Food and Agriculture Organization of the United Nations

Trees, forests and land use in drylands

The first global assessment

PRELIMINARY FINDINGS

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Food and Agriculture Organization of the United Nations (FAO)
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1

Trees, forests and land use in drylands: why?

Drylands cover about 41 percent of the Earth's land surface and are characterized by a scarcity of water (Box 1 contains a full definition). About 90 percent of the estimated 2 billion people living in drylands are in developing countries (Millennium Ecosystem Assessment, 2005). The majority of these people depend on forests and other wooded lands, grasslands and trees on farms to meet basic needs for food, medicines, shelter, cooking, heating, wood, and fodder for livestock, and for income.

Trees and forests in drylands generate a wealth of environmental services; for example, they provide habitats for biodiversity, protect against water and wind erosion and desertification, help water infiltrate soils, and contribute to soil fertility. They also help increase the resilience of landscapes and communities in the face of global change (FAO, 2015).

Life in the drylands is precarious, and the socioeconomic status of people in drylands is significantly lower than that of people in many other areas. Water availability in drylands, already (on average) one-third below the threshold for minimum human well-being and sustainable development, is expected to decline further due to changes in climate and land use (Millennium Ecosystem Assessment, 2005). Poor people living in areas remote from public services and markets and dependent on marginal natural resource bases will be most vulnerable to food shortages (World Food Programme and Overseas Development Institute, 2015). Challenges such as land degradation and desertification, combined with drought, hunger and violence, are already leading to forced migration in dryland regions in Africa and western Asia.

Urgent action is needed, therefore, to improve the management and restoration of drylands. Such action requires a comprehensive understanding of

BOX 1

What are drylands?

The United Nations (UNEP, 1992; UN Environment Management Group, 2011) defines drylands as lands where the ratio of annual precipitation and mean annual potential evapotranspiration, also known as the aridity index (see formula below), is less than 0.65. Under this definition, the world's drylands cover about 6.1 billion hectares – an area more than twice the size of Africa.

Aridity index (AI) = MAP/MAE

Where MAP = mean annual precipitation and MAE = mean annual potential evapotranspiration

The global drylands can be divided into the following four zones based on the aridity index:

1) hyperarid (AI <0.05)

2) arid ($0.05 \leq$ AI <0.2)

3) semiarid ($0.2 \leq$ AI <0.5)

4) dry subhumid ($0.5 \leq$ AI <0.65).

Figure 1 presents a global map of the drylands, showing the four aridity zones. It also shows areas defined as "presumed drylands", which were not included in the Global Drylands Assessment (UNEP-WCMC, 2007).

The dry subhumid zone – the least-dry of the four zones – accounts for 22 percent of the total drylands area. Major components of this zone are the Sudanian savanna, forests and grasslands in South America, the tree steppes of eastern Europe and southern Siberia, and the Canadian prairie. Most dryland forests occur in this zone, as do some large, irrigated, intensively farmed areas along perennial rivers.

At the other extreme, the hyperarid zone is the driest zone, constituting 16 percent of the total drylands area. Deserts dominate this zone – the Sahara alone accounts for 45 percent of it, and the Arabian Desert is another large component.

The remaining drylands are made up of the semiarid and arid zones, at 37 percent and 25 percent, respectively, of the total drylands area. The concepts of aridity zones and land-use categories (described later in the text) were used in the Assessment to help encompass the complexity and variability of this very large area of land.

the complexity, status and roles of drylands, as well as context-specific approaches tailored to the unique conditions of drylands. But dryland forests and other ecosystems have not attracted the same level of interest and investment as other ecosystems, such as humid tropical forests. Tree cover and land use in drylands are poorly known, even though recent studies have indicated the need to restore drylands to cope with the effects of drought, desertification, land degradation and climate change.

BOX 2

The Rome Promise

FAO organized the first Drylands Monitoring Week in January 2015 in collaboration with the World Resources Institute, the International Union for Conservation of Nature and the Global Environment Facility. The Week was supported financially by the European Union within the framework of the African, Caribbean and Pacific Group of States (ACP) Action Against Desertification[1] initiative in support of the Great Green Wall and south–south cooperation in ACP countries.

The Week, which had the theme "monitoring and assessment of drylands: forests, rangelands, trees and agrosilvopastoral systems", gathered more than 60 experts to discuss the gap between the need for and current state of drylands monitoring; opportunities for filling this gap; and case studies of monitoring tools in drylands. The Week produced the Rome Promise on Monitoring and Assessment of Drylands for Sustainable Management and Restoration[2], which aims to advance the monitoring and assessment of drylands, including by increasing the understanding of users, communicating the value and importance of monitoring to relevant stakeholders, and developing a dynamic roadmap for collaborative action.

One of the main actions defined in the roadmap is to undertake the first global drylands assessment using the Collect Earth tool, which was presented during the first Drylands Monitoring Week.

[1] www.fao.org/in-action/action-against-desertification
[2] www.fao.org/dryland-forestry/monitoring-and-assessment/the-rome-promise

At its 22nd session in 2014, the FAO Committee on Forestry (COFO) called for greater action on, and investment in, the assessment, monitoring, sustainable management and restoration of drylands. It requested FAO to undertake a global assessment of the extent and status of dryland forests, rangelands and agrosilvopastoral systems, with a view to better prioritizing and targeting the investments needed for dryland restoration and management.

As part of its response to this request, FAO organized the first Drylands Monitoring Week in January 2015[3], which concluded with the adoption of the Rome Promise and a roadmap outlining the next steps for advancing the assessment and monitoring of drylands globally (Box 2).

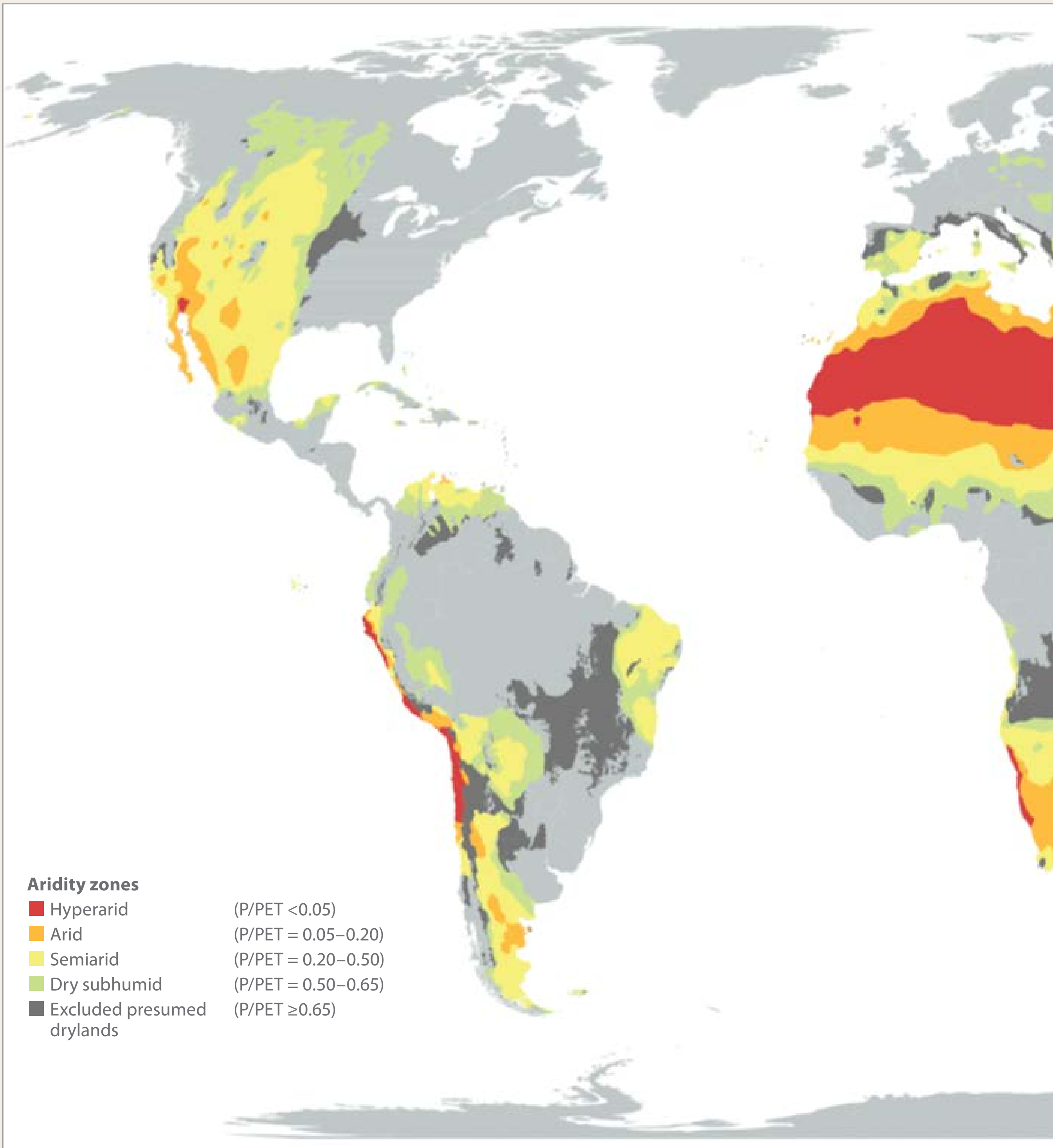
[3] www.fao.org/dryland-forestry/monitoring-and-assessment/dryland-monitoring-weeks/dryland-monitoring-week-2015

THIS DOCUMENT

This document presents preliminary results of the first global assessment of trees, forests and land use in drylands (referred to hereafter as the Global Drylands Assessment or simply the Assessment). The Assessment is a response by FAO and partners to COFO's request for a drylands assessment and to the Rome Promise. It benefits from earlier work, including by UNEP-WCMC (2007), Miles *et al.* (2006) and Sorensen (2007). The Assessment covers the four aridity zones described in Box 1 but does not include presumed drylands.[4] The results presented here are subject to revision and completion in a full report, to be published following field measurements and further analysis.

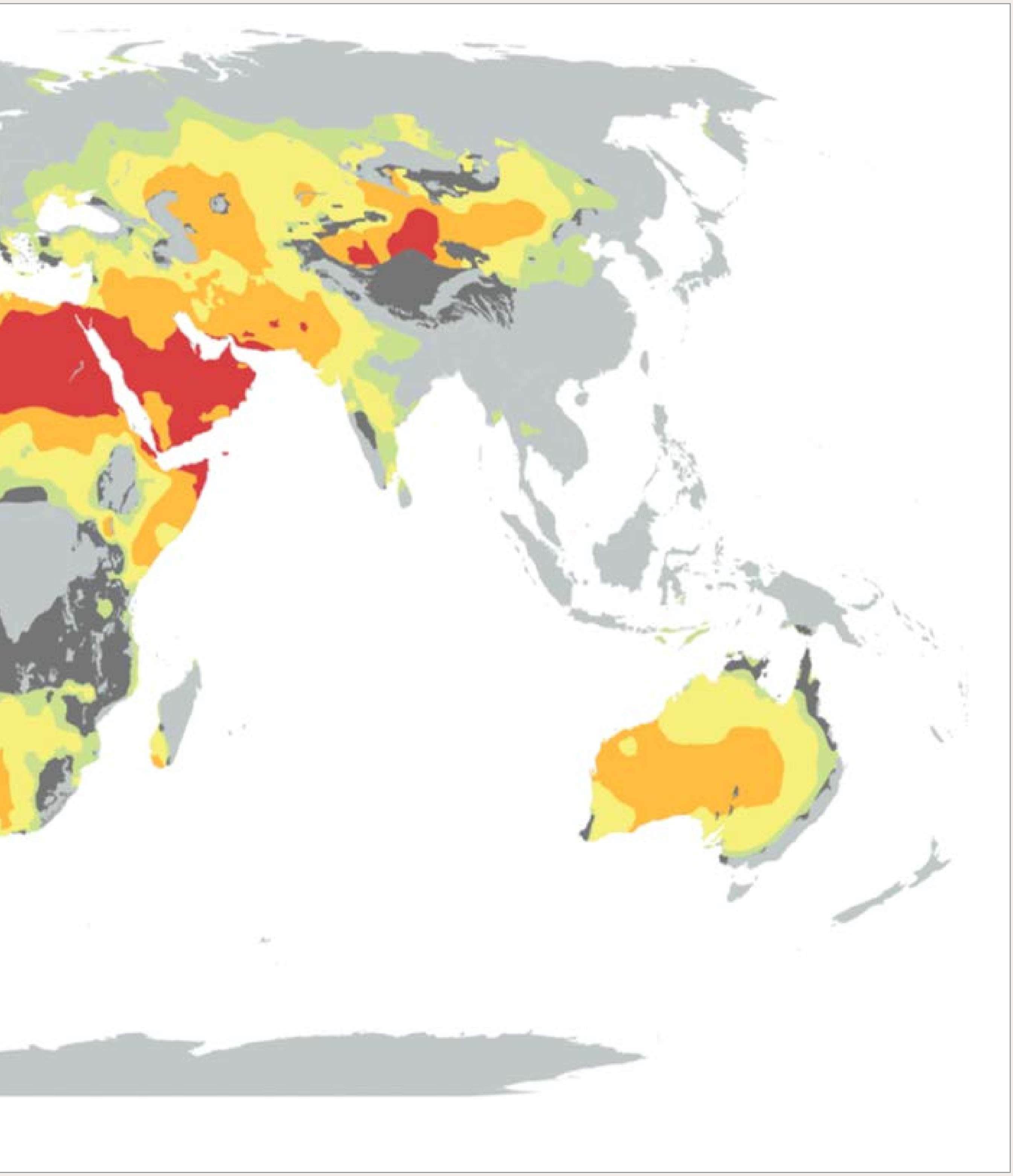
[4] Presumed drylands are areas with dryland features but an aridity index equal to or higher than 0.65 (UNEP-WCMC, 2007).

Figure 1. *The world's drylands*



Note: P = precipitation and PET = potential evapotranspiration.

Source: UNEP-WCMC (2007)



2

Methodology

The Global Drylands Assessment is a thematic study complementing the FAO Global Forest Resources Assessment, from which it differs in both scope and method. No individual country reported data to the Assessment, and no official country information has been used. Instead, the Global Drylands Assessment is based on the visual interpretation of satellite images in publicly available repositories (such as Google Earth Engine and Bing Maps), and it focuses solely on drylands. The results, therefore, are reported at the global and regional levels, not the country level.

More than 200 experts with knowledge of the land and land uses in specific dryland regions conducted the interpretation using an Open Foris software tool called Collect Earth (Box 3). The interpretation was made in the second half of 2015 in regionally focused workshops convened by FAO in collaboration with partner organizations.

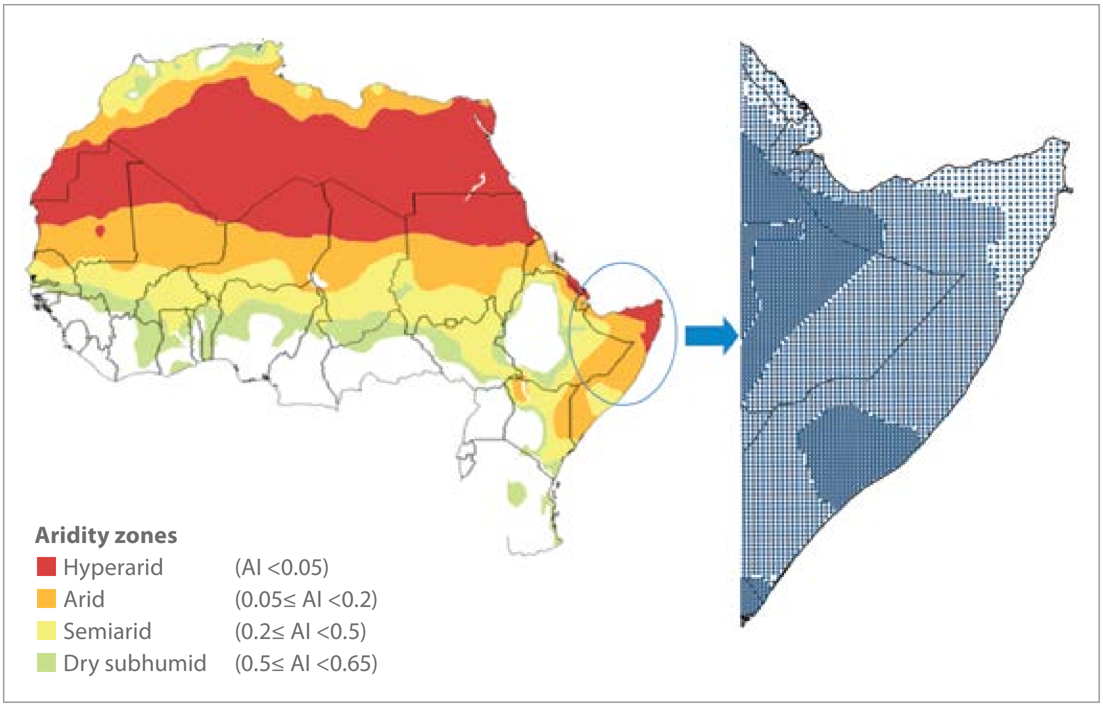
SAMPLING DESIGN

The Assessment draws on information from 213 795 sample plots in the world's drylands. Each plot measured 70 x 70 m (approximately 0.5 hectares), a size corresponding to the smallest patch that qualifies as forest according to the forest definition used by the FAO Global Forest Resources Assessment.[5]

In locating sample plots in a grid across the drylands, each aridity zone was treated as an independent stratum. The dry subhumid and semiarid zones were sampled at a higher intensity than the arid and hyperarid zones because the probability of finding trees is lower in areas with higher aridity indices (Figure 2). The relative sampling intensity assigned to each aridity zone was as follows: hyperarid = 0.5; arid = 1; and semiarid and dry subhumid = 1.5. That is, the sampling intensity in the hyperarid zone was one-third that in the semiarid and dry subhumid zones.

[5] That is, the FAO definition of forest specifies, "land spanning more than 0.5 hectares …". See the full definition in Table 1.

Figure 2. *Illustration of sampling intensity, by aridity zone*



The sampling error for the estimate of the total area of forest land (as defined by the Intergovernmental Panel on Climate Change – Table 1) for all drylands is about ±1 percent. A comprehensive analysis of the uncertainty in other estimates, including sampling error, will be conducted during the refining of preliminary results.

DATA SOURCES

Sample-plot data were collected from online libraries of satellite images using Collect Earth. Typically, each plot was overlaid on several images available through Google Earth Engine and Bing Maps. Landsat (resolution = 30 m) imagery was available for all plots, and 89 percent of plots were also covered by higher-resolution images, including more than half in images from Digital Globe with a spatial resolution finer than 1 m (Figure 3). The proportion of satellite image types was similar for all land-use categories. The visual interpretation was facilitated by temporal profiles of interannual vegetation indices, which were derived from lower-resolution satellite data (ground resolution = 30–250 m).

Figure 3. *Distribution of sample plots, by highest-resolution source of data*

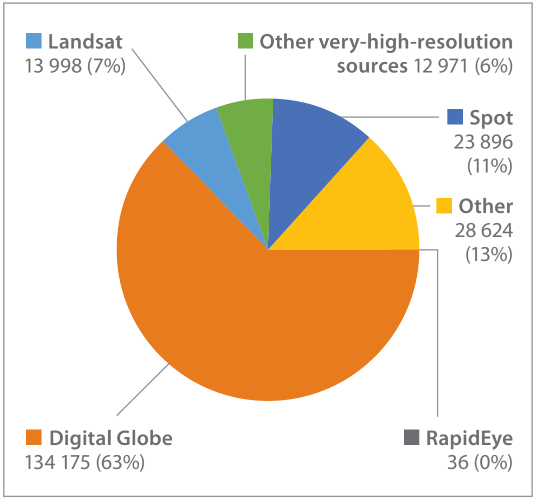


Table 1. *Land-use categories of the Intergovernmental Panel on Climate Change*

CATEGORY	DESCRIPTION
Forest land	Includes all land with woody vegetation consistent with thresholds used to define forest land in national greenhouse-gas inventories. It also includes systems with a vegetation structure that currently falls below, but *in situ* could potentially reach, the threshold values used by a country to define the forest land category. *For this assessment, the thresholds used are those defined by the FAO Global Forest Resources Assessment definition of forest: "land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use"*
Cropland	Includes cropped land, including rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the forest land category
Grassland	Includes rangelands and pasture land not considered cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the forest land category. The category also includes all grasslands, from wild lands to recreational areas, as well as agricultural and silvopastoral systems, consistent with national definitions
Wetlands	Includes areas of peat extraction and land covered or saturated by water for all or part of the year (e.g. peatlands) and that does not fall into the forest land, cropland, grassland or settlement categories. It includes reservoirs as a managed subdivision and natural rivers and lakes as unmanaged subdivisions
Settlements	Includes all developed land, including transportation infrastructure and human settlements of any size, unless already included in other categories
Other land	Includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. If data are available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g. into unmanaged forest lands, unmanaged grasslands, and unmanaged wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above

Source: IPCC (2006)

DATA COLLECTION

The design of the Global Drylands Assessment benefited from consultation with drylands experts engaged in the Action Against Desertification initiative and the Rome Promise Collaborative Network (a network of partner organizations and experts). The survey was set up using Collect, a software tool in the Open Foris suite and then embedded in Collect Earth (Box 3). For each sample plot, data on more than 70 characteristics were collected and recorded for the most recent point in time for which satellite images were available. The variables were selected to characterize land cover, land use, land-use change and other significant land dynamics (such as desertification and greening) along with biophysical indicators (Box 4). In addition, land-use data were collected for the year 2000, the first year for which consistent global coverage of satellite data (Landsat 7) is available.

The simultaneous use of low-resolution and very-high-resolution satellite imagery facilitated the detection of land use and land-use change. For some

BOX 3

Collect Earth: a tool in the Open Foris suite

Open Foris is a suite of free, open-source software tools developed by the FAO Forestry Department to facilitate flexible and efficient data collection, analysis and reporting.

Collect Earth is a tool in the Open Foris suite developed in cooperation with Google Earth Outreach. Collect Earth communicates with Google Earth Engine to facilitate access to freely available satellite images from Earth Engine, and it can also connect to other services, such as Bing Maps. By submitting pre-programmed scripts to Google Earth Engine Playground, Collect Earth can visualize reflectance values and user-defined indices such as the Normalized Difference Vegetation Index, the Normalized Difference Water Index and the Enhanced Vegetation Index based on Landsat and MODIS satellite images. Collect Earth enables operators to visually assess pre-defined sample locations and to store the results directly in a database by completing an onscreen data-collection form.

For the Global Drylands Assessment, the data-collection form was structured to guide operators in the survey process, starting with the identification and quantification of simple land elements (e.g. trees and shrubs) and the identification of the main land-use categories. The approach enabled operators to report on impacts and disturbances over the reference period whenever these could be detected in plots.

Collect Earth projected each sample plot as a frame containing a grid of 49 control points, enabling users to make precise estimates of the proportion of plots taken up by trees, shrubs and other land elements. In the visual interpretation, each expert used his or her knowledge of the location and information provided by remote sensing data to support the survey process.

land elements (e.g. distinguishing between trees and shrubs), satellite data and local knowledge were sometimes insufficient, and a decision rule based on the crown diameter of trees and shrubs was therefore adopted. Elements with a crown diameter larger than 3 m were considered trees; elements with smaller diameters were considered shrubs. Collect Earth does not allow the direct measurement of tree height; therefore, tree shadows, where visible, were used in addition to the crown-diameter threshold to determine whether elements were sufficiently tall (i.e. 5 m or taller, consistent with the definition of forests used in the Assessment) to be considered trees.

Land use was assessed based on the six land-use categories of the Intergovernmental Panel on Climate Change (IPCC, 2006) – forest, cropland, grassland, wetlands, settlements, and other land. The Assessment adopted the forest definition used in the FAO Global Forest Resources Assessment (FAO, 2015) (Table 1).

A predominant land use was assigned to each sample plot based on the presence of key land-use indicators interpreted according to a hierarchical rule (Box 5). For example, a sample plot with more than 10 percent crown cover was not classified as forest unless the prevailing land use could be identified as forest. Only one land use could be assigned per sample plot.

THE IMPLEMENTATION APPROACH

The assessment was conducted as a series of regionally focused training and data-collection workshops, organized in collaboration with universities, research institutes, governments and non-governmental organizations worldwide (Table 2). Such workshops were conducted in Argentina, Australia, Brazil, Ethiopia, Italy, Kyrgyzstan, Niger, Tunisia, Turkey, Spain, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

In the first week of each workshop, participants were trained by FAO experts in the use of Collect

TABLE 2. *Regions, partner institutions and participants involved in the first Global Drylands Assessment*

REGION/ SUBREGION	PARTNER INSTITUTION	NO. OF PARTICIPANTS	FOCAL POINT
Southern Africa	Department of Environmental Biology, Sapienza University of Rome (Rome, Italy)	20	Fabio Attorre
Northern Africa	General Directorate of Forests in Tunisia (Tunis, Tunisia)	20	Aloui Kamel
Southwest Asia	School of Geography, Faculty of Environment, Leeds University (Leeds, UK)	20	Alan Grainger
Sahel	CILSS / AGRHYMET Regional Centre (Niamey, Niger)	20	Bako Mamane
North America	United States Department of Agriculture, United States Forest Service and RS/GS Laboratory, Utah State University (Utah, USA)	6	Doug Ramsey and Paul Patterson
Europe and Russian Federation	Department of Forest Engineering, Technical University of Madrid (Madrid, Spain)	20	Luis Gonzaga
Horn of Africa	World Resources Institute (Washington, DC, USA)	20	Fred Stolle
Middle East	International Forest Fire Education Centre, Turkey General Directorate of Forestry (Antalya, Turkey)	20	Caglar Bassullu
Central Asia	Department of Forest and Hunting Inventory of Kyrgyzstan (Bishkek, Kyrgyzstan)	20	Venera Surappaeva
Western South America	Argentine Dryland Research Institute (IADIZA) as Executive Unit of the National Council for Scientific and Technical Research (CONICET) and part of the Mendoza Center for Science and Technology (CCT Mendoza) (Mendoza, Argentina)	5	Elena Maria Abrahm
Eastern South America	National Institute for the Semi-Arid (Campina Grande, Brazil)	20	Ignacio Salcedo
Oceania	Terrestrial Ecosystem Research Network and School of Earth and Environmental Sciences, Faculty of Science, University of Adelaide (Adelaide, Australia)	20	Ben Sparrow
Total	**15 partner institutions**	**211**	

BOX 4

Indicative list of collected data

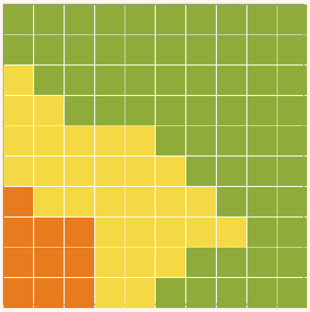
- Plot identification: number; location; operator; time when saved
- Land use: category and accuracy of interpretation; subcategory and accuracy; initial land use; year of change
- Remote sensing data source: satellite; date
- Plot elements: farming method; soil type; climate zone; elevation; slope; aspect; dryland category; country; FAO Global Forest Resources Assessment class; dryland region; calculated elevation range; calculated aspect; calculated slope; realm; biome; ecoregion; FAO ecozone
- Type and cover of 1) vegetation elements: tree, shrub, palm, bamboo, crop; 2) infrastructure elements: house, other buildings, paved road, unpaved road; 3) water bodies: lake, river; 4) other elements: rock, bare soil, other
- Desertification trend
- Disturbances: impact type and grade; continual or year; accuracy
- Land class: main; sub; confidence
- Trees: many (if more than 30), or individually counted
- Shrubs: many (if more than 30), or individually counted
- Length of linear features: vegetation; paved road; unpaved road; path

BOX 5

Hierarchical rule for classifying predominant land use

The identification of the predominant land use in sample plots according to the categories of the Intergovernmental Panel on Climate Change is not always straightforward, and a single plot may be subject to several land uses. In the Global Drylands Assessment, a hierarchical rule was applied that was consistent with the requirements of the United Nations Framework Convention on Climate Change. The rule is summarized below, and Martinez and Mollicone (2012) provide a more detailed explanation.

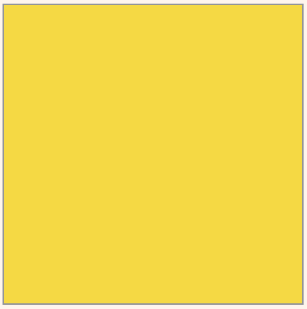
To determine and assign the predominant land use in a sample plot that contains several types of land use (A in the figure below), the various land uses are considered in a predetermined order of priority (B). Highest in this hierarchy is settlement: if this land use covers more than 20 percent of the sample plot, it is considered predominant, no matter what other land uses are present. If the settlement land use covers less than 20 percent, cropland, the second item in the list, is treated in the same way: it is considered predominant if it covers more than 20 percent of the plot. If not, forest land (the third item in the list) is treated in the same way, and so on. In the figure, settlement does not reach 20 percent, but cropland does. The predominant land use is therefore considered to be cropland (C), even though more than 50 percent of the sample plot is covered by grassland.



A

Hierarchy	Threshold (%)
1 Settlement	20
2 Cropland	20
3 Forest land	20
4 Grassland	20
5 Wetland	20
6 Other land	20

B



C

Earth. In the second week, participants collected data for pre-defined sample sites. The purpose of this approach was to ensure that the interpretation was done consistently in all regions while also benefiting from the regional and local knowledge of participants.

DATA PROCESSING

A grid of geographically referenced sample plots was prepared by FAO and divided into geographically defined subsets – one for each regional training and data-collection workshop. For each sample plot, the expert conducting the assessment saved the data directly to an electronic database. FAO collated the data in a unified database and cleansed them (both automatically and manually) based on the results of an automatic consistency check. The analysis was conducted using Saiku Analytics, a web-based software that enables users to visualize and analyse data using a simple drag-and-drop interface. The uncertainly analysis was performed in Microsoft Excel.

3

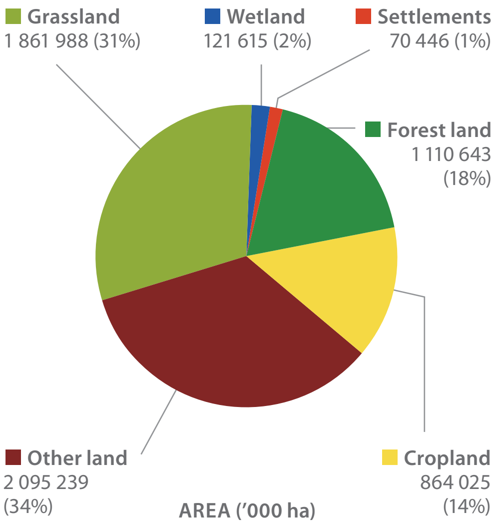
Results

LAND USE IN DRYLANDS

▶ *Nearly one-third of drylands is covered by grasslands*

Drylands cover 6.1 billion hectares, an area more than twice the size of Africa. Grassland is the second most common land use (31 percent), followed by forest (18 percent) and cropland (14 percent); the category other land (such as bare soil and rock) comprises 34 percent of the global drylands (Figure 4).

Figure 4. *Land-use distribution in drylands, by area*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

▶ *Land use is highly dependent on aridity*

The distribution of land use varies substantially by aridity zone. Almost the entire hyperarid zone (92 percent) is classified as other land. This is because most of it is desert, characterized by sandy and rocky landscapes and extremely hot, dry climates.

The proportion of other land decreases with decreasing aridity: it is 48 percent in the arid zone, 17 percent in the semiarid zone and 4 percent in the dry subhumid zone.

Croplands exhibit the opposite distribution pattern: they make up 25 percent of the dry subhumid zone but only 2 percent of the hyperarid zone. Despite this low percentage, croplands play crucial roles in the driest areas by providing food for people living in those harsh environments. Croplands in the hyperarid zone are found almost exclusively near rivers – such as the Nile in Egypt – and other water bodies.

The proportion of grasslands increases from 5 percent in the hyperarid zone, to 39 percent in the arid zone, to 41 percent in the semiarid zone. Grasslands constitute only 22 percent of the dry subhumid zone, however, where other land uses such as forests and croplands are predominant (Table 3, Figure 5).

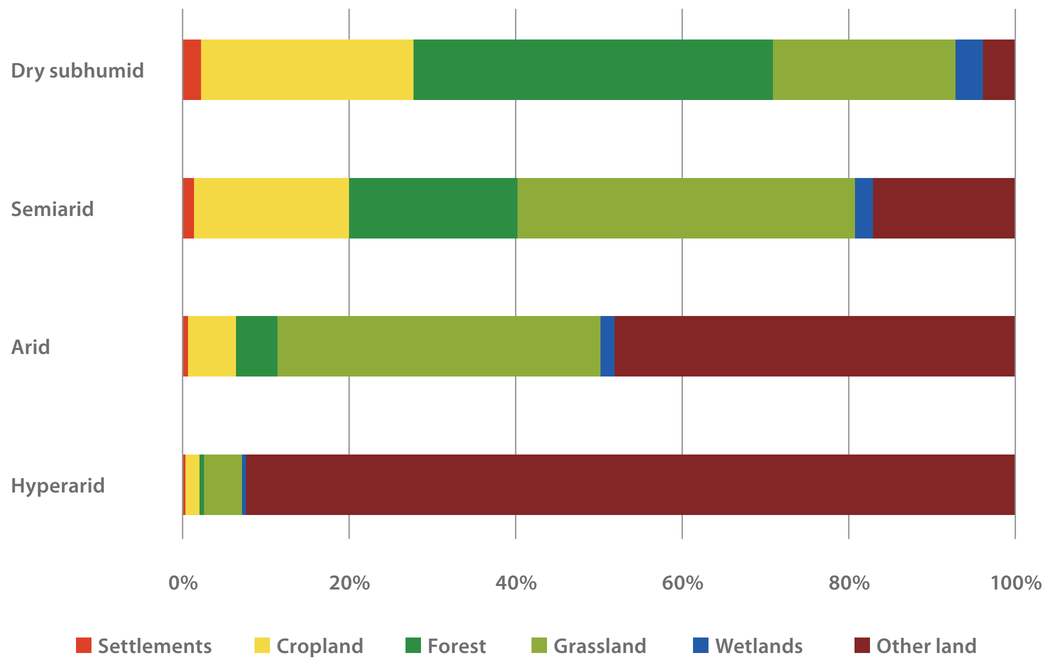
Drylands occur at all elevations, from sea level to above 2 000 m, but 80 percent of all drylands are found below 500 m. Most wetlands are at very low elevations and croplands, too, are most prevalent at lower altitudes – they cover a larger area than forests up to 200 m, but forests account for a larger area than croplands above 200 m. Grasslands and other lands occur at all elevations but are proportionally more prominent at higher elevations. All land uses are represented at all altitudes (Figure 6).

Table 3. *Land-use distribution, by aridity zone*

CATEGORY	HYPERARID		ARID		SEMIARID		DRY SUBHUMID		TOTAL	
	Area ('000 ha)	Share of total (%)	Area ('000 ha)	Share of total (%)	Area ('000 ha)	Share of total (%)	Area ('000 ha)	Share of total (%)	Area ('000 ha)	Share of total (%)
Forest	5 284	1	77 560	5	458 016	20	569 781	43	1 110 641	18
Cropland	16 293	2	89 928	6	420 684	19	337 119	26	864 024	14
Other land	904 220	92	753 461	48	386 666	17	50 892	4	2 095 239	34
Grassland	44 264	5	608 603	39	919 054	41	290 067	22	1 861 988	30
Wetlands	4 905	1	25 660	2	47 798	2	43 252	3	121 615	2
Settlements	2 880	0	9 283	1	29 829	1	28 454	2	70 446	1
Total	**977 846**	**100**	**1 564 495**	**100**	**2 262 047**	**100**	**1 319 565**	**100**	**6 123 953**	**100**

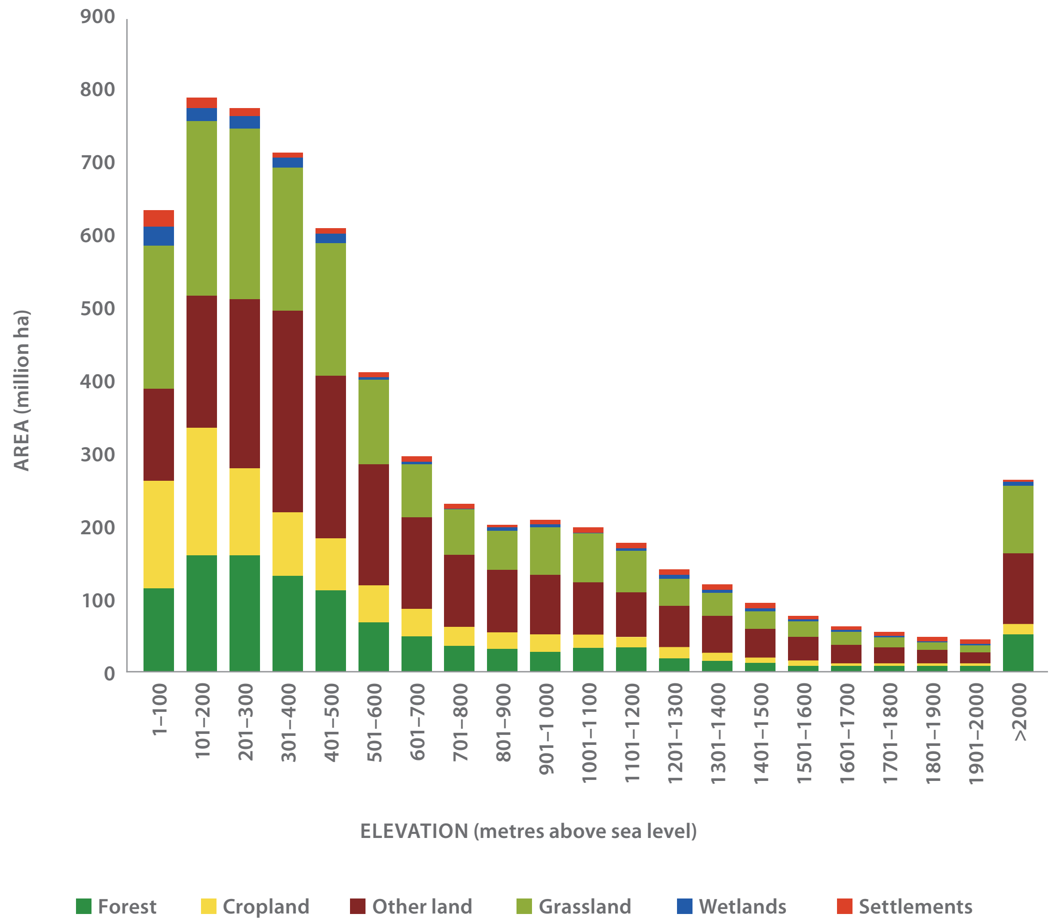
Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Figure 5. *Land-use distribution (proportion of total area), by aridity*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Figure 6. *Land-use distribution, by elevation*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

FORESTS IN DRYLANDS

▶ *Drylands contain 1.1 billion hectares of forest*

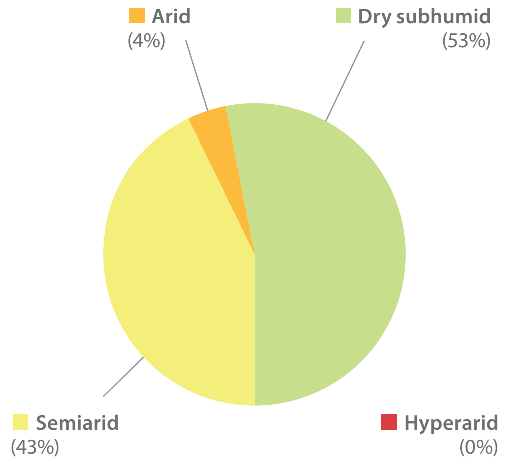
According to the Assessment, the world's drylands contain 1.11 billion hectares of forest. More than half (53 percent; 566 million hectares) are in the dry subhumid zone, mostly in the northeast of southern Africa and the western (pre-Andean) inland of South America. At the other extreme, the hyperarid zone contains only a tiny proportion (0.3 percent) of the total forest area in drylands, mostly in the northwest of South America and the Horn of Africa (Figure 7).

▶ *Two-thirds of dryland forests are dense forests*

Crown cover density is the proportion of land area covered by tree canopies when viewed from above. About two-thirds of dryland forests (67 percent; 742 million hectares) can be considered closed forests because they have a crown cover density of more than 40 percent. More than half these forests (most of which are in Europe and South America) have a crown cover of 90 percent or more.

Almost one-third of dryland forests (31 percent; 348 million hectares) are open forests with a crown cover of 10–40 percent. A small proportion (2 percent) of dryland forests has a crown cover of less than 10 percent (i.e. below the threshold of the FAO Global Forest Resources Assessment definition of forest); mostly these are temporarily unstocked areas in which forest is the prevailing land use (Figure 8).

Figure 7. *Forest distribution as a proportion of total forest area, by aridity zone*

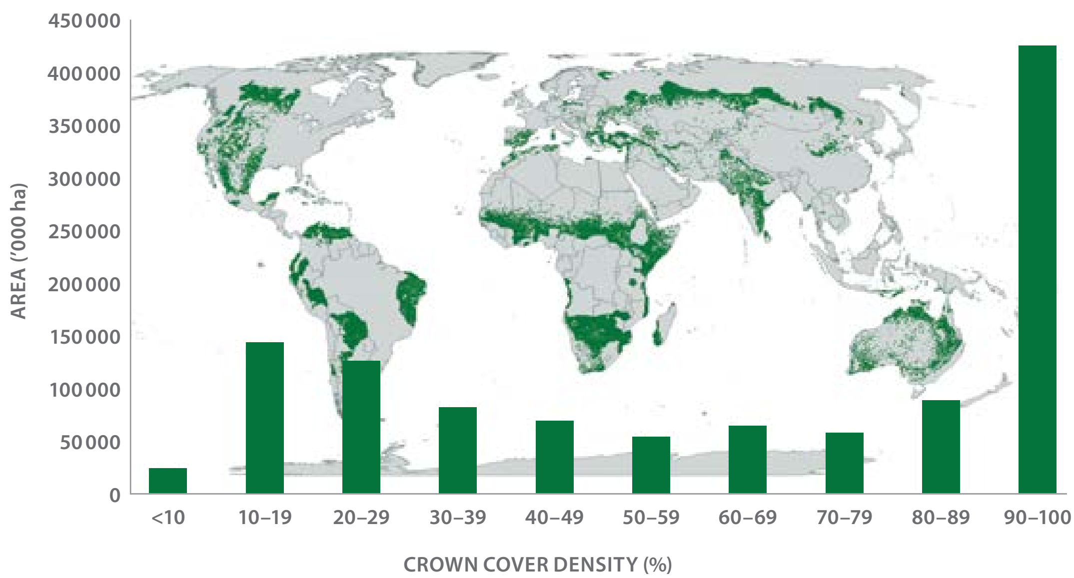


Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

TREES IN DRYLANDS

Trees are an important part of the vegetation in drylands, and they grow both in and outside forests. Trees tend to be integral parts of traditional food systems in drylands because crops and livestock thrive in their presence. Their leaves and fruits are sources of food for people and fodder for animals. An important example is *Adansonia digitata* (the baobab tree), which produces food for humans and is a significant source of vitamins and nutrients. Another example is *Faidherbia albida*, a valuable tree in agroforestry systems because it improves soil fertility and its pods are an important animal feedstock (Sacande *et al*., 2012, 2016).

Figure 8. *Dryland forest distribution, by crown cover density*



Trees in drylands protect soils, crops and animals from sun and wind. The leaves that fall to the ground improve soils and help them retain nutrients and moisture. Some trees capture nitrogen from the air and add it to the soil, where it acts as a fertilizer. Trees provide fuel for cooking and heating. In many communities, having trees near villages is a boon for women because it reduces the distances they must walk to collect wood. In times of extreme hardship, trees can be cut down and the proceeds used to buy food. Trees both in and outside forests play crucial roles, therefore, in food security and resilience in drylands; they also help reduce poverty, stabilize the water cycle, and prevent and combat desertification. Expected changes in climate – which will make many drylands even drier – add to their importance.

Until now, there has been little statistically based knowledge on the extent of trees in drylands, particularly those growing outside forests. This is a significant gap because the health and future of trees is crucial for the livelihoods and well-being of millions of people living in drylands. New information on trees in drylands is presented below.

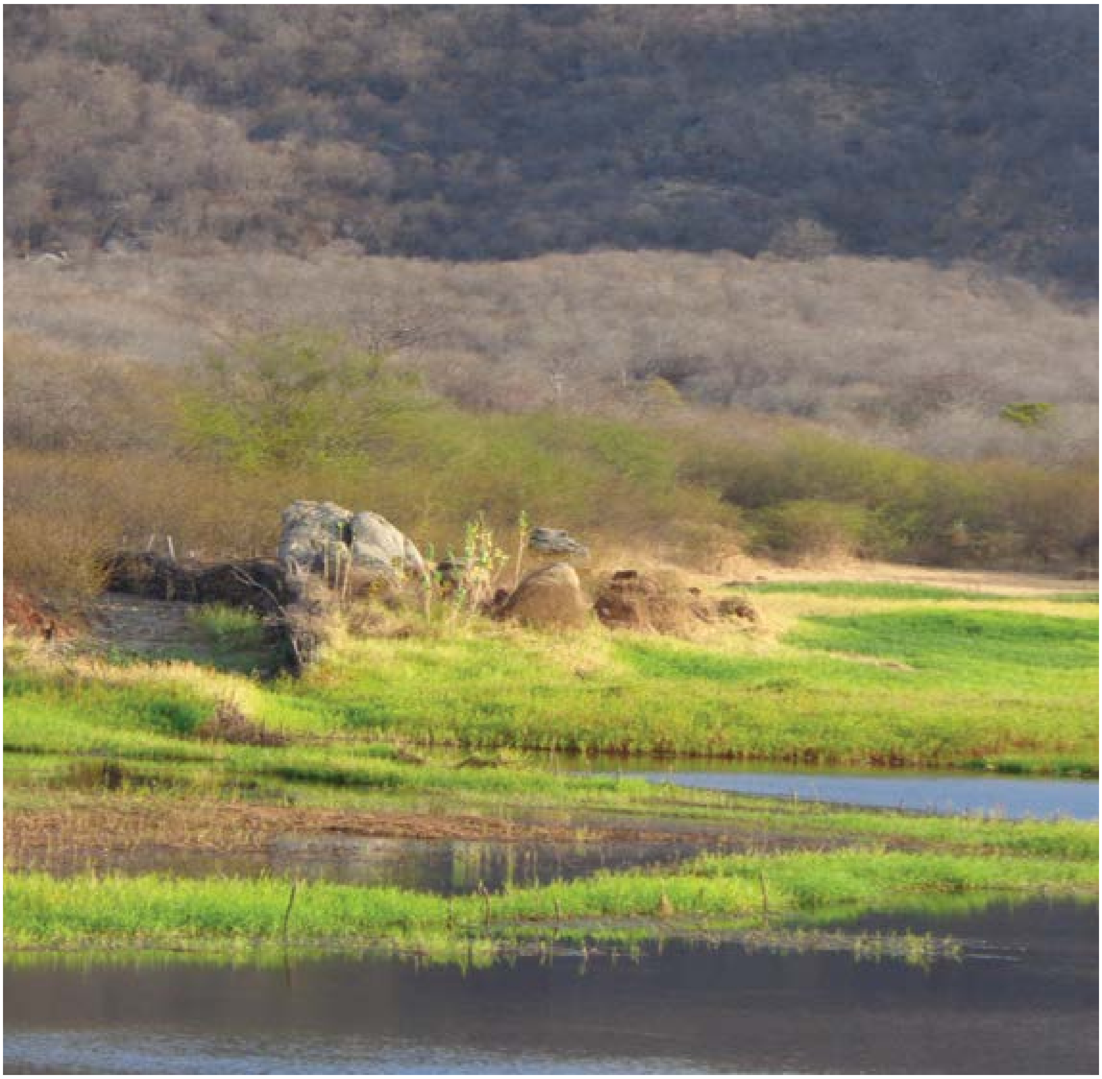
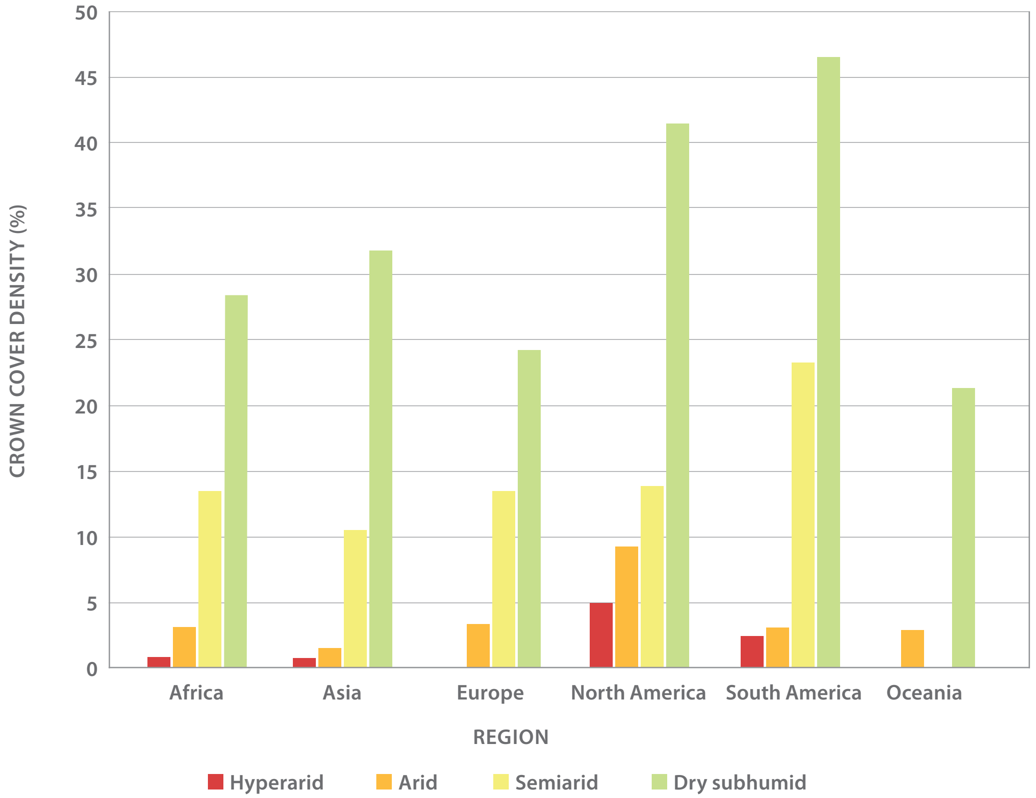


Figure 9. *Average crown cover density, by region and aridity zone*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Crown cover

▶ *Crown cover density declines with increasing aridity*

The density of crown cover differs by region as well as by aridity zone: on average, it is ten times higher in the dry subhumid zone than in the hyperarid zone (Figure 9). Of all the regions, South America generally has the highest crown cover density, but for the arid and semiarid zones it is much higher in North America than elsewhere. This suggests that crown cover density in those zones in other regions could increase substantially, at least to the level of North America, provided other ecological factors (such as soils) are favourable.

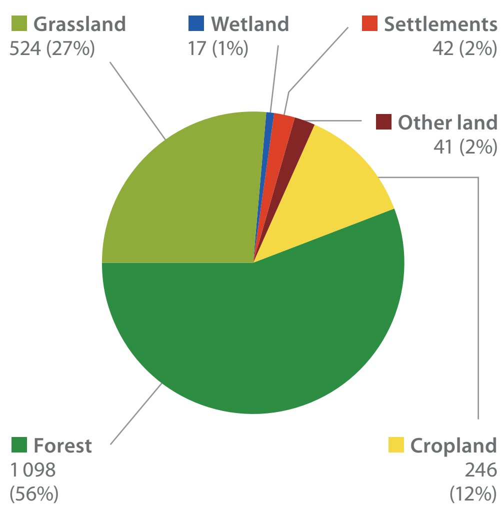
Crown cover density by land-use type

▶ *Trees are present on 1.9 billion hectares in drylands*

Trees are present on almost one-third (31 percent; 1.9 billion hectares) of the world's drylands, if all land with more than 0 percent crown cover is included, but their density varies hugely. Almost half the land with some crown cover is assigned to a land use other than forest: roughly half this is grassland and another quarter is cropland (Figure 10).

There is a wide range of crown cover density within each land-use type. Forest land, for example, contains areas of very dense crown cover as well as areas with crown cover density as low as 10 percent

Figure 10. *Land with a presence of trees (million ha), by land use (share of total)*



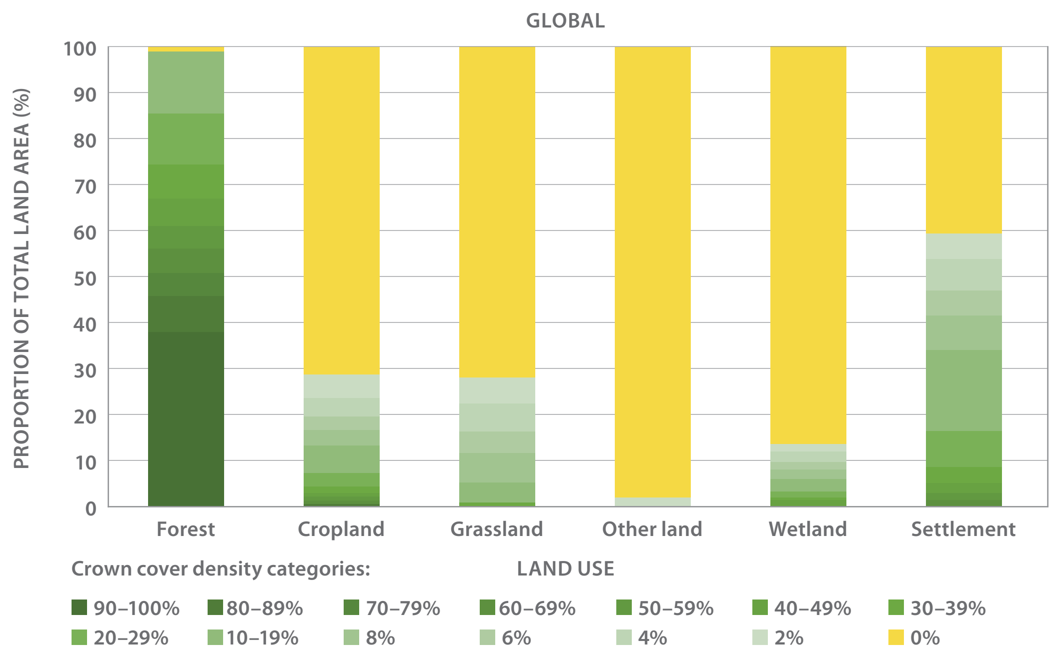
Note: Presence of trees is defined as any crown cover density equal to or above 2 percent. Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

(by definition, land with a crown cover density of less than 10 percent does not count as forest).

Forest land has the most trees of any land use, and other land has the least. Crown cover density is generally low in other types of land use. Nearly 30 percent of croplands and grasslands have trees at a density of 2 percent or higher (Figure 11).

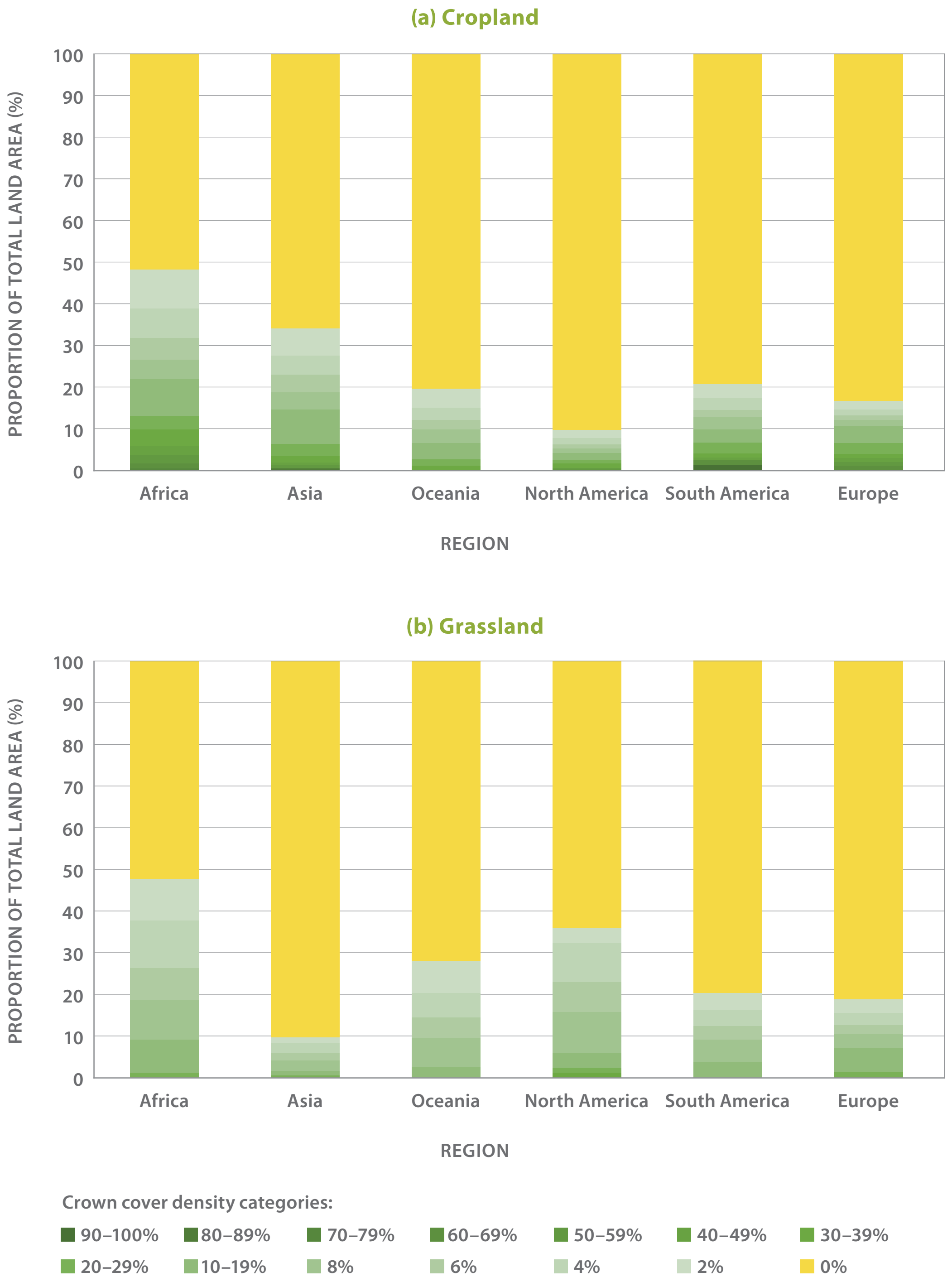
There is wide variation in crown cover density between regions, including within the same land use. Crown cover is denser in the croplands of Africa and Asia than in this land use in other regions, and the croplands of North America have the lowest-density crown cover for that land use, suggesting large differences in cropland systems between regions (Figure 12a). The grasslands of Africa and North America have the highest crown cover density in that land use among the regions, and Asia's grasslands have the lowest (Figure 12b).

Figure 11. *Crown cover density as a proportion of total land area, by land use*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Figure 12. *Crown cover density as a proportion of cropland (a) and grassland (b), by region*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

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Trees outside forests

▶ *13.5 billion of trees are outside forests in drylands*

There are about 13.5 billion trees in drylands globally, not counting trees on forest land. Most of these trees are in either grasslands (6.5 billion trees; 50 percent) or croplands (5.2 billion trees; 39 percent), and another 1 billion trees are on lands classified as settlements. Figure 13 shows the distribution of trees by region and land use: compared with other regions, a very high proportion of trees in Asia and Europe are in croplands.

Excluding forest land, the majority of land with a tree presence in arid and semiarid zones is classified as grassland. Almost half the land with trees outside forests in the dry subhumid zone is classified as cropland, where trees are often part of agroforestry and silvopastoral systems and are sources of food, fodder and energy supply and can increase agricultural productivity. The majority of the land with trees outside forests in the hyperarid zone comprises grasslands, croplands and other land (Figure 14).

Average tree density (number of trees per hectare) is about five times higher in orchards than in other types of cropland (Figure 15), and it is higher in rainfed croplands than in irrigated croplands.

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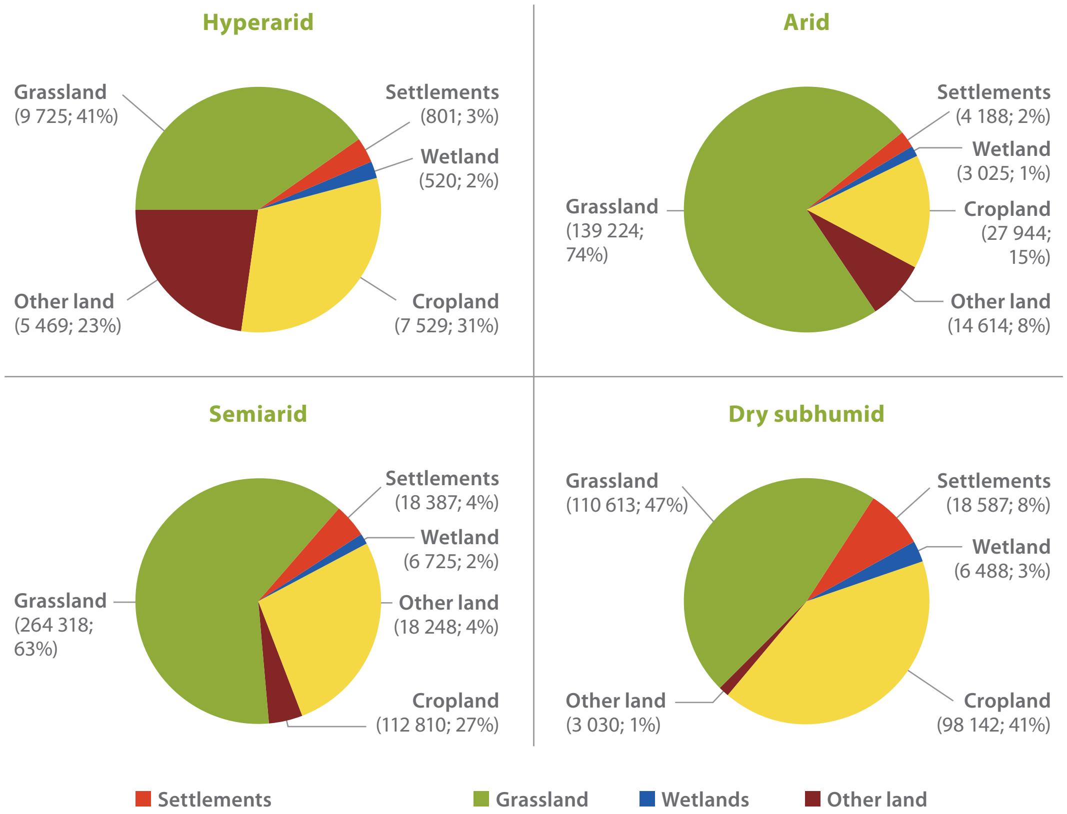
Figure 13. *Distribution of trees outside forests in each of five land-use categories in drylands, by region (million trees)*

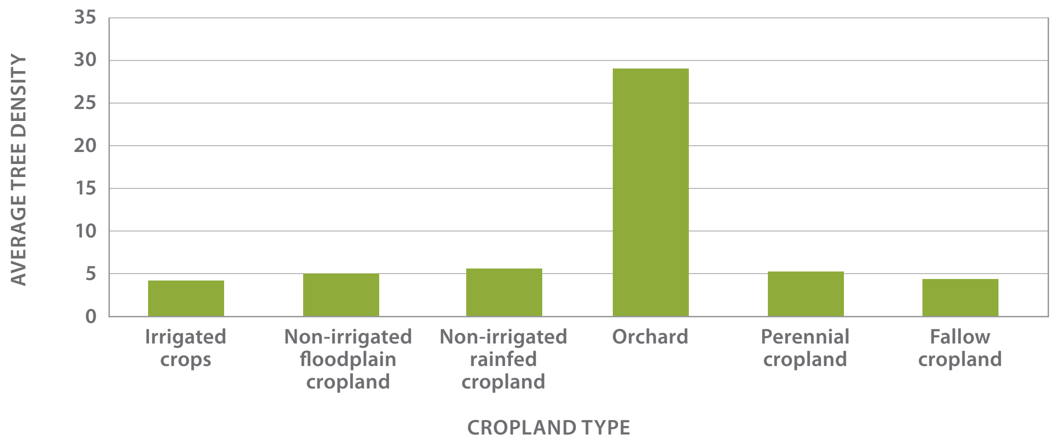
Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Figure 14. *Distribution of land with tree presence, by land use and aridity zone ('000 ha)*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

Figure 15. *Tree density, by cropland type*



Note: Calculated by the Global Drylands Assessment team using the land-use categories of the Intergovernmental Panel on Climate Change.

4

Concluding remarks

FINDINGS

The Global Drylands Assessment is the first statistical sampling-based assessment of land use, including forests and tree cover, in the global drylands. It therefore provides a baseline for monitoring changes in dryland forests, tree cover and land use – globally, regionally and by aridity zone. Preliminary findings include the following:

- The global drylands contain 1.11 billion hectares of forest land (according to the definition of the Intergovernmental Panel on Climate Change), which is 27 percent of the global forest area, estimated at approximately 4 billion hectares (FAO, 2015b).
- Two-thirds of the drylands forest area has closed canopies (i.e. a canopy cover greater than 40 percent).
- The second most common land use in drylands is grassland (31 percent), followed by forest (18 percent) and cropland (14 percent). The category other lands constitutes 34 percent of the global drylands area.
- The least-arid zones have the most forest. The proportion of forest land is 51 percent in the dry subhumid zone, 41 percent in the semiarid zone, 7 percent in the arid zone and 0.5 percent in the hyperarid zone. The average crown cover density is ten times higher in the dry subhumid zone than in the hyperarid zone.
- Trees outside forests are present on 1.9 billion hectares of drylands (31 percent of the global drylands area), if all land with more than 0 percent crown cover is included. Thirty percent of croplands and grasslands have at least some crown cover, as do 60 percent of lands classified as settlements.

- An estimated 13.5 billion trees grow outside forests in the global drylands. Most of these are in grasslands (6.5 billion trees; 50 percent) and croplands (5.2 billion trees; 39 percent), and 1 billion trees are on land classified as settlements.

ADVANTAGES, CAVEATS, LIMITATIONS AND LESSONS

The Assessment collects data from publicly and freely available online libraries of satellite images using an easy-to-use visual interpretation tool, and it engages people with land-use expertise in systematic data collection. This approach has the following advantages:

- Individual trees outside forests can be assessed with meaningfully high precision, thanks to very-high-resolution imagery, which was available for 89 percent of the global drylands area.
- A statistically based assessment of a basic set of variables can be conducted rapidly and inexpensively to complement other methods, because sample plots are assessed using satellite images rather than in the field.
- A large number of people can be engaged in the assessment process, thanks to the ease of use of the interpretation and because the software and data are both available free of charge.

The first Global Drylands Assessment produced preliminary results in less than one year from conception and in a participatory and collaborative manner. It involved experts worldwide with extensive knowledge of the lands and land uses in the regions they assessed. The results presented in this publication are subject to revision and completion in a full report, following field measurements and further analysis.

The Global Drylands Assessment has provided an opportunity to test the methodology described herein at a global scale. The methodology has limitations that should be kept in mind in considering the results reported here. It will be further developed and improved, for example to reduce interpretation errors.

A potential source of error is inconsistency: more than 200 people were engaged in the visual interpretation of satellite images, and the supply of images was not the same for all 213 795 sample plots assessed. The risk of inconsistency was mitigated by ensuring that all experts used the same training modules and tools. Additional measures to reduce interpretation inconsistencies and errors will be implemented in a pilot assessment of all lands worldwide (see below).

The global drylands map that underpinned the assessment did not clearly delineate drylands at the regional scale. In further assessments, the global drylands map should be supplemented with more precise drylands maps at the regional and subregional scales.

The number of trees outside forests has likely been underestimated in this assessment. Individual trees could not be counted on plots with more than 30 trees (18 percent of the assessed plots) due to a saturation effect. Such plots were reported as having 30 trees, which was fewer than the actual number in some plots.

The methodology can be adapted to accommodate more intensive sampling to meet specific regional, national and landscape-scale needs, if so desired by countries and other users. For example, it is being used at the landscape scale for the baseline assessment and monitoring of intervention areas in the FAO-implemented project, "Action Against Desertification" in each of the six Great Green Wall partner countries, as well as at the regional scale for the baseline assessment of the Great Green Wall area over more than 20 countries, both north and south of the Sahara, building on data already collected in North Africa, the Sahel and the Horn of Africa. The methodology is also being tested for use in a baseline assessment of landscapes in Rwanda in the context of forest and landscape restoration.

GLOBAL DRYLANDS ASSESSMENT: THE WAY FORWARD

The results of the Global Drylands Assessment will be reported in full later in 2016, following supplementary ground measurements and analysis. The full report will be accompanied by a scientific paper, to be published in a peer-reviewed scientific journal. The findings will provide a baseline for monitoring and help in identifying priority intervention areas for restoration at the global and regional levels. When the full report is published, data will be made available publicly through a web-based data portal under a common creative licence. It is expected that the Global Drylands Assessment will be repeated every two years, integrating new developments in the methodology, lessons learned, and user feedback.

The Rome Promise Collaborative Network has agreed to supplement the Global Drylands Assessment with further data and information, including population dynamics and socioeconomic data, to help in understanding the complexity of dryland

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ecosystems and land-use systems and as a contribution to the implementation of the Rome Promise roadmap. The Network also identified the need to further promote the methodology and the use of Collect Earth and other relevant tools for baseline assessments and monitoring through capacity-development events and workshops at the regional and national levels.

The combining of technologies developed by FAO and Google provides a new and economically feasible way of assessing trees, forests, land use and land-use change in any area of the world, as shown by the first Global Drylands Assessment. FAO intends to apply the methodology in a global pilot assessment of all types of land, and it is also available to support individual countries, on request, in developing country-level applications.

FEEDBACK

This is a pioneering application of a new methodology and tool at a global scale. Comments and suggestions are welcome, as FAO and partners continue to improve the approach for potential application at the global and regional scales as well nationally and at the project level on request from countries or project-leading organizations. FAO is willing to work with those interested in using, developing and refining the methodology and new tools for their own purposes.

Please contact us at: **drylands.report@fao.org**

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Drylands cover about 41 percent of the Earth's land surface and are home to 2 billion people, the majority of whom depend on forests and other wooded lands, grasslands and trees on farms for income and to meet basic needs. Yet surprising little is known about such ecosystems in drylands, despite widespread recognition of the need to restore drylands to cope with the effects of drought, desertification, land degradation and climate change.

This document presents preliminary results of the first global assessment of trees, forests and land use in drylands. It reports, among other things, that the global drylands contain 1.11 billion hectares of forest, which is more than one-quarter of the global forest area. There are also about 13.5 billion trees outside forests in drylands.

More than 200 experts with knowledge of the land and land uses in specific dryland regions conducted the assessment, using freely available satellite imagery and a newly developed survey methodology. The pioneering study by FAO and many partners will be fully reported later in 2016.

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