Humans dominate the planet and their influence extends to every part of the world. Over the last 20 years the extent of land area harvested has increased by 16 per cent, the area under irrigation has doubled, and agricultural production has grown nearly threefold. Yet close to one billion people remain undernourished. There is enormous pressure on global land resources due to rising food demand, a global shift in dietary habits, biofuel production, urbanization, and other competing demands. Landfills, mining, and other extraction activities also contribute to the pressure on land resources. Hence, healthy and productive land is becoming scarce.

It is clear that unsustainable human activities put land at risk and at the same time threaten the ecosystem services on which all humanity depends. In Europe alone, poor land management practices account for an estimated 970 million tons of soil loss due to erosion each year; worldwide, the annual loss of soil is estimated at 24 billion tons. Satellite observations suggest that globally between 2000 and 2012, 2.3 million km² of forest were lost, while only 0.8 million km² were reforested. The loss of forests and other natural ecosystems directly affects biodiversity and ecosystem services, such as nutrient, carbon, and water cycles and climate regulation.

Agriculture provides food, fiber, and other products that sustain human life. Croplands occupy about 14 per cent of the total ice-free land area on the planet while pastures occupy about 26 per cent. Almost 45 per cent of the world’s agricultural land is located on drylands, mainly in Africa and Asia; it supplies about 60 per cent of the world’s food production. While increases in food production are essential to feed a growing population, agricultural expansion threatens local and regional ecosystem functions and the vital services they provide to all species.
INTRODUCTION

Measuring the extent of land degradation is difficult; experts disagree about both the status and trends even in well-studied areas like Europe and North America. The World Atlas of Desertification (WAD), a project coordinated by the Joint Research Centre (JRC) of the European Commission with collaboration of the United Nations Convention to Combat Desertification (UNCCD), looks beyond conventional desertification analyses to consider, more generally, the status and trends in global anthropogenic land change processes, with an emphasis on croplands and rangelands. The WAD is further complemented with the large evidence base on forests, water resources, biodiversity, and soil conditions that is summarized in Part Two of this Outlook. After summarizing some of the key findings of the WAD, this chapter concludes by contrasting current status and trends in land productivity dynamics with some of the goods and services that widespread land degradation will put at risk.

By evaluating a reference period of approximately 15 to 20 years, the time since the publication of the last Atlas, and taking account of the findings of the Millennium Ecosystem Assessment in 2005, the WAD global mapping approach is designed to help identify areas potentially affected by persistent land degradation as well as areas that are showing signs of recovering their productive capacity. These maps are overlaid with information on the most commonly documented direct and indirect causes of land degradation, and also include, when available, information on sustainable land use and management practices, such as agroforestry and conservation agriculture.

The WAD implements a systematic and transparent framework to trace where the main human-environment processes and interactions coincide. This geographic convergence of evidence is instructive in that it highlights areas and possible pathways of land degradation as well as responses including the protection, sustainable management, and restoration of land resources. The third edition of the WAD focuses on global datasets that yield discernable patterns in potentially stressed areas. The combination of these stressors is then filtered through a variety of stratifications representing a range of stakeholder interests, such as cropland or rangeland perspectives. As a global scale exercise, the WAD remains limited in its ability to interpret specific local situations, which need to be addressed with contextual information and interpreted based on the understanding of their interactions at that scale. Nevertheless, the WAD convergence framework can be useful in providing background information for more detailed studies at national or sub-national scales.

Decreasing productivity trends do not per se indicate land degradation, or increasing trends indicate recovery. For further evaluation with the aim of identifying critical land degradation zones, an analytical convergence of evidence framework using additional thematic information is required.
Land productivity addresses the net primary production (NPP) per unit of area and time. It reflects the overall quality of land and soil that results from environmental conditions and land resource use/management. Persistent decreases in land productivity point to the long-term alteration of the health and productive capacity of the land. Such decreases directly and indirectly impact on virtually all terrestrial ecosystem services, i.e., the benefits that form the basis for sustainable livelihoods and economic growth in all human communities. This indicator relies on multi-temporal and thematic evaluation of global long-term time series of remotely-sensed land productivity measures equivalent to NPP, at high spatial resolution (1 km or better) and operationally addressed by existing Earth Observation Systems.

Box 4.1: Methodology for assessing the status of land cover

In the past, land degradation maps have been controversial; their value questioned due to the multifaceted nature of the phenomenon, the complexity of processes involved, and the difficulty of interpretation at a global scale. However, progress in the last two decades – the emergence of improved global datasets, a better understanding of underlying processes, and rapidly advancing analytical tools – has improved the accuracy of this type of analysis.

The state of the Earth’s vegetative cover and its development over time is a generally accepted representation of land productivity and dynamics, reflecting integrated ecological conditions and the impact of natural and anthropogenic environmental change. The term “land productivity dynamics” (LPD) as used in the WAD reflects the fact that the primary productivity of a stable land system is not a steady state, but often highly variable between different years and vegetation growth cycles due to natural variation and/or human intervention. This implies that land productivity changes cannot be assessed meaningfully by comparing land productivity values of single reference years or averages of a few years, and emphasizes the need for approaches based on longer term trends. Therefore, the LPD dataset relies on multi-temporal and thematic evaluation of long-term global time series of remotely-sensed vegetation indices, allowing for the calculation of equivalents to net primary productivity. These time series datasets coupled with model-derived biophysical variables are increasingly being provided by existing national and international Earth Observation Systems, such as the Group on Earth Observations.

The LPD map used does not provide a numerical measure of land productivity. Rather, it depicts the persistent trajectory of land productivity dynamics during the last 15 years. It provides five qualitative classes of persistent land productivity trajectories from 1998 to 2013: in other words, a qualitative combined measure of the intensity and persistence of negative or positive trends and changes of vegetation cover. The main elements of the LPD dataset processing chain are summarized in Annex 2, considering also aspects of validation and accuracy of the data product.

<table>
<thead>
<tr>
<th>Class Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Persistent severe decline in productivity</td>
</tr>
<tr>
<td>2</td>
<td>Persistent moderate decline in productivity</td>
</tr>
<tr>
<td>3</td>
<td>Stable, but stressed; persistent strong inter-annual productivity variations</td>
</tr>
<tr>
<td>4</td>
<td>Stable productivity</td>
</tr>
<tr>
<td>5</td>
<td>Persistent increase in productivity</td>
</tr>
</tbody>
</table>

The WAD’s key message is that land degradation is a multifaceted global phenomenon with distinct variations between regions and across key land cover/land use systems and which cannot be captured by one or a limited set of indicators.
It must be clearly understood and communicated that “land productivity” in the context of the LPD dataset strictly refers to the overall above-ground vegetation biomass productivity. This is not conceptually the same as, nor necessarily directly related to, agricultural income per area unit or “land productivity” as used in conventional agricultural terminology.

The WAD’s key message is that land degradation is a multifaceted global phenomenon with distinct variations between regions and across key land cover/land use systems and which cannot be captured by one or a limited set of indicators. A crucial indicator in the WAD framework is the Land Productivity Dynamics (LPD) dataset that refers to the standing biomass productivity, and is derived from phenological analyses of a 15-year time series (1998-2013) of global normalized difference vegetation index (NDVI) observations from SPOT-VGT, composited in 10-day intervals at a spatial resolution of 1 km. The map shows 5 classes indicating areas of negative or positive change or stability and is an indicator of change or stasis of the land’s apparent capacity to sustain the dynamic equilibrium of primary productivity in the given 15-year observation period.

Indications of decreasing productivity can be observed globally, with up to 22 million km² affected, i.e., approximately 20 per cent of the Earth’s vegetated land surface shows persistent declining trends or stress on land productivity. These global trends are evident in 20 per cent of cropland, 16 per cent of forest land, 19 per cent of grassland, and 27 per cent of rangeland (i.e., shrubland, herbaceous and sparsely vegetated areas). For grasslands and rangelands, the global extent of the areas experiencing decreases in productivity exceeds that showing increases. South America and Africa are the most affected by productivity declines in absolute terms, with Australia and Oceania showing the largest proportion of areas affected: approximately 37 per cent for Australia, 27 per cent for South America, and 22 per cent for Africa.

Considering that immense effort and resources are being committed to maintain and enhance the productivity of arable and permanent cropland as well as the fact that there are clear limitations to the further expansion of cropland, these figures are cause for concern and action. This analysis can be further disaggregated according to land cover/land use classification. In the next step of the analysis, the distribution of LPD classes is further broken down to coarse land cover/land use categories at global and continental levels:

- Cropland including arable land, permanent crops, and mixed classes with over 50 per cent crops
- Grassland including natural grassland and managed pasture land
- Rangelands including shrub land, herbaceous, and sparsely vegetated areas
- Forestland including all forest categories and mixed classes with tree cover over 40 per cent

This breakdown reveals significant differences in the respective areas (Figure 4.3) and proportions (Figure 4.4) affected by declining or stressed (i.e., unstable) land productivity dynamics. The overall picture gets more nuanced when disaggregating at continental/regional and sub-regional levels. This is evident in the substantial differences between continents as regards the dimension and extent of potentially critical areas and their association to land cover/land use.
Figure 4.1: Global Land Productivity Dynamics map 1999 to 2013 showing 5 classes of persistent land productivity trajectories during the observation period. Decreasing productivity trends do not per se indicate land degradation, or increasing trends indicate recovery. For further evaluation with the aim of identifying critical land degradation zones, an analytical convergence of evidence framework using additional thematic information is required.

**Key**
- Declining
- Moderate decline
- Stressed
- Stable
- Increasing

Figure 4.2: Regional groupings refer to a continental classification system (Australia & Oceania includes New Zealand, Papua New Guinea, and Pacific Islands; North & Central America includes the Caribbean).

**Key**
- Declining and moderate decline combined
- Stressed
Figure 4.3: Global spatial extent of LPD classes under selected LC/LU categories

Figure 4.4: Per cent distribution of LPD classes for 4 major LC/LU categories at global level
In Africa, approximately 16 per cent of the vegetated land surface is assigned as cropland, of which about 23–24 per cent shows signs of decreasing or unstable land productivity. African rangelands and grasslands, an essential resource for livestock production and livelihoods of large parts of the population, are experiencing productivity declines similar to that of affected croplands. The overall expansion of declining land productivity appears to be above global averages and exceeds the extent of areas experiencing increasing productivity or recovery, especially in the croplands and grasslands.

These critically unbalanced land productivity trends in African cropland and grasslands are particularly concerning given expected population growth. Forests in Africa still cover about 7 million km², 16 per cent affected by decreasing or stressed land productivity and 34 per cent of the tree covered land showing signs of increasing productivity. This may be a positive signal that programmes stimulating forest protection, afforestation, and tree planting for sustainable agro- and silvo-pastoral land use systems have made some progress in the last 10 to 15 years.
In Asia, croplands show relatively small proportions of declining productivity trends that are below global averages, with approximately 12 per cent. Nevertheless, this accounts for up to 1 million km² of croplands that appear to be affected. Some critical pressures potentially leading to decreasing land productivity at the ecosystem level may be masked by effects of the relatively recent changes towards more input-intensive agriculture in many Asian countries. Areas where accumulation of anthropogenic pressures exist are identified on the convergence of evidence maps below.

Rangelands are proportionally the most affected by declining land productivity trends (up to 20 per cent), greater than the proportion of increasing or recovering land productivity. This is most apparent in the belt of decreasing land productivity trends across the Central Asian region, which has undergone dramatic changes in land use after the foundation of independent states during the 1990s. In many cases, more sedentary forms of livestock production have led to overstocking and overgrazing of vulnerable rangeland systems while at the same time large-scale collective arable and livestock land use systems were abandoned. About 12 per cent of Asian forest lands show signs of persistent decline or instability in primary productivity while more than 35 per cent experience increasing trends, i.e., recovery. This is evident in around 2 million km², with large patches of cover emerging in Siberia and complex patterns of decreasing and increasing productivity in south and southeast Asia, which reflect the high dynamics of forest transformations in these regions.
Globally, **Australia/Oceania** shows the largest proportion of area under decreasing land productivity trends, which total approximately 37 per cent of vegetated land, clearly above the global average. This primarily reflects the situation on the Australian continent and holds throughout all mainland cover/land use classes; in all classes, areas with decreasing land productivity trends exceed those with increasing trends. This is a result of the specific climate conditions and recurrent drought situation of the Australian continental land mass during the observation period 1999-2013.

These trends are clearly visible on the map depicting an increase in affected areas along a pronounced gradient from East to West following the general aridity gradient of Australia. The northernmost part of Queensland falling in the humid tropical zone is also apparently affected by declining trends of primary productivity, which may be decoupled from the general gradient of aridity and drought. There is evidence that land cover has recovered after significant periods of rainfall in 2015.6

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**Figure 4.11: Land Productivity Dynamics map 1999 to 2013 for Australia/Oceania showing 5 classes of persistent land productivity trajectories during the observation period**

**Figure 4.12: Spatial extent of LPD classes in Australia/Oceania under selected LC/LU categories**

**Figure 4.13: Per cent distribution of LPD classes for 4 major LC/LU categories in Australia/Oceania**
In South America, all of the LC/LU classes were affected by negative land productivity trends, considerably above global averages, while at the same time the areas with increasing land productivity areas typically do not exceed those declining, remaining below global averages in this regard. One of the main anomalies of declining productivity trends on the global map is located in the vast semi-arid plain of the Dry Chaco in the border region between Argentina, Brazil, and Paraguay.

The spatial distribution of the declining productivity areas generally correlates with the rapid expansion of crop production and cattle ranching at the expense of ecologically high-value primary dry forests. The patterns of productivity decline or instability in the tropical rainforest areas are more diffuse. The north-eastern Brazilian dryland area shows the effect of severe drought conditions towards the end of the observation period. Long term effects of this anomaly, now visible as declining productivity, cannot be estimated yet.
In North America, declining productivity trends within the 4 LC/LU types are typically similar to or below global averages. Grasslands and rangelands appear to be the most affected where the extent of area with declining trends are estimated at 20-22 per cent in both classes, clearly greater than areas showing signs of increasing or recovering primary productivity.

Only 13 per cent of the croplands are characterized by declining trends or persistent instability, nevertheless approximately 500,000 km². The most prominent declining anomaly falls in the southern part of the semi-arid Great Plains in the border region between New Mexico, Texas, Oklahoma, and Kansas, where large areas are dedicated to input-intense, irrigated crops (e.g., cotton in northwest Texas) that depend primarily on fossil groundwater.
In Europe, declining productivity trends within the LC/LU classes are typically below global averages. However, being the continent with the relatively highest proportion of croplands, European farmland is proportionally the most affected when compared to the other land cover types considered. An estimated 18 per cent of the croplands may be subject to significant drivers leading to productivity declines, especially in the south of Eastern Europe where, similar to Central Asia, large-scale collective arable and livestock land use systems have been substantially transformed as a result of the economic crisis.

Some hotspots of declining land productivity in Western Europe, especially in the Mediterranean region, are characterized by agricultural intensification often intermingled with the rapid expansion of infrastructure and built-up areas into croplands. In many European croplands, the impacts of land and soil degradation on productivity may be masked by the sustained capacity to compensate for losses in soil fertility but at a significant cost to biodiversity and quality of freshwater resources.

When disaggregated and viewed by broad land cover/land use categories, the LPD allows for the identification of meaningful patterns of land transformations occurring at continental to national levels. Thus, LPD provides a first approximation and comparison of different regions or even countries according to their capacity to sustain primary productivity in land use systems. In order to substantiate this type of information in the context of underlying causes and drivers of land degradation, the WAD promotes the concept of convergence of evidence.
Global maps on convergence of key issues

Together with land use and environmental histories, a range of variables influences the occurrence and rate of land degradation, such as interest rates, livestock prices, and agricultural support policies. The progression of this change is guided by slow or fast variables. However, both the pathways towards degradation and the variable interactions that steer them are numerous, volatile, and generally unknown, making it difficult to model land degradation at a global scale. The physically-measurable outcomes that can be observed through the use of satellite data, such as LPD or ground observations (e.g., decreases in biomass, biodiversity, soil organic carbon, or increases in soil erosion or undesirable plant species), cannot be interpreted meaningfully without an understanding of the social and economic conditions at all scales considered.

Box 4.2: Developing global maps on convergence of evidence

To accommodate the complex interactions and dynamics that trigger land cover/use change, the World Atlas of Desertification (WAD) relies on the concept of "convergence of evidence": when multiple sources of evidence are in agreement, strong conclusions can be drawn even when none of the individual sources of evidence is significant on its own. Convergence maps are compiled by combining global datasets on key processes, using a reference period of 15–20 years. Combinations are made without prior assumptions in the absence of exact knowledge of land change processes at variable locations. Patterns indicate areas where substantial stress on land resource is to be expected.

The resulting convergence maps demonstrate one approach by which these data can be combined, viewed, and analyzed for multiple land use/land cover strata. Convergence is undertaken in two steps: (i) a global land cover/use stratification is compiled representing shares of cropland and rangeland, and tree cover in 2007 (other preliminary stratifications could be based on climate, soil, or ecosystem services, depending on the available data); and is partitioned into classes (unsupervised classification); and (ii) for each class, zonal or class statistics are calculated for each dataset or potential issue. The issues are reclassified as being above or below a statistically derived threshold, taking into account their expected effect in terms of land degradation (positive or negative). The resulting layers have values of 0 (no stress) and 1 (potential stress), and are summed together to provide the number of co-existing issues at any geographical position. The method is flexible and can be applied at all scales. Based on the literature, datasets relating to the various issues have been grouped as follows:

Related to the human environment
- changing population densities
- migration and urban sprawl

Related to land use
- agriculture expansion
- agriculture industrialization
- livestock density and practices
- deforestation, fragmentation, and fires

Related to the natural environment
- land productivity
- water availability and use
- soil condition
- changed aridity and drought

Global datasets are now available for most of these issues and the WAD analysis illustrates convergence based on 13 consistent and geographically continuous datasets on socio-economic and biophysical issues. As land degradation in itself is a process, dynamic datasets are ideally to be used, but only a limited number currently provide consistent and harmonized global coverage:

Dynamic data layers:
- Built-up area change (2000–2014)
- Land biomass productivity dynamics (1999–2013)
- Tree loss (2000–2014)

State data layers:
- Population density in 2015
- Gross national income per capita in 2015
- Area equipped for irrigation (2005)
- Nitrogen balance on landscape level (2000)
- Livestock density (2006)
- Fire occurrence (during period 2000 to 2013)
- High water stress (2010)
- Aridity (aridity index 1981 to 2000)
- Climate and vegetation trend anomalies (1982 to 2011)
Maps of the convergence of evidence show where human-environment land change processes are impacting croplands (Figure 4.23) and rangelands (Figure 4.24). They show distinct patterns suggesting areas under different levels of pressure; however, the higher or lower number of concurring issues does not necessarily imply a higher or lower impact or outcome in terms of land degradation. In cropland and rangeland where more potential pressures are present, more attention is generally required in terms of land management and further monitoring of the situation, even though the analysis does not mean that land degradation is currently underway everywhere. As much as possible, interpretation needs to take into account ancillary contextual knowledge and evidence. Paper maps are limited and cannot represent the full depth of data, therefore a digital portal is being developed that will allow for more complete data and information query.

**The state of land in the croplands**

The analysis shows that approximately 9 per cent (or 1.38 million km²) of the global area with more than 50 per cent of cropland suffers from potential pressure from 8 to 143 coinciding issues that trigger land change processes that are relevant to land degradation, with practically all occurring on drylands. When a number of related cropland issues combine with a decline in land productivity, this suggests that an observable transformation has happened or is underway. This is observed in 2 per cent of the area (0.3 million km²) and can be a good proxy for ongoing degradation in those areas. More than half or approximately 60 per cent (8.9 million km²) of the global area with more than 50 per cent of cropland experiences potential pressure from 4 to 7 concurrent issues that trigger land change processes that are relevant to land degradation, which are evenly distributed over drylands and non-drylands. On 12 per cent of the area (12.4 million km²), they concur with signs of decline in the land productivity. Just 2 per cent of global cropland, all on non-drylands, does not face any pressure from the 13 issues assessed. In areas where cropland covers 10 to 50% of the land, the proportion of the land that faces more than 8 of the 13 concurrent issues drops to 3 per cent (or 0.6 million km²) while 69 per cent (11.7 km²) of the area sustains 4 to 7 coinciding issues.
The main cropland areas facing multiple pressures include, but are not limited to:

- Asia including Indian and Pakistani croplands, agricultural expansion areas in northwest China, and hotspots in the Philippines and Java;
- southeast Australia and small areas in southwest Australia;
- sub-Saharan Africa including Burkina Faso, northern Nigeria, eastern Sudan, south Kenya, Malawi, and Zimbabwe;
- North Africa and the Middle East including northern Morocco, Egyptian Nile area, the Tigris-Euphrates region;
- intense agricultural areas in the Mediterranean and central Europe;
- Central Asia around the Aral sea and croplands in eastern Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan;
- hotspots in Latin America and the Caribbean, including the northeast Brazilian drylands, agriculture expansion areas in the Argentinean Chaco area, central Chile, southern Mexican croplands, and parts of Cuba and Haiti; and
- irrigated areas in the western USA.

The state of land in the rangelands

Approximately 5 per cent (0.5 million km$^2$) of global rangeland suffers from potential pressure from 8 to 13 concurrent issues that trigger land change processes that are relevant to land degradation, with practically all occurring on drylands. Approximately 52 per cent (13.1 million km$^2$) of global rangeland experiences potential pressure from 5 to 8 concurrent issues that trigger land change processes that are relevant to land degradation, more than two-thirds of this is on drylands. Again, only 2 per cent of rangelands, all on non-drylands, do not face pressures from any of these issues.

The main rangeland areas facing multiple pressures include, but are not limited to: India; Central Asia; China’s Inner Mongolia area; areas of eastern Australia; the fringes of the Sahel; eastern Africa and parts of southern Africa; southwest Madagascar; north-central Chile and southern Ecuador; central Mexico; and south-central USA.
Regional and national highlights

Middle East and Central Asia A fundamental issue in this area is the scarcity and management of water resources. Over 70 per cent of the global net permanent surface water loss occurred in the Middle East and Central Asia. Irrigation demands combined with intensive agriculture pose unsustainable pressure on the land resource. Livestock numbers remain high and productive pastureland is reduced or fragmented by population increase and agriculture expansion.

India Since the 1700s, high population density has been a major pressure throughout India. India hosts 18 per cent of the world population and 15 per cent of its livestock, but has only 2.4 per cent of the world’s land area. Since the 1960s, the portion of cropland available per person decreased three-fold, to 0.12 ha per person; 53 per cent of India is farmland, using an average of 157 kg/ha of fertilizer with more than 36 per cent under irrigation; annual freshwater withdrawal is one of the highest globally at 761 billion m³. This suggests a significant pressure on cropland. Land productivity dynamics, however, show a stable state during the last 15 years. Some areas, but not all, overlap with the detailed national assessment of ongoing degradation that is based on identification of biophysical processes observed by satellite data.

China Biomass land productivity status, observed by satellite from 1999-2014, is mapped as stable or increasing over most of China. However, in the Beijing-Hebei-Shandong area, dense population combined with intensive, mostly irrigated, agriculture is leading to water stress and poor land quality. The introduction of agriculture in marginal lands traditionally used for grazing sheep and cattle has caused erodible soil surfaces, a process known as “sandification,” in large areas of northern China, especially Inner Mongolia and western Xinjiang. In Inner Mongolia, government policies aiming to settle nomadic pastoralists and privatize collective grasslands have increased pressure on rangeland resulting in large-scale degradation. From 1980, the privatization of farmland and introduction of state incentives increased productivity in northern China, largely driven by groundwater irrigation and fertilizer use. Together with legal access regulations and restrictions, the expansion of cropland into environmentally-sensitive rangelands has been slowed, and moving dunes and sand sheets partially stabilized. However, this has been accompanied by the rapid depletion of groundwater resources where smallholder irrigation systems have increasingly been replaced by large-scale pivot irrigation schemes. These schemes tend to lower water tables and today many lakes and wetlands have disappeared as seen in satellite images.

Sahel In the past 50 years, an increase in sedentary human presence and activities, together with climatic variability, has caused major environmental changes in the semi-arid Sahelian zone. The accumulation of land change processes over vast stretches of the Sahel’s croplands is significant, considering that water resources are limited. Population is still growing, domestic food demands are increasing, and cropland resources are scarce and managed by smallholders with limited means and income. Cultivation is mainly rainfed (except in parts of Ethiopia) and, in general, on rather poor soils with medium or low soil organic matter. Smallholder systems are mainly low-input farming systems mixed with high livestock densities and increasing pressure from a growing sedentary population.
The degradation of arable lands has been a major concern for livelihoods and food security in the Sahel, but despite decades of intensive research on human–environmental systems, there is no overall consensus about the severity of land degradation. Earth observation data suggest an overall increase in vegetation greenness that can be confirmed by ground observations. However, it remains unclear if the observed positive trends provide an environmental improvement with positive effects on people’s livelihoods. While there is no widespread decrease in biomass productivity over the last 15 years, pockets of biomass decline can be seen.

Long-term assessments of biodiversity at finer scales highlight in some cases a negative trend in species diversity. The Sahel underlines the need to monitor land dynamics by combining long-term information from Earth observation with in situ observations that improve the understanding of the site specific impact of changes in land use and observed land cover trends.

Brazil/Argentina Input-intensive farming schemes on prime quality land, using large quantities of water and fertilizer, for short-term economic gain put land resources at risk by depleting and/or polluting soil and water. Deforestation with subsequent irrigated farming is, for instance, a threat to land resources in the vast Chaco area in Argentina, Paraguay, and Bolivia, where the native vegetation, particularly dry forests, is undergoing one of the highest deforestation rates in the world (see Figure 4.26). This is attributed to rapid agricultural expansion and intensification, especially for crop production (e.g., soy, maize) and cattle ranching.

Land transformations driven by cultivation have resulted in significant losses of biodiversity, landscape fragmentation, and a reduction in essential ecosystem services, which will likely lead to further land degradation. Monitoring is essential to identify biophysical, social, political, and economic drivers of changes and to develop land use planning and management policies that mitigate or reverse land degradation trends.

As in other countries where tropical and subtropical climate predominates, agriculture in Brazil was initially developed using traditional inversion tillage, based on farmers’ experiences acquired in temperate regions of the Northern Hemisphere. In this climate, the potential for land degradation arises from a combination of soils highly vulnerable to erosion, high pressure on land use, and intense rainfall when soils are most susceptible to erosion. Annual soil losses were estimated at 0.8 billion tons in areas under crops and pastures. Off-farm costs of erosion were estimated at USD 1.3 billion.

United States and Europe Input-intensive food production systems are driven by mechanization and high fertilizer applications that have made farmland dependent on continuous inputs of nutrients to ensure high yields. This is a risky balancing act, but favorable economic situations have so far made it possible to keep the land resource mostly in equilibrium. Local farming practices often result in water and wind erosion and other degradation phenomena that, however, cannot be captured universally at the scale of analysis with the current datasets available.

Figure 4.26: Between 1976 and 2012, 20 per cent of the whole ecoregion has been transformed, with an exponentially growing annual transformation rate in Paraguay. Areas colored from red (transformed in 1976) to yellow (transformed in 2013) show the extent and rapid pace of transformation of Dry Chaco into crops or pastures.
WHAT WE STAND TO LOSE: THE IMPORTANCE OF ECOSYSTEM SERVICES

Land condition, including its productivity, plays a key role in the potential of any given area to deliver multiple goods and services; it is clear that declines in LPD directly undermine their quantity and quality. The key role that a healthy land base plays in the delivery of ecosystem services is a fundamental tenet of the Global Land Outlook, yet the preceding analysis supports other studies that suggest that the quality of ecosystem services is in decline. To put this into perspective, in this section, we outline the main terrestrial ecosystem services, many of which we take for granted and which are now threatened by land degradation and/or declines in productivity.

Ecosystem services are the goods and services produced by or in conjunction with natural capital that directly and indirectly benefit humans. Land degradation and the subsequent loss of biodiversity leads to a reduction in many vital ecosystem services and thus greater food and water insecurity. The impacts of land degradation can be seen in lower crop yields, the reduced ability of agricultural systems to resist exotic pests and pathogens, and a general decline in the resilience of ecosystem functions. This has negative consequences for everyone, but generally impacts the vulnerable and poorest people most severely.

Ecosystem services are defined and categorized in several ways. For example, the Millennium Ecosystem Assessment suggests a simple typology to summarize the various services from natural capital, dividing them into supporting, provisioning, regulating, and cultural services. There are countless ecosystem services associated with thousands of species and ecological interactions. Some are only known to a small group of people who recognize their value, such as the medicinal benefits of a particular plant. As our societies become more homogeneous, much of this traditional ecological knowledge is being lost. Other ecosystem values are much more widely recognized, affecting whole communities, cities, countries, or acting at a global level. Some of the key land-based ecosystem services affected by land degradation are:

- Food security
- Water security
- Physical and mental health
- Disaster risk reduction
- Mitigating and adapting to climate change
- Cultural values
- Tourism including particularly ecotourism
- Raw materials

Many of these services are discussed in more detail in Part Two of this Outlook (e.g., food, water, energy, and climate) and only touched on briefly here; others are discussed in slightly greater detail. The concept of actively managing land resources to ensure the delivery of ecosystem services (i.e., benefits to humans) is increasingly being recognized, often under the umbrella term “nature-based solutions.”

1. Food security

Agriculture is dependent on a range of ecosystem services (see Chapter 7): supporting services like nutrient cycling and soil formation; and regulating services such as water purification, atmospheric regulation, and pollination. In addition, an estimated 150 million people rely directly on wild harvested food, including plants, fodder, game, and fish. In southern Africa, the value of wild resource consumption was estimated at USD 800 million per year in 2005. Ecosystem services contribute directly to food and nutritional security. Insects and birds provide pollination services that are vital for agriculture and currently estimated at having a total economic value of USD 160 billion annually, albeit under threat.

A wide range of genetic variation is needed for crop breeding to help species adapt to changing environmental conditions, including new pests and diseases. Agronomists draw on two sources for the genetic materials to help develop crop resilience and adaptability: the variation that exists in traditional varieties of crops, known as landraces, and that from closely-related wild species, known as crop wild relatives (CWR). Given the multitude of crop threats, both landraces and CWR are vital resources that will help ensure future food security. It was estimated some time ago that the introduction of new genes from CWRs contributed approximately USD 20 billion towards increased crop yields per year in the US alone and USD 115 billion worldwide. Yet these values are often under-recognized and many centers of crop diversity – places where a disproportionate number of the world’s crop species originated – are poorly conserved.
2. Water security

Resilient, functioning ecosystems play a critical role in water security, maintaining the quality and in some cases the quantity of water as well as regulating flows. Natural vegetation and healthy soil can help maintain water quality and in some circumstances increase the quantity of water available (see Chapter 8). Today most of the world’s population lives downstream of forested watersheds; these offer higher quality water supply than watersheds under alternative land uses, which tend to be more disturbed, have increased soil erosion, and are likely polluted by pesticides, fertilizers, or toxic waste.

Some ecosystems, such as cloud forests and the paramos vegetation of central South America absorb water droplets from clouds and increase net water flow. For example, the cloud forests of La Tigra National Park in Honduras provide more than 40 per cent of the water supply to Tegucigalpa, and in Ecuador 80 per cent of Quito’s population receive drinking water from two protected areas. Over a third of the world’s 100 largest cities draw a significant proportion of their drinking water from protected forests. In some cases, the effects may be felt hundreds or thousands of miles away from the ecosystem supplying the service. Water vapor from the Amazon travels thousands of miles south to provide rainfall for some of the richest agricultural area on the continent, which without these so-called “flying rivers” would be far more arid.

3. Physical and mental health

Natural ecosystems are increasingly recognized as important places that promote physical and mental health and well-being. Much of modern medicine is derived from or replicated synthetically from natural sources. Locally-collected traditional medicines are a major resource for primary health care needs in Asia, Latin America, and Africa, with more species of medicinal plants harvested than any other natural product. India and China harvest 90 per cent and 80 per cent respectively of their medicinal plants from the wild. Natural medicines are traded internationally, with a market estimated at over USD 50 billion annually. Wild species also provide raw material for pharmaceutical development; forests are particularly important sources of medicinal compounds and some companies pay for the right to explore in protected areas or other high biodiversity regions.

More fundamentally, spending time in nature is recognized as a critical factor in maintaining mental and physical health. It has been calculated that, in the United States, every USD 1 invested in physical activity leads to a saving in medical costs of USD 3.2, and people with access to attractive public spaces are likely to walk more. A growing number of countries are encouraging walkers, runners, and cyclists to use nature reserves as places to exercise, also known as the green gym concept. In Scotland, the health benefits of woodlands have been estimated at between USD 17.6–23.6 million per year (at 2006 prices) by helping to avoid premature deaths and morbidity through increased physical exercise, reduced air pollution, savings in mental health costs, and reduced absence from work. Natural environments help people recuperate from mental fatigue and can enhance the ability to recover from illness and injury, and cope with stress.

4. Disaster risk reduction

Natural and well-managed ecosystems are important for mitigating the impacts of extreme weather events and the progression into full-fledged disasters. The worst disasters, in terms of loss of human life and economic costs, are often in those places where natural defenses have been degraded or destroyed. Forests protect against floods, avalanches, typhoons and hurricanes, desertification, droughts, and landslides; wetlands can mitigate flooding; and coral reefs and mangroves help to protect against storm surges, tsunamis, and flooding.

Some key benefits of ecosystem services in terms of disaster risk reduction (DRR) are outlined in Table 4.2. Ecosystems that are healthy, functioning, and diverse are more resilient to these hazards. After the Asian tsunami of 2004, a study in Sri Lanka found that an area with a diverse landscape of sand, mangrove-fringed lagoons, coconut plantations, scrub forest, and home gardens, was much less seriously affected than areas that had been cleared of natural vegetation, as these ecosystems absorbed much of the energy of the waves. Conserving natural ecosystems is increasingly seen as a way of protecting against hazards from weather or severe events.
5. Climate change mitigation and adaptation

Healthy forests, grasslands, wetlands, and the soil and sedimentation beneath them hold carbon stocks and sequester atmospheric carbon, thus playing a key role in climate change mitigation (see Chapter 10): for example, wetlands hold approximately 33 per cent of the planet’s carbon. Conversely, their destruction and release of carbon is one of the factors leading to accelerating climate change. Carbon flux management is an important argument for persuading governments to conserve natural ecosystems, although current compensation schemes under Reducing Emissions from Deforestation and Forest Degradation (REDD+) are not usually enough on their own to make up for the values forgone in development. The climate mitigation values of natural ecosystems have also now been reflected in the role of protected areas.

Natural and well-managed ecosystems also help society to adapt to changing climate by maintaining the ecosystem services that are critical for survival: for example, protecting shorelines from rising seas, watersheds against flooding caused by heavy rain, and wild food sources often help communities to survive periods of emergency created by droughts or other weather events.

6. Cultural values

Natural ecosystems are not devoid of human influence. Many contain important archeological sites, historic buildings, pilgrimage routes, and traditional or sacred land uses. In the same way that iconic buildings, writers, and football teams can embody the heart of a nation or region, so too can heritage landscapes and their species. Natural areas often contain sacred sites or landscapes that are cherished by local communities, such as sacred groves, waterfalls, and mountains. Iconic national parks like Yellowstone, the Blue Mountains outside Sydney, the Lake District in the UK, and the Japanese Alps have inspired artists and writers for generations. On a more local scale, these natural habitats provide rich sources of ideas and energy for poets, painters, musicians, and other artists.

Box 4.3: Ecosystem services in the Mekong delta

Inland fisheries in the Mekong watershed yield an estimated 2 million tons of fish a year, for example contributing almost 80 per cent of animal protein for people in Cambodia. Rising human populations put these resources under threat. Protected areas help regulate off-take: 60 per cent of fish caught in the region come from Tonle Sap Lake, a UNESCO Man and Biosphere reserve, and the Ream National Park in Cambodia produces an estimated USD 1.2 million a year to local residents from fishing. In Lao PDR, Fish Conservation Zones are co-managed for fisheries; villagers report significant increases in stocks of over 50 fish species.

Ecosystem services are an important form of disaster risk reduction. Low-lying land and frequent storms open the Mekong delta to coastal damage, a situation likely to increase under climate change. Natural barriers such as mangroves and corals are increasingly valued. In Sri Lanka and Thailand, mangrove species were found to be effective barriers. The storm protection value of mangroves in Thailand has been estimated at USD 27,264-35,921 per hectare. Restoring mangroves can be a cost-effective option for improving coastal protection. A USD 1.1 million mangrove restoration scheme in northern Vietnam provided effective protection during typhoons and saved an estimated USD 7.3 million a year in sea dyke maintenance.

Poorer people still rely on collecting natural products from the forest. In Nam Et National Biodiversity Conservation Area in Lao PDR, 81 village communities depend on non-timber forest products with a value estimated at USD 1.88 million/year (30 per cent cash income and the rest subsistence), providing villagers in the region with a higher than average per capita income.
<table>
<thead>
<tr>
<th>Event</th>
<th>Role of Ecosystems</th>
</tr>
</thead>
</table>
| Flooding                     | Providing space for floodwaters to dissipate without causing major damage  
Absorbing the impacts of floods with natural vegetation                                                                 |
| Landslide                    | Stabilizing soil  
Packing snow  
Slowing earth, rock, and snow movement and limiting extent of damage                                                                                           |
| Storm surge, tsunamis, erosion | Corals and mangroves creating a natural barrier to the force of waves  
Roots stabilizing wetlands                                                                                               |
| Droughts and desertification | Reducing pressure (particularly grazing pressure) thus reducing desert formation  
Maintaining populations of drought resistant plants to serve as food during droughts                                                          |
| Fires                        | Limiting encroachment into the most fire-prone areas  
Maintaining traditional management systems that have controlled fire  
Protecting intact natural systems better able to withstand fire                                                                 |
| Hurricanes and typhoons      | Mitigating floods and landslides  
Buffering communities against impacts of storm events (e.g. storm surge)                                                                 |
| Earthquakes                  | Preventing or mitigating associated hazards including landslides and rock falls                                                                            |
7. Tourism

Tourism is a major source of income, generating USD 7.2 trillion (or 9.8 per cent of global GDP) and 2.84 million jobs (1 in 11 jobs) to the global economy in 2015.81 For many countries, natural or semi-natural landscapes have allowed the development of ecotourism, defined as “Responsible travel to natural areas that conserves the environment and improves the well-being of local people.”82 Global spending on ecotourism has been increasing by 20 per cent a year, about six times the industry-wide rate of growth.83 In Kenya, an estimated 80 per cent of the tourism market is centered on wildlife, with the overall tourism industry generating a third of the country’s foreign exchange earnings.84 Ecotourism depends on maintaining the quality of land resources; a degraded landscape or disappearing wildlife will no longer be attractive to visitors.

8. Raw materials

Many raw materials are collected from the wild, often in huge volumes, including timber, fuelwood, resin, rubber, grass, rattan, and minerals, with many communities dependent on these for their livelihoods. Examples are shown in Table 4.3 below.

### Estimating the value of natural ecosystems

While provisioning services, such as food, fuel, and fiber, have market values, the value of other benefits from natural ecosystems can be assessed at three levels: qualitative, quantitative, and monetary.85 Qualitative valuation focuses on non-numerical values, for example by describing the role of a particular mountain or landscape in defining local culture and identity. Quantitative indicators of value focus on numerical data, such as the number of visitors to or quantity of carbon stored in a national park. Monetary valuation reflects service values in monetary terms, for example, by calculating

### Table 4.3: Examples of materials collected from natural ecosystems.

<table>
<thead>
<tr>
<th>Typology</th>
<th>Value</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials for construction</td>
<td>Housing</td>
<td>In Mexico’s Yucatan peninsula, the value of palm thatch for roofing material is estimated at USD 137 million per year.86</td>
</tr>
<tr>
<td>or for physical protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including timber, reeds, bamboo, and grasses)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials for grazing livestock</td>
<td>Food</td>
<td>A significant percentage of India’s 471 million livestock are sustained by forest grazing or fodder collected from forests.86</td>
</tr>
<tr>
<td>(e.g. grasses, plants)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuels</td>
<td>Fuel</td>
<td>In developing nations, 2.4 billion people — more than a third of the world population — rely on wood or other biomass fuels for cooking and heating.87</td>
</tr>
<tr>
<td>(e.g. timber, fuelwood)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials for handicrafts</td>
<td>Income</td>
<td>In Namibia’s Caprivi Game Reserve, one of the few sources of income for local women is through the sale of palm baskets to tourists. By 2001, these producers had grown from 70 in the 1980s to more than 650.88</td>
</tr>
<tr>
<td>(including grasses, reeds, seeds, wood, bamboo, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials collected and sold</td>
<td>Income</td>
<td>Matsutake mushrooms collected from China’s Baimaxeshan Nature Reserve have helped to increase incomes 5 to 10-fold in 70 villages.89 A kilogram of these mushrooms can bring more income than the average annual wage in Yunnan Province.90</td>
</tr>
<tr>
<td>(either as such or as inputs into other products) to provide income (including corals, sea shells, rubber, cork, honey, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials with traditional, cultural, or spiritual value</td>
<td>Cultural/spiritual</td>
<td>In the Nordic region NTFPs such as mushrooms, herbs, and berries are extremely important culturally as well as economically.91</td>
</tr>
</tbody>
</table>
the revenue generated by fish caught in a river system or the value of carbon stored in a peatland assuming there are markets for these services. It is primarily the provisioning services that can be captured through monetary indicators. Therefore, a comprehensive assessment of benefits is likely to build on a combination of all three.

An estimate for the total global ecosystem services in 2011 was USD 125-145 trillion per year. The challenge is how to incorporate these values in decision-making: for an individual land owner or someone using a natural resource, it is often more profitable in the short term to degrade the resource even though the cost to the wider society is much greater. Payment for Ecosystem Service (PES) schemes is an attempt to address these issues by making direct payments to those who maintain and restore ecosystem services. How these values benefit the poorest people is a more complex question and depends on issues such as governance quality, rule of law, degree of corruption, and the willingness of decision-makers to support poverty reduction programmes.

**Box 4.4: Assessing the value of national parks systems in Eastern Europe**

In the Dinaric Arc region of Europe (the countries of former Yugoslavia and Albania), an assessment was carried out in 2013 and 2014, using a standardized methodology, of ecosystem services in all the national parks in the region. Workshops provided an insight into local cultures and traditions and raised awareness on the range of benefits provided by the park. Some clear patterns emerged across the region of how protected areas can better promote conservation, protect local culture, and develop sustainable funding strategies: in 96 per cent of protected areas, stakeholders receive economic benefits from tourism, and commercial water use has a major economic value in over half, while 60 per cent of protected areas have local food values. There is potential in developing branding for local/regional products from protected areas (e.g. honey, mushrooms, medicinal plants, cheese). Protected areas were a major employer in regions that had suffered rural decline, making their future important to local politicians. A bottom-up assessment system, involving over a thousand people in 58 national parks, provides clear information about the values of ecosystem services, even if many of these had not been calculated in economic terms.

**CONCLUSION**

Maintaining or improving the productive capacity of land and its associated resources requires us to maintain and surpass a position of “no net loss” of land quality. This is a matter of preserving or enhancing the ability of soil, water, and biodiversity to support the necessary ecosystem functions and services to meet the demands of today and the needs of the future.

More sustainable management of land resources can help close yield gaps, increase resilience to stress and shocks, and thus support human health, well-being, and security in the long term. The WAD provides a useful global overview of status and trends in the condition of our land resources as well as the potential human impacts. By identifying those areas under stress, decision-makers can be empowered to take remedial actions and create a supportive environment for stakeholders to do the same.
REFERENCES
