Food wasted, food lost

Food security by restoring ecosystems and reducing food loss

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Food security by restoring ecosystems and reducing food loss

Editorial team Rannveig Knutsdatter Formo
Hanne Jørstad
Christian Nellemann
Clever Mafuta
Richard Munang
Jesica Andrews
Julie Nåvik Hval

Cartography Riccardo Pravettoni

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Summary

Food security is critical for health, labour productivity, economic growth and sustainable development. Regional and local food insecurity, coupled with the need to develop innovative and sustainable solutions aimed at increasing food production, are some of the pressing challenges the world faces in securing the food demands of its population which is expected to grow to 9.6 billion by 2050. It is argued in this assessment that ecosystem degradation is a major cause of loss in potential food production, while human practices and consumer preferences, among other factors, are blamed not only for food loss but also food waste.

The world's attention has been primarily focused on expanding the area under food production to meet growing demand. If the same model is to be pursued, it is estimated that an additional 130 million hectares of cropland will be needed to support food production. This represents six per cent of the estimated 2 billion hectares of land that is already degraded, of which 560 million hectares are agricultural land. It therefore makes economic and sustainability sense to include the restoration of degraded land as part of the solution to the world food demand, while also pursuing other ecosystem-based management and green investment approaches. Such approaches will unlock the capacity of food producing ecosystems, thus reducing losses in potential food.

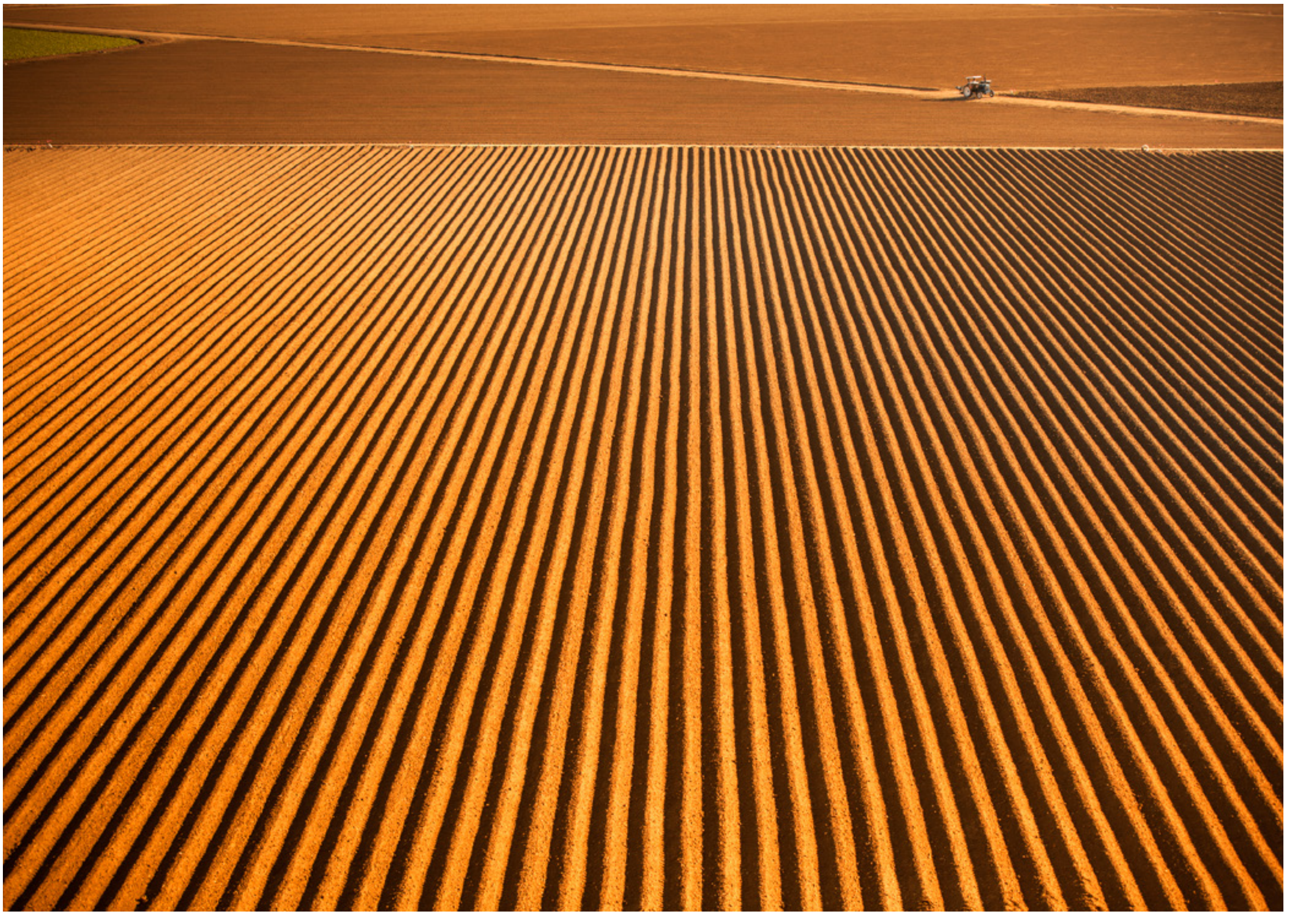
By restoring just a quarter of the 560 million hectares of degraded agricultural land, the increase in yields could potentially feed an additional 740 million people. As such, the restoration of agro-ecosystems can result in the production of enough food to meet the needs of a quarter of the expected growth in the world's human population by 2050. Such measures should complement other innovative ways such as the safe capture and conversion of food waste to animal feed. This can provide one of the greatest opportunities for improving future food supplies and minimizing the global environmental footprint. Freeing the cereals currently used as animal feed for direct human consumption could, in principle, increase available food calories by as much as 70 per cent, which could feed an additional 4 billion people. No other single factor can increase food security this dramatically or counter the effects of the rising share of cereals that will be used for animal feed from today's 30–40 per cent to the 40–50 per cent anticipated to be needed by 2050.

The majority of the degraded land occurs in the geographic areas where local food insecurity is most prevalent. Estimates show that between 2 and 5 million hectares of land are lost annually due to land degradation, chiefly soil erosion, with losses being 2 to 6 times higher in Africa, Latin America and Asia than in North America and Europe. Africa is perhaps the continent most severely impacted by land degradation. As a result, yield reductions due to land degradation in some African countries are as high as 40 per cent, while the global average ranges from 1–8 per cent.

The restoration of agricultural systems can also provide major economic improvements, as has been demonstrated in Niger where land rehabilitation not only helped in improving soil conservation and water-harvesting, but also resulted in increased crop yields and tree cover thus affording communities regular incomes. The restored areas in Niger continued to be expanded without development assistance and this, together with the establishment of a land market, resulted in a positive learning process and a green economy mode of thinking that became self-driven.

As much as 1.4 billion hectares of land are used to produce the total amount of food that is lost and wasted. This translates to more than 100 times the area of tropical rainforests that are being cleared every year, of which 80 per cent is cleared for agricultural expansion. Global food production amounts to more than 4 billion tonnes, or 4 600 kilocalories per capita per day. However, not all the food produced becomes available for human consumption since at least one third – over 1.3 billion tonnes – is lost or wasted annually. The lost and wasted food can easily meet the needs of the daily net increase in population of 200 000 – 230 000. Food is lost and wasted for different reasons. In developing countries food is lost mainly during the first stages of the food supply chain – in the field, in storage or during transportation to markets. In sub-Saharan Africa alone, food worth US$4 billion is lost before reaching consumers, and this is enough to feed 48 million people for a year. In industrialized countries, an estimated 20 – 50 per cent of food that is bought is wasted by consumers, in addition to the losses between post-harvest and sale.

The fisheries sector, a major source of protein and livelihoods, continues to be hampered by unsustainable practices such as overfishing that is partly blamed on industrial-scale illegal



fishing mainly by foreign vessels. Small-scale fishers are vulnerable as they have a lower fishing range, lower capacity in terms of harvest efficiency and a lower buffer or alternative operational range if local areas are overexploited by industrial-scale fishing. In fewer places is this more critical than in West Africa where foreign vessels are increasingly overexploiting local fish stocks, including illegal, unreported and unregulated fishing. Globally, illegal fisheries account for 14–33 per cent of the total landings, but in West Africa it is as high as 40 per cent. Similar problems also exist on the east coast of Africa. Both regions have high population growth rates and high incidents of food insecurity – and it is therefore highly problematic that foreign vessels cause overexploitation of their fish stocks. Estimates show that the recovery of depleted fish stocks has the potential of feeding an additional 90 million people, while the 40 million tonnes of fish and seafood that are discarded can satisfy the daily protein needs of a further 370 million people for a year.

Preventing further food loss due to degradation of ecosystems is a challenge. An estimated 5–25 per cent of the world's food production may be lost by 2050 due to climate change, land degradation, cropland losses, water scarcity and species infestations. Of these, water scarcity and land degradation are the most significant, strengthening further the importance of restoring ecosystems to become more resilient to change.

Dependence on cropland expansion, intensified fisheries and aquaculture as the only solutions to increasing demands for food is likely to undermine the very environmental resources upon which food production is based. Restoring degraded lands through improved water conservation, tree planting and organic farming systems, along with reducing illegal fisheries and unsustainable harvest levels are key components to improving food security where it is needed most, while sustaining a green economy and local livelihoods and markets.

In conclusion, with over 2 billion hectares of degraded land, food produced on 1.4 billion hectares being lost and wasted and an increasingly large share of food production going to animal feed, a new agricultural and food consumption paradigm is needed for sustainable food production. Such a paradigm shift towards sustainable production calls for investing in better management of food producing ecosystems.

Recommendations for action

Restoring agro-ecosystems can help meet the food security needs of as many as 740 million more people by 2050, a figure that amounts to more than a quarter of the expected growth in the world population. By recovering depleted fish stock, the increase in available proteins could cover the daily needs of an additional 90 million people. This report recommends the following options to protect and restore ecosystems in order to maintain and secure future food production and reduce food loss and waste:

1. Prioritize ecosystem restoration by implementing sustainable ecosystem-based management practices as a means to increase food security and maintain ecosystems.

2. Reduce deforestation and degradation of the world's forest ecosystems by increasing enforcement efforts against illegal logging through strengthening national enforcement capacity and international collaboration.

3. Enhance sustainable small-scale farming in developing countries, particularly sub-Saharan Africa, by encouraging agricultural practices that are beneficial to the environment and food production such as integrated farming, agroforestry and conservation agriculture.

4. Promote sustainable farming that limits the use of agro-chemicals and avoids fragmentation of habitats for important species such as pollinators. Regulate and prohibit pesticides that may threaten pollinators, particularly honey bees that are responsible for the pollination of one-third of food crop production. Improve food storage and preservation capacity and farmers' access to markets, particularly in developing countries.

5. Prevent overfishing and illegal discards of fish by strengthening national enforcement of fishing regulations and increasing international collaboration to curb illegal, unreported and unregulated fishing practices.

6. Reduce the amount of food that is wasted at the retail and consumer levels by at least half of the current level of 40 per cent and explore safe ways to utilize food that is not fit for human consumption for animal feed or other uses.

Introduction

Ensuring food security for a growing global population is not only about producing more food, but also about reducing the enormous amount of food that is either lost or wasted. Globally, one-third of all food produced is either lost or wasted. Ecosystem degradation is yet another form of food loss as it inhibits the ability of food producing ecosystems to provide optimal yields. Ecosystem degradation may alone account for the loss of food supply for up to 2.4 billion people by 2050. Salinization and soil erosion are already blamed for grain yield reductions that could have provided the annual calorie needs of 38 million people. The long-term solution for the increasing demand for food for a growing population lies in optimum food production through sustainable ecosystem-based management practices and in strategies to reduce food waste and losses.

Ecosystems and food provisioning

Ecosystems and the services they provide are the building blocks of human food supply. Ecosystems can be described as a dynamic network of plants, animals and microorganisms that interact with and depend on each other. Humans are a part of that system and depend on its many functions and benefits, which are commonly referred to as 'ecosystem services'. Ecosystem services can be grouped into four major categories: provisioning services such as food, water and medicines; regulating services such as soil erosion and flood control, carbon sequestration in forests and coastal protection; supporting services, such as water cycling and nutrient dispersal and cycling; and, cultural services, which refer to the spiritual, recreational and cultural benefits received from nature (MA 2005).

Ecosystems such as forests, agricultural land, pastures, freshwater and marine systems have a direct link to food provisioning because this is where people farm, pick, hunt or fish for food. Animals, insects, roots, fruits, mushrooms, vegetables and berries, which are found in forests, provide the main livelihood for an estimated 60 million indigenous people (FAO 2012a), while an additional 410 million people derive subsistence and income from forests (UNEP 2011a). Agricultural ecosystems, which cover an estimated 40 per cent of the world's land surface (Power 2010), provide the basis for subsistence and commercial crop and livestock production. According to the Food and Agriculture Organization of the United Nations (FAO) about 3 billion people in the world live in rural areas, where around 2.5 billion depend on agriculture for their livelihoods (FAO 2013a). Almost 45 million people derive their livelihoods directly from captured fisheries and aquaculture, supplying the world market with 148 million tonnes of fish and seafood every year, an amount that is enough to meet 15 per cent of the annual animal protein needs of 4.3 billion people (FAO 2012b).

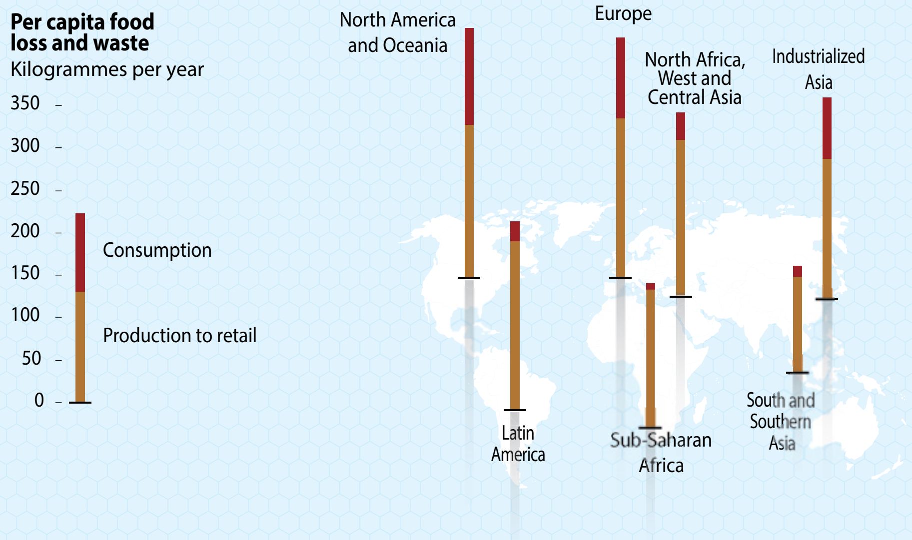
Besides agricultural, forest and aquatic ecosystems, the main systems that provide food, there are other ecosystems that are important for food provisioning. These include, amongst others, mountains and mangroves. Mountains are the source or catchment areas of the majority of the world's great rivers, which supply freshwater for more than half of the world's population (UNEP-WCMC 2002; Price 1998). This freshwater is essential for downstream agro-ecosystems and forests, as well for the generation of energy needed in food production processes. Mountain water is particularly critical

Defining food loss

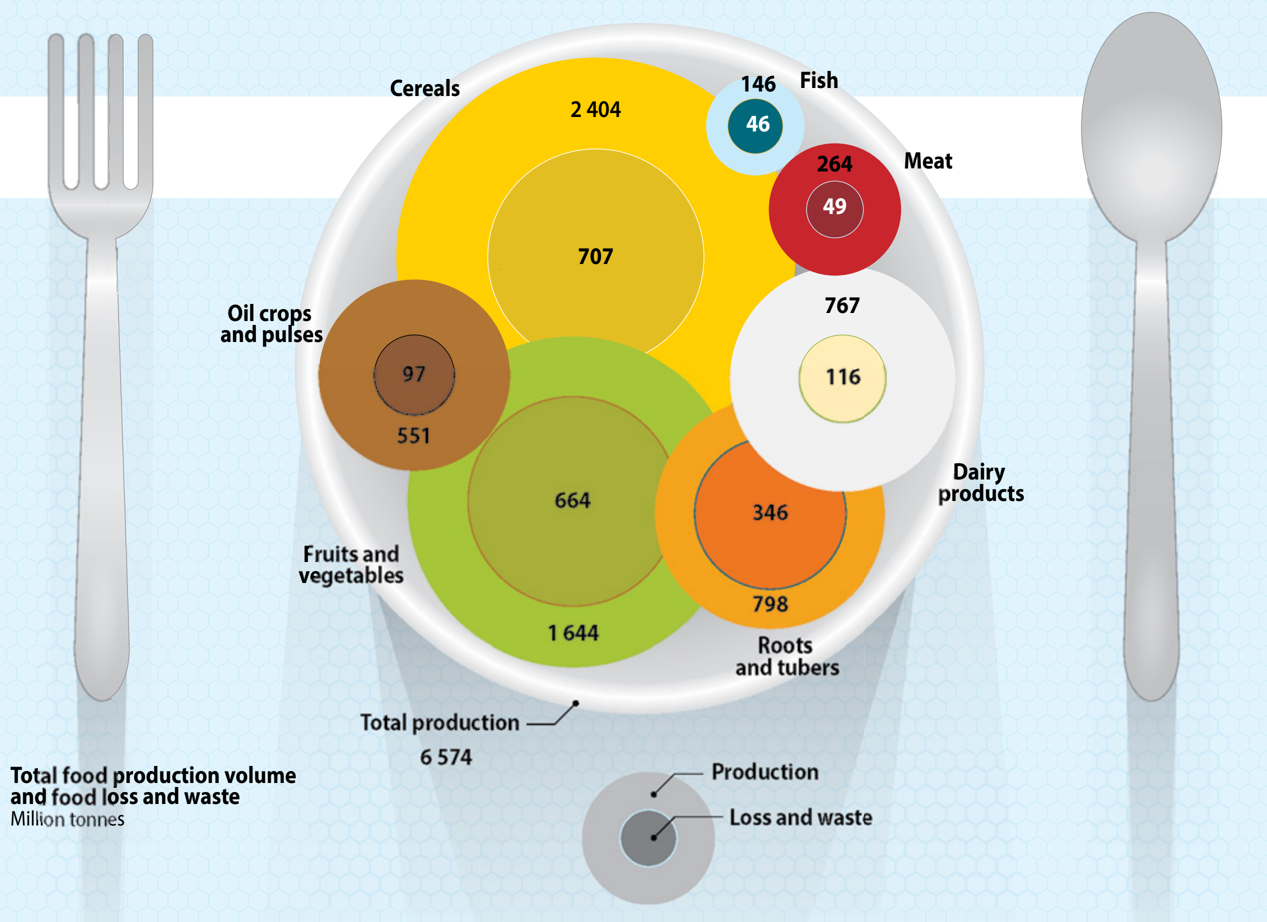
Food loss due to environmental degradation – Potential or absolute decrease in food production caused by environmental degradation. Such losses also refer to food that will never be produced due to the degradation of ecosystems.

Food loss – A decrease in mass or nutritional value of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chain such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors and lack of access to markets. Natural disasters also cause food loss. Food is lost during pre-harvest production, post-harvest handling and storage and processing

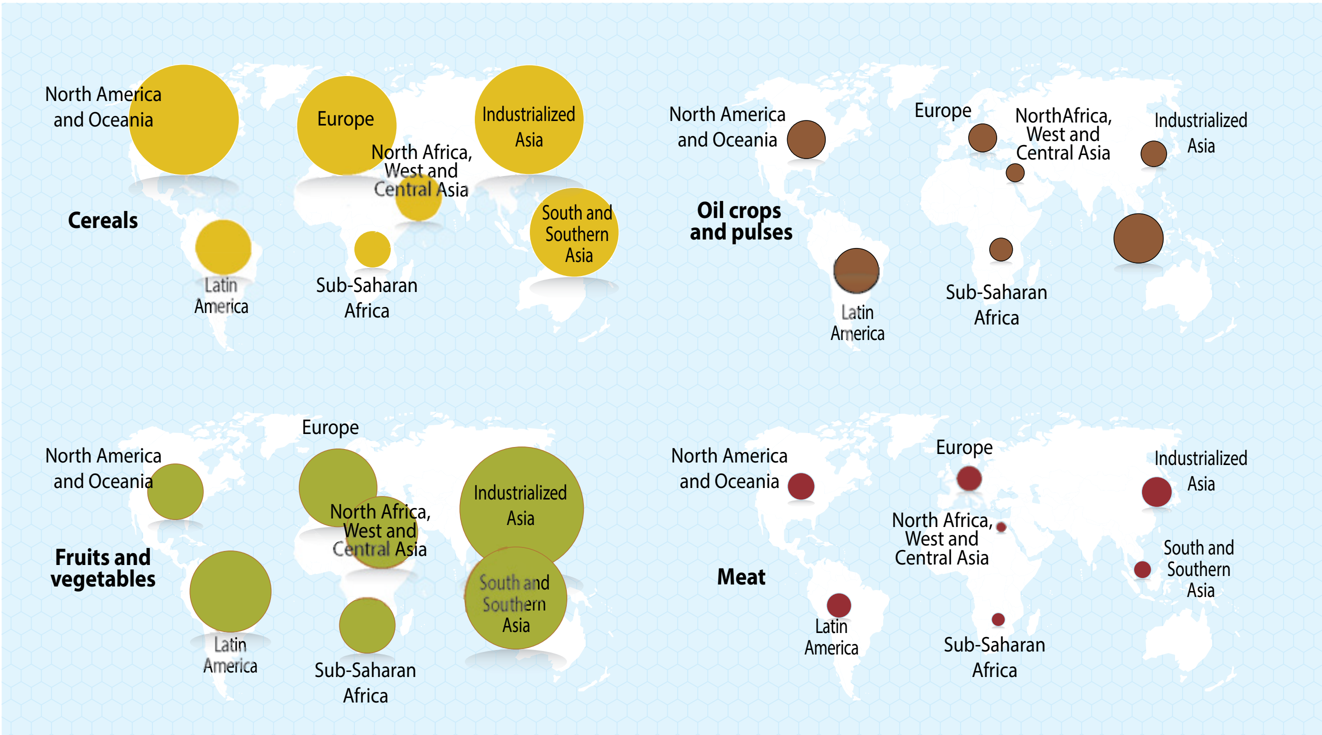
Food waste – Food appropriate for human consumption, which is discarded, whether or not after it has been kept beyond its expiry date or left to spoil. Food waste is often due to food having been spoilt, but it can also be for other reasons such as oversupply or individual consumer shopping/eating habits. Food waste occurs at distribution and household consumption levels.



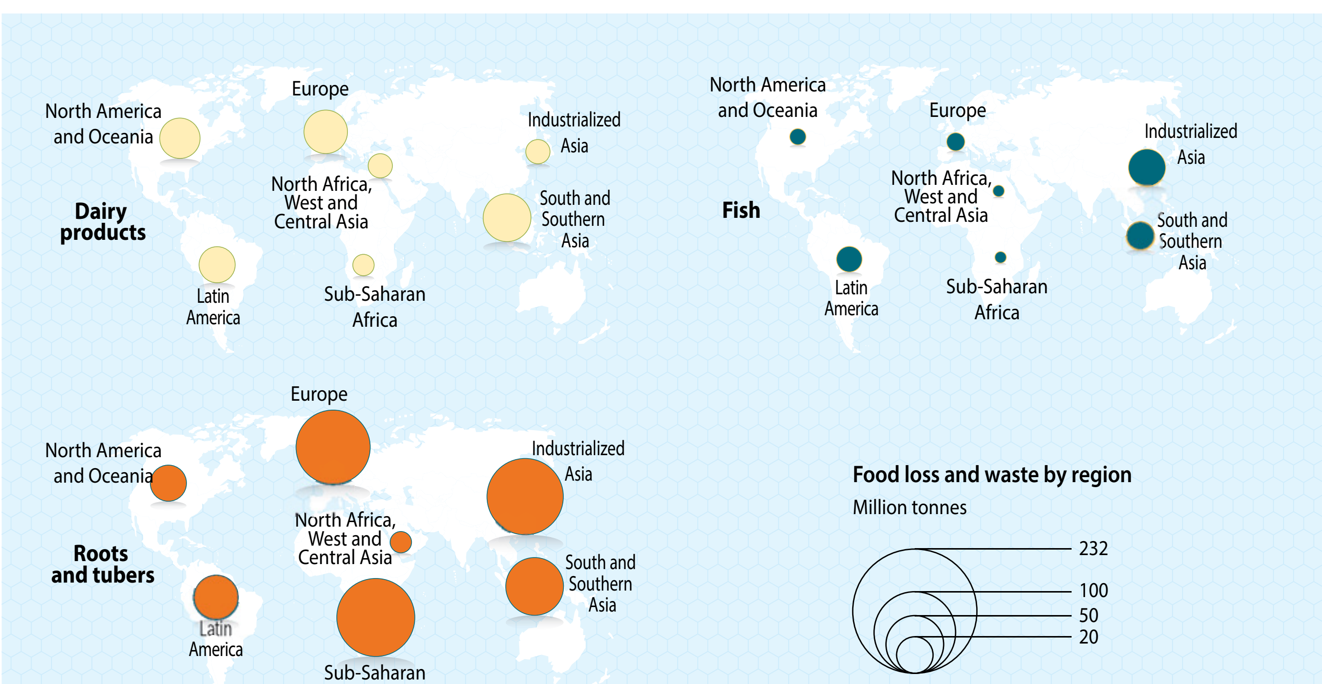
Per capita food loss and waste
Kilogrammes per year
350
300
250
200
150
100
50
0
Consumption
Production to retail
North America and Oceania
Latin America
Europe
Sub-Saharan Africa
North Africa, West and Central Asia
Industrialized Asia
South and Southern Asia



Cereals
2 404
707
146
Fish
46
264
Meat
49
767
116
Dairy products
Oil crops and pulses
97
551
664
Fruits and vegetables
1 644
346
798
Roots and tubers
Total production
6 574
Production
Loss and waste
Total food production volume and food loss and waste
Million tonnes



Food loss and waste



Source: FAO, Global Food Losses and Food Waste, 2011

in arid and semi-arid areas, supplying over 90 per cent of their river flows (Price 1998). With an annual economic value of at least US$1.6 billion (Costanza *et al.* 1997), mangroves are important ecosystems that provide protection from storms, flooding and soil erosion; cycle nutrients; improve water quality; and provide a nursery ground for juvenile fish. For coastal communities, mangroves are used for shelter, securing food and fuel wood as well as a site for agricultural production (MA 2005).

Broadening the concept of food loss and waste

Food loss and waste have gained increasing attention over the past years. Through campaigns such as Think.Eat.Save. food loss and waste have been identified as an urgent global issue with negative humanitarian, financial as well as environmental implications. Food losses are mainly unintentional and are caused by limitations in agricultural processes, infrastructure, storage and packaging that cause a reduction in quality to the extent that the food becomes unsuitable for human consumption (FAO 2013b). Food waste refers to good quality food that is discarded at the retail and consumer stage of the supply chain (Gustavsson *et al.* 2011a).

Another significant form of food loss that is addressed in this report comes from the lost opportunities for food production due to the degradation of ecosystems. When vital ecosystems for food production are degraded, the ability of these ecosystems to produce or support food production decreases. The solutions to ensure global food security for a growing population lie in reducing food loss and waste, as well as reducing food loss due to environmental degradation by implementing sustainable management practices that protect and restore degraded ecosystems.

Food loss due to ecosystem degradation

Ecosystems across the world are being degraded at an unprecedented rate. The Millennium Ecosystem Assessment (MA), which assessed the state of the world ecosystems in 2001–2004, found that 60 per cent of the ecosystems examined were either degraded or being used unsustainably (MA 2005). This degradation of ecosystems means a potential loss of food for human consumption, through reduced yields from agro-ecosystems, forests and fisheries. As much as 2 billion hectares of agricultural land, permanent pastures and forest and woodland have been degraded since 1945, mainly due to deforestation (Pinstrup-Andersen and Pandya-Lorch 1998).

Potential agricultural yield is being lost due to degradation of soil, freshwater and other ecosystem services essential for food provisioning. An estimated 10 million hectares of cropland is lost annually due to soil erosion (Pimentel 2006). This is equivalent to a loss of 5 million tonnes of grain in potential yield (Döös 1994), enough to meet the annual food calorie needs of 23.8 million people.[1]

Bee colonies and other pollinators, vital for food production, are declining across the world. While honeybee colonies have been reduced by 54 per cent in the United Kingdom since 1986, the United States have seen a reduction of between 30 and 40 per cent since 2005 (Tirado *et al.* 2013). The widespread use of agrochemicals such as pesticides, as well as pathogens, the fragmentation of habitats, and climate change are blamed for the rapid decline in the populations of bees and other pollinators (Farooqui 2013; Pettis *et al.* 2013; Grunewald 2010). About 35 per cent of global crop production (Nicholls and Miguel 2013) or 84 per cent of all crop species cultivated for human consumption in Europe depend on pollinators (Grunewald 2010). In the context of a growing food demand, the loss of these pollinators is likely to have dramatic consequences on crop yields (Tirado *et al.* 2013).

Forests currently cover about one-third of the world's land area (FAO 2012a), but rapid deforestation is still threatening the forests with an annual deforestation rate of 13 million hectares between 2000 and 2010 (FAO 2010a). The loss of forests has severe consequences for the food supply and livelihoods for over 410 million people (UNEP 2011a), including 60 million indigenous people who are directly dependent on forests for their survival (FAO 2012a). Forests provide food items such as fruits, mushrooms, nuts, honey, wild meat and insects (FAO 2011a). Just as important are the ecosystem services provided by forests that are fundamental to other food provisioning ecosystems. These include filtering, storing and regulating water flows (Power 2010), preventing soil erosion, increasing

1. Estimates of additional people to be fed are based on findings from Döös (1994), average calories from cereals, as well as average daily calorie needs for people.

Feeding the 9.6 billion

About 200 000 to 230 000 people are added to the world food demand daily, and the UN estimates that by 2050 the world population will reach 9.6 billion (UN DESA 2013). Developing countries, especially in sub-Saharan Africa, will contribute much of this population growth. For example, Nigeria's population is expected to increase from the current 163 million to a staggering 440 million people by 2050, and will remain the most populous country on the African continent. By 2050, Nigeria's population will have surpassed that of the United States of America – the third largest country in the world in terms of population today. Population growth will continue in Asia, and by 2050, India will have the most citizens of any country in the world with a projected population of 1.6 billion (UN DESA 2013).

Population increases will place additional pressures on already limited natural resources and food security will remain a big challenge. Even today, when the world is producing enough food to feed its 7 billion citizens, about 805 million people are classified as undernourished (FAO *et al.* 2014). If global food security needs are to be met in 2050, FAO (2013a) estimates that global agricultural production must increase by 60 per cent. In developing countries food availability will need to be doubled (Alexandratos and Bruinsma 2012). Against the background of growing food demand, Nellemann *et al.* (2009) warn that one-quarter of the world's food production may be lost due to environmental degradation by 2050 unless action is taken.

World agricultural and fish production growth is projected to decline from an average 2.1 per cent per year between 2003 and 2012, to 1.5 per cent towards 2020. Meat production growth, for example is estimated to decline from an annual 2.3 per cent to 1.6 per cent, while growth of wheat yields are projected to decline from 1.5 per cent to 0.9 per cent (OECD and FAO 2013). The slowing trend in food production growth is mainly due to limitations in the available agricultural land, increases in production costs, resource constraints and increasing environmental pressures (OECD and FAO 2013).

Estimates suggest that productivity has declined on about 20 per cent of the global cropland between 1981 and 2003 (Bai *et al.* 2008) and that about 38 per cent of all agricultural land is degraded (Oldeman 1992). Availability of arable land will become even more important as there is practically no more available suitable agricultural land in South Asia, the Near East and North Africa. In regions where land is available, including sub-Saharan Africa and Latin America, more than 70 per cent of the land has poor soils or is on terrain that is unsuitable for farming (Bioversity *et al.* 2012).

Growth in aquaculture, which many see as an alternative to declining wild fish stocks, will continue to increase during the next decade, reaching about 79 million tonnes per year by 2021. However this growth will decrease over time due to water constraints, limited availability of optimal production locations and the rising costs of fishmeal, fish oil and other feeds (FAO 2012b).

soil productivity (Kang and Akinnifesi 2000), storing carbon as well as providing habitats for wild pollinators (FAO 2011a).

The world's fish stocks are also increasingly being overexploited. In the mid-1970s, only 10 per cent of world fish stocks were categorized as overexploited. Forty years later, about 30 per cent of world fish stocks were defined as overexploited. Fully exploited fish stocks have increased from 50 to 57 per cent from the 1970s to 2009 (FAO 2012b). Overexploitation of fish stocks is not only detrimental to individual species such as the North American cod, tuna and shark species (FAO 2012b; Schmidt *et al.* 2013), but it also means that fish stocks are unable to replenish themselves and will not reach their full production potential. It has been estimated that in 2000, an additional 17 per cent of fish catch in low-income food deficit nations could have been harvested had the fish stocks been sustainably managed (Srinivasan *et al.* 2010).

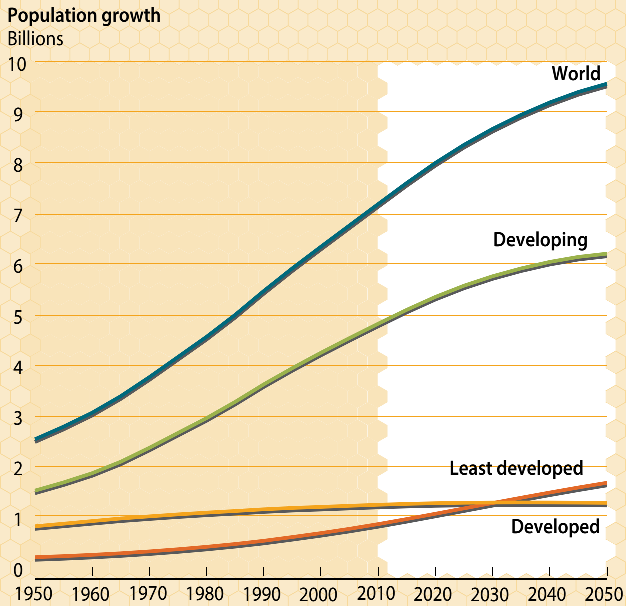
Ecosystem approaches to avert food loss

Through advances in technology conventional food production has delivered increasing yields. However, these same advances have also reduced the capacity of ecosystems to provide food (FAO 2013a) as an overuse of fertilizers and other chemicals in agriculture pollutes soil, water and air (FAO 2013a), and kills insect pollinators vital for food production (Farooqui 2013; Pettis *et al.* 2013). Improved fishing technologies have caused fishing vessels to catch fish at unsustainable rates resulting in depletion of fish stocks and extinction of some fish species (WWF 2012). While the rate of increase in overall food production is falling, the human population and the demand for food continue to increase (OECD and FAO 2013). It is increasingly being recognized that conventional food production systems are undermining the ecosystem services that food production depends on, and in order to ensure future food security it is necessary to implement management approaches that are less damaging to the environment (Munang *et al.* 2011).

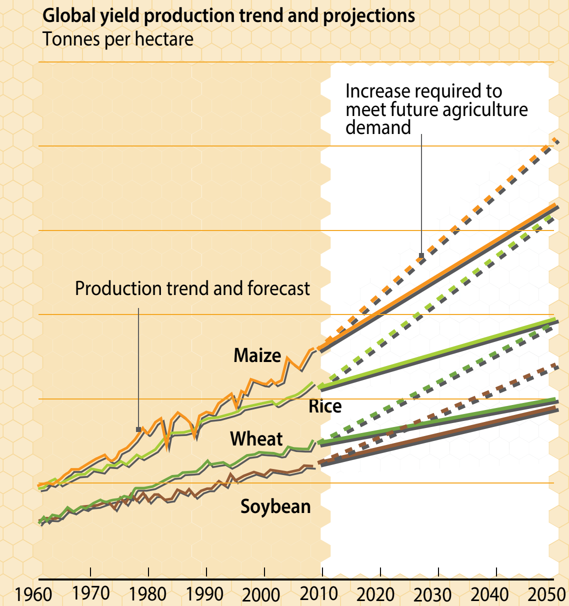
Ecosystem approaches represent an alternative to conventional food production. Ecosystem approaches are defined by the Convention on Biological Diversity (1992) as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems."

Through ecosystem approaches humanity will not only reduce its footprint on the environment, but also improve the Earth's

Will there be enough food for 9.6 billion people?



Source: UN Population Division, from van der Mensbrugghe *et al.* 2009



Source: Deepak, K. R., Yield Trends Are Insufficient to Double Global Crop Production by 2050, PLoS ONE, 2013

biocapacity. Ecosystem approaches are alternative approaches to food production that aim not only to maintain but also to improve the fertility and productivity of ecosystems. Such sustainable food production approaches are implemented to prevent soil erosion, improve soil fertility and enhance biological diversity. Ecosystem approaches in agriculture often include traditional practices such as conservation agriculture, crop rotation, inter-cropping and biological control of pests. For example, maize in rotation with soybean yields 5–20 per cent more than continuous crops of maize monocultures. Soil nitrogen levels have also been shown to increase by 6–14 kg/ha following a rotation of peas and wheat (Bullock 1992; Stevenson and van Kessel 1996). In forestry, sustainable forest management is a move away from the traditional focus of managing forests only for timber production, and towards management of a range of forest ecosystem services, including food production and wild food harvesting (MA 2005). Ecosystem approaches to fisheries include approaches such as Integrated Coastal Zone and Marine Protected Areas that all seek to ensure sustainable management of marine resources, including fish stocks to reduce overexploitation (UNEP 2011b).

Food loss and food waste

Much of the data on food loss do not include potential losses due to ecosystem degradation. About one-third, equivalent to 1.3 billion tonnes, of all edible parts of food produced for human consumption are either lost or wasted (FAO 2013b). This is in addition to a far greater amount of non-food waste such as straw. Estimates by Smil (2001) as cited by Stuart (2009) show that as much as 4 600 kcal of agricultural food is harvested per day for every person on the planet, but around 2 000 kcal on average are consumed, implying that more than half of agricultural food products are lost or wasted along the food production and distribution chain.

There is a clear variation between developing and developed countries with regards to food loss and waste. In developing countries, food loss is the greatest problem. It is estimated that over 75 per cent of the food loss and waste occur in developing countries before the food reaches the retailer, compared to 57 per cent in developed countries (Gustavsson *et al.* 2011b,c). This is typically due to poor capacity in developing countries to store, process and transport food as well as lack of access to markets (Moomaw *et al.* 2012). In sub-Saharan Africa alone, grain enough to feed 48 million people is lost every year (FAO 2012c).

In developed countries, food waste at the retail and household levels is the biggest problem. As much as 43 per cent of all loss and waste occur at this stage, compared to 25 per cent in developing countries (Gustavsson *et al.* 2011b,c). Food waste by consumers in developed countries equals the entire food production of sub-Saharan Africa (FAO 2014a). On average, 20 to 25 per cent of food that is bought in developed countries is wasted by consumers (Juul 2013), while in the United States, food loss and waste are estimated to be as high as 50 per cent (Stuart 2009).

Food loss and waste are not only a threat to food security, but also have significant economic costs. Globally, the direct economic cost of food loss and waste is estimated at between US$750 billion (FAO 2013b) and US$980 billion annually (Gustavsson *et al.* 2011b,c). The economic cost is highest in developed countries, representing over 65 per cent of the global cost (Gustavsson *et al.* 2011b,c).

Food loss and waste are not only about lost calories for human consumption, but also about the negative environmental impacts and degradation of ecosystems that production of food causes throughout the food supply chain. For example, it takes over 1 600 litres of water to produce 1 kilogramme of wheat bread (Mekonnen and Hoekstra 2010), or 5 060 litres of water to produce 1 kilogramme of cheese (Mekonnen and Hoekstra 2012). The same amount of water is wasted if the food is never consumed. In total it is estimated that about 28 million tonnes of fertilizers are used annually to produce the food that is lost and wasted (Lipinski *et al.* 2013), while causing the threat of eutrophication of nearby water ecosystems. A projected 5 to 25 per cent of the world's food production capacity may be lost by 2050 due to climate change, land degradation, cropland losses, water scarcity and species infestations (Nellemann *et al.* 2009), which is equal to the food supply of an estimated 0.4–2.4 billion people by 2050. According to the FAO (2013b), 1.4 billion hectares of land are used to produce the amount of food that is lost and wasted. The land area used to produce lost and wasted food is more than 100 times the 13 million hectares of forests that are being cleared every year (FAO 2010a), 80 per cent of which is for agricultural expansion (Kissinger *et al.* 2012). Developing countries account for about two-thirds of all land used to produce food that is lost or wasted. On the contrary they account for less than half of all food loss and waste. The large share of land is to a great extent explained by the countries' reliance on grassland for feeding animals. For example, in North Africa, Western Asia and Central Asia, grasslands have low productivity, which increases the area needed for grazing. Combined, food loss and waste occupy over 360 million hectares of land in these regions (FAO 2013b).

Food loss and waste are closely linked to climate change in that petroleum fuels are heavily used in nearly all aspects of food production. One estimate suggests that food loss and waste have an annual carbon footprint of 3.3 giga-tonnes of carbon dioxide (FAO 2013b). In the United States, about 300 million barrels of oil are used annually to produce food that is lost or wasted. In addition, when food decomposes it produces emissions of methane gas, which is 25 times more potent than carbon dioxide in trapping heat, thus making food waste a significant contributor to climate change (FAO 2012c). It is a paradox that lost and wasted food threatens the production of new food by contributing to climate change. According to the Intergovernmental Panel on Climate Change (IPCC 2014:18) "all aspects of food security are potentially affected by climate change, including food access, utilization, and price stability". While estimated impacts differ between regions, some projects suggest yield losses of more than 25 per cent for the period 2030 to 2049 compared to the late 20th century (IPCC 2014).

Ecological Footprint accounting for food production

Ecological Footprints tell the extent to which people use what the biosphere provides. The Footprint methodology can therefore also measure the environmental demands of food production and show to what extent food production contributes to the overall demand of people on the biosphere.

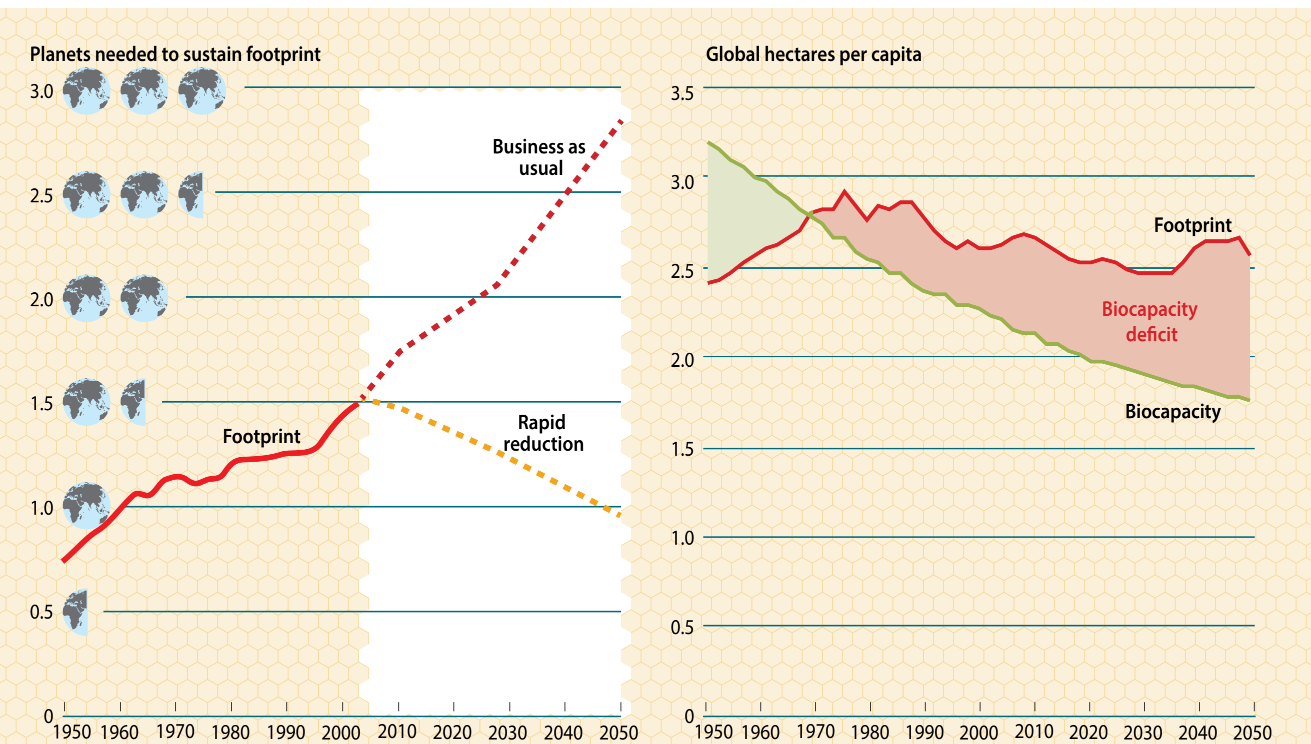
Ecological Footprint accounting quantifies both the annual availability of biocapacity and human demand on that capacity (Wackernagel *et al.* 2002; Borucke *et al.* 2013). Demand on ecosystems is mapped onto land uses, which are divided into six Footprint components, or area types: cropland for food and fiber production, including feed for animals; grazing land for livestock production; forest land for both timber and other forest products; forest land for the carbon Footprint to sequester the carbon dioxide from fossil fuel burning; built-up land for housing and infrastructure; and fishing grounds for fish products (marine and inland). Two demand categories are provided for by one biocapacity category: forest products and the carbon Footprint both compete for forestland. Hence only five categories make up biocapacity.

Results are expressed in a globally comparable, standardized unit called the global hectare (gha). A global hectare is a biologically productive hectare with world average productivity in a given year (Galli *et al.* 2007; Monfreda *et al.* 2004). Average bio-productivity differs between land use types, as well as between countries. For any given land use, the global hectare is normalized to take this into account. For example, a global hectare of high-yielding cropland would occupy a smaller physical area than an area of pastureland with less biologically productivity, as more pasture area is needed to provide the same productivity as one hectare of cropland.

With this metric, one can assess human demand on nature, and guide personal and collective action in support of a world where humanity lives within the Earth's bounds. According to Global Footprint Network estimates, humanity demanded resources and services equivalent to the capacity of 1.5 Earths in 2008. Since 1961, the total Footprint has increased by 150 per cent (being now 2.5 times larger). In the meantime, with changing management practice and increased agricultural inputs, biocapacity expanded globally by 20 per cent (Global Footprint Network 2013, Borucke *et al.* 2013).

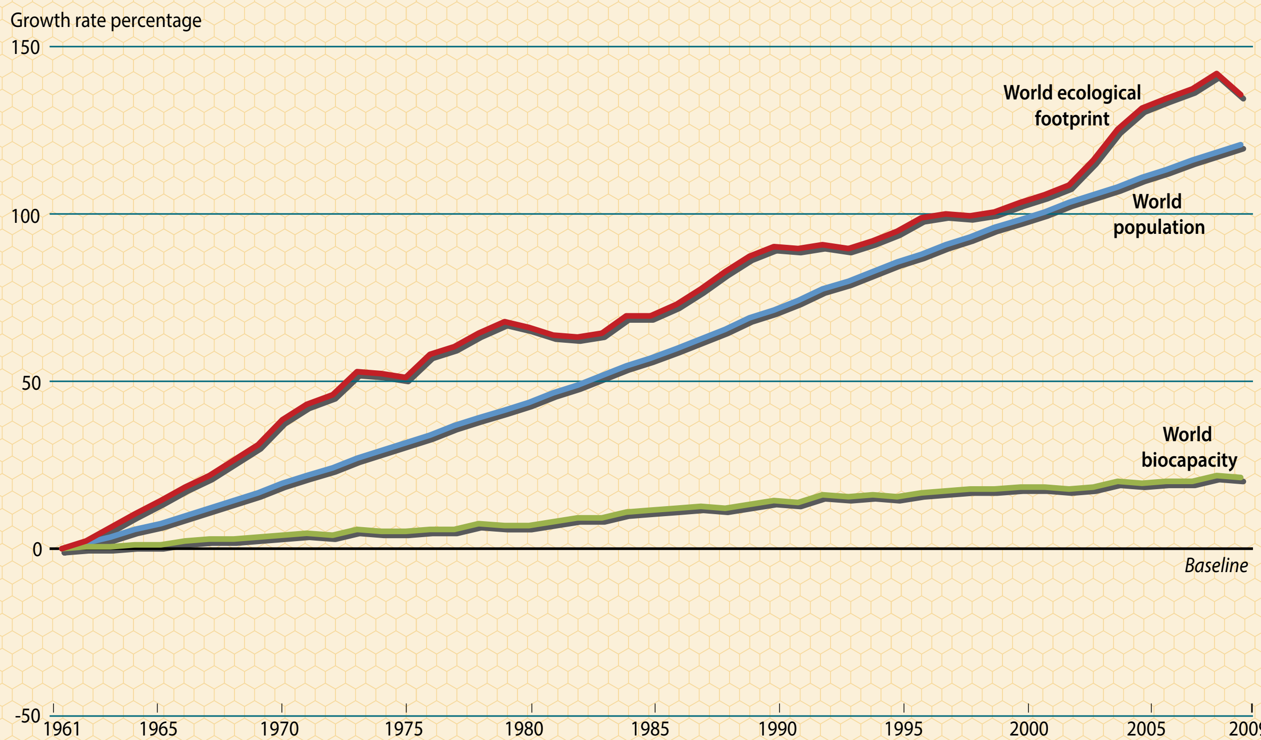
When total demand for ecological goods and services exceeds the available capacity of a given location to meet this demand, the situation is referred to as overshoot. Global overshoot is

Stretching the ecosystems beyond their limits



Source: The Global Footprint Network, 2013

Footprint and population are growing faster than the Earth's biocapacity



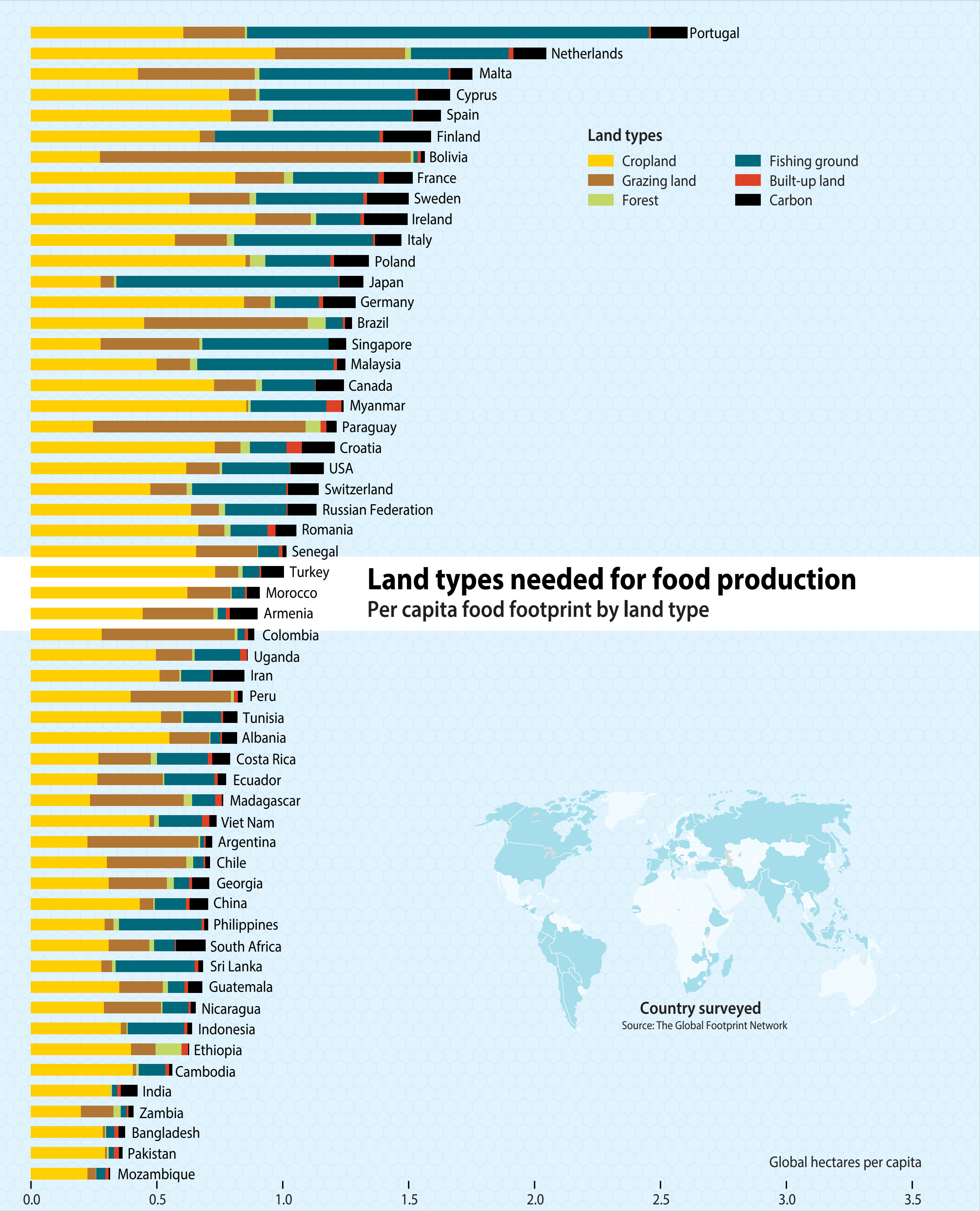
Source: Global Footprint Network, 2013

possible, for a limited time, by depleting stocks of ecological capital (harvesting resources faster than they are regenerated) and/or by exceeding the sink capacity of the biosphere, resulting in the accumulation of waste in the atmosphere, oceans and soil. Overall projections of future human demand on the Earth's biocapacity, based on aggregating moderate UN scenarios of population growth, food demand and energy use, conclude that by 2050 humanity's Ecological Footprint would be 2.5 to three times the planet's biocapacity. It is unclear whether such overuse can be physically achieved, and if it can, how long this level of overshoot can persist (FAO 2002; FAO 2006; UN DESA 2006, WWF *et al.* 2008).

In addition to analyzing the Ecological Footprint by the type of productive area on which demand is being placed, Footprints can also be determined for consumption categories, such as food. The "foodprint" includes all the biocapacity required not only to grow food such as crops, livestock and fish, but also to absorb the emissions from the fossil fuel used to create fertilizer, run farm machinery, process, transport and store food. The demand for food is amongst the greatest drivers of land use change (Lambin and Meyfroidt 2010). Land use change also adds to humanity's Footprint through the release of additional carbon dioxide into the atmosphere.

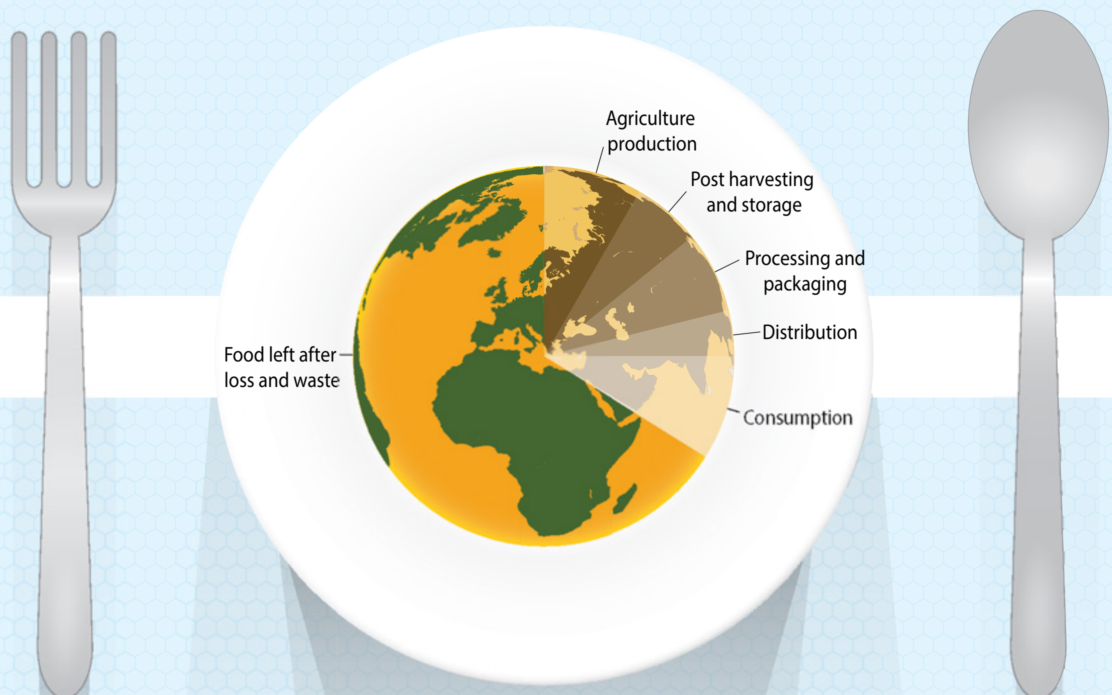
The average "foodprint" today is at least 0.66 global hectares per person, which corresponds to more than one-third of the Earth's biocapacity, or about one-fourth of humanity's Ecological Footprint (calculations based on Global Footprint Network, 2013). Cropland represents the largest portion of the global foodprint (nearly two thirds), while fish consumption makes up about 10 per cent of the overall biocapacity demand of food.

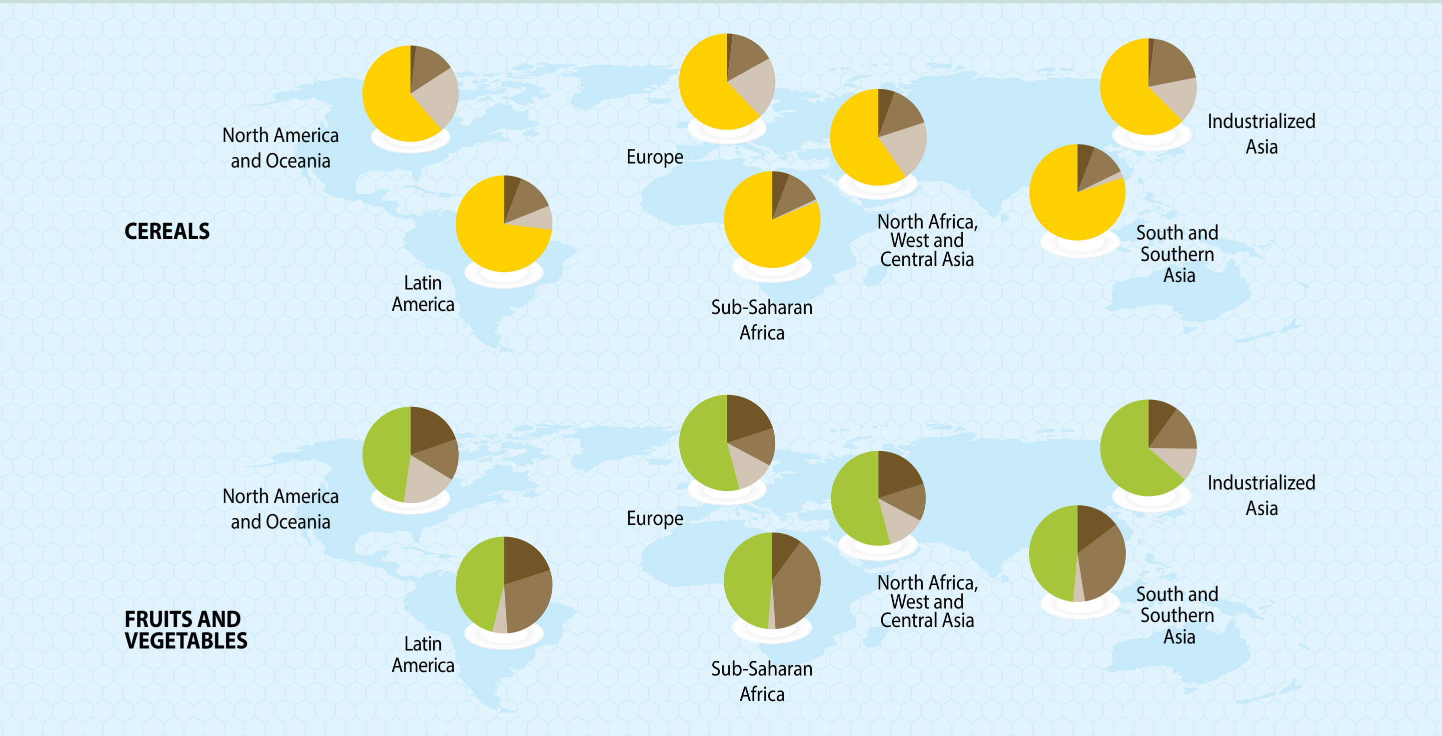
Food consumption varies in both amount and composition in different parts of the world. Germans, for example, consume about 3 539 kcal/person/day, with 30 per cent coming from meat and dairy (FAO 2014b). Their "foodprint" of a little over one global hectare per person constitutes 20 per cent of their total Footprint measuring five global hectares per capita. In contrast, lower-income countries typically have smaller per capita Footprints, but a larger percentage devoted to food. Bangladesh, for example, with a food consumption of 2 430 kcal/person/day and only 4 per cent coming from meat and dairy (FAO 2014b), has a "foodprint" of 0.3 global hectares per capita, which is nearly half of its total Footprint of 0.65 global hectares per capita (calculations based on Global Footprint Network 2013).



Land types needed for food production
Per capita food footprint by land type
Land types
Cropland
Grazing land
Forest
Fishing ground
Built-up land
Carbon
Portugal
Netherlands
Malta
Cyprus
Spain
Finland
Bolivia
France
Sweden
Ireland
Italy
Poland
Japan
Germany
Brazil
Singapore
Malaysia
Canada
Myanmar
Paraguay
Croatia
USA
Switzerland
Russian Federation
Romania
Senegal
Turkey
Morocco
Armenia
Colombia
Uganda
Iran
Peru
Tunisia
Albania
Costa Rica
Ecuador
Madagascar
Viet Nam
Argentina
Chile
Georgia
China
Philippines
South Africa
Sri Lanka
Guatemala
Nicaragua
Indonesia
Ethiopia
Cambodia
India
Zambia
Bangladesh
Pakistan
Mozambique
Country surveyed
Source: The Global Footprint Network
Global hectares per capita
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

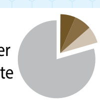
One third of the food produced in the world for human consumption every year gets **lost or wasted**





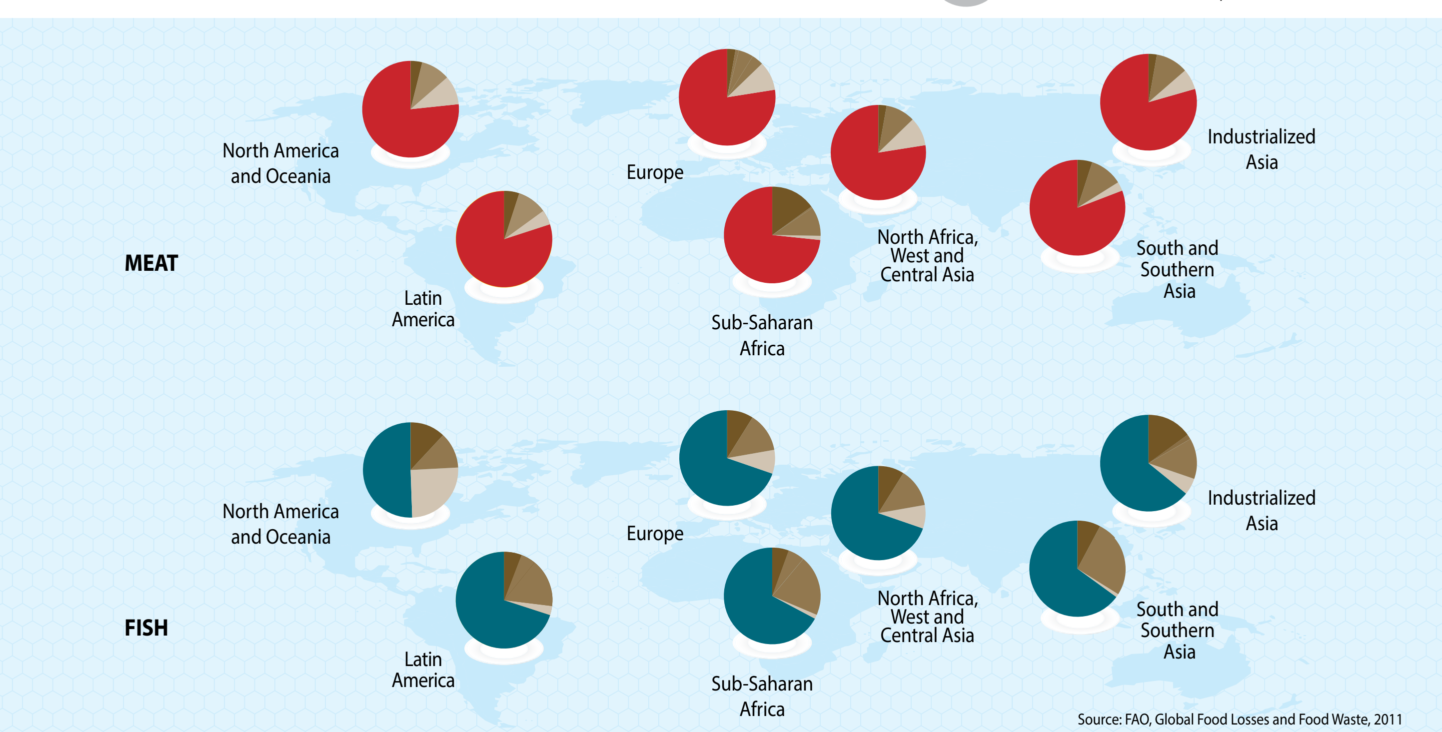
How food is lost and wasted

Food left after loss and waste



Percentage of food lost and wasted

- Agriculture
- Post harvest, processing and distribution
- Consumption



Source: FAO, Global Food Losses and Food Waste, 2011

Ecosystem restoration for food security

It is estimated that another 130 million hectares of cropland will be needed to support food production in developing countries. This amount represents less than a quarter of the 560 million hectares of degraded agricultural land that could be restored through sustainable practices and green investments. Restoring a quarter of the degraded agricultural land could theoretically boost food production on that land and feed about 740 million people. By recovering depleted fish stocks the resultant increase in fish catch could cover the annual protein needs of over 90 million people. In addition, shifting the usage of crops produced for animal feed and other uses towards direct human food consumption would not only decrease the pressure on limited cropland, but increase available food calories by as much as 70 per cent – enough to feed 4 billion people.

Restoring agro-ecosystems for food security

Food security is not simply a function of production or supply, but of availability, accessibility, stability of supply, affordability, quality and safety of food. Hence, improving food security must focus on threats to local food security where it is needed and not simply increasing global harvests alone. Current projections suggest that an additional 130 million hectares of cropland will be required to support the growth in food production needed in developing countries by 2050 (Alexandratos and Bruinsma 2012). At the same time there are great potentials in restoring degraded land. Globally there are over 560 million hectares of degraded agricultural land (Oldeman 1992) that could be restored through sustainable agricultural practices and green investments.

Land degradation refers to long-term losses in ecosystem function and productivity from which land cannot recover without assistance. When agricultural land is degraded, the ability of that land to produce food may decrease up to the level where it is no longer feasible to farm the land (Bai *et al.* 2008). Land degradation is therefore a direct threat to food security.

Soil erosion remains one of the key challenges to land degradation with over 80 per cent of the global agricultural land suffering from moderate to severe erosion. Every year, about 10 million hectares of agricultural land is abandoned due to soil erosion (Pimentel and Burgess 2013). Throughout the world it is estimated that 75 billion tonnes of soil are lost every year due to degradation (Lal 1998).

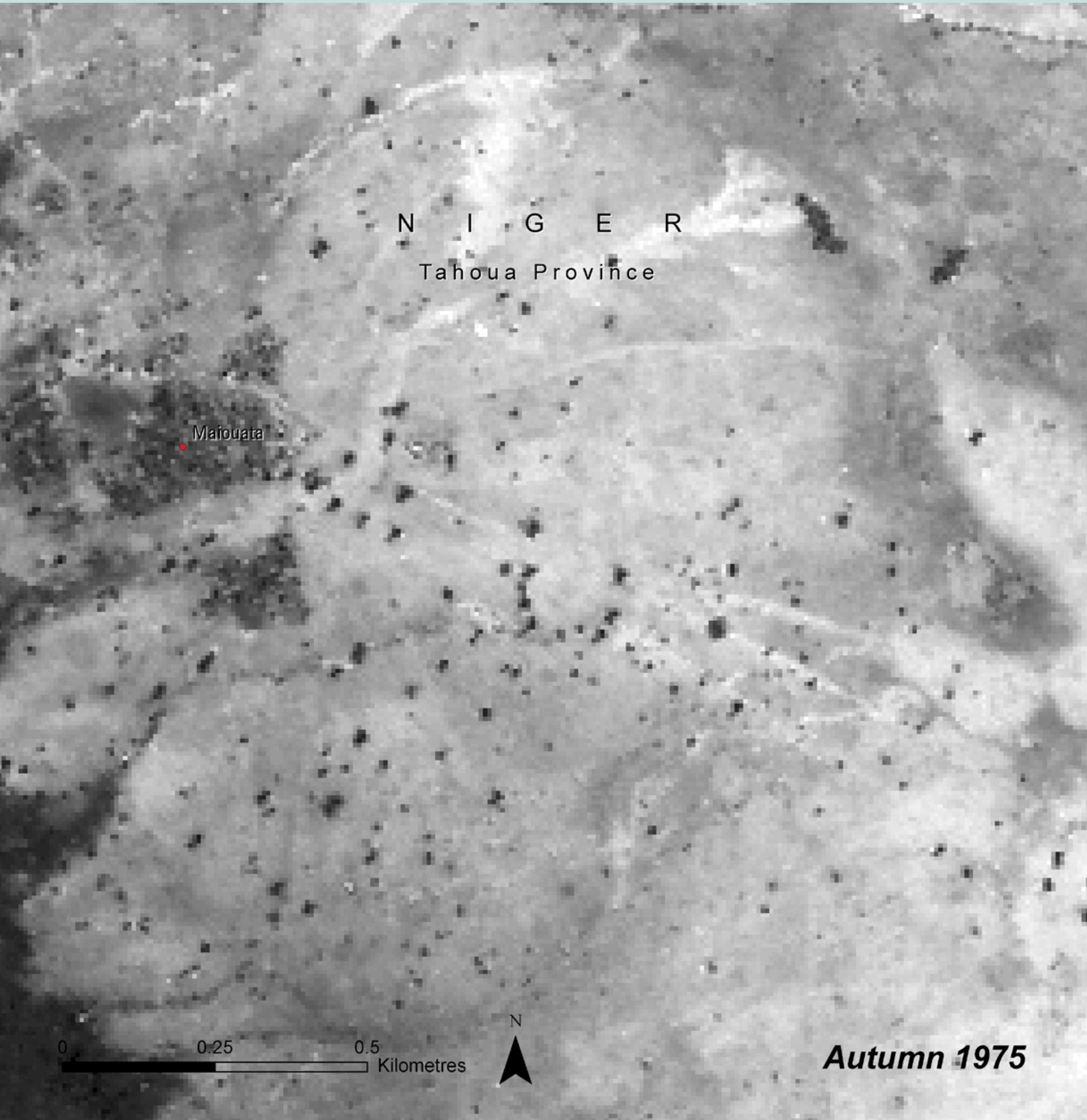
The majority of land degradation takes place in the geographic areas where local food insecurity is rampant. According to den Biggelaar *et al.* (2003) losses of land due to soil erosion are 2 to 6 times higher in Africa, Latin America and Asia than in North America and Europe. For example, in China about 40 per cent of arable land suffers from soil degradation (Hartemink *et al.* 2007), where as many as 450 million rural people depend on land that is degraded (Bai and Dent 2007a). In South Asia, the annual economic loss due to land degradation is at least US$10 billion (FAO 1994).

Africa is perhaps the continent most severely impacted by land degradation. Yield reductions in Africa due to soil erosion range from 2 to 40 per cent (Lal 1995). Sub-Saharan Africa is particularly impacted by land degradation (Bai *et al.* 2008). About 95 million hectares of land in the region is threatened with irreversible degradation (Henao and Baanante 2006). At the same time, Africa has the highest prevalence of hunger in the world, with almost a quarter of the population affected (FAO *et al.* 2014). It is further projected that by 2050 the region's population will have doubled, reaching over 2 billion people (UN DESA 2013). Country studies reveal that the productivity of Africa's land is decreasing, with crop varieties failing to reach their full genetic potential. Between 1981 and 2003, productivity declined on 40 per cent of Kenya's cropland due to land degradation. During the same period the country's population doubled (Bai and Dent 2006). Similar trends were observed in South Africa where over the same period the productivity declined on 41 per cent of the country's cropland while the population increased by 50 per cent (Bai and Dent 2007b).

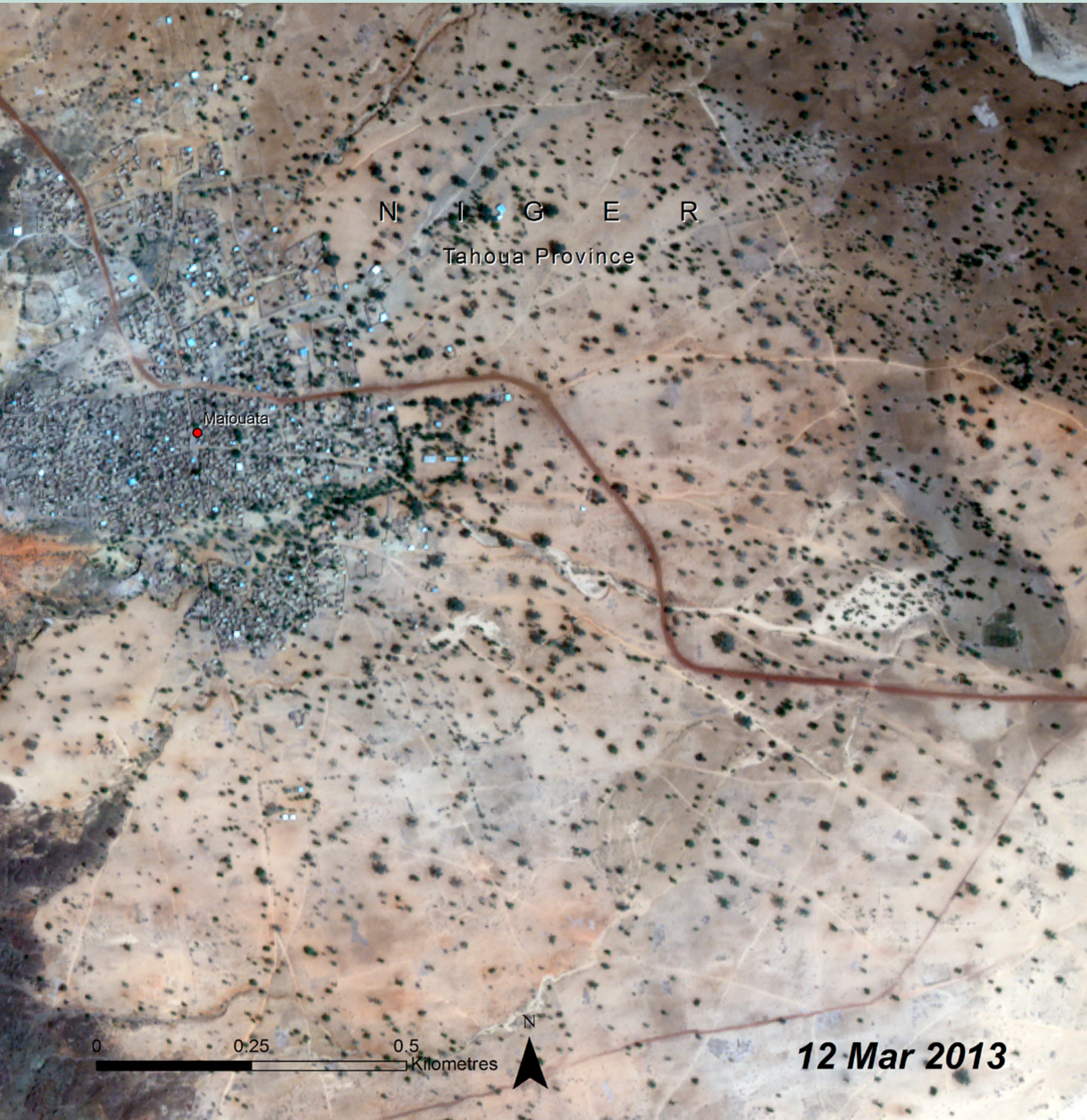
In order to increase food security for a growing global population, it is crucial that sustainable agricultural practices that prevent land degradation and restore degraded land are implemented (Power *et al.* 2012, Winterbottom *et al.* 2013). Restoring agricultural systems can provide major improvements, such as has been demonstrated in Niger. Drought was strongly hitting Niger during the 1970s and 1980s, but in the early 1980s rehabilitation took place across 300 000 hectares of crusted and barren land. The land was rehabilitated by promoting simple soil and water conservation techniques such as contour stone bunds, half moons, stone bunding and improved traditional planting pits (zaı¨). As a result, both crop yields and tree cover increased. The expansion of the rehabilitated area continued without further

Ecological Footprint accounting for food production

Sub-Saharan Africa faces some of the greatest population increases and food insecurity in the world. The region has the highest prevalence of famine in the world, and by 2050 it is projected that the population in sub-Saharan Africa will more than double, reaching over 2 billion people. The region also has some of the highest losses of crop and rangelands



due to degradation, along with the highest levels of illegal fisheries in the world of up to 40 per cent of total fish catches when foreign industrial fishing fleets are included. Restoring degraded lands by conserving water and implementing tree planting and organic farming systems, along with reducing illegal fisheries and unsustainable harvest levels by foreign fishing fleets, would have major effects on food security. It would also improve food security where it is needed most, while sustaining a green economy, local livelihoods and market development.



development assistance and a land market was developed, which suggested a positive learning process and a green economy-thinking that became self-driven (Charles *et al.* 2010).

Another study of 286 agricultural sustainability projects in developing countries, involving 12.6 million smallholder farmers on 37 million hectares, found an average yield increase of 79 per cent across a very wide variety of systems and crop types while at the same time increasing the supply of ecosystem services (Pretty *et al.* 2006). The farmers used a variety of resource-conserving technologies and practices including integrated pest management, integrated nutrient management, conservation tillage, agroforestry, aquaculture in farm systems and water harvesting, as well as livestock integration.

A conservative estimate suggest that if a quarter of the 560 million hectares of degraded agricultural land (Oldeman 1992) were restored, the food calorie increase could feed up to 740 million people.[2] While the actual numbers may be lower, as production potential varies, these rough estimates suggest a highly and vastly unexplored opportunity for boosting food availability locally, especially as regions with wide prevalence of food insecurity are also often characterized by extensive land degradation.

2. The estimate is based on a modest production of 1.925 tonnes of cereal per hectare, equivalent to 50 per cent of the current global average (FAO 2014c), a calorie value of 3 million kcal per tonne, a daily calorie need of 3000 kcal and 365 days a year.

Another initiative that would reduce the pressure on global cropland, as well as free up food is to shift crop production towards primarily producing food for human consumption. Today 30 to 40 per cent of all cereals produced are used for animal feed, and it is anticipated that by 2050 as much as 50 per cent may be needed (Nellemann *et al.* 2009). According to Cassidy *et al.* (2013), shifting the production of crops for animal feed and biofuels towards crops for direct human consumption could theoretically increase available food calories by as much as 70 per cent, which could feed an additional 4 billion people. Food waste represents one alternative that to some extent can replace crop-based animal feed (FAO 2013c). While it is still a much debated topic on the industrial level there are examples of countries where it is practiced. In Japan for example, the so called Food Recycling Law of 2007 encourages food-related businesses to convert all food waste to animal feed or fertilizers (FAO 2013c). Identifying safe ways to capture and convert food waste to animal feed provides great opportunities for improving future food supplies as well as minimizing the global environmental footprint.

Restoring forest for food security

Ensuring that forest ecosystems are preserved and restored while simultaneously producing enough food for a growing population is a key challenge to sustainability (Lambin and Meyfroidt 2010). Historically, forests have to a great extent been cleared to increase food production. According to Kissinger *et al.* (2010) agriculture is the key driver to as much as 80 per cent of deforestation. While recent findings reveal that

deforestation is decreasing, the annual deforestation rates are still high (FAO 2010a). Between 2000 and 2010 as much as 13 million hectares of forest were cleared every year. While clearing land for agriculture provides a quick solution for increased food production, it also threatens environmental sustainability as well as future food security.

Forests play an essential role in food security, both indirectly and directly. Across the world, forest ecosystems provide supporting and regulating ecosystem services that agro-ecosystems depend on if they are to remain productive. Forest ecosystems provide fundamental ecosystem services to agro-ecosystems such as water filtration and regulation, habitat for wild pollinators and soil erosion control, as well as nutrient cycling that enhances agricultural productivity. Just as important, forests mitigate climate change by sequestering carbon (Minnemeyer *et al.* 2011).

Forest ecosystems provide a vital source of food for millions of people. As many as 410 million people are directly dependent on forests for food (UNEP 2011a). This includes food items such as nuts, fruits, mushrooms, wild animals, insects and honey. Forests provide fodder for livestock, and the selling of forest products is a common income generating activity in many developing countries (FAO 2011a). Preserving forests from further degradation as well as restoring forest landscapes is therefore an important component to food security that policy makers needs to take into account.

According to Minnemeyer *et al.* (2011), more than 2 billion hectares of deforested and degraded forest land offer opportunities for forest landscape restoration. Africa has by far the greatest potential with 720 million hectares of restorable forest landscapes, followed by South America and Asia with about 450 million hectares each. Roughly three-quarters of the total degraded land has moderate human pressure of between 10 and 100 people per square kilometre and is best suited for mosaic type restoration in which new trees support other land uses such as agroforestry, smallholder agriculture and settlements. These areas provide great opportunities for restoring degraded forests while at the same time increasing food production (Minnemeyer *et al.* 2011).

The positive role of new trees is not limited to the forest as trees in drylands outside the forests can bring major benefits to their often cash-poor inhabitants, as shown by examples from Senegal and Ethiopia. In the Kaffrine and Diourbel regions of Senegal, a project by World Vision is regenerating indigenous trees on 40 000 hectares of cropland. The farmers involved in the project have adopted the Farmer-Managed Natural Regeneration (FMNR) technique. FMNR utilizes pre-existing tree stumps or root systems, thereby making it possible for poor people to restore degraded land to productive farmland or forest without having to invest in seedlings. According to World Vision (2013), the increase in tree density on cropland from an average of 4 to 33 trees per hectare has improved soil fertility, crop yields and wildlife, while soil erosion has been reduced.

In Ethiopia, a similar project has restored 2 700 hectares of barren mountain terrain. The need for firewood and agricultural land had driven the local communities to overexploit the forest on the mountainside, but through FMNR and planting of new seedlings it is once again forested. The reported benefits include increased food security and reduced poverty through an increase in income from forest product and livestock fodder; improved water infiltration, which has improved the ground water levels as well as reduced flash flooding; and reduced erosion and increased soil fertility in the region. The participants also earn carbon credits through the Kyoto Protocol's Clean Development Mechanism (World Vision 2012).

Restoring aquatic-ecosystems for food security

Fish accounts for 17 per cent of the world's animal protein supply, and 6.5 per cent of all protein for human consumption (FAO 2012b). From the 1950s to 1996 the world's marine fisheries increased from 16.8 million tonnes to 86.4 million tonnes before declining and stabilizing at around 80 million tonnes. In 2010 global fish production was 77.4 million tonnes (FAO 2012b).

The drastic increases in captured fisheries from the 1950s was a result of new and more effective fishing technologies that allowed for fishing vessels to fish deeper and farther at sea. The intensification of fisheries has however come at a cost. Overexploited stocks have increased from 10 per cent in 1974 to about 30 per cent in 2009. These fish stocks are producing lower yields than potentially possible and are in acute need of restoration to regain their ecological and biological potential.

Keita project, Niger

Sub-Saharan Africa faces some of the greatest population increases and food insecurity in the world. The region has the highest prevalence of famine in the world, and by 2050 it is projected that the population in sub-Saharan Africa will more than double, reaching over 2 billion people. The region also has some of the highest losses of crop and rangelands due to degradation, along with the highest levels of illegal fisheries in the world of up to 40 per cent of total fish catches when foreign industrial fishing fleets are included. Restoring degraded lands by conserving water and implementing tree planting and organic farming systems, along with reducing illegal fisheries and unsustainable harvest levels by foreign fishing fleets, would have major effects on food security. It would also improve food security where it is needed most, while sustaining a green economy, local livelihoods and market development.

Further, over half of the global fish stocks were fully exploited in 2009. Fully exploited stocks produce catches close to or beyond their maximum sustainable production. Most of the top ten species, which account for about 30 per cent of world marine capture, are either fully exploited or overexploited giving only minor potential for increases in production (FAO 2012b).

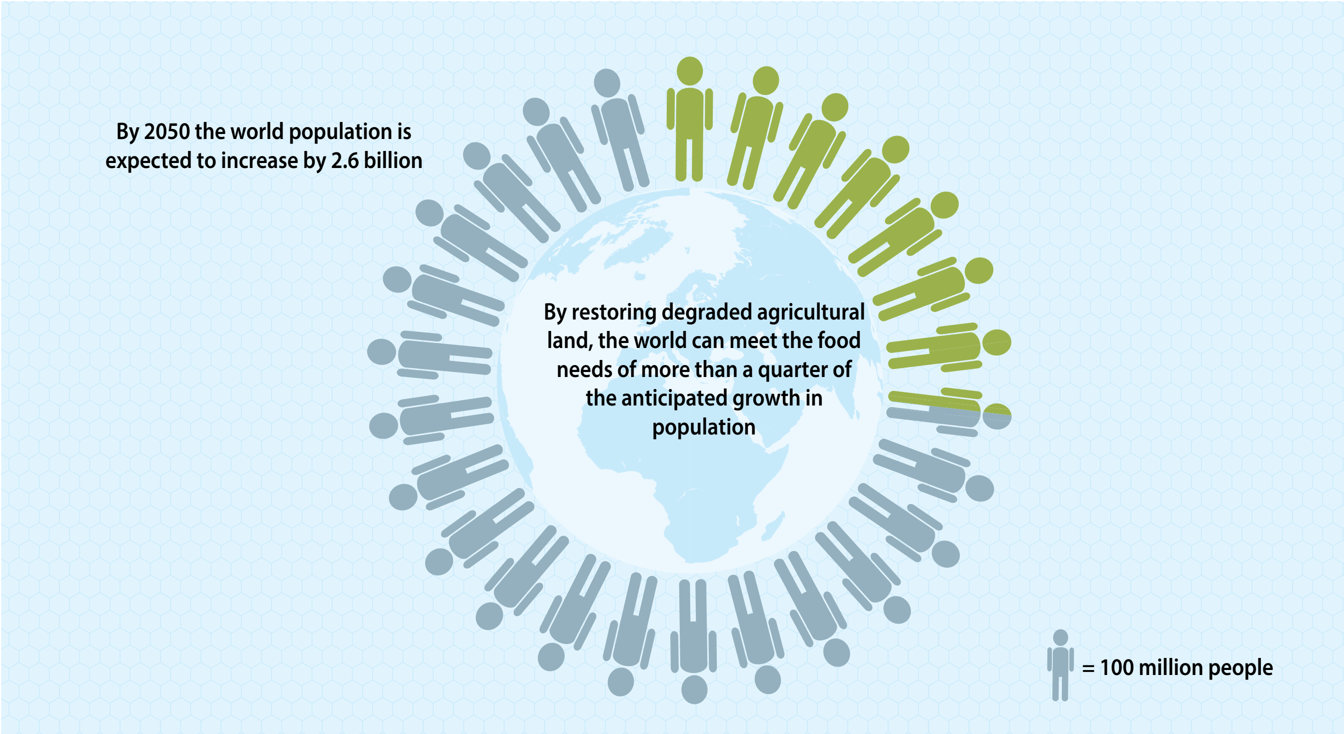
The greatest declines in fish stocks in the past 40 years have been in the Northwest, Northeast and Southeast Atlantic, which combined, albeit in different periods, peaked at 19 million tonnes and are now at around 12 million tonnes per year. At the same time that fish stocks are decreasing, a substantial increase in fisheries has happened in the Western and Eastern Indian Ocean and Western central Pacific, mainly by Asian fishing fleets, where harvests have increased from around a total of 6.5 million tonnes to over 23 million tonnes, increasing the pressure on the global fish stock and with high risk of overexploitation (FAO 2012b).

A study conducted by Srinivasan *et al.* (2010) identified potential catch losses due to unsustainable fishing practices in countries' exclusive economic zones (EEZs) and on the high seas. According to the study, the global fish catch could have been over 9.9 million tonnes higher in 2004 had overfishing been averted since the 1950s. Rough estimates suggest that if the fish stocks were restored to the 1950s level, the increase in fish catch could cover the annual protein needs of over 90 million people.[3]

However, new trends are also promising in fisheries management. Rather than simply fishing more intensively to increase catches, with overexploitation as the invariable result, some nations have implemented sustainable management practices. In Argentina, for example, high exploitation of the shrimp, *Pleoticus muelleri*, from the 1980s caused a severe drop in catch in the early 2000s. To help the species recover, national authorities implemented management plans which proved so successful that by 2011 the catches had rebounded tenfold, reaching a new maximum recorded level of 80 thousand tonnes (FAO 2012b). Restoring marine ecosystems thus has major potential for improving long-term harvests.

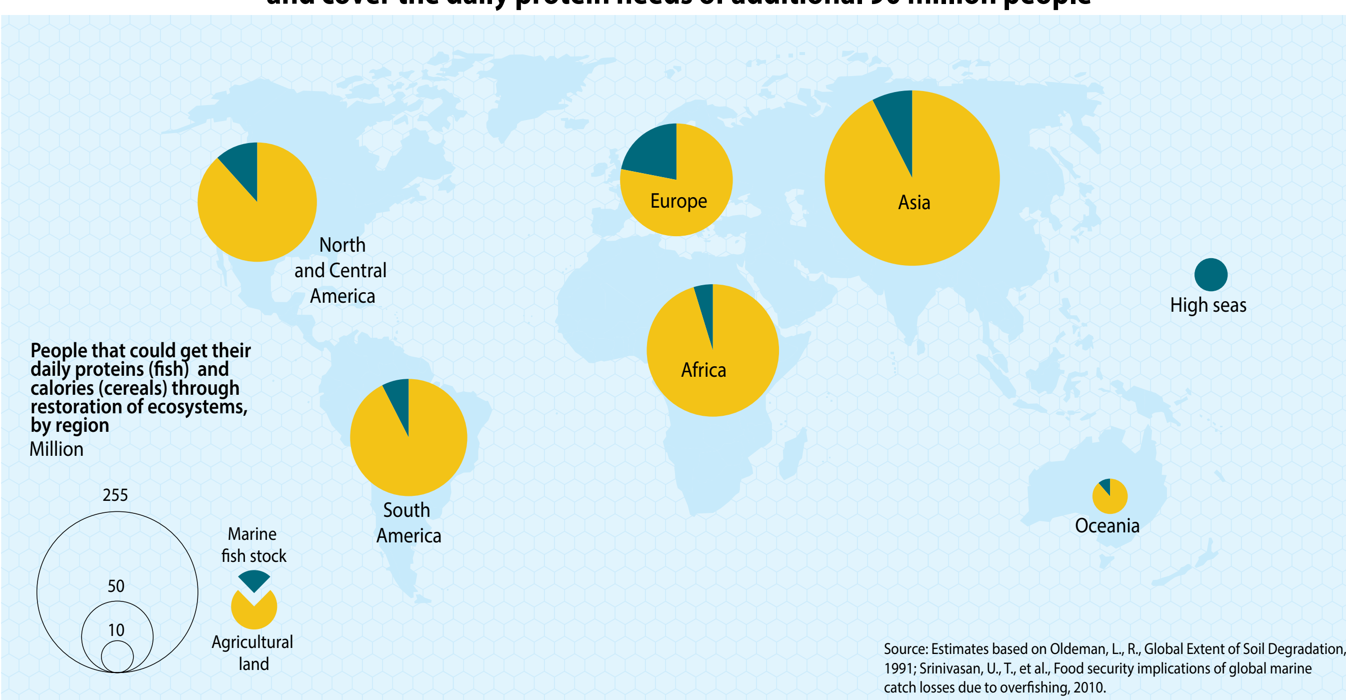
Another crucial aspect of improving food security from marine fisheries is prevention of illegal, unreported and unregulated (IUU) fishing. Though difficult to estimate, experts suggest that the annual illegal catch is between 11 and 26 million tonnes (Schmidt *et al.* 2013). Developing countries are especially vulnerable to illegal fisheries. Low salaries to fisheries administrators as well as lack of priority and capacity to enforce national legislation are some of the reasons for the high prevalence of illegal fisheries in developing countries (Schmidt *et al.* 2013).

3. Calculation is based on the findings from Srinivasan *et al.* (2010), average protein in fish and average daily protein needs for people.



Restoring ecosystems could feed 740 million people

and cover the daily protein needs of additional 90 million people



Source: Estimates based on Oldeman, L., R., Global Extent of Soil Degradation, 1991; Srinivasan, U., T., et al., Food security implications of global marine catch losses due to overfishing, 2010.

Illegal fishing is particularly critical in West Africa where the total estimated catch is 40 per cent higher than the reported amount (Agnew *et al.* 2009), indicating high levels of IUU. Due to already overexploited fish stocks in the region (Schmidt *et al.* 2013) illegal fisheries place an additional stress factor on food security in West Africa (Atta-Mills *et al.* 2004). Fisheries, and especially small-scale fisheries, play a direct as well as an indirect role to food security through nutrients from fish as well as income (WorldFish Centre 2011). Africa has the highest proportion of non-engine fishing vessels of about 60 per cent compared to 5–32 per cent in other regions of the world (FAO 2012b). While being more sustainable, small-scale fisheries are vulnerable as they have a lower fishing range, lower capacity in terms of harvest efficiency and lower buffer or alternative operational range if local areas are overexploited. In Ghana and Senegal small-scale fishers are struggling with decreasing fish stocks due to overexploitation forcing them to travel further out at sea (Atta-Mills *et al.* 2004; Fessy 2014). Due to low fish catches the small-scale fishers become easy targets for recruitment into illegal fisheries (Fessy 2014).

As a result of rapid population growth it is expected that the demand for fish will increase by 30 per cent by 2030 in sub-Saharan Africa. At the same time, estimates suggest that increases in fish capture in sub-Saharan Africa will be marginal, rising from an average of 5.42 million tonnes in 2007–2009 to 5.47 million tonnes by 2030 (World Bank 2013). In order to ensure that fisheries play an important role in food security in Africa in the future, it is crucial that the local fishing industry is protected, further degradation is prevented and restoration of degraded ecosystems is prioritized. Given the high levels of illegal fisheries, it is critical to support enforcement by tapping into the expertise and experience of international enforcement agencies and monitoring systems.


GUENE
MBINDEF

Food loss and waste in agro-ecosystems

Agriculture takes up 37.6 per cent of the world's land area, producing food, forage, bio-energy and pharmaceuticals. Against the backdrop of an increasing population, the food production capacity of agro-ecosystems is under threat from climate change, land degradation and loss of biodiversity. Soil erosion alone is blamed for losses in potential grain yield of as much as 5 million tonnes per year, an amount that is enough to meet the annual food calorie needs of 24 million people. A further 3 million tonnes of grain is lost through salinization of croplands, which could potentially feed 14.3 million people over a year. The losses in potential food production from agriculture due to environmental degradation are in addition to the 1.3 billion tonnes of food that are produced but never consumed every year. About 1.4 billion hectares of land are used to produce food that is either lost or wasted. At the same time the rates of increase in food production are falling, a trend that shows the planet is reaching its full potential for food production through conventional agricultural practices. A shift towards ecosystem approaches that can maintain or enhance the quality of agro-ecosystems could reverse the trend and significantly increase overall food production in a sustainable manner.

An estimated 37.6 per cent of the world's total land area is used for agriculture (FAO 2013a), and this ratio continues to expand. Crop and grazing lands, the main agricultural ecosystems, are a major source of food. In addition, agriculture also provides forage, bioenergy and pharmaceuticals (Power 2010). As much as 1.5 billion hectares, constituting 12 per cent of the world's land area, is used for arable and permanent crop production. Considerable amounts of more land are suitable for crop production, but these are covered in forests, used for settlements or protected for environmental conservation (FAO 2013a). According to the FAO (2009), agricultural systems include agro-forestry, pastoralism, crop monocultures, grazing systems, mixed cropping, paddy rice farms, perennial orchards, shifting cultivation, small home gardens and plantations of oil palm, coffee, cacao and sugarcane.

Food production through agriculture depends on services provided by natural ecosystems, including biological pest control, hydrological services, maintenance of soil structure and fertility, nutrient cycling and pollination (Power 2010). At the same time, agriculture also produces ecosystem services and disservices, depending on management practices. Ecosystem services from agriculture include carbon sequestration, disease control, regulation of soil and water quality, cultural services and support for biodiversity, while disservices include greenhouse gas emissions, loss of wildlife habitat, nutrient runoff, pesticide poisoning and sedimentation of waterways (Power 2010). Since the food provisioning role of agriculture is dependent on and has impacts on other ecosystems, there is a clear connection between agricultural ecosystems and other ecosystems such as mountain, forest and freshwater.

Good management practices can reduce the negative impacts of agriculture on ecosystems, while at the same time maintaining or increasing food production (Power 2010). Food provisioning can therefore be optimized through appropriate management practices targeted at supporting and regulating ecosystem services, as well by reducing ecosystem disservices (Zhang *et al.* 2007).

Food production trends

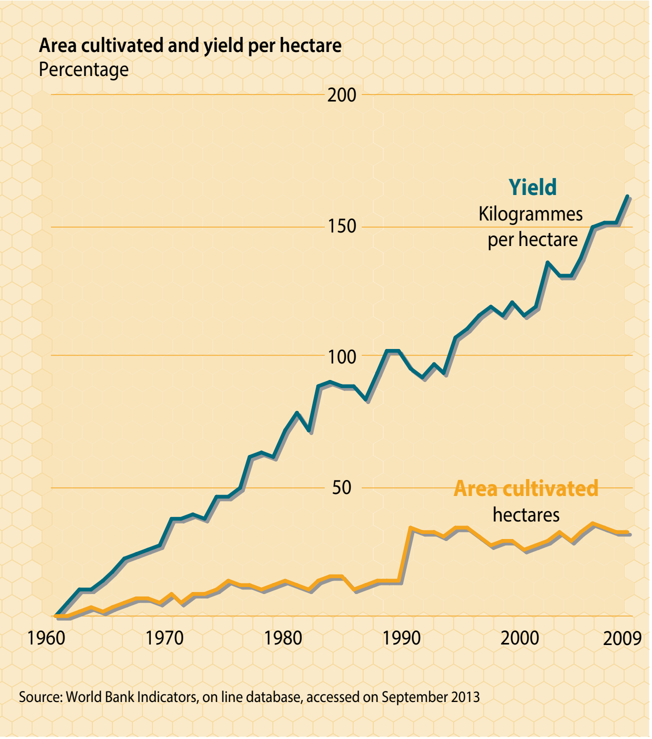
As a result of population growth and changing consumption patterns, the demand for food and production of food is increasing. Cereals such as wheat, rice and maize provide about two-thirds of all energy in human diets (Cassman 1999) and are grown on about half of the world's total harvested land area (FAO 2013a).

The past 50 years have seen global crop production expand threefold, with cereal production reaching 2.3 billion tonnes in 2012. Of this amount, about 1 billion tonnes was used for food and 750 million tonnes for animal feed. About two-thirds of the remaining food went to industrial processing or was used as seed or wasted (FAO 2013a). While there are regional differences, world cereal production increased by an annual average of 2.2 per cent between 1995 and 2009 (FAO 2012d). In the 1990s annual growth in production of cereals averaged 1 per cent, having declined from 1.6 per cent in the 1980s and almost 3 per cent in the 1970s (FAO 2013a). The increase in cereal production in the 1960s was driven by the Green Revolution, while an economic recession, bad weather and low prices depressed growth in cereal production in the 1990s and early 2000s (FAO 2013a). The increase in food production in recent decades has resulted in a corresponding increase in per capita food supply, which rose from 2 200 kcal/day in the early 1960s to about 2 800 kcal/day by 2009 with Europe having the highest supply averaging 3 370 kcal/person/day (FAO 2013a). Annual increases are projected to remain low in the next decade, averaging 1.4 per cent in cereal production to the year 2022, with 57 per cent of this growth in developing countries (OECD and FAO 2013).

Besides cereals, other key dietary needs for people include proteins, which are largely provided through meat and milk. About 296 million tonnes of meat were produced across the world in 2010 (FAO 2012d). The annual growth rate in cattle production has declined gradually from about 2 per cent in the 1960s to less than 1 per cent in the 2000s. The annual growth rate in pigmeat production fell from about 4 per cent 50 years ago to 0.8 per cent per year since 2000. However, the growth in poultry production continues to be robust averaging 3 per cent per year (FAO 2012d). Over 720 million tonnes of milk were produced in 2010. The average annual increase in milk production was about 2.2 per cent between 2000 and 2010 (FAO 2012d).

The 35 years leading up to the turn of the millennium saw the doubling of agricultural food production driven by an almost sevenfold increase in nitrogen fertilization, a 3.5-fold increase in phosphorus fertilization, a 1.7-fold increase in the amount of irrigated cropland and a 1.1-fold increase in land put

Cereal production increase



under cultivation (Tilman 1999). Wrong or excessive application of chemical fertilizers may have negative effects on the environment as well as human health (Godfray *et al.* 2010; FAO 2013a). Ecologist David Tilman (1999) argues that the next doubling of global food production would be driven by a threefold increase in nitrogen and phosphorus fertilization rates, a doubling of the irrigated land area and an 18 per cent increase in cropland. The concern is that these inputs will further alter the diversity, composition and functioning of the world's natural ecosystems significantly, and affect their ability to provide society with essential ecosystem goods and services such as food. Based on past trends in agricultural expansion, Tilman *et al.* (2001) estimated that 1 000 million hectares of natural ecosystems would need to be converted to agriculture by 2050, and this together with increases in nitrogen- and phosphorus-driven eutrophication of terrestrial, freshwater and near-shore marine ecosystems, would cause dramatic ecosystem simplification and significant loss of ecosystem services such as food production.

Food loss and waste in agricultural production

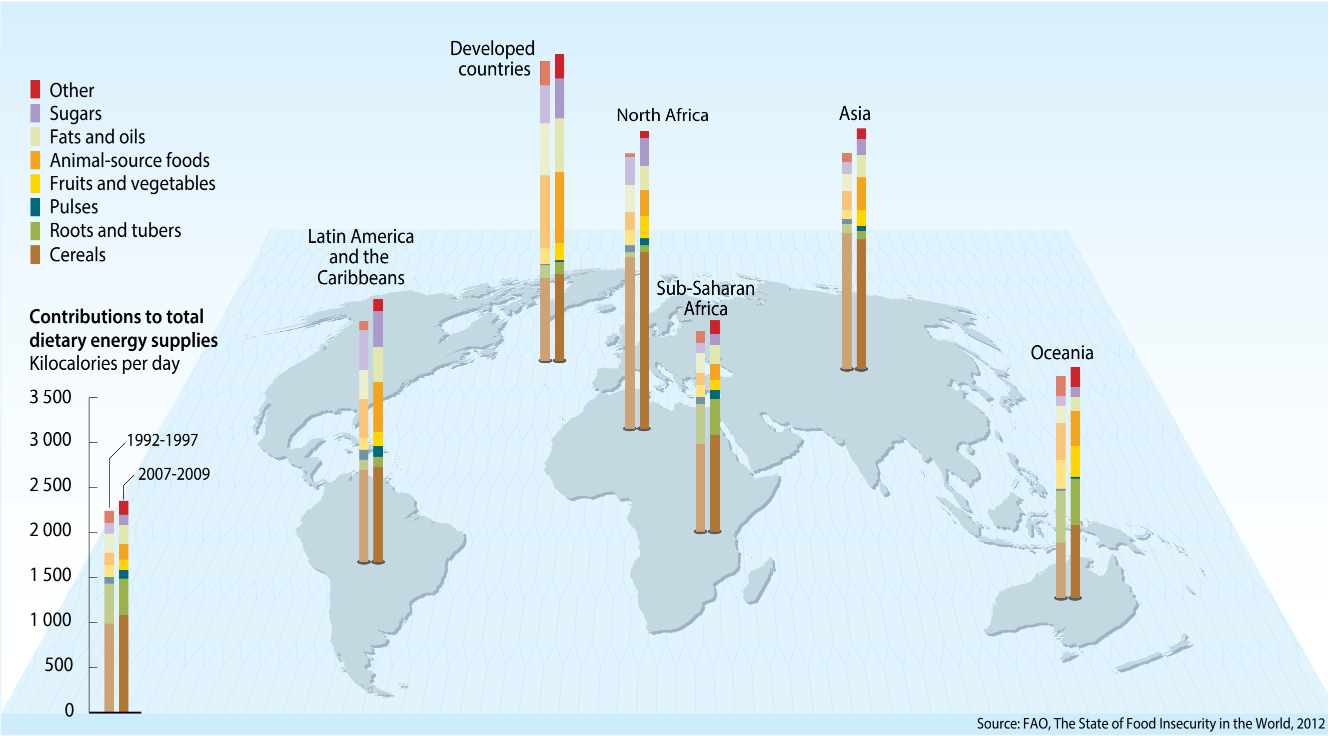
Food loss during agricultural production is caused by a variety of factors including damage by pests, diseases and unfavorable weather, poor handling and premature harvesting. Selective harvesting, labour shortages, over-planting, natural drying, spillage and spoilage during transportation also cause food loss and waste. Market-based practices such as stringent quality standards and processing requirements contribute to food loss en route to consumers (Springer 2013).

In developing countries, losses in the agricultural production and post-harvest stage are highest. Of the total amount of food that is lost and wasted in sub-Saharan Africa, as much as 67 per cent is lost during the two first stages of the supply chain. In South and South-East Asia the situation is similar, with just over 60 per cent lost during production and post-harvesting, closely followed by Latin America at about 62 per cent. High losses in the early stages of the supply chain are mainly due to inadequate financial and structural resources for proper harvesting, storage and transportation, as well as unfavourable climatic conditions for food preservation (FAO 2013b).

Two food categories – fruits and vegetables, and roots and tubers – have the highest percentage of loss during agricultural production and post-harvest, at about 22–26 per cent. These are also the commodities that have the highest overall loss and waste rates, both at approximately 45 per cent. About 30 per cent of all cereal production is lost or wasted, while 23 per cent of oilseeds and pulses, and meat, and 17 per cent of dairy products are lost or wasted (FAO 2012c).

According to the FAO (2013b), 1.4 billion hectares of land, or 28 per cent of the world's agricultural land area, is used every

Diet composition



year to produce food that is wasted. Food loss and waste are therefore not only about lost calories for human consumption, but also about the loss of resources put into growing food that is never consumed as well as the degradation of the ecosystems throughout the food supply chain. It takes between 5 000 to 20 000 litres of water to produce one kilogramme of meat. If meat is never consumed, the water used to produce the meat is wasted (Lundqvist *et al.* 2008).

Some agricultural practices threaten biodiversity, causing land conversion processes such as deforestation. About 80 per cent of deforestation is due to agricultural expansion (Kissinger *et al.* 2012). Estimates from the FAO (2013b) suggest that 66 per cent of threats to species are due to agriculture. Further, about 28 million tonnes of fertilizers are used annually to produce food that is lost and wasted (Lipinski *et al.* 2013), which may cause eutrophication of nearby water ecosystems. On the larger scale, food loss and waste are causing significant greenhouse gas emissions along the food supply chain (FAO 2013b) and therefore become a contributor to climate change. Food waste in landfill sites, for example, produces methane gas, which is 25 times more potent than carbon dioxide as a greenhouse gas (FAO 2012c). Food loss thus degrades the vital base that food production relies on, decreasing the ecosystem's productivity and hence its ability to produce high yields.

Further, degradation of ecosystems, through soil erosion, salinization and chemical and biotic stresses is blamed for losses in potential food yields. Soil erosion, which is the most common form of land degradation, is responsible for an annual loss of topsoil on about 10 million hectares of cropland globally, a rate that is 10 to 40 times greater than the rate of soil renewal (Pimentel 2006). Using conservative average yields of grain, climatologist Bo R. Döös (1994) estimated that at least 5 million tonnes in grain production could be lost every year due to the loss of topsoil on 10 million hectares of agricultural land through erosion. Such losses in potential food production are significant given that humans get the majority of their food calories from the land (Pimentel 2006). A rough estimate suggests that the losses can cover the annual calorie needs of 24 million people.[4]

Salinization, which results in the accumulation of salts in the soil, is common on irrigated lands and results in the abandonment of as much as 2 million hectares of land in the world per year (FAO 1991). This loss of agricultural land could result in food grain losses of 3 million tonnes per year (Döös 1994) enough to feed 14.3 million people annually.[5] Salinization is a major problem in low-lying coastal areas

4 & 5. Estimates of additional people to be fed are based on findings from Döös (1994), average calories from cereals, as well as average daily calorie needs for people.

such as Bangladesh, Egypt and Vietnam (FAO 1991). Besides salinization, acidification, the concentration of ground-level ozone and the increase in intensity of ultra-violet radiation are also blamed for causing chemical and biotic stresses to crops. According to Brown (1990), about 4 million tonnes of grain are lost per year due to chemical and biotic stresses.

Ecosystem degradation, such as groundwater pollution, soil erosion, salinization and loss in biodiversity, is also blamed for the failure of most farming systems to reach the potential ceiling of most animal and crop varieties. Although the difference between farm yields for cereals and genetic yield potential is closing (Peltonen-Sainio *et al.* 2008; Cassman 1999), the majority of farmers produce cereal yields that are far below genetic potential. Irrigated wheat, rice and maize produce as much as 80 per cent of potential yield, while rain-fed agriculture produces less than 50 per cent of potential yield (Lobell *et al.* 2009). While this suggests that there is room for greater yields, it also points to losses in potential food production.

Declines in food production are also caused by the loss of ecosystem services such as pollination, which is essential to food crop production. Clara Nicholls *et al.* (2013) estimate that 35 per cent of global crop production depends on animal pollination. However, looking at mango production as a case, the population of pollinators is declining due to cropland increases, which isolate crop fields from insect and animal habitats (Carvalheiro *et al.* 2012), as well as the use of insecticides (Alaux *et al.* 2010; Gill *et al.* 2012). Pollinator-dependent crops include alfalfa, sunflower, fruits and vegetables (Spivak

The potential of reutilizing food waste as animal feed

While the animal industry was originally based on converting non-food materials such as pasture and kitchen waste into animal feed, the modern animal industry is largely based on converting low-cost food ingredients such as cereals and legumes to produce high-value foods such as meat, milk and eggs. The quality standards for these high-value foods have risen to the extent that many of the traditional food waste sources are no longer used to any large degree. Many of the food wastes are being dismissed due to strict hygienic standards, variable nutrient composition and challenges in using these ingredients in the highly industrialized and efficient animal production systems currently in use.

However, there is a great potential in an increased use of food waste as animal feed. If the global 1.3 billion tonnes of edible food waste (FAO 2013b) were used as animal feed, this could save at least 260 million tonnes of animal feeds based on food-grade ingredients such as cereals and legumes, under the very moderate assumption that the value of food waste is only one-fifth of that of animal feed due to a higher water and fiber content (Westendorf *et al.* 1998).

An increased use of food waste as animal feed would require development of systems that effectively collect and treat food waste so that it could safely be used as animal feed for cattle, pigs and poultry. This could be done by providing specific containers to commercial kitchens and even private households, combined with training of the users in sorting the waste into food waste suitable for feed. Also, adaptations would be required in the animal industry. Feeding systems that blend food waste into feeds would have to be implemented, as well as the way of feeding to adapt to these kinds of perishable feeds. In addition, the high growth rate and the streamlined production systems now commonly used would have to be compromised to some extent, allowing for a more variable and less concentrated feed to be used in the animal feed. Such systems have been proved to work effectively without large losses in efficiency or in food quality, including the use of food waste from cafeterias in the feeding of pigs (Westendorf *et al.* 1998).

A change in legislation would also probably have to be implemented since the use of food waste could increase the risk of disease transmission between animals or the risk of an impaired animal health due to poor storage or poor quality of the ingredients. In short, increasing the use of food waste as animal feed would require rethinking the balance between food safety and food waste, or striking a balance between food security and food safety. It can be argued that an important factor driving the increased food waste is increased food safety requirements, which result to food being discarded in processing plants, grocery stores and kitchens in far larger quantities than before. A classic example is the ban on the use of meat and bone meal in Europe. While meat and bone meal produced from slaughter residues was previously used as a high-value protein ingredient in feed, slaughter residues are now a costly waste problem for the slaughter industry. The ban on the use of slaughter residues was imposed as a result of concerns of the link between Creutzfeldt-Jakob disease in humans and the use of ruminant slaughter residues in ruminant feeds, which could result in the spread of Bovine spongiform encephalopathy (Hueston 2013). Despite the lack of documented risk from using meat and bone meal to other animal species like pigs and poultry, the European authorities decided to ban the use of the product throughout the animal food industry.

et al. 2010), which have an annual global value of about US$35.6 billion (Lautenbach *et al.* 2012).

Ecosystem approaches to agriculture

The world cannot afford to lose or waste a lot of food, and must acknowledge that technological solutions alone are inadequate, and extreme agricultural expansion is not possible. Sustainable agricultural practices must be adopted in order to restore and protect the foundation upon which food production is based. According to Iris Lewandowski *et al.* (1999), sustainable agricultural approaches are ecologically sound in that they maintain and enhance the quality of natural resources, including preventing soil erosion, improving soil fertility and enhancing biological diversity by causing as little disturbance to natural habitats as possible. Sustainable farming approaches are also economically viable in that farmers are able to produce enough to ensure food security, as well as earn viable incomes. Sustainable agricultural practices have been used traditionally, and are therefore easily adopted in most rural communities. The practices include crop rotation, inter-cropping, conservation tillage, biological nitrogen fixation, biological control of diseases and pests and integrated farming.

It has been demonstrated that crop rotation increases yields, as well as allowing for sustained production. According to Bullock (1992), maize in rotation with soybean yields 5–20 per cent more than continuous crops of maize, due to improvements in the soil's physical properties and organic matter. Stevenson and van Kessel (1996) made similar observations where nitrogen levels increased by 6–14 kg/ha following a pea-wheat rotation. This

Integrated dairy farming in Njombe, Tanzania

The Kaduma family in Njombe, southern Tanzania, is building a new pen for their dairy cows. Their three cows and two calves will soon move from their current wooden home into a pen of brick and concrete. The pen is of a quality many small-scale farmers cannot afford. Mr. Kaduma explains, “Before we got the cows we were poor farmers. Our cows have given us what we have today, so we have to treat them as good as the rest of the family.”

The family practices integrated farming, an agricultural practice that integrates livestock and crop production. This practice has helped the family to increase milk productivity, as well as improve crop and vegetable yields. Integrated farming can be described as holistic resource management where by-products from cattle become inputs in crop farming. Farmers in 10 villages in Njombe are participating in research projects undertaken by the Sokoine University of Agriculture. Through the projects the small-scale farmers are being trained on how to create synergies between livestock and crop and vegetable production.

The fields around the Kaduma homestead are planted with crops such as Irish potatoes, plantain, maize and beans. Some of these are inter-cropped. There is maximum use of available space, with a “tower” vegetable garden and a multi-purpose nursery and timber trees occupying the homestead. Trees and grasses are used as boundaries between different crops. They are used not only as a wind-break and protection against soil erosion and water runoff, but also provide fodder for the cattle. The farmers dry the hay and preserve the grass for cattle fodder in the dry season.

Since the dairy cows have had access to quality fodder throughout the year, milk yields have increased significantly from 6 to 16 litres per day during the dry season. The milk provides a valuable source of nutrition and income to the family as the surplus is sold to a local processer, providing a steady year-round income. The farmers have also been trained on how to preserve excess milk by making fermented milk and cottage cheese, especially during the wet season when farmers produce more milk than the processing factory can take.

Milk is not the only valuable output from the cows. The farmers make dry compost, as well as generate renewable energy from biogas. The Kaduma family uses the biogas for cooking and lighting. Biogas is not only a much cleaner source of energy, but also saves the environment from deforestation. Biogas production also produces bio-slurry, a wet compost that is very rich in nitrogen. The Kaduma family dries the bio-slurry and stores it for the planting season. As a result of the use the organic fertilizers, vegetable crop yields have increased by 50 per cent.

The farmers have also been trained on how to develop tower gardens. Previously farmers would have their vegetable gardens in the wetlands (vinyungu). This is an environmentally harmful and time-consuming practice, as the gardens are a distance away from the home.

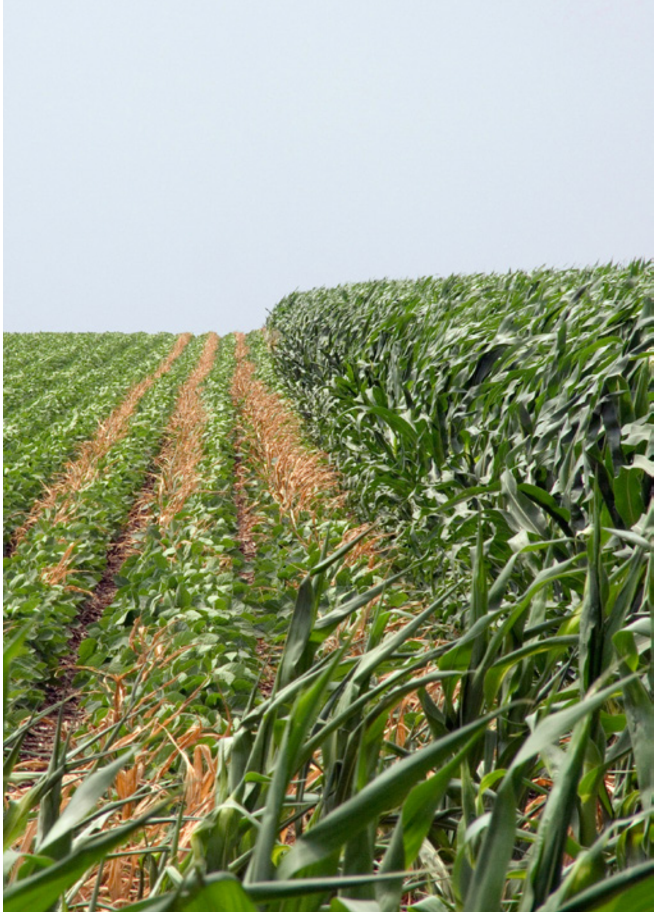
The information about this project was provided by Sokoine University of Agriculture (Morogoro, Tanzania). The farmers are participating in the on-going research project Up-scaling and Out-scaling Technologies for Enhancing Integrated Dairy Production System in Njombe District, under the Enhancing Pro-poor Innovation for Natural Resource and Agricultural Value Chains Programme.

resulted in an 8 per cent increase in the yield of wheat. Stanger and Lauer (2008) made similar findings in a study spanning 35 years. Together with conservation tillage, crop rotation has been shown to significantly increase structural stability of soil and the concentration of organic carbon in a 0–8 centimetre depth of soil. This has the potential to maintain crop productivity, protect the soil and improve soil quality (Carter and Sanderson 2001).

According to Lithourgidis *et al.* (2011), inter-cropping results in greater yields due to the use of a mixture of crops with different but complementing rooting ability, canopy structure, height and nutrient requirements. For example, inter-cropping maize with cowpea increases light interception in the crops, reduces water evaporation and improves conservation of soil moisture compared with a maize mono-crop (Ghanbari *et al.* 2010). The soil is better conserved through greater ground cover than in mono-cropping, while the incidence of pests and diseases is also reduced. Inter-cropping enhances the abundance of predators and parasites, preventing the build-up of pests and reducing the use of chemical pesticides. For example, black aphid (Aphis fabae) infestations of beans are lowered when beans are intercropped with taller maize plants, which interfere with aphid colonization (Ogenga-Latigo *et al.*1993). Intercropping beans with maize also decreases the incidence and severity of bacterial blight and rust (Fininsa 1996).

There is growing interest in integrated farming due to its potential for profitability and stability of farm income, long-term sustainability and greater food yields as well as because of concerns about natural resource degradation (Russelle *et al.* 2006). Integrated crop-livestock systems foster diverse cropping systems, including seasonal and perennial legume forages and cereals, which bring multiple environmental benefits. For example, integrated systems may use animal manure, which enhances soil fertility, while the perennial crops are important for carbon sequestration (Russelle *et al.* 2006).

The Millennium Ecosystem Assessment (MA 2005) strongly suggested that in order to meet the need to increase global food output there should be more emphasis on the development of environmentally and ecologically sound methods for the intensification of food production. Systems such as crop rotation, mixed cropping and integrated farming provide greater sustainability than approaches that solely use chemicals and other non-ecosystem-based practices.



Food loss and waste in forest ecosystems

Forests play an essential role in feeding the world's population. More than 410 million people are directly dependent on forests for food supplements. In addition to providing food directly they play an indirect role by delivering ecosystem services that other food provisioning ecosystems depend on, including carbon sequestration, water recycling and soil fertility improvement. Historically, forests have been cleared to make way for agriculture. Currently there is a net loss of 5.2 million hectares of forest every year. Deforestation reduces the planet's capacity to produce food in the long-term as important services such as habitat for pollinators and soil fertility improvement provided by forests are lost. A shift towards ecosystem-based management approaches that recognize the role of forests in food security is necessary to ensure that forests will be part of the long-term solution for feeding the world's growing population.

Forests for food security

As one of the most diverse ecosystems on earth, forests are central to the survival of many people. According to UNEP (2011a), more than 410 million people are highly dependent on forests for their livelihood and for food supplements, especially the rural poor in developing countries. About 60 million indigenous people who live in forests are directly dependent on the health of the ecosystem and the services it provides (FAO 2012a). The value of extracted non-wood forest products in 2005 was estimated at US$18.5 billion of which the majority came from edible products (MA 2005).

Forests provide a wide variety of food items such as fruits, mushrooms, nuts, seeds, roots, tubers, leaves, honey, wild animals, birds and insects. For many, especially indigenous and low-income groups living in or nearby forests, these food items constitute a significant part of their diet (FAO 2011a; Sunderland *et al.* 2013). Bush-meat is the main source of protein for the rural poor in the Amazon Basin while over 4.5 million tonnes of bush-meat are extracted each year from the Congo Basin for both rural and urban dwellers (Nasi *et al.* 2011). Forests also provide valuable feed for livestock in developing countries, enhancing the quality and quantity of milk and meat (FAO 2011a).

In poor communities, diets are often high in cereals, which lack vitamins and proteins that are crucial for a healthy life. Nutrient-rich food from the forest is therefore important for children (Sunderland *et al.* 2013). Nutrients from forest products include minerals and vitamins from fruits, carbohydrates from roots and oils and proteins from nuts and seeds (FAO 2011a). Insects, commonly collected in forests in Africa, Latin America and Asia, are also nutrient-rich food. According to van Huis *et al.* (2013) about 2 billion people eat insects regularly. Mealworms, for example, are rich in protein, vitamins and minerals with comparable levels to that of fish and meat.

Collecting and selling forest food items as well as other non-wood forest products is a common income-generating activity in many developing countries (FAO 2012a). For rural poor, forests serve as vital safety nets during periods of food shortages or low incomes (FAO 2011a). In Ethiopia, beekeeping and honey production from wild honeybees is a central element of rural livelihoods. The beekeepers use honey as a dietary supplement as well as an income generating strategy (Kebede and Lemma 2007).

State of the world's forests

Ten thousand years ago forests covered 6 billion hectares of land. However by 2010 the world's forests had been reduced to about 4 billion hectares, or approximately 31 per cent of the Earth's land cover. In spite of improvements in recent years, an alarming 13 million hectares of forest is lost each year

due to deforestation and natural events (FAO 2010a). This is equivalent to an area about the size of 36 football fields being lost every minute (WWF 2013). When taking into account the expansion of natural and planted forests, the annual net loss in forest area between 2000 and 2010 was 5.2 million hectares (FAO 2010a).

Deforestation rates are highest in the tropical areas of South America and Africa (FAO 2010a), where the majority of forest dependent people live (MA 2005; FAO 2012a). Between 2000 and 2010 South America had a net loss of 4 million hectares per year, while Africa had a net loss of 3.4 million hectares per year. As a region, Asia had a 2.2 million hectare net increase per year from 2000 to 2010, but this was mostly due to China's large contribution to afforestation as other countries in South and South East Asia are still experiencing high rates of net loss (FAO 2010a). While Central and North America had about the same extent of forests in 2010 as in 2000, European forests are expanding.

Deforestation is due to a combination of economic, political and institutional factors (MA 2005). They include agricultural expansion, timber extraction, illegal logging and land conversion to grazing land and plantations (FAO 2012a). Agricultural expansion is by far the main driver, causing about 80 per cent of deforestation worldwide (Kissinger *et al.* 2012).

This illustrates the complexity of the relationship between forests and food security. A change in land use from forest to agricultural or grazing land will most likely increase net food production. However, while such land cover change may ensure short-term food security it is important to consider the long-term consequences.

Food loss and waste in forest ecosystems

Although forests are one of the key food provisioning ecosystems, their role and contribution to food security, food loss and waste is not as obvious, since forest foods are not part of commercial food production. There are no detailed studies that have estimated the global or regional quantity or value of forests' contribution to food production or food loss and waste. The challenges with such studies lie with the difficulty of estimating a monetary value for non-market food items and quantifying how much food forests produce. The most significant contribution of forests to food security however may be the ecosystem services they provide that are vital for other food-providing ecosystems.

Forest ecosystems' regulating and supporting services are fundamental to other food provisioning ecosystems, especially agro-ecosystems (MA 2005; FAO 2011a). Clean water is a necessity for all food production. Forests capture, filter, store and regulate the flow of water across landscapes, ensuring steady water flows to agricultural production downstream and clean drinking water for people and livestock (Power 2010). Further, forests prevent soil erosion and landslides as tree and plant roots bind soil particles together. Deforestation is one of the key drivers of the estimated 10 million hectares of arable land that are degraded each year due to soil erosion (Kang and Akinnifesi 2000; Pimentel 2006). Trees also play a vital role in increasing soil productivity by adding nutrients that are necessary for crop production (Pimentel *et al.* 1997; Kang and Akinnifesi 2000). In addition, trees serve as habitat for insects and birds that provide pollination and natural pest control in wild and agricultural food production (Sunderland *et al.* 2013).

Forests are one of the richest ecosystems on earth with over 80 per cent of the terrestrial biodiversity (FAO 2012a). Conserving biodiversity in forests is not only crucial for today's food security, but also for future generations. Forests act as a gene pool containing numerous varieties of crops that are cultivated today. Coffee, cacao, tea and avocado are all examples of cultivated food items that can be found in their natural form in forests (FAO 2011a). Protecting wild food items is crucial as future events, such as changes in climate or diseases, may affect the productivity of crops commonly grown today.

The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC 2007) estimated that the forest sector, including deforestation, contributes 17.4 per cent of all greenhouse gases from anthropogenic sources. On the other hand, forests absorb about 2.4 billion tonnes of carbon dioxide per year, equivalent to one-third of the carbon dioxide released through the burning of fossil fuels (Pan *et al.* 2011). The ability of forests to store carbon dioxide in trees and soil, and hence mitigate climate change, is therefore an important ecosystem service (MA 2005; FAO 2011a) that indirectly contributes towards securing future food production, especially for rural farmers who are struggling with changing weather patterns.

One of the challenges related to forest food is that it is seasonal, meaning that large proportions are harvested at the same time. Rural households as well as local markets often lack sufficient storage and preservation capacity to prevent the food from decomposing. Traditional methods of processing food such as drying and smoking are important strategies (FAO 2011a) that can contribute towards reducing food waste and extending the food supply into non-productive periods. Fuel wood is the main source of energy used for processing and cooking food, making wood from forests an essential component of local food systems (Sunderland *et al.* 2013). It is estimated that 2.4 billion people use biomass (wood, crop residues, charcoal and dung) energy for heating and processing food (UNEP 2011a).

Ecosystem approaches to forest management

National forest policies should give more priority to the contributions of forests to food security and to millions of livelihoods (UNEP 2011a; FAO 2011a). Managing forests sustainably is essential for healthy ecosystems and for the continuation of forests as a provider of food as well as other supporting and regulating services important for the productivity of other ecosystems. Through deforestation practices such as timber extraction and land conversion, food is being lost directly through cutting down plants that produce food and destroying habitat for animals, insects and birds. Food is also lost indirectly through the degradation of forest ecosystems that provide services crucial for other food producing ecosystems, such as water regulation, pollination, soil fertility improvement and nutrient cycling.

Ecosystem approaches to forest management can play a crucial role in averting food loss by recognizing the inter-linkages with other ecosystems as well as the value of forest ecosystem

services. Sustainable forest management is the leading ecosystem approach today, taking into account economic and social factors while sustaining forest ecosystems (FAO 2012a). It is a move away from species-focused management approaches, such as managing forests solely for timber production, towards sustainable management of a wide range of forests' ecosystem services (MA 2005).

Agroforestry, the practice of combining agricultural production with trees in or outside of forest ecosystems, has gained momentum as a sustainable practice beneficial for food and nutrition security. By planting trees amongst crops on cultivated land, agroforestry provides many of the same forest ecosystem services that are beneficial for food production (Dawson *et al.* 2013). Though agroforestry is an interdisciplinary practice, residing between forestry and agriculture, it can be viewed as a complement to sustainable forest management (Schoeneberger and Ruark 2003) that enhances food production, increases farmers' incomes and improves the overall health of surrounding ecosystems (Jose 2009; FAO 2013d).

The combination of agriculture and trees provides more environmental benefits than other agricultural models. When managed well, agroforestry can avert 'disservices' from agriculture, such as greenhouse gas emissions, loss of wildlife habitat, nutrient run-off and soil erosion by providing ecosystem services similar to forests (Power 2010). Though the benefits from agroforestry differ between management practices and climatic regions they include water regulation, regulation of soil fertility and nutrient cycling, carbon sequestration, soil erosion control and increased pollination, pest control and biodiversity conservation (MA 2005; Jose 2009; FAO 2013d). In India, agroforestry systems have been used to rehabilitate salt-affected land by planting salt-tolerant trees (Nair 2007). Pimentel and Kidd (1992 in Pimentel *et al.* 1997) found that planting leguminous trees between maize crops in Central America reduced soil erosion from 30 tonnes/ha/yr to 1 tonne/ha/yr on slopes of 2–5 per cent. In the Shandong province in China, farmers who introduced agroforestry in 1977 saw a 10 per cent increase in agricultural productivity by 1990 (Yin and Hyde 2000).

In spite of its long traditions and documented benefits, investment in agroforestry has been relatively low. There is a need for decision-makers as well as agricultural organizations to realize the potential of agroforestry and its role in food production, environmental protection and poverty reduction (FAO 2013d).

Food loss and waste in aquatic ecosystems

Aquatic ecosystems are crucial for food security. Overfishing is depleting the world fish stocks and the resource base for many people. Yet, an estimated 35 per cent of all caught fish and seafood is never consumed, because it is either lost or wasted along the food supply chain. Estimates suggests that discards from fishing vessels alone could satisfy the daily protein needs of 370 million people for a year, and by recovering depleted fish stocks the increase in fish catch could cover the protein needs of an additional 90 million people. Food loss and waste from aquatic ecosystems is to a great extent caused by prevailing management practices. A shift to ecosystem approaches in fisheries could avert such loss and waste by reducing the degradation of aquatic ecosystems, curbing overfishing and allowing fish stocks to recover.

Food provisioning by aquatic ecosystems

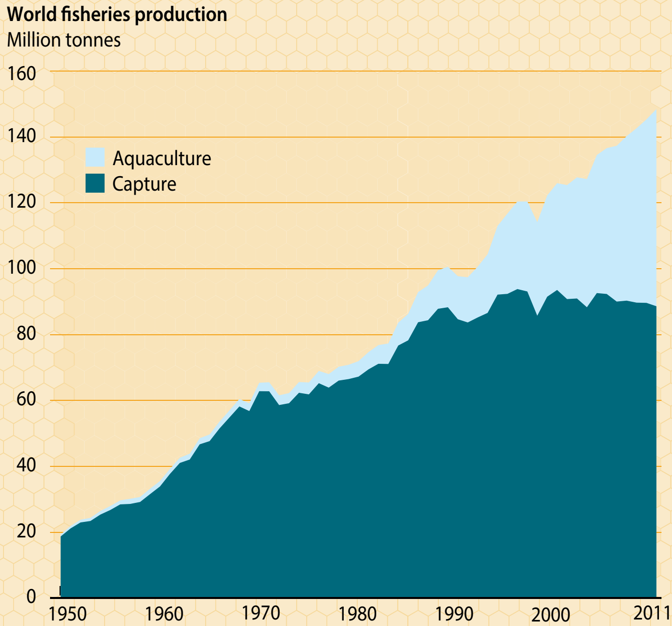
Aquatic ecosystems, including rivers and lakes, inland seas, floodplains, estuaries, coastal lagoons and open oceans, are the source of multiple ecosystem services and human benefits. The aquatic ecosystems deliver supporting and regulating services such as nutrient cycling, atmospheric and climate regulation and biological regulation. Mangroves are a source of wood, provide nursery for juvenile fish and other marine organisms and provide protection from storms, flooding and soil erosion. Wetlands are important conservation areas and floodplains are used for agriculture (MA 2005). More importantly, aquatic ecosystems are a crucial source of food and provide livelihood for many people across the globe.

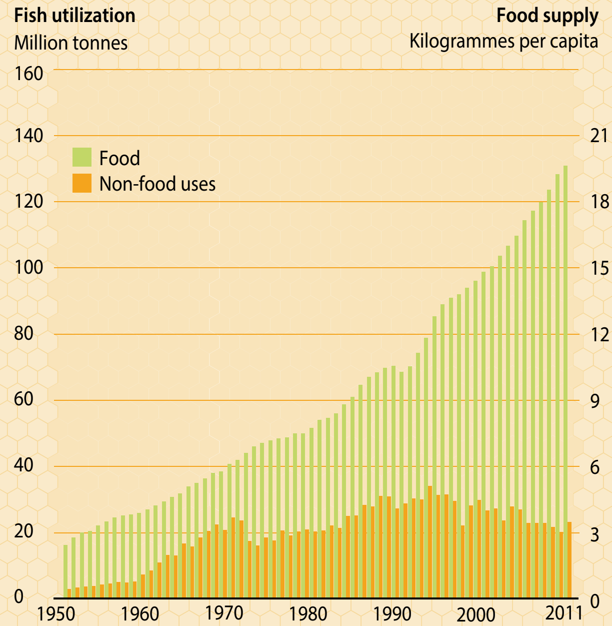
Fisheries, including aquaculture, support the livelihoods of an estimated 180 million people (FAO 2012d). Ninety per cent of those employed in the fisheries sector work in small-scale enterprises, of which women constitute a significant part (World Bank 2012). Fish are not only important for livelihoods, but also provide a crucial and affordable source of protein, especially in developing countries. In 2009, 145 million tonnes of fish were caught or farmed through aquaculture globally, of which about 122 million tonnes were used as food for people (FAO 2012d). In 2010, the estimated annual per capita fish consumption was 18.6 kilogrammes as compared to 9.9 kilogrammes in the 1960s (FAO 2012d). Africa consumes the least amount of fish per person while Asia is responsible for two-thirds of all fish consumption globally with China representing about half of the fish consumed in this region (FAO 2012d). It is estimated that fish provide about 10 per cent of human calorie intake globally (Nellemann *et al.* 2009). In 2008 fish represented 15 per cent of the average protein intake of more than 3 billion people (FAO 2011b).

The state of the world's fisheries

World fisheries have gone through drastic expansion over the last 50 years. Between 1950 and 1990 there was a fourfold increase in the global fish catch. Since then, the total amount of fish, shellfish and crab caught in the seas has remained more or less constant, while aquaculture has grown steadily at an annual growth rate of 8.8 per cent between 1980 and 2010 (FAO 2012b; Schäfer *et al.* 2010).

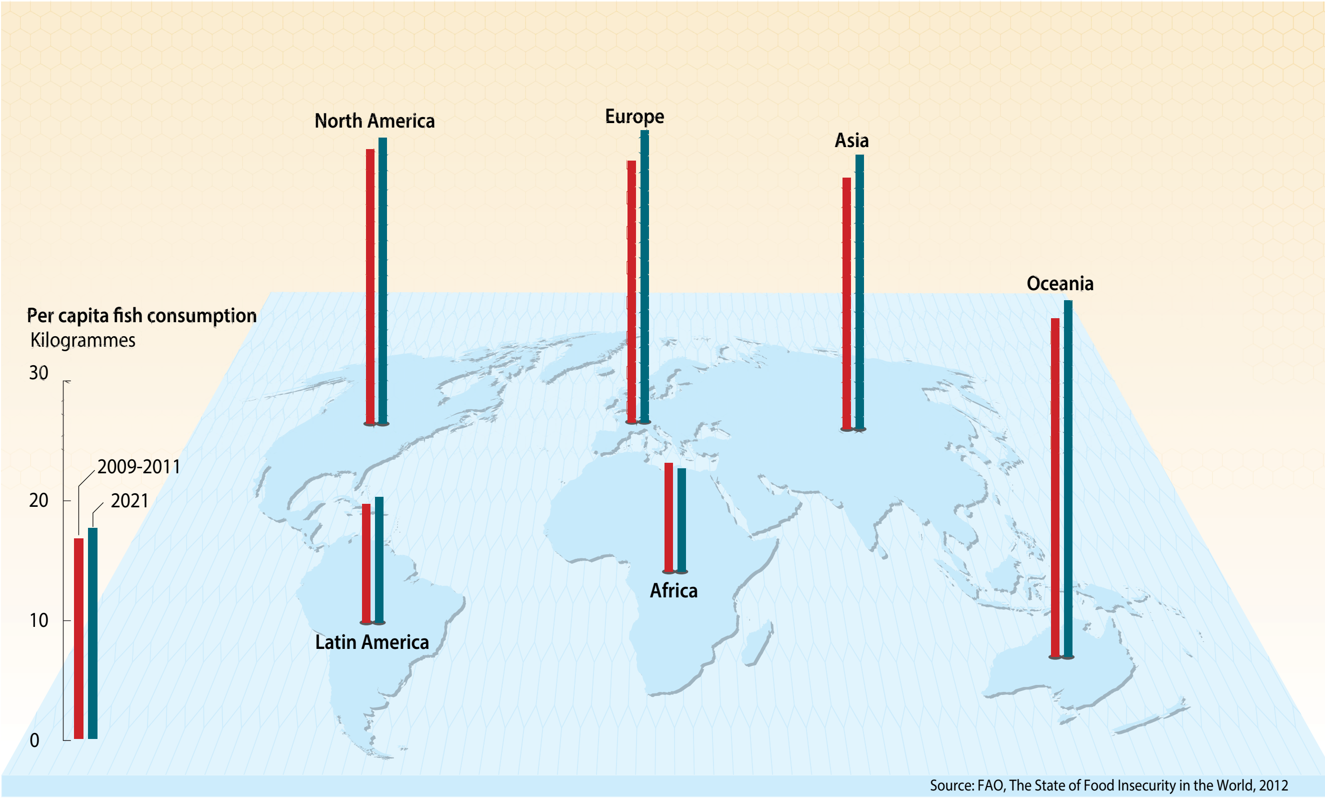
The intense use of fish stocks that are commercially exploited worldwide has come at a cost. According to estimates made by the FAO more than half of the world's fish stocks are categorized as fully exploited and 30 per cent as overexploited (FAO 2012b). The fishing capacity of the European Union's fishing fleet has been estimated to be two to three times the size oceans can sustainably support (European Commission 2008). Illegal, unreported and unregulated (IUU) fishing is perhaps just as, or more, significant than overfishing. Though difficult to estimate, experts suggest that the annual illegal catch is between 11 and 26 million tonnes (Schmidt *et al.* 2013). Overfishing causes a total net loss of about US$50 million annually (World Bank 2009), and based on calculations from Sirinivasan *et al.* (2010), had





Source: FAO, The State of World Fisheries and Aquacultures, 2012

Fisheries production, utilization and supply



Source: FAO, The State of Food Insecurity in the World, 2012

Aquaculture

As yields from captured fish are leveling out, the question has been raised as to whether aquaculture will be able to provide the extra fish yields needed for the world's expected 9.6 billion inhabitants in 2050. According to the FAO (2013e), 62.7 million tonnes of seafood were produced for human consumption in 2011 through aquaculture. With an annual growth rate of 8.8 per cent between 1980 and 2010 (FAO 2012b), no other food production sector has grown as fast in the past 40 years (UNEP 2012). Aquaculture is gaining a dominant position within fisheries with a 40 per cent share of the total fish production (FAO 2013e) and experts predict that aquaculture will gain an increasing role in the global food supply (FAO 2010b).

Asia is the leading producer in the sector contributing nearly 90 per cent of all aquaculture production. Eight out of the top 10 aquaculture producing countries are found in Asia, with China as the main producer with 38.6 million tonnes, followed by India, Vietnam, Indonesia and Bangladesh (FAO 2013e). In addition to being an important contribution to national economies, aquaculture is an important provider of nutrient-rich food to the Asian region. The majority comes from large-scale commercial production, but Asia also has long traditions of fish farming for local food production. In several Asian countries, fish is traditionally farmed on flooded rice fields (Halwart and Gupta 2004). In fact, developing countries are the main producers of aquaculture with as much as 80 per cent of all aquaculture taking place in developing countries. This highlights the sector's importance for economic development, poverty reduction and food security (Asche and Khatun 2006). In Africa, aquaculture production is still low with only 1.4 million tonnes produced in 2011 (FAO 2013e). Scientists (Schmidt *et al.* 2013) as well as international organizations such as the FAO (Moehl *et al.* 2008) and WorldFish (2012) are promoting the potential for aquaculture in Africa, and predict that it can play an increasing role in supplying food for the continent.

In spite of its future prospects, aquaculture has been criticized. Perhaps one of its most censured practices is feeding farmed fish fishmeal made up of large proportions of wild fish as this increases pressure on current forage fish stocks (Naylor *et al.* 2000) and their dependent species. The ratio of wild fisheries inputs to farmed fish output is currently 0.63, though it takes about five kilogrammes of wild fish to produce 1 kilogramme of salmon (Naylor *et al.* 2009). Fishmeal is usually made up of small pelagic fish such as anchovies, herring, sand eels, mackerels, menhaden and sardines (Stuart 2009). While there is no direct evidence, there is concern that fishmeal will compete with human food consumption, especially in regions where small pelagic fish are important components to diets, typically in Africa, Asia and Latin America, regions that also have the highest number of hungry people in the world (WorldFish 2011; Tacon and Metian 2009).

Intensive aquaculture practices may also lead to environmental degradation and changes in local ecosystems. For example, intensive fish farming pollutes waters with uneaten feed, fecal and metabolic waste from the fish. This can lead to over-fertilization (eutrophication), that can cause algal bloom and oxygen deprived dead zones, harmful to both wild and farmed species (Schmidt *et al.* 2013). When alien fish species, raised in aquaculture systems, enter the natural habitat, either through release or escape, these non-native fish can cause loss of native stocks through predation, competition or transmission of diseases (Naylor *et al.* 2000).

In spite of these criticisms, many fish farms are more environmentally friendly than other food producing systems. For example, aquaculture has lower nitrogen and phosphorus emissions than beef and pork. It takes 15 times less feed to produce one kilogramme of carp compared to one kilogramme of beef (Schmidt *et al.* 2013). According to the FAO (2011b) "responsible aquaculture can provide substantial environmental benefits, such as recovery of depleted wild stocks, preservation of wetlands, desalinization of sodic lands, pest control, weed control, and agricultural and human waste treatment". About one-third or 20 million tonnes of all farmed fish is produced without artificial feed (FAO 2012b). Mussel farming relies on natural feed from the ocean and intensive mussel farming has been shown to be beneficial for the ecosystems as mussels filter water to sieve out tiny particles of food, counteracting over-fertilization and algal blooms (Schmidt *et al.* 2013).

As the aquaculture sector grows, it is crucial that the environmental and social concerns are thoroughly addressed and that sustainable management practices are adopted (Diana *et al.* 2013). If managed sustainably, aquaculture can be part of the solution to feeding a growing human population as well as to restoring the dwindling fish stocks, since increased investment in aquaculture can potentially take the pressure off wild fish stocks, giving them time to recover (Asche and Khatun 2006).

overfishing been prevented since the 1950s the increase in fish catch in 2000 would be enough to cover the annual protein need of 90 million people.

The increase in fish catch from the 1950s was a result of new and more effective fishing technologies that made it possible to fish further out and gain access to deep-sea fish stock. These fish stocks, however, are long-lived and late-maturing which makes them particularly vulnerable to overfishing (WWF 2012). While improved technologies, such as bottom trawling, increase yields in the short-term they can cause long-term and permanent declines in fish stocks. The east coast of North America and European Union fishing waters, in particular, have been severely over-fished in recent decades. Many fish stocks, including the cod off the east coast of Canada have been overfished to the extent of depletion (MA 2005). Similarly, overfishing has severely reduced the tuna stock in the Atlantic and Pacific Oceans (Srinivasan *et al.* 2010). Research has shown that fish stocks are often highly resilient and capable of recovery even if overexploited. However, overexploitation over a prolonged period of time is detrimental for stocks, and recovery is highly improbable for the majority of the world's fish stock, including the Canadian cod (Neubauer *et al.* 2013). This is not only devastating for the survival of the fish stock, but also for food security as overfishing results in a permanent decline in fish catch.

Food loss and waste in the fishery sector

Overfishing has resulted in marine and freshwater ecosystems losing their potential productivity. According to Srinivasan *et al.* (2010), the total fish catch in 2004 could have been 9.9 million tonnes higher had fish stocks not been overexploited. From a regional perspective, the fish catch of North America could have been 23 per cent higher, while Europe and Africa could have had a 17 per cent higher fish catch.

Habitat destruction is another reason why fish stocks are decreasing (Graham *et al.* 2007; Paddack *et al.* 2009). Coral reefs serve as important nursery habitats for fish (Nagelkerken *et al.*

Ghost fishing

Too often fishers lose or leave their used nets, hooks and traps in the ocean. This equipment then floats around and continues to 'fish' on its own, often for a long period of time. This phenomenon, referred to as 'ghost fishing', traps and kills thousands of fish and other marine life including dolphins, sea turtles, seals and whales every year. Fishing gear can get lost when passing vessels cut the marker buoys or when trawl and seine wraps break during fishing. In some cases, old or broken gear is purposely dumped because the fishers see no value in it and treat the ocean as a waste bin (Smith 2005a). It is primarily passive fishing gear such as longlines, gillnets, entangling nets, trammel nets, traps and pots that are involved in ghost fishing (Smith 2005b). At first smaller fish get trapped in the nets and then the nets get filled with other marine animals including sharks, dolphins and seals as they try to scavenge off the trapped fish and other marine species (Macfadyen *et al.* 2009). While data is scarce on the number of fish nets being left in the sea worldwide, research on European fisheries suggests that 25 000 nets are either lost or discarded every year in European waters (Brown *et al.* 2005). In European waters deep water gillnet fisheries targeting deep water shark and monkfish represent the greatest portion of ghost fishing (Brown *et al.* 2005). Ghost fishing, which affects target fish species, the seabed environment and often endangered marine species, has severe environmental impacts while also constituting a great waste of potential human food (Macfadyen *et al.* 2009).

2000), and it is estimated that reef-associated fish constitute about a quarter of the total fish catch in developing countries (Burke *et al.* 2011). Globally, as much as 75 per cent of coral reefs are threatened by local and global pressures including overfishing, destructive fishing, coastal development and pollution, as well as rising ocean temperatures (Burke *et al.* 2011). A study by Paddack *et al.* (2009) links fish loss in the Caribbean of 2.6 to 6 per cent per year between 1986 and 2007 to a gradual degradation of coral reefs. Since the 1970s, the region has seen an 80 per cent reduction in coral cover. Similar findings have been observed in the Indo-Pacific where the coral bleaching event of 1998 lead to a wide-scale loss of coral reefs. After five to ten years there was an increase in larger fish (>45cm) while the amount of smaller fish (<30 cm) were declining, indicating a reduction in juvenile fish (Graham *et al.* 2007).

Of all fish and seafood extracted from oceans and freshwater, FAO reports that about 35 per cent is lost or wasted along the food supply chain (Gustavsson *et al.* 2011a). However it must be noted that there are inconsistencies in data about the global fish and seafood loss and waste of fish and seafood. This is because there is a lack of data on bycatch and discards, but also because there is a debate about how much of the discards should be considered food loss.

Fish discards – the most direct form of fish waste

Bycatch, the capture of non-targeted aquatic organisms, is threatening the world's remaining fish stock. Bycatch is a result of unselective gear that leads to the capture of untargeted fish of incorrect species, size or sex as well as other marine species, such as turtles and sea birds. Though some bycatch is sold, or eaten by crew, most of it is discarded or dumped back into the sea, often dead or dying (Davies *et al.* 2009; Gilman *et al.* 2013).

The amount of fish that is discarded in commercial fisheries is debated. Average discards in the 1990s were estimated at 7.3 million tonnes, or 8 per cent of total catches (Kelleher 2005).

When unmanaged catch is added to the figures, the number rises to approximately 40 million tonnes of fish and other seafood. Unmanaged catch refers to catch "that does not have specific management to ensure the take is sustainable" (Davies *et al.* 2009). In European fisheries alone approximately 2.3 million tonnes of fish is discarded in the North Atlantic and the North Sea each year, accounting for about 40 to 60 per cent of all fish caught in Europe (Stuart 2009; Schäfer *et al.* 2010). Bycatch is especially high in shrimp fisheries with discard rates as high as 95 per cent of the total catch (Clucas 1997). Small-scale fisheries are reported to show considerably lower discard rates than large-scale fisheries. In developing countries, discard percentages of the total catch of small-scale fishing operations have been estimated to be as low as 1 per cent (World Bank 2012).

Elsewhere the magnitude of bycatch is high, resulting in extreme losses of food for humans. Based on the global figure of bycatch, it is estimated that the loss of food through bycatch is enough to meet the total protein calorie needs of 370 million people.[6]

6. Estimate is based on findings from Davies *et al.* (2009), average protein in fish and average daily protein needs for people.

Although not all bycatch is discarded or suitable for human food and some can be re-fished, bycatch and discards cause an enormous amount of food waste. Converting suitable bycatch to aquaculture feed is one way of reducing fish waste while also increasing fish availability. One estimate suggests that the amount of fish discarded at sea can support a 50 per cent increase in aquaculture production – approximately the same increase needed to maintain per capita fish consumption at current levels by 2050 (Nellemann *et al.* 2009).

Ecosystem approaches to managing aquatic ecosystems

The desperate situation of the world's fish stocks has resulted in a critical review of prevailing practices in fisheries management. For example, many critics argue that the fisheries management within the European Union has largely failed to manage its fish resources sustainably because short-term jobs have been given priority over protection of fish stocks. Within the European Union, the annual fish quotas in recent years have been 48 per cent higher than scientists' recommendations and this has resulted in 88 per cent of Europe's fish stocks being overexploited (Schäfer *et al.* 2010).

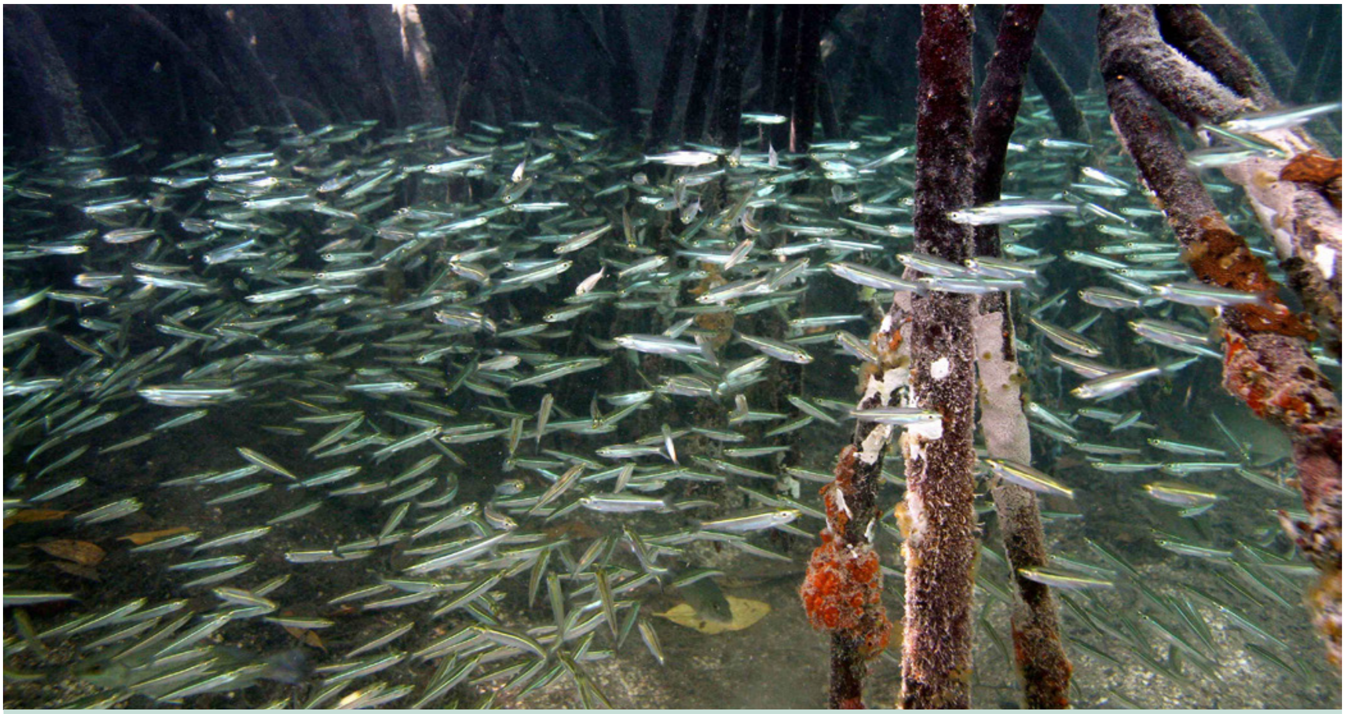
At the same time, aquatic ecosystems are being degraded through pollution from coastal development, intensive fishing methods and aquaculture, while ocean temperatures are increasing due to anthropogenic climate change, which is destroying the vulnerable coral reefs. These problems have led to increased recognition that better fisheries management is necessary to restore aquatic ecosystems and fish stocks. To do this fisheries management needs to become more holistic as well as better integrated with other sectors that have competing interests for ocean, coastal and freshwater resources.

Ecosystem-Based Management (EBM) is one such management practice that has gained momentum in recent years and which can be applied to marine and coastal areas, freshwater fisheries and aquaculture. While traditional fisheries management tends to view fish species in isolation from each other, EBM is a cross-sectoral approach that addresses the impacts fisheries have on the marine ecosystems as well as the impact that other sectors, such as agriculture or shipping, have on fisheries. On a policy level this means that fisheries, maritime, energy, agriculture, coastal development, environmental and other relevant sectors' policies must be coordinated. EBM does not compete with other holistic management approaches, such as Ecosystem-Based Fisheries Management (EBFM), Integrated Coastal Zone Management (ICZM) or Marine Protected Areas (MPAs). Rather these become tools to successfully implement EBM or where they are already in place EBM builds on them (Garcia *et al.* 2003; UNEP 2011b). Through EBM and related management approaches, food loss and waste due to degraded ecosystems and poor management practices could be averted. For example, EBFM considers the status of commercial fish stocks and ecosystem components that interact with and thus threaten those stocks, such as predators, prey and habitats (WWF 2007; UNEP 2011b; Nguyen 2012).

In Brazil, the government and local authorities have engaged with communities and the fishery sector to develop a management scheme, which ensures that fishers have sustainable livelihoods while also protecting fish stocks and habitats. The management scheme includes fish refugia, areas zoned for multiple use, restrictions on gear to reduce by-catch and discards and support for small-scale fisheries and family-

based aquaculture (UNEP 2011b). The Marine Protected Areas are similar in that the objective is to protect special habitats or species through no-take reserves, maintain livelihoods, facilitate restoration or control access to an area. In the San Andres Archipelago in Colombia, an MPA was established in 2000 as a first step towards EBM, to conserve the largest open ocean coral reefs in the Caribbean as well as protecting the livelihoods and tenure of the people (Agardy 2010).

Integrated Coastal Zone Management (ICZM) aims to achieve sustainable use of the coast by coordinating the initiatives of various coastal economic sectors, such as agriculture, fisheries and shipping, targeting all levels of governance and encouraging the involvement of all stakeholders in the planning of management strategies for the coast (Clark 1992; Post and Lundin 1996). The link between eutrophication of water bodies due to agricultural pollution and reduced fish stocks is one example of the inter-linkage between human land-based activities and water bodies. In worst-case scenarios, agricultural runoff and seepage of phosphorus and nitrogen into water systems create so-called 'dead zones' that impact fish populations and other aquatic biodiversity. Such negative side effects can be avoided through ICZM (Clark 1992). ICZM can therefore serve as a good starting point for EBM. From assessing the sustainable use of coastal areas, EBM can further link land use activities in the coastal zone to the ocean (UNEP 2011b).



Mikoko Pamoja – community-led mangrove conservation protecting local fisheries resources

Located 65 kilometers south of Mombasa, Kenya, Gazi Bay is home to several villages surrounding a mangrove forest. Local communities depend on the mangroves for wood and non-wood forest products and services such as seafood, firewood, building poles and traditional medicine. However, mangroves have been extensively used and degraded since the 1970s, through commercial logging and conversion of mangrove land to other land uses particularly agriculture and coastal development. Loss of mangroves has led to shortages of firewood and building poles, a decline in fisheries and increased coastal erosion, hence the urgent need for the rehabilitation, conservation and sustainable utilization of the mangroves at Gazi Bay.

One of the major services provided by mangroves is their role as a breeding and nursery habitat for fish. The intertwining mangrove roots provide a home and shelter from predators for juvenile fish, crabs and other marine life, supporting biodiversity while also filtering water and protecting shorelines. The mangroves at Gazi Bay support both on- and offshore fisheries, providing food and income to local communities. Researchers have estimated that approximately 31 per cent of the fish landed in Gazi in 2010 was directly related to the mangrove habitat (UNEP 2011c). The total economic value of the rehabilitated mangroves in Gazi Bay has been estimated at US$3,000 per hectare per year (Kairo *et al.* 2009).

Thought to be the first community-led mangrove carbon project in the world, the Mikoko Pamoja project, translated as Mangrove Together from the Kiswahili language, aims to use carbon finance to support sustainable management practices. Mikoko Pamoja is verified under the Plan Vivo Standard, a certification framework for projects supporting the rural poor with sustainable natural resource management, using payments for ecosystem services – in this case carbon. The project includes requirements and processes to ensure that it benefits livelihoods and ecosystems, and provides ethical and fairly traded climate services.

Mikoko Pamoja includes community-based mangrove reforestation, restoration and avoided deforestation activities in an area of 107 ha. The 3 000 tonnes CO_2-equivalent of carbon credits generated through the project are to be sold onto the voluntary carbon market, generating approximately US$12,000 for the local community per annum. One-third of the annual carbon income generated through the project will be used for the rehabilitation and protection of mangroves.

Through the Mikoko Pamoja experience, it is expected that coastal fisheries and communities throughout Kenya and potentially internationally will benefit from mangrove conservation, restoration and protection supported with revenue from carbon credits.

Conclusion

There are many challenges to world food security. Key among them are high population growth, the large amount of food lost or wasted, unsustainable use of scarce natural resources and the degradation of ecosystems.

In order to meet the needs of the world's growing population, estimated to reach 9.6 billion by 2050, food production should increase by as much as 60 per cent. Conventional means to increase food production, including technological solutions such as high-yielding hybrid seed varieties and livestock progeny, will result in very marginal annual increases in food production (around 1 per cent per year over the next two decades). Accelerated cropland expansion will result in further negative impacts on forests and other ecosystems.

Global food security is further threatened by the large amount of food that is either lost or wasted. This food does not feed people, and also wastes the natural resources used to produce it, leaving fewer resources to produce the next food crop, meat or fish catch. Against such a background, it is evident that the solutions to the world's food security challenges depend on both significant reductions in the amount of food that is lost or wasted and the restoration of ecosystems so that food production is not only sustained but also increased.

Food losses due to degraded agro-ecosystems are particularly alarming, with soil erosion, the most common form of land degradation, responsible for the annual loss of topsoil at rates that are 10 to 40 times greater than soil renewal. In drylands yield losses of as much as 4 – 10 per cent in crop production are incurred due to land degradation, desertification and drought. Reductions in food production are also caused by the loss of ecosystem services such as insect pollination. About 35 per cent of crops produced depend on insect and animal pollination, and the depletion and death of insects including bees are likely to have dramatic consequences for food production. A conservative estimate suggests that restoration of a quarter of the global degraded agricultural land could be enough to feed 740 million people.

Similarly, much potential food is lost in the world's fisheries due to overharvesting and overexploitation of the global fish stocks. If fish stocks were sustainably managed, an additional 9.9 million tonnes of fish and other seafood would be available on the global market, enough to meet the daily protein needs of 90 million people. Discards from commercial fisheries is one of the most wasteful practices found in food production, with as much as 40 million of the total global catch being discarded every year. Discards from fishing vessels alone could fulfill the daily protein needs of 370 million people for a whole year.

A significant amount of the food that is wasted, while deemed unfit for human consumption, is still fit for use as animal stock feed, as well as feed in aquaculture. By finding safe and healthy ways to capture and reinvest food waste to feed animals and fish in aquaculture, significant amounts of the cereals and fish now used in animal feeds could be freed for human consumption. Cereals currently used as animal feed could, in principle, feed an additional 4 billion people.

Forests provide a variety of foods including fruits, mushrooms, nuts, seeds, roots, honey, birds, insects and bush-meat. For example, forest insects form part of the traditional diet for about 2 billion people in Africa, Latin America and Asia. Food from forests is under threat from rapid deforestation, with a net of 5.2 million hectares of forest being lost each year. Deforestation also threatens food security as forests deliver crucial ecosystem services that other food-providing ecosystems depend on, causing a reduction in potential yields.

The bulk of world food losses are in the developing countries where the tremendous efforts to improve agricultural yields have not been matched with the development of infrastructure to transport, process and store food. At least 40 per cent of all food losses in developing countries occur during post-harvest and at the processing stages. If the US$4 billion worth of food that is currently lost in sub-Saharan Africa could be avoided, it would provide food to meet the needs of 48 million people. In developed countries more than 40 per cent of food losses occur at retail and consumer levels – losses that can be reduced significantly with consumer and industry education.

In order to meet current and future food demands while preserving the world's ecosystems and sustainably exploiting their full potential for producing food, new and more appropriate management practices must be implemented in agriculture, fisheries and forestry. Ecosystem approaches represent an alternative to conventional food production that will not only reduce the human footprint on the environment, but also improve the Earth's biological capacity and thus its food production potential. Ecosystems approaches to food production, including inter-cropping, integrated farming, conservation tillage, biological control of pests, agroforestry and integrated coastal zone management are some of the important strategies to be adopted in order to achieve this goal and feed the world in 2050.

Contributors and reviewers

Editorial team
Rannveig Knutsdatter Formo
Hanne Jørstad
Christian Nellemann
Clever Mafuta
Richard Munang
Jesica Andrews
Julie Nåvik Hval

Cartography
Riccardo Pravettoni

Layout
GRID-Arendal

Copy edit
Leslie Cole
Janet Fernandez Skaalvik
Allison Bredbenner

Photo credits
1 David Bathgate/Corbis **4-5** iStock/pius99 **6** iStock/no_limit_pictures **6** iStock/Abdolhamid Ebrahimi **8** iStock/Pgiam **9** Wendy Stone/Corbis **10** iStock/mr_morton **14** iStock/Michał Krakowiak **15** iStock/Claudiad **16** iStock/sam_ **18** iStock/Steve Froebe **24** iStock/SimplyCreativePhotography **28** iStock/guenterguni **29** iStock/UygarGeographic **32** iStock/Peeter Viisimaa **33** iStock/Peeter Viisimaa **34** iStock/martb **36** Lawrence Hislop **36-37** Wenzel Prokosch **38** iStock/Kary Nieuwenhuis **40** Yuan Qing/Xinhua Press/Corbis **43** iStock/Bryngelzon **43** iStock/Cynthia Baldauf **44** iStock/RicAguiar **45** iStock/andrearoad **46** iStock/MsLightBox **46** Peter Prokosch **47** iStock/luoman **48** iStock/Brasil2 **48** iStock/RicAguiar **49** iStock/hippostudio **50** iStock/andipantz **51** iStock/Peeter Viisimaa **54** iStock/Howard Oates **55** iStock/Jane Sheldon **56** iStock/rbouwman **57** iStock/Tarzan9280 **58** iStock/Hans Martens **58** iStock/Danielrao **59** Steven Lutz **60** iStock/Sasha Radosavljevic **72** iStock/duglasp

Contributors and reviewers
Keith Alverson, UNEP
Elli Borge, Norwegian University of Life Science
Michael Borucke, Global Footprint Network
Jared Bosire, Kenya Marine and Fisheries Research Institute
Tanya Bryan, GRID-Arendal
Silvio Dorati, World Vision Australia
Steve Goldfinger, Global Footprint Network
Martin Halle, Global Footprint Network
Katsunori Iha, Global Footprint Network
Mathilde Iweins, FAO
Lucita Jasmin, UNEP
Selina Juul, Stop Spild Af Mad
James Kairo, Kenya Marine and Fisheries Research Institute
Tiina Kurvits, GRID-Arendal
Lars Laestadius, World Resources Institute
Elis Lazarus, Global Footprint Network
Sunday Leonard, UNEP
James Lomax, UNEP
Steven Lutz, GRID-Arendal
Desta Mebratu, UNEP
Aitan Miltao, Global Footprint Network
Elizabeth Mrema, UNEP
Christian Neumann, GRID-Arendal
Waiganjo Njoroge, UNEP
Rober van Otterdijk, FAO
Akpezi Ogbuigwe, UNEP
Dharashree Panda, Global Footprint Network
Elizabeth Paulukonis, Global Footprint Network
Firesenai Sereke, Global Footprint Network
U. Thara Srinivasan, Pacific Ecoinformatics and Computational Ecology Lab
Ibrahim Thiaw, UNEP
Ndelilo Urio, Sokoine University of Agriculture
Mathis Wackernagel, Global Footprint Network
Shereen Zorba, UNEP

Glossary

Afforestation
Establishment of forest plantations on land that is not classified as forest.

Agro-forestry
The practice of traditional and modern land-use where trees are managed together with crops and/or animal production in agricultural settings.

Biocapacity
The capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using available extraction technologies.

Deforestation
Conversion of forested land to non-forest areas.

Ecological Footprint
A measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices.

Ecological overshoot
The situation that occurs when humanity's demand on the biosphere exceeds supply or regenerative capacity.

Ecosystem
A dynamic and complex set of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem approaches
Strategies for the integrated management of land, water and living resources that promote conservation and sustainable use in an equitable way. Ecosystem approaches recognize that humans, with their cultural diversity, are an integral component of many ecosystems.

Ecosystem-Based Management (EBM)
An environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation.

Ecosystem services
The benefits of ecosystems, including provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational and cultural benefits; and supporting services such as nutrient cycling, which maintain the conditions for life on Earth.

Ecosystem-Based Fisheries Management (EBFM)
An approach that strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. It considers the impact fisheries have on all components of the broader marine environment, as well as the impact of other marine and coastal activities on fisheries.

Food loss due to environmental degradation
Potential or absolute decrease in food production caused by environmental degradation. Such losses also refer to food that will never be produced due to the degradation of ecosystems.

Food loss
A decrease in mass or nutritional value of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chain such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. Natural disasters also cause food loss. Food is lost during pre-harvest production, post-harvest handling and storage and processing

Food waste
Food appropriate for human consumption, which is discarded, whether or not after it has been kept beyond its expiry date or left to spoil. Food waste is often due to food having been spoilt, but it can also be for other reasons such as oversupply or individual consumer shopping/eating habits. Food waste occurs at distribution and household consumption levels.

Ghost fishing
Lost or abandoned fishing gear that continues to catch fish.

Integrated coastal zone management (ICZM)
An approach that considers economic, social and ecological perspectives in the management of coastal resources and areas.

Integrated farming
A resource-efficient crop, fish and livestock production system that seeks to maintain productivity and profitability, while at the same time protecting the environment and the health of farmers and their families. It involves the recycling of farm waste for productive purposes, and takes the form of crop-fish integration, livestock-fish integration, crop-fish-livestock integration or a combination of crop, livestock, fish and other enterprises.

Inter-cropping
The cultivation of two or more crops simultaneously on the same field.

Marine Protected Areas (MPA)
An area designated to protect marine ecosystems, processes, habitats and species, which can contribute to the restoration and replenishment of resources for social, economic and cultural enrichment.

Mono-cropping
Agricultural practice of producing or growing a single crop or plant species over a wide area and for a number of consecutive years.

Reforestation
Planting of forests on lands that previously contained forest, but had since been converted to other uses.

Sustainable Forest Management (SFM)
The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems.

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GRID-Arendal
A Centre Collaborating with UNEP

GRID-Arendal
Teaterplassen 3
N-4836 Arendal
Norway
grid@grida.no
www.grida.no

www.unep.org
United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: uneppub@unep.org
www.unep.org

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