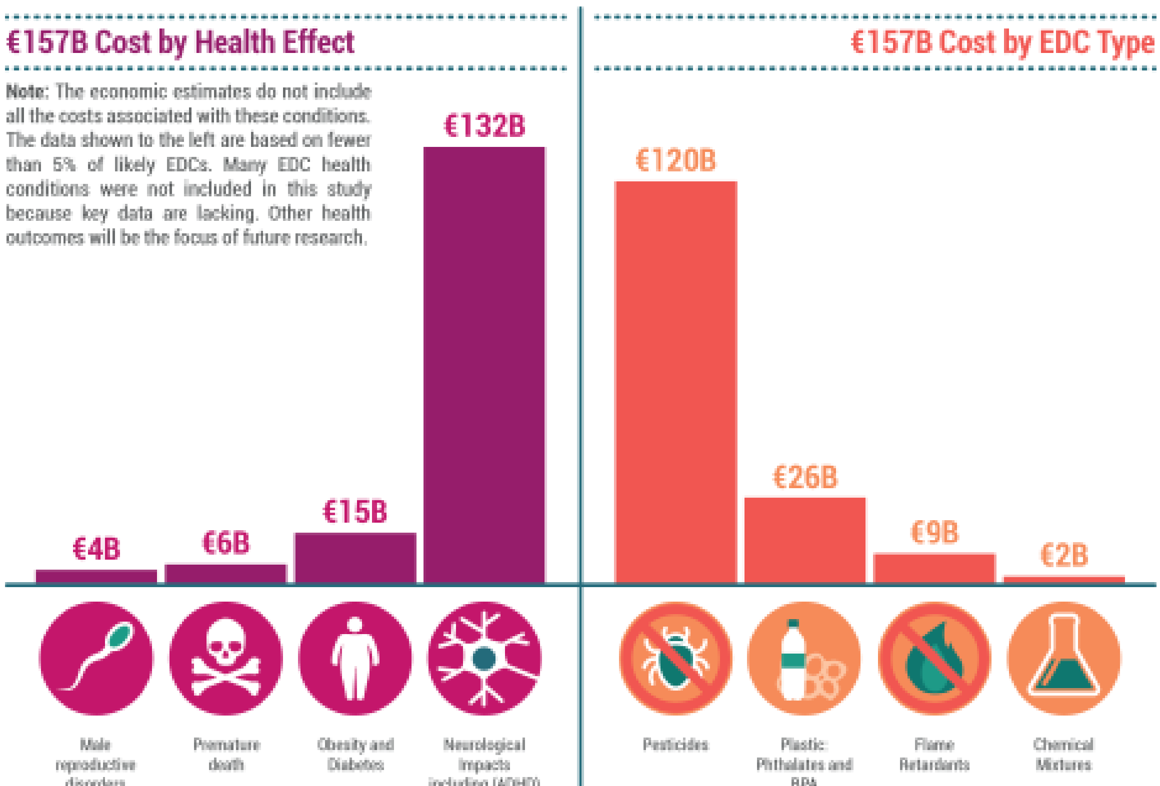
Figure 1.3 Percentage of global population that is overweight or obese (today and in 2030) and its economic impact

Source: Dobbs, R. et al. (2014) *Overcoming obesity: an initial economic analysis - discussion paper*, McKinsey Global Institute.

Health impacts are also a cause for concern on the production side of eco-agri-food systems, usually through exposure to agricultural chemicals or the use of antibiotics.

While research on the health impacts from exposure to agrochemicals is limited, evidence is starting to build. Recent research explores the health impacts of pesticides as 'endocrine disrupting chemicals' (i.e. chemicals that interfere with hormones). The results in Figure 1.4 show that, in the EU alone, pesticide exposure causes the highest annual health and economic costs at roughly US$127 billion, almost four times as high as the second highest category: plastics (which is also linked to eco-agri-food systems through the storage of edible goods)[34].

Figure 1.4 Health effects from endocrine disrupting chemicals cost the US$167 billion each year



Source: New York University Langone Medical Center (2015), accessed on 18 November 2015 [https://www.endocrine.org/news-room/current-press-releases/estimated-costs-of-endocrine-disrupting-chemical-exposure-exceed-150-billion-annually-in-eu].

Indeed, pesticides by their very nature are designed to be toxic, either to herbs, insects or fungi. However, the vast majority is distributed into the environment and the food chain, where they come into direct contact with humans.

Through direct and indirect exposure, an estimated 20,000 unintentional deaths occur every year as a result of pesticide poisoning[35], while causing acute adverse health impacts to anywhere between 1 and 41 million people[36].

The agricultural sector is also the world's largest user of antibiotics, estimated to use 70 per cent of all that is manufactured globally[37]. This use of antibiotics is suspected to create resistant strains of microbes in humans, posing serious threats to human health. For example, in the US alone, two million people each year develop antimicrobial resistant (AMR) infections, killing at least 23,000 people and incurring treatment costs of around US$20 billion on top of costs to society for lost productivity that are as high as US$35 billion a year, totalling US$55 billion per annum[38].

Fulfilling the needs of future generations

The needs of future generations are an integral part of the concept of sustainability. Today humanity uses the equivalent of 1.5 planets (or 18 billion global hectares) to provide the resources we use and absorb our waste[39]. As humans continue to cause irreversible damage to our biosphere and place unsustainable demands on the natural resources on which future food security depends, we bring into question the ability of our planet to accommodate humans and human actions.

In order for modern agriculture to become sustainable, it is imperative to preserve the natural resource base - including land, water, and biodiversity - as well as account for the contribution of agriculture to climate change.

Soils and land productivity

The year 2015 is the UN International Year of Soils. Soils are the basis for more than 90 per cent of food production[40], and yet every year, approximately 24 billion tonnes of fertile soil are lost due to erosion[41]. It is estimated that fertile soils can take hundreds, even thousands, of years to generate[42], which highlights the fact that current practices quickly become unsustainable.

Soils provide a critical service by storing more than 4000 billion tonnes of carbon whereas, by contrast, forests and the atmosphere store only 360 and 800 billion tonnes, respectively[43]. As a result of land conversion for crop production, carbon and nitrogen are lost from the soil, which can lead to substantial reductions in the role of soil as a methane sink[44]. Moreover, the loss of carbon and nitrogen also reduces soil organic matter, particularly humus, which greatly increases the water retention properties of soil[45], natural disease resistance in crops[46] and total yield potential[47].

Directly linked to soils is the question of land productivity. Due to severe land degradation (see Box 1.6) in developing countries over the past fifty years, usually in the form of increased

Box 1.6 Half of agricultural land is degraded

It is estimated that 52 per cent of land used for agriculture worldwide is moderately or severely affected by land degradation and desertification[48].

salinization of soil, nutrient depletion and erosion, the productivity of lands has decreased by as much as 50 per cent[49]. As a result, it is further estimated that some 50 million people may be displaced within the next ten years[50].

In contrast, several farming techniques and management practices exist that have proven to reverse these processes, for example by regenerating soil structure and attracting beneficial organisms within the soil food web.

Water

Irrigated agriculture currently draws 70 per cent of all water globally withdrawn from rivers and aquifers, despite the fact that rainfed agriculture is the predominant form of agriculture worldwide[51]. With food demand expected to continue to rise, global water demand is projected to increase by 55 per cent by 2050[52].

Nutrient pollution into water sources is arguably one of the most impactful consequences of agricultural systems, occurring primarily as a result of large increases in the use of fertiliser and manure, both of which are rich in nitrogen and phosphorus. The biogeochemical flows of nitrogen and phosphorus have been identified as one of the nine planetary boundaries that indicate safe operating spaces for humanity. They comprise two of three boundaries considered to be 'high risk'[53].

When excess amounts of these nutrients flow into nearby water sources due to run-off and wastewater discharge, a process known as 'eutrophication' occurs. This is when nutrients provide a food source for blooms of blue-green algae ('cyanobacteria') that, as they die and decompose, deplete water of oxygen and slowly choke aquatic life, creating 'dead zones' (see Box 1.7).

Box 1.7 400 dead zones[54]

Eutrophication has contributed to the creation of over 400 oceanic dead zones worldwide, primarily concentrated in Europe, eastern and southern US, and Southeast Asia. In total, these zones cover an area of 245,000 square kilometres, or greater than half the size of California.

Biodiversity

The conversion of natural habitats to agricultural land has major implications for biodiversity. As noted in the recent Global Biodiversity Outlook 4[55], agriculture is thought to cause around 70 per cent of the projected loss of terrestrial biodiversity. In particular, the expansion of cropland into grasslands, savannahs and forests contributes to this loss.

An estimated 60 to 70 per cent of global terrestrial biodiversity loss is related to food production, while 'regulating and maintenance' ecosystem services are under pressure[56]. Moreover, recent reviews have highlighted how land use change leads to a decline in biodiversity, including wild pollinators such as bees, flies, beetles, and butterflies[57]. Such environmental degradation can constrain the amount and stability of crop yield, which are essential components of human food security[58]. Indeed, land use change already has reduced the capacity of many ecosystem services to support human activity[59], including crop pollination and the yield of pollinator-dependent crops[60].

Apart from providing biomass in the form of food, feed, fuel and fibre, agriculture provides a variety of 'regulating and maintenance' services to the environment. Pollination, for example, is a crucial ecosystem service for crop production. Although crops can provide abundant resources to wild insect pollinators, the short duration of floral availability, the low diversity of resources, the application of insecticides, and the presence of tillage may limit the capacity of one crop species to support wild pollinator populations on its own[61]. Therefore, sowing crops that bloom in different periods may increase wild-insect populations. For example, in Sweden, bumble bee reproduction was improved in landscapes with both late-season flowering red clover and early-season mass-flowering crops[62]. As a result, an adequate proportion of cropland in heterogeneous landscapes with proper crop management can be beneficial to some wild fauna taxa[63].

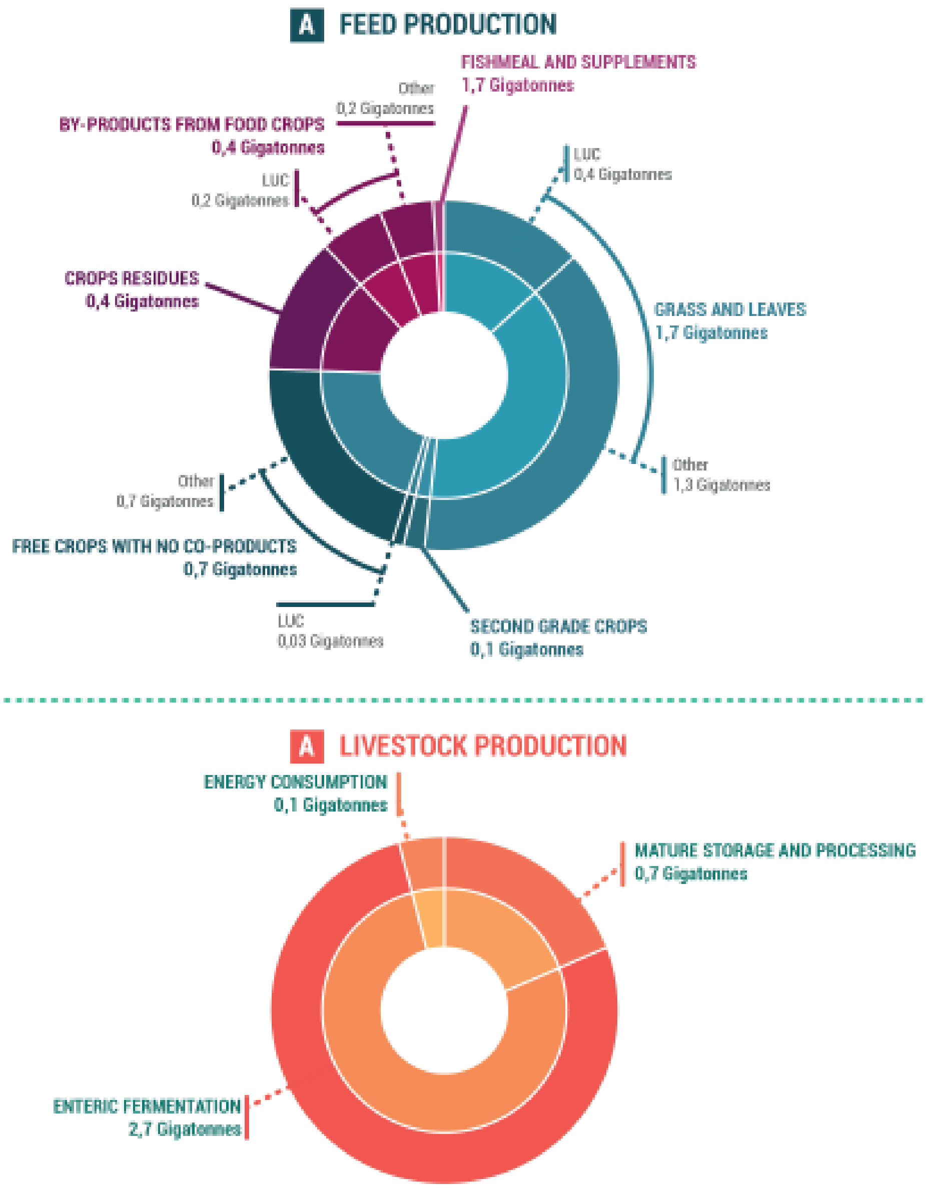
Climate change

Agriculture accounts for around 22 per cent of total greenhouse gas emissions (GHG)[64]. Within agriculture, the most emissions are caused by the livestock sector, which contributes 40 per cent of that total (roughly 14.5 per cent of total global GHG emissions), mostly in the form of methane (MH_4) and nitrous oxide (N_2O).

In terms of activities within the livestock sector, Figure 1.5 displays the two main sources of emissions within livestock: (A) 'feed production' including processing, transport and land use change (LUC); and (B) 'livestock production' including enteric fermentation (digestion and belching from ruminants), manure storage and processing, and energy consumption related to manufacturing. Feed production accounts for 45 per cent of the total from livestock, while livestock production accounts for 50 per cent, 80 per cent of which comes from enteric fermentation alone[65].

Under 'business-as-usual', global temperatures are projected to gradually increase up to 3.5°C higher by 2100 from climate change[66], with potentially dire consequences on agricultural production. For example, not only might crop yields be negatively impacted, but levels of carbon stored in the soil could be reduced as a result of faster decomposition and fewer inputs from shortened crop lifecycles. Moreover, land cover types like plantations and others with lower levels of biodiversity are expected to suffer more from climate change impacts due to lower resilience.

Figure 1.5 GHG emissions from global livestock supply chains, by production activities and products



Source: FAO, Global Livestock Environmental Assessment Model (GLEAM).

How does the eco-agri-food systems complex score overall?

While recognizing the centrality of agriculture and food to human well-being and sustainable development, essentially every statement on the future of agriculture acknowledges that a transformation is needed in the way the sector operates and how it impacts on the environment, human health and culture even if and while production is increased to meet food security needs[67, 68, 69, 70].

Another challenge facing current agricultural systems is that, in many parts of the developing world, conventional high-input agriculture has not – and has little chance – to take hold. In such regions, resource-poor farmers contend with issues of marginal high-risk environments, and experience poor yields just where food security is most vulnerable. The agricultural research establishment has only recently begun to focus increasingly on such sites, and to recognize that highly site-specific resource management systems are needed to sustain productivity under these conditions[71].

Yet the approaches which can address both the heavy negative impacts of conventional production systems and the challenges of resource-poor farmers have a central common thread: they recognize that agriculture and food systems of all kinds are biological and social systems. They can be designed to build upon and harness the forces of biodiversity and ecosystem services such that the processes that underpin agricultural production - soil fertility, natural pest control, pollination, water retention - are optimized and encouraged. This applies to all systems.

A report[72] on a "Biosphere Smart Agriculture in a True Cost Economy: Policy Recommendations to the World Bank" states:

"In the face of a rapidly overheating climate, collapsing fisheries, degraded soil, depleted water resources, vanishing species, and other challenges directly related to agriculture, we can no longer afford to pursue a flawed accounting system."

In summary, there are evidently many opportunities for re-evaluation and reform, along many dimensions of our agricultural systems. But we 'cannot manage what we do not measure', and that points to our first task: how do we evaluate the complexity of these systems in a manner which is universal, holistic and fair, enabling comparisons and choices to be made and responses to be optimized in a truly informed manner? As a step towards a framework for such evaluations, it is first important to understand the many invisible flows within the eco-agri-food systems complex, which are discussed and illustrated with an important showcase in Chapter 2.

1 Tillman, D. & Clark, M. (2014) 'Global diets link environmental sustainability and human health', Nature, 515, 518-522.

2 DeSchutter, O. (2010) Report submitted by the Special Rapporteur on the right to food, Sixteenth session of the Human Rights Council, United Nations General Assembly.

3 At the World Food Summit in 1996, food security was described to exist when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

4 Alexandratos, N. & Bruinsma, J. (2012) 'World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.

5 FAO (2008) 'An introduction to the basic concepts of food security', EC-FAO Food Security Programme.

6 WHO (2015) 'Micronutrient Deficiencies', accessed on 18 November 2015 [www.who.int/nutrition/topics/ida/en/].

7 FAO (2015) The State of Food Insecurity in the World. Rome.

8 WHO (2015) 'Obesity and overweight – fact sheet no. 311', accessed on 18 November 2015, [http://www.who.int/mediacentre/factsheets/fs311/en/].

9 WHO 'Micronutrient deficiency', accessed on 18 November 2015, [http://www.who.int/nutrition/topics/vad/en/].

10 FAO (2013) 'Food wastage footprint: impacts on natural resources - summary report', Rome.

11 Ibid.

12 Regmi, A. & Meade. B. (2013) 'Demand side drivers of global food security', Global Food Security, 2(3), 166-171.

13 Kearney J. (2010) 'Food consumption trends and drivers', Philosophical Transactions of the Royal Society of London B: Biological Sciences, 365(1554) 2793–2807.

14 Khoury, C.K., Bjorkmanc, A., Dempewolfd, H., Ramirez-Villegasa, J., Guarinof, L., Jarvisa, A., Riesebergd, L. & Struik, P. (2014) 'Increasing homogeneity in global food supplies and the implications for food security', Proceedings of the National Academy of Sciences, 111(11), 4001-4006.

15 Daly, H. & Cobb, J. (1989) For the Common Good: Redirecting the Economy Toward Community, Environment, and a Sustainable Future, Beacon Press: Boston.

16 Sen, A. (2004) 'Capability and well-being', in Nussbaum, M. & Sen, A., The quality of life, New York: Routledge.

17 FAO (2013) Statistical Yearbook 2013: World Food and Agriculture, Rome.

18 FAO (2014) The State of Food and Agriculture 2014: innovation in family farming, Rome.

19 Ibid.

20 FAO (2014) 'Family farmers: feeding the world, caring for the earth', accessed on 18 November 2015 [http://www.fao.org/resources/infographics/infographics-details/en/c/270462/].

21 Ibid.

22 FAO (2014) The State of Food and Agriculture 2014: innovation in family farming, Rome.

23 IFAD/UNEP (2013) 'Smallholders, food security and the environment', Rome.

24 FAO (2011) 'The role of women in agriculture', ESA Working Paper No. 11-02, Rome.

25 FAO (2011), The State of Food and Agriculture: women in agriculture - closing the gender gap for development, Rome.

26 FAO (2011) 'The role of women in agriculture', ESA Working Paper No. 11-02, Rome.

27 FAO (2009) 'Women and rural employment: fighting poverty by redefining gender roles', Economic and Social Perspectives Policy Brief 5, Rome.

28 FAO, 'Men and women in agriculture: closing the gap - key facts', accessed on 18 November 2015 [http://www.fao.org/sofa/gender/key-facts/en/].

29 FAO (2011), The State of Food and Agriculture: women in agriculture - closing the gender gap for development, Rome.

30 FAO (2013) 'Accenting the culture in agriculture', accessed on 18 November 2015 [http://www.fao.org/fileadmin/templates/giahs_assets/Information_Resources_Annexes/Success_stories/FAO_Publication_-_Partnering_for_Results._Ch_9_Accenting_the_Culture_in_Agriculture_GIAHS_.pdf].

31 Black, R., Victora, C., Walker, S., Bhutta, Z., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R. & Uauy, R. & the Maternal and Child Nutrition Study Group (2013) 'Maternal and child undernutrition and overweight in low-income and middle-income countries', The Lancet, 382(9890), 427-451.

32 WHO (2015) 'Obesity and overweight – fact sheet no. 311', accessed on 18 November 2015, [http://www.who.int/mediacentre/factsheets/fs311/en/].

33 Dobbs, R., Sawers, C., Thompson, F., Manyika, J., Woetzel, J., Child, P., McKenna, S. & Spatharou, A. (2014) 'Overcoming obesity: an initial economic analysis - discussion paper", McKinsey Global Institute.

34 Trasande L., Zoeller, R., Hass, U., Kortenkamp, A., Grandjean, P., Myers, J., DiGangi, J., Bellanger, M., Hauser, R., Legler, J., Skakkebaek, N. & Heindel, J. (2015) 'Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union', The Journal of Clinical Endocrinology and Metabolism, 100(4), 1245-55.

35 WHO (2003) The world health report 2003 – shaping the future, Geneva.

36 PAN (2010), Communities in Peril: global report on health impacts of pesticide use in agriculture, Manila.

37 WHO (2014) Antimicrobial resistance: global report on surveillance, Geneva.

38 Center for Disease Control and Prevention (CDC) (2014) Antibiotic resistance threats in the United States, 2013, Atlanta.

39 Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A. & Wackernagel, M. (2010) Ecological Footprint Atlas 2010, Global Footprint Network, Oakland.

40 IASS (2014) 'Fertile soils: fundamental in the struggle against hunger and climate change!', Potsdam.

41 UNCCD, 'Desertification, land degradation and drought (DLDD) - some global facts & figures', accessed on 18 November 2015 [http://www.unccd.int/Lists/SiteDocumentLibrary/WDCD/DLDD%20Facts.pdf].

42 Henrich Böll Foundation and Institute for Advanced Sustainability Studies (IASS)(2015) Soil Atlas 2015 - Facts and figures

about earth, land and fields, Berlin and Potsdam.

43 IASS (2014) 'Fertile soils: fundamental in the struggle against hunger and climate change!', Potsdam.[4]

44 Nazaries, L., Murrell, J., Millard, P., Baggs, L. & Singh, B. (2013) 'Methane, microbes and models: fundamental understanding of the soil methane cycle for future predictions', Environmental Microbiology, 15, 2395-2417.

45 Acharya, M., Rauchecker, M. & Wei, W. (2014) 'Determination of water absorption and water holding capacities of different soil mixtures with MINIDRAIN system to enhance the plant growth', Geophysical Research Abstracts, 14th EGU General Assembly 2014.

46 Dordas C. (2008) 'The role of nutrients in controlling plant diseases in sustainable agriculture: a review', Agronomy for Sustainable Development, 28, 33-46.

47 Johnston, A., Poulton P. & Coleman, K. (2009) 'Soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes', in Advances in Agronomy Vol. 101 (edited by Sparks D.), Academic Press: Burlington.

48 Economics of Land Degradation (ELD)(2015) The value of land, quick guide to the report, Bonn.

49 Bai, Z. (2008) 'Proxy global assessment of land degradation', Soil Use and Management, 24(3), 223-234.

50 UN, 'Desertification', accessed on 18 November 2015 [http://www.un.org/en/events/desertificationday/background.shtml].

51 UN World Water Assessment Programme (2014) The United Nations World Water Development Report 2014: Water and Energy, UNESCO: Paris.

52 Ibid.

53 Steffen, W., Richardson, K., Rockström, J., Cornell, S., Fetzer, I., Bennett, E., Biggs, R., Carpenter, S., de Vries, W., de Wit, C., Folke, C., Gerten, D., Heinke, J., Mace, G., Persson, L., Ramanathan, V., Reyers, B. & Sörlin, S. (2015) 'Planetary Boundaries: Guiding human development on a changing planet', Science, 347(6223).

54 Diaz, R.J. & Rosenberg, R. (2008) 'Spreading dead zones and consequences for marine ecosystems', Science, 321(5891), 926-929.

55 CBD (2014) Global Biodiversity Outlook 4: a mid-term assessment of progress towards the implementation of the Strategic Plan for Biodiversity 2011-2020, Montréal.

56 Kok, M. & Alkemade, R. (2014) 'How sectors can contribute to sustainable use and conservation of biodiversity', CBD Technical Series No. 79.

57 Vanbergen, A.J. & the Insect Pollinators Initiative (2013) 'Threats to an ecosystem service: pressures on pollinators', Frontiers in Ecology and the Environment, 11, 251-259.

58 Schmidhuber, J. & Tubiello, F. (2007) 'Global food security under climate change', Proceedings of the National Academy of Sciences, 104(50), 19703-19708.

59 Foley, J., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, S., Chapin, S., Coe, M., Daily, G., Gibbs, H., Helkowski, J., Holloway, T., Howard, E., Kucharik, C., Monfreda, C., Patz, J., Prentice, C. Ramankutty, N. & Snyder, P. (2005) 'Global consequences of land use', Science, 309(5734), 570-574.

60 Garibaldi, L., Carvalheiro, L., Leonhard, S., Aizen, M., Blaauw, B., Isaacs, R., Kuhlmann, M., Kleijn, D., Klein, A., Kremen, C., Morandin, L., Scheper, J. & Winfree, R. (2014) 'From research to action: enhancing crop yield through wild pollinators', Frontiers in Ecology and the Environment, 12(8), 439-447.

61 Ibid.

62 Rundlöf, M., Persson, A., Smith, H. & Bommarco, R. (2014) 'Late-season mass-flowering red clover increases bumble bee queen and male densities', Biological Conservation, 172, 138–145.

63 Garibaldi, L., Carvalheiro, L., Leonhard, S., Aizen, M., Blaauw, B., Isaacs, R., Kuhlmann, M., Kleijn, D., Klein, A., Kremen, C., Morandin, L., Scheper, J. & Winfree, R. (2014) 'From research to action: enhancing crop yield through wild pollinators', Frontiers in Ecology and the Environment, 12(8), 439-447.

64 Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E., Haberl, H., Harper, R., House, J., Jafari, M., Masera, O., Mbow, C., Ravindranath, N., Rice, C., Robledo Abad, C., Romanovskaya, A., Sperling, F. & Tubiello, F. (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, edited by Edenhofer, O. et al., Cambridge University Press: Cambridge and New York.

65 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.

66 IPCC (2014) Climate Change 2014: Synthesis Report, Bonn.

67 Foley, J., Ramankutty, N., Brauman, K., Cassidy, E., Gerber, J., Johnston, M., Mueller, N., O'Connell, C., Ray, D., West, P., Balzer, C., Bennett, E., Carpenter, S., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. & Zaks, D. (2011), 'Solutions for a cultivated planet', Nature, 478, 337-342.

68 Godfray, H., Beddington, J., Crute, I., Haddad, L., Lawrence, D., Muir, J., Pretty, J., Robinson, S., Thomas, S. & Toulmin, C. (2010) 'Food security: the challenge of feeding 9 billion people', Science, 327(5967): 812-818.

69 IAASTD (2009) Agriculture at a crossroads: global report, Island Press: Washington DC.

[70] Royal Society London (2009) Reaping the benefits: science and the sustainable intensification of global agriculture, The Royal Society: London.

[71] Altieri, M.A. (2002) 'Agroecology: the science of natural resource management for poor farmers in marginal environments', Agriculture, Ecosystems and Environment, 1971, 1–24.

[72] Imhoff, D. (2015) 'Biosphere Smart Agriculture in a True Cost Economy: Policy Recommendations to the World Bank' (p. 5), Foundation Earth and Watershed Media, Washington, DC & Healdsburg.