FOOD PRODUCTION AND NATURE CONSERVATION

Conflicts and solutions

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FEEDING THE 10 BILLION WITHIN THE SUSTAINABLE DEVELOPMENT GOALS FRAMEWORK

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1 Introduction

Global food security poses unprecedented challenges for humanity in terms of feeding the population and, at the same time, ensuring the sustainability of ecosystems. The coming decades will see increasing pressure on the global agri-food system as the global human population is predicted to continue to grow for the rest of the century (9.6 to 12.3 billion in 2100) (Gerland et al 2014). Greater per capita consumption, and westernization of diets (Pingali 2015), will intensify the competition for critical food inputs such as water, land and energy (Bird 2014). Climate change will also pose complex challenges to food and nutrition security and the sustainable intensification of food production (Golub et al 2013). The magnitude of the challenge is such that policy actions and investments are urgently needed across the entire food value chain in order to tackle demand, ensure sustainable intensification of food production and provide better governance to distribute food more equitably, as well as to enhance the resilience of the ecosystems (Grafton et al 2015a, McKenzie & Williams 2015).

Sustainable solutions for the production and supply of food should come from a mix of choices and diverse strategies involving a whole-of-systems social, economic and market approach at a scale that also integrates nature conservation into food policies. In order to sustainably feed humanity within planetary boundaries, a paradigm shift is needed to transition from enhanced productivity and reduction of environmental impacts to ecosystem sustainability as the entry point for all agricultural development (Billen et al 2015, Charles et al 2015, Chartres & Noble 2015, Dearing et al 2014, Poppy et al 2014, Rockstrom et al 2009, Rockstrom et al 2016). This will require investments in international public goods (IPGs), research, innovation, science, and technology, to support more sustainable production and consumption, regeneration of degraded agricultural ecosystems (Qadir et al 2015), promotion of resource recovery and reuse (RRR) (Drechsel et al 2015), and support for the transition towards the Circular Economy. How humanity tackles global food security issues also has profound implications for investment markets, sustainable management, and the efficient use of natural resources including water, nature conservation, equitable societies, future development pathways and outcomes and the prosperity of the global population.

The Sustainable Development Goals (SDGs) accord high priority to ending hunger – enhancing food security is interwoven within all the proposed 17 goals (OWG 2014). At least four SDGs focus directly on food-security issues: end poverty in all its forms (SDG1); end hunger, achieve food security and enhanced nutrition (SDG2); ensure sustainable water management and sanitation (SDG6); and ensure sustainable production and consumption patterns (SDG12). Rather than combining poverty and hunger in the same goal, as in Millennium Development Goal (MDG) 1, the proposed SDGs contain a dedicated goal on food security – SDG2. Beyond calorie intake, as in MDG1, SDG2 seeks to end "all forms of malnutrition", "hidden hunger" (deficiency of essential nutrients), and over-nutrition (obesity). Thus, there is widening agreement on two major issues (Webb et al 2015): first, the food security and nutrition goal cannot be achieved through agricultural production alone – targeted nutrition-sensitive interventions, with an emphasis on women and children, are needed as well; and second, the actions required cannot be proxied by a single target or metric – progress is needed on multiple fronts, including investments in sustainable agriculture, nutrition-sensitive actions, and social safety nets, to achieve food and nutrition security. What is also new is a clear target to "double the agricultural production and incomes of small scale producers through secure and equal access to land, inputs, markets and non-farm employment" (SDG2.3). The SDG2 on food security also covers the environmental sustainability dimensions – "ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems", highlighting the need to link food production with nature conservation to protect ecosystems and to improve soil and land quality.

The SDGs are still evolving and science-based contributions are emerging; for example, the Bill and Melinda Gates Foundation (BMGF 2014), European Commission (2014), German Development Institute (Funch 2015), UK government (ODI 2015), UN Sustainable Development Knowledge Platform (HLPE 2015) and Key IFPRI Resources provide evidence for supporting greater investment in sustainable agriculture to end poverty and hunger, and priority investments in sustainable water management (FAO & WWC 2015, Wichelns 2015a) to achieve water-related SDGs (van der Bliek, McCornick & Clarke 2014, ABD 2016).

In this chapter we address issues of sustainable agriculture, water management, resource recovery and reuse, and national policies for food security and nutrition within the framework of the SDGs. We focus on SDG2, dedicated to ending hunger and enhanced food security, as well as other SDGs related to sustainable agriculture, improved food security and nutrition, resource recovery and reuse, and nature conservation. The analysis first discusses the linkages between food security and all the SDGs, with a focus on those that seek to end poverty, end hunger and enhance food security (section 2), and then discusses issues of sustainable water management for food security, including the water, food, and energy nexus, land degradation, and business models for resource recovery and reuse (section 3). It then examines the impacts of global climate policy on food security by considering low-carbon-economy policy and the nutritional transition towards low-emission development pathways, as well as policies for nature conservation to minimize the harm to biodiversity of producing more food globally (section 4). Pro-poor national policies and investments to end hunger (section 5) and, finally, global actions to invest in IPGs to enhance food security are presented (section 6).

2 Global food security and the SDGs framework

The MDGs made a profound difference to the lives of many people by halving global poverty five years ahead of the 2015 timeline and enhanced food security for millions around the globe (UN 2015). There was important progress across the majority of goals, but with notable exceptions; progress was uneven and MDGs were unfair, for instance, in sub-Saharan Africa (Easterly 2009), where issues of poverty and food security are most intense and continue to be a drag on human dignity, equality, equity, and prosperity. Southern Asia also lags behind. The majority of the global extreme poor/food insecure live in a few countries (India 33%, China 13%, Nigeria 9%, Bangladesh 5%, Democratic Republic of the Congo 5%, others 13%). Greater efforts are needed in the areas where advancement has been too slow and has not reached all people (UN 2015).

The SDGs make sustainability a core element of the future programs to feed humanity. Amid notable progress in ending hunger (12% in 2015, down from 24% in 1990 benchmark) and enhancing food security (UN 2015), major trends that threaten environmental sustainability continue, although examples of best practice on sustainability do exist (Schulte et al 2014). The SDGs framework addresses key systemic barriers to sustainable development – such as rising inequality that puts the breaks on sustainable growth and poverty reduction; unsustainable production and consumption patterns; weak institutional capacity; and environmental degradation amid unmet food needs, unstainable production patterns beyond the regional thresholds and carrying capacity of the ecosystems, and changing lifestyles that in some areas are already crossing safe operating space and planetary boundaries (Rockstrom et al 2009).

The SDGs seek to integrate the social, economic, and environmental dimensions of sustainable progress to end poverty, achieve zero hunger, and enhance food security. In that *people, planet and prosperity* are the core focus of SDGs, individual wellbeing is essential to sustaining and passing on to the next generation(s) the gains in health, productivity, and social engagement of families in communities that underpin the sustainable development agenda (OWG 2014). The goals must address the interlinked challenges of climate change, food security, water management, health, and others with a clear vision or big picture for people and the planet and the ultimate overarching end goal – *a prosperous world with high quality of life that is equitably shared and sustainable* (ICSU & ISSC 2015). There is no clear means–ends continuum or theory of change underpinning the SDGs framework to help project how the ensuing socio-ecological change and impact pathways will enhance the social and economic development of a country.

All the SDGs matter for food security and most are mutually supportive and interlinked. For instance, if production patterns can be aligned in the direction of sustainability globally (SDG12), this will also support the achievement of food security (SDG2). A reduction in inequality within nations (supporting SDG10) also involves gender equality (SDG5) and would accelerate economic growth that is pro-poor and contributes to a reduction in poverty and gains in food security. Integrating explicit nature conservation objectives within regional, national and international food policies can help to address the widespread tradeoffs between agricultural yield and biodiversity. Likewise the linkages between SDGs and food security are multi-directional, both direct and indirect (Table 2.1) (BMGF 2014, ICSU & ISSC 2015, OWG 2014, Webb 2014, Webb et al 2015), such that food security represents both *inputs* to and *outcomes* of the overall *objectives* within the framework of SDGs.

TABLE 2.1 Linkages between food security and the Sustainable Development Goals

SDG		*Contribution of SDG to food security*	*Contribution of food security to SDG*
1	End poverty	Gains in income cut stunting, wasting, undernourishment	Improved labor productivity, income, intelligence, longer lives, access to water and basic services
2	End hunger, promote sustainable agriculture	Zero hunger, better, regular nutritious diets, to conduct active lives	Better maternal and child nutrition, life outcomes, and healthy workforce
		Sustainable agri-food systems build food barriers against hunger, improve income, assets, investments	Greater, sustainable food production, consumption, off-farm jobs, *also some trade-offs with the environmentally focused goals* (SDG 6, 13, 14, 15)
3	Ensure healthy lives	Better child nutrition, growth, and less disease burden in later life	Lower sickness, mortality, national disease burden, food–health synergies, age not affecting work capacity
4	Ensure inclusive education	Better food choices, incomes, food, nutrition, health outcomes, sustainable agriculture, healthy lifestyles	Better school attainment, mental capacity, social development, understanding of nutrition, sustainable agriculture

5	Achieve gender equality	Gains in child nutrition, women's status, earnings, assets, delays in marriage and first birth, micronutrient deficiencies	Girls, youth, and women with better ability and performance at school and in work life, women's central role in food, water, sanitation, agriculture
6	Ensure sustainable water management and sanitation	Improved food productivity, processing, hygiene, nutrition outcomes, also cuts to pollution and food-chain contamination	Clean, green, resilient agri-food systems, high return on investment. Demand for quality sanitation, resource recovery and reuse, and circular economy. *Also competition for investment, land, water (biofuels)*
7	Ensure sustainable energy	Reduced time burden of women, indoor pollution, sickness, safety risk	Greater demand for food, fuel, electricity, refrigeration, food processing, food safety
8	Promote sustainable growth	Green, clean, inclusive, resilient growth moves people from poverty to prosperity, adequate and quality diets, greater public investments in food security programs	Stimulates inclusive growth, labor productivity, income, decent employment, human capital formation
9	Build resilient infrastructure	Innovations in value chain, agri-food systems, marketing, food safety, diet quality, science impact, and communication to poor. Less disasters, loss, relief costs	Supported learning potential, agro-industry, thriving markets, demand across food systems; upgraded rural infrastructure, agri-technology adoption, better use of land, water, investments
10	Reduce inequality	Balanced productivity, social equity investments, land reforms, governance, greater growth but fewer blind spots	Resolves stunting, current inequality in nutrition, transmission to future inequalities
11	Make cities and settlements safe and sustainable	Food demand supports rural economic activity, enhancing urban food security, less water waste supports nutrition gains in both	Lower morbidity, mortality, fertility, population pressure on natural resources, reduction of disasters in settlements, better rural–urban connections
12	Ensure sustained consumption	Supports food-production patterns, quality, safety, diet diversity, good nutrition year round, less obesity	Greater demand for higher quality, organic, low carbon, diverse diets, lean consumption, fair distribution, resource recovery and reuse (RRR)

(continued)

TABLE 2.1 *(continued)*

SDG		*Contribution of SDG to food security*	*Contribution of food security to SDG*
13	Take urgent action to combat climate change	Mitigate enormous negative impacts on agriculture, food chain, crops, livestock, fish, poor people	Hardy landraces, resilient crop varieties, traits, conservation on-farm and in local seed banks, supporting vitality and resilience of agriculture; however, agriculture also impacts climate change, but net positive impact approaches are available in agriculture and forestry sectors
14	Conserve and sustainably use resources	Oceans, seas, marine resources as bases supporting global food security, ocean and artisanal fish as "bank in the water"	Improvements in marine food system, product choices, attention to sustainability, phosphorus recovery from oceans, but also tradeoffs from pollutant run-off and coastal land clearing
15	Protect terrestrial ecosystems	Land, crops, forests, animals, biodiversity, and nature are greatest resource among all the bases for food security. Indigenous knowledge, local practices mean equitable food access	Provides safe operating space, creates thriving businesses, broadening food diversity and informed food choices, to halt degradation, improve natural resource management, also potential tradeoffs such as halting biodiversity loss
16	Promote peaceful and inclusive societies	Peace and economic equality uproot conflict, destruction, crime, malnutrition, and build robust institutions, governance, fiscal capacity	Justice, accountability, governance, improved dialogue, engagement, effective policy, improves prospects for peace
17	Strengthen the global partnership	Shared interests, responsibilities, not just governments/agencies but multi-actor landscape, incentives for delivery of SDGs, and monitoring of all the SDGs	Global priority on food security, zero hunger, and scaling up nutrition offers innovation platforms for renewed investments in SDGs. Enhanced finance, technology, capacity, and policy coherence

Source: Authors' synthesis, based on the literature (BMGF 2014, ICSU & ISSC 2015, OWG 2014, Webb 2014, Webb et al 2015).

SDG1. End poverty

This SDG notes that poverty is a global and multidimensional issue that requires a multi-faceted approach in order to completely eradicate chronic/extreme poverty and reduce the transient poverty which arises due to seasonal fluctuations in income/consumption. Actions are needed everywhere – in both developing and developed countries. Data shows that transient poverty often constitutes nearly half of the total poverty in Asia (India, Sri Lanka, Pakistan) (Hussain & Hanjra 2003) and requires only low-cost, short-term interventions to reduce fluctuations in income/consumption, such as microcredit, seasonal jobs, and crop/livestock insurance programs. Ending poverty must avoid negative tradeoffs for the poor; for instance, transition to a low-carbon future without appropriate social protection could be inequitable for the poor, due to the effects on food prices and potential implications for food security (Bindraban et al 2009).

Better nutrition equals less poverty (World Bank 2006, World Bank 2013), and ending poverty, in all its forms, also contributes to food security (Webb 2014); malnutrition results in direct productivity losses to individuals and lower lifetime earnings (10%) and in loss of annual national output (average 2–3%) (World Bank 2006); poor nutrition inflicts higher income losses in Asia and sub-Saharan Africa (11% GNP) (Horton & Steckel 2011); obesity has high economic costs (Finkelstein et al 2010), for instance in China (8% of national income by 2025, double from 2000) (Popkin et al 2008); whereas tackling most forms of food insecurity and under-nutrition for mothers and infants offers a high return on investment (ROI) with a benefit-cost ratio (BCR) of 15:1 ($15 return per $1 invested). For countries with a high burden of child stunting the BCR ranges from 4:1 (Democratic Republic of the Congo) to 48:1 (Indonesia) (Hoddinott et al 2013) – far higher ratios than the investments in public health (Jamison et al 2013, Stenberg et al 2013). Thus, investments in food security and nutrition represent essential investments to end poverty. "Pursuing economic growth will rapidly reduce income poverty but not malnutrition" (World Bank 2006), despite providing budgetary resources for governments to support interventions for broader economic development (Webb 2014).

SDG2. End hunger, achieve food security

The world as a whole is food secure, yet hunger and food security issues continue to affect millions worldwide. One in eight people (approximately 840 million) in the world suffer from chronic hunger (UN 2015). Hunger continues to decline across the globe but there is uneven progress in reducing undernourishment – defined as individuals unable to obtain enough food regularly to conduct an active and healthy life (14% in 2013, down from 24% in 1990) (UN 2015). One in seven children (approximately 100 million) in the world remain underweight, one in four children remain stunted (UN 2015), and stunting, wasting, and micronutrient deficiencies are estimated to underlie nearly 3.1 million child deaths annually across the globe (Bhutta et al 2013). Nutritional deficiencies account for an annual burden of 85 million disability life adjusted years (DALYs) (Murray et al 2012), and obesity accounts for 94 million DALYs (Lim et al 2012).

Evidence-based interventions and nutrition-sensitive approaches offer higher payoffs. Investments in reducing child stunting and wasting have phenomenal returns of 15 times higher than the costs (Bhutta et al 2013), as they lead to lifetime benefits; the discounted cost of implementing evidence-based interventions is around $370 per DALY saved (Bhutta et al 2013). The benefits are far greater if direct nutrition-specific interventions to avert maternal and child malnutrition and micronutrient deficiencies can be linked to nutrition-sensitive approaches (Ruel & Alderman 2013) – agriculture, women's empowerment, agri-food systems, schooling, education, employment, social protection, and safety nets (Bhutta et al 2013). Yet, there is relatively limited evidence to support scaling up of food security and nutrition interventions. Effective delivery platforms and delivery options are needed to engage poor populations and promote behavioral change for the testing and uptake of interventions at scale.

Ending hunger and enhancing food security would reduce the *social burden* of sickness and premature deaths, the *economic burden* of lost productivity and the escalating healthcare costs, generating *intergenerational benefits* not only during lifetimes but across generations (Black et al 2013).

Smarter policy implications can be drawn by examining different dimensions of food security; for example, children who are underweight and child stunting might co-exist alongside good access to sufficient food. Here, sustainable food production is one factor, but not the only one, in enhanced food security. Food security must underpin human development by enhancing capabilities beyond food entitlements, access, and livelihoods, to nutritional capabilities (Burchi & De Muro 2015). High payoffs could come from improving the nutritional aspects of food security through nutrition-enhancing interventions which include all-encompassing improvements in health, hygiene, water, and sanitation, especially safe water storage, maternal education, preferential breast feeding during the first 1,000 days, and others. To date there has been too much emphasis on the access and availability aspects of food security. A paradigm shift is needed to fully capture the complexity of food security and its different dimensions by considering a broad range of issues involving agriculture, water, natural resources, livelihoods as well as policy, institutions, and incentives.

3 Sustainable agri-food systems

Sustainable agriculture can itself directly contribute to the three interrelated SDG dimensions to end hunger, achieve food security, and improve nutrition, as these are intimately linked. There is a two-way causal link with sustainable agriculture, including (Pinstrup-Andersen 2011): the impact of agriculture on food security and nutrition; health and nutrition in turn affecting agriculture and food systems via sickness and impaired productivity leading to lower up-take, the continued use of traditional technology and sub-optimal use of land, water, investments, and other resources that poor men and women already have access to. At best, there is a weak link between agriculture and improved nutrition; sustainable agriculture alone will not address nutritional issues.

Amid global change, dynamic pathways are needed to link consumers and producers with sustainable and healthy agri-food systems (food safety, water security, sanitation, hygiene) through public policy actions and investments, including private investment.

Sustainable water management solutions for food security

Ensuring the availability and sustainable management of water and sanitation for all is a key SDG (SDG6) with linkages to other goals and stronger synergies for ending hunger and enhanced food security, but also some potential tradeoffs with nature conservation and biodiversity that need to be managed. The evidence for the nutritional effects of agricultural programs is limited (Ruel & Alderman 2013). However, substantial evidence exists regarding the need for investments in water management to boost food production, increase incomes, keep food prices low, and make food available and affordable for the vast majority of consumers in rural and urban areas (Namara et al 2010). For example, the World Economic Forum's *Global Risks Report 2016* ranks water crises as a top long-term global risk for the next 10 years (Figure 2.1).

To meet global food demand by 2050, agricultural production must increase by 60% (Farming First 2015). Solutions for a water-secure world exist (IWMI 2014) but suitable land, sustainable water, and timely investments are the key constraints. Many analyses show that by 2050 there will be enough water to feed the nine billion even on a diet of 3,000 Kcal per person per day (Hanjra & Qureshi 2010), provided that water resources are managed sustainably – through a combination of measures including expansion of irrigation, enhanced water-use efficiency in irrigated areas, improved productivity in rain-fed areas, and changes in diets (FAO & WWC 2015, UNESCO 2015, Wichelns 2015b). For instance, a vast range of opportunities exist for feeding the world sustainably while addressing tradeoffs between diet, nitrogen

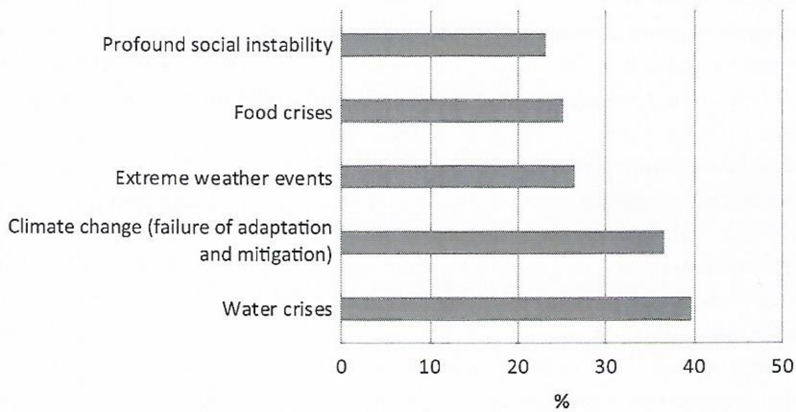

FIGURE 2.1 The global risks of highest concern by 2025 (World Economic Forum 2016)

contamination of soils and water, less international trade, and higher levels of inter-regional trade to co-optimize resource efficiency and enhance food security (Billen et al 2015). While the outlook for 2050 is encouraging, the emerging evidence on slowing crop-yield growth entails serious threats that must be addressed immediately (Ray et al 2013, Ray et al 2012). A multi-faceted and linked global strategy for sustainably and equitably feeding the people is needed (Godfray et al 2010).

Preliminary results from recent modelling studies (Grafton et al 2015b) indicate that crop-based food supply can meet food requirements by 2050 but this is only possible with "input intensification" – increased rates of water use in irrigated agriculture, fertilizer application, and continued annual gains in crop yield at 0.5% over the period. "Increased water withdrawals for agriculture with input intensification would, without any increase in withdrawals in the mining, manufacturing or households uses, place the world in the safe operating space in terms of overall water by 2050" (Grafton et al 2015b). Input intensification alone will leave a large food gap to 2050 in some 19 countries, especially in South Asia. Input intensification alone could further harm the environment and the sustainability of crop-based food supply. This will have to be achieved not just through intensification of agriculture, but through some form of sustainable intensification – involving the application of existing scientific knowledge and emerging principles for the sustainable management of land and water resources, backed up by improved national and regional governance strategies to minimize the ecological footprint of future food security and to link with nature, making agriculture more sustainable (Charles et al 2015, Chartres & Noble 2015, Rockstrom et al 2016).

Solutions for a water-secure world offer high economic and social benefits. For example, irrigated agriculture covers just 20% of agricultural land but contributes around 40% to global food production (Hanjra & Qureshi 2010). Past investments in irrigation have helped to protect communities across Asia against food insecurity and hunger. Yet, less than 5% of the land area in sub-Saharan Africa is irrigated and just 4% of the renewable water resources are drawn for agriculture (Hanjra et al 2009). Investments in irrigation can transform the opportunity structure of smallholders by integrating them into markets and making more productive use of their water resources for food security and greater wellbeing. This makes it necessary to renew investments in agricultural water management and irrigation so as to contribute to poverty reduction and increase gains in food security. Revitalizing irrigation is also a critical intervention for improving agricultural productivity so as to reduce poverty and build resilient communities in the face of hunger and climate change (Lankford et al 2016). Targeted agricultural programs can complement these investments by supporting income and employment opportunities, improving livelihoods, enhancing access to diverse diets for the poor, and fostering the empowerment of women. Data for the US (Troy et al 2015) show that irrigation essentially decouples crop yields from climate, such that investments in irrigation may be a beneficial adaptation to changes in climate extremes in coming decades (Ward & Crawford 2016).

Business models for financing irrigation are emerging and could also help to modernize smallholder farming systems and agri-food value chains and offset the cost of *public service provision while enhancing food security* (Hanjra et al 2016). However, there is a lack of information on how business models could leverage small-scale irrigated agriculture where issues of food and water security are most intense, systems are fragile or already under huge pressure, and private finances and local capacity are constrained. Also, very little evidence exists regarding the cost structure of large commercial farms and their social benefits.

Water, food, and energy nexus

Water, food, and energy are inextricably linked (Bird 2014). Energy and water are key drivers of economic growth to improve prosperity through local economic development and poverty reduction (Walsh et al 2014) and to underpin social development – education, health, clean drinking water, reduction of indoor pollution by replacing firewood with clean energy for cooking, and actualization of human rights including the rights to food and to water and sanitation. Global change also poses challenges to the nexus: of all the people on earth today around 2.5 billion have unreliable or no access to electricity, and 2.8 billion live in areas of high water stress. By 2035 energy consumption will increase by 35%, which will increase water consumption by 85%, thus increasing pressure on finite water resources (Schuster-Wallace et al 2015).

Hydropower is a core element of the water, food, and energy nexus primarily because most infrastructure projects were not commissioned to enhance food security, and also due to the seasonal nature and potential mismatch between demand for hydropower and the need for irrigation, as well as jurisdictional issues (e.g., central Asia) creating points of tension across sectors and at scale. For instance, the global energy sector is worth $6 trillion per year and thus is far greater than the water sector ($360 billion), such that the energy sector has greater leverage for investment and innovation (Freed et al 2010). Most investments in the energy sector come from the private sector and generate vast revenue for government programs, including the water sector (Schuster-Wallace et al 2015). Water for food is largely a social sector and most investments come from government revenue. Water and wastewater are heavily subsidized by state governments and foreign assistance worldwide. Policy disconnects are also common, and water and energy sectors compete for capital investments, whereas policy incentives are inadequate due to too lax or too stringent regulations and a mismatch between government priorities and those of foreign donors. Policy triggers are needed to develop sustainable energy solutions for enhancing food security.

Water-use efficiency programs can promote changes in behavior but may not always save water or energy. In agriculture, some caution is needed as such programs may not always save water (Ward & Pulido-Velazquez 2008) but will almost definitely raise energy consumption (Jackson & Hanjra 2014). The need for food security and to expand the area of irrigated land will drive water competition between the sectors, and additional demand could partly be offset by improving agricultural water productivity (Molden et al 2010). Interactions are pertinent where demand for water, energy, and land are increasing in agriculture and other sectors, particularly where efforts to sustain food security remain a high national priority, such as in Africa (Barron et al 2015, Mukuve & Fenner 2015, Nicol et al 2015).

Co-optimizing resource productivity, economic efficiency, and sustainability entails the identification and consideration of the tradeoffs for maximizing synergies among food security, energy access, and environmental sustainability goals (McCornick et al 2008). Quantification of tradeoffs to address the blue impacts of green energy (Bird 2014, de Fraiture et al 2008, Schuster-Wallace et al 2015, Jackson & Hanjra 2014) includes the following.

- Water for food security vs water for sustainable energy: the economic value of energy may be higher for the operator, while national food security and employment have social benefits which may far outweigh the economic benefits.
- Modern irrigation vs energy cost: a switch to modern irrigation systems such as drip and sprinkler systems to enhance efficiency of water use may not always save water but will inevitably increase energy costs and the carbon footprint when using surface water.
- Water vs greenhouse gas (GHG) tradeoffs: policies to cut GHG emissions can increase water use in the energy sector, due to increased demand for biofuels and surges in consumer demand for low-carbon foods.
- Hydropower vs agriculture: assessing tradeoffs in terms of environmental and social impacts and exploring opportunities for multi-purpose hydropower projects – and need for the energy sector to exploit non-freshwater sources such as saline waters collected in the drainage networks of irrigation systems – could show the way forward for synergies.
- Dry cooling vs cost of electricity: using wastewater for plant cooling, including in large business establishments and communication facilities, also offers alternatives, but their finances and economics need further study.

A land degradation-neutral world

Land degradation is extensive, covering approximately 23% of the world' terrestrial area, is increasing at an annual rate of 5–10 million ha, and affects about 1.5 billion people globally. Such vast impacts call for urgent action to halt land degradation (Stavi & Lal 2015). The SDG15.3 seeks to combat desertification, to restore degraded land and soil, including land affected by desertification, droughts and floods, and to strive to achieve a land degradation-neutral world by 2020. Salinity also affects rain-fed agriculture, especially in arid regions. The extent of salt-affected soils in irrigated areas continues to increase, i.e. 62 million ha in 2013, up from 45 million ha in 1990 (Qadir et al 2014). Currently, salt-affected soils occur within the sovereign boundaries of 75 countries; Bangladesh, India, China, Iraq, Pakistan, Syria, Central Asia, and downstream reaches of the Murray Darling Basin in Australia are the major salinity hotspots. Investments in sustainable land and water management policies and practices hold the greatest promise for halting land degradation (Khan & Hanjra 2008).

Recent evidence (Qadir et al 2015) suggests that a significant contribution to food, feed, and renewable energy security can be achieved by recycling and reusing saline water until it becomes unfit for any economic activity. This could potentially restore salt-affected soils, return salt-affected irrigated areas to higher levels of production, generate new business opportunities while obviating the need to expand agricultural areas and avoid the associated issues that this brings, and put land back into the service of nature and humanity.

Potential business opportunities from saline waters include (Qadir et al 2015):

- serial biological concentration of salts for income-generating crops, aquaculture, green energy and salt production for industrial and table use (California, Australia, China) (Blackwell et al 2005);
- saline drainage collector networks for energy production, involving small-scale, off-grid decentralized, and renewable energy generation using micro-hydro turbines along the natural flow of saline water in drainage collector networks (the Aral Sea Basin, Central Asia, China, India, Vietnam) (ADB 2003);
- profitable horticulture by harnessing solar energy for seawater desalination to produce freshwater for greenhouse irrigation (South Australia) (Sundrop Farms 2015);
- business opportunities for large-scale drainage water reuse in the Nile Delta, with mixed benefits, challenges, and opportunities (Omar 2011).

Examples of interventions for reversing and restoring salt-affected irrigated land include (Qadir et al 2015):

- phytoremediation of highly saline and abandoned farmland by growing salt-tolerant shrubs to restore field crop production (licorice production in Central Asia, with significant economic and medicinal value for the industry) (Kushiev et al 2005);
- agroforestry systems on salt-affected waste land, planting multipurpose salt-tolerant trees for biomass and bioenergy production (Central Asia, Amu-Darya River Basin in Uzbekistan) (Lamers & Khamzina 2008);
- large-scale remediation of sodic soils via gypsum application, supported by a number of coordinated actions and stakeholder engagement (Uttar Pradesh, India) (World Bank 2008).

Sustainable sanitation, and business models for resource recovery and reuse (RRR)

There is extensive scientific information linking sustainable water supply and sanitation with gains in health, labor productivity, food and nutrition security, and wellbeing (Bell 2015, Brands 2014). The evidence can be consolidated into sub-themes:

- water, sanitation, and health safety;
- ecosystem safety by incentivizing safe reuse of wastewater;
- protecting water quality/source, and increasing efficiency;
- urban agriculture with social benefits, including local food security;
- business approaches for promoting resource recovery and reuse (RRR), including nutrient capture, energy recovery, and wastewater reuse (emerging evidence) (Drechsel et al 2015).

Urban agriculture can play a substantial role in reducing urban poverty and food insecurity in much of Africa and Asia. Data from 15 developing or transitional economies show that engagement in urban agriculture contributes to dietary adequacy indicators (Zezza & Tasciotti 2010) and dietary diversity and may be associated with improved food consumption, with mixed but some positive impacts on stunting (Warren et al 2015).

Agricultural use ranks highest amongst all the wastewater reuses, yet the global and regional extent of direct and indirect use of untreated wastewater in peri-urban agriculture remains a major knowledge gap. New assessment approaches are emerging, for instance, using earth observation systems, novel data collection, and data integration. For example, early results from an ongoing International Water Management Institute (IWMI) study show that, globally, 24 million ha of irrigated croplands are located within urban agglomerations and 130 million ha of irrigated croplands are within 20 km of urban areas (Thebo et al 2014), indicating the overall relevance of wastewater reuse for global food security.

Business approaches for promoting resource recovery and reuse at scale are emerging (Drechsel et al 2015). The RRR cuts across SDG6 and SDG12: by 2030, substantially reduce waste generation through prevention, reduction, and recycling (OWG 2014). This entails RRR strategies, whereas the proponents of reuse often operate in fragmented and unsupported policy settings that are weakly linked to safety – safeguarding public health and environment. Sanitation service-chain models are emerging with support from authorities and businesses to promote the beneficial use of water, energy, and nutrients and offsetting the cost of sanitation service provision (Drechsel & Hanjra 2016). These business models offer significant social benefits, including safeguarding public health by removing excreta and excess nutrients from the environment, enhancing food security by closing the nutrient loop locally, and supporting a transition towards the Circular Economy (Figure 2.2).

Research on business models for revenue generation and improved cost recovery through value-added products and services will encourage private companies to provide services in areas currently not covered by the public network. However, there is a need to address the risks associated with reuse. To that end and scale, the tool newly developed by the World Health Organisation (WHO) (Gordon et al 2015), *Sanitation safety planning manual for safe use and disposal of wastewater, greywater and excreta*, can help many stakeholders along the sanitation–agriculture value chain to maximize the health benefits and minimize risks.

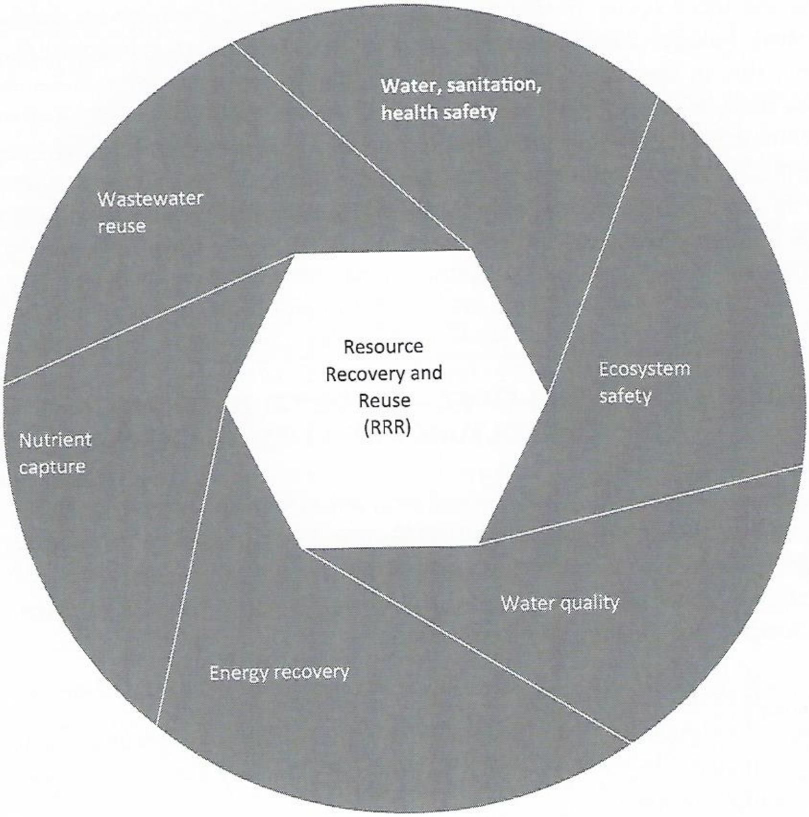

FIGURE 2.2 Resource recovery and reuse (RRR) for supporting the transition towards the Circular Economy (own elaboration)

4 Global climate policy impacts on food security

Climate change poses ever greater risk to humanity and greatly increases the vulnerability of food- and water-insecure people to weather events, droughts, flooding, and rainfall failure. Addressing this challenge requires both adaptation and mitigation (Bird et al 2016). Climate change adaptation is mostly related to sustainable water management and will increasingly necessitate investments in sustainable water management for agriculture to enhance adaptation, and also in climate mitigation strategies, as agriculture and food systems are a significant net contributor to global GHG emissions (Box 2.1) and must become climate smart or carbon neutral (Farming First 2015). In the Paris Climate Agreement (COP21 2015), the large number of countries that included agriculture in their climate commitments is an indication that agriculture has now become central to the climate debate. Agriculture will likely be *fully* included in future global agreements, with significant consequences for food and energy prices, production and consumption, finances, social equity, livelihoods, and climate justice. Carbon credits and food-security linkages demonstrate the need to look beyond global croplands and water use, to consider climate change and low carbon-economy policies along with their implications for food security in the twenty-first century. Yet there are almost no tools to quantify, define, validate, and report carbon credits in agriculture. Guidance and tools are emerging, for example LEAF (USAID 2015), as agriculture is a central focus of low-emission development strategies and achieving emission reductions requires a substantial amount of additional finance to be mobilized.

BOX 2.1 FARMING FIRST – GUIDE TO NEGOTIATIONS ON AGRICULTURE AND CLIMATE CHANGE

A recent guide by the CGIAR Research Program on Climate Change, Agriculture and Food Security (Farming First 2015) argues that, as climate negotiations gain momentum, it is timely to take action on agriculture, the sector that can ensure our future food security and play a key role in adapting to climate change and mitigating future emissions.

- Agriculture accounts for 14–24% of total global emissions.
- The cumulative cost of adaptation to climate change in agriculture up to 2050 is $250 billion globally – a cost that ultimately has to be borne by food consumers.
- Every $1 invested in climate-adaptation initiatives is estimated to save up to $7 in future relief costs.

Carbon markets have the potential to redefine future food security by changing the allocation of land and water resources and investments away from staple food production. Carbon markets are likely to redefine the very basic entitlements of food-insecure populations, the worst-affected of whom will be those whose entitlements are poorly recognized or defined informally – for instance, poor people and food-importing nations in Asia (Qureshi et al 2013). Carbon markets may not be positive for agriculture; for example, the Australian government's proposed Carbon Pollution Reduction Scheme (later scrapped) had the potential to reduce agricultural production by $2.2 billion per annum by 2020 and $10.9 billion per annum by 2030 (Jiang et al 2009). By 2030 the farm-gate price of beef was projected to rise by 5%, with the emission-permit cost being equivalent to 22% of the farm-gate price and a reduction of 8.5% in the net price actually received by the farmer – whereas consumers would pay higher food prices (Jiang et al 2009), and this could have serious financial implications for farmers (Maraseni & Cockfield 2015).

Nutritional transition towards low-emission development pathways

Less meat could mean more food, but affluent people tend to consume more meat (Stokstad 2010). Complementing beef demand with efficient converters such as poultry can help to reduce the pressure on water resources that emanates from dietary changes. However, concerns over avian flu and other health risks may deter consumers from such diets (Hassouneh et al 2012). Water pollution from intensive livestock production operations associated with manure management, feed production, and water use for stall flushing, such as in pig farms in China, the Philippines, Thailand, Vietnam, and Colombia can exert significant negative effects on surface and groundwater systems (for instance, groundwater became polluted within 10 years of the start of pig farms in Brittany, France (Yann Chemin, personal communication, March 2015)).

Discerning consumers may switch diets toward organic foods but they have lower resource-use efficiencies, i.e., production per unit area is lower than for conventional crops (Topp et al 2007). Transition towards low-carbon foods requires supportive policies, and innovative approaches are emerging. Data shows (Garnett 2011) that the best opportunities for reducing GHG emissions across the food chain exist at global, regional, and national scales by:

- targeting both GHG-intensive stages in the food chain (packaging, transport) and GHG-intensive food types (meat, dairy). Technological measures are suited to developed nations but are insufficient on their own to cut GHG emissions and often have environmental and ethical issues.
- shifts in consumption patterns, necessary to move diets away from the GHG-intensive foods of the affluent such as meat and dairy; these are needed in both developed and developing countries. This move seems initially beneficial to food-secure rich populations but has serious implications for the food security of the world's poor.
- sustainability labels such as 'food miles' and 'carbon footprint', now emerging on food products to raise consumer awareness (Warren et al 2015);
- transitions towards low-carbon foods that integrate agricultural, environmental, nutritional, and food-security objectives within wider discussions of sustainably feeding the future.

Nature conservation

Currently, agriculture and nature are disconnected (see Chapter 1); for instance, human interventions in nature such as large dams for hydropower and irrigated agriculture supporting food production contribute significantly to malaria risk, particularly in malarious areas of unstable transmission in sub-Saharan Africa (Kibret et al 2015). Such developments should take place in harmony with nature and include additional control measures to reduce the impact of dams. Food production must reconnect with nature to support sustainable food production and healthy ecosystems. Food production has historically increased, but with an escalating conflict with and footprint on nature – including biodiversity and habitat loss, land degradation, soil erosion, water pollution, and reduction in ecosystem services (Khan & Hanjra 2009). Greater efforts are needed to protect vulnerable species and agro-ecosystems within a matrix of agricultural landscapes and to include wildlife species within farming systems. Proactive national policies and global governance systems are needed for the integration of explicit conservation objectives into local, regional, and international policies and food-security goals to address the trade-offs in the management of land, water, energy, wildlife, other natural resource, and socio-economic systems.

Traditionally, most nature conservation policies and programs have focused on a protected-area system such as *land sparing* and set-aside programs (e.g., in the USA) that restrict development, including agriculture. For instance, about 15% of the land surface of the Earth is protected in parks and reserves; by 2020, this should reach the agreed global target of 17% (Hill et al 2015). Biodiversity loss continues apace, despite these global agreements and conservation actions, and is unlikely to stop any time soon.

The focus must extend from land to sea (SDG14), targeting biodiversity hotspots and increasing the connectivity across protected areas for their greater contribution to long-term sustainability of food production. Minimizing the harm to biodiversity of producing more food globally must also integrate production and conservation on the same land, e.g., wildlife-friendly farming; however, a large proportion of wildlife species cannot survive even in the most benign farming systems, such that protection of wild land will remain essential (Phalan et al 2011). Sustainable intensification can facilitate land sparing but requires as much attention to protecting habitats as to raising yield. Bringing degraded land back into production and the service of nature can also reduce pressure on wild and protected lands. Above all, restricting human requirements for land globally holds the greatest promise in limiting the impacts on nature and biodiversity (Phalan et al 2011). Evidence links biodiversity to ecosystem services and health to nature exposure (Sandifer et al 2015), thus, the connections between nature, biodiversity, and human health and wellbeing also offer opportunities to enhance human health and the conservation of biodiversity while advancing the SDGs on food security.

5 Pro-poor national policies and investments

SDGs offer the opportunity to nations and state governments to enhance food security and advance the poverty-reduction and shared-prosperity agendas through sustained investments in agriculture and rural infrastructure – especially higher research expenditure on agriculture and greater private sector involvement – and in tackling climate change issues. Greater publicly funded research and investment support are needed to inform smallholders' sustainable land use and intensification (tends to plateau at around 500–600 persons/km^2 in Kenya) (Muyanga & Jayne 2014) that will support the continuous intensification of smallholder crop, livestock, and fish production while conserving nature. Pro-poor policies and investments remain critically relevant today for all major regions including Asia, Africa, and Latin America to end hunger and advance social development. Food security issues can be best tackled locally through state interventions and national policies (Hanjra & Qureshi 2010).

6 International actions to enhance food security

International support is needed to strengthen efforts for the mobilization of domestic resource. This includes global investments to create IPGs, making climate change adaptation and food security a global political priority, and Big Data to strengthen the evidence base globally.

International public goods (IPGs)

Data shows that there are high economic returns and social payoffs from investments in agricultural research and development, especially where it creates and delivers global public goods such as those by the CGIAR and other organizations worldwide (Fan & Rosegrant 2008). The global donor community and governments must continue to make greater investment in agricultural research and development which contributes to ending poverty and hunger. The research on water security and agricultural water-management solutions (see www.iwmi.cgiar.org) also has an interface with environmental sustainability, ecosystem services, climate change, and broader SDGs (Jeremy Bird, staff communication, 8 May 2015), and contributes immensely to ending poverty and hunger and enhancing food security at scale. Financial crises and exchange rate movements such as those that have occurred during 2015 in the EU and Australia and the refugee crisis in Europe have resulted in huge cuts in public funding, with implications for the sustainability of core research programs on IPGs. There is, therefore, ever greater need to deliver a high ROI through the strategic prioritization of research programs. For instance, investments in RRR programs and partnerships with large municipalities across Asia and Latin America can bring new business opportunities, also contributing to protecting public health and the global commons, including the environment (Drechsel et al 2015). The global community must also develop regional food-security hubs and Global Development Labs (Box 2.2).

BOX 2.2 EXAMPLES OF GLOBAL EFFORTS UNDERWAY TO ADDRESS CLIMATE CHANGE AND FOOD SECURITY ISSUES

- *Feed the Future Program* is an inter-agency US government Global Hunger and Food Security Initiative.
- *Brazil Agropensa System*, established in 2013 by the Brazilian government, creates and delivers innovations for agriculture, both within Brazil and worldwide.

(continued)

(continued)

- *CGIAR's Research Program on Water, Land, Soil and Ecosystems (WLE) led by IWMI* with several Global Commons (van der Bliek et al 2014).
- *Climate Change, Agriculture, and Food Security Research Program* (CCAFS), involves all 15 research centers of the CGIAR to focus on climate risk management, agricultural adaptation, low-emissions agriculture, and national and global policy arenas.

Source: Authors.

Climate change adaptation and food security as a global political priority

Governments must place climate change and food and nutrition security at the center of international agreements, including those on climate and trade. Climate change and food security should become the cornerstone of public policy (Chicago Council 2014). Policy distortions that hinder food security should be removed. Infrastructure projects funded by donors must embed climate resilience. Governments worldwide must also make global food security one of the highest priorities of economic and development policy, and commit to a global food and nutrition security strategy, direct whole-of-government efforts on poverty and sustainable food security amid climate change (Chicago Council 2014), urge international action on climate change mitigation, and fund solutions for a water-secure world to promote adaptation.

Big Data and SMART indicators to monitor SDGs

Robust data and metrics on agricultural production, food and nutrition, and water management are critical for tailoring smart policies and investments to advance the SDGs. Basic data on food security and poverty, such as agricultural productivity and employment, are still missing across many developing countries. Most sub-Saharan African countries lack birth registers, food-production records, and basic data on access to water and sanitation and water use for crops and livestock. This is likely to limit the transition towards a rights-based approach to water for food security. Better data and assessment tools are needed.

Priorities for data collection in the context of food security include Big Data on agri-food systems, production, consumption and income, land use and its intensity, water availability, water use, water quality, wastewater reuse, sludge reuse, and future water requirements, weather, crop models, consumer preferences, and economic modelling. There is a need for a Data Revolution – better, faster, more accessible, and more disaggregated local data – to end poverty and hunger in local areas, enhance food security, and achieve the SDGs.

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