Chapter IV

UN Photo/Eskinder Debebe

Rural development within planetary boundaries

Introduction

A sustainable rural transformation is needed in order to achieve the Sustainable Development Goals (SDGs) by 2030. The objective of such a transformation should be to improve the lives of rural people while preserving the environment. Meeting this objective will require a shift in the current patterns of rural development towards greater emphasis on balancing the goals of eradicating poverty, protecting and preserving natural, landscape and cultural resources, and ensuring the sustainable production of food.

While sustainable rural development involves the realization of all the SDGs, the focus of this chapter is particularly on five environment-related Goals: SDG 6 (water and sanitation), SDG 7 (energy for all), SDG 13 (climate change), SDG 14 (life below water) and SDG 15 (life on land).

The chapter has two main objectives: *first*, to examine the impact of the current patterns of rural development on land, water, air, and biodiversity in general, and how this is affecting the achievement of the SDGs, and, *second*, to suggest ways in which rural development can be made more environmentally sustainable and conducive to the achievement of the SDGs by 2030. Agriculture is generally the core sector in rural areas, particularly in developing countries, in terms of both value and employment. In developed countries, where the sector is smaller, its environmental footprint is often significant. A special focus is thus given to agriculture when assessing the environmental impact of the current patterns of rural development.

The planetary boundaries framework includes nine of the core Earth system processes, which, if exceeded, could generate irreversible environmental change, endangering human existence and ecosystems in general.[1] The impact of the current rural development patterns on planetary boundaries, particularly with regard to agricultural production, manifests itself through multiple interacting channels, such as land-use change, greenhouse gas emissions, excessive water use and pollution, and loss of biodiversity. The state of the nine planetary boundaries greatly affects the future of rural development and thus provides the context for the chapter.

Chapter IV is organized around three sections:

Section I focuses on the impacts of the current patterns of rural development on the environment and natural resources, particularly water, land and air, as well as the achievement of the SDGs by 2030. The world is not on track to realize the water- and land-related SDGs due to the growing depletion, degradation and pollution of these resources, as well as the loss of biodiversity, depletion of forests and wilderness, degradation of soil, and the despoliation of landscapes.

Section II discusses the strategies that countries can adopt to make rural development more environmentally sustainable and conducive to the achievement of the SDGs. A portfolio of strategic initiatives consisting of water- and land-use technologies, circular and conservation practices and institutional strengthening measures are proposed to promote sustainable rural development. The adoption of such initiatives would represent a shift in strategy away from a business-as-usual approach to strong commitment to sustainable rural development and the achievement of the SDGs. Scenario analysis in several areas also

1 The nine planetary boundaries are currently defined as (i) land-system change; (ii) freshwater use; (iii) biogeochemical flows (nitrogen and phosphorous cycles); (iv) biosphere integrity; (v) climate change; (vi) ocean acidification; (vii) stratospheric ozone depletion; (viii) atmospheric aerosol loading, and (ix) introduction of novel entities (Steffen et al., 2015b).

shows that it is possible to make development in rural areas more sustainable with the adoption of the right policies, management practices and technologies.

Section III presents the conclusions and key policy recommendations. The chapter calls, in particular, for more effective use and management of water and land resources because of their impact on the achievement of almost all SDGs. Rethinking agricultural practices—including through diversification and further expansion of non-farm activities, and the greening of settlements and infrastructure—will be central to achieving a sustainable and resilient rural development that includes food and water security, by 2030.

The environmental impact of current patterns of rural development

This section examines how existing rural development patterns are adversely affecting both water and land resources, including their depletion, degradation, and pollution. It also shows how these effects are making the achievement of some SDGs more daunting.

Impact of rural development on water resources

Some 97 per cent of the Earth's water is salt water, with only 3 per cent being freshwater. These limited freshwater resources are needed to meet multiple human needs, including for drinking water, irrigation, electricity generation, industrial processes, municipal purposes, fisheries, navigation and recreation. The extraction of both surface and groundwater is currently exceeding their renewal capacity and resulting in the depletion of those resources (Dasgupta, 2021). The state of the renewability of freshwater resources is thus an important indicator of water and food security.

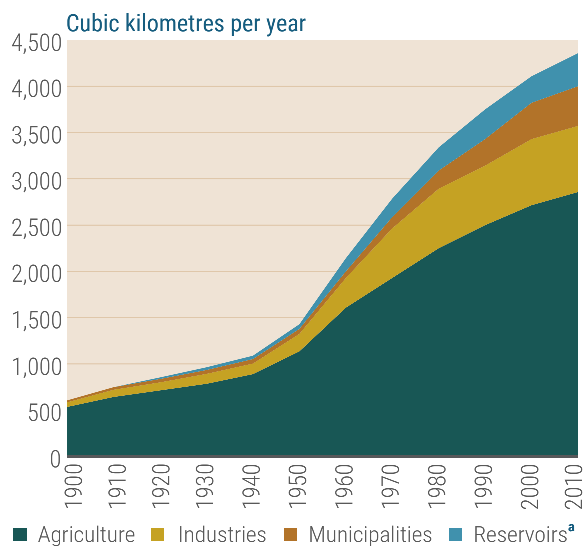
Depletion and degradation of water resources

Over the last century, the resource-intensive water consumption patterns have resulted in nearly six-fold growth in the use of global freshwater resources, which is more than twice the rate of population increase during the same period (UNESCO WWAP, 2020). Five emerging economies, namely Brazil, the Russian Federation, India, China and South Africa, or the so-called BRICS countries, represent the largest share of global freshwater use (45 per cent), while the share of Organisation for Economic Co-operation and Development (OECD) countries has reached a plateau since the 1980s, representing about 20–25 per cent of global withdrawals (Steffen et al., 2015a). While the water withdrawal shares of industries and municipalities have increased over the last century, especially since the 1970s, agriculture remains by far the largest sector in terms of overall water consumption (figure IV.1).

Globally, approximately 70 per cent of all freshwater withdrawals is used by agriculture, but the share of this sector in total water use varies by country and income level (figure IV.2). The share of agriculture in total water withdrawals tends to decrease as the income of countries grow, and so the proportion of water withdrawals by individual sectors is closely linked to the patterns of traditional structural transformation, as discussed in chapter 2. In 2015, the average agricultural share of total water demand for low-, mid-

Figure IV.1

Global water withdrawals throughout the previous century, by sector



Source: UNESCO WWAP (2020).
a Evaporation from artificial lakes.

dle- and high-income countries was 73, 66 and 60 per cent, respectively. There are countries across South Asia, Africa and Latin America and the Caribbean that use more than 90 per cent of total water withdrawals for agriculture. South Asia has the highest share of agricultural water consumption mainly due to high use of irrigation in food production.

Irrigation has been an important factor in increasing yields per unit of land across many countries, and has thus contributed to higher agricultural productivity growth, poverty reduction and rural transformation, as discussed in Chapter 2. Irrigation has been particularly important across South and East Asia and the Middle-East. Pakistan, Bangladesh and South Korea all irrigate more than half of their agricultural land, while India's share is 35 per cent. The level of irrigation in sub-Saharan Africa has increased, yet the region continues to irrigate less land than South Asia and the Middle-East and North Africa. Intensive groundwater pumping for irrigation has also led to depletion of aquifers and contributed to environmental degradation, with significant economic impact on crop production (Ritchie and Roser, 2018).

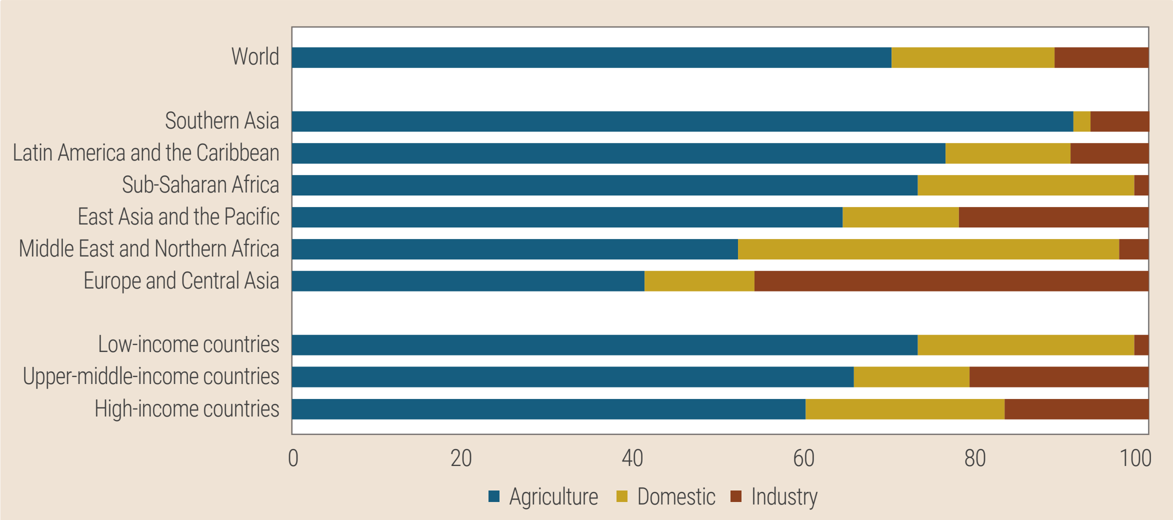
The amount of water depletion also depends on the efficiency of use, which is strongly influenced by the economic structure of a country and the share of water-intensive sectors. Water-use efficiency (SDG 6.4.1) is defined as the value added in United States dollars per volume of water withdrawals in cubic metres (m^3) by a given economic activity. Global water-use efficiency, according to the latest reporting, is $18/$m^3$ (2017), with the lowest regional ratio at $2/$m^3$ in Central and Southern Asia; about $12/$m^3$ in sub-Saharan Africa; and $11/$m^3$ in Northern Africa and Western Asia. Countries with highest water-use efficiency are mostly located in Northern and Western Europe, where some countries surpass $100/$m^3$ (figure IV.3). These countries generally have a large service sector, often accounting for more than 60 per cent of gross domestic product (GDP).

Agriculture tends to have a much lower water-use efficiency relative to other productive sectors, so countries with a relatively large agricultural sector tend to score badly on this indicator. The water-use efficiency in the agricultural sector also varies among countries, although only a few, mostly located in Europe have this SDG indicator (SDG 6.4.1) exceeding $10/$m^3$. One country that stands out is the Netherlands, with a water-use efficiency in the agricultural sector at $55/$m^3$. The agricultural sector in that country is one

Figure IV.2

Share of freshwater withdrawals by region and income grouping, 2015

Percentage

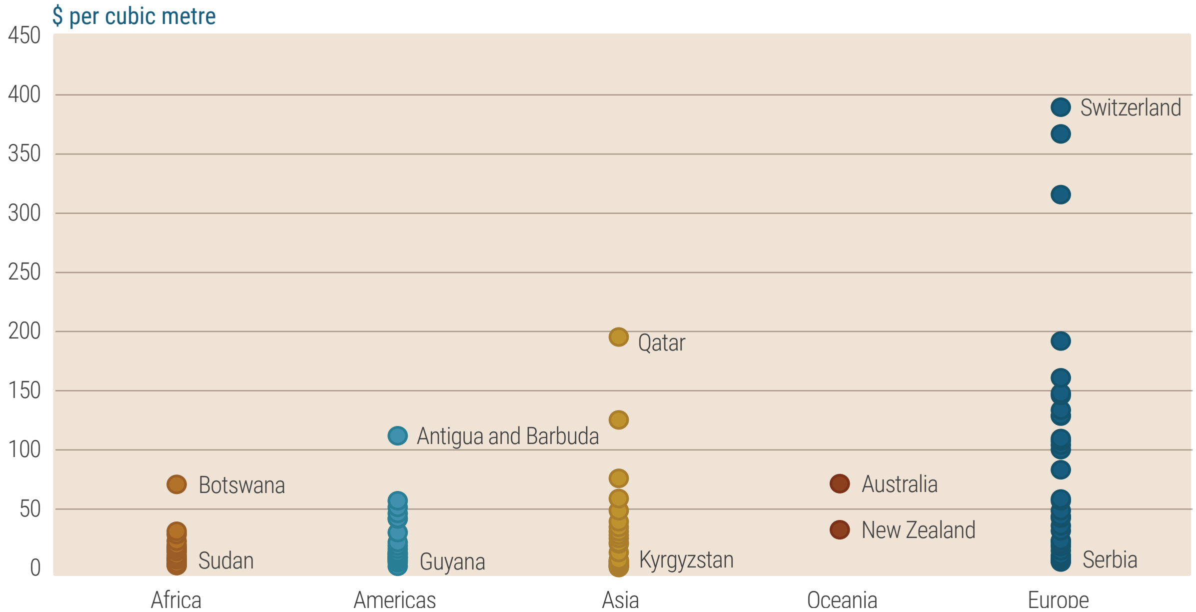


Source: UN DESA, based on data from World Bank (2021).

Note: Withdrawals for domestic include uses by homes, municipalities, public services and commercial establishments.

Figure IV.3

Water use efficiency, 2017



Source: UN DESA, based on data from UNSD SDG database.

of the most innovative and productive in the world and has adopted numerous measures to maximize water-use efficiency. In the Netherlands, steps such as covering of basins, rainwater storage and water recirculation, are obligatory. The adoption of innovations on a large scale, such as hydroponic farming (growing plants without soil in nutrient-rich solutions) and closed greenhouses, have also contributed to high water-use efficiency in the Netherlands.

▸ Growing concern about water stress

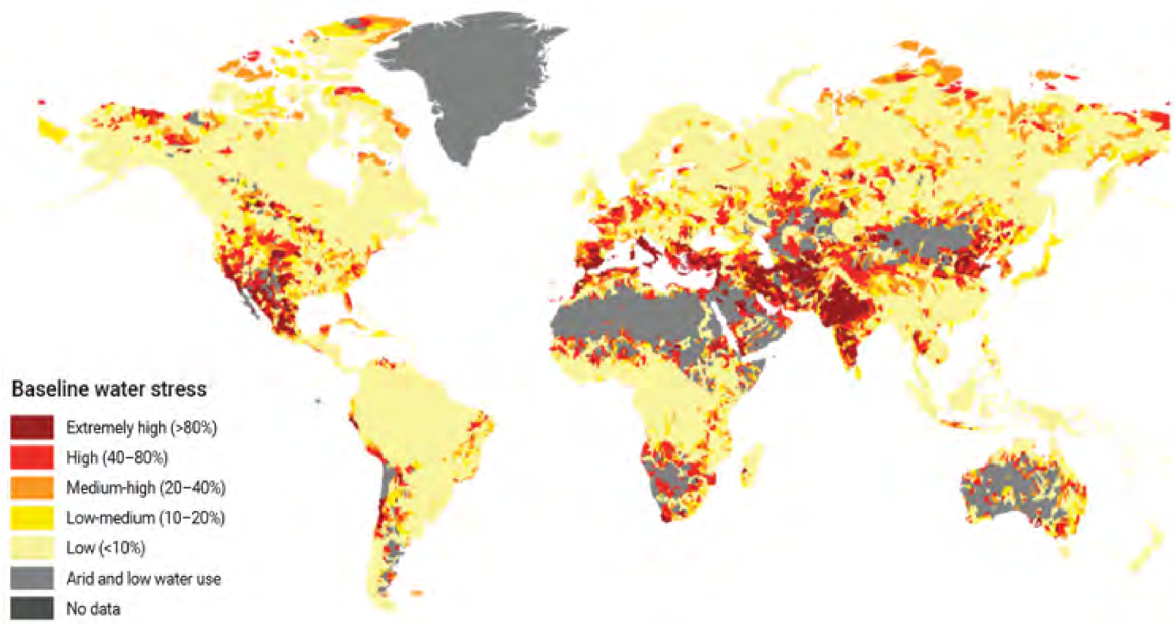
Many Middle Eastern, Northern African and South Asian countries have high levels of water stress due to resource-intensive water consumption patterns. Countries like India, Iran, Libya, Pakistan, Saudi Arabia and United Arab Emirates, for example, have withdrawal rates of over 100 per cent, which means that they are overextracting from existing surface or groundwater aquifers. The United States of America and much of Southern and Eastern Europe have medium-to-high water stress. Canada, much of Latin America and the Caribbean (with the exception of Chile, Mexico and the southern part of Peru), Northern Europe, Oceania and sub-Saharan Africa (except Namibia and Botswana), in contrast, have water stress defined as low or low to medium, due to their large endowment of water resources (figure IV.4). Water stress can heighten security risks by impacting irrigation, manufacturing or energy generation. It also impacts human health, by limiting the access of people to basic water and sanitation.

Some parts of the world also experience water scarcity during particular periods of the year. For example, over four billion people live under conditions of severe water scarcity at least one month of the year (Mekonnen and Hoekstra, 2016). These seasonal patterns often affect women disproportionally because they have to spend more time and travel longer distances to collect water during the dry season.

In many places, the per capita availability of renewable freshwater resources is also further disrupted because of climate change (Ritchie and Roser, 2018). While the water supplies of some regions have been stable, others have experienced considerable fluctuations. The world's high-latitude regions, including the northern half of the United States, the global tropics and the low latitudes are getting wetter. By contrast, the mid-latitudes are getting drier. The shifting patterns of water availability, along with falling groundwater levels, will further limit the access of people to drinking water and water for irrigation in rural areas.

Figure IV.4

World map of annual baseline water stress, 2014



Source: UNESCO WWAP (2020).

Climate factors, such as droughts, are also playing a significant role in population movements from rural to urban areas. In the last century, the American Dust Bowl of the 1930s and the Sahelian droughts of the 1970s and 1980s drove many people to migrate to California and the regional urban centres in African countries like Burkina Faso, Mali, Mauritania and Niger, respectively. A common factor in many of these country experiences is that a period of relatively humid conditions was upended by significant decline in precipitation, meaning that the land could no longer sustain the same population size.

Large-scale withdrawal of water for irrigation purposes has diminished freshwater flows reaching the sea, thereby affecting marine life (Islam, 2020). Many fabled rivers of the world, such as the Colorado in the United States, Murray-Darling in Australia, and Huang He in China, fail to reach the sea. The drying up of major rivers through extraction of water for commercial uses is disrupting the Earth's basic hydrological cycle. It is estimated that the expansion of irrigation has decreased global river discharge to the oceans by 0.3 per cent, equalling 118 km^3 between 1901 and 2002 (Gerten et al., 2008). As an example, the Aral Sea has been suffering because of the interception of rivers for irrigation purposes and the excessive use of water for cropland. This is contributing to lowering the water table and the rise of salinity and toxicity, which impacts the biodiversity of the sea. Saline soils also reduce the ability of agricultural crops to absorb water and vital nutrients, while the constant accumulation of salts degrades soil quality and makes it infertile. In the Central Asia region, this process has provoked a migration of the population from former coastal areas, which has built up pressure on other parts in the region (Golovleva, 2016).

The overexploitation of freshwater resources over decades has thus contributed to an alarming level of global ocean degradation (SDG 14), with implications for biodiversity. This, over a period of nearly 100 years, has contributed to the habitat loss of some 20 per cent of coral reefs, 19 per cent of mangroves and 29 per cent of seagrass. The destruction of coral reefs has particularly damaging consequences for biodiversity because they provide the habitat for about 25 per cent of all oceanic species (United Nations, 2020b). Wetlands, the ecosystem where land meets water, are similarly being lost due to agricultural expansion and rural development. Wetlands are an essential part of the water cycle as they filter pollutants and hold significant volumes of the world's available freshwater. An estimated 40 per cent of the world' s species live and breed in wetlands, but they are disappearing at a rate three times faster than forests (Portier, 2021). According to Earth observation data, there has been a 54 per cent loss of the extent of natural wetlands (SDG 6.6) worldwide between 2001 and 2015 (UN-Water, 2018b).

Water pollution

Water pollution is mainly the result of human activities that introduce contaminants in the natural environment. In many countries, agriculture has overtaken settlements and industries as the major source of pollution of inland and coastal waters, with farms discharging large quantities of chemicals, organic matter, sediments and saline drainage into water bodies.

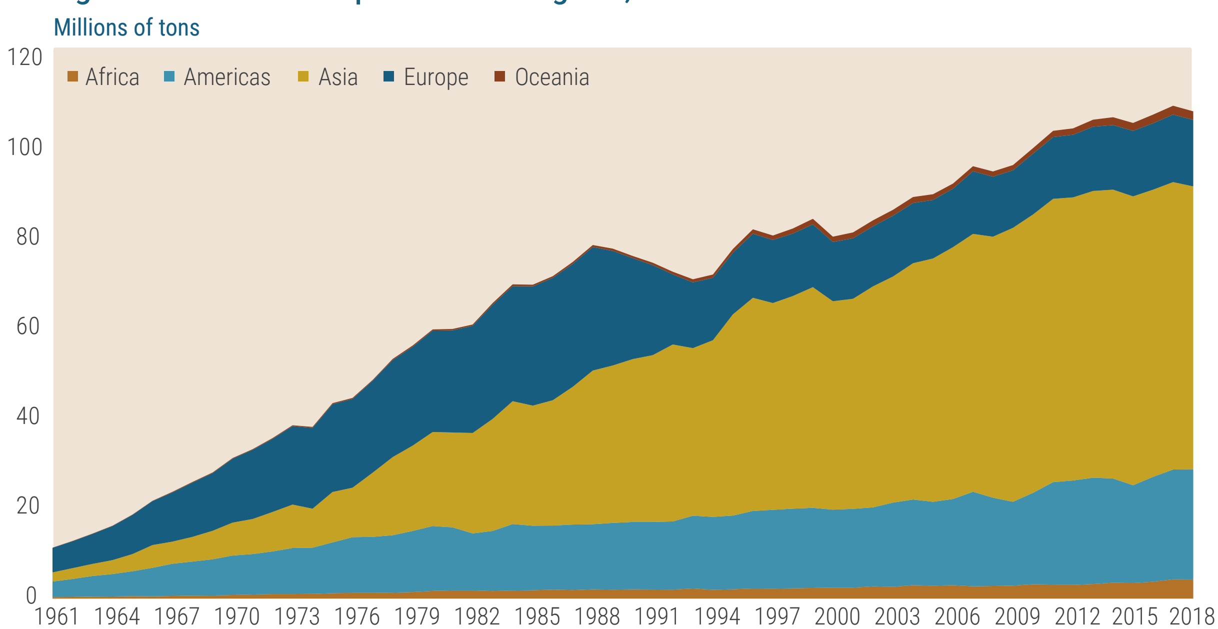
The global growth of agricultural production in recent decades has been achieved, in no small measure, by more intensive use of inputs such as chemical fertilizers and synthetic pesticides. While beneficial for food production, excessive and unsustainably managed use of such chemicals has contributed to significant growth in water pollution in many regions. Nitrate is the most common chemical contaminant found in the world's groundwater aquifers. In European Union countries, 38 per cent of water bodies are under significant pressure from agricultural pollution (UNESCO WWAP, 2015). Excessive fertilizer use has also led to run-off that has contributed to eutrophication, caused by an increase in plant and algal life, which has created "dead zones" that rob water of the oxygen necessary to support marine life, fish stocks and coral reefs (Walker, 2019).

The Baltic Sea, which is an arm of the Atlantic Ocean, has been heavily affected by eutrophication, with about 50 per cent of all nutrients in the sea originating from agriculture. Since 1995, however, nitrogen and phosphorus inputs into the Baltic Sea have decreased by 17 and 20 per cent, respectively, but it will take time before there are materially significant improvements in its water quality. It took decades for the Baltic Sea to become eutrophic and it will take decades for it to recover (McCrackin and Svanbäck, 2016).

Today, the world consumes ten times more mineral fertilizers than it did in the 1960s (figure IV.5). In

Figure IV.5

Nitrogen fertilizer consumption across regions, 1961–2018



Source: UN DESA, based on data from FAOSTAT (2020).

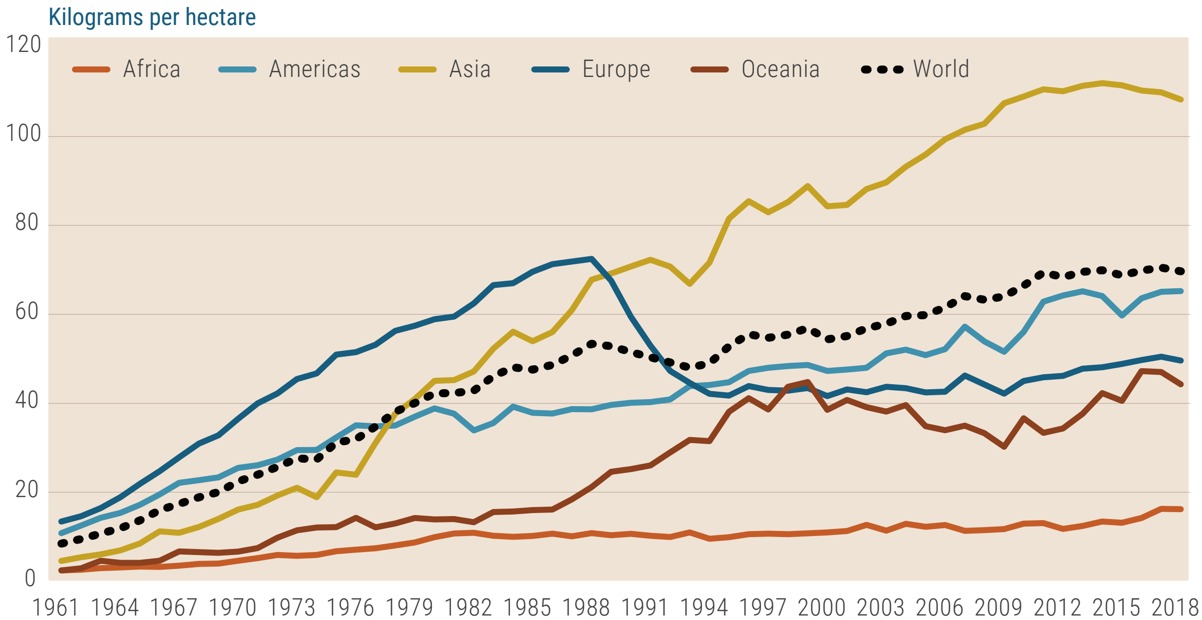
Europe, the use of fertilizers increased dramatically from the 1960s into the 1980s. However, fertilizer use decreased in Europe in the late 1980s and early 1990s, due in particular to the economic recession in Eastern Europe. Since the mid-1990s, fertilizer inputs in Europe have remained relatively stable at medium levels. The largest contribution to the global increase in nutrient consumption since 1990 has come from developing countries, particularly in Asia. Figure IV.6 shows that fertilizer use per hectare of arable land has been increasing in all regions except Europe between 1961 and 2018, with the most significant growth in the Asia region. The rate in East Asia is currently about 330 kilograms (kg) per hectare of cropland, with a slight stabilization in recent years. This stands in strong contrast to sub-Saharan Africa, where the use of fertilizers remains low and inputs have only marginally increased from 11 kg per hectare of cropland in 2000 to 16 kg per hectare in 2018. Hence, while in many regions the use of such chemicals is excessive, in other regions, especially sub-Saharan Africa, fertilizer use remains low, limiting agricultural productivity growth in many countries.

The increasing contamination of groundwater and freshwater resources is also affecting the health and well-being of rural people, particularly in terms of access to basic drinking water. Some 82 per cent of people in urban centres have access to safe drinking water, while the share in rural areas is only 43 per cent (figure IV.7). Inadequate water quality due to contamination thus hampers the provision of safe drinking water in rural areas.

The use of plastic products in agriculture is also contributing to water pollution. The global demand for agricultural plastics is estimated at about 8–10 million tons (Cassou, 2018). While agriculture is not the largest user of plastic products, accounting for around 3.4 per cent of total consumption in the European Union in 2014, this material is increasingly used in farming. Plastic films, for example, are used to cover greenhouses, to hug plants around the root zone, in plastic irrigation systems, and as ingredients in chemicals. Data on the final destination of agricultural plastics is missing, but recycling is limited—estimated at about 10 per cent in the United States, for instance, with the

Figure IV.6

Nitrogen fertilizer consumption across regions, per area of cropland, 1961–2018



Source: UN DESA, based on data from FAOSTAT (2020).

majority of such waste dumped in landfills, or ending as pollutants in land, water, or the oceans.

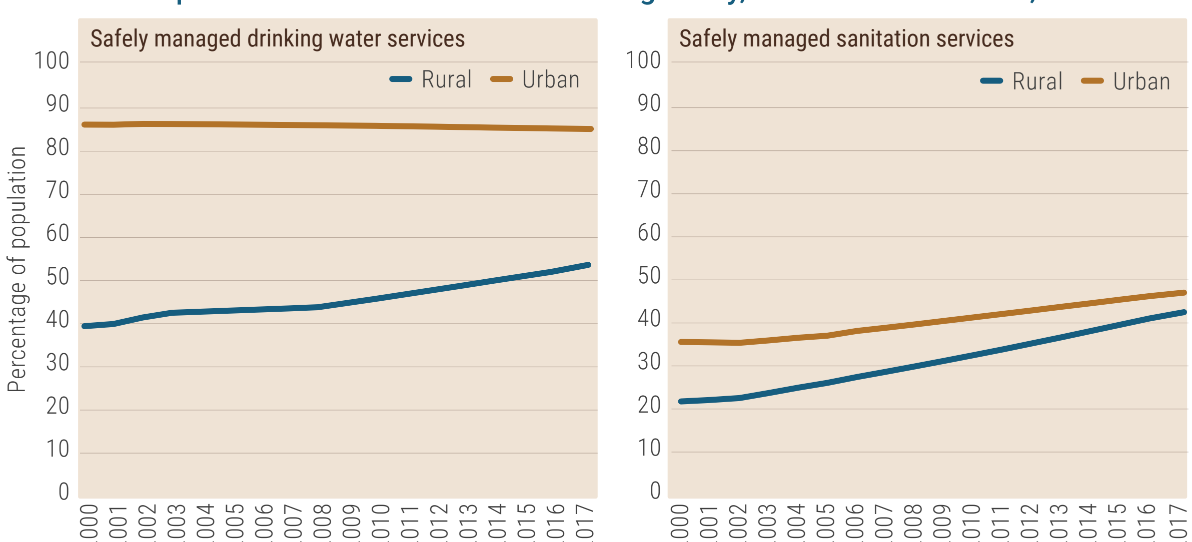
Plastic mulching (a farming technique in which crops are grown through holes in sheets laid over the ground) has also become a major agricultural practice because of benefits such as higher yields, earlier harvests, improved quality and greater water-use efficiency. The recycling level of plastic mulching, however, is very low. Mulching can contribute to enhanced pesticide run-off, and plastic residues are likely to fragment into microplastics and accumulate in the soil, as well as in water and coastal areas. Plastic production for agricultural mulch is growing rapidly and projected to increase from 4.4 million tons in 2012 to 7.4 million tons in 2019 (Srinidhi and Nazareth, 2018). The most common method for disposing plastic mulch is open burning in the farm, and the detrimental effects of such waste present an increasing challenge for many agricultural communities.

Agriculture and food production, at the same time, are being negatively affected by water pollution. The global crop area irrigated with unsafe wastewater is estimated to be ten times larger than the area using treated wastewater. Polluted water used in agriculture has caused contamination and accumulation of micro-biological and chemical pollutants in crops, livestock products, soil or water resources, with potentially severe health impacts for consumers and farm workers (Rosegrant, 2020).

The expansion of human settlements, industries, infrastructure and other non-farm activities, is also a major source of pollution of water bodies in rural areas. Municipal and industrial wastewater is often discharged untreated into water bodies (UNESCO WWAP, 2017). High-income countries, on average, treat about 70 per cent of the municipal and industrial wastewater, while the ratio in upper-middle-, lower-middle- and low-income countries is 38, 28 and 8 per cent, respectively. Compared to urban regions, wastewater treatment in rural areas is generally much less advanced. Many rural areas, for example, are typically served by on-site wastewater treatment, without any formal sewer systems. While on-site systems can be well-suited to rural areas with low population density, their management may be expensive and complex, often resulting in unsafe emptying or waste being dumped or abandoned (UNESCO WWAP, 2017). In China, nearly 93 per cent of the municipal wastewater from residents of cities was treated in 2016, while the percentage in the rural regions stood at only 22 per cent (Wang and Gong, 2018).

Figure IV.7

Access to improved sanitation and water source globally, rural and urban areas, 2000–2017



Source: UN DESA, based on data from UNSD Global SDG database.

Women, especially in rural areas, are most affected by the lack of sufficient wastewater treatment, as they are often the main caretaker and user of domestic water.

Rural areas are also lagging behind in terms of access to safely managed sanitation services vis-à-vis urban centres, while the gap is smaller than when compared to access to basic drinking water, as shown in figure IV.7 earlier. A consequence of this is that rural areas with low access to safe latrines have higher rates of open defecation and experience greater soil and groundwater contamination.

Expansion of rural infrastructure such as roads can also create problems for the management of water resources. Paved roads have increased rapidly in recent decades and are projected to grow by another 25 million kilometres by 2050 (United Nations, 2020b). Filling up of wetlands and other water bodies and misalignment of roads, highways, and railways with rivers and streams can reduce the availability of water in rural areas. Rainfall run-off from roads and highways, furthermore, frequently washes harmful pollutants into nearby rivers, streams, and lakes. Rain that falls on roadways is thus not able to soak into the ground as it would naturally, and instead generates run-off into local water bodies, carrying with it the polluting substances present on the road's surface.

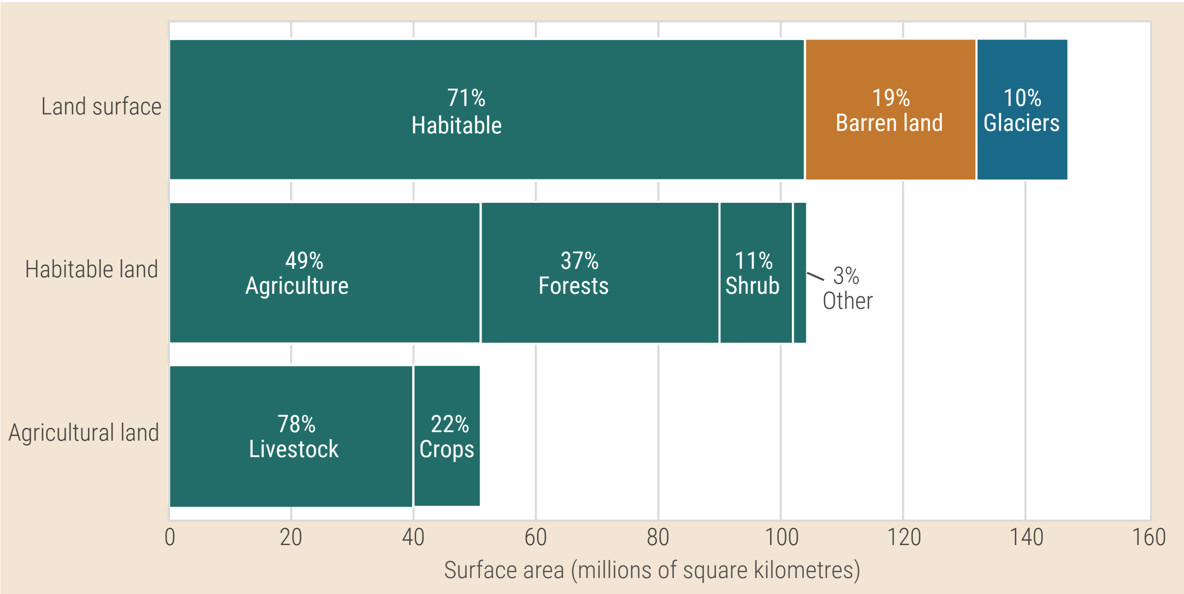
In addition, the number of dams has grown rapidly in the past 50 years, reaching an estimated 50,000 large dams and 17 million reservoirs. Dams are predominantly constructed in rural areas for agricultural irrigation. A dam can be used to divert water for irrigation needs and limit the amount of water downstream. Dams contribute to the fragmentation of rivers, which affects aquatic life forms and contributes to upstream sedimentation and toxification of the return water. The use of reservoir water for industrial use also contributes to toxification as the return water carries many organic and inorganic pollutants (Islam, 2020).

Impact of current rural development strategies on land

Land is essential for the survival and prosperity of humanity, accounting for roughly 29 per cent of the Earth's surface (figure IV.8). Half of the Earth's habitable land is used for agriculture, with 37 per cent covered by forests. How land is used plays a critical role in determining the supply of food, fibre, energy and

Figure IV.8

Overview of global land use, 2015



Source: UN DESA, based on data from FAOSTAT (2020).

Note: The length of the bar is the surface in million km^2. Each bar breaks down the components of the bar right above.

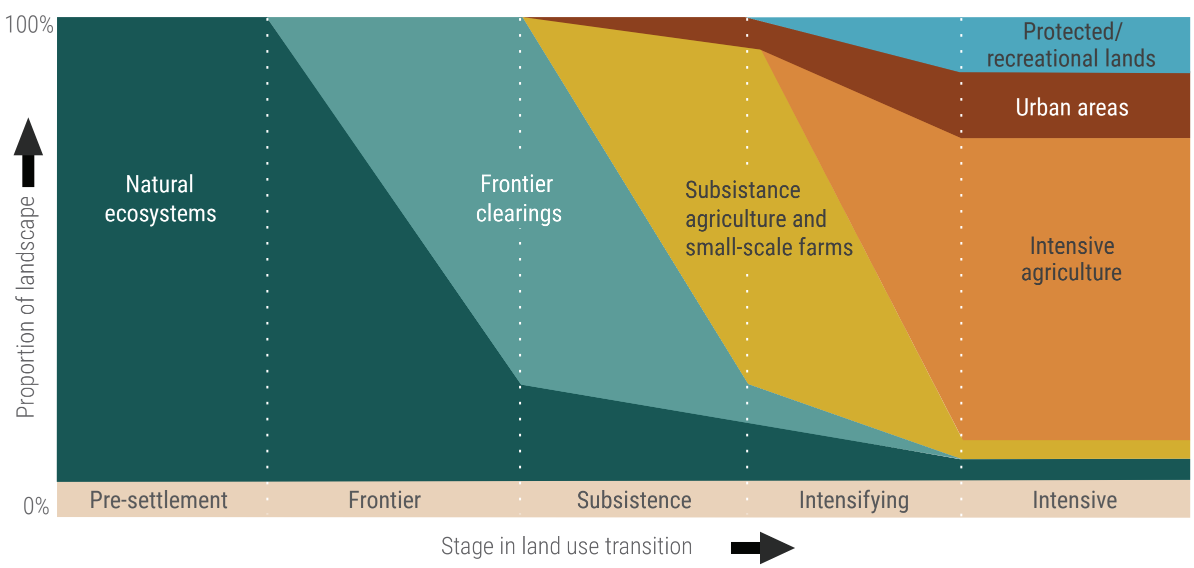
materials. Land also provides many vital functions for ecosystems, biodiversity, the climate system and people. This section examines how the current patterns of agricultural and rural development are affecting the sustainability of land resources.

Large swaths of the planet's land surface have been transformed by land-based activities. Clearing of forests, unsustainable agricultural intensification, and growth of human settlements and recreational lands have all reduced the share of natural ecosystems. Croplands and pastures have become one of the largest terrestrial biomes on the planet, surpassing forest cover in terms of size of land surface. The rapid expansion in croplands and pastures has resulted in losses of ecosystem services and the depletion of forests and wilderness. Figure IV.9 illustrates changes in composition of land use as it advances across stages.

The Intergovernmental Panel on Climate Change (IPCC) attributes 31 per cent of global greenhouse gas emissions directly to agriculture and land-use changes (IPCC, 2019). If the processing, transport, storage, cooling and disposal of food are added (which the IPCC ascribes to other sectors), more than 40 per cent of all global greenhouse gas emissions depend on the way we farm and eat. Land-use and land-cover change increases the release of carbon dioxide by disturbing soils and vegetation and is the main driver of deforestation. This means that rural land management practices have direct impact on climate change (SDG 13). Food-related emissions alone may result in the world exceeding the 1.5 degrees Celsius limit by 2050, and food emissions by themselves could bring the world close to the 2 degrees Celsius limit by 2100 (Clark et al., 2020). Without changes to food systems and consumption patterns in urban areas, food-related emissions could double by 2050. The climate goals are thus unlikely to be reached without changes to agricultural practices and food systems, including reduction of food waste and changes in food consumption patterns in urban areas. About 17 per cent of total global food production is wasted (11 per cent in households, 5 per cent in food service and 2 per cent in retail). This means that about 8-10 per cent of global greenhouse gas emissions are associated with food that is not consumed (UNEP, 2021a). Livestock-based food similarly tends to have a higher footprint than plant-based food. For example, producing one kilogram of beef leads to 60 kilograms of greenhouse gases, while producing one kilogram of peas causes just 1 kilogram of greenhouse gas emissions.

Figure IV.9

Illustration of transitions in land-use activities



Source: Foley et al. (2005).

Depletion of forests and wilderness

Deforestation has claimed about 30 per cent of global forest cover in the last century, and 20 per cent of the standing forest has been degraded in the 1990 to 2015 period (Griscom et al., 2017). The rate of deforestation has been increasing in tropical areas, especially in sub-Saharan Africa and Latin America and the Caribbean (FAO and UNEP, 2020). The forest areas as a share of total land mass decreased from 31.1 to 30.7 per cent between 2000 and 2015, with this decline continuing but at a slower rate. Since 1990, the world has lost forests equivalent to the size of South Africa (United Nations, 2019a). Only 54 per cent of current forest cover is subject to sustainable management plans (SDG 15.2.1).

The estimated annual rate of deforestation was 10 million hectares in the 2015–2020 period, down from 16 million per year in the 1990s. However, the global average masks significant regional variations, especially in sub-Saharan Africa and Latin America and the Caribbean, where forest areas have declined in the last decade. Forest degradation is also serious in other regions. In Australia and North America, for example, forest fires have been occurring at increasing frequency, with devastating impacts on forests and ecosystems.

Agriculture is the main driver of deforestation worldwide, with some variations between regions, as shown in figure IV.10. In Latin America and the Caribbean, commercial agriculture is the most important driver, accounting for about two thirds of all deforested area. In Africa and tropical and subtropical Asia, subsistence agriculture, on the other hand, accounts for a larger share of deforestation. When it comes to forest degradation, the need for fuelwood is the main driver in Africa, and timber logging in subtropical Asia and Latin America and the Caribbean.

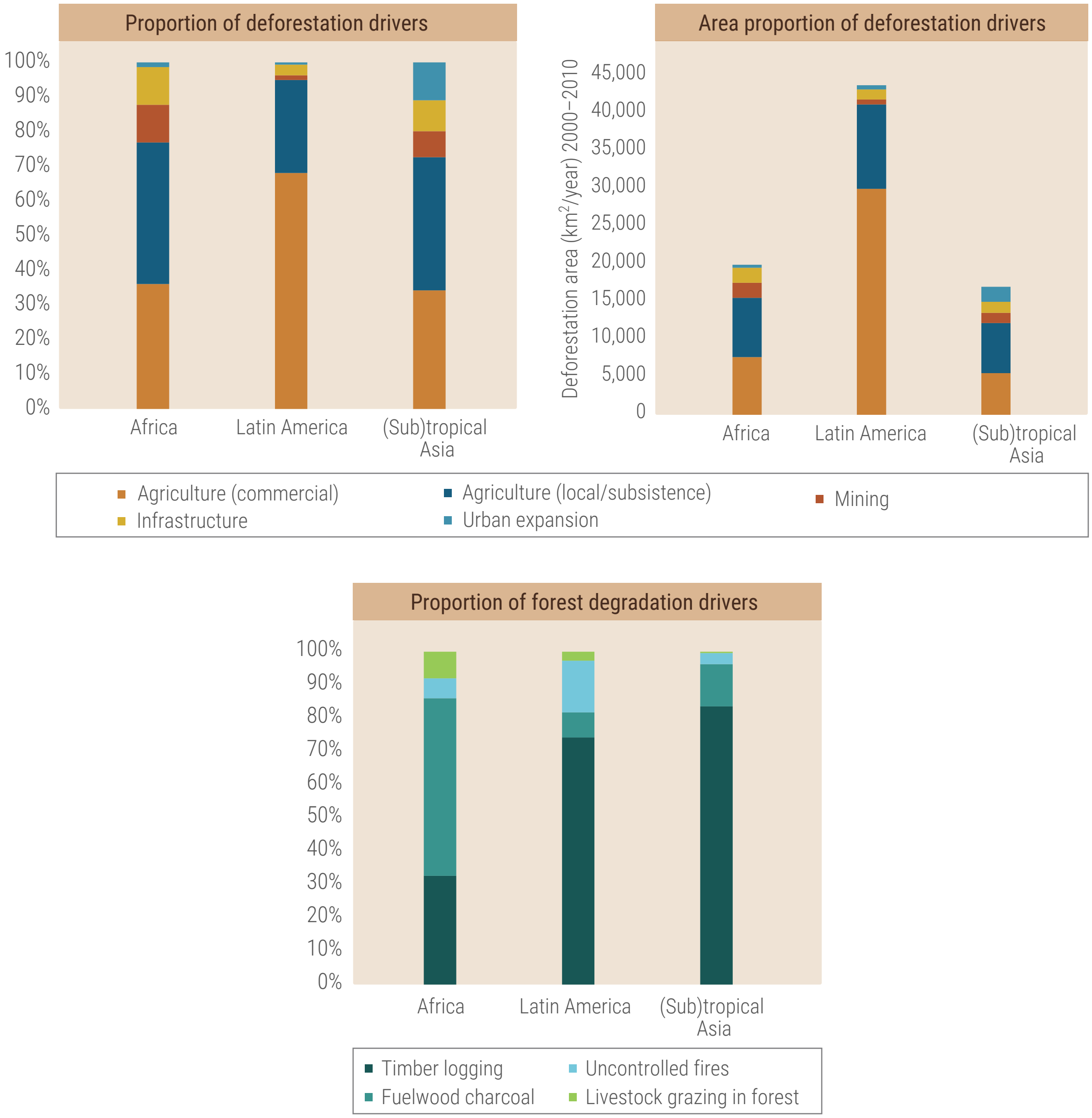
Many experts have argued that improving agricultural productivity is key to reducing deforestation. If countries can produce more food per hectare, they can protect critical forest areas while meeting the growing food demand. In Brazil, for example, the increase in agricultural productivity attributed to the expansion of rural electrification contributed to less forest loss, while in Zambia, improved maize seeds reduced the rate of deforestation (Assunção et al., 2016; Pelletier et al., 2020). However, it is not clear if the relationship between agricultural productivity and deforestation applies at the more local levels, where the increase in profitability for farmers may raise the opportunity cost of conserving natural forests, which can lead to greater agricultural land expansion. Effective government policies and the role of local communities in managing natural resources, have also been found to play an important role in improving the relationship between agricultural productivity and deforestation.

Another important driver of deforestation has been the high demand for fuelwood. Rural development strategies have not been successful in displacing the use of traditional fuelwood with cleaner energy sources. In sub-Saharan Africa, fuelwood consumption remains high due to habits, taste, customs and experience, and is often preferred, even when alternative energy sources are available (FAO, 2017a). The introduction of incentives and appropriate policies may be required to change this dynamic. While fuelwood is used in both urban and rural areas, the share is generally much higher in the latter. If current rural development patterns continue, 2.3 billion people could still be deprived of access to clean cooking fuels and technologies by 2030, which means that the world is not on track to reach SDG target 7.1 (universal access to affordable, reliable and modern energy services), and the demand for fuelwood is likely to continue to contribute to deforestation.

Biofuels have also been promoted as a cleaner alternative to fossil fuels, which sparked a production surge in the early 2000s. Biofuels have also been promoted because of their potential to promote rural development through new employment opportunities and higher local revenues. However, growing biofuels production has added to existing pressures on forests in tropical regions. The relationship between biofuel production and deforestation is also complex and often difficult to quantify, with biofuels from oil palm estimated to have been responsible for up to 2.8 per cent and 6.5 per cent of direct deforestation in Indonesia and Malaysia, respectively. Biofuel from soy-

Figure IV.10

Deforestation and forest degradation drivers, 2000–2010



Source: Kissinger, Herold and De Sy (2012).

beans in the Brazilian State of Mato Grosso may also have been responsible for up to 5.9 per cent of annual deforestation over the last few years (Gao et al., 2011).

Infrastructure development, in addition, has contributed to significant deforestation. A classic example is the impact of construction of roads in the Amazon in the 1960s, which accelerated deforestation. A more recent study in the Democratic Republic of the Congo shows that road development caused reduction of more than 2 per cent of all forest cover (Li et al., 2015).

▸ COVID-19 is exacerbating deforestation

The COVID-19 pandemic has also had an impact on forests, according to a global assessment by the United Nations Forum on Forests. Reduced monitoring by public forest agencies has created opportunities for increased illegal activities, including logging, poaching, charcoal production and land-use change (FAO, 2020e). In many cases, forest management activities, such as reforestation projects, have also been postponed or cancelled. Furthermore, the negative economic impact of COVID-19 on livelihoods has increased the encroachment of forest reserves by farmers. As a result, there are concerns that the COVID-19 pandemic has led to increased depletion and degradation of forests and associated biodiversity loss. On the other hand, some positive benefits of COVID-19 have also been recorded, such as cleaner coastlines and reduced crowds in ecotourism sites. Due to the movement restrictions, the isolation of natural spaces has also enabled the regeneration of fauna and flora in some locations.

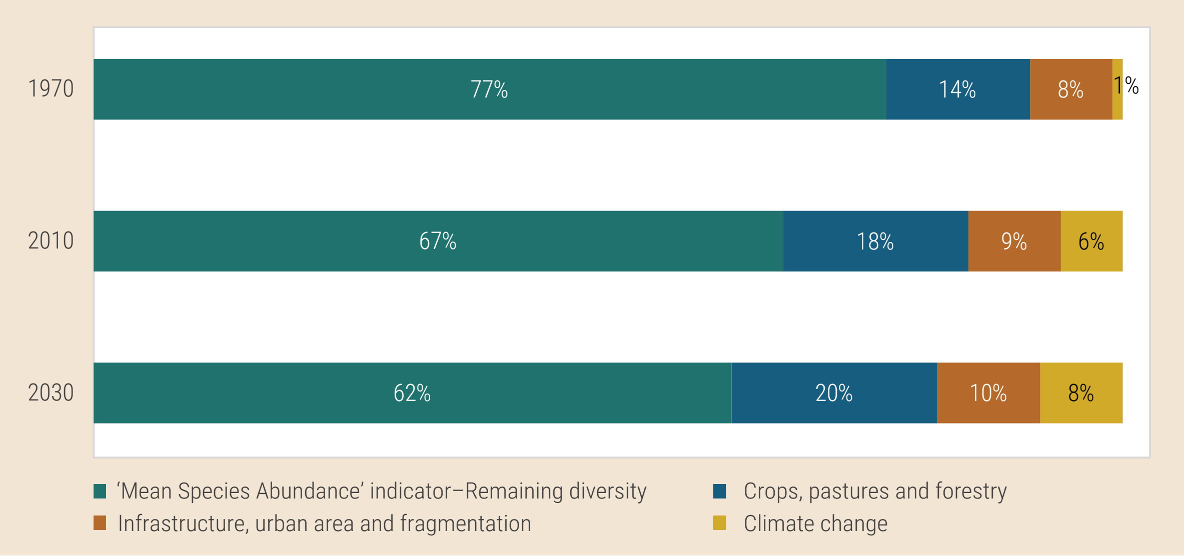
Loss of biodiversity

Land-use changes brought about by rural development around the world are threatening more species with extinction than ever before. An average of about 25 per cent of species in assessed animal and plant groups are threatened, suggesting that about 1 million species already face extinction in the next decades, unless action is taken to reduce the intensity of the drivers of biodiversity loss. Tropical forests, which account for two thirds of the world's biodiversity, have experienced the highest loss, driven primarily by expansion of agriculture (Wilson and Peter, 1988). As a result, it is estimated that, by 2030, 40 per cent of insects could be extinct (van Huis et al., 2013). Many pollinating species have also declined in large numbers and are threatened with further loss, putting at risk the production of 75 per cent of the current food crops (United Nations, 2019a).

The unprecedented loss of biological diversity is driven by a range of human activities. Figure IV.11 shows the main drivers of biodiversity loss. By 1970, about 23 per cent of the original naturalness of ecosystems globally had disappeared. By 2010, the loss had increased to 33 per cent, and by 2030, it is estimated that 38 per cent of the original naturalness of ecosystems could be lost. Historically, the conversion of natural habitats to agricultural land has had the largest impact on biodiversity, contributing 60–70 per cent of total biodiversity loss in terrestrial ecosystems. In the projections for 2030, the impact of infrastructure and urban areas as well as climate change will increase, but

Figure IV.11

Pressures driving global terrestrial biodiversity loss, 1970, 2010 and 2030



Source: Kok et al. (2014).

conversion of natural habitats will continue to have the largest impact on biodiversity.

The impact of agriculture, climate change and infrastructure development on biodiversity loss is also expected to further accelerate until 2030. None of the Aichi targets set out in the Convention on Biological Diversity, were fully achieved by 2020.[2] At the United Nations Climate Ambition Summit in 2020, countries such as Chile, Colombia, France, Italy and the United Kingdom of Great Britain and Northern Ireland and others thus pledged to go beyond the Aichi targets by more than doubling the protection of biodiversity and ecosystems.

The COVID-19 pandemic has also highlighted the importance of the relationship between people and nature, including the consequences of human ecological disruption caused by deforestation and loss of biodiversity. Pandemics emerge from the microbial diversity found in nature, with land-use change causing more than 30 per cent of new diseases reported since 1960 (IPBES, 2020).

Degradation of soil

Roughly one quarter of the global soils is estimated to have been degraded, an area nearly the size of India and the Russian Federation (IPCC, 2019). Up to 24 million km^2 of land has become degraded, largely due to unsustainable agricultural practices such as excessive fertilizer use and heavy tillage practices. It is estimated that 3.2 billion people globally are affected by land degradation, while an estimated 12 million hectares of land in the European Union alone are affected by soil erosion, reducing crop yields by 0.43 per cent at an annual loss of €1.25 billion (Panagos et al., 2018). Climate change also exacerbates land degradation, particularly in low-lying coastal areas, river deltas and in permafrost areas (IPCC, 2019).

2 The Convention on Biological Diversity has stipulated five Aichi targets to be achieved by 2020: (i) address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society; (ii) reduce the direct pressures on biodiversity and promote sustainable use; (iii) improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; (iv) enhance the benefits to all from biodiversity and ecosystem services; and (v) enhance implementation through participatory planning, knowledge management and capacity-building.

If the current trend continues, some 95 per cent of the Earth's land areas could become degraded by 2050. So far, only 40 countries have committed to setting voluntary targets to achieve "land degradation neutrality" (SDG 15.3) by 2030, with 80 countries endorsing the target.

The per hectare loss of soil nutrient is highest in sub-Saharan Africa and the cost of restoration is estimated at 7 per cent of the continent's GDP (Craswell and Vlek, 2013). On a global scale, the annual loss of about 75 billion tons of soil each year costs the world about $400 billion, or approximately $70 per person (Eswaran et al, 2001). In the United States, soil erosion from agriculture is estimated to cost annually about $44 billion, or about $247 per hectare of cropland and pasture, while in India, the cost is nearly $50 billion annually, or 2.5 per cent of the country's GDP (Sethi, 2018). Changes in land use and land cover also increase the risk of floods and destruction of infrastructure, which has come at high cost to many countries. In Bangladesh, the 1998 floods inundated two thirds of the land area, resulting in damages and losses estimated at over $2 billion, or 4.8 per cent of the country's GDP.

Pollution of rural land and air

Air quality in rural areas remains a neglected issue, but all over the world and particularly in some developing countries, the pollution of the air is a significant problem. Industries such as mining, coal processing and cement-making contribute to air pollution in rural areas. The production processes of these industries are not only harmful to the environment because of their impact on water quality; they also cause air and land pollution, such as soil contamination, through direct exposure to the pollutant, leakage of toxic gases, and improper waste disposal. Cement manufacturing in rural areas, also generates serious atmospheric pollution and contributes to the deterioration of the air quality by producing hazardous air pollutants. Cement manufacturing, furthermore, requires large energy consumption, making that industry alone contribute about 8 per cent of global CO^2 emissions.

Economic growth and urbanization have led to increased demand for construction materials. Brick is one of the major building materials, and brick kilns have become a leading source of air pollution in many rural areas, particularly in Asia. The technologies used for brick-making in South Asia are generally both inefficient and polluting. In Bangladesh, the contribution of the brick sector to the country's total annual CO^2 emissions is 17 per cent, much higher than its share of the national GDP (1 per cent). Air pollution caused by brick-making has important health effects, with 6,100, 55,000 and 600 deaths attributed to the brick kiln industry in Bangladesh, India and Nepal, respectively, in 2015 alone (Eil et al., 2020).

Sparsely populated and remote rural areas are also often the most neglected by waste management services (e.g., due to financial and geographical constraints). Low-income countries tend to collect, on average, only about 48 and 26 per cent of the waste in cities and rural areas, respectively (Kaza et al., 2018). Because of the lack of waste collection schemes in many rural areas, household and industrial garbage often ends up in dumps in the wilderness and subject to open burning practices, which cause considerable air pollution.

Current agricultural practices also contribute to air and land pollution. This includes manure and other wastes from farms, poultry houses and slaughterhouses; harvest waste; fertilizer run-off from fields; pesticides that enter into air or soils; and salt and silt drained from fields. Intensive production methods and the growing concentrations of animals have also contributed to increased waste pollution in many rural areas, leading to nutrient depletion and soil degradation. The indiscriminate use of pesticides and burning of wheat and paddy straw, also contribute to the rising levels of air pollution in rural areas. Sugar cane farmers without access to heavy machinery, for example, burn the crop just before harvest. This makes it easier to harvest the sugar cane crop and clear the weeds, but can be a major cause of rural air pollution, as is the case in Thailand and the Mekong region.

Despoliation of the rural landscape

The construction of infrastructure such as roads, electricity and water supply in rural areas often causes irreplaceable loss to natural and cultural sites. Many such projects have been constructed without adequate attention to the impact on the rural landscape. As a result, *pristine* natural landscapes are becoming increasingly rare. The design of many infrastructure projects is also often heavily focused on functionality, utility and efficiency, with resulting despoliation of the rural landscape. In addition, in many countries, dams are being built without due regard to the preservation of the original landscape. The construction of dams for hydroelectric power generation and for irrigation of agricultural land has thus often left behind large areas where the ground surface has been disfigured, contributing to land erosion and climate change.

The increasing sprawl of both rural and urban settlements has implications for the natural rural landscape. The rapid urban growth and sprawl have direct impact on the rural landscape by turning pristine and fertile lands into settlements, often encroaching on critical ecosystems like wetlands and forest habitats. Rural settlement projects are also driving changes to the natural landscape and generating deforestation.

In many European countries, the long-term discussion on the impact of roads and hydropower projects on the rural landscape is now shifting to the negative aesthetic effects of windfarms. Wind energy projects are sometimes promoted as a part of a rural development strategy to provide new jobs and additional revenue for farmers, while simultaneously increasing the local tax base. While wind power can generate economic benefits for rural areas and is likely to play an important role in the global renewable energy mix of the future, policies to regulate the construction of windfarms must take into account their impact on the local population, as well as the value of pristine landscapes and wildlife.

Hill cutting and clearing in rural areas is another growing development challenge in many developing countries. Hills are cut and levelled for reasons such as informal settlements, housing projects, farming, industrialization, and for the construction of dams and roads. Hill cutting and clearing of vegetation and forests are often done to promote cultivation of commercial crops such as rubber, pineapples and tea. The impact of such hill cutting has been the degradation of habitats, ecological imbalances, loss of biodiversity, deforestation and, in some instances, weakening of indigenous cultures and heritage. The nature and lifestyle of the people connected to the hills may thus be under threat from the drastic changes to the balance of their ecosystems.

Towards rural development strategies more conducive to achieving the SDGs

Rural development has had considerable impact on the achievement of many SDGs, as discussed in the previous section. This section focuses on strategies that countries can adopt to help ensure that rural development is more conducive to the protection of the environment and achievement of the SDGs. At the same time, rural development is intrinsically dependent on greater preservation of the environment. The preservation of natural resources is a means to building resilience and sustainability and reducing the vulnerability of rural livelihoods to climate change, pandemics, climate-related natural disasters or extreme weather. The adoption of the various initiatives discussed in this section would signal a marked shift in rural development strategy away from a business-as-usual approach (baseline scenario) to a strong commitment to a sustainable and resilient rural development and the achievement of the SDGs by 2030 (sustainable scenario).

The framework for fostering more sustainable and resilient rural development is organized around significant strengthening in three key areas: water- and land-use technologies, circular and conservation practices, and investment in institutions (table IV.1).

Water- and land-use technologies

Increasing water-use efficiency

Reducing global water demand will require improvements in irrigation efficiency in agriculture. The adoption of modern irrigation and other precision technologies in agriculture can significantly improve water-use efficiency (Rosegrant et al., 2017). However, an increase in water-use efficiency for an individual farmer may not save water in the river basin or the irrigation system. In accordance with this approach, much of the water that is "wasted" by farm-level upstream irrigation is recovered through downstream use of drainage water and recharge of groundwater that can be used for irrigation. There is thus a need to translate improved water-use efficiency at the farm level to the larger basin. For example, introducing appropriate physical controls and incentives on water usage, which could include rationing, quotas, and trading through enforce-

Table IV.1
A portfolio of strategies to foster sustainable rural development

Water and land-use technologies	Circular and conservation practices	Institutions
Drip irrigation	Circular wastewater use	Social institutions (e.g. water user associations)
Precision agriculture	Conservation agriculture	Economic institutions (e.g. water and tenure rights)
Rainwater harvesting	Organic farming	
ICTs for smallholder farms	Rotational livestock grazing	
Crop productivity	Land restoration	
Agricultural intensification	Indigeneous seed banks	
Small-scale hydropower		
Land-use planning		

Source: UN DESA.

ment of water rights, can lead to improved basin-wide water use after the introduction of new technologies.

Irrigation technologies with potential to materially reduce water use include small-scale pumps, solar irrigation pumps, canal lining, drip irrigation and microsprinklers. In the Coimbatore City of India, the use of drip irrigation methods has increased grain yields by almost 30 per cent, while using 27 per cent less water relative to conventional rice production. In the San Joaquin Valley in California, the yield of tomatoes under drip irrigation was about 20 per cent higher than under sprinkler irrigation when a similar volume of water was used (FAO, 2020d). Similarly, water losses in unlined canals are usually high. Lining of canals is a method to reduce water losses due to seepage, which has proved to be efficient and appropriate for smallholder farmers.

Precision farming can greatly improve water-use efficiency, while having other benefits as well, such as better time management and reduced use of chemicals, both of which contribute to healthier crops and better yields, and ultimately to higher productivity and income of farmers, as discussed in chapter 2. In precision agriculture, farmers can optimize returns on inputs while preserving resources by using satellite imagery and advanced sensors, which enable them to decide when to plant and harvest crops. Precision agriculture, however, has mainly been applied in large-scale farming, thus potentially further disadvantaging smallholder farmers due to lack of technology and expertise and high financial start-up costs. It is important to develop precision technologies in agriculture that are suited to smallholder farmers (Rosegrant, 2019).

More widespread application of sensor technologies that measure surface and groundwater levels can also provide local governments and water utility companies with a better picture of the available resources to meet current and projected water demand. In Somalia, a water and land information management project developed by the Food and Agricultural Organization of the United Nations (FAO) is monitoring surface and groundwater levels with a view to promoting more efficient management of water resources. The Africa Regional Data Cube is another recent tool harnessing remote sensing and satellite-based technologies to help Ghana, Kenya, Senegal, Sierra Leone and the United Republic of Tanzania monitor the state of their water resources. In Central Tanzania, a satellite-based data system is used to monitor the impact of droughts on the availability of water resources, including on Lake Sulunga, which many surrounding communities rely on for drinking water, fishing, agriculture, livestock farming and salt production. The use of Earth observation data has made it possible for local governments and the affected communities in the Lake Sulunga area to use the water resources more efficiently.

Box IV.1 discusses the likely state of global water resources by 2030 under both a *baseline* and a *sustainable scenario*. As shown in box IV.1, there is likely to be a significant water deficit by 2030, unless countries make concerted efforts to improve water-use efficiency, particularly in the agricultural sector.

Enhancing water harvesting

While more efficient irrigation will continue to play a key role in increasing agricultural productivity, the harvesting of rainwater also has much potential. Rainwater harvesting involves the collection and storage of this resource, rather than allowing it to run off. The water Johads of India provide an example of a low-cost method to collect rainwater. The technique collects rainwater by placement of thousands of small structures throughout the rural areas, which store excess rainwater from the monsoon months and allow it to slowly percolate into the groundwater during the dry season. In Rajasthan in India, the installation of such harvesting structures brought back water to 1,000 drought-stricken villages, with five rivers that used to run dry but are now flowing again, and groundwater levels rising by an estimated six metres (UNESCO WWAP, 2018).

Tamil Nadu was the first State in India to make rainwater harvesting compulsory for every building to avoid groundwater depletion. The project was launched in 2001 and has been implemented in all rural areas of Tamil Nadu. Posters placed all over the State create public awareness about rainwater harvesting. The rainwater harvesting strategy of Tamil Nadu delivered excellent results within five years, and over time every

BOX IV.1

Depletion of water resources by 2030: a baseline and a sustainable scenario

Global water consumption is now about 4,500 billion m^3, with 70 per cent used by agriculture. Water demand is projected to increase annually by 2 per cent by 2030 (Addams, et al., 2009). The Organisation for Economic Co-operation and Development also estimated in 2012 that water demand could increase by 55 per cent globally between 2000 and 2050. Industrial water demand is likely to grow faster than that for agriculture, although agriculture will remain the largest water user in 2030.

Baseline scenario

Water demand in 2030 is thus projected to be around 6,030 billion m^3, based on 30 per cent growth in agricultural and municipal use and 50 per cent in industry. Figure IV.1.1 shows the baseline scenario for the estimated total water withdrawals from agricultural, industrial and municipal users by 2030. The projected total withdrawals by 2030 will exceed the available water supply, at around 4,400 billion m^3, resulting in a water deficit of around 1,630 billion m^3.

Sustainable scenario

In the sustainable scenario (figure IV.1.1), the focus is on achieving water-use efficiency improvements that exceed the historical trajectory, with a view to reducing total water withdrawals by 2030. Improvement in water-use efficiency in agriculture (WUE agr) is achieved through modernization of irrigation systems, including investment in water delivery infrastructure; enhanced groundwater governance; increased role of farmers in irrigation management (e.g., through water user associations); and more widespread adoption of farm-level irrigation technology. Rosegrant (2020) estimates that such measures can reduce agricultural water use, relative to the above baseline, by 9.5 per cent in 2030, or some 400 billion m^3. Integrated soil and water management measures (ISWM)—which include the benefits of technologies such as no-till agriculture, water harvesting, and integrated soil and water management to increase the water holding capacity of the soil or make precipitation readily available to plant—can save another 1.5 per cent of water use by 2030, compared to the baseline scenario, or 150 billion m^3. Another 250 billion m^3 in water demand can be saved by 2030 by reducing leakage and improving water efficiency in the domestic and

continued >>

State in India has adopted it as a model. The State of Chennai, for example, had a 50 per cent rise in water level in a five-year period and the water quality improved significantly. In Uganda, the high demand for clean drinking water has led many local governments to invest in rainwater harvesting technologies. The uptake of such technology in local communities has been stimulated by the introduction of microfinancing schemes and cost-sharing grants. Apart from promoting rainwater harvesting at offices, schools, hospitals and households, the adoption of other technologies, such as subsurface and sand dams, ponds and floodwater buffering, has been promoted by many local communities in Uganda. Canada is an example of a developed country that has actively encouraged local communities to harvest rainwater for agricultural, industrial and residential use. Rainwater is used for a number of purposes including stormwater reduction, irrigation, laundry and portable toilets. Rainwater harvesting is also the normal practice for most rural households in New Zealand, although the western and southern parts of the country have plentiful rainfall. And, in Bermuda, a law has been established that requires all new construction to include rainwater harvesting.

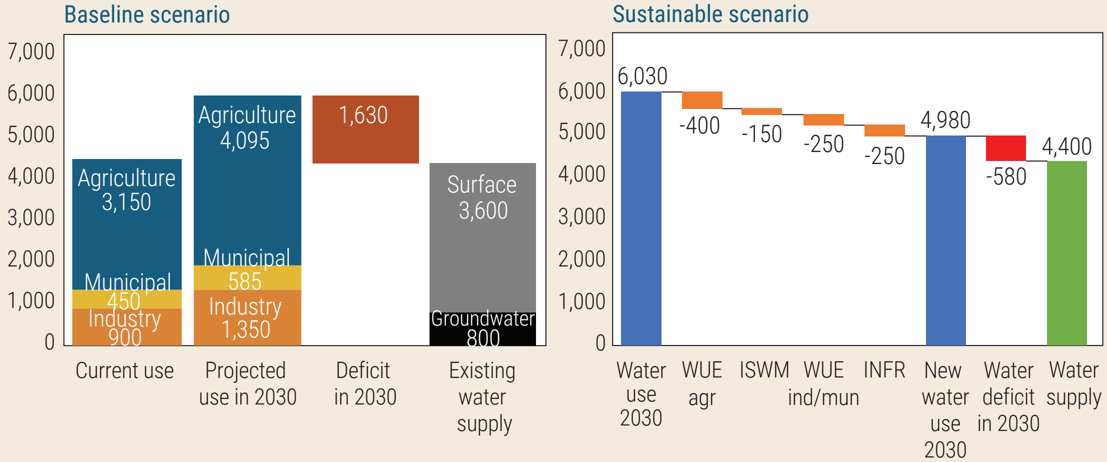
Improving water quality

The rapid growth in agricultural production in recent decades has taken a heavy toll on the environment in many rural areas, especially rivers, lakes and coastal zones, which are often suffering from nutrient, pesticides and soil sediment run-off, as discussed earlier. Various technologies are available to help increase the

BOX IV.1 continued

Figure IV.1.1

Projected water demand, supply and deficit by 2030 (billions of cubic metres)



Source: UN DESA projections, based on Addams et al. (2009), UNESCO WWAP (2019) and OECD (2012).

industrial sectors (e.g., through water recycling and reuse and shift to biomass produced from waste material) or, otherwise, by not having water impacts (WUE ind/mun). Greater reliance on water harvesting, water recycling and other water-related infrastructure (INFR) can also reduce water demand by an estimated 250 billion m^3.

The above measures would reduce the estimated water deficit in 2030 from 1,630 billion m^3 to some 580 billion m^3 (see figure IV.1.1, sustainable scenario). Knowing that water supply has historically increased by around 1 per cent annually, the above measures would help close the water deficit soon after 2030. Otherwise, there is considerable risk that more fossil reserves would need to be depleted, water reserved for environmental needs would be drained, or water demand would go unmet with associated social and economic costs.

Source: UN DESA.

efficiency of fertilizer application in agriculture. This includes conservation tillage practices that help reduce surface run-off, including nitrogen in water bodies. Improved fertilizer management and water-saving irrigation are other source control methods in agriculture. The creation of ecological ditches as part of an irrigation and drainage system can also remove pollutants during the transport of the agricultural run-off. Breeding crops for nitrogen use efficiency, in addition, has shown great promise to reduce water pollution in the agricultural sector.

Technology options for household water treatment in rural areas are generally based on either filtration or disinfection methods. However, few household treatment technologies have so far achieved significant scale in rural areas, particularly in developing countries. In some low-income countries, particularly in South and South-East Asia, commercial water treatment kiosks are reaching a growing number of people. The water treatment kiosks can vend water at low prices and have been shown to reduce the incidence of diarrhea (Sima et al., 2012). However, there is need for increased investment in capacity development and improved financing mechanisms to significantly scale up such commercial water treatment enterprises in developing countries.

Salinity is one of the leading sources of low water quality for irrigation. Salinity from irrigation can occur over time wherever irrigation occurs, since almost all water (even natural rainfall) contains some dissolved salts. When the plants use the water, the salts are left behind in the soil and eventually begin to accumulate. Effective salinity control also requires coordination between countries sharing water resources and a combination of agronomic practices that focus on better fertilizer management, improved soil quality and more effective crop management. There are also promising technologies available that, through innovative water treatment, can efficiently reduce salinity in soils and negate the harmful effects of irrigating with saline water.

Water pollution caused by road run-off is a significant problem in many rural areas. Installing effective stormwater control measures, such as constructed wetlands, can reduce the costly impact of such water pollution. The adoption of green infrastructure that is infiltration based can also help maintain or restore the natural hydrology of the watershed. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier rural environments.

Box IV.2 presents both a baseline and a sustainable scenario for significantly reducing water pollution by 2030. The sustainable scenario demonstrates that with significant investments in water and wastewater treatment policies, technologies and management practices, it is possible to achieve major reductions in water pollution and accelerate progress towards SDG 6.3 on water quality by 2030, with positive impact on SDGs related to human health, economic development and aquatic ecosystems.

Promoting sustainable agricultural intensification

There have been substantial benefits from agricultural intensification in terms of feeding the world and reducing hunger and malnutrition. Global production of cereals has increased at a higher rate than the growth of the global population. Countries have raised agricultural output either through land expansion or improvement in yields, or a combination of both. Globally, most of the increase in output stems from increases in yields, which have allowed the “sparing” of land that would otherwise have been converted to agricultural use.

Regions have differed in terms of whether increased agricultural output has been achieved through land expansion or improved yields, as shown in figure IV.12. In South Asia, land use for cereal production has increased by less than 20 per cent since 1961, as yields have more than tripled, which has meant that much more food could be produced without an expansion of the agricultural land. This is in contrast to sub-Saharan Africa where land use for cereal production has more than doubled since 1961, while yields have only increased by 80 per cent. This highlights the potential to improve agricultural yields in sub-Saharan Africa through greater use of fertilizers; improved planting material and breeds; enhanced water management; and better agronomic practices.

Going forward, the demand for food, fibre and fuel, which have been key drivers of increased land use in recent decades, is likely to continue to grow. With the global population projected to increase from 7 billion in 2010 to nearly 10 billion in 2050, and incomes growing across the developing world, overall food demand could rise by more than 50 per cent (WRI, 2019). The rising global demand for food could require the conversion of natural land to cropland ranging between 320 and 850 million hectares, with the higher estimate equivalent to the size of Brazil (UNEP and IRP, 2014). To avoid further shrinkage of forests and wilderness because of the need for further expansion in food production, agricultural intensification and productivity will have to continue to increase. The previous agricultural revolution resulted in rapid productivity growth due to high reliance on chemical inputs and farming practices, such as deep ploughing, which has caused serious problems of topsoil loss. The concept of sustainable agricultural intensification implies that yield gains must not come at the expense of forests, biodiversity or other ecological factors.

Weighing the benefits and downsides of agricultural biotechnology

Rapid advances in biotechnology, especially in genetically modified crops, have also played an important role in agricultural development in recent decades. This has, in some instances, contributed to higher crop

BOX IV.2

Major reduction in water pollution by 2030: a baseline and sustainable scenario

Approximately 650 million people live in areas where water quality risks are high due to elevated levels of biochemical oxygen demand (BOD), and about 1 billion people live in river basins experiencing excessive nitrogen (N) and phosphorous (P) loadings. High BOD levels can indicate contamination with fecal matter, while too much N and P in water equates with pollution. The estimated total annual loadings of BOD, N and P, are 209, 131 and 10 million metric tons, respectively, or 350 million metric tons per year.

Baseline scenario

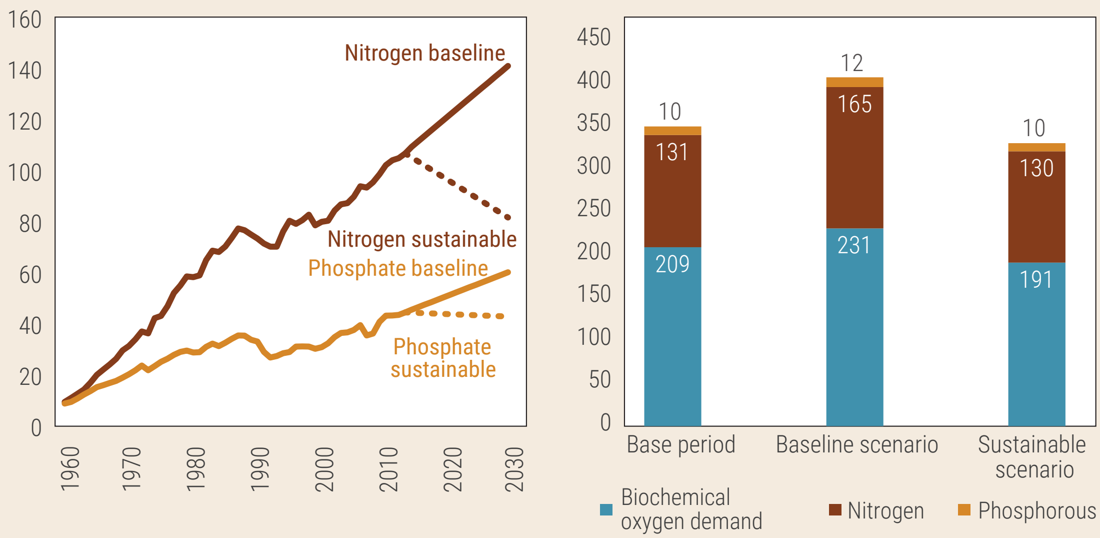
Growing population, income, crop and livestock production, and fertilizer use, are the main drivers of increases in water pollution. Agricultural intensification with extensive use of inorganic fertilizers is regarded as the major source of N and P (Rosegrant, 2020, based on International Food Policy Research Institute and Veolia, 2015), estimates that total annual loadings of the three key water pollutants could reach 409 million metric tons in 2030 (figure IV.2.1), with BOD, N and P increasing to 231, 165 and 11.5 million metric tons, respectively, with 1 in 4 and 1 in 6 people subject to high risk of N and P pollution, on one hand, and BOD, on the other.

Sustainable scenario

In the sustainable scenario, there would be 40 and 24 per cent improvement in N and P use by 2030 in agriculture as the result of increased investment in breeding techniques; adoption of sustainable agricultural methods; advanced irrigation technology; and more effective water management, coupled with several other complementary measures (Rosegrant, 2020). As a result, nitrogen fertilizer consumption in 2030 would decline from 143 million tons in the baseline scenario to 83 million tons in the sustainable scenario, with phosphate consumption reducing from 62 to 45 million tons as well (figure IV.2.1). The sustainable scenario also assumes that all developing countries reach 90

Figure IV.2.1

Projected growth in BOD, N and P by 2030 under baseline and sustainable scenarios (millions of metric tons)



Source: Data from FAOSTAT (2020). Projections by UN DESA based on Rosegrant (2020), Sutton et al. (2013), and IFPRI and Veolia (2015).

continued >>

BOX IV.2 continued

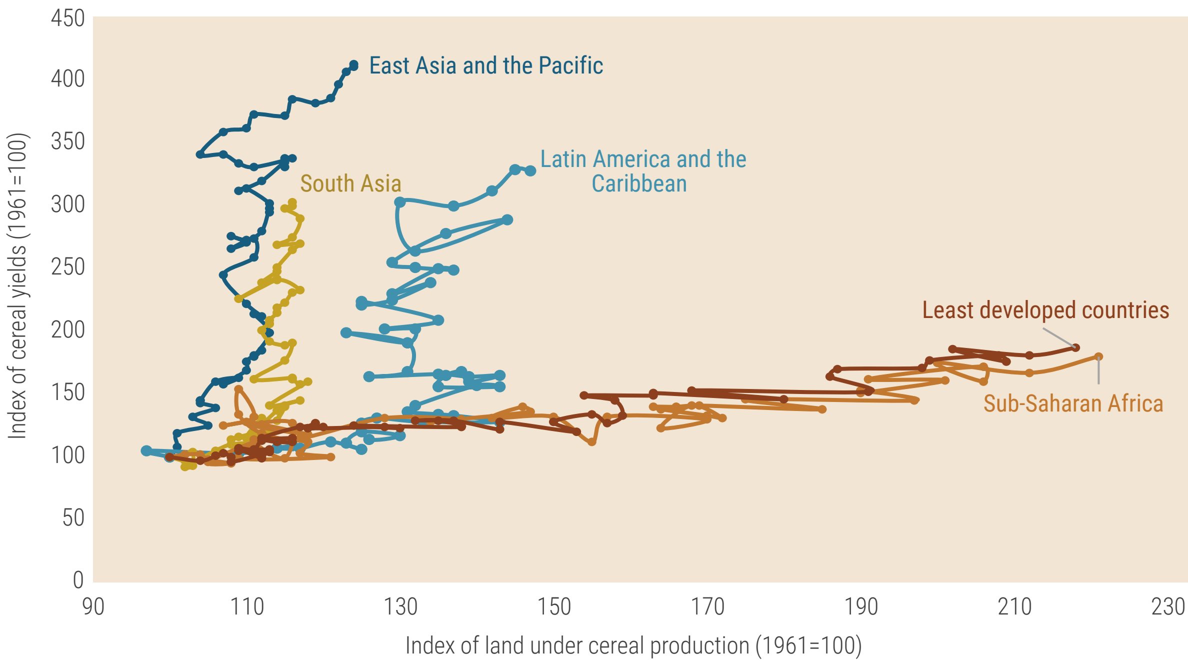
per cent connection to sewerage systems by 2030, with 50 per cent of households receiving primary waste treatment, 30 per cent secondary treatment and 10 per cent tertiary treatment. The reduction in fertilizer consumption, improvements in pollution control and more sustainable water resource management practices would result in projected total loadings of the three pollutants of 331 million metric tons in 2030, or 191, 130 and 9.5 million metric tons of BOD, N and P, respectively. These figures are lower than the corresponding values in the base period.

The sustainable scenario shows that with significant investments in water and waste treatment and improved policies, technologies and management practices, it is possible to achieve major reductions in water pollution, and accelerate progress towards SDG 6.3 on water quality, with positive impact on a range of other SDG related to human health, economic development and aquatic ecosystems.

Source: UN DESA.

Figure IV.12

Interlinkages between land use and yields in different regions



Source: United Nations (2018b).

Note: Figure IV.12 shows the indexed change in land area used for cereal production from 1961–2014 (on the y-axis), measured against the indexed change in cereal yield over the same period (on the x-axis).

yields; lower pesticide and fertilizer application; less demanding production techniques; and more nutritious staple foods. Improved productivity from genetically modified crops can thus contribute to less expansion of land for agricultural production and reduced pollution from excessive fertilizer use. A prominent example is how genetically modified cotton in India has been beneficial to most farmers by contributing to increased profits and yields, while reducing pesticide use (Raman, 2017).

However, these benefits must be weighed against the environmental concerns regarding genetically modified crops, which are manifold. Environmental risks include genetic pollution, effect on non-target organisms, evolution of resistance, and loss of biodiversity. The replacement of local varieties with genetically modified ones has contributed to genetic erosion, which threatens plant genetic diversity. Only approximately 170 crops are currently grown at commercially significant scale and the majority of the nutrient and calorie uptake is limited to about 30 crops. For example, more than 40 per cent of daily calories come from three staple crops: rice, wheat and maize. As a result, roughly three-quarters of the crop genetic diversity has been lost as farmers have switched to genetically modified crops and abandoned local varieties (FAO, 2013). Genetically modified crops have also evoked a range of social, economic and ethical concerns such as loss of traditions, private sector monopoly and loss of income of resource-poor farmers (FAO, 2012).

Making smallholder farming more sustainable through the application of technology

Smallholder and family farms account for a significant share of the global food production. Major improvement in the productivity of smallholder farmers, particularly in low-income countries, will require enhanced adoption of new technologies. The new technologies at the same time must contribute to better performance on various sustainability metrics.

A number of information and communications technologies (ICTs) have recently been developed to enhance the productivity of small-scale farmers in a sustainable way, including

- ***Zenvus***, a Nigerian precision farming start-up, measures and analyses soil data including temperature, nutrients, and vegetative health to help farmers apply the right amount of fertilizer and optimally irrigate their farms. Zenvus seeks to improve farm productivity and reduce waste of water and fertilizer by using analytics to enable data-driven practices by small-scale farmers;
- ***UjuziKilimo***, a Kenyan start-up, uses big data and analytics capabilities to transform farmers into knowledge-based communities with the goal of improving productivity by adjusting irrigation.;
- ***SunCulture***, another Kenya company has developed drip irrigation kits that use solar energy to pump water from any source, with a view to making irrigation more affordable;
- ***FruitLook***, developed by a South African company, helps fruit and grape farmers in the Western Cape to become water efficient and climate-smart;
- ***Chameleon and Wetting Front Detector Sensors*** have enabled small-scale farmers in Mozambique, the United Republic of Tanzania and Zimbabwe, to cut irrigation frequency and double the productivity of water use.

Promoting clean energy by investing in small-scale hydropower

Investment in energy is essential for small farmers in developing countries. Energy is needed to pump and distribute water from ground and surface sources in the field, and for many applications in the agricultural value chain. Hydropower is a renewable and clean energy source (SDG 7). But expansion of hydropower from dams can create other environmental challenges, such as forcing the resettlement of the rural population, flooding biodiversity hotspots, disrupting river systems and blocking the migration of wildlife. Growing water stress and scarcity are also affecting the functioning of hydroelectric plants in various regions. For hydropower plants to be truly sustainable, the construction of such infrastructure must consider and address these environmental issues. Small-scale hydropower plants, as an alternative to large hydropower dams, can also be designed to run "in-river" (rather than constructing new storage facilities), which is considered more environmentally friendly because it does not interfere with the flow of the river.

Improving land-use planning

Innovations in remote sensing and high-resolution technologies, along with computer modelling, is making it possible for rural planners to better assess the environmental impact of different agricultural and human settlement strategies. Through the application of such technologies, local authorities can better deal with the challenges of depletion, degradation and pollution of water and land resources. The growing availability of affordable remote sensing technologies also allows rural planners to use high-resolution topographical and hydrological data in the design and construction of roads with a view to reducing soil erosion or encroachment on critical habitats. In addition, land-use planning methods can help ensure that road and market infrastructure is designed in a way to facilitate the most efficient connection between rural producers and consumers in urban areas.

The availability of rural services often plays a pivotal role in the decision-making of farmers and other businesses regarding whether to adopt improved land management technologies and participate in markets. The most critical rural services, in terms of direct impact on agriculture, include all-weather roads, extension and veterinary services, market infrastructure, water, access to credit, and communications infrastructure. Access to markets, for example, has been found to increase investment in grazing land improvement in Africa (Kihiu and Amuakwa-Mensah, 2017). The decisions of landowners to improve the land are also generally driven by their expected return on investment. Remunerative returns are enhanced when producers have easy access to markets to buy inputs and sell their produce. Poor market access increases transaction costs and lowers the returns and is thus likely to reduce the incentives of smallholder farmers to invest in land improvement.

Circular and conservation practices

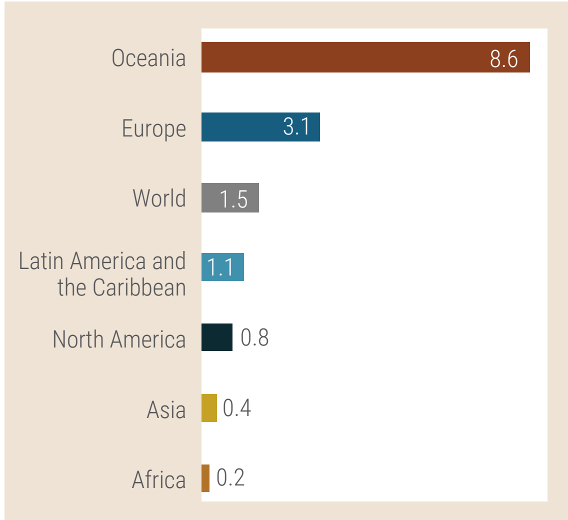
Scaling up organic farming

A shift to organic farming offers an increasingly viable approach to strengthening the sustainability of agriculture. Organic farming has lower environmental impact than conventional agriculture. Organic farming minimizes inputs by focusing on the use of legumes, green manures, crop rotation and organic fertilization, with a view to increasing soil organic matter, maintaining soil quality, reducing groundwater pollution, delivering greater ecosystem services, and protecting biodiversity. Some 1.5 per cent of the global agricultural land is currently cultivated in an organic manner. The highest

Figure IV.13

Organic share of total agricultural land, 2018

Percentage



Source: Willer et al. (2020).

organic share of the total agricultural land, by region, is in Oceania (8.6 per cent) and the European Union (7.7 per cent) (figure IV.13). Australia was an early adopter of organic agriculture and is now the country with the largest certified organic area, nearly 23 million hectares. Organic agricultural land has increased more than sixfold since 1999, reaching 71.5 million hectares in 2018.[3]

While the largest share of the global demand for organic agricultural produce is in developed countries, almost 90 per cent of organic farmers live in developing countries in Asia, Africa, and Latin America and the Caribbean. The countries with the largest number of organic farmers are India (0.6 million), Ethiopia (0.2 million), and Mexico (0.2 million). The largest organic markets in terms of retails sales are Europe and North America (figure IV.14).

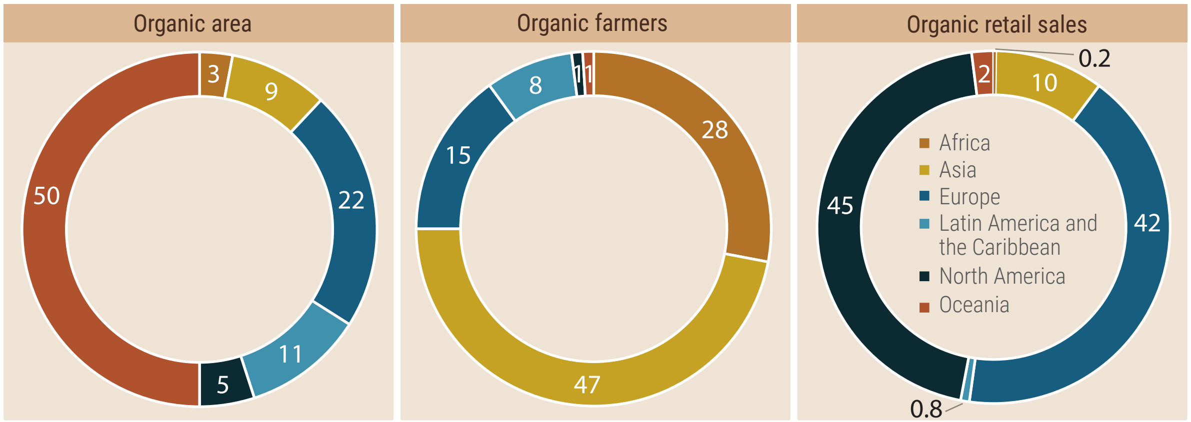
While conventional agriculture has historically produced higher yields than organic farming, the deple-

3 Smallholder farmers in many low-income countries also practice organic farming as crops are grown with no external inputs. In Uganda, only 5 per cent of farmers use fertilizer. However, this is seldom certified and thus often not classified as organic farming.

Figure IV.14

Share of global organic area, farmers and sales, 2018

Percentage



Source: Willer et al. (2020).

tion of the soil quality has reduced this advantage over time. Crop yields in organic farming have also increased significantly, which has narrowed the gap between the two methods. Under certain conditions and management practices and for crop groups such as rice, soybean, corn and grass clover, organic farming has come close to matching conventional agricultural systems in terms of yields and land requirements (Reganold and Wachter, 2016).

Organically managed farms have also been shown to produce higher yields than those relying on conventional methods in some context—for example, where there is greater risk of drought. Techniques such as rotational farming, cover cropping, multi-cropping, and polyculture in organic systems further reduce the yield and land-use difference (Ponisio et al., 2015). Conventional farming systems have provided growing supplies of food, but their negative externalities have not been properly accounted for when compared against organic agriculture. This has made it difficult to compare the total environmental impact of conventional and organic farming practices.

In terms of rural development and structural transformation, an issue discussed in chapter 2, one of the successes of conventional agriculture has been its ability to produce more with less labour, which has enabled surplus workers to move to other productive sectors. Organic farming, on the other hand, is typically more labour intensive, thereby absorbing more workers and furthering social inclusion and creating sustainable economic opportunities.

There are still considerable obstacles to the adoption of organic farming practices presented by vested interests and existing policies; lack of information and knowledge; weak infrastructure; and other economic challenges, as well as misconceptions and cultural biases. Weak certification institutions in developing countries also often do not capture the share of smallholder farmers practicing organic farming. Agricultural companies enjoying a high share of food markets have an interest in maintaining the conventional model. Organic farming has also been subject to less public and private research and investment than conventional practices, especially in developing countries. To scale up the role of organic agriculture in food production, the factors limiting organic yields need to be more fully understood and addressed. Also, scaling up organic farming without expanding arable land, could require a change in food consumption behaviour, including a shift in diets and reduced food waste.

Nonetheless, some countries have already set ambitious goals for developing organic agriculture. Bhutan has set the goal of becoming the world's first 100 per cent organic nation. Sikkim, a State in north-eastern India managed to go 100 per cent organic in 2016 by implementing a phase out of chemical fertilizers and pesticides, as well as a total ban on the sale and use of chemical pesticides. Denmark adopted an action plan in 2010 to encourage organic farming and consumption and has the highest market share of such products in the world at 10 per cent, with almost 80 per cent of the population purchasing organic food. Austria, as part of its strategy to protect biodiversity in rural areas, has focused on creating incentives for farmers to practice organic agriculture (ELCI, 2002). This agricultural strategy has not only been successful in terms of preserving biodiversity, but strengthened Austria's attraction as a tourist destination as well. In Germany, the provision of subsidies to encourage organic farming has played an important role in fostering the growth of this sector (Brenes-Muñoz, Lakner and Brümmer, 2016).

Box IV.3 presents both a *baseline* and a *sustainable scenario* for making food and agricultural systems more sustainable by 2030, based on work by the FAO. While there are significant limitations and uncertainties associated with this approach, the scenarios provide a globally comprehensive and consistent foresight exercise on food and agricultural systems. As shown in box IV.3, it will not be necessary to substantially increase agricultural production by 2030 in order to meet the SDG targets for ending hunger and achieving food security. These targets can be met with modest expansion of agricultural output, as long as agricultural

BOX IV.3

Achieving sustainable agriculture and food security by 2030: a baseline and a sustainable scenario

Globally, agricultural systems are facing many challenges, such as providing sufficient food and other agricultural products to meet a growing demand; eradicating hunger and food insecurity; enhancing the productivity and sustainable use of natural resources; and responding to the impact of climate change. The Food and Agricultural Organization of the United Nations has extensively studied what changes are required to food and agricultural systems to end hunger and food insecurity by 2030 in a sustainable way.

Baseline scenario

In the baseline scenario, there is limited innovation in production processes and little progress towards sustainability, including hardly any changes in the energy mix. Lifestyle changes are also minimal. As a result, agricultural CO^2 emissions increase by 16 per cent by 2030, further exacerbating the risk of climate change. The share of arable land is also estimated to increase by 6 per cent by 2030, from 1,600 million hectares in 2012 to 1,703 hectares in 2030. The share of undernourished people in the baseline scenario would decline from around 11 per cent in 2012 to 6.7 per cent in 2030, but this will not be sufficient to reach Sustainable Development Goal (SDG) 2.

Sustainable scenario

In the sustainable scenario, production processes experience a shift towards more sustainable, less resource-intensive technologies in response to changing consumer preferences. There is increase in research, development and innovation in agriculture, including the use of environmentally sound technologies, precision farming and applied robotics. Boosted investment ensures a transition towards a more sustainable use of natural resources and climate change mitigation, and a shift to a "circular" economy. Farmers in countries with sufficient per capita income and adequate public support gradually shift towards more sustainable practices such as conservation agriculture and organic farming. Chemical fertilizer use is also restrained, which favours the adoption of precision and organic agriculture. Consumers receive information on the origin, content, quality and sustainability levels of processed food. As a result, food preferences are assumed to shift to less emphasis on animal-based foods and vegetable oils and fats, creating incentives for farmers to adopt more sustainable farming practices.

continued >>

systems become more sustainable and food is more equitably distributed across and within countries.

Promoting smallholder, mixed farming and conservation agriculture

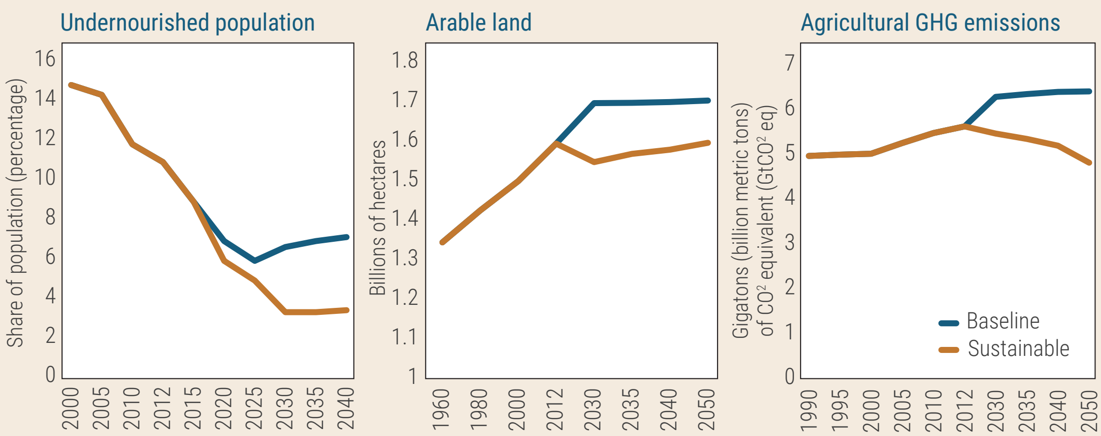
Smallholder agriculture may also be more sustainable than large-scale, mono-crop farming when pursued in combination with the benefits of organic, mixed and circular approaches. Under mixed-farming practices, the waste from one crop is used as a fertilizer for another. Mixed farming also allows for combination of crop cultivation and animal husbandry, so that waste from one can serve as production input for the other. Mixed farming can play an essential role in land management and promote sustainable practices, and the combined production of different crops and legumes can raise yields in a sustainable way. Smallholder farms, for example, are important for maintaining nutrient diversity, as the shift to large-scale industrial agriculture often implies a decline in the diversity of production. Smallholder farmers and indigenous peoples can also play a critical role in the conservation of crop genetic diversity, as local varieties are often more resilient than the modern ones. The adoption of smallholder organic farming, in addition, often has the complementary benefits of ecosystem services in terms of improved soil organic matter, reduced soil erosion and greater biodiversity (Walpole et al., 2013).

BOX IV.3 continued

This makes it possible to reduce global CO^2 emissions from agriculture by 3 per cent by 2030. The share of arable land is also reduced from 1,600 million hectares in 2012 to 1,554 million hectares in 2030, a decrease of 3 per cent. The share of undernourished people is more than halved compared to 2012 and reduced to 3.4 per cent of the global population by 2030. It is thus possible to achieve a strong reduction in the number of undernourished people without expanding arable land while also lowering CO^2 emissions. In sum, it will not be necessary to substantially increase agricultural production by 2030 in order to meet the SDG targets for ending hunger and achieving food security. These targets can be met with modest expansion of farming output as long as agricultural systems become more sustainable, and food is more equitably distributed across and within countries. The shift to sustainable food and agricultural systems thus constitutes a pathway for ending hunger and food insecurity by 2030 with potential impact across the entire SDG agenda.

Figure IV.3.1

Projections for baseline and towards sustainability scenario, varying time periods



Source: UN DESA, based on data from FAO (2018b).

Conservation agriculture is another alternative approach to conventional farming that aims to foster a more balanced use of land resources. While similar to organic farming in many ways, conservation agriculture is based on the principle of minimum mechanical soil disturbance. Conservation agriculture increases soil organic matter and soil fertility in general, and can reduce soil erosion by up to 75 per cent on gently sloping soils (Panagos et al., 2018). Agroforestry practices can help smallholder farmers overcome some of the barriers to conservation agriculture. In Zambia, the integration of nitrogen-fixing trees and maize has reduced the need for fertilizers. In China, conservation agriculture has contributed to yield increases from 2 to 8 per cent for wheat, maize and rice. In India, this practice has substantially reduced production costs for farmers and increased irrigation water productivity (FAO, 2020d). Conservation agriculture has expanded rapidly, reaching about 180 million hectares across 79 countries in 2018, an increase of approximately 69 per cent globally since 2008–2009 (Kassam, Friedrich and Derepsch, 2019).

Increasing wastewater recycling and use

Reusing wastewater for both municipal and agricultural purposes means less pollution, more conservation, and additional resources for recharging aquifers. The use of treated wastewater for peri-urban irrigation has the most potential in rural towns and villages, where wastewater is more easily available and there is a market for agricultural produce. If adequately treated and safely applied, wastewater is a valuable source of both water and nutrients, contributing to food and nutrition security and the improvement of livelihoods.

Municipal wastewater accounts for the majority of wastewater used in agriculture. Such use is common in many countries of the Middle-East and North Africa as well as in Australia, China, Mexico, and the United States. In 2013, 71 per cent of the wastewater collected in the Arab States was safely treated, of which 21 per cent was used for irrigation and groundwater recharge. Municipal water demand corresponds to 11 per cent of global water withdrawals, of which only 3 per cent is consumed and the remaining 8 per cent is discharged as wastewater. If used in agriculture, such wastewater could potentially irrigate 40 million hectares or 15 per cent of all irrigated land (Mateo-Sagasta, Raschid-Sally and Thebo, 2015). Agricultural drainage and wastewater also account for 32 per cent of water withdrawals, a much larger share than municipal use. These figures show the enormous potential for increasing water recycling of municipal and agricultural wastewater.

Whereas public health and safety concerns have traditionally been the main reason for public resistance to wastewater use, cultural aspects and consumer behaviour appear to be the overriding factors today, even if the reclaimed water resulting from advanced treatment processes is safe (UNESCO WWAP, 2017). Awareness-raising and education are important tools to overcome social, cultural and consumer barriers and to contribute to building trust among consumers and changing public perception about wastewater use. In Singapore, a comprehensive educational and awareness campaign branding reclaimed water as “NEWater” increased social acceptance regarding wastewater use.

Large-scale recycling plants tend to be energy intensive and produce sludge that is sometimes difficult to discard. Newer technologies may be able to alleviate these problems by developing new sludge by-products that move towards recycling at net zero energy cost by capturing biogas. Biogas, a by-product of the treatment process, could then be captured and used to offset the energy consumption of the facility. These advances offer new opportunities not just to close the water cycle, but also to reduce carbon emissions, energy costs, and environmental contaminants.

The use of ICTs like smart meters can also help reduce water consumption and waste at the household and community level and improve the treatment and recycling of wastewater. The use of telephone applications and text messages to alert local latrine emptying services can also help ensure that such waste is properly discarded for people living in informal settlements in rural areas with no connection to sewerage networks (Ryder, 2018).

Shifting to more sustainable livestock management practices

Livestock production systems contribute significantly to total greenhouse gas emissions and land degradation. Multi-pronged approaches are required to address such emissions and environmental pollution from livestock. Breeding programmes have generated animal breeds with up to 20 per cent less methane emissions (González-Recio et al., 2020). Increasing feed conversion efficiency and improved livestock solid waste management, can also contribute to reducing CO^2 emissions and environmental pollution. A low-cost strategy to addressing the problem of land degradation is to increase rotational livestock grazing (Bogaerts et al., 2017). Soil carbon stored in rotational grazing plots is 19 per cent higher than on continuously grazed plots. Rotational grazing also increases soil carbon by 25 per cent and is often feasible in dry areas with expansive rangelands (Byrnes et al., 2018). Rotational grazing, however, is becoming less amenable in mixed crop-livestock systems and in areas with high human population density.

Investing in land restoration and reforestation

Land restoration can raise groundwater levels, increase crop yields, and induce positive changes in the fauna of the respective region (United Nations, 2019a). It is estimated that roughly 40 per cent of the currently degraded land has the potential for restoration at low cost (UNEP and International Resource Panel, 2014). In Europe, it has been observed that reduced tillage plots can increase topsoil organic matter and microbial biomass by 25 and 32 per cent, respectively, compared to the conventional approach (Krauss et al., 2020). Soil organic matter is one of the indicators used by the United Nations Convention to Combat Desertification to monitor achievement of SDG 15.3 (land degradation). Low-cost soil fertility management techniques have also been found to work in low-income countries experiencing high loss of soil organic matter (Zomer et al., 2017).

Addressing deforestation and forest degradation requires tree-planting and protection programmes. Farmer-managed natural regeneration, tree planting and protection, have been used successfully on agricultural lands in the drylands of the Sahelian region. These practices reduce soil erosion, increase soil carbon, soil fertility and provide solid bioenergy and other non-timber forest products for poor households. In tree-planting programmes, native trees have proven to have higher survival rate and more resilience than exotic trees (Hänke et al., 2016). Using native trees avoids the risk of disrupting local ecosystems. Trees with multiple functions are also more likely to be widely adopted than single-purpose trees (Benz et al., 2020).

The COVID-19 recovery process could accord high priority to ecological investments—such as land restoration, reforestation and revitalization of rural ecosystems—as they can be implemented quickly, have few training requirements, and meet social distancing norms. Many countries have also already planned such projects as part of international agreements on climate change.

Protecting indigenous seed banks

Seed banks developed by farmers and indigenous peoples are an important instrument for protecting and conserving crop genetic diversity. Indigenous communities around the world have been pioneers in preserving traditional agricultural varieties in such seed banks. The seed banks are not only archives containing records of crop genetic diversity, but their use can open up new opportunities to protect the environment and boost food security by developing more resilient, productive and nutritious crops. Given the changing climate, traditional crops can become the key for sustainable food production as local varieties with a high degree of genetic diversity may better withstand and adapt to environmental stress and change. It may thus be critical for sustainable rural development to protect indigenous seed banks and ensure their ability to conserve the local seed collection, as well as to ensure that scientists and farmers have access to seeds, which can foster crop improvement efforts and result in positive ripple effects for food production.

Investment in institutions

Empowering local actors

The perceived inefficiency of large-scale water schemes operated by local and central governments, and the legal, administrative and regulatory challenges of relying on private providers in the water sector, has prompted many countries to strengthen the role of social institutions, such as water-user associations, in the management of water resources, particularly at the local level.

In Europe, water-user associations have a long tradition in water management at the local level. This includes farmers creating water associations to manage irrigation systems. Such associations may collect water tariffs, organize irrigation procedures, control the application of rules, establish sanctions, and deal with the operation and maintenance of the irrigation system. In other regions, such as the Middle-East and Northern Africa, the creation of water associations is a more recent development, generally dating from the 1990s (Kroll, 2002).

Lao Peoples Democratic Republic is an example of a country that has managed to close the rural-urban gap in water and sanitation services by strengthening the involvement of local communities in the management of water resources along with enhanced emphasis on sanitation marketing tools, often in partnership with the private sector. In 2002, only 20 per cent of people in rural areas of Lao Peoples Democratic Republic, compared to 48 per cent in urban centres, had access to basic sanitation; but by 2016, the percentages were 53 and 61 per cent, respectively.

Paraguay is another country that has managed to significantly improve the percentage share of the rural population with access to clean water through institutional reform, from 51 per cent in 2000 to 94 per cent in 2015. The responsibility for water and sanitation in the rural areas of Paraguay was assigned to community associations and subsidies were provided for groups of less than 150 people. Paraguay also placed its sanitation and water agency within the Department of Health, which helped to ensure that access to clean water was defined as a public health priority. In addition, in 2007, the country recognized—in law—that equal access to water of sufficient quantity and quality is a human right, shared by all.

The collective management of communities of forests and wilderness has also shown to be more effective than relying on individuals or central authorities, particularly when it comes to the restoration of degraded forests (Poteete, Janssen and Ostrom, 2010). This suggests that the achievement of SDG 15.2 (sustainable management of forests) may require a stronger mandate to local institutions to manage forests and for rural people to share in the benefits of such resources.

The impact of farmer groups on forest management is often seen to provide evidence for Elinor Ostrom's eight principles for managing common pool resources (Ostrom, 1990; Ostrom, 2008).[4] A recent review by the FAO of community-based forest management also confirms its effectiveness (Gilmour, 2016). Community-based forest management has been increasing in developing countries, but less so in sub-Saharan Africa (figure IV.15), where deforestation has often been more severe due to land and water grabbing for large-scale agriculture and livestock production systems.

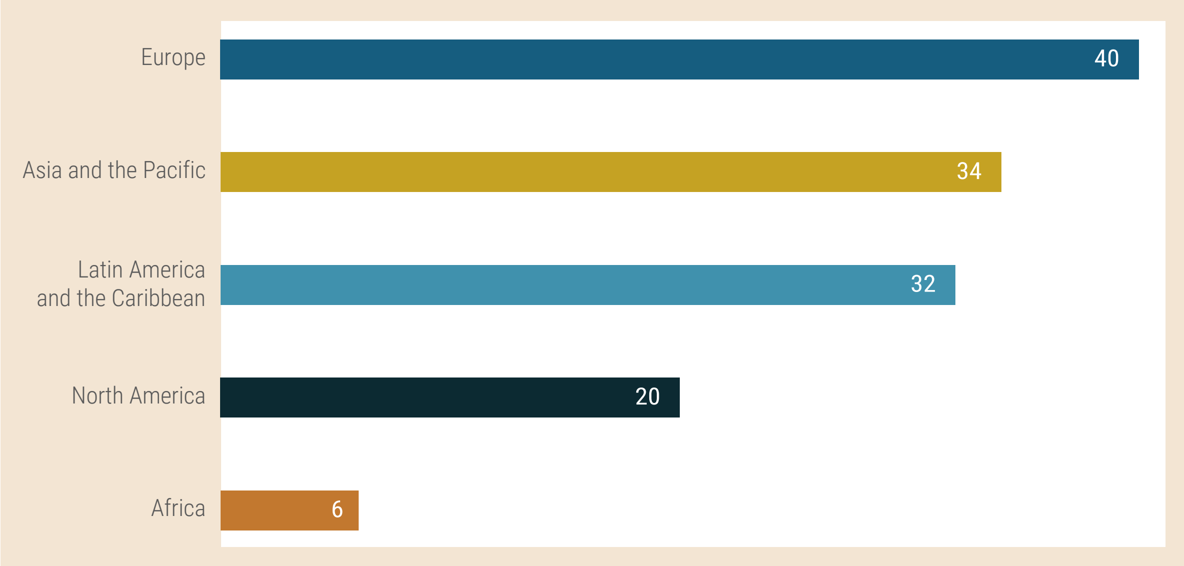
Local and indigenous communities could also play a greater role in addressing forest deforestation. Indigenous communities have been successful when it comes to forest protection. In Bolivia, Brazil and Colombia, the average annual deforestation rates in tenure-secure indigenous lands in 2000–2012 were 2-3 times lower than in similar forests without secure tenure (Ding et al., 2016). Experience also suggests that the conservation of protected biodiversity areas benefits from the adoption of community-based approaches (Buschke, Brownlie and Manuel, 2019).

4 The eight principles are (i) define clear group boundaries; (ii) match rules governing use of common goods to local needs and conditions; (iii) ensure that those affected by the rules can participate in modifying the rules; (iv) make sure the rule-making rights of community members are respected by outside authorities; (v) develop a system, carried out by community members, for monitoring members' behaviour; (vi) use graduated sanctions for rule violators; (vii) provide accessible, low-cost means for dispute resolution; and (xiii) build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system.

Figure IV.15

Share of total forest extent owned by communities across regions, 2015

Percentage



Source: Gilmour (2016).

The introduction of market-based strategies, such as biodiversity offsets, have also proven to be effective in expanding and conserving protected areas. Successful biodiversity conservation programmes have generally relied on strong local institutions and financial incentives. Poaching in the Mburo National Park in Uganda, decreased significantly after community-based management was introduced (Ullah and Kim, 2020). Another example comes from the Kruger National Park in South Africa where 25,000 hectares were assigned to a local Makuleke tribal group, which has since managed this area in a sustainable manner (Brockington, Duffy and Igoe, 2008).

In middle- and high-income countries where government capacity is generally strong, local institutions usually play a key role in implementing participatory natural resource management. In the European Union, over 60 per cent of forests are privately owned, but managed under government regulations (EEA, 2016). Despite such high private share of forest ownership, government policies and regulations in Europe have been effective because they were developed with active participation of local communities.

In Eastern and Western African countries, decentralization of authority has fostered greater propensity of local communities to enact natural resource bylaws and regulations than generally is the case with the central government (Nkonya et al., 2015). Compliance with the bylaws and regulations enacted by local councils is also higher than for those established by the central authorities (Nkonya, Pender and Kato, 2008). Furthermore, decisions of farmers to adopt agricultural intensification practices that reduce the demand for land have been found to be positively correlated with the perceived state of local governance (Ceddia et al., 2014).

For example, the 2004 forestry law in Niger gave landowners tenure for trees on their farmland. These and other changes improved the ability of the Government to manage forests more effectively than other countries in West Africa (Moussa et al., 2016). The tenure system incentivized landowners to plant and protect trees. The value of timber and non-timber forest products also increased since deforestation created severe shortages (Specht et al., 2015). As a result, there was no longer need for an expensive government programme to implement a tree planting and protection programme (Carey, 2020), yet Niger succeeded in significantly reducing deforestation. Such institutional changes and incentives contributed to the regreening of the Sahel (Herrmann, Anyamba and Tucker, 2005). The results from Niger demonstrated the key role that incentives play in achieving sustainable forest and tree management even among the poorest landowners.

Capitalizing on the potential of economic instruments

Today, governments in most countries amplify adverse environmental externalities by providing more subsidies to exploit nature than they do to protect it. Direct subsidies that are harmful to biodiversity total about $500 billion per year globally, while financing associated with the conservation and sustainable use of biodiversity amount to some $68 billion annually (Dasgupta, 2021). Policy reforms should include the elimination of perverse subsidies in agriculture, energy and transportation, which damage natural resources and common-pool resources. Removing such harmful subsidies could improve both economic and environmental outcomes. Also, adopting a tax on the extraction of certain natural resources and the disposal of waste to reflect their full costs would increase incentives to recycle and reuse existing materials (UNEP, 2021b).

Since the 1980s, there has been growing interest among policymakers in how economic instruments and institutions can play such an effective coordination role in the area of water resources management. Generalized water, energy and fertilizer subsidies incentivize the overuse of such inputs, with resultant environmental degradation. In addition, subsidies are often ineffective at reaching the poor because they tend to mostly support richer farmers. Such subsidies could be phased down or eliminated with the savings invested in agricultural and water research and development, compensatory income support to small farmers, and targeted smart subsidies to achieve specific water management goals.

The capital intensity and economy of scale of surface water supply often provide a strong rationale for public provision of this resource, whether by a user collective or a monopoly seller such as a utility company. The incentive problem has led some economists to argue for a greater role for economic instruments such as water rights in the management of this scarce resource. A system of water rights can create incentives for improved irrigation management by farmers, including the adoption of more advanced technology. With strong water rights, farmers know they can retain their additional income in the long-term to invest in new irrigation technologies and crop varieties and improved crop management (Rosegrant and Binswanger, 1994).

Some countries have opted to strengthen the role of private providers in the water sector with a view to fostering incentives for greater efficiency and reduction of operating costs. One of the factors driving the argument for a greater role for private providers in the water sector is often the perceived inability of governments to finance the necessary infrastructure, operations and maintenance of water systems. It is recognized at the same time that a greater role of private providers in the water sector requires more effective regulatory and enforcement capacity of governments. It is also important to note that water privatization has gender implications, and rural women might be disadvantaged by such market mechanisms.

Economic instruments can play an important role in furthering sustainable land management. Landowners are generally more likely to invest in long-term land improvement if they have secure tenure (Abdulai, Owusu and Goetz, 2011; de Soto, 2001). A study of Peruvian indigenous communities has shown that giving titles to indigenous people significantly reduces deforestation (Blackman et al., 2017). In many countries, women are without property rights. The recognition of women's land and forest rights could contribute to the fight against deforestation. The definition of secure tenure, at the same time, is contextual. The majority of smallholder farmers in developing countries do not have a formal title, yet they have been observed to invest as much in land improvements as those granted such a right, if they perceive that land ownership is secure (Barrows and Roth, 1990). This suggests that a major driver of long-term investment in land improvement is the perception of land security, regardless of formal titling (Lawry et al., 2014).

In some sub-Saharan African countries, farmers have been incentivized to improve soil management through direct subsidies. Governments have also introduced specific subsidies to target poor, smallholder farmers, which has contributed to improved food security (Jayne and Rashid, 2013). Subsidy programmes in the region could be further improved by treating them as payment for ecosystem services. The subsidies could, for example, be paid on the condition that farmers adopt an easily verifiable organic soil fertility management practice, which sequesters a certain amount of carbon. Such conditional fertilizer subsidies have been shown to be acceptable to smallholder farmers in Malawi (Marenya, Smith and Nkonya, 2014).

Conclusion and key policy recommendations

The rapid growth that has taken place in agriculture, industry, infrastructure and settlement in rural areas in past decades has resulted in major depletion, degradation and pollution of the environment and natural resources. This chapter particularly calls for more sustainable use and management of water and land resources because of their impact on the achievement of almost all SDGs.

The chapter shows that a business-as-usual approach to water- and land use is not sufficient to achieve the SDGs by 2030. For example, by 2030, an estimated 20 per cent of the global rural population is not likely to have access to basic drinking water (SDG 6.1.1) and 41 per cent could be without access to basic sanitation services (SDG 6.2.1). The population affected by water stress, a significant share of which resides in rural areas, could also increase from 2.5 billion to 3.7 billion people by 2030, despite the projected increase in global water-use efficiency (SDG 6.4.1).

With water demand estimated to increase to about 6,000 billion m^3 by 2030, the world is likely to experience a significant water deficit. The share of people exposed to high water pollution is also projected to increase significantly if the current patterns in chemical fertilizer use are not modified. Some 38 per cent of biodiversity could similarly be lost by 2030 because of the impact of agricultural and industrial activities and climate change (SDG 15.5). It is also predicted that about 95 per cent of the Earth's land areas could become degraded by 2050, and the world could run out of topsoil in 60 years, unless there is a major change in the current rural development strategy (SDG 15.3). Furthermore, food-related CO^2 emissions alone—which are projected to double by 2050 without changes to current foods systems and consumption and production patterns—could result in the global average temperature rising 1.5 and 2.0 degrees Celsius by 2050 and 2100, respectively (SDG 13).

The chapter has proposed a sustainable scenario as an alternative to the business-as-usual approach, which involves the adoption of a strategic portfolio of initiatives aimed at significantly improving the performance of the water sector and achieving land neutrality by 2030. If successfully implemented, this portfolio of initiatives focused on new investment in water- and land-use technologies, greater application of circular and conservation practices, and renewed efforts to strengthen institutions and incentives, could help ensure food and water security in rural areas, and the achievement of the respective SDGs by 2030. This shift in rural development strategy must also be accompanied by changes in food consumption and production patterns in both rural and urban areas, including a shift in diets and a reduction in food waste.

In the ***agricultural sector***, it will be important to select technologies on the basis of their effectiveness in contributing to both productivity growth and environmental sustainability. The introduction of advanced technologies such as drip and sprinkler irrigation, precision farming, ICTs and remote sensing, could contribute to increased income of farmers from higher value crops, enhanced convenience in farming operations, reduced labour use, lower pumping costs and enhanced water savings. The adoption of integrated soil fertility management and agroforestry practices could also contribute to enhanced agricultural productivity and lower the use of inorganic fertilizers. Conservation and organic farming, furthermore, offers many environmental benefits in terms of reduced CO^2 emissions and the rejuvenation of soil quality. Other measures such as increased research on crops that use less chemicals like nitrogen and phosphorous; modernization of irrigation systems; and development of precision technologies suited to smallholder farmers in developing countries, would also be important to ensure that agriculture is effectively aligned with planetary boundaries. Furthermore, countries could consider establishing a global target for halting the expansion of croplands at the expense of grasslands, savannahs and forests.

Industries and services account for significant resource extraction in rural areas and this sector needs considerable environmental sustainability improvements. There is need to diversify from agriculture and further expand non-farm activities in rural areas, as discussed in Chapter 2. If done in a coordinated way, this could be a win-win strategy by reducing the pressure on land and water, creating employment and reducing post-harvest losses. This will require new investments in the expansion of water supply and connectivity, including putting in place incentives for more efficient water use and cost recovery. The strengthening of wastewater collection and treatment is particularly critical to reduce pollutants discharged into the environment in rural areas. Improved management, recycling and use of wastewater also requires new investment in treatment facilities combined with better regulation of pollution and taxes on polluters. In sum, there is much need to accelerate the adoption of circular approaches in the industry and services sector.

The greening of ***settlements and infrastructure*** could also be accorded high priority in rural areas. This could include further institutionalizing sustainability considerations in rural development planning. Greater participation of stakeholders in rural development planning is also likely to result in enhanced public demand for the greening of infrastructure and settlement projects. ICTs and remote sensing, furthermore, are new tools that can improve the participation of young people and vulnerable groups in shaping the future of rural areas and communities. There is also significant potential in rural settlements to increase the use of small-scale technology such as standpipes, water kiosks, and household-based water filters and purification devices to improve wastewater collection and treatment. Another priority in rural settlements could be to climate-proof infrastructure, e.g., by changing the composition of road surfaces so that they do not deform in high temperatures and cause run-off during the rainy season. The use of small-scale hydropower plants could also be scaled-up in many rural areas.