WORLD RESOURCES INSTITUTE

DRYLANDS, PEOPLE, AND ECOSYSTEM GOODS AND SERVICES: *A Web-Based Geospatial Analysis (PDF Version)*

Robin P. White
Janet Nackoney

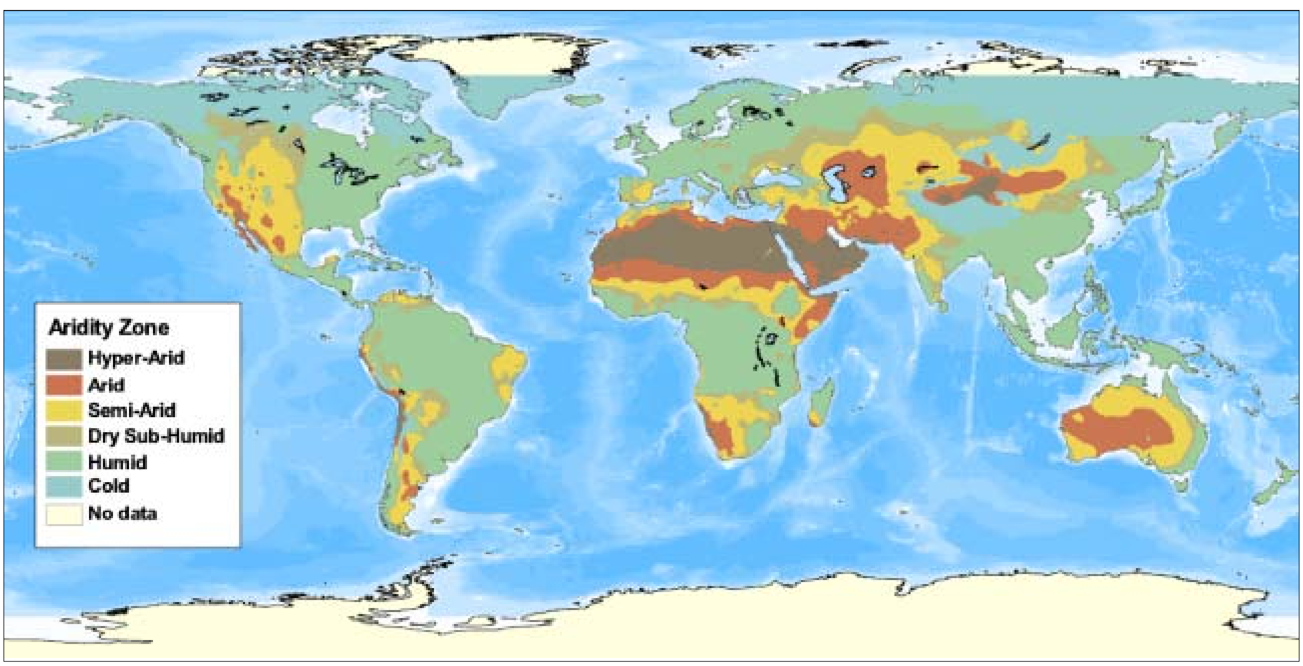
INTRODUCTION

This web-based analysis takes advantage of the power of geospatial technologies to examine the world's drylands. We consider drylands from the perspective of human livelihoods, examining how these livelihoods are integrated with dryland ecosystem goods and services. Our presentation is map-rich using combinations of remotely-sensed data and computer-based data management systems (GIS). Where global data are not available, we use regional and national studies. We focus on a selected set of dryland goods and services: forage and livestock; food production; biodiversity conservation; freshwater; carbon storage; energy production; and tourism and recreation. The final two sections examine drylands and trade and drylands and the impacts of human activities. Each subject area is generally presented with a brief overview, map, map description, and list of sources. Links are provided to associated data tables and text boxes. All maps are shown in Geographic projection.

DEFINITION OF DRYLANDS

We define drylands according to the definition provided by the United Nations Convention to Combat Desertification (CCD). The CCD uses the ratio of mean annual precipitation to mean annual potential evapotranspiration to identify drylands of the world. Potential evapotranspiration is the amount of moisture that, if it were available, would be removed from a given land area by evaporation and transpiration.

Map 1. Aridity Zones of the World



Source: UNEP/GRID, 1991.
Projection: Geographic

10 G Street, NE
Washington, DC 20002

1.202.729.7600 Telephone
1.202.729.7610 Fax

www.wri.org
February 2003

Map Description (Map 1)

Using the ratio of mean annual precipitation to mean annual potential evapotranspiration, the world is divided into six aridity zones. Drylands include arid, semi-arid, and dry sub-humid areas (other than polar and sub-polar regions) in which this ratio ranges from 0.05–0.65. Areas where the ratio is less than 0.05 are hyper-arid zones. Areas where the ratio is greater than 0.65 are humid zones.

Of the approximately 135 million km^2 of terrestrial land area globally, the humid zone is the most extensive including about 46.5 million km^2 (or 34 percent of total land area). This zone covers most of Europe and Central America, and large portions of Southeast Asia, eastern North America, central South America, and central Africa. The hyper-arid zone is the least extensive, including approximately 11 million km^2 (or 8 percent of total land area), and is represented most predominantly by the Saharan Desert. Hyper-arid lands generally are unsuitable for growing crops.

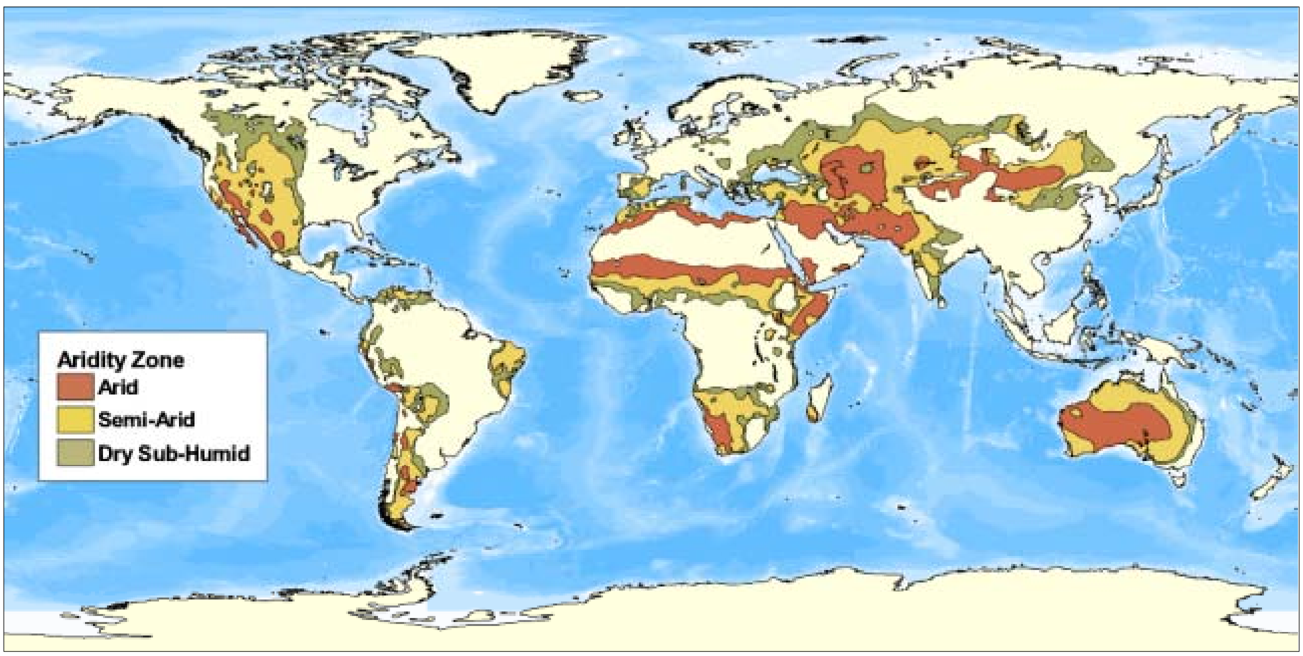
Drylands cover almost 54 million km^2 of the globe. Semi-arid areas are most extensive followed by arid areas and then dry sub-humid lands. These aridity zones spread across all continents, but are found most predominantly in Asia and Africa (Table 1).

Where Are the World's Drylands?

Approximately 40 percent of the global land area (excluding Greenland and Antarctica) is considered dryland.

Commonly recognized drylands include the African Sahel, Australian Outback, South American Patagonia, and North American Great Plains.

Map 2. Extent of the World's Drylands



Source: UNEP/GRID, 1991.
Projection: Geographic

Map Description (Map 2)

The extent of drylands within each region ranges from approximately 1.3 to 18 million km^2. Asia and Africa have the largest total amounts (18 and close to 13 million km^2, respectively); Central America and Europe have the least (Table 1).

Table 1. Regional Extent of Drylands

	Aridity Zone							
Region	Arid	%	Semi-Arid	%	Dry Sub-Humid	%	All Drylands	%
Asia (Incl. Russia)	6,164	13	7,649	16	4,588	9	18,401	39
Africa	5,052	17	5,073	17	2,808	9	12,933	43
Oceania	3,488	39	3,532	39	996	11	8,016	89
North America	379	2	3,436	16	2,081	10	5,896	28
South America	401	2	2,980	17	2,233	13	5,614	32
C. America & Caribbean	421	18	696	30	242	10	1,359	58
Europe	5	0	373	7	961	17	1,339	24
World Total	15,910	12	23,739	18	13,909	10	53,558	40

Source: UNSO/UNDP 1997.

Australia has more dryland than any other country in the world, with approximately 6.6 million km^2. Other countries with large amounts of dryland include the United States and three countries in Asia: Russia, China, and Kazakhstan—all with more than 2 million km^2. Nine additional countries have more than 1 million km^2 of dryland (Table 2).

Table 2. Countries with Over 1 Million Square Kilometers of Dryland

Country	Total Land Area (000 km^2)	Total Dryland Area (000 km^2)
Australia	7,705	6,605
United States	9,459	3,902
Russia	16,852	3,672
China	9,337	3,177
Kazakhstan	2,715	2,693
India	3,091	1,848
Sudan	2,508	1,676
Canada	9,909	1,565
Argentina	2,781	1,469
Iran	1,624	1,466
Mexico	1,962	1,357
Brazil	8,506	1,305
Mongolia	1,559	1,015
Mali	1,256	1,007

Source: WRI Calculations based on ESRI 1993 and UNEP/GRID 1991

While large countries, like Russia and China, have large amounts of dryland, other generally smaller countries are 100 percent, or nearly 100 percent dryland: Botswana, Burkina Faso, Turkmenistan, Iraq, and Moldova. Twelve additional countries are at least 90 percent dryland (Table 3). Two countries are both large and predominantly dryland: Kazakhstan with over 2.6 million km^2 is 99 percent dryland; and Iran with over 1.4 million km^2 is 90 percent dryland.

Table 3. Countries with Over 90 Percent Dryland

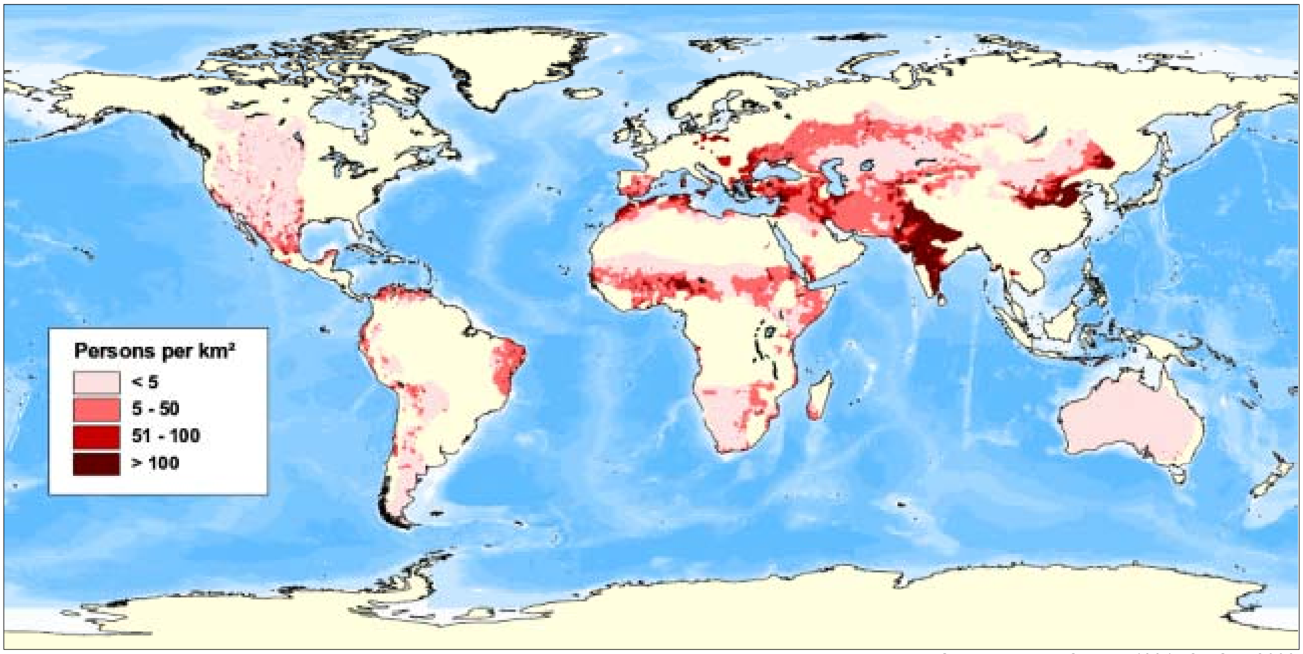
Country	Total Land Area (000 km^2)	Percent Dryland
Botswana	580	100.0
Burkina Faso	273	100.0
Turkmenistan	471	100.0
Iraq	437	99.9
Moldova	34	99.9
Uzbekistan	446	99.2
Kazakhstan	2,715	99.1
Armenia	30	98.1
Syria	188	98.0
Gambia	11	97.2
Senegal	197	94.1
Afghanistan	642	94.0
Tunisia	155	93.7
Kuwait	17	92.2
Morocco	404	92.2
Namibia	826	90.8
Iran	1,624	90.2

Source: WRI Calculations based on ESRI 1993 and UNEP/GRID 1991

Who Lives in the World's Drylands?

Drylands are inhabited by over two billion people world-wide. As lands that sometimes are poorly understood and thought of as unproductive and barren, they support nearly 40 percent of the world's population. The distribution patterns of these dryland populations vary within each region and among the aridity zones comprising drylands. A global map of population densities within drylands and a table of the number of people living in drylands within each of the world's regions provide tools to examine these patterns.

Map 3. Population Density in Drylands



Source: UNEP/GRID, 1991; CIESIN 2000.
Projection: Geographic

Map Description (Map 3)

Regionally, Asia has the largest population living in drylands, both in terms of numbers and percent: over 1.4 billion people, or 42 percent of the region's population. Africa has nearly the same percent of people living in drylands—41 percent—although the total number is less than Asia's: nearly 270 million. South America has 30 percent of its population in drylands or approximately 87 million people (Table 4).

Table 4. Human Populations in the World's Drylands

	Aridity Zone							
Region	Arid	%	Semi-Arid	%	Dry Sub-Humid	%	All Drylands	%
Asia (Incl. Russia)	161,554	5	625,411	18	657,899	19	1,444,906	42
Africa	40,503	6	117,649	18	109,370	17	267,563	41
Europe	629	0	28,716	5	111,216	20	140,586	25
South America	6,331	2	46,852	16	33,777	12	86,990	30
North America	6,257	2	41,013	16	12,030	5	59,323	25
C. America & Caribbean	6,494	6	12,888	11	12,312	8	31,719	28
Oceania	275	1	1,342	5	5318	19	6,960	25
World Total	222,043	4	873,871	4	941,922	17	2,038,047	37

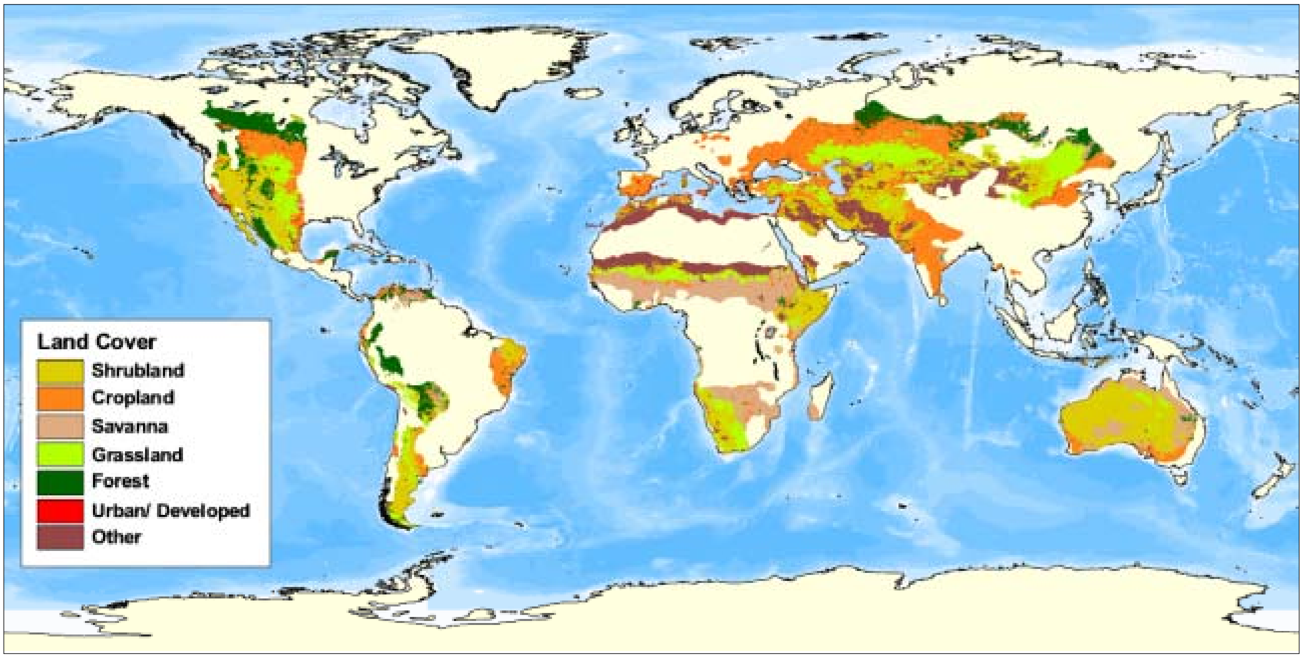
Source: UNSO/UNDP 1997.

Of the three aridity zones defining drylands, semi-arid and dry sub-humid lands are favored, with population levels rising with increases in humidity. Some of the highest population densities in the world are found in the semi-arid and dry sub-humid zones of India. Other pockets of high population densities occur in the dry sub-humid zones of eastern China, the Middle East, and West Africa.

Land Cover in the World's Drylands

Perhaps surprisingly, various land cover types are found in drylands, ranging from shrubland to forest to croplands and urbanized areas. Globally, six major land cover categories can be described within drylands–using a world map of the dry aridity zones superimposed on land cover types. Patterns can then be examined using the population density map.

Map 4. Land Cover in Drylands



Source: ESRI 1993; GLCCD 1996; NOAA/NGDC 1996; UNEP/GRID 1991
Projection: Geographic
Note: Category "Other" includes barren or sparsely vegetated land; open water; permanent wetlands; snow and ice; and islands

Map Description (Map 4)

To calculate the area of different land cover types within drylands, we have used a combination of datasets. Our primary source is the most recent available global dataset based on satellite imagery of land cover and vegetation types—the International Geosphere-Biosphere Project (IGBP) 1-km Advanced Very High Resolution Radiometer (AVHRR) land cover classification.

We have included from the IGBP legend, land characterized as shrubland including both open and closed shrublands; cropland including cropland mosaics (areas with up to 70 percent cropland mixed with forest or grassland); savanna including woody savannas; grassland (as non-woody or herbaceous grassland); forest including evergreen needleleaf, evergreen broadleaf, deciduous needleleaf; deciduous broadleaf; and mixed forest; and urbanized or developed areas.

For defining urbanized area, instead of using the Digital Chart of the World database, we modified the IGBP classification using a more recent dataset. The Nighttime Lights of the World database is a 1-km resolution map derived from nighttime satellite imagery. This data set identifies the locations of stable lights at night, indicating built-up areas.

In terms of the major land cover types, shrubland is the most predominant followed by cropland, savanna, grassland, forest, and urban areas. When the three aridity zones are examined separately, shrubland is most extensive in the arid zone; cropland, savanna, grassland, and urban areas are most extensive in the semi-arid zone; and forest is most common in the dry sub-humid zone. Although cropland is most extensive in the semi-arid zone, the extent of cropland within the dry sub-humid zone is relatively similar while the amount of cropland in the arid zone is considerably less (Table 5).

Table 5. Land Cover in Drylands (in 000 km²)

Land Cover	Aridity Zone: Arid	Semi-Arid	Dry Sub-Humid	All Drylands
Shrubland	6,834	5,344	499	12,677
Cropland	469	5,299	4,747	10,515
Savanna	834	4,018	3,026	7,878
Grassland	1,808	4,728	649	7,185
Forest	114	1,402	2,839	4,355
Urban/Developed	257	818	658	1,733
Other	5,594	2,130	1,491	9,215
Total	15,910	23,739	13,909	53,558

Source: GLCCD 1998; ESRI 1993; UNEP/GRID 1991
Note: Category "Other" includes barren or sparsely vegetated land; open water; permanent wetlands; snow and ice; and islands

Map Description ***(cont'd)***

Several patterns emerge from this map when compared with the map of population density. Areas of highest population densities in drylands correspond with dry sub-humid and semi-arid areas of cropland such as in India, eastern China, and Europe. The savannas of Africa also correspond generally with the dry sub-humid and semi-arid zones and fairly dense human populations. In contrast, forests tend to be found only in the dry sub-humid zone with few people; shrublands correspond with primarily the arid zone, also with few people.

Goods and Services Provided by Drylands

Dryland ecosystems, although providing a wide array of goods and services, are not always recognized as fully as other terrestrial ecosystems on the planet. Drylands support flora, fauna, and people in important and often unique ways (Box 1: Dryland Misconceptions).

Drylands produce forage for domestic livestock, which in turn support human livelihoods with meat, dairy products, and clothing materials such as wool and leather. Drylands are used extensively for the production of food. Many of our major food crops, such as wheat, barley, sorghum, and millet originated in drylands. Today wild varieties from these centers of origin serve as sources of genetic plant material for developing drought-resistant crop varieties. Freshwater resources in drylands, often limited and variable in availability, are important water sources for drinking, irrigating crops, and supporting wetland flora and fauna.

Drylands provide habitat for species uniquely adapted to variable and extreme environments. Dryland species range from micro-organisms, to ants, grasshoppers, and snakes to large carnivores such as cheetahs and leopards. Drylands, because of their extensive area, can store large amounts of carbon, most of it in the soil rather than in vegetation. Improving the carbon storage capacity of drylands may be one method to help offset global warming by lowering CO^2 concentrations in the atmosphere.

Drylands supply a critical source of wood fuel for cooking and are potentially important locations for wind and solar power. In some places they are the source of a wealth of mineral fuels such as natural gas and petroleum. Aesthetically, drylands are often open, vast, and picturesque landscapes. As tourisms destinations, they support recreational activities such as hunting, wildlife-watching, and photography.

Box 1. Dryland Misconceptions

The term "drylands" often conjures up images of large, seemingly lifeless expanses. Many popular misconceptions surround the concept of drylands. Three common misconceptions are described below:

MISCONCEPTION:

Drylands are empty and unproductive places where people are unable to survive.

REALITY:

Drylands have supported people's livelihoods for thousands of years. Today, drylands are home to approximately two billion people worldwide and support many modern cities, such as Cape Town, Los Angeles, Madrid, and Teheran.

MISCONCEPTION:

Drylands cannot support plant and animal life.

REALITY:

Drylands present challenges to plant and animal survival, but many species have evolved with special adaptations that allow them to cope with the climate and variable water supply in drylands. One common plant adaptation is the development of deep and extensive root systems. Animals may adapt by becoming inactive, using shade, and taking cover underground during the hottest times of the day.

MISCONCEPTION:

All drylands are degraded due to misuse and overuse from human activity.

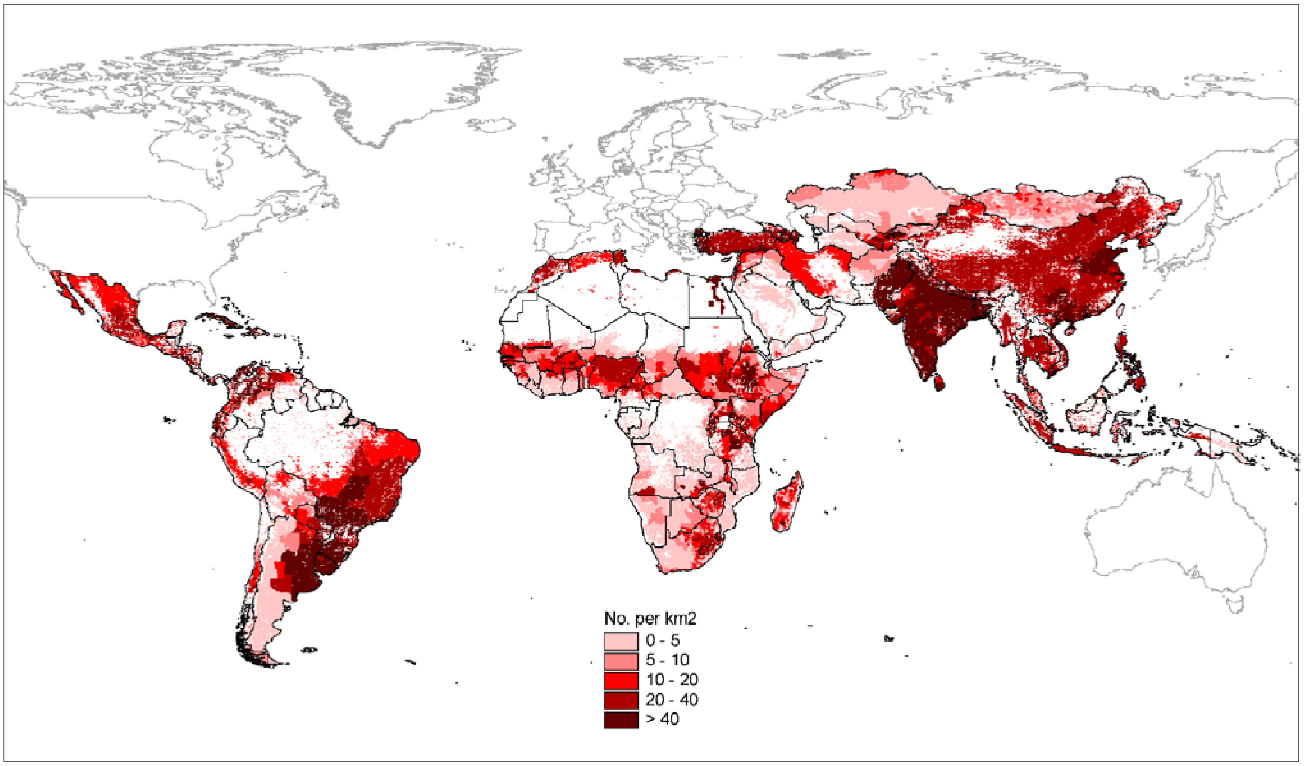
REALITY:

Drylands are sensitive but resilient environments. Overuse can lead to severe degradation; however, low productivity, sparse plant and animal life, and low soil fertility characterize some drylands, even without human influence.

Drylands, Forage and Livestock

More so than any other use today, people rely on drylands to provide forage for the production of domestic livestock. From cattle, sheep, and goat herds, to horses and camels, drylands support large numbers of domestic animals, which become the source of meat, milk, wool, and leather products for humans.

Map 5: Tropical Livestock Unit Density



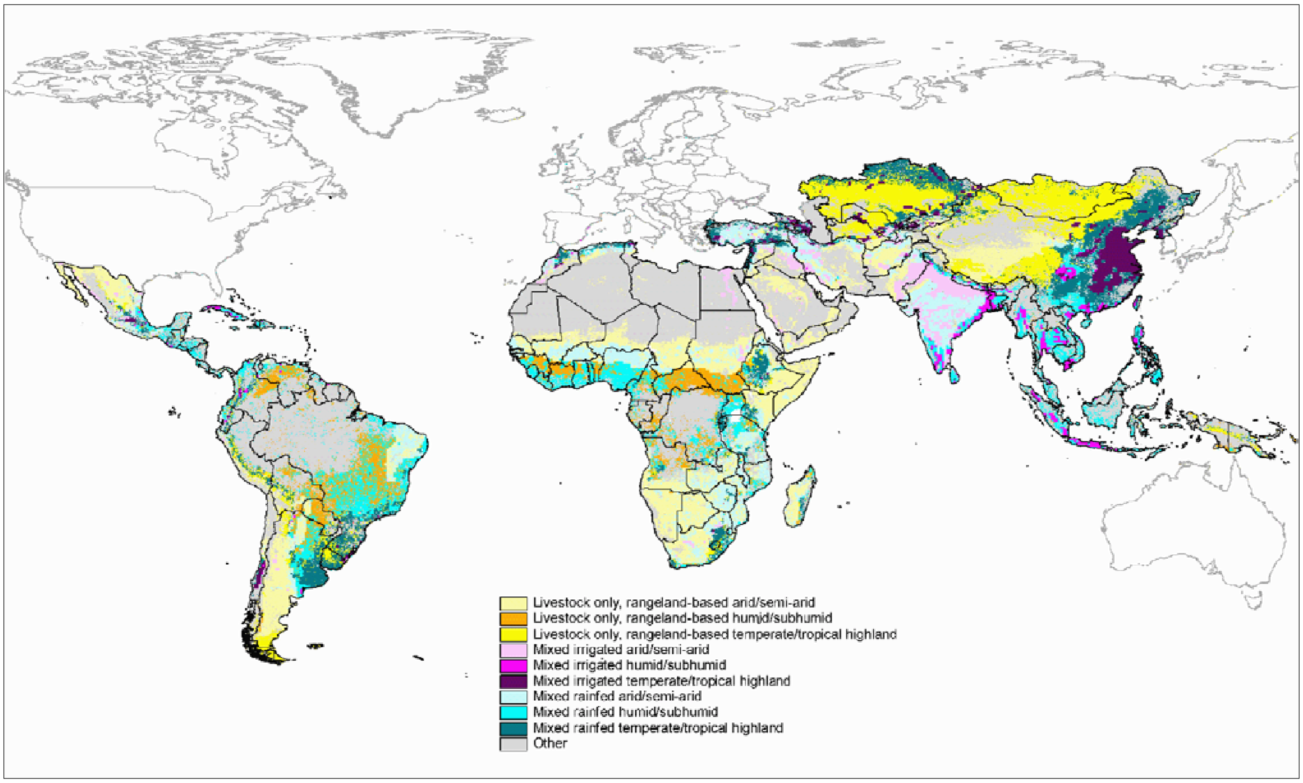
Source: Thorton P.K., Kruska R.L., Henninger N., Krisjanson P.M., Reid R.S., Atieno F., Odero A.N. and Ndegwa T. 2002. Mapping Poverty and Livestock in the Developing World. *ILRI (International Livestock Research Institute), Nairobi, Kenya. 124pp.*

Map Description (Map 5)

This map show the density of livestock, including cattle, buffalo, sheep, goats, horses, mules, donkeys, and pigs. Densities range from less than 5 tropical livestock units (TLUs) to more than 40 TLUs per square kilometer. A tropical livestock unit is the common unit for describing livestock numbers of different species; as a single value this expresses the total amount of livestock present regardless of the specific composition.

Some of the highest livestock densities in the world are in the drylands of Asia, Africa, the Middle East, and South America. Very high densities in drylands (greater than 40 TLUs per square kilometer) are found in India and Pakistan, eastern China, the Sahel, Turkey, and parts of southeastern South America. Livestock can help maintain soil fertility, increase nutrient retention and water-holding capacity, and create a better climate for micro-flora and fauna. If drylands are overgrazed, soil compaction and erosion may follow with a decrease in soil fertility, organic matter, and water-holding capacity.

Map 6: Global Livestock Production Systems



Source: Thorton P.K., Kruska R.L., Henninger N., Krisjanson P.M., Reid R.S., Atieno F., Odero A.N. and Ndegwa T. 2002. Mapping Poverty and Livestock in the Developing World. ILRI (International Livestock Research Institute), Nairobi, Kenya. 124pp.

Map Description (Map 6)

The International Livestock Research Institute (ILRI) has prepared this global map of livestock production systems (for the developing world only). ILRI defined these 10 production systems based on whether the systems were livestock only, livestock mixed with irrigated cropland, or livestock mixed with rainfed cropland. Each system is further defined according to agro-ecological zone: arid/semi-arid; humid/subhumid; or temperate/tropical highland. The last category, "other," includes areas where human and livestock populations are low and where native vegetation is widespread.

In comparing the livestock production systems map with the map of dryland extent, a fairly obvious pattern emerges. Livestock only, rangeland-based systems are most predominant in drylands — in Mexico, southern South America, the Sahel, southern Africa and parts of China. Some important areas of mixed irrigated and mixed rainfed production systems are found in drylands, but are much less extensive.

SOILS IN DRYLANDS

The capacity for drylands to produce forage for livestock is determined, in part, by soil condition. The Global Assessment of Human-Induced Soil Degradation (GLASOD) and, more recently, the Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia (ASSOD) represent efforts to qualitatively assess soil degradation *(See, "Measuring soil condition")*.

GLASOD indicates substantial areas of soil degradation around the world. Globally, approximately 20 percent of the soils in drylands are degraded — 17 percent lightly to moderately degraded; over 2.5 percent strongly to extremely degraded (Table 6). Regionally, the soils in Asia and Africa are the most degraded, approximately 370 million hectares of degraded dryland in Asia; 319 in Africa. Although Asia has more total degradation in its drylands, Africa has more soils in the strong to extremely degraded classes (43.5 million hectares in Asia vs. 74.2 million hectares in Africa).

Table 6. Soil Degradation in Drylands (in million ha)

Region	Light	Moderate	Strong	Extreme	Total Degraded	Total Non-Degraded	Total
Asia	156.7	170.1	43.0	0.5	370.3	1301.5	1671.8
Africa	118.0	127.2	70.7	3.5	319.4	966.6	1286.0
Europe	13.8	80.7	1.8	3.1	99.4	200.3	299.7
Oceania	83.6	2.4	1.1	0.4	87.5	575.8	663.3
North America	13.4	58.8	7.3	0.0	79.5	652.9	732.4
South America	41.8	31.1	6.2	0.0	79.1	436.9	516.0
World	427.3	470.3	130.1	7.5	1035.2	4134.0	5169.2

Source: UNEP 1997
Note: Data for table are from GLASOD after the World Atlas of Desertification. This table replaces Australasia with Oceania.

ASSOD focuses on South and Southeast Asia, including seven countries: China, India, Myanmar, Nepal, Pakistan, Sri Lanka, and Thailand. When analyzed according to aridity zone within these seven countries, more than half of the drylands (approximately 53 percent) have degraded soils, most predominantly in the arid zone. More so than the sub-humid zone, the arid and semi-arid zones include more dryland area in the strong and extremely degraded classes. (Table 7).

Table 7: Soil Degradation in South and Southeast Asian Drylands (million ha)

Aridity Zone	Negligible	Light	Moderate	Strong	Extreme	Total Degraded	Total Non-Degraded	Total
Arid	10.82	61.69	19.68	33.16	0.03	125.38	74.21	199.59
Dry Sub-humid	46.37	49.51	17.03	4.70	3.09	120.70	74.93	195.63
Semi-arid	15.68	45.02	29.00	18.97	1.70	110.37	168.81	279.18
Total	72.87	156.22	65.71	56.83	4.82	356.45	317.95	674.40

Source: UNEP 1997
Note: Data for table are from ASSOD after the World Atlas of Desertification. This table replaces Australasia with Oceania. Column and row total may not correspond due to round of decimals.

VEGETATION IN DRYLANDS

Several indicators based on satellite images and with long-term trends can be used to examine dryland vegetation. These indicators include the Normalized Difference Vegetation Index, Net Primary Productivity, and Rain- Use Efficiency.

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The Normalized Difference Vegetation Index is a remote sensing tool used to track global vegetation cover. It is derived from Advanced Very High Resolution Radiometer (AVHRR) data and related to the proportion of photosynthetically-absorbed radiation. This index describes the capacity of vegetation canopies to absorb solar radiation.

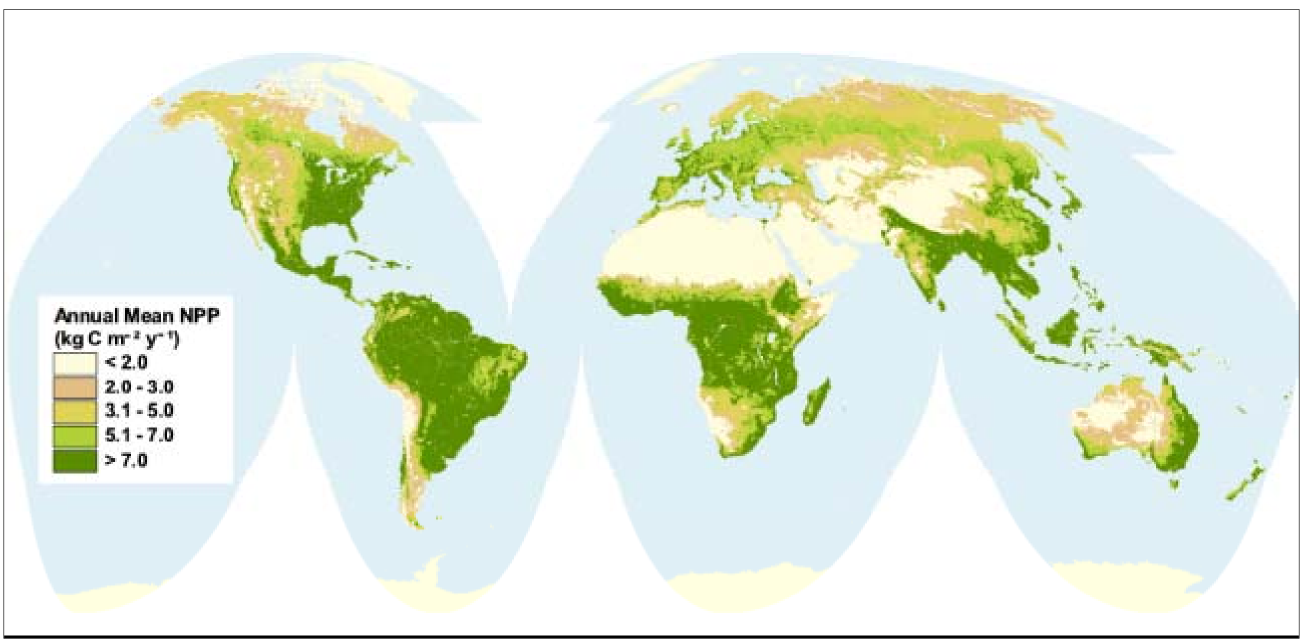
Various institutions have used NDVI for an array of applications, including the USGS-IGBP Global Land Cover Characterization and the USGS-FAO Map of the World's Forests. A long term analysis of NDVI by UNEP showed wide variation across the world's drylands. In some semi-arid environments, positive trends in NDVI have corresponded to areas with irrigation systems, increased production, and cover of wetland plant species while negative trends have corresponded to areas with negligible rainfall.

One drawback of the NDVI is that while it provides values for total vegetation, it cannot distinguish species composition. For example, high NDVI values might represent relatively luxuriant vegetation, but in semiarid rangelands they also could represent disturbed vegetation communities with unpalatable forbs.

NET PRIMARY PRODUCTIVITY

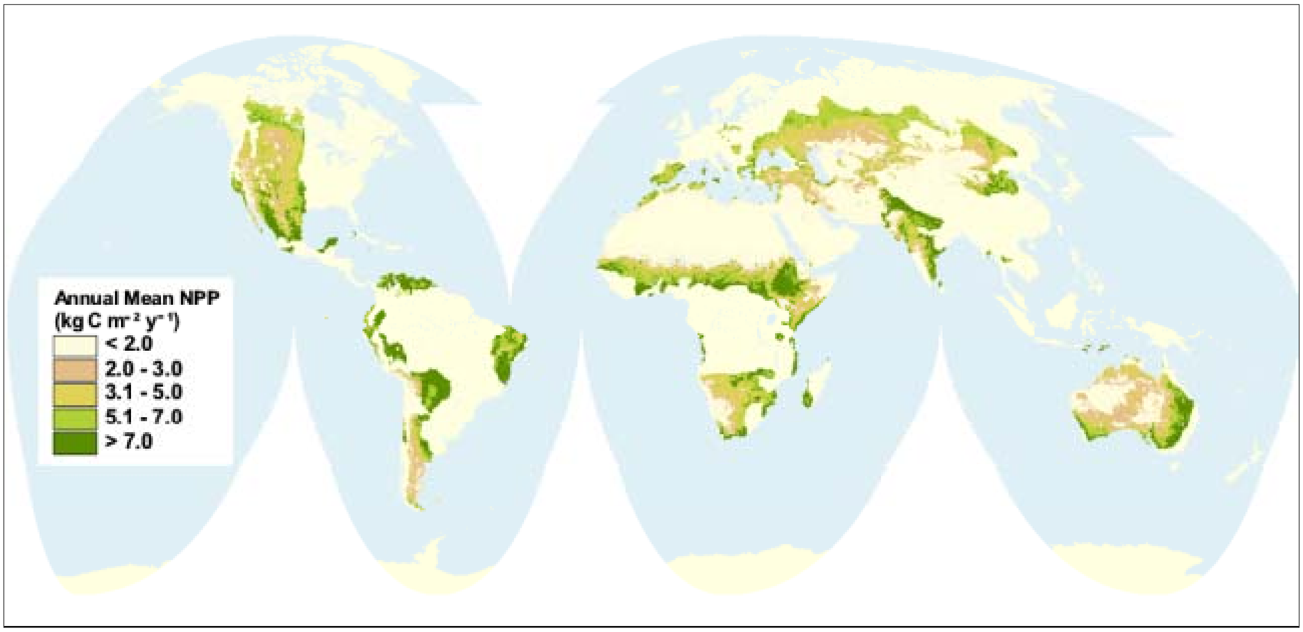
Net Primary Productivity is the total vegetative production of an ecosystem minus losses due to respiration. As the amount of organic carbon that plants actually make available to other organisms in an ecosystem, NPP may be a more direct indicator of actual yield of vegetation than the NDVI, which is a measure of light absorption. Direct observations of NPP are not available globally, but computer models derived from local observations and NDVI have been developed to represent global NPP.

Map 7: Global Net Primary Productivity (1982 - 1993)



Source: GLCCD, 1998; Goetz et.al. 1999; Prince and Goward, 1995; UNEP/GRID, 1991.
Projection: Interrupted Goode's Homolosine

Map 8: Net Primary Productivity in Drylands (1982 - 1993)



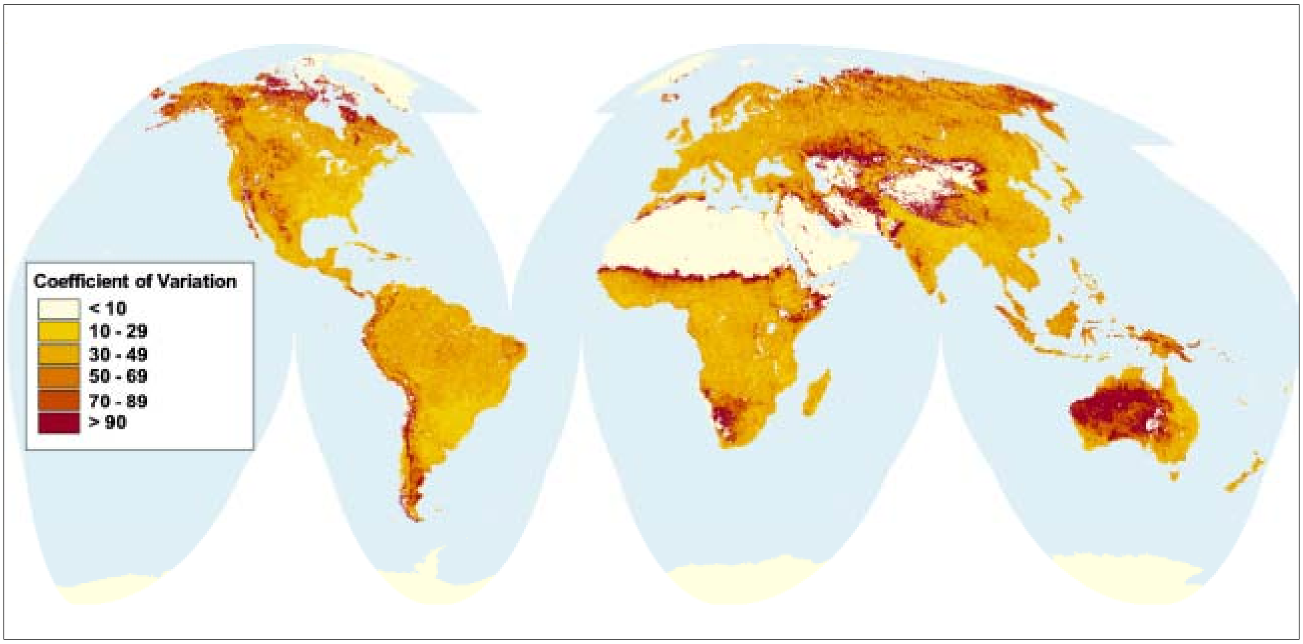
Source: GLCCD, 1998; Goetz et.al. 1999; Prince and Goward, 1995; UNEP/GRID, 1991.
Projection: Interrupted Goode's Homolosine

Map Description (7 and 8)

Map 7 shows the pattern of mean annual NPP for a twelve year period (1982-1993). Globally, NPP is highest in low latitudes and lowest at the poles. The tropics and eastern edges of the continents tend to have high mean annual NPP. Western and more poleward continental areas have lower productivity.

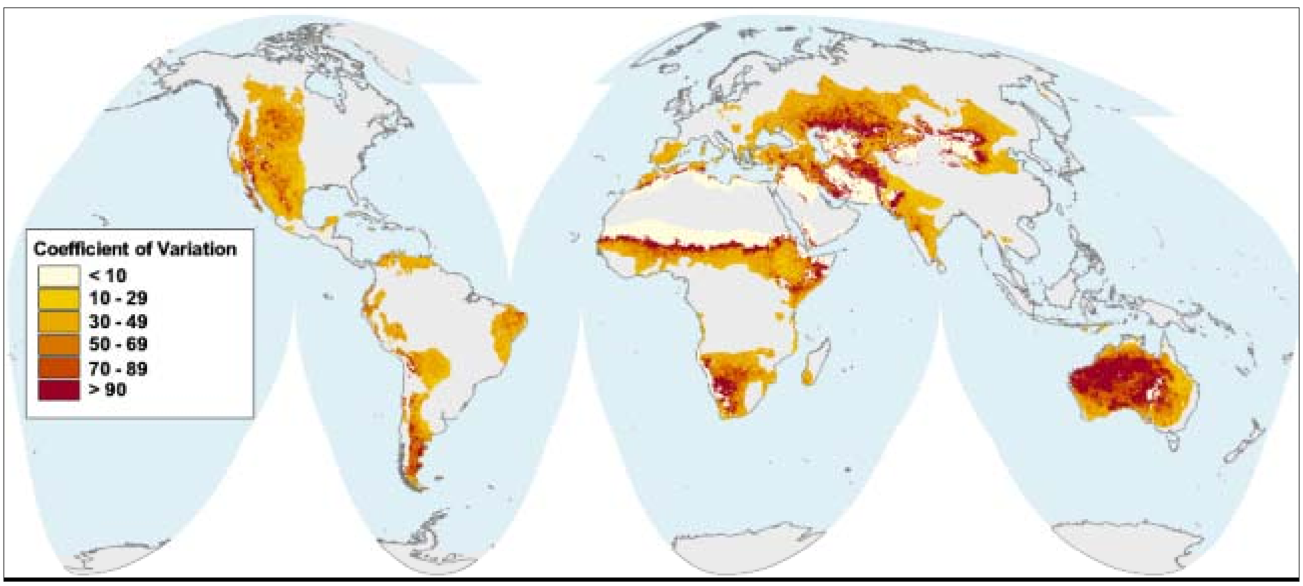
When drylands are clipped from the global map of NPP (Map 8) several additional patterns become apparent. Drylands exhibit a range in productivity around the globe, from low NPP values around the Sahara and Namib deserts and in portions of central Asia and western Australia to the highest values, most extensive in low latitudes, in the tropical areas of South America, Asia and Africa. Dry sub-humid areas tend to correspond to the highest NPP values while arid and semi-arid areas average lower mean annual NPP.

Map 9: Global Variation in Net Primary Productivity (1982 - 1993)



Source: GLCCD, 1998; Goetz et.al. 1999; Prince and Goward, 1995.
Projection: Interrupted Goode's Homolosine
Note: These values represent the ratio of the standard deviation of annual net primary productivity to mean NPP values in the period between 1982 and 1993.

Map 10: Variation in Net Primary Productivity in Drylands (1982 - 1993)



Source: GLCCD, 1998; Goetz et.al. 1999; Prince and Goward, 1995.
Projection: Interrupted Goode's Homolosine
Note: These values represent the ratio of the standard deviation of annual net primary productivity to mean NPP values in the period between 1982 and 1993.

Map Description (9 and 10)

Researchers have used eight years of NDVI data (1982-1989) to analyze interannual variation of NPP and to determine the coefficient of variation (ratio of the standard deviation of annual totals to the long-term mean) from the Global Production Efficiency Model (GLO-PEM) developed by the University of Maryland, Department of Geography. Interannual variation in mean NPP can reveal the complexity of spatial variation in species composition and biomass that is caused by climate, topography, soil types, and human-induced change.

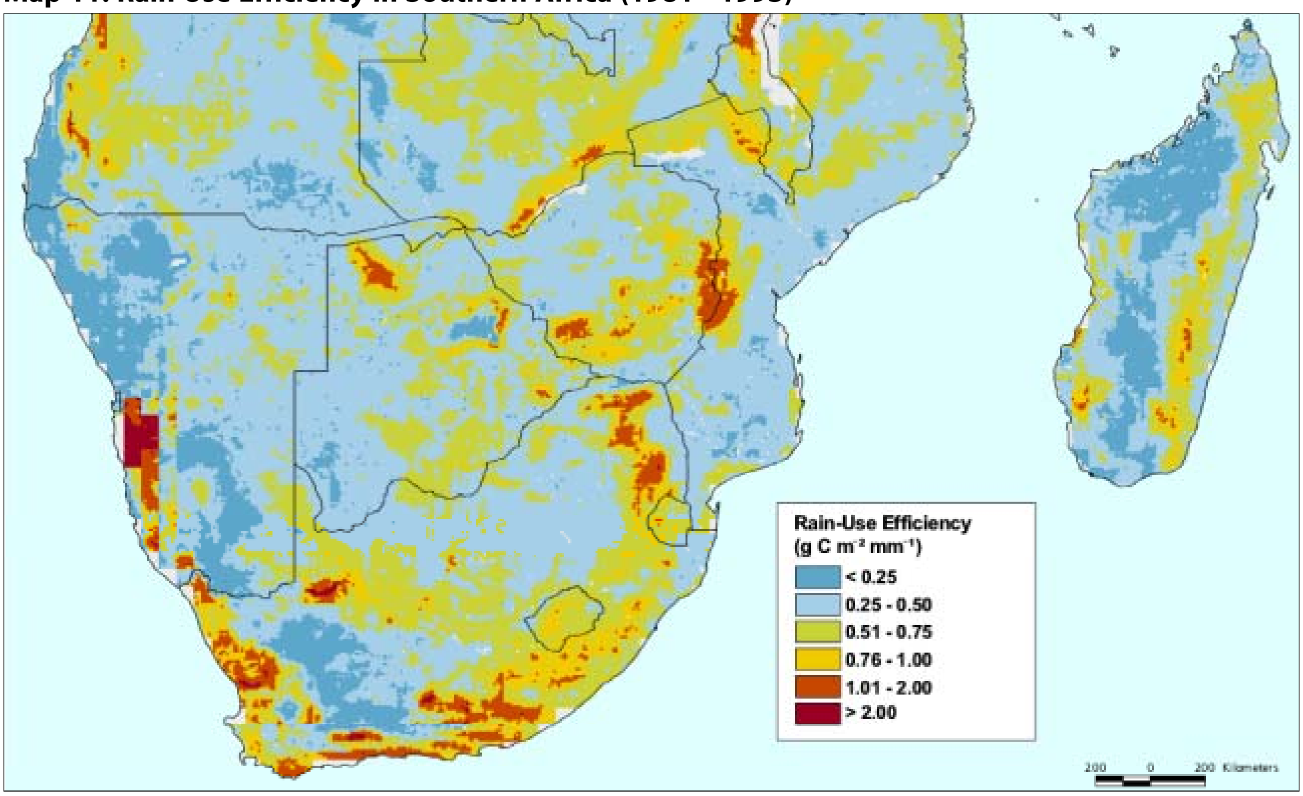
Map 9 illustrates that some regions have stable NPP values from year to year, whereas other regions have highly variable values. Generally, the regions of lower NPP correspond to areas with the largest percentage variation in productivity from one year to the next.

Map 10, focusing on the variation in NPP in drylands only, shows that many of the areas with high variability in NPP are found in drylands–on all continents–the Great Plains of North America, southern Patagonia, the Sahel, Southern Africa, and much of central Asia and Australia. This variation may affect human behavior and household decisions. It may influence whether people migrate on a seasonal or permanent basis or whether they abandon livestock herding for a more sedentary, agrarian existence.

RAIN USE EFFICIENCY

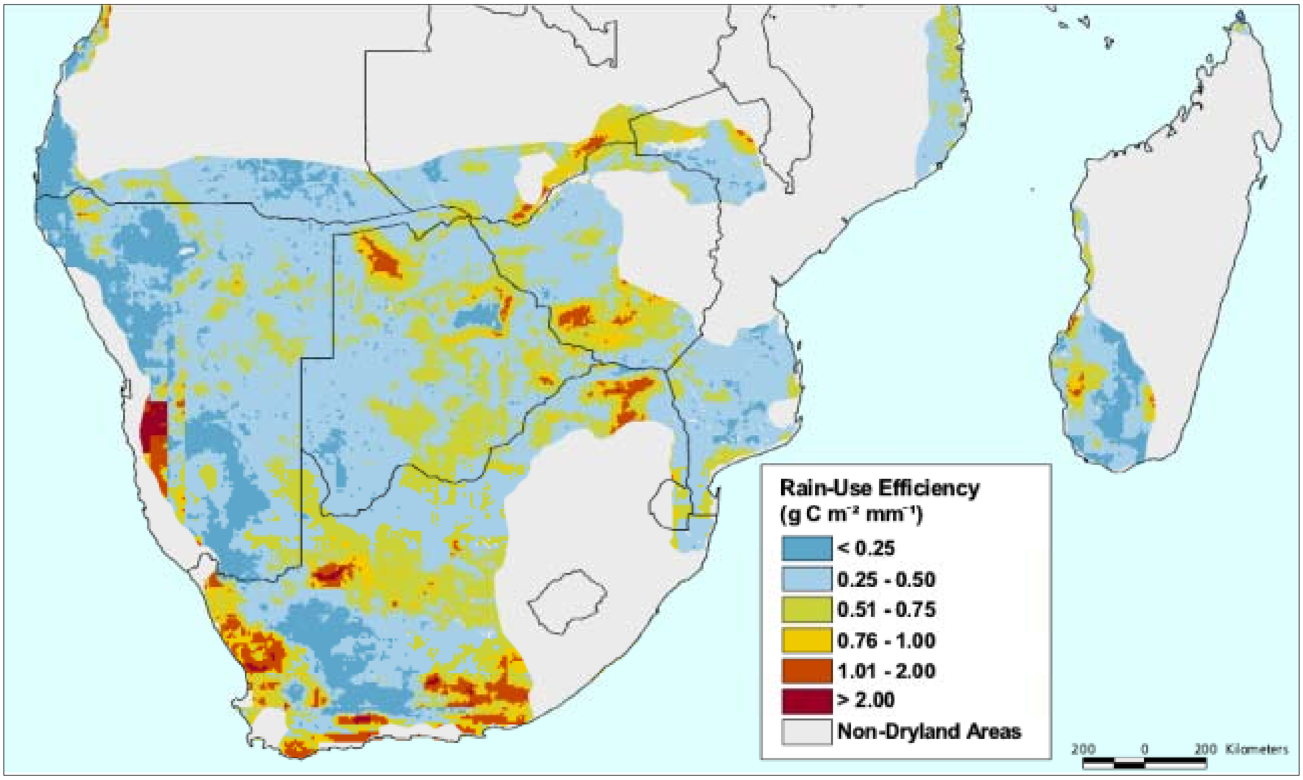
Rain use efficiency is the ratio of net primary productivity to rainfall. It normalizes vegetative production to rainfall and may be helpful in revealing trends in land degradation, by separating vegetation declines due to lack of rainfall from declines associated with longer-term degradation. This index can be calculated from satellite observations of NPP (modeled with annual integrals of NDVI) and rain gauge data. Some studies using local NPP observations have found strong correlations between declines in RUE and increases in livestock followed by reductions in rangeland condition. Further study is needed, however, to determine whether these local correlations hold on a regional scale.

Map 11: Rain Use Efficiency in Southern Africa (1981 - 1993)



Source: ESRI 1993; GLCCD 1998; Goetz et. al. 1999; Prince and Goward 1995.
Projection: Albers Equal-Area Conic, Central Meridian 20, Reference Latitude 1
Note: The values in this map represent rain-use efficiencies, expressed as the ratio of annual net primary productivity estimated with the GLO-PEM model to annual precipitation. A maximum rain-use efficiency of 11.50 occurs in Namibia's Namib Desert.

Map 12: Rain Use Efficiency in Drylands of Southern Africa (1981 - 1993)



Source: ESRI 1993; GLCCD 1998; Goetz et. al. 1999; Prince and Goward 1995.
Projection: Albers Equal-Area Conic, Central Meridian 20, Reference Latitude 1
Note: The values in this map represent rain-use efficiencies, expressed as the ratio of annual net primary productivity estimated with the GLO-PEM model to annual precipitation. A maximum rain-use efficiency of 11.50 occurs in Namibia's Namib Desert.

Map Description (11 and 12)

Map 11 shows the rain-use efficiency index for countries of southern Africa. Differences in the water balance of various climatic regimes make drylands influenced by the same climate more meaningful than cross-continental comparisons of RUE. This map shows the RUE indexes for a 13-year period. Low indexes, most extensive along the west coast, may indicate low biomass production regardless of rainfall patterns and thus possible land degradation; high indexes, scattered across the region and in several countries, may indicate high biomass production and potentially drylands in good condition.

Accurate interpretations of RUE require information on topography, soil texture, soil fertility, vegetation type, human population, and management regimes. Low and decreasing RUE could be due to various factors, including degradation and run-off, soil evaporation, and infertile soils. Conversely, high and increasing RUE may be due to factors such as run-on, fertilizer use, and changes in species composition.

Map 12 shows the RUE map of southern Africa clipped for drylands. Generally, much of the low RUE areas are included within drylands — areas with a ratio below .25 along the west coast from Angola south to South Africa. A large portion of the drylands in the region has indexes of less than .5. The less extensive, scattered areas of high RUE (ratios greater then 1) may indicate “bright spots,” or drylands that are in good condition in terms of biomass production.

Measuring Soil Condition

GLASOD

In 1987, the United Nations Environment Program (UNEP) requested an expert panel to produce, based on incomplete knowledge and in the shortest time possible, a scientifically credible global assessment of soil degradation (GLASOD). UNEP's recommendation led to the publication of a world map on the status of human-induced soil degradation at a scale of 1:10 million. This map is based on input from more than 250 scientists on soil degradation in the 21 regions into which the world was divided for analytical purposes.

UNEP's immediate objective in producing the map was to help decision– and policy– makers better understand the dangers of inappropriate land and soil management.

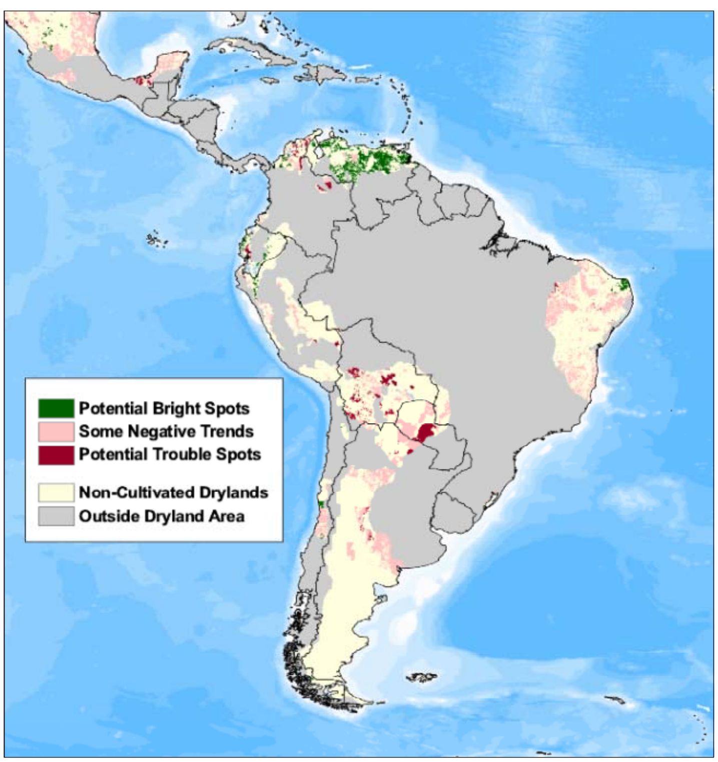
GLASOD is criticized today as inaccurate, subjective, and not appropriate for assessing soil degradation at the country-level. Despite these drawbacks, it remains the only database to define the status of human-induced soil degradation and the extent of desertification at the global scale.

ASSOD

In response to requests for more detailed information on soil degradation, the Asia Network on Problem Soils in 1993 recommended preparation of a soil degradation assessment for South and Southeast Asia (ASSOD) at a scale of 1:5 million. The methodology of this assessment reflects comments from the peer review of GLASOD. As a result, ASSOD has a more objective cartographic base and uses the internationally endorsed World Soils and Terrain Digital Database (SOTER) to delineate mapping units.

Like GLASOD, ASSOD focuses on displacement of soil material by water or wind and in-situ deterioration of soil by physical, chemical, and biological processes. ASSOD, however, places more emphasis on trends of degradation and the effects of degradation on productivity. Although an improvement over GLASOD, ASSOD is not without problems. The assessment of the degree, extent, and recent past rate of soil degradation is still based on expert opinion, and the scale (1:5 million) is still not adequate to guide national soil improvement policies.

Map 13: Soil Fertility in Cultivated Areas of America's Drylands



Drylands and Food Production

Drylands are generally subject to climate regimes that are not highly favorable to crop production. Low total rainfall and high variability in rainfall patterns present difficult challenges for growing crops. Nevertheless, local populations depend on these lands for producing food.

Source: GLCCD 1998; UNEP/GRID 1991; Wood et. al. 2000.
Projection: Geographic
Note: Cereal nutrient balances are estimated as the difference between mineral and organic fertilizer application and crop residue recycling for cereals (inputs) and the nutrients extracted in cereal grain (outputs). Nutrient balances were allocated to specific geographic areas using subnational 1993-95 production statistics and information on climate, soil, and elevation. Cereal yield trends are based on subnational 1975-95 data for rice, wheat, maize, and sorghum. The map of potential trouble spots and bright spots combine the nutrient balance and cereal yield trends information.

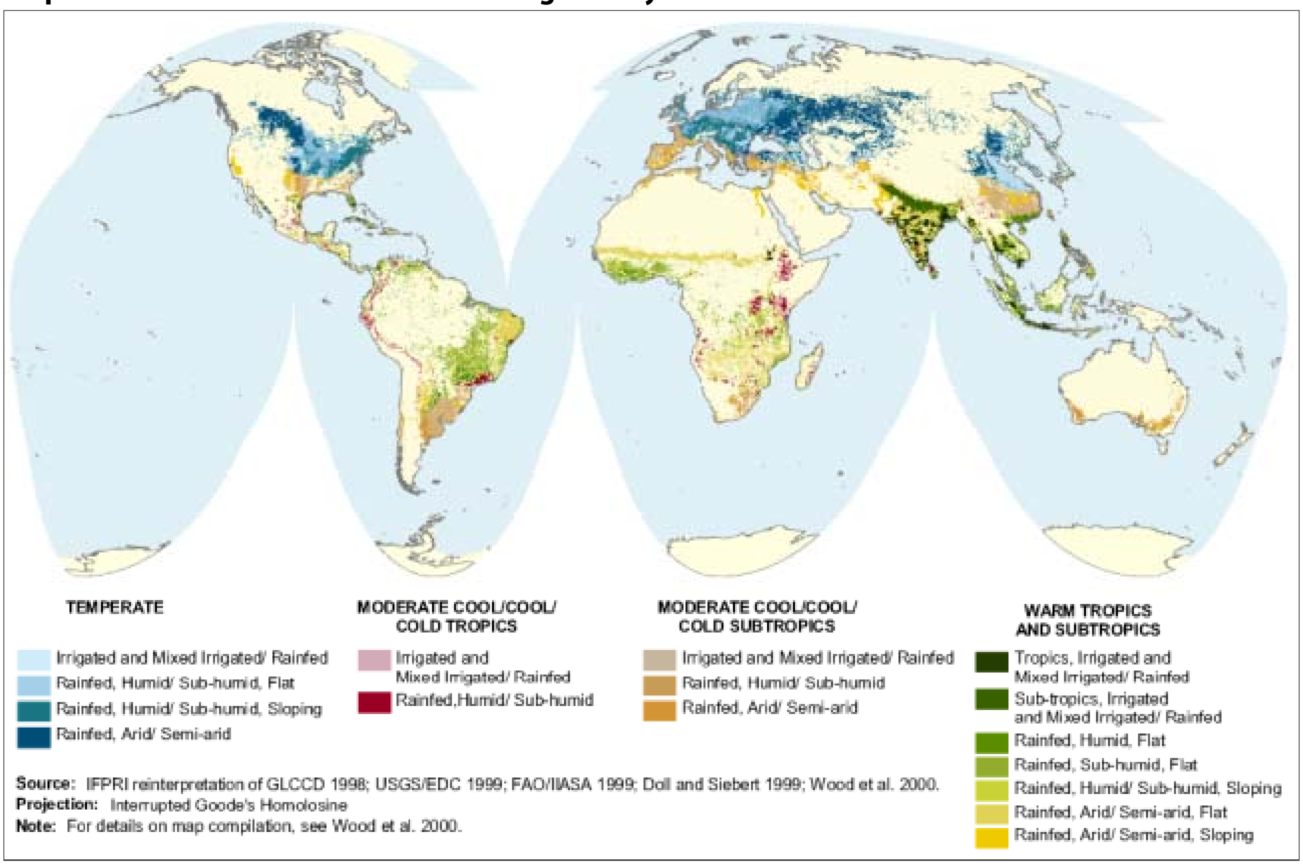
Map Description (Map 13)

In a spatial analysis of food production data for Latin America, the International Food Policy Research Institute (IFPRI) developed nutrient balance maps for the major Latin America and the Caribbean cereals: wheat, rice, maize, and sorghum. These maps were aggregated to one soil nutrient balance map for lands under cereals and combined with information on cereal yield trends for the years 1975 through 1995. A final map was created that superimposed the yield trend and nutrient balance maps to arrive at a soil fertility map of potential trouble spots and bright spots. In Map 13, we have clipped the IFPRI map to show only drylands of Latin America. On this map, potential bright spots are defined as stable or increasing yields with positive or only slightly negative nutrient balances (0 to –25 kg/ha per year). Potential trouble spots are identified as areas where yields are decreasing and nutrient deficits are greater than 25 kg/ha per year, or where yields are stable but the nutrient deficit is greater than 100 kg/ha per year.

This soil fertility map in cultivated areas of Latin America identifies a few potential bright spots in drylands, in Venezuela, Ecuador, Peru, Chile, and Brazil. Some negative trends show up most prominently in Mexico, Bolivia, Argentina, and Brazil. Potential trouble spots are found in Mexico, Colombia, Venezuela, Bolivia, and Argentina. These trouble spots may have experienced either decreasing cereal yields and high soil nutrient deficits or, stable yields but very high nutrient deficits.

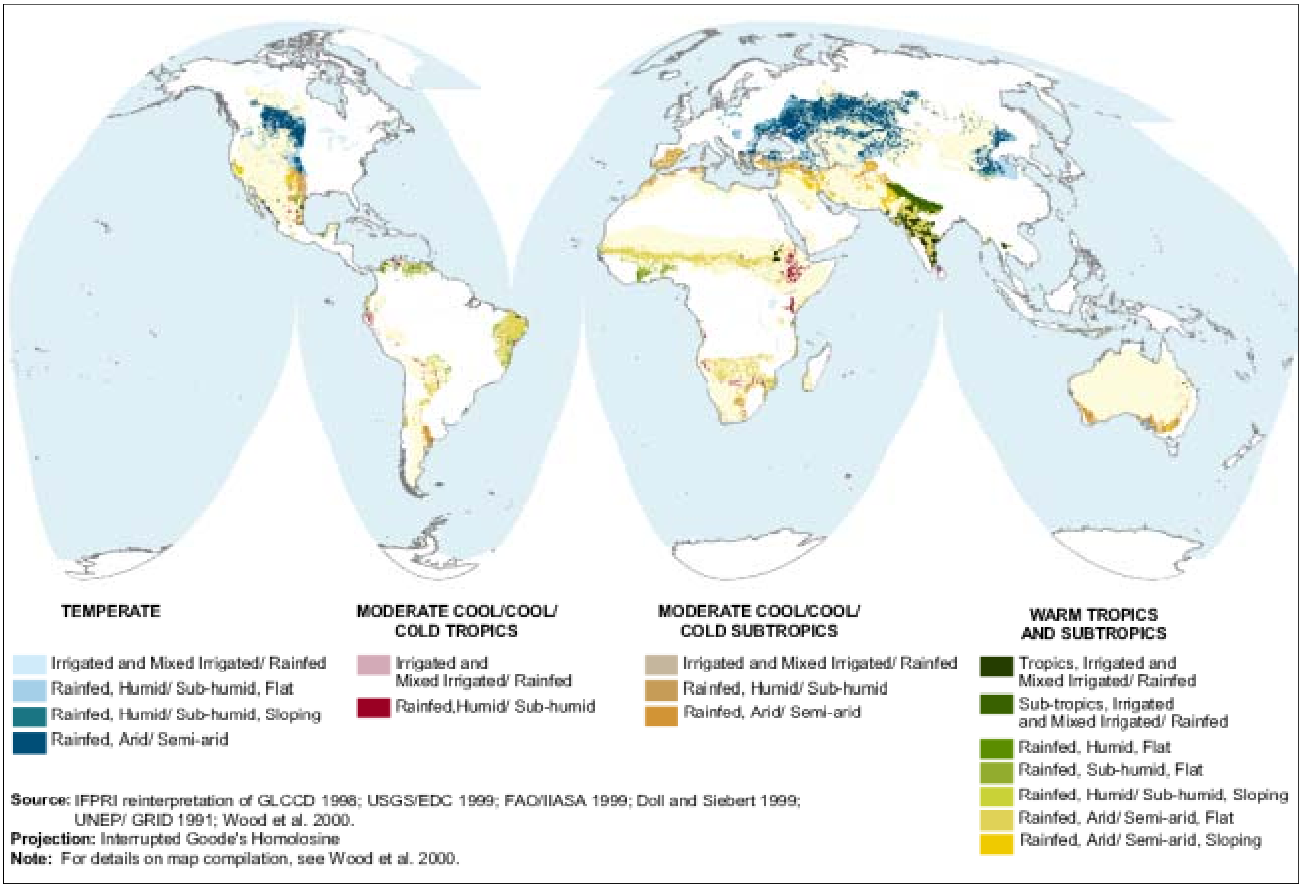
Caution should be used when interpreting these classifications. For example, the bright spots in Venezuela generally coincide with places of large application of fertilizer with high yields and excess nutrients in the soil. Field reconnaissance and further analysis must be used to verify specific conditions at each location.

Map 14: Characteristization of Global Agroecosystems



Source: IFPRI reinterpretation of GLCCD1998; USGS/EDC 1999; FAO/IIASA 1999; Doll and Siebert 1999; UNEP/GRID 1991; Wood et. al. 2000.
Projection: Interrupted Goode's Homosoline
Note: For details on map compilation, see Wood et. al. 2000

Map 15: Characteristization of Global Agroecosystems in Drylands



Source: IFPRI reinterpretation of GLCCD1998; USGS/EDC 1999; FAO/IIASA 1999; Doll and Siebert 1999; UNEP/GRID 1991; Wood et. al. 2000.
Projection: Interrupted Goode's Homosoline
Note: For details on map compilation, see Wood et. al. 2000

Map Description (14 and 15)

In Map 14, the International Food Policy Research Institute (IFPRI) combined agroclimatic, slope, and irrigated area data with agricultural extent. While not a true systematic classification of agroecosystems, it identifies areas which are likely to share common features and to face similar environmental constraints and opportunities. Sixteen agroecosystem groupings are included with the majority of agricultural land found in temperate and warm tropic/ subtropical areas. Arid and semi-arid lands comprise approximately one third of the total agricultural extent. Although dry sub-humid zones are not mapped separately here, if they were included with the arid and semi-arid lands, drylands would comprise over one third of the global lands used for agriculture.

When drylands are isolated from the global extent of agroecosystems, non-agricultural drylands are more easily spotted (Map 15). These non-agricultural drylands generally coincide with the arid zone; semi-arid and dry sub-humid zones are more typically cropland. The non-agricultural drylands also tend to coincide with the livestock only, rangeland-based livestock production system as shown in Map 6 (See, "Livestock").

Table 8. Food Production in Dryland Countries

	Cropland (Total hectares) (000) 1999	Average Cereal Crop Yields (kg per hectare) 1999-2001 {c}	Average Cereal Crop Yields Percent change since 1989-91	Variation in domestic Cereal Production (% variation from mean) 1992-2001	Net trade of cereals (imports - exports) as a percent of consumption 2000 {d}	Average daily per capita calorie supply {a,b} (kilocalories) 1999	Irrigated land as a percentage of total cropland 1999
ASIA	**16,068**	**3,678**	**X**	**3.9**	**4**	**2,710**	**35.5**
Armenia	560	1,675	X	13.0	67	2,167	51.3
Kazakhstan	30,135	1,162	X	32.5	(111)	2,181	7.8
Turkmenistan	1,695	1,771	X	22.7	X	2,746	106.2
Uzbekistan	4,850	2,603	X	19.4	15	2,871	88.3
EUROPE	**7,682**	**4,187**	**X**	**4.7**	**(5)**	**3,230**	**7.9**
Moldova, Rep	2,181	2,437	X	19.5	(0)	2,728	14.1
MIDDLE EAST & N. AFRICA	**4,367**	**2,585**	**14**	**6.2**	**44**	**3,003**	**27.8**
Afghanistan	8,054	1,285	7	10.2	X	1,755	29.6
Iran, Islamic Rep	19,265	1,806	32	9.9	44	2,898	39.3
Iraq	5,540	530	(43)	25.1	78	2,446	63.6
Kuwait	7	2,260	(45)	26.4	100	3,167	100.0
Morocco	9,445	670	(50)	48.8	72	3,010	13.8
Syrian Arab Rep	5,502	1,304	95	16.5	33	3,272	21.6
Tunisia	5,100	1,109	(0)	36.2	68	3,388	7.5
SUB-SAHARAN AFRICA	**3,616**	**1,221**	**6**	**6.9**	**13**	**2,238**	**3.8**
Botswana	346	146	(52)	52.4	86	2,288	0.3
Burkina Faso	3,450	880	23	7.8	8	2,376	0.7
Gambia	200	1,298	20	25.1	45	2,598	1.0
Namibia	820	347	(28)	36.5	X	2,096	0.9
Senegal	2,266	854	4	11.3	44	2,307	3.1

Source:
WRI, Earth Trends, October 7, 2002.

Notes:
Negative numbers are shown in parentheses.

a. Data are collected from Oct. 1 to Sept. 30. Data from 1999, for example, are actually from October 1998 to September 1999.

b. 1 kilocalorie = 1 Calorie (U.S.) = 4.19 kilojoules. Figures represent only the average supply available for the population as a whole and do not indicate what is actually consumed by individuals.

c. Data from three years are averaged to produce the above values.

d. Includes food aid.

In this analysis, we have examined various statistics on food production in countries with extensive dryland (at least 90 percent of total land area). Of these 17 countries, total cropland varies from as few as 7,000 hectares in Kuwait to over 30 million hectares in Kazakhstan. Noteworthy, is that average cereal crop yields, for the period 1999-2001, when compared to the respective regional averages, are all below average (with one exception: Gambia) with large declines in some countries of over 50 percent. The lowest average cereal crop yields for this period were in Sub-Saharan Africa, in Botswana and Namibia, with less than 350 kilograms per hectare.

Equally noteworthy, are the data on variation in domestic cereal production (or the average percent variation from the mean in cereal production). As expected for countries in regions characterized by variability in rainfall, the variation in domestic cereal production is greater for these countries with extensive dryland than the regional averages. The variation in domestic cereal production, between 1992 and 2001, is 20 percent or higher in 9 countries where regional average variation from the mean range from approximately 4 percent in Asia to 7 percent in Sub-Saharan Africa. When variation in cereal production is high, it can indicate unstable food production and thus an unpredictable food supply, especially when most of the cereal crop is consumed locally as a primary dietary mainstay.

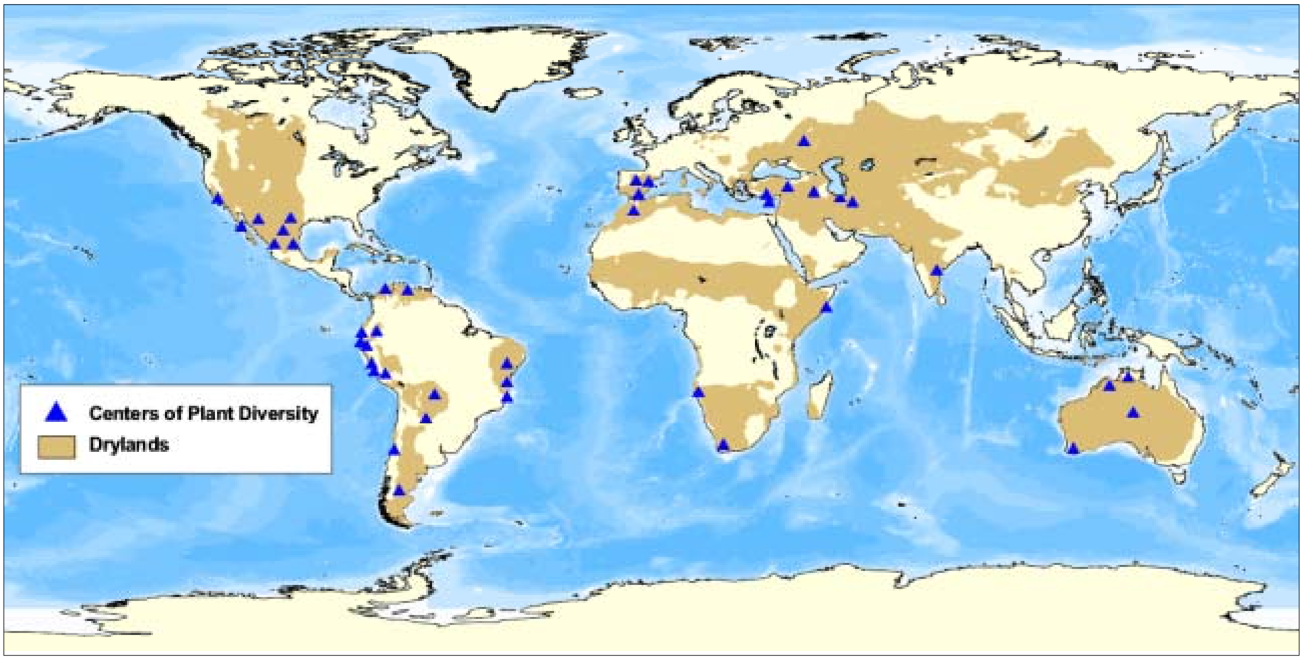
Two additional country-level statistics suggest a more complex pattern for food production in drylands. In many of these dryland countries (10 of 17), in the year 2000, net trade of cereals as a percent of consumption (including food aid), were at or above their respective regional averages. In addition, as a potential indicator of whether a country has achieved sufficient food security to keep its population healthy, the values for average daily per capita calorie supply show that more than half of the countries are above average. Thus, below average cereal crop yields and high variability in cereal production characterize these dryland countries, but there are exceptions and some countries appear to be able to produce sufficient food to support local populations.

Another measure of potential food production in drylands is the amount of land under irrigation. When compared to their respective regional averages, for the year 1999, half of the 17 dryland countries were below average in irrigated land as a percent of cropland. Sub-Saharan Africa had a very low regional average, but the five dryland countries within this regional all still fall below this low average. Additional countries with very low irrigated land in relation to total cropland include Kazakhstan and Tunisia.

Drylands and Biodiversity

Dryland species must adapt to an environment known for its variation in climate, both in terms of temperature and water availability. Some areas have been identified as especially important to the survival of these uniquely adapted plants and animals: Centers of Plant Diversity; Endemic Bird Areas; Protected Areas; and Global 200 Ecoregions.

Map 16: Centers of Plant Diversity in Drylands



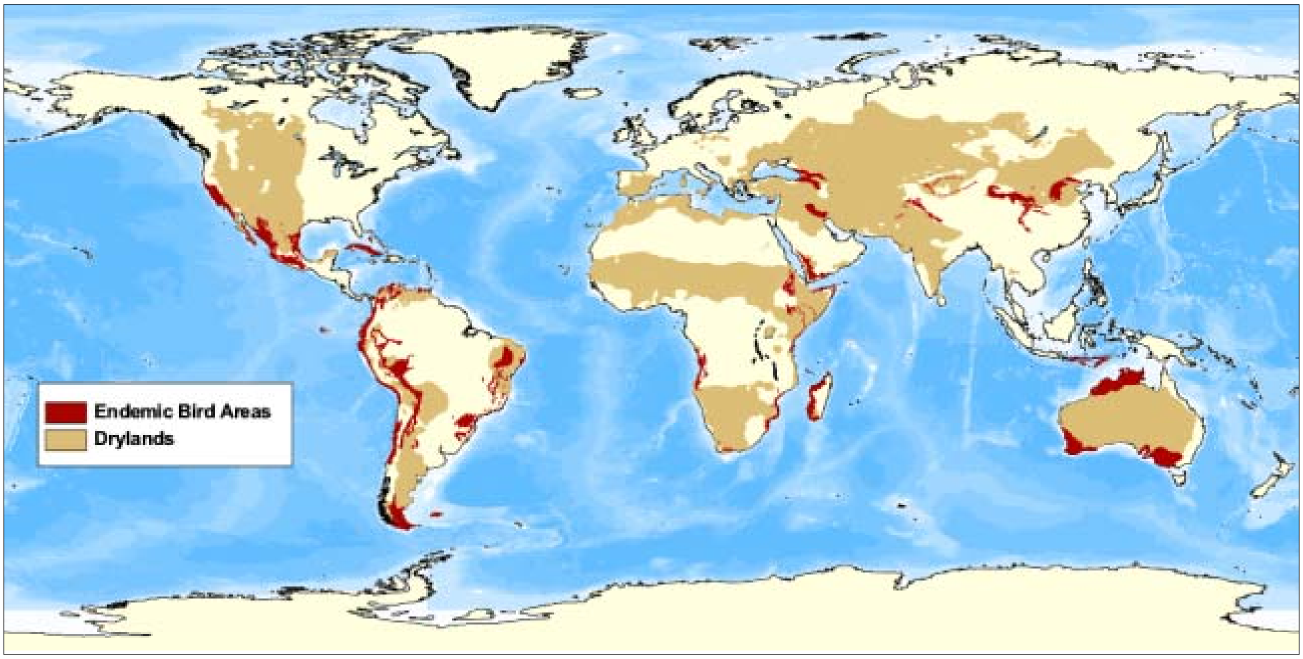
Source: Davis et. al. 1994 and 1995; UNEP/GRID 1991.
Projection: Geographic

Map Description (Map 16)

The IUCN-World Conservation Union and World Wildlife Fund-US (WWF-US) have identified 234 Centers of Plant Diversity (CPDs) worldwide. To qualify as CPDs, mainland centers must contain at least 1,000 vascular plant species and at least 10 percent endemism; island centers must contain at least 50 endemics or at least 10 percent endemic flora. CPDs house important gene pools of plants of value to humans, encompass a diverse range of habitat types, support a significant proportion of species adapted to special soil conditions, and are subject to the threats of large-scale devastation. The size of CPDs ranges from approximately 100 to more than 1 million square kilometers.

The 234 CPDS can be mapped according to aridity zone. At least 42 of the 234 CPDs are found in drylands. These dryland CPDs are more abundant in lower latitudes, especially in South America. However, every region has at least one dryland CPD and thus, each region includes an area where the diversity of dryland plants is high and where conservation practices could safeguard a great variety of species. For example, the Southwest Botanical Province in Western Australia, an area of nearly 310,000 square kilometers of Eucalypt forests and woodlands, has approximately 2,472 vascular plant species restricted entirely to the province.

Map 17: Endemic Bird Areas in Drylands



Source: Stattersfield et. al. 1998; UNEP/GRID1991.
Projection: Geographic

Map Description (Map 17)

Diversity in drylands has been identified in areas with a large number of endemic bird species. Birdlife International has identified 217 endemic bird areas (EBAs) worldwide. An EBA is defined as:

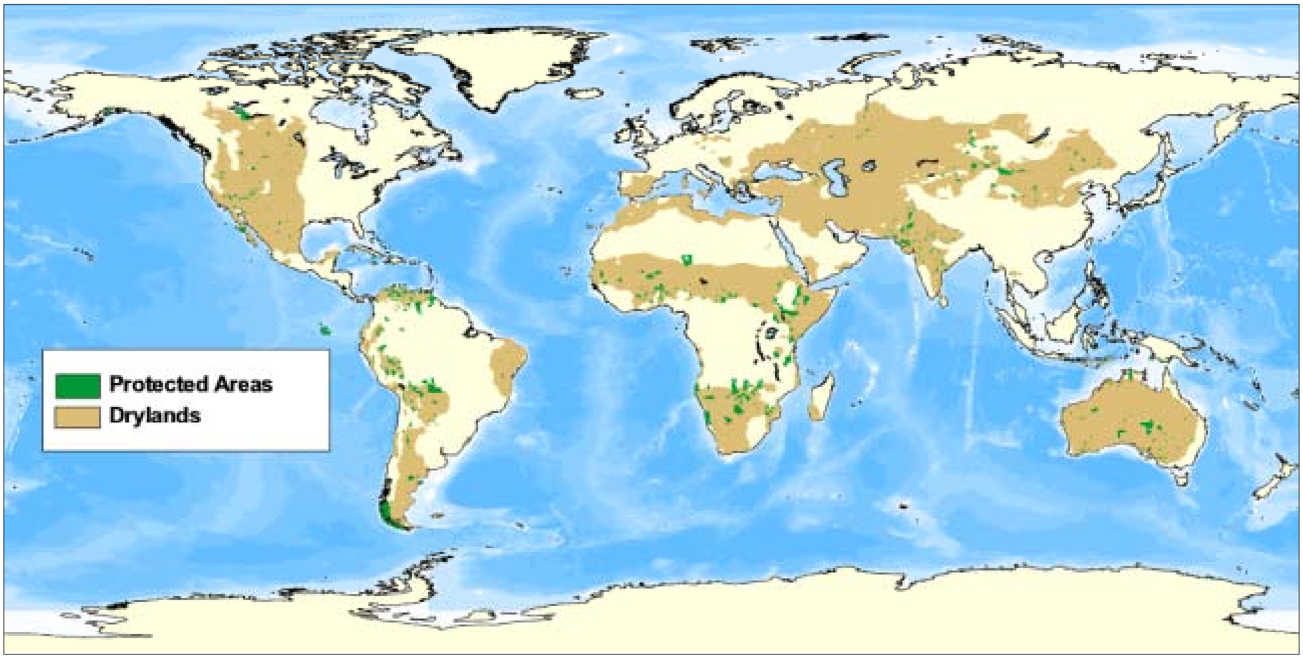
An area which encompasses the overlapping breeding ranges of restricted-range bird species, such that the complete ranges of two or more restricted-range species are entirely included within the boundary of the EBA. This does not necessarily mean that the complete ranges of **all** of an EBA's restricted-range species are entirely included within the boundary of that single EBA, as some species may be shared between EBAs.

Birdlife International defines restricted-range species as all landbirds which have had a breeding range of less than 50,000 square kilometers throughout historical times (i.e. post-1800, in the period since ornithological recording began). Some birds that have small ranges today were historically widespread, and are therefore not treated as restricted-range species. Extinct birds that qualify on range size are included.

Approximately 60 EBAs are found in whole or in part within the three dryland aridity zones. These EBAs range from 11 to 100 percent dryland; 42 (or 70 percent) are at least 40 percent dryland. They are most extensive in South America and Australia, and are not present at all in Europe. All other regions, Africa, Middle East, Asia, and North and Central America contain at least one EBA which is at least partially dryland.

Each EBA is assigned a biological importance rank from 1 to 3 (most biologically important) on the basis of its size and the number and taxonomic uniqueness of its restricted-range species. Several dryland EBAs have the highest rank for biological importance. For example, the Central Chile EBA is 160,000 square kilometers of scrub and semi-arid drylands with 8 restricted-range species.

Map 18: Protected Areas in Drylands



Source: UNEP-WCMC 1999;UNEP/GRID 1991.
Projection: Geographic

Map Description (Map 18)

Protected areas around the globe have been identified by IUCN-The World Conservation Union and mapped by UNEP-World Conservation Monitoring Centre (WCMC). IUCN defines protected area as:

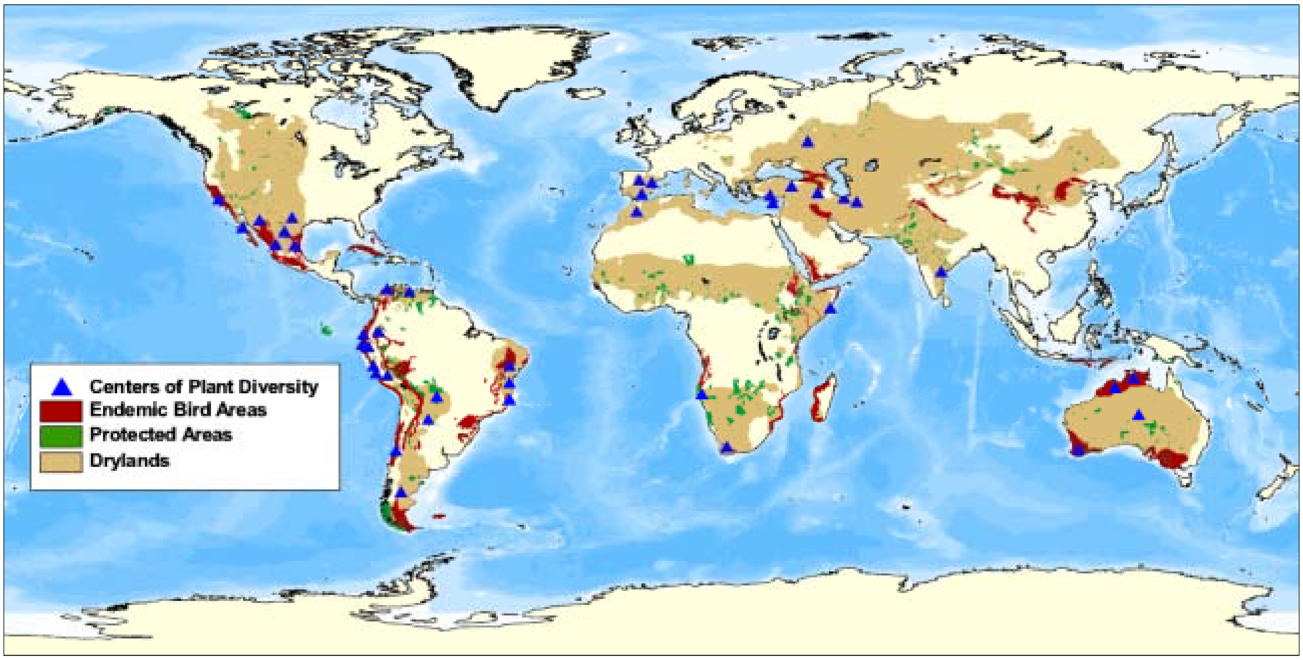
An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.

IUCN assigns each protected area to one of six management categories. These categories vary in management purpose from scientific research to sustainable use, and include:

- strict nature reserves and wilderness areas (Category I);
- national parks (Category II);
- national monuments (Category III);
- habitat or species management areas (Category IV);
- protected landscapes (Category V); and
- areas managed mainly for the sustainable use of natural ecosystems (Category VI).

Approximately 1300 protected areas—in Categories I-VI—are located in whole or in part within the three dryland aridity zones. Of these 1300 protected areas, over three-fourths are entirely dryland; nearly 90 percent are at least 40 percent dryland. The dryland protected areas are most extensive in South America and Africa, followed by Asia, Australia, and North America.

Map 19: Biodiversity Conservation in Drylands



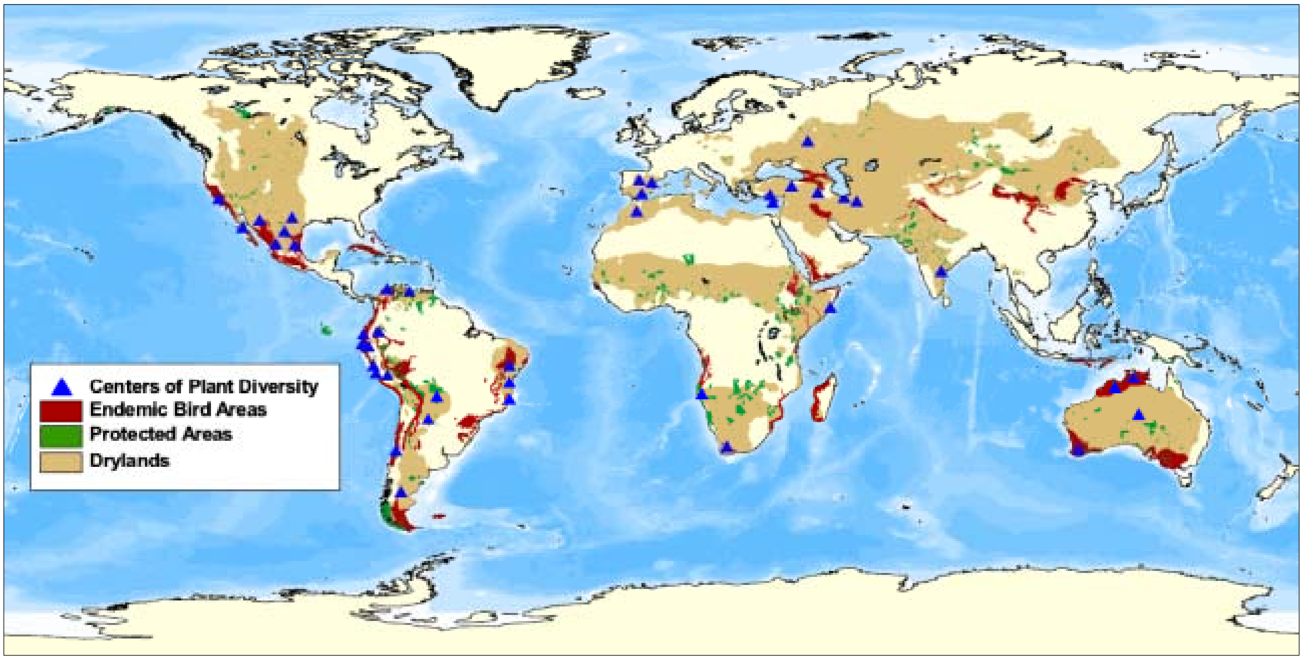
Source: Davis et. al. 1994 and 1995; UNEP-WCMC 1999; Stattersfield et. al. 1998; UNEP/GRID 1991.
Projection: Geographic

Map Description (Map 19)

When all three types of biodiversity conservation areas are combined on one map—Centers of Plant Diversity, Endemic Bird Areas, and Protected Areas—several patterns appear that are worthwhile noting in relation to drylands:

- Every continent has some type of conservation area designated within the dryland aridity zones and thus preserving dryland biodiversity;
- Endemic Bird Areas and Centers of Plant Diversity within drylands are generally close to or overlap with each other; both are poorly represented in much of central Asia, the drylands of Africa, and the drylands of Canada and the United States.
- South America and Australia appear to be the regions best represented by all three dryland biodiversity conservation areas: EBAs, CPDs, and protected areas.

Map 20: Global 200 Ecoregions in Drylands



Source: Olson and Dinerstein1997; WWF-US 1999; UNEP/GRID 1991.
Projection: Geographic

Map Description (Map 20)

The World Wildlife Fund-US has identified 232 ecoregions worldwide as "outstanding examples of the world's diverse ecosystems and priority targets for conservation actions." Of the 138 terrestrial ecoregions within this "Global 200," 24 can be characterized as dryland ecoregions with at least 40 percent land area within the dryland aridity zones (Table 9: Global 200 Ecoregions in Drylands).

Table 9: Global 200 Ecoregions in Drylands

Ecoregion Name	Percent Dryland
Central Asian deserts	100
Sandy Australian deserts and central ranges	100
Ethiopian highlands	100
Chihuahuan and Tehuacan deserts	98
Carnavon xeric scrub	97
Horn of Africa acacia savannas	95
Namib and Karoo deserts and shrublands	89
Southwest Australian shrublands and woodlands	88
Daurian/Mongolian steppe	87
Sonoran and Baja deserts	86
Madagascar spiny desert	84
Patagonian steppe and grasslands	83
Kaokoveld desert	79
California montane chaparral and woodlands	78
Fynbos	74
Sudanian savannas	70
Northern Australia and Trans-Fly savannas	68
Mediterranean shrublands and woodlands	67
Bolivian lowland dry forests	66
Galapagos Islands scrub	65
Mexican pine-oak forests	65
Llanos savannas	56
Chilean mattoral	44
Southern Mexican dry forests	42

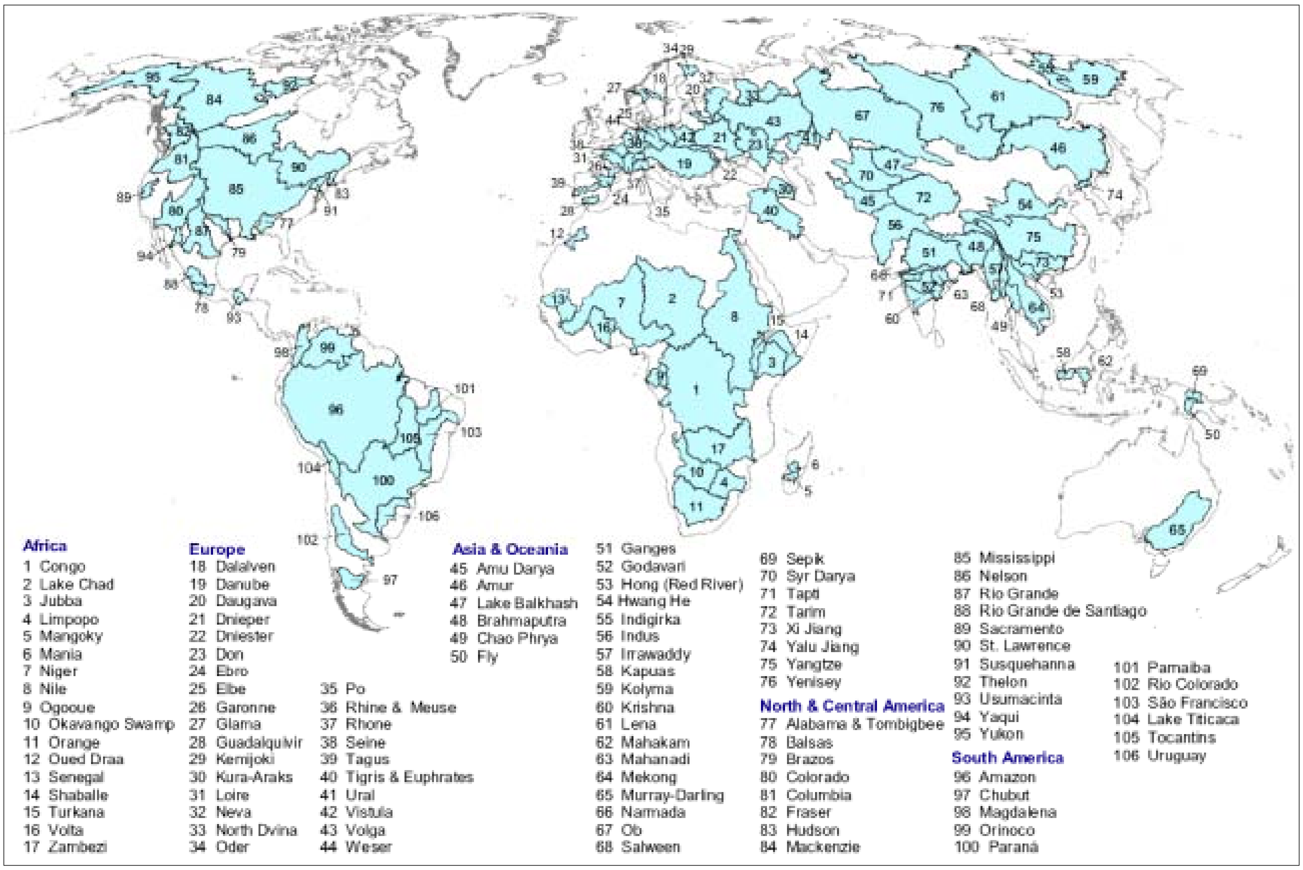
Source: Olson and Dinerstein 1997; WRI calculations based on ESRI 1993 and UNEP/GRID 1991.

The dryland ecoregions included in the Global 200 were selected on the basis of species richness, species endemism, unique higher taxa, unusual ecological or evolutionary phenomena, and global rarity of major habitat types. For example, the Madagascar Dry Forests along the western coast of Madagascar was selected because it contains some of the world's richest tropical dry forests with very high island and local endemism. It supports one of the world's most threatened reptiles (the angonoka tortoise (*Geochelone yniphora*). These 24 dryland ecoregions contain some of the most important drylands biodiversity in the world today.

Drylands and Freshwater

Freshwater resources in drylands are limited and variable in supply. This lack of water and its variability render the ecosystem goods and services in drylands provided by surface water, groundwater, and wetland habitats critically important. Irrigation water for crop production in drylands is discussed more fully under food production. This section examines freshwater resources in drylands in terms of watershed characteristics and projected water supply.

Map 21: Major Watersheds

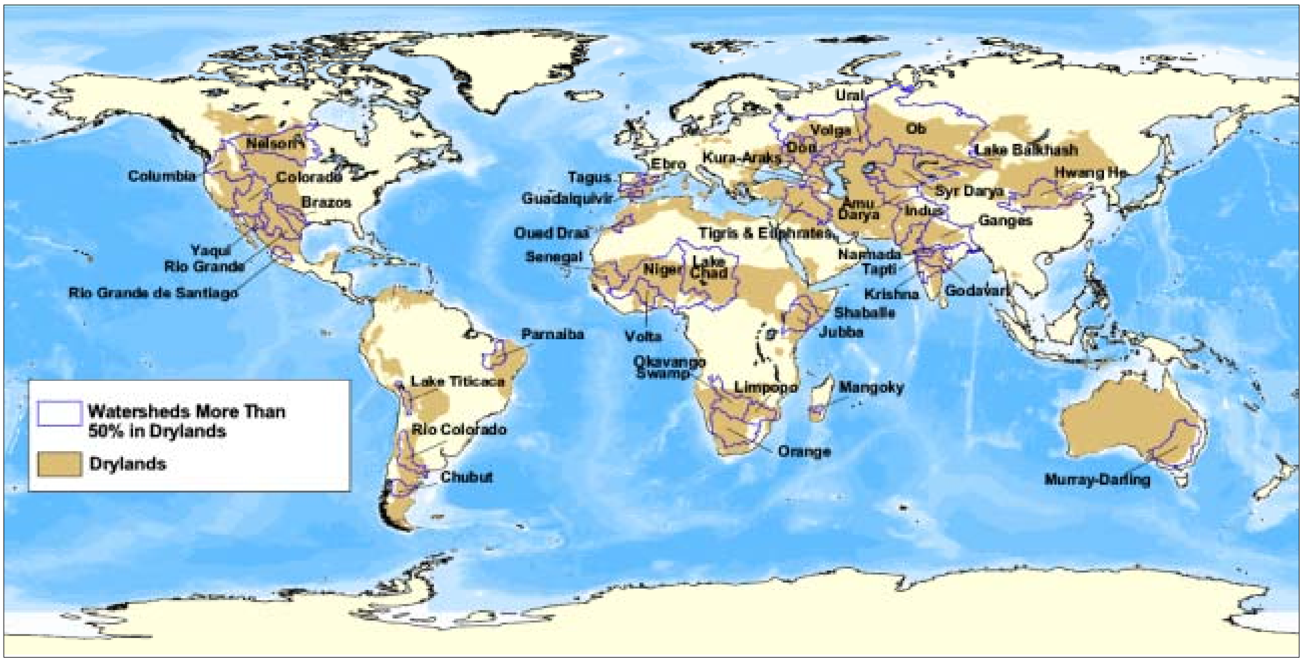


Source: Revenga et al. 1998.

Map Description (Map 21)

In a joint study by WRI and Worldwatch Institute, 106 major watersheds of the world were mapped and described according to a series of characteristics. Watersheds were defined as the entire area drained by a major river system or by one of its main tributaries. At least one watershed was mapped for each continent. This map shows all 106 watersheds numbered by continent. The numbering begins in Africa and progresses through Europe, Asia, North and Central America, and ends with South Africa. The names of the basins are listed by region below the map.

Map 22: Major Watersheds in Drylands



Source: Revenga et. al. 1998; UNEP/GRID 1991.
Projection: Geographic

Map Description (Map 22)

In Map 22, we have superimposed the aridity zone map over the watershed map and selected basins with at least 50 percent of their area within the dryland aridity zones. From the 106 major watersheds of the world (Map 21), we identified 42 that fall within drylands.

Summary statistics of these basins show that their area ranges from approximately 52 thousand square kilometers to nearly 3 million square kilometers (Table 10).

Table 10: Major Watersheds in Drylands

Major Watersheds	Modeled Watershed Area {a} (km²)	Countries within the Watershed (number)	Average Population Density (per km²)	Percent of Watershed: Crop-land	Forest	Grass-land	Built-up Area {b}	Irrigated Area	Wetlands	Ramsar Sites {c} (number)	Water Available Per Person (m³/person/year)	Large Dams in Progress (number)	Degree of River Fragmentation {d}
ASIA													
Amu Darya	534,739	5	39	22.4	0.1	57.3	3.7	7.5	0.0	0	3,211	2	High
Ganges	1,016,124	4 e	398	72.4	4.2	13.4	6.3	22.7	17.7	4	X	5	X
Godavari	319,810	1	203	64.0	6.8	22.5	6.7	11.7	1.2	0	1,602	0	X
Hwang He	944,970	1	157	29.5	1.5	60.0	5.9	7.2	1.1	0	361	7	High
Indus	1,081,718	4	163	30.0	0.4	46.4	4.6	24.1	4.2	10	830	3	X
Krishna	226,037	1	263	66.4	2.8	22.7	8.8	16.2	16.2	0	786	2	X
Kura-Araks	205,037	5	75	54.0	7.1	30.6	6.3	10.7	0.9	2	1,121	4	High
Lake Balkhash	512,015	2	11	23.2	4.0	61.1	1.5	1.9	4.7	0	439	0	X
Narmada	96,271	1	177	76.5	0.8	15.8	6.1	24.0	0.8	0	2,159	2	X
Ob	2,972,493	4	10	36.9	33.9	16.0	3.0	0.5	11.2	4	14,937	0	Medium
Syr Darya	782,617	4	28	22.2	2.4	67.4	3.2	5.4	2.0	1	1,171	4	High
Tapti	74,627	1	239	78.3	0.2	14.7	7.6	13.3	0.8	0	1,107	1	X
Tigris & Euphrates	765,742	4	57	25.4	1.2	47.7	6.2	9.1	2.9	0	2,189	19	X
EUROPE													
Don	458,694	2	46	83.1	1.4	5.4	8.8	3.2	0.5	1	1,422	0	High
Ebro	82,587	1 e	34	58.2	5.1	22.1	13.7	10.0	0.9	4	8,235	5	High
Guadalquivir	52,664	1	73	52.7	0.5	27.2	18.9	10.4	3.2	3	2,645	1	X
Tagus	78,467	2	118	46.8	0.1	34.8	16.6	5.2	1.6	2	2,248	0	High
Ural	244,334	2	14	59.3	2.3	33.4	4.2	0.9	0.2	0	2,003	0	X
Volga	1,410,951	2 e	42	60.2	22.5	7.3	8.2	0.4	1.1	2	4,260	0	High
AFRICA													
Jubba	497,626	3	12	6.6	2.7	87.9	0.2	0.1	3.5	2	1,076	0	X
Lake Chad {f}	2,497,738	8	12	3.1	0.2	45.2	0.2	0.0	8.2	1	7,922	0	Low
Limpopo	421,123	4	32	26.3	0.7	67.7	4.5	0.9	2.8	1	716	0	High
Mangoky	58,851	1	18	4.5	3.3	90.8	0.1	2.3	0.2	0	19,059	0	Low
Niger	2,261,741	10	32	4.4	0.9	68.6	0.5	0.1	4.1	6	4,076	1	High
Okavango {g}	721,258	4	2	5.5	1.7	91.1	0.2	0.0	4.1	1	X	0	X
Orange	941,351	4	11	6.0	0.2	85.0	2.2	0.5	0.8	1	1,050	1	High
Oued Draa	114,544	3	10	0.3	0.2	12.0	0.5	3.2	0.2	0	2	1	X
Senegal	419,575	4	10	4.8	0.1	68.2	0.1	0.0	3.6	4	5,775	0	High
Shaballe	336,604	2	30	7.1	1.2	87.9	0.1	0.5	1.8	0	X	0	X
Volta	407,093	6	42	10.4	0.7	85.6	0.5	0.1	4.6	3	2,054	0	High
NORTH & CENTRAL AMERICA													
Brazos	137,098	1	18	25.0	1.9	58.8	13.8	5.6	14.8	0	1,288	0	X
Colorado	703,148	2	10	0.9	17.0	74.9	6.9	2.0	2.5	0	2,105	1	High
Columbia	657,501	2	9	6.4	50.0	35.5	7.3	3.6	6.3	1	39,474	0	High
Nelson-Saskatchewan	1,093,141	2	5	47.4	31.9	6.1	7.1	0.5	86.8	5	15,167	0	High
Rio Grande	607,965	2	18	5.2	7.5	80.9	6.0	2.6	2.1	1	621	0	X
Rio Grande de Santiago	136,694	1	111	4.2	36.3	45.0	13.9	9.0	0.0	0	655	0	High
Yaqui	79,162	2	8	1.9	61.5	33.0	3.0	2.1	0.0	0	173	0	X
SOUTH AMERICA													
Chubut	182,622	2	1	0.6	24.8	67.7	0.6	0.0	0.0	0	171,362	0	X
Lakes Titicaca & Salar de Uyuni	193,090	3	7	0.6	0.1	89.4	0.9	0.4	0.0	5	15,980	0	X
Parnaíba	322,887	1	10	44.8	5.8	47.4	1.8	0.1	18.8	0	7,729	0	Medium
Rio Colorado	403,005	2	6	9.7	1.1	71.2	2.0	1.3	2.0	1	3,196	0	X
OCEANIA													
Murray-Darling	1,050,116	1	2	28.4	8.0	62.1	1.2	1.6	3.4	9	11,549	0	X

Source:
UNDP et. al 2000. For more detailed source notes please check this reference:
Data Table FW.3, p. 280 and pp. 338-340; also available on the web at www.wri.org.

Notes:
For more detailed notes and definitions of indicators, please see source listed above.
Percentages presented in this table do not add up to 100 because different sources were used to estimate land cover and land use within watersheds, land cover types overlap, and not all land cover types were accounted for. "0" is either zero or less than one-half the unit of measure.
a. Watershed area was digitally derived from elevation data using a geographic information system;
thus, area may differ from other published sources.
b. Based on stable nighttime lights data. These figures overestimate the actual area lit.
c. Sites designated as "wetlands of international importance" under the Convention on Wetlands.
d. Indicates the level of modification of a river due to dams, reservoirs, interbasin transfers, and irrigation consumption.
e. Countries that have <1 percent area in the watershed are excluded.
f. Watershed includes intermittent tributaries in northern Chad, Niger, and Algeria.
g. Watershed includes intermittent tributaries in Botswana (northern Kalahari Desert).

A summary of some of the indicators for these dry basins include the following:

- These basins include a wide range of population densities, from an average of 1 person per square kilometers (Chubut: Map 23) to an average of 398 people per square kilometers (Ganges: Map 24);

- The major dryland basins of Asia and Europe tend to have larger percentages of their area in cropland and built-up area than other regions of the world;

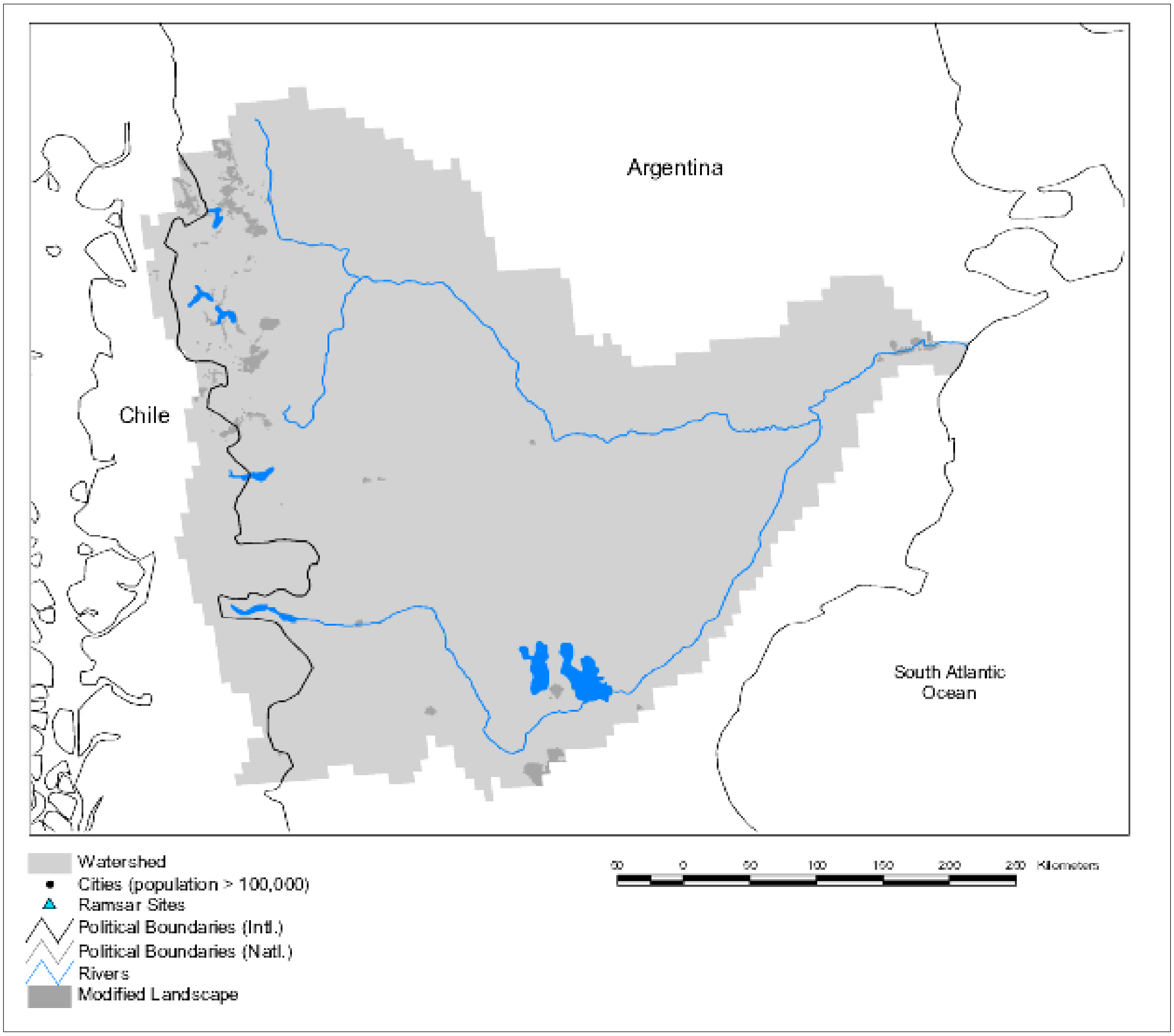
- These major dryland basins of Asia and Europe also tend to have larger percentages of irrigated area, up to as high as 24 percent (Indus and Narmada), contrast ing with the dryland basins in the remaining regions, such as Senegal (Map 25) without any irrigated land;

- The percent of these major dryland basins in wetland is generally low, but over half of them contain at least one Ramsar site and some contain over five Ramsar sites;

- These basins tend to have very few or not any large dams under construction, with one major exception: Tigris & Euphrates (Map 26) with 19 large dams in progress.

- Although generally without large dams in progress, many (where data are available) exhibit a high degree of modification (i.e. existing dams, reservoirs, interbasin transfers, and irrigation consumption), including many in Asia such as the Huang He (Map 27).

Map 23: Chubut Watershed

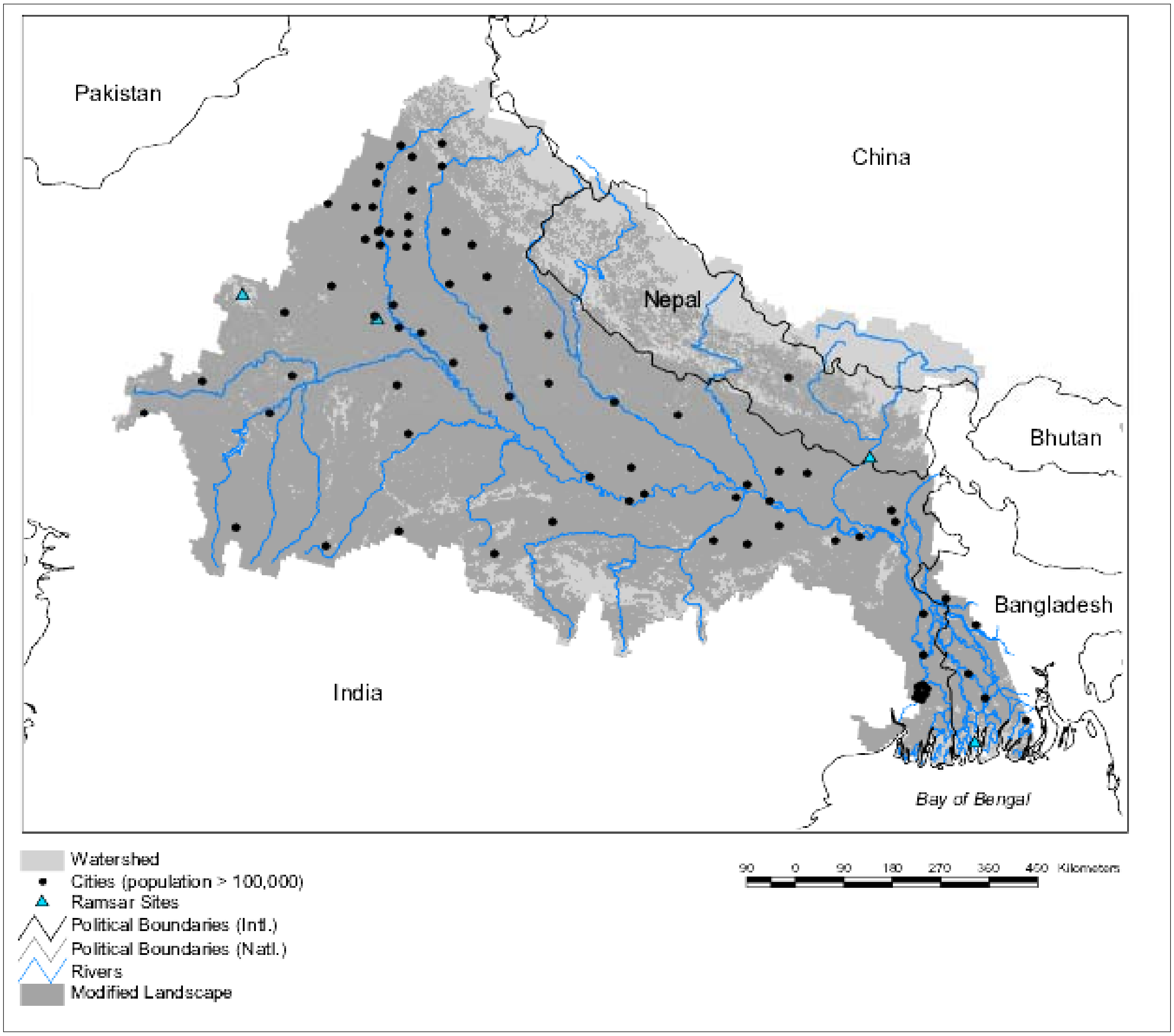


Source: *Ecological Value and Vulnerability.* Washington, DC: World Resources Institute.

Statistics for the Chubut Basin:

Basin Area: 182,631 sq.km.
Forest: 25%
Population Density: 2 people per sq.km.
Cropland: 1%
Urban Growth Rate: —
Cropland Irrigated: 0%
Large Cities: 0
Developed: 1%
Total Fish Species: —
Shrub: 0%
Fish Endemics: —
Grassland: 67%
Threatened Fish Species: 0
Barren: 5%
Endemic Bird Areas: 1
Loss of Original Forest: 28%
Ramsar Sites: 0
Deforestation Rate: —
Protected Areas: 3%
Eroded Area: 0%
Wetlands: 0%
Large Dams: 2
Planned Major Dams: —

Map 24: Ganges Watershed



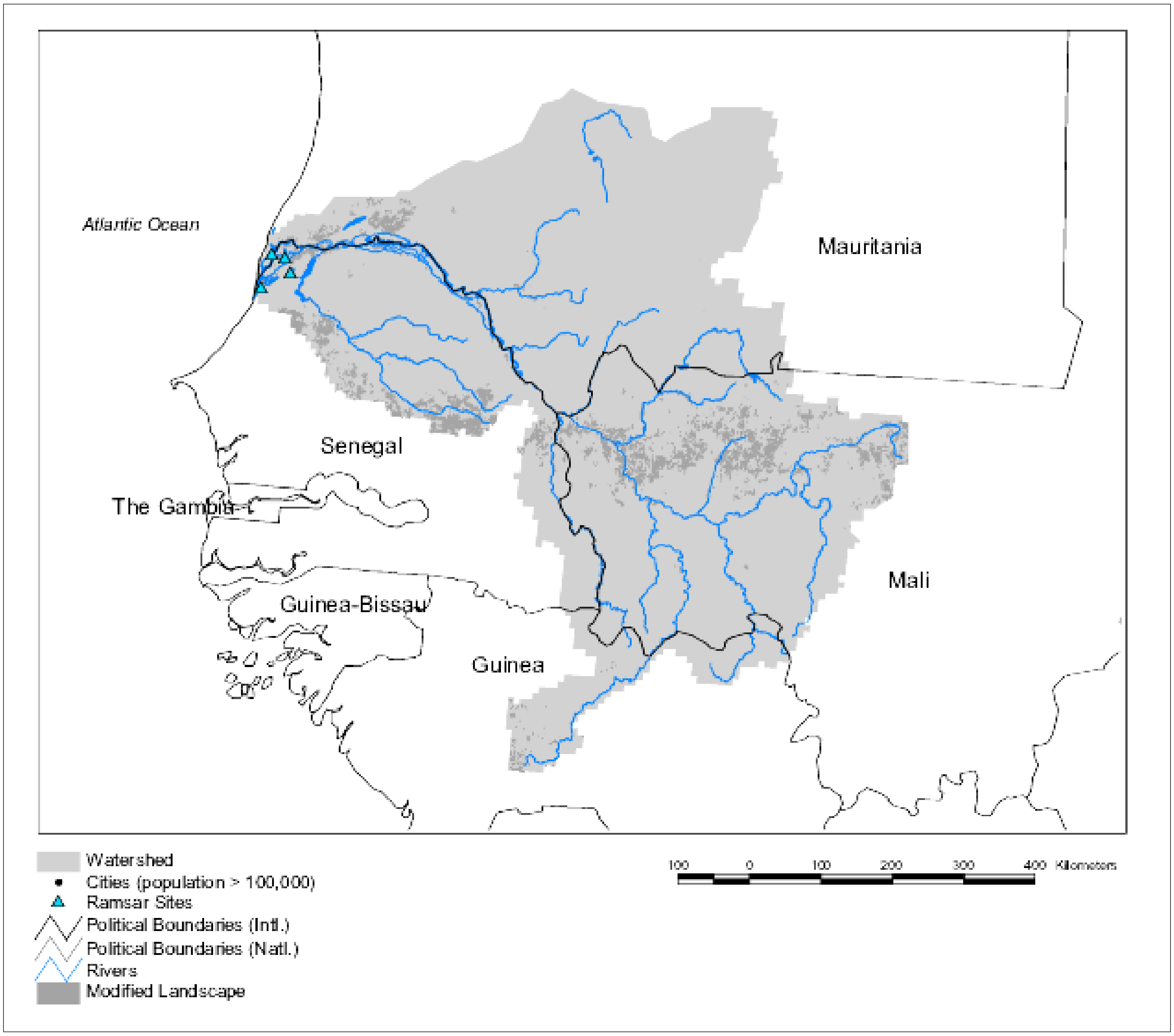
Source: Revenga, C., S. Murray, J. Abramovitz, and A. Hammond, 1998. *Watersheds of the World: Ecological Value and Vulnerability.* Washington, DC: World Resources Institute.

Statistics for the Ganges Basin:

Basin Area: 1,016,104 sq.km.
Forest: 4%
Population Density: 375 people per sq.km.
Cropland: 71%
Urban Growth Rate: 3.2%
Cropland Irrigated: 15%
Large Cities: 82
Developed: 8%
Total Fish Species: 141
Shrub: 6%
Fish Endemics: —

Grassland: 7%
Threatened Fish Species: 0
Barren: 1%
Endemic Bird Areas: 5
Loss of Original Forest: 85%
Ramsar Sites: 4
Deforestation Rate: 5%
Protected Areas: 6%
Eroded Area: 10%
Wetlands: 18%
Large Dams: 6
Planned Major Dams: 6

Map 25: Senegal Watershed

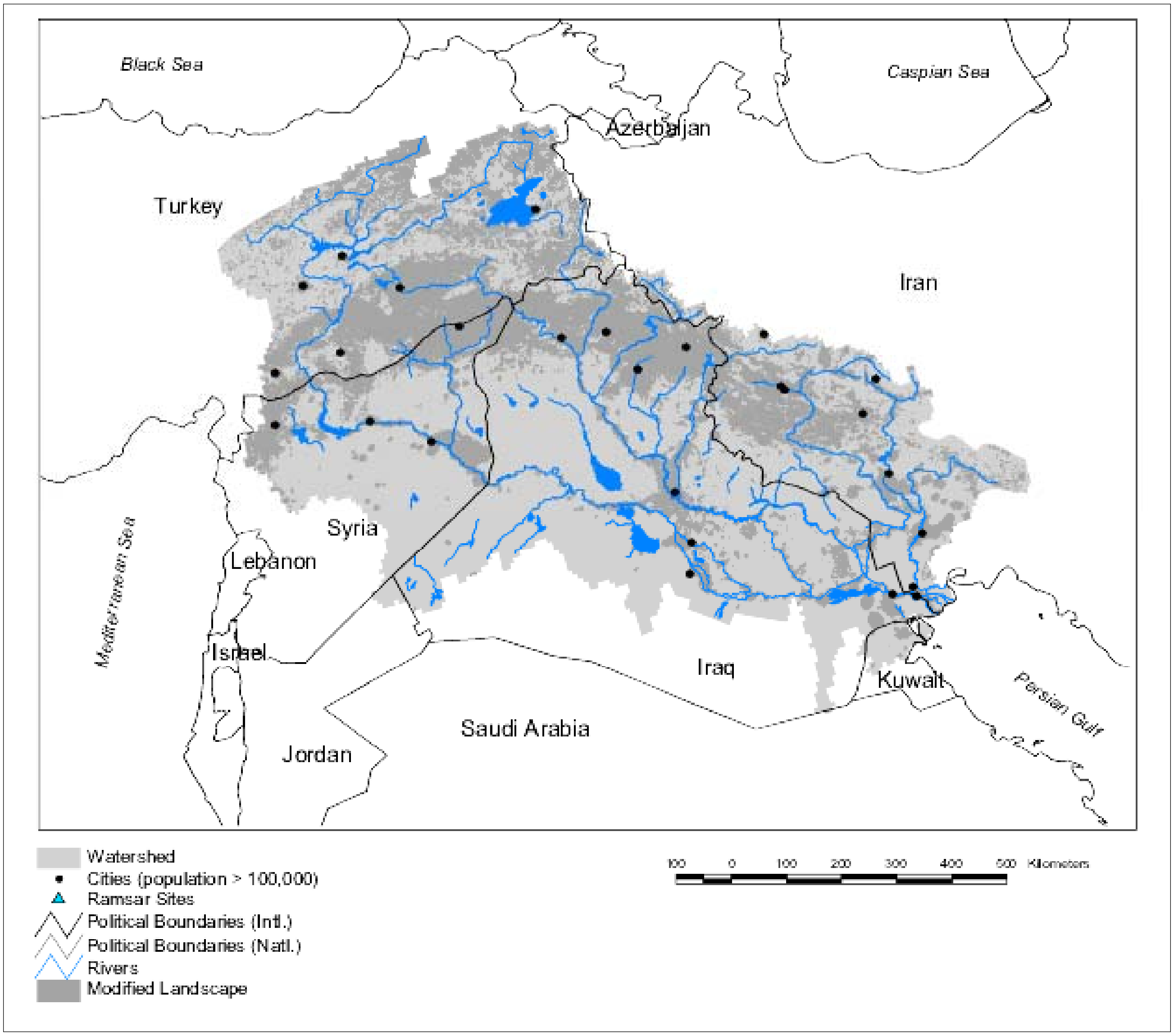


Source: Revenga, C., S. Murray, J. Abramovitz, and A. Hammond, 1998. *Watersheds of the World: Ecological Value and Vulnerability.* Washington, DC: World Resources Institute.

Statistics for the Senegal Basin:

Basin Area: 419,659 sq. km.
Forest: 0%
Population Density: 12 people per sq.km.
Cropland: 5%
Urban Growth Rate: —
Cropland Irrigated: 0%
Large Cities: 0
Developed: < 1%
Total Fish Species: 115
Shrub: 10%
Fish Endemics: 26
Grassland: 59%
Threatened Fish Species: 0
Barren: 25%
Endemic Bird Areas: 0
Loss of Original Forest: 100%
Ramsar Sites: 4
Deforestation Rate: 5%
Protected Areas: 6%
Eroded Area: 1%
Wetlands: 4%
Large Dams: 1
Planned Major Dams: —

Map 26: Tigris & Euphrates Watershed

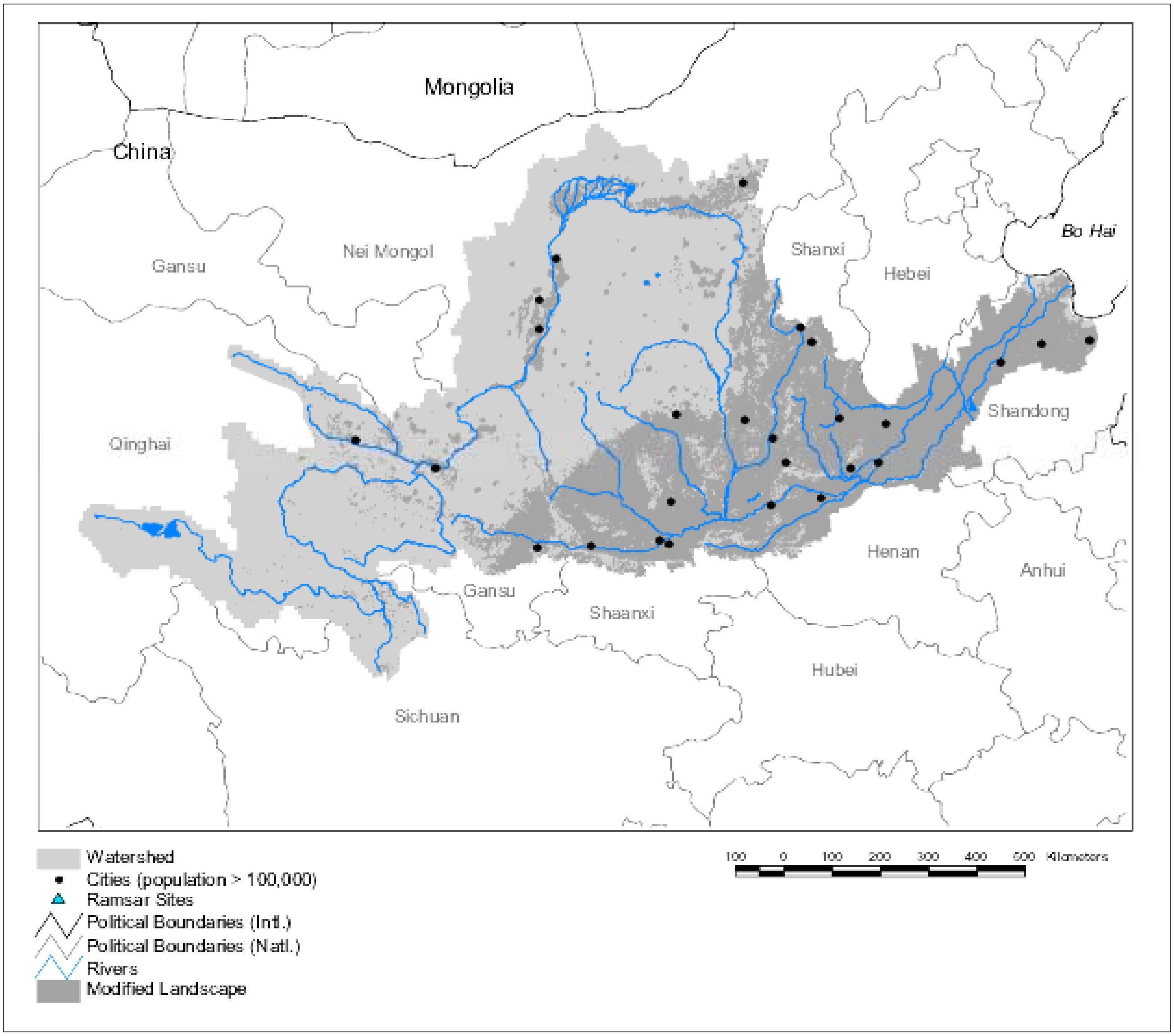


Source: Revenga, C., S. Murray, J. Abramovitz, and A. Hammond, 1998. *Watersheds of the World: Ecological Value and Vulnerability.* Washington, DC: World Resources Institute.

Statistics for the Tigris and Euphrates Basin:

Basin Area: 765,831 sq.km.
Forest: 1%
Population Density: 58 people per sq.km.
Cropland: 25%
Urban Growth Rate: 3.9%
Cropland Irrigated: 2%
Large Cities: 27
Developed: 9%
Total Fish Species: 92 (intr: 21)
Shrub: 32%
Fish Endemics: 28
Grassland: 14%
Threatened Fish Species: 0
Barren: 17%
Endemic Bird Areas: 1
Loss of Original Forest: 100%
Ramsar Sites: 0
Deforestation Rate: —
Protected Areas: 0%
Eroded Area: 8%
Wetlands: 3%
Large Dams: 19
Planned Major Dams: 7

Map 27: Huang He Watershed



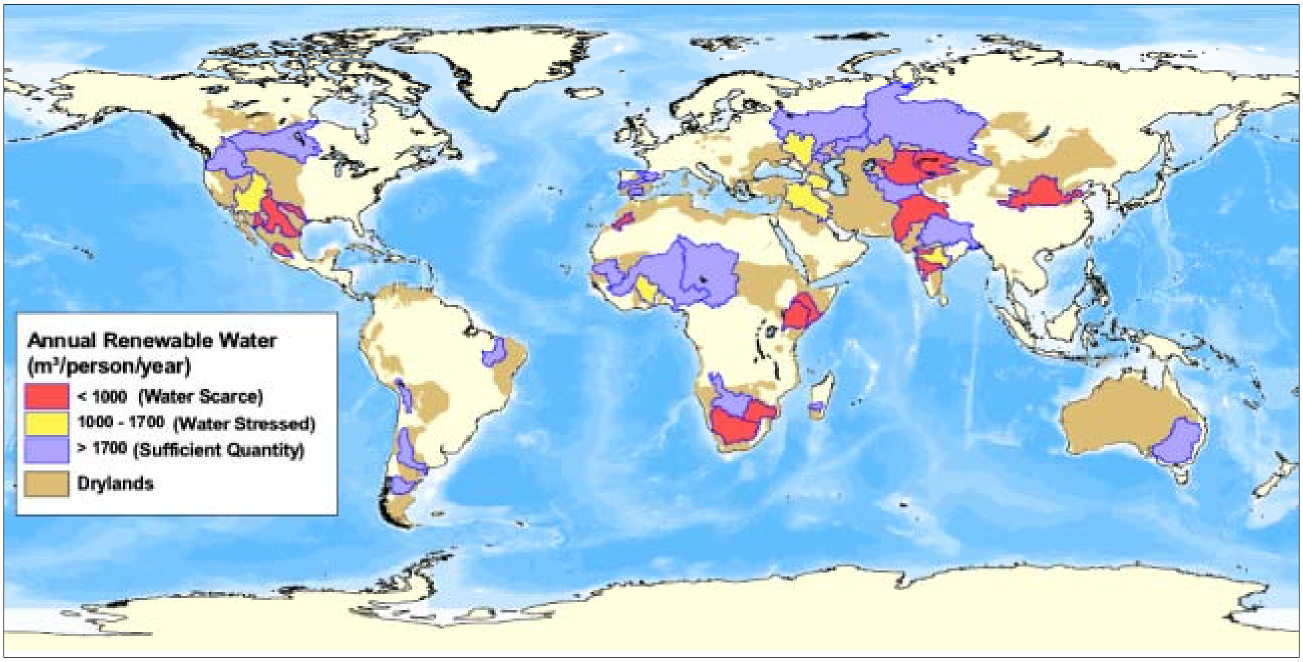
Source: Revenga, C., S. Murray, J. Abramovitz, and A. Hammond, 1998. *Watersheds of the World: Ecological Value and Vulnerability.* Washington, DC: World Resources Institute.

Statistics for the Hwang He Basin:

Basin Area: 945,065 sq.km.
Forest: 3%
Population Density: 162 people per sq.km.
Cropland: 29%
Urban Growth Rate: 2.9%
Cropland Irrigated: 32%
Large Cities: 27
Developed: 7%
Total Fish Species: 160
Shrub: 19%
Fish Endemics: —

Grassland: 39%
Threatened Fish Species: 0
Barren: 2%
Endemic Bird Areas: 4
Loss of Original Forest: 78%
Ramsar Sites: 0
Deforestation Rate: —
Protected Areas: 1%
Eroded Area: 20%
Wetlands: 1%
Large Dams: 6
Planned Major Dams: 4

Map 28: Projected Water Supply in Major Watersheds in Drylands, 2025



Source: Revenga et. al. 1998; Fekete et. al. 1999; UNEP/GRID 1991
Projection: Geographic
Note: This map projection is for display purposes only. All map calculations were done using an equal-area projection.

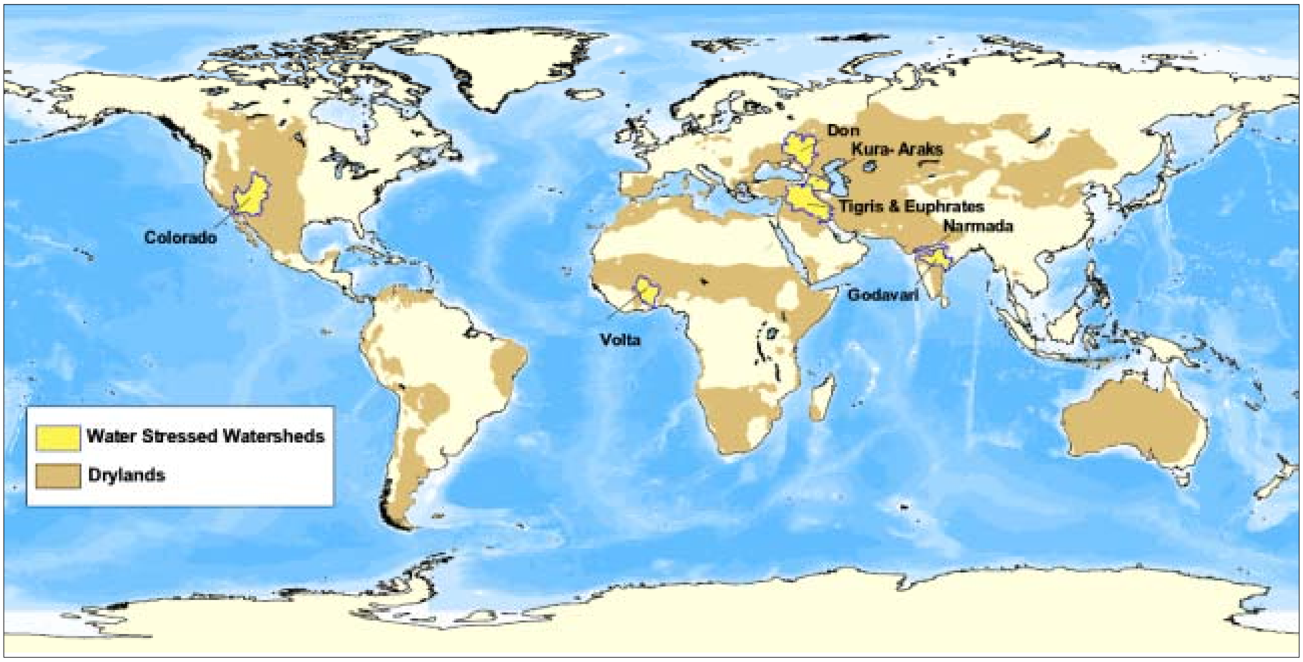
Map Description (Maps 28-30)

Two indicators used to evaluate the status of freshwater resources include water stress and water scarcity. Water stress has been defined as when a country's annual water supplies are below 1,700 cubic meters per person and is characterized by periodic water shortages. Water scarcity is when annual water supplies are below 1,000 cubic meters per person, producing chronic shortages of freshwater and subsequent negative effects on food production, economic development, and ecosystem health.

Using these indicators of the status of freshwaters resources, this map shows the projected water supply in major watersheds in drylands for the year 2025. Many basins appear to have sufficient water for the population of that basin in 2025. For other basins, these indicators suggest that problems with water supply will occur in the near future.

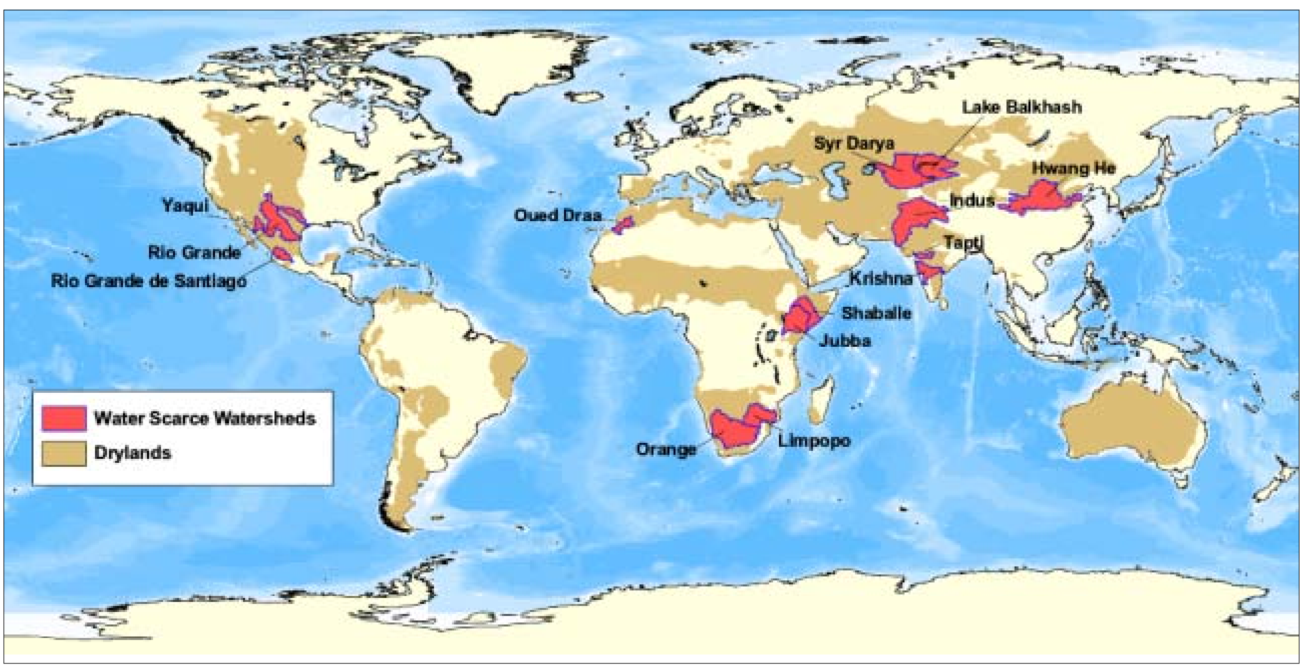
Of the 42 major watersheds in drylands, 7 are projected to be water stressed in 2025 (Map 29: Projected Water Stress in Major Watersheds in Drylands, 2025). These basins, found mostly in Asia, with one in Africa and one in North America, may experience periods of water shortages, with less than 1,700 cubic meters of water available per person per year. Fourteen of the 42 major watersheds in drylands are projected to be water scarce in 2025, (Map 30: Projected Water Scarcity in Major Watersheds in Drylands, 2025). These 14 basins in Asia, Africa, as well as North America may experience chronic shortages of freshwater with less than 1000 cubic meters of water available per person per year. In total, half of the major watersheds examined in drylands are predicted to experience some type of water shortage in the coming years.

Map 29: Projected Water Stress in Major Watersheds in Drylands, 2025



Source: Revenga et. al. 1998; Fekete et. al. 1999; UNEP/GRID 1991
Projection: Geographic
Note: This map projection is for display purposes only. All map calculations were done using an equal-area projection.

Map 30: Projected Water Scarcity in Major Watersheds in Drylands, 2025

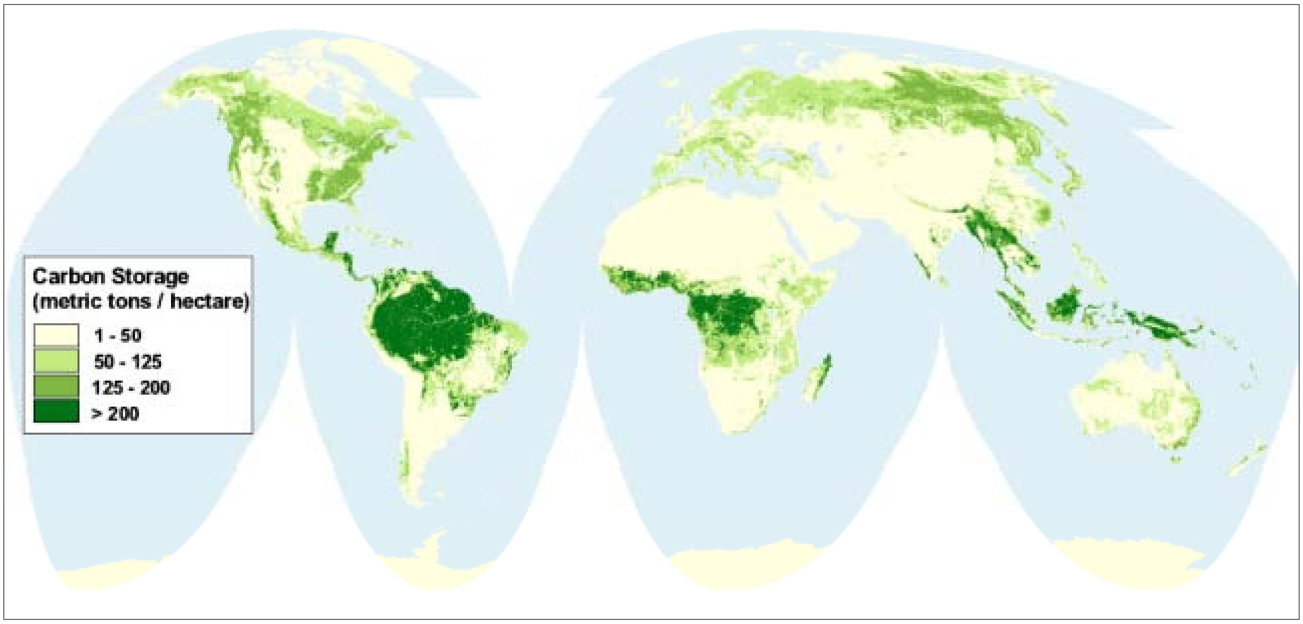


Source: Revenga et. al. 1998; Fekete et. al. 1999; UNEP/GRID 1991
Projection: Geographic
Note: This map projection is for display purposes only. All map calculations were done using an equal-area projection.

Drylands and Carbon Storage

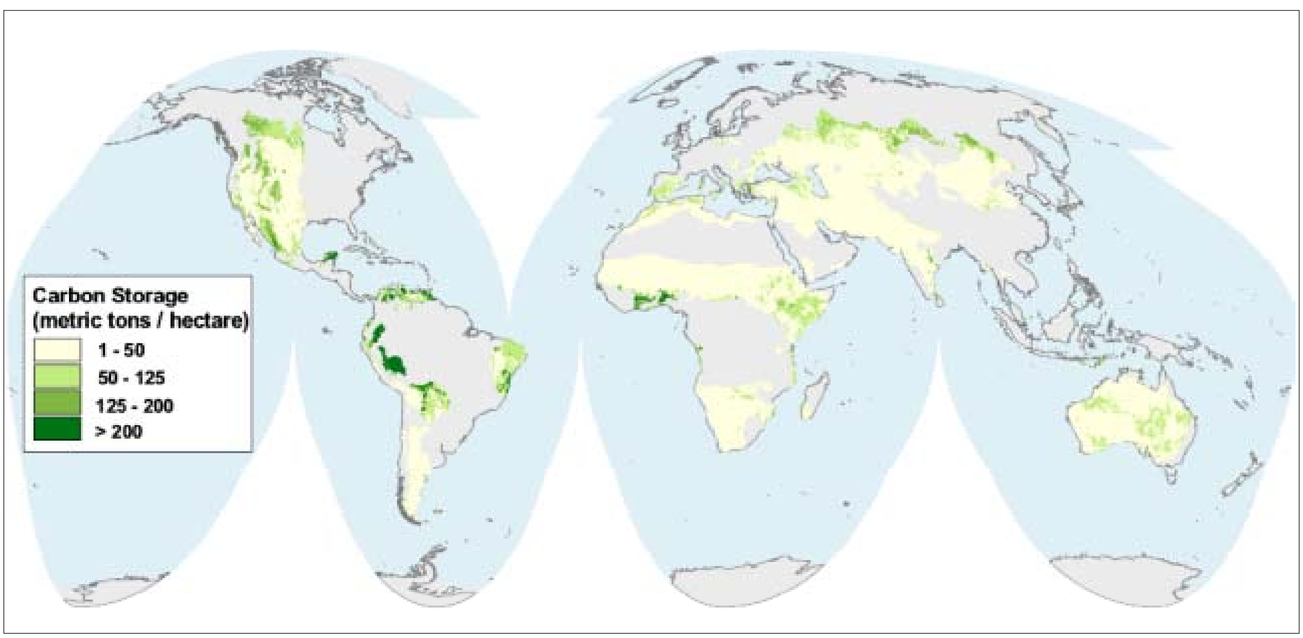
Over time, human activities have altered the amount of carbon that flows through and is stored in various reservoirs. The global net flux of carbon to the atmosphere from land use changes may have increased as much as 19 percent since 1850. To stop rising concentrations of CO_2 in the atmosphere, countries actively are seeking ways to increase carbon storage capacity on land. Drylands, as an ecosystem with extensive surface area across the globe, have been suggested as a potential candidate for major carbon storage efforts.

Map 31: Global Carbon Storage in Vegetation



Source: Olson et. al. 1983; USGS/EDC 1999.
Projection: Interrupted Goode's Homosoline

Map 30: Projected Water Scarcity in Major Watersheds in Drylands, 2025



Source: Olson et. al. 1983; USGS/EDC 1999.
Projection: Interrupted Goode's Homosoline

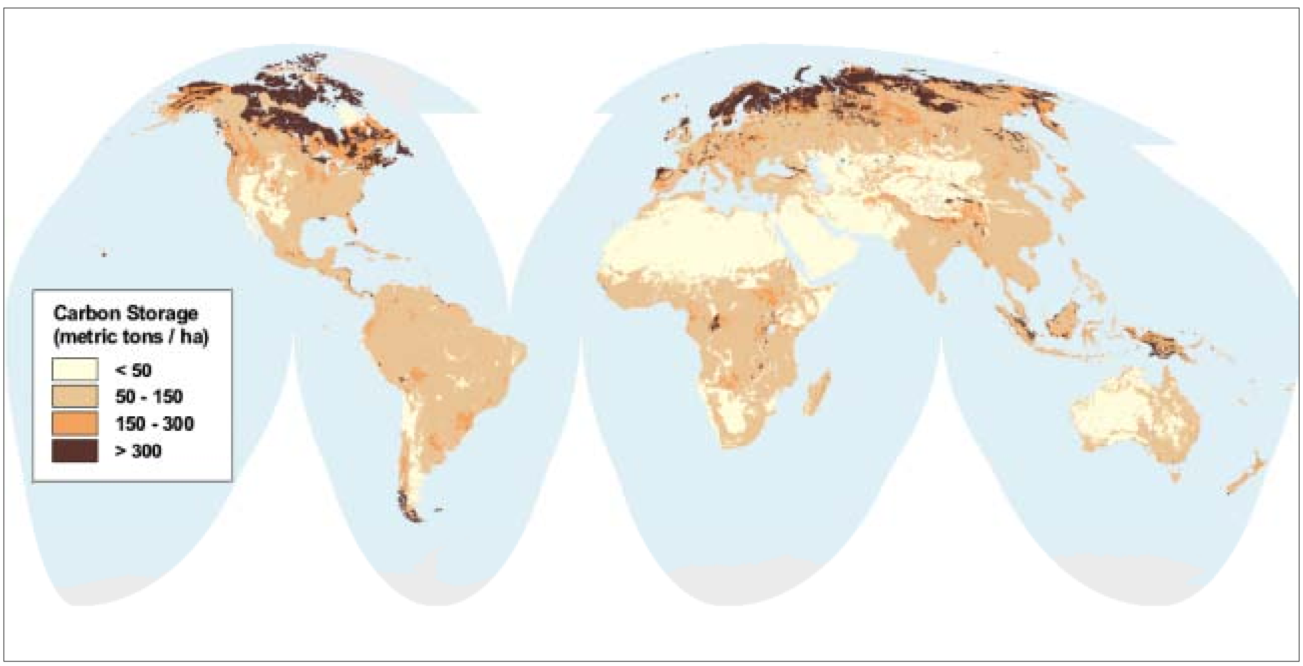
Map Description (Maps 31-32)

Map 31 displays the global variation in the density of carbon storage in live vegetation (both above and below-ground). The carbon values are expressed as a range, in metric tons of carbon per hectare; this map shows storage values at the high end of the range. These estimates of above- and below-ground live vegetation carbon storage are based on those developed at the Oak Ridge National Laboratory (ORNL) and are described as the most commonly used and spatially explicit estimates of biomass carbon densities at a global scale. We applied the ORNL estimates to a land cover database (GLCCD) and the various ecosystems were then matched with the low and high estimates of carbon storage.

In terms of quantity of carbon stored, tropical and boreal forests are visibly outstanding. The values for carbon storage in vegetation in the tropics reach a maximum of 250 metric tons per hectare. Temperate forests and tropical savannas store less than the tropical and boreal forests. Non-woody grasslands and drylands store less than the forested areas, and sparsely vegetated and bare desert areas have the least carbon storage potential.

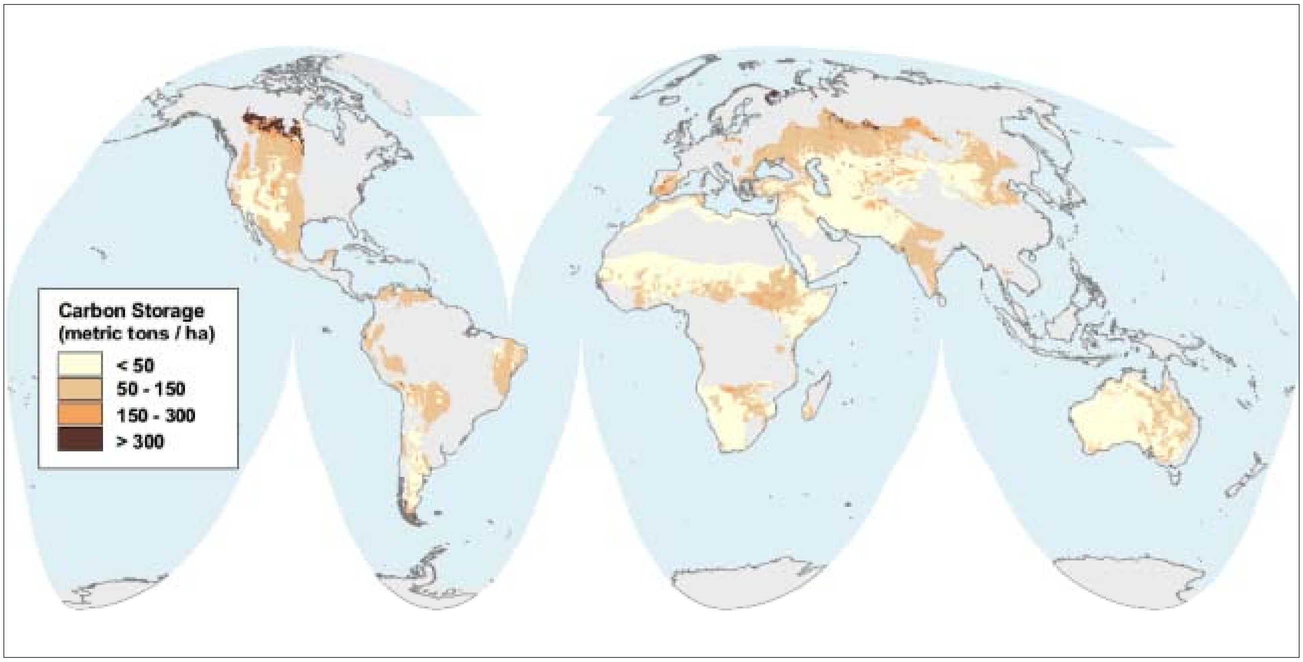
Map 32 shows the carbon storage in vegetation for drylands only. As described for Map 31, but now much more obvious, drylands generally do not store large amounts of carbon in vegetation. Although there are some exceptions, worldwide drylands store less than 50 metric tons of carbon per hectare.

Map 33: Global Carbon Storage in Soils



Source: Batjes 1996; FAO 1995.
Projection: Interrupted Goode's Homosoline
Note: Carbon storage values greater than 1,000 metric tons of carbon per hectare account for 2 percent of the area falling in the greater than 300 metric tons per hectar class. Carbon storage values are not shown for Greenland and Antarctica, where limited data were available.

Map 34: Global Carbon Storage in Soils in Drylands



Source: Batjes 1996; FAO 1995.
Projection: Interrupted Goode's Homosoline
Note: Carbon storage values are not shown for Greenland and Antarctica, where limited data were available.

Map Description (Maps 33-34)

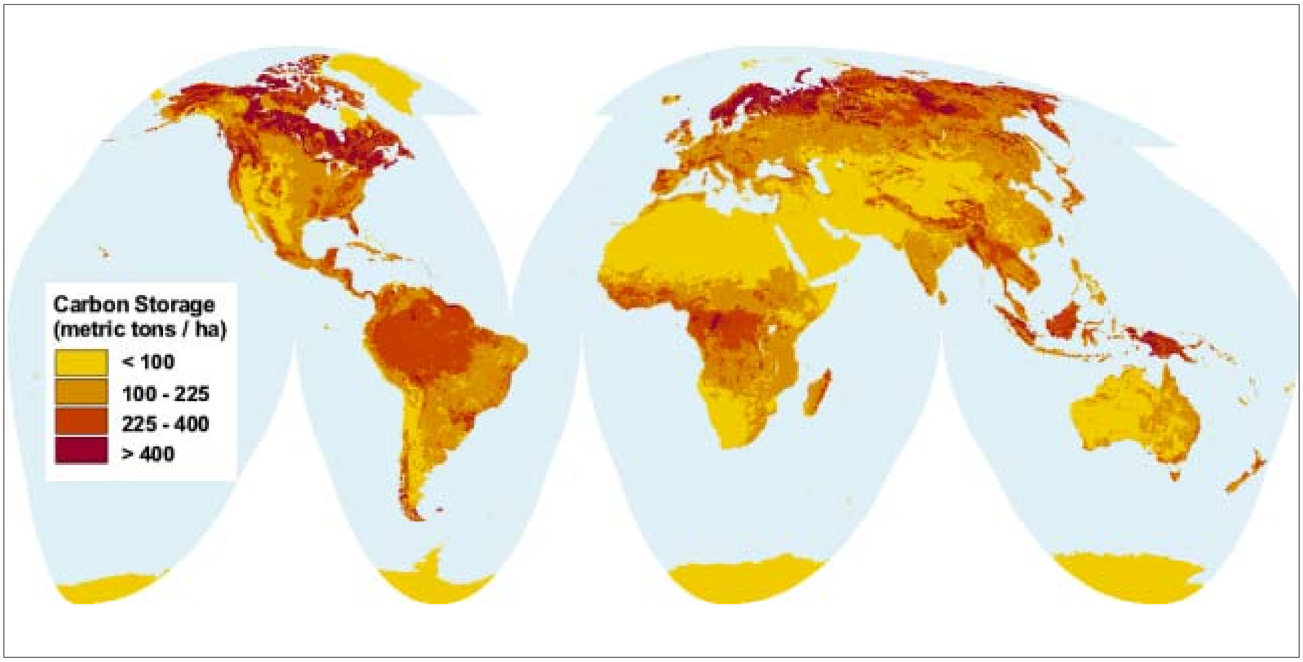
Map 33 shows potential for global carbon storage in soils. These estimates are based primarily on soil samples taken within 100 centimeters of the soil profile with special reference to the upper 50 centimeters, the depth most directly influenced by interactions with the atmosphere and with land use and environmental change.

To produce this map, over 4,000 soil profiles from the World Inventory of Soil Emission Potentials (WISE) database compiled by the International Soil Reference and Information Centre (ISRIC) were analyzed to determine average soil organic carbon (SOC) at several depths for world soil types defined by the Food and Agriculture Organization of the United Nations (FAO). The SOC content of the soil types found in each 5 x 5 minute grid of the digitized FAO-UNESCO Soil Map of the World were summed and weighted according to the portion of soil type area within each grid cell.

This global carbon storage map for soils, as with the global vegetation carbon map, shows forested areas, especially in northern latitudes with the highest carbon storage potential. Carbon storage values in soils in these boreal regions reach a maximum of 1,250 metric tons of carbon per hectare.

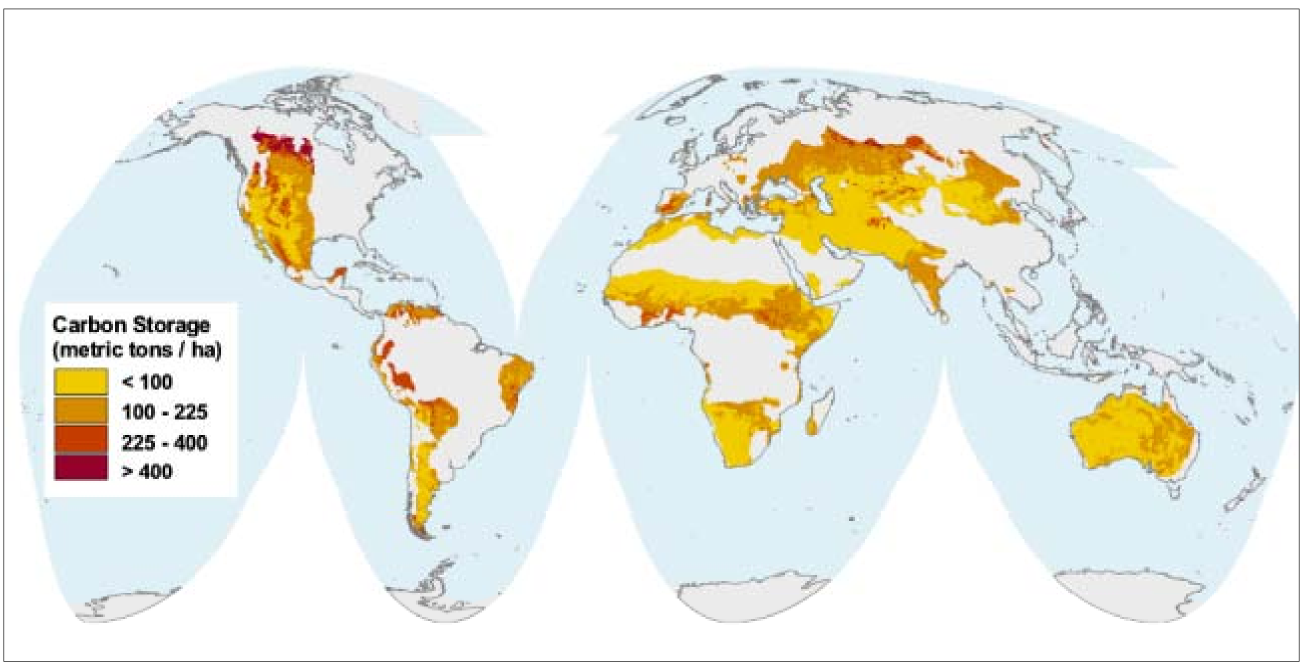
Map 34 shows the carbon storage in soils for drylands only. In this display, extensive dryland areas store up to 300 metric tons of carbon per hectare. This illustrates that dryland soils have larger potential carbon storage than dryland vegetation. And, that unlike tropical forests, where carbon is stored primarily in vegetation, carbon in drylands is stored predominantly in the soil.

Map 35: Global Carbon Storage in Vegetation and Soils



Source: Batjes 1996; FAO 1995; Olson et. al. 1983; USGS/EDC 1999.
Projection: Interrupted Goode's Homosoline
Note: Global carbon storage values include above-and below-ground live vegetation. Carbon stores for vegetation in Greenland and Antarctica are included but soil carbon stores in these regions are not available.

Map 36: Global Carbon Storage in Vegetation and Soils in Drylands



Source: Batjes 1996; FAO 1995; Olson et. al. 1983; USGS/EDC 1999.
Projection: Interrupted Goode's Homosoline
Note: See map 35.

Map Description (Maps 35-36)

Map 35 shows combined estimates for potential carbon storage in vegetation and soils. These estimates range from 1,752 GtC (in the unvegetated regions) to 2,385 GtC (in forested areas). Here again, carbon storage potential appears highest in the tropical and boreal forests (with carbon storage values ranging from 300- 400 metric tons per hectare).

Map 36 shows the distribution and concentration of total carbon stores, in both vegetation and soils, but for drylands only. The carbon storage potential for drylands ranges from greater than 400 to less than 100 metric tons per hectare, although the majority of drylands store less than 225 metric tons per hectare. Thus, while drylands generally store less carbon than forests on a carbon/unit area basis, the total amount of carbon that drylands store is potentially significant because the area of these ecosystems is extensive.

Drylands and Energy

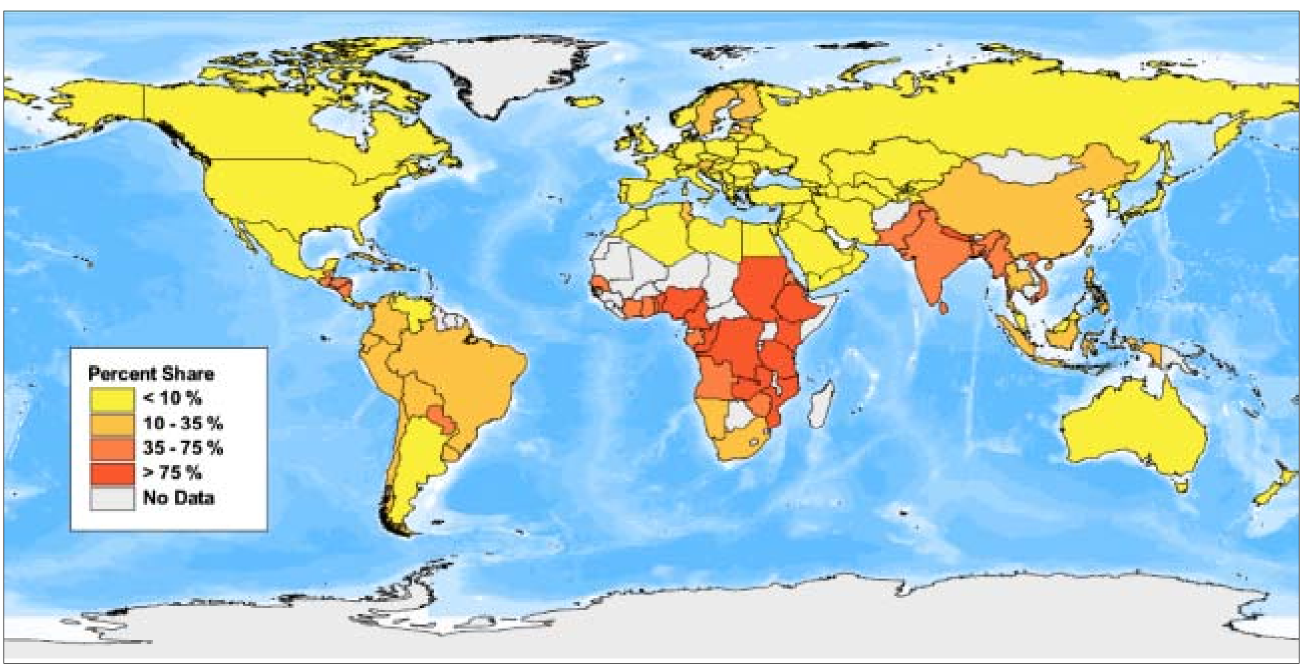
Drylands provide energy resources to local populations as well as global markets. These resources include woodfuels and a variety of fuel minerals. In some cases, energy resources supply local people with daily heating and cooking fuels. In other cases, mining, processing, and marketing of fuel mineral commodities play a significant role in supporting national economies.

ROLE OF WOOD ENERGY IN DRYLANDS

According to the best estimates available, wood plays an important role in providing energy to many dryland countries. Wood energy data tend to be scarce with a high degree of uncertainty and many gaps. Several organizations have attempted to present consistent statistics from the best national knowledge or field surveys; these organizations include the Food and Agriculture Organization of the United Nations (FAO) and the International Energy Agency (IEA).

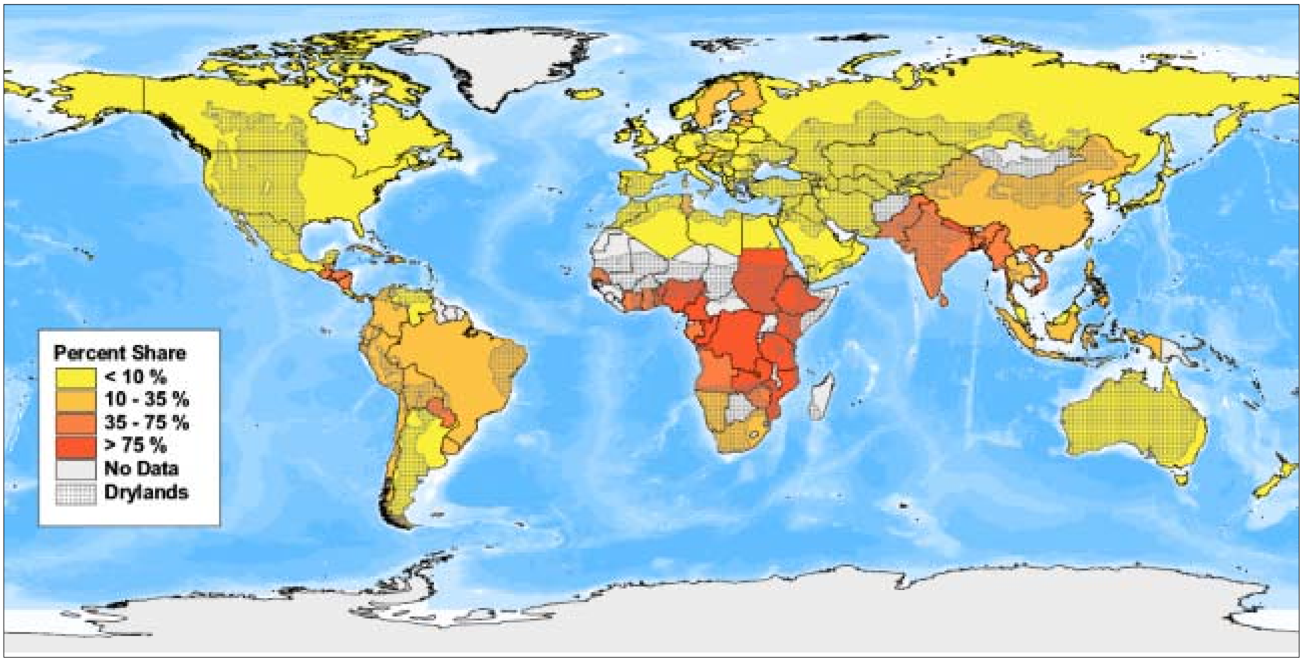
FAO reported that woodfuel consumption in Africa reached 623 million cubic meters in 1994 — the highest per capita woodfuel consumption of any continent. Many African countries depend heavily on wood for providing energy needs with the share of woodfuel often more than 50 percent of primary energy consumption.

Map 37: Share of Biomass Fuels in National Energy Consumption, 1999



Source: IEA 2001
Projection: Geographic

Map 38: Share of Biomass Fuels in National Energy Consumption in Drylands, 1999



Source: IEA 2001; UNEP/GRID 1991.
Projection: Geographic

Map Description (Maps 36-35)

Map 37 shows the percent share of biomass fuels in national energy consumption in 1999 for the world. In general, biomass fuels in developed countries and countries with large mineral fuel resources contribute less than 10 percent to total energy consumption. Countries where biomass fuels provide greater than 75 percent of total energy consumed are located predominately in Sub-Saharan Africa.

Using specific national level data for the 17 countries with over 90 percent dryland, four consumed relatively large amounts of biomass fuels — over 100,000 metric tons of oil equivalent (ktoe) in 1999: Senegal, Tunisia, Iran, Morocco, and Namibia. For Namibia and Tunisia, biomass fuels equaled at least 15 percent of the total energy consumed; for Senegal, biomass fuels equaled approximately 57 percent of the energy consumed (Table 11).

In Map 38, we have superimposed the drylands area (in black cross-hatching) on the map of national biomass energy consumption. This map shows that many of the countries in Sub-Saharan Africa with no data available fall within the dryland aridity zones and may rely on biomass fuels. In addition, because the data presented on this map are national, sub-national patterns cannot be determined. If we had sufficient biomass fuel consumption data for smaller administrative units, patterns might emerge where greater biomass fuel consumption is concentrated within the drier portions of a country.

Table 11: Energy in Dryland Countries

	Consumption of Biomass Fuels (including fuelwood)		Consumption of Mineral Fuels: Crude Oil & Natural Gas Liquids	
	(000 metric tons oil equivalent, ktoe) 1999	(as percent of total energy consumption) 1999	(000 metric tons oil equivalent, ktoe) 1999	(as percent of total energy consumption) 1999
Asia				
Armenia	1.0	0.1	0.0	0.0
Kazakhstan	73.3	0.2	7,483.7	21.1
Turkmenistan	0.0	0.0	6,837.9	50.1
Uzbekistan	0.2	0.0	7,748.2	15.7
Europe				
Moldova	58.8	2.1	0.0	0.0
Middle East and N. Africa				
Afghanistan	X	X	X	X
Iran, Islamic Rep	786.0	0.8	70,184.3	67.7
Iraq	26.3	0.1	24,600.1	85.4
Kuwait	0.0	0.0	48,302.0	279.4
Morocco	428.7	4.3	6,749.9	68.0
Syrian Arab Rep	5.0	0.0	12,748.8	70.6
Tunisia	1,223.7	15.9	1,826.2	23.8
Sub-Saharan Africa				
Botswana	X	X	X	X
Burkina Faso	X	X	X	X
Gambia	X	X	X	X
Namibia	169.0	15.2	0.0	0.0
Senegal	1,678.1	56.7	868.4	29.4

Sources:
IEA 2001; various USGS publications, see source notes at end of energy section.

Notes:
Biomass fuels include any plant matter used directly as a fuel or converted into other forms before combustion; wood, vegetal waste including wood waste and crop waste used for energy, animal materials and wastes, sulphite lyes (i.e. black liquor: a sludge containing lignin digested from wood for papermaking), and other biomass. Charcoal is not included in this estimate.

Dryland countries include countries with more than 90 percent of their land within the three dryland aridity zones.

At the sectoral scale, household consumption of woodfuel in Africa is more important than consumption by industry and commercial sectors. The household sector represented more than 86 percent of total consumption in Africa in 1994 (Table 12). The industry sector accounted for about 10 percent of woodfuel consumption; the commercial sector only 4 percent. This breakdown of sectoral use generally was constant over the 14-year period from 1980 through 1994.

Table 12: Contribution of Various Sectors to African Woodfuel Consumption

	1980		1990		1994	
	Million m^3	Percent of Total Woodfuel Consumption	Million m^3	Percent of Total Woodfuel Consumption	Million m^3	Percent of Total Woodfuel Consumption
Households	461.9	90.0	520.2	87.9	537.2	86.3
Industry	37.0	7.2	49.8	8.4	59.4	9.5
Commercial	14.6	2.8	21.9	3.7	25.9	4.2
Total	513.5	100.0	591.9	100.0	622.4	100.0

Source: Amous 1997.

In contrast, small quantities of wood are used in some dryland countries. Although oil reserves may be found in different ecosystem worldwide, many drylands are associated with abundant mineral fuels. As regions with extensive dryland area, the Middle East, North Africa, and Asia contain a wealth of energy resources. In extensive dryland countries in these regions, biomass fuels contribute very low percentages of the total energy consumed. All three of these regions are major producers of mineral fuels for world markets (Table 11: Energy in Dryland Countries).

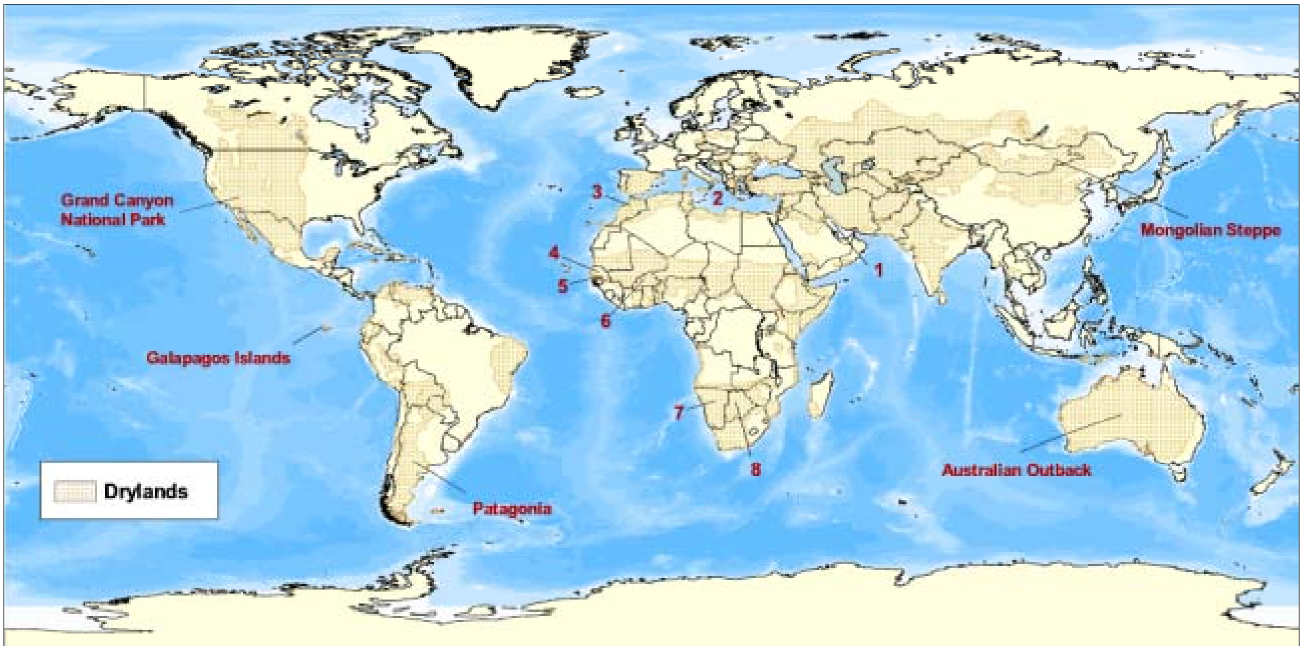
Highlights in terms of production of crude petroleum and natural gas in dryland countries include the following (all statements refer to the year 2000):

- Iran was the world's fourth largest producer of crude oil, producing an average of approximately 3.72 million barrels per day.
- Kuwait's economy revolved around the production and refining of crude oil, contributing about 48 percent of the GDP and 93 percent of government revenues.
- Oil, critical to Syria's economy, accounted for 55 to 60 percent of total exports and more than one-third of its GDP
- Turkmenistan was among the world's leading producers of natural gas.

Drylands, Tourism, and Recreation

Drylands can be popular tourist destinations. People may travel to drylands to view specific plants and animals such as endemic species that have special adaptations to these variable environments. Drylands exhibit unique landscape features such as rocky mesas and dramatic sunsets that attract rock-hounds and photographers. Some recreationists rely on drylands for hiking and camping, others may regard specific dryland sites as culturally and spiritually important.

Map 39: Selected Tourist Attractions in Drylands



1 - Kuwait: Plant and animal life; Bedouin camel herds
2 - Tunisia: Date palm oases, saline lakes, camel riding
3 - Morocco: Desert oases, Mediterranean beaches
4 - Senegal: Palm-fringed white sandy beaches
5 - Gambia: Savanna landscape, birding
6 - Burkina Faso: Landscape photography, clear springs, waterfalls
7 - Namibia: Large sandunes, wildlife safaris
8 - Botswana: Okavango Delta, birding, large game viewing

Source: UNEP/GRID 1991.

Map Description (Maps 39)

What are some specific tourist attractions in drylands? Map 39 plots selected tourist attractions — by region and dryland countries. This map is not comprehensive but helps to provide context for the following discussions.

To develop a rough estimation of trends in tourism within drylands, we summarized data from countries that are predominantly dryland — countries with at least 90 percent of their land area considered dryland. The World Tourism Organization (WTO) and the World Bank provide data on the number of international tourists and the amount of international tourism receipts for various countries around the world. The data are collected primarily from questionnaires sent to government offices and supplemented with published data from other official sources. The number of international inbound tourists is the number of visitors traveling to a foreign country for purposes other than business. These data refer to the number of visitors arriving rather than the number of persons traveling. Thus, a visitor making several trips to a country during a given period is counted each time as a new arrival. International visitors include tourists (overnight visitors), same-day visitors, cruise passengers, and crew members. These receipts include any other prepayment for goods or services received in the country being visited. The share of receipts in exports is calculated as a ratio of goods and services to exports. Although progress has been made in harmonizing definitions and measurement units for these data, differences in practices of data collection and reporting among countries still prevent full international comparability.

Of the 14 predominantly dryland countries (with data available), 10 experienced an increase in the number of international tourists between 1990 and 2000. Iran's increase in number of tourists over this period was the largest (1,004 percent) followed by Kuwait (413 percent), Burkina Faso (195 percent), and Namibia (188 percent). Four countries experienced a decrease in number of international tourists: Moldova, Iraq, Afghanistan, and Gambia (Table 13).

Table 13. Tourism in Dryland Countries

	International Inbound Tourists (thousands)			International Tourism Receipts ($ millions)			
	1990	2000	Percent Change	1990	2000	Percent Change	Percent of Exports 2000
Asia							
Armenia	15	30	100	X	45	X	10
Kazakhstan	X	X	X	X	363	X	5
Turkmenistan	X	300	X	X	192	X	23
Uzbekistan	X	272	X	X	21	X	1
Europe							
Moldova	226	17	(93)	4	4	0	1
Middle East and N. Africa							
Afghanistan	8	4	(50)	1	1	0	X
Iran, Islamic Rep	154	1,700	1,004	61	850	1,294	3
Iraq	748	78	(90)	55	13	(76)	X
Kuw ait	15	77	413	132	243	84	2
Morocco	4,024	4,113	2	1,259	2,040	62	20
Syrian Arab Rep	562	916	63	320	474	48	7
Tunisia	3,204	5,057	58	948	1,496	58	17
Sub-Saharan Africa							
Botswana	543	843	55	117	234	100	8
Burkina Faso	74	218	195	11	42	282	11
Gambia	100	96	(4)	26	49	89	19
Namibia	213	614	188	85	288	239	18
Senegal	246	369	50	167	166	(1)	12

Source: World Bank. 2002. World Development Indicators. International Bank, Washington D.C.
Notes: Data provided by the World Bank are from the World Tourism Organization.

Of 13 predominantly dryland countries, 9 experienced an increase in international tourism receipts between 1990 and 2000. These receipts include all payments for goods and services by international inbound visitors. Iran, Burkina Faso, and Namibia experienced increases of over 200 percent, ranging from 239 percent for Namibia to 1,294 percent for Iran. Iraq experienced the largest decline in international tourism receipts (76 percent); two countries remained very low and constant in receipts over this 10-year period: Afghanistan and Moldova.

In 2000, international tourism receipts contributed up to 23 percent of exports in these dryland countries and over 18 percent of total exports in 5 countries: Tunisia (17 percent), Namibia (18 percent), Gambia (19 percent), Morocco (20 percent), and Turkmenistan (23 percent). While not approaching figures of top countries for number of international tourists (e.g., 51 million for USA) or international tourism receipts (e.g., $85 million for USA), international tourism contributes a greater percent of total exports for some dryland countries than for other countries with more tourists (e.g., 8 percent in USA vs. 23 percent in Turkmenistan).

Drylands and Human Impact

Drylands, and the forests, grasslands, and other ecosystems they encompass, are highly dynamic systems. Characterized by inherent variability, these systems experience dramatic changes in rainfall, over periods of weeks and months as well as over years and decades. In addition, drylands face major changes from a variety of human activities. People are playing a major role in altering drylands through agriculture; urbanization and human settlement; desertification; domestic livestock grazing; global warming; mining; fire and biomass burning; introduction of exotic species; tourism; and wildlife exploitation.

AGRICULTURE

Dramatic changes in drylands are brought about by conversion of these areas to agriculture. Native vegetation is removed and replaced with seed for crops; soil is exposed and becomes vulnerable to wind and water erosion; fertilizers and pesticides are added, changing soil composition; and water-holding capacity is altered, changing the moisture regime for plants and animals.

In addition, conversion to agriculture can reduce the carbon storage potential of drylands and limit their capacity to provide this service. When drylands are converted to croplands, removal of vegetation and cultivation, especially clean plowing, reduces surface cover and destabilizes soil, and can lead to the loss of organic carbon.

URBANIZATION/HUMAN SETTLEMENTS

Human settlements and urbanization greatly alter the functioning of dryland ecosystems. Although generally thought of as rural and primarily agrarian, drylands support large centers of government and commerce. Some large, well-known cities are found in drylands including Teheran, Cape Town, Los Angeles, and Madrid. Urbanization leads to increased development of transportation networks with roads dissecting the landscape and altering drainage patterns as well as animal migration routes. Additional roads and paving of dryland soil lead to compaction of the surface and increased runoff and erosion.

DESERTIFICATION

Desertification initiates loss of vegetative cover, soil erosion and carbon loss. The United Nation's Convention to Combat Desertification (UNCCD) defines desertification as land degradation in arid, semi-arid, and dry sub-humid areas that results from numerous factors, including climatic variations and human activities. Thus, desertification includes not only climatological aspects, but also social, political, economic, and cultural factors that can strain dryland systems beyond ecologically sustainable limits.

DOMESTIC LIVESTOCK GRAZING

Grazing of large numbers of livestock can lead to reductions in plant biomass and cover as well as trampling and compacting of the soil surface, decreases in water infiltration, and increases in runoff and soil erosion, along with losses of soil carbon.

Domestic livestock, when raised to maximize animal biomass (through various techniques, including veterinary care and predator control, as well as water, mineral, and feed supplements) may result in densities that change floristic composition, structural characteristics of vegetation, reduced biodiversity, increased soil erosion, and elimination vegetation cover. The extent to which these changes occur depends not only on the number of livestock but also on the pattern of their grazing. Thus, choice of management objectives in raising domestic livestock, in addition to the physical and biological characteristics of the area, will determine the degree of human impact on drylands.

GLOBAL WARMING

Although the significance of future global warming for dryland climates cannot be assessed with confidence, predictions based on general circulation models suggest temperatures will rise in all dryland regions in all seasons. Predicted increases in temperature are expected to increase potential evapotranspiration rates in drylands and, without large increases in precipitation, many drylands could become more arid in the coming century. Thus, UNEP warns that for inhabitants of drylands, the message is clear: global warming is likely to further reduce the already limited availability of moisture.

MINING

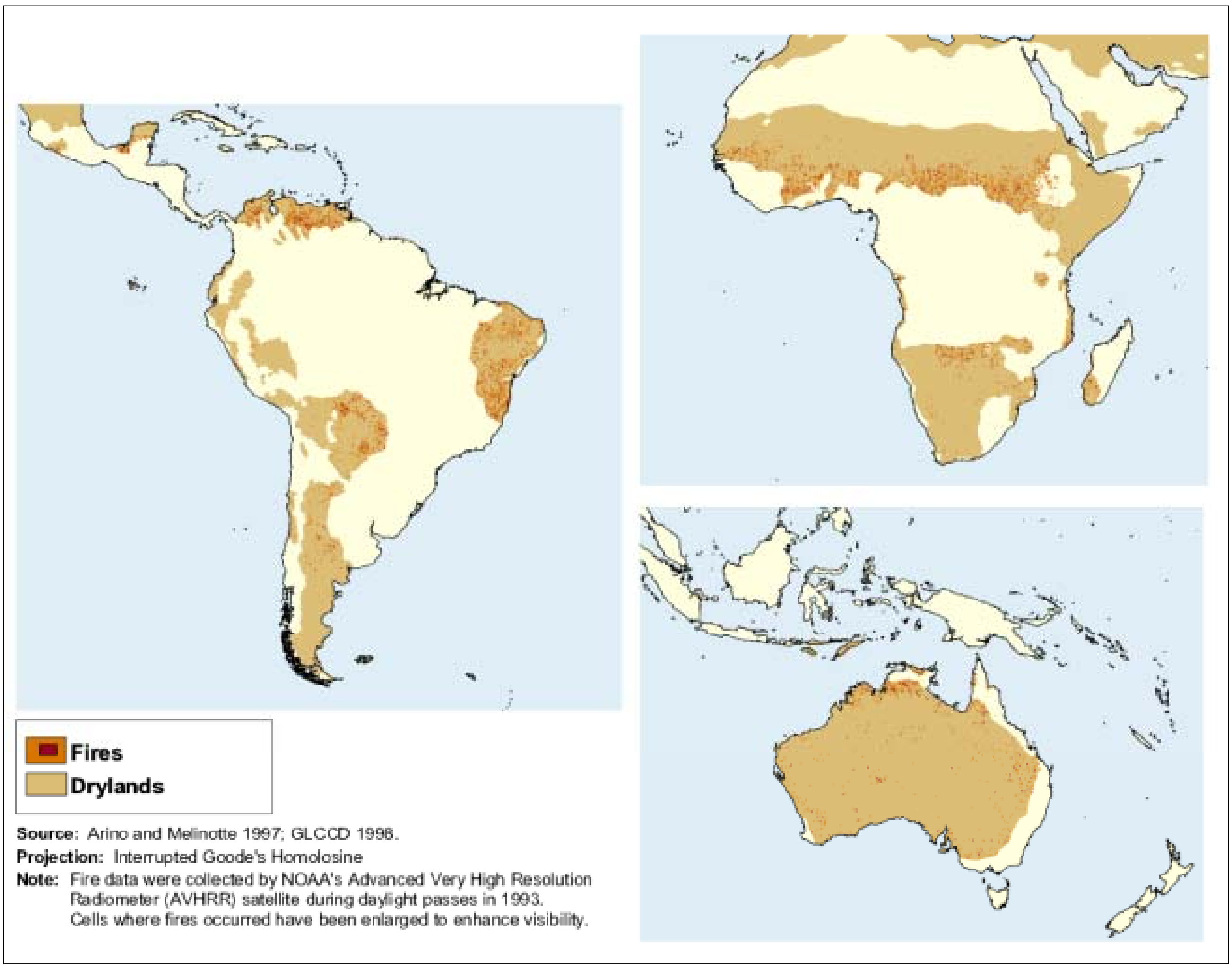
Mining activities can include major excavation of dryland soils and geologic formations along with major impacts on air and water quality. The health of human populations as well as plants and animals in drylands can be impaired by these activities, especially if environmental planning is not well thought-out and implemented. Some mining activities can be especially harmful, for example when toxic materials are a byproduct of processing. The storage and disposal of toxic waste then adds to the hazards of dryland inhabitants living nearby or within the same watershed. For example, rapid development of mining and mineral-processing industries in Kazakhstan, a country of extensive dryland, has contributed to intensive air, water, and soil pollution along with a rise in mortality rates and ecosystem degradation.

FIRE

Fires occur naturally in dryland areas, approximately once every 1 to 20 years. Today, the frequency of fires in drylands varies naturally with climate but also with choice of management objectives. In many African countries, burning clears away dead debris and is highly desirable for maintaining good conditions for grazing of livestock. Large parts of the African savannas are burned annually; burned areas in the arid Sudan Zone range from 25 to 50 percent of the total land surface.

Despite providing important services for maintaining drylands, fire can be harmful. Especially when very hot and frequent, fire can destroy vegetation and increase soil erosion. Fire also releases atmospheric pollutants. Biomass burning, such as the burning of forests, savannas, and agricultural lands after harvest, is recognized as a significant source of atmospheric emissions and described as the source of nearly 40 percent of gross carbon dioxide and tropospheric ozone. Burning of tropical savannas may destroy three times as much dry matter per year as the burning of tropical forests. Because two-thirds of the world's savannas are in Africa, that continent is now recognized as the 'burn center' of the planet.

Map 40: Fire in Drylands



Map Description (Maps 40)

The European Space Agency for Africa, Latin America, and Indo-Malaysia/Oceania has used AVHRR data to map the location of all fires detected during 1993. The fire maps show that fire on the African continent is confined by the Sahara Desert to the north, by the Horn of Africa to the east, and by the Kalahari Desert to the south. A somewhat similar pattern is found in South America where the least number of fires occur in the Amazon Basin and southern Patagonia, and the greatest number occur in areas of eastern Brazil and Venezuela.

Although some fires are recognized as important management tools in drylands, new fire datasets showing broad-scale fire distribution raise new questions. Is the frequency and extent of fires shown in these maps typical or has there been a recent increase? What are the short- and long-term effects of these fires on ecosystem services? Continued monitoring using satellite data as well as field studies should provide answers.

INTRODUCTION OF EXOTIC SPECIES

Although some non-indigenous species such as food crops, pets, ornamentals, and biological control agents are usually considered beneficial, others can change the composition of ecosystems and affect their capacity to sustain biodiversity. The Congressional Office of Technology Assessment estimated that at least 4,500 species have been introduced into the United States and that approximately 15 percent of those species have caused severe harm. Since European settlement of Australia, more then 1,900 vascular plant species have been either intentionally or accidentally added to the country's 15,000 indigenous species. More than 220 of these introduced species have been declared as noxious; at least 46 percent of the 220 noxious plants were introduced deliberately.

Several projects conducted under the auspices of the Global Invasive Species Programme (GISP) could facilitate analysis of invasive species in drylands. The Early Warning Systems project, led by the Invasive Species Specialist Group (ISSG) of IUCN-The World Conservation Union, is developing a database of invasive species in regions around the world including a pilot database on 100 invasive species in all taxonomic groups that represent global threats to biodiversity. The database will be called "World's Worst 100." These databases will aid evaluation of the species' impact on ecosystem health.

TOURISM

Tourism provides revenues but at the same time can cause environmental damage and disturb wildlife due to use of diesel engines, lights, latrines, and garbage pits. The decline in quality of national parks and reserves in some African drylands is attributed to poorly controlled and excessive tourism and accompanying increases in lodges; water, wood, and electricity consumption; waste; off-road driving; and poaching.

WILDLIFE EXPLOITATION

Wildlife in drylands may be exploited by various human activities such as pesticide use, predator control, and hunting, as well as those activities described previously such as urban sprawl, introduction of invasive species, and overgrazing. In a comprehensive assessment of North America, WWF–US assesses ecoregions according to three exploitation categories: hunting and poaching; unsustainable extraction of wildlife as commercial products; and harassment and displacement of wildlife by commercial and recreational users (Table 14).

Table 14: Wildlife Exploitation in Dryland Ecoregions of North America

Dryland Ecoregion	Wildlife Exploitation Category
Hawaiian Dry Forests	0
Puerto Rican Dry Forests	0
California Central Valley Grasslands	0
Northern Tall Grasslands	0
Central Tall Grasslands	0
Flint Hills Tall Grasslands	0
Nebraska Sand Hills Mixed Grassland	0
Western Short Grasslands	0
Central and Southern Mixed Grasslands	0
Central/Forest/Grassland Transition Zone	0
California Interior Chaparral and Woodlands	0
Hawaiian Low Shrublands	0
Northern Mixed Grasslands	5
Montana Valley and Foothill Grasslands	5
Texas Blackland Prairies	5
Snake/Columbia Shrub Steppe	5
Great Basin Shrub Steppe	5
Wyoming Basin Shrub Steppe	5
Colorado Plateau Shrublands	5
Mojave Desert	5
Chihuahuan Deserts	5
Northern Short Grasslands	8
Palouse Grasslands	10
Canadian Aspen Forest and Parklands	10
Edwards Plateau Savannas	10
Western Gulf Coastal Grasslands	10
California Montane Chaparral and Woodlands	10
California Coastal Sage and Chaparral	10
Hawaiian High Shrublands	10
Sonoran Desert	10
Tamaulipan Mezquital	10

Source:
Ricketts, et al. 1999.

Notes:
Exploitation categories are ranked according to three levels of exploitation: high (elimination of local populations of most target species is imminent or complete; 20 points); moderate (populations of game and trade species persist but in reduced numbers; 10 points); and non-existent (0 points).
Data are based on expert opinion from regional workshops.

The index of wildlife threat ranges from 0 to 10 (none to moderate) for the 31 dryland ecoregions in North America; none of the dryland ecoregions have an index of above 10, or high intensity exploitation. Twelve of the dryland ecoregions have not experienced wildlife exploitation; of the remaining 19 dryland ecoregions, 10 are somewhat below moderate wildlife exploitation while 9 experience moderate exploitation where populations of game and trade species persist but in reduced numbers. Thus, while some dryland populations do not appear to be threatened, over 60 percent of the dryland ecoregions in North America have been characterized with some level of wildlife exploitation.

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