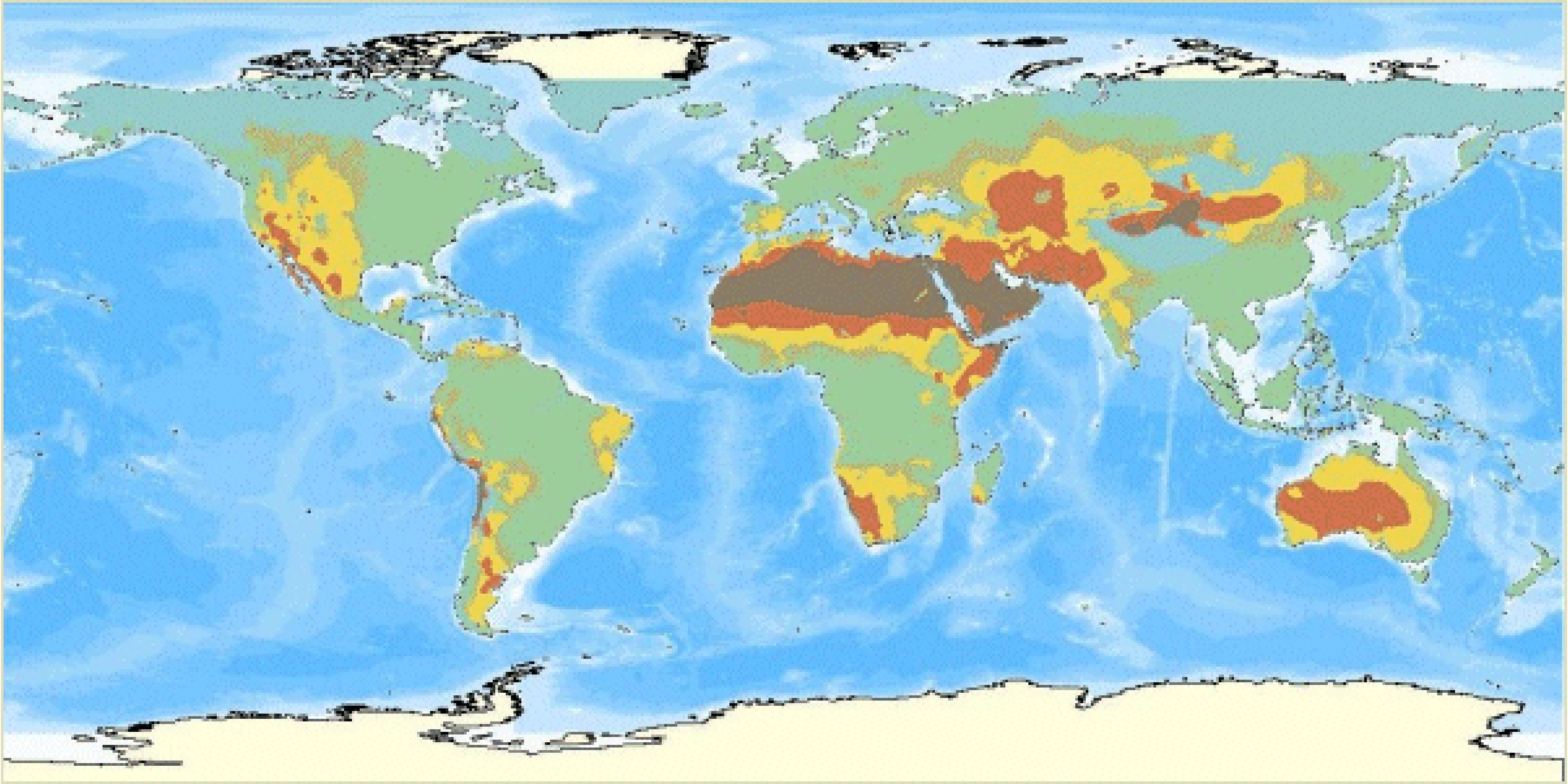
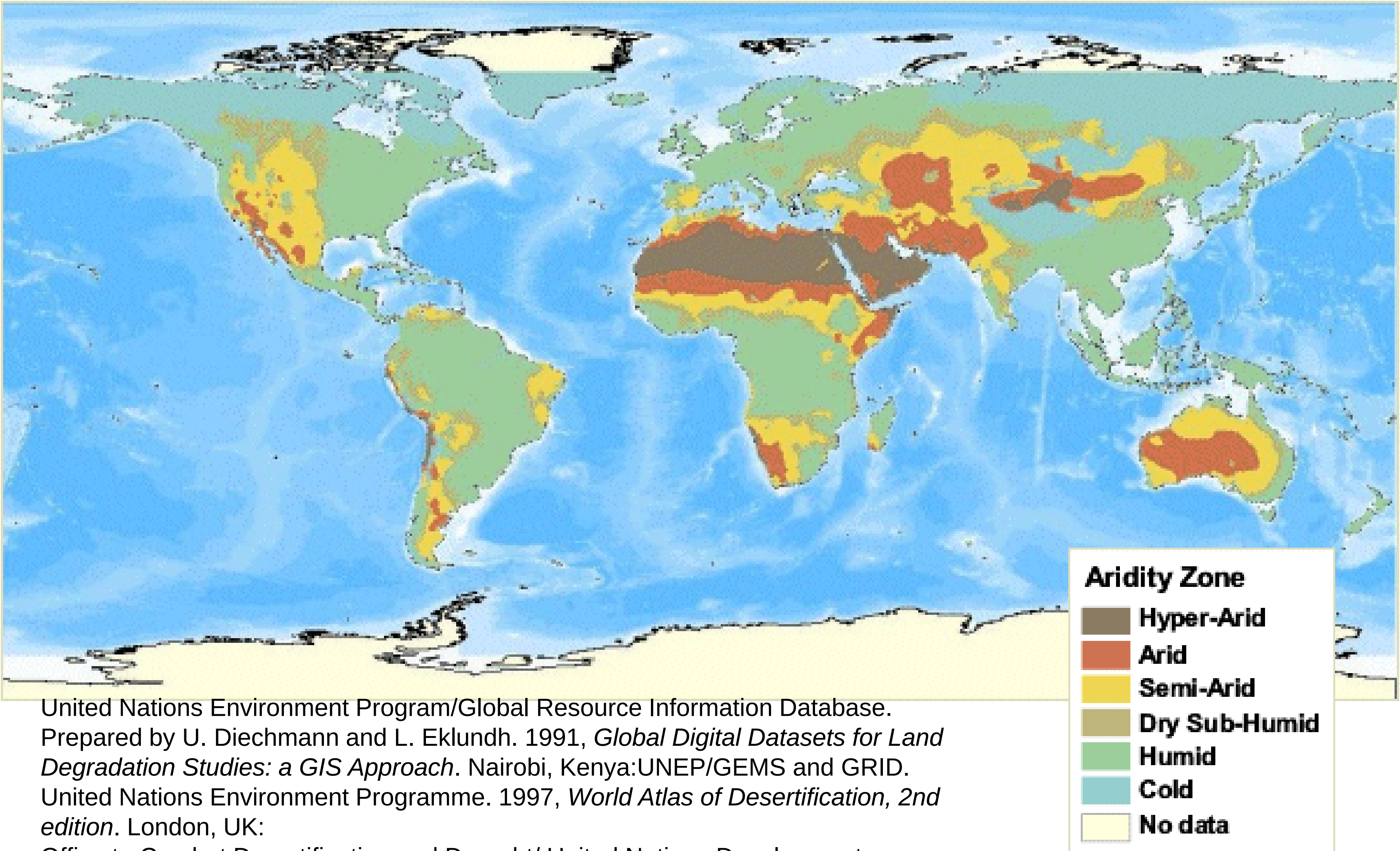
Lesson 9: Drylands



Lesson 9: drylands

- This lesson is a case study of application of IWRM principles in a specific condition. It will define drylands, specific conditions in drylands, impact of climate change and the specific application of IWRM in drylands

Drylands



United Nations Environment Program/Global Resource Information Database. Prepared by U. Diechmann and L. Eklundh. 1991, *Global Digital Datasets for Land Degradation Studies: a GIS Approach*. Nairobi, Kenya:UNEP/GEMS and GRID.
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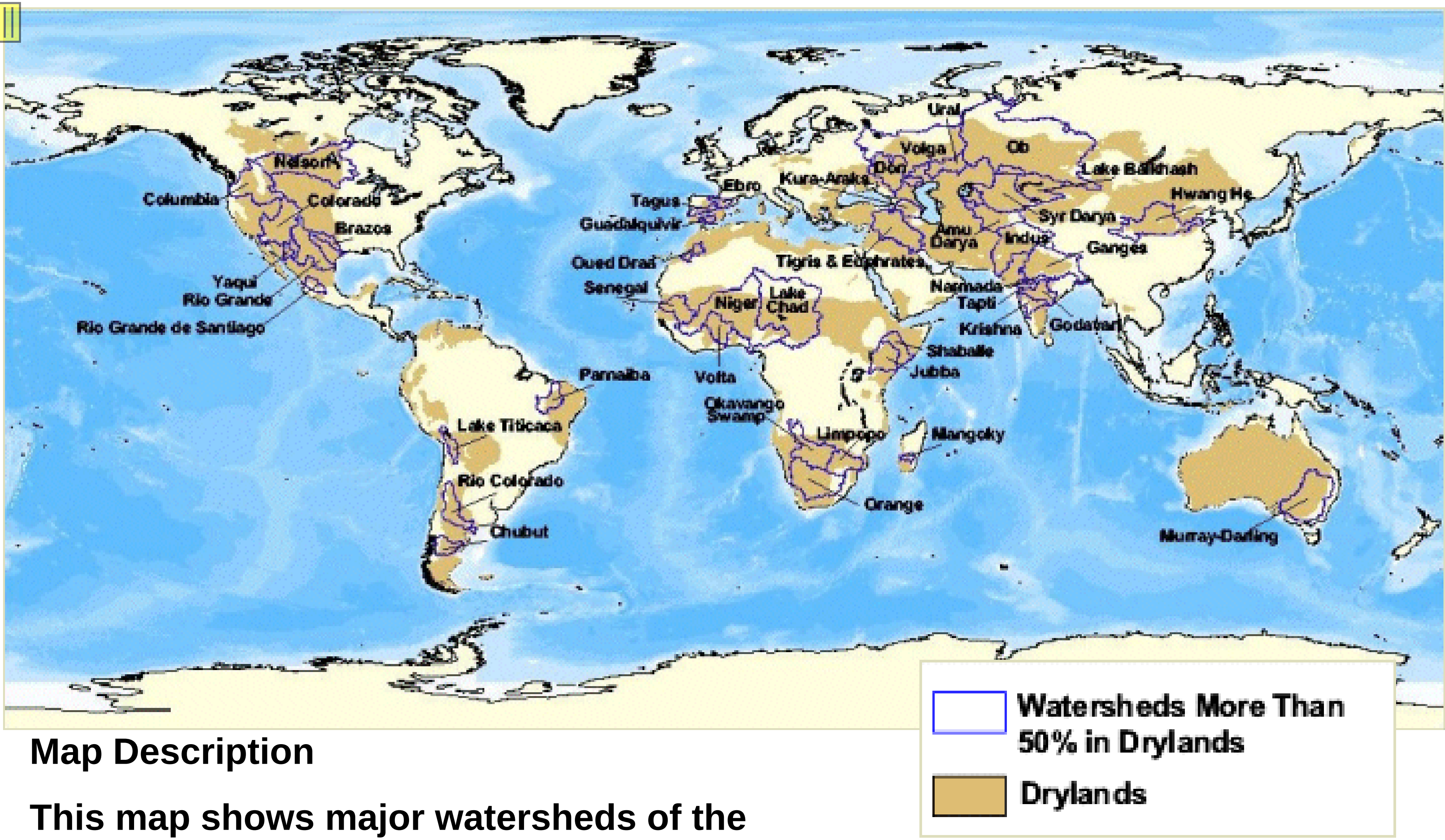

Map Description

This map shows major watersheds of the world with at least 50 percent of their area within the dryland aridity zones. Summary statistics of these basins show that their areas range from approximately 52 thousand km2 to nearly 3 million km2.

Citation:WRI. 2002. World Resources Institute. *Drylands, People, and Ecosystem Goods and Services: A Web-based Geospatial Analysis.* Available online at: http://www.wri.org

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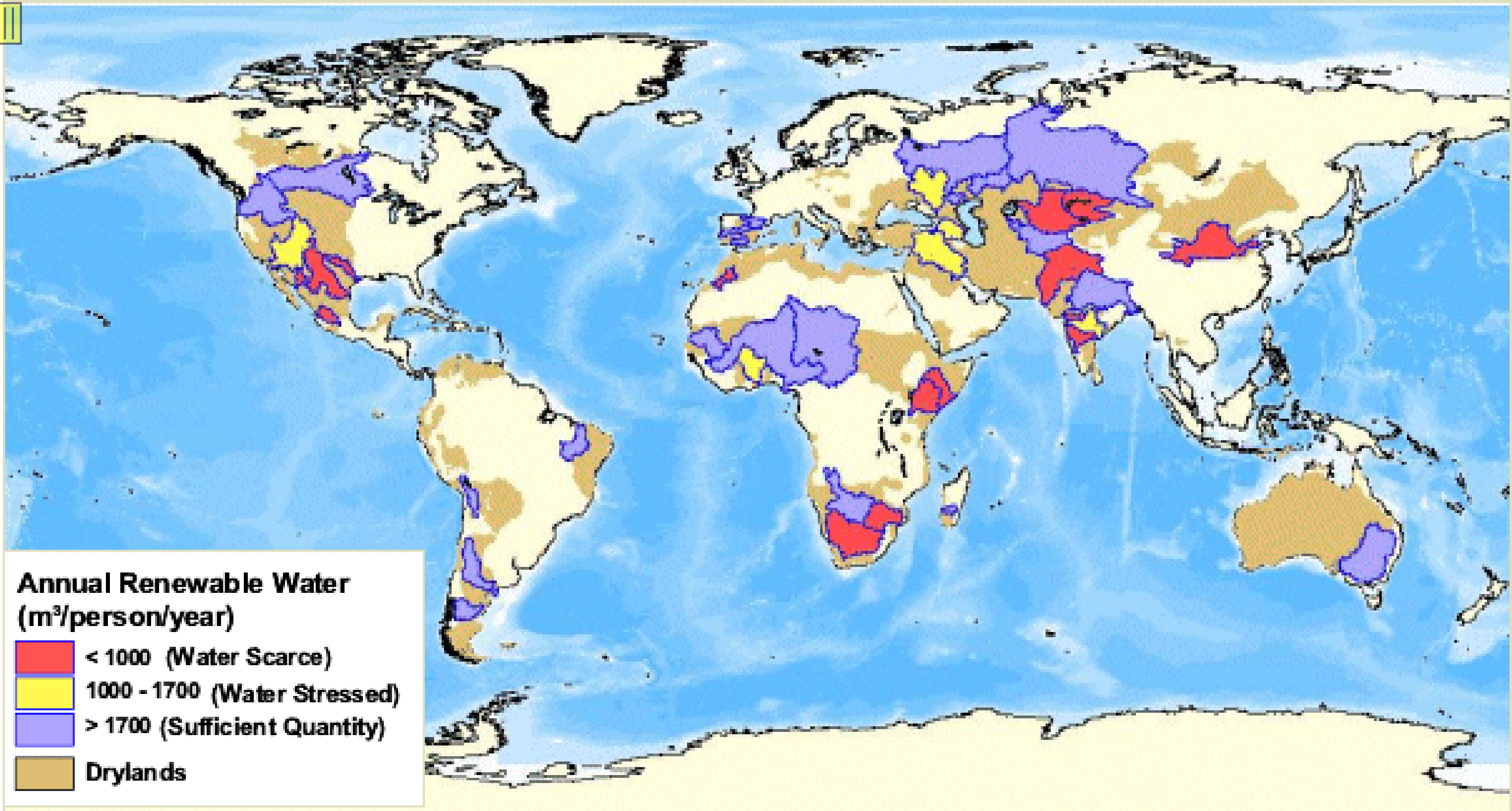

The projected water supply data for the year 2025 used in this map was developed by combining a global population database for 1995 that uses census data for over 120,000 administrative units (CIESIN et al. 2000) and a global runoff database developed by the University of New Hampshire and the WMO/Global Runoff Data Centre (Fekete et al. 1999).

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- **Drylands cover about 41% of the earth's land surface and over 2 billion people (about 35% of the human population) inhabit them.**

- **Their primary productivity is limited by low soil water resulting from low precipitation and high evaporation.**

- **They range from hyper-arid and arid deserts to semi-arid rangelands and dry sub-humid areas.**

- **In arid regions, ecosystem use is traditionally limited to pastoralism.**

- **Semi-arid and dry subhumid areas can support croplands and rangelands**

- **Populations living in drylands lag far behind in the areas of human well being and development indicators.**
- **A stark manifestation of this is available in the various indicators - a typical example is the infant mortality rate, which ranges in value from 16 to 70 per 1,000 (mean is 54 per 1,000) for drylands in developing countries.**
- **The OECD average value is 4.**
- **Approximately half of the people worldwide who live below the poverty line are in drylands.**
- **Poverty reduction in drylands is therefore critical to meeting the Millennium Development Goals (MDGs**

- **A number of driving factors underlie the plight of people living in drylands and the degraded condition (desertification) of ecosystem services.**

- **Anthropogenic activities are almost entirely responsible for these factors. Included in the list of factors are over-utilization of vegetative cover through improper rangeland management, poorly planned conversion of rangelands to croplands through irrigation schemes, and degradation of soil quality through salinization and input of chemical pollutants.**

- **The impacts of these factors on the human society are quite profound and often lead to trans-migration to other eco-regions as well as social and political strife.**

- Ecosystems and populations in semi-arid (as opposed to arid or dry subhumid) areas are the most vulnerable to loss of ecosystem services and goods.
- As aridity decreases, population density within drylands increases.
- Therefore, the adverse effect of human impact on drylands' goods and services is heightened with reduced aridity.
- Conversely, as aridity increases, so does dryland sensitivity; it is highest in the hyper-arid drylands and lowest in the dry-subhumid ones.
- The semi-arid drylands, with their intermediate aridity, are most vulnerable to loss of services due to human impact.

- Existing water stresses in drylands are projected to increase this century and beyond due to global climate change.
- This increased water stress will lead to reduced productivity of croplands and reduced freshwater availability, which will lead to adverse impacts on human well- being in drylands.
- Transformation of rangelands to cultivated croplands leads to significant decrease in plant productivity.
- Removal of the rangeland vegetation cover takes place both by overgrazing of forage and by transforming rangelands to cultivated systems. This removal of vegetation cover brings about soil erosion, thus curtailing the provision of many soil- and water-related services.
- When cultivated systems are irrigated, productivity is typically reduced due to accumulated salinization of soil.

- The condition of drylands can be significantly improved by better and integrated management of water and natural resources.
- Management of dryland resources must be viewed in the broader socioeconomic context.
- It should provide opportunities for local communities to explore viable, alternative livelihoods while maintaining their own cultural and societal fabric.
- Many approaches to the management of the scarce water resources are available and form the base of overall resource management in drylands.
- These include water harvesting techniques, water storage and conservation measures, safe re-use of treated wastewater for irrigation, afforestation to arrest soil erosion, improving ground water recharge, deficit irrigation and intensifying agriculture using novel technologies that do not increase pressure on dryland water and soil provision services.

Drylands Definitions:

Drylands encompass areas where available soil water is limited because of low precipitation and high evaporation - they do not provide adequate quantity or the year-round distribution of precipitation needed to sustain enough water resources to meet the society's livelihood. These geographical regions are climatologically described as hyper-arid, arid, semi-arid or dry sub-humid.

Aridity Index:

The aridity index is the ratio of the ecosystem's mean annual precipitation to its mean annual potential evapotranspiration. The AI expresses the magnitude of the water deficit, which varies by location. A spatial delineation of "aridity gradient" can be established.

Drylands Categories:

The drylands subtypes are defined in terms of the AI values. The range of AI values is assigned as follows: hyper-arid (AI<0.05), arid (AI=0.05 - 0.20), semiarid (AI=0.20 - 0.50), and dry subhumid (AI=0.50 - 0.65).

Land Degradation:

As defined in the text of the UNCCD, "land degradation" means the reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of drylands.

Land degradation results from a process or combination of processes, including those arising from human activities and habitation patterns, such as:

- (i) soil erosion caused by wind and/or water;
- (ii) deterioration of the physical, chemical, biological or economic properties of the soil, and
- (iii) long-term loss of natural vegetation.

Marginal Drylands:

Marginal lands are understood primarily in a socioeconomic sense, where biological and economic productivity are low due to adverse climatic conditions (high variability in precipitation), edaphic conditions (low organic matter in soils) and topographic terrain (slopes).

People living in these areas typically suffer from poverty and are vulnerable to threats related to food scarcity.

Species diversity in marginal drylands is much lower than in the more favoured humid zones, although plant and animal species have developed remarkable adaptations to severe ecological and climatic conditions such as salinity and aridity.

Sustainability in Drylands

Sustainability is defined as a "characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs." This definition includes both temporal and spatial dimensions; the latter has been added to the earlier definition in the Brundtland report.

Vulnerability in Drylands:

Vulnerability is can be defined, in part, as lack of sustainability; however, the term "vulnerability" has been used in a richer and more complex sense. In drylands context, vulnerability can be understood as a situation where there are high risks to populations as well as to the sustainability of ecosystem goods and services.

Productivity in Drylands:

Productivity is defined as the total production of all ecosystem services. In the case of drylands, this includes crops, livestock and water. This is a bit different from the common usage of primary and secondary productivity.

Descriptive Statistics of Drylands

Subtypes	Aridity Index	Current area		Dominant Biome	Current population	
		Mkm^2	% global		× 1000	% global
Hyperarid	<0.05	9.78	6.6	Desert	101,615	1.7
Arid	0.05 - 0.20	15.66	10.6	Desert	222,204	3.7
Semiarid	0.20 - 0.50	22.59	15.3	Grassland	828,341	13.9
Dry subhumid	0.50 - 0.65	12.87	8.7	Forest	909,273	15.3
Totals		**60.90**	**41.2**		**2,061,433**	**34.7**

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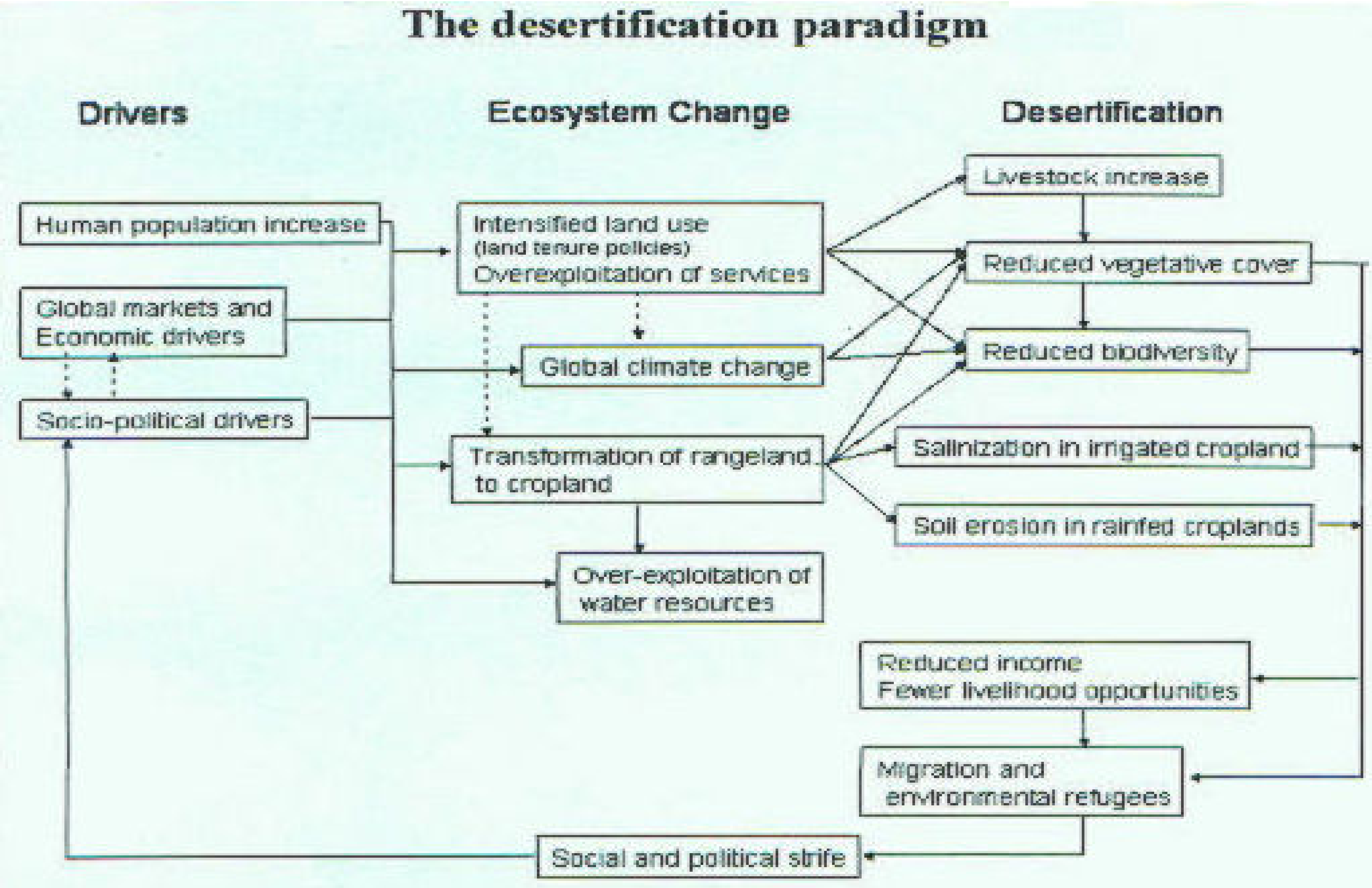
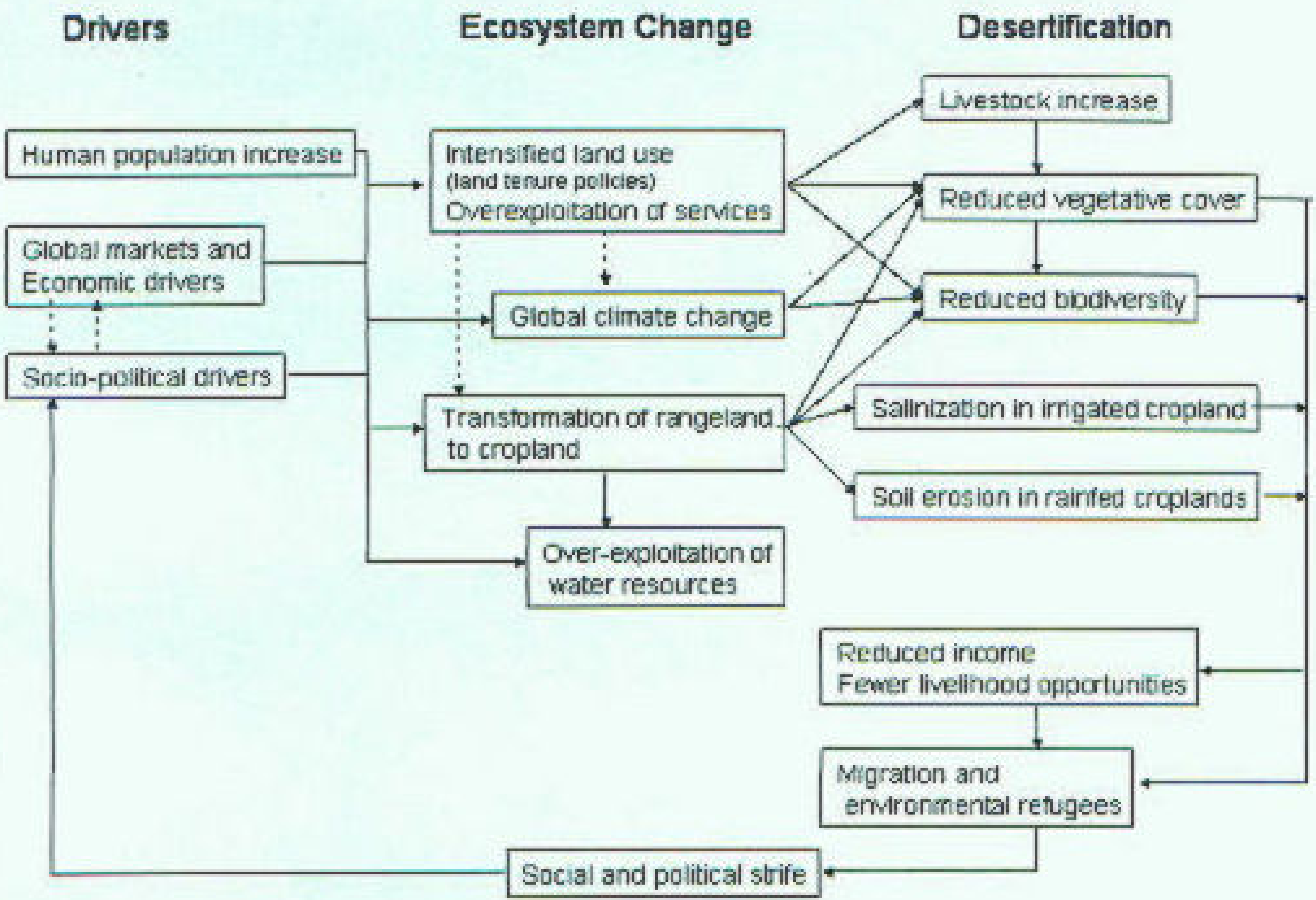
In dryland ecosystems, the moisture deficit not only constrains primary productivity directly, but it also affects its sensitivity to human use.

A conceptual framework of these impacts, leading to desertification is shown in the diagram



The desertification paradigm



- Drylands ecosystems typically cope with large inter-annual variability in precipitation.

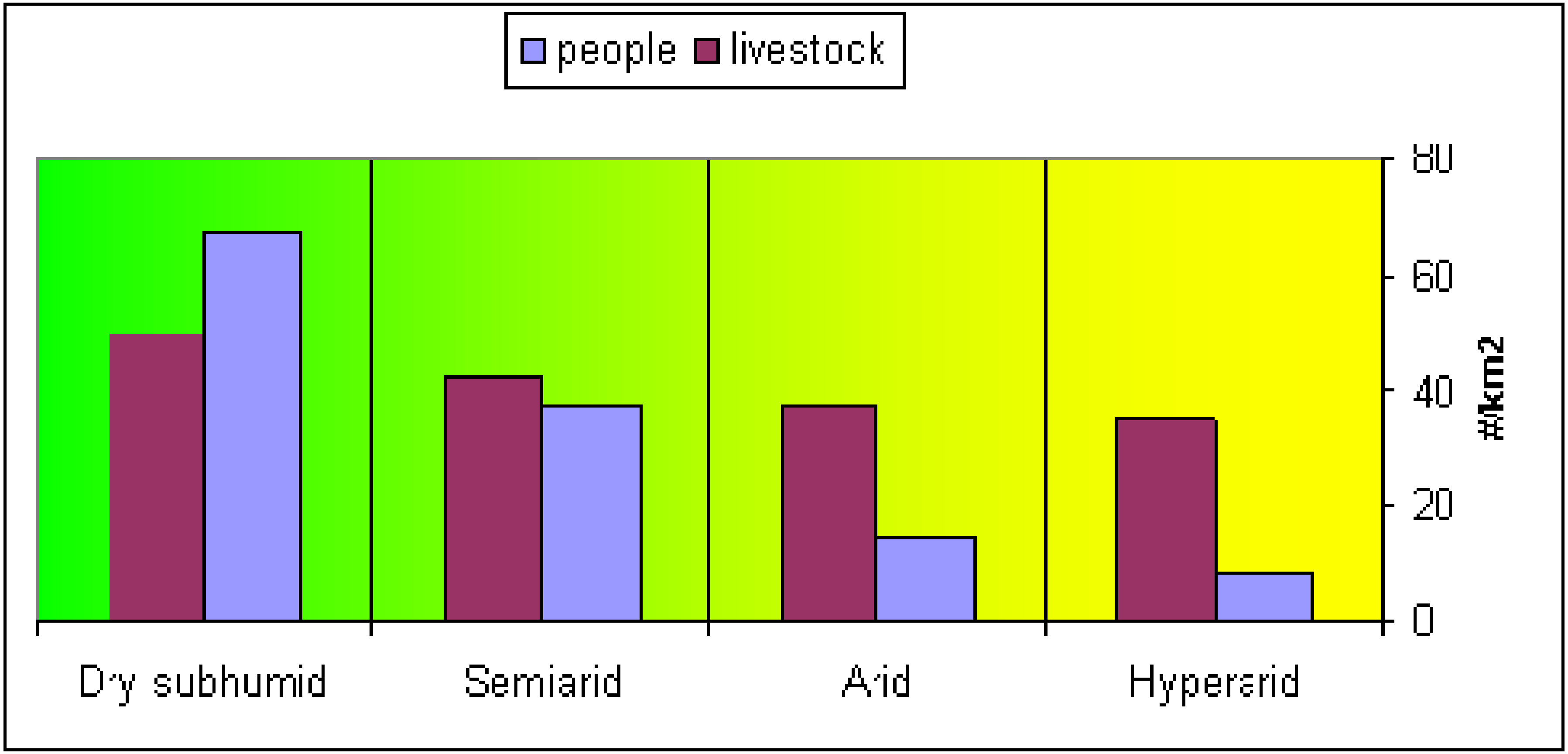
- The biota of each of the dryland types have adapted to this variability. However, the impacts exerted by anthropogenic activities can disrupt this stability and a new ecosystem state, with primary productivity futher diminished, is established.

- This phenomenon is called *desertification* or *land degradation*. It is an expression of a decline in the ability of a dryland ecosystem to provide the goods and services associated with primary productivity.

- The sensitivity of dryland ecosystems to anthropogenic impacts likely increases with their aridity - a little human pressure may not destabilize a dry subhumid ecosystem, but will degrade the productivity of an arid one.

- Conversely, human population pressures and the associated pressure of livestock decrease with aridity, as shown in the graph below.

Human and Livestock Densities in Drylands

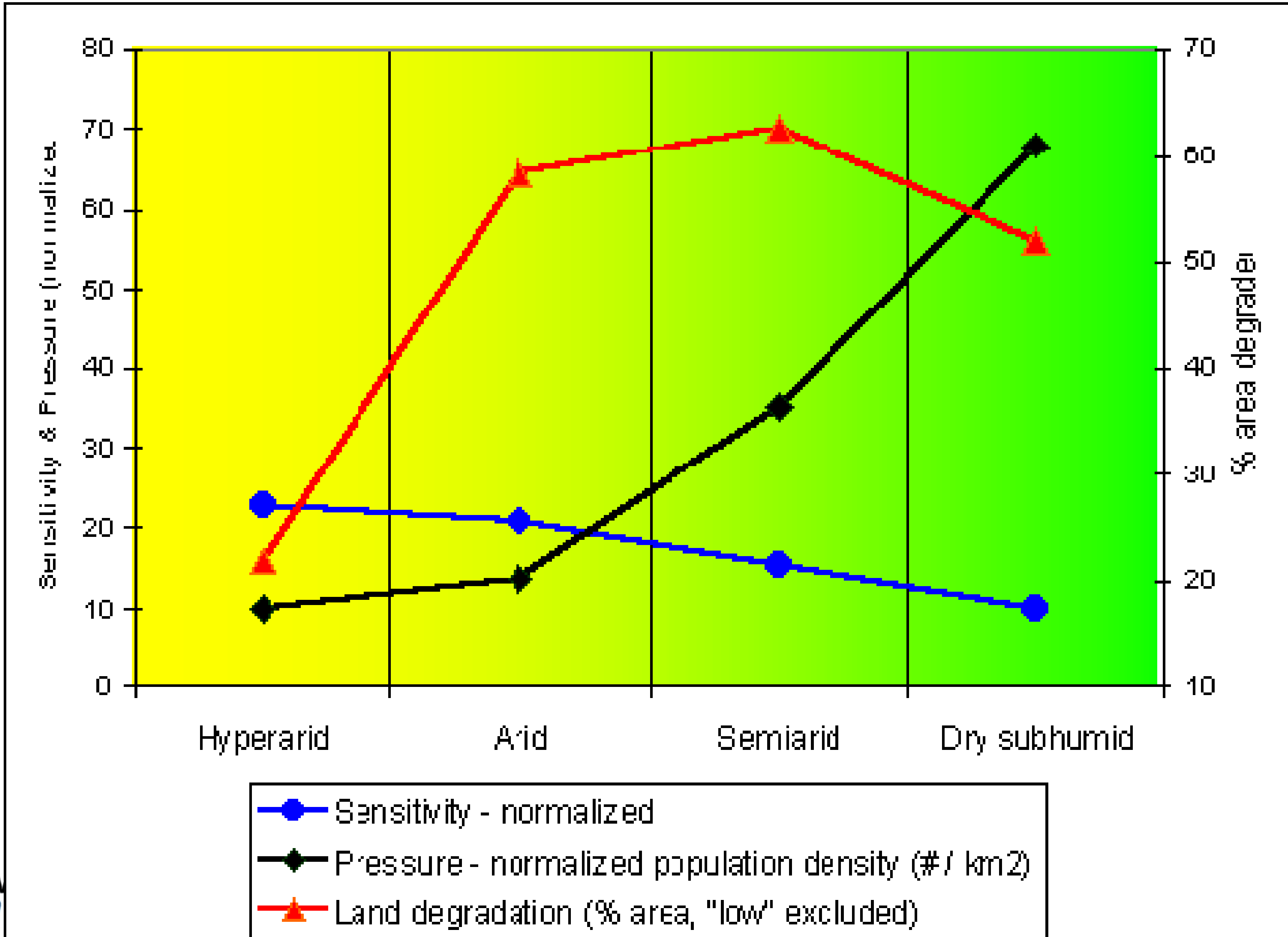


- **The vulnerability of dryland ecosystems with respect to their ability to provide goods and services can be described by a hump shaped curve along the aridity gradient, with a peak at the central section of the range.**

- **Semiarid and arid ecosystems, and especially the transition between the two, have medium sensitivity and are driven by a medium anthropogenic driving force, a combination that generates the highest vulnerability and consequent impact, i.e., desertification (please see graph below).**

- **As illustrated in the graph below, population increases as aridity declines but the degradation curve is hump shaped, indicating that sensitivity to human pressure [1- median of AI] increases with aridity. Sensitivity and pressure are normalized and lowest values set to 10.**

Population pressure and land degradation in drylands



- Based on data from the late 1980s, 29% of the land used by people in the drylands (excluding the hyperarid drylands that comprise less than 7% of all drylands, and are not tangibly used), is degraded.

- That is, its potential for primary productivity is reduced due to the attempts to increase its productivity above the natural state. For the same period, only 15% of land used by people outside the drylands was so degraded, indicating that drylands are more sensitive to human pressure.

- A more recent estimate is that 70% of all cultivated drylands are affected by desertification, 17% of drylands are already desertified, 24 billion tonnes of topsoil is lost every year due to desertification. This affects the livelihoods of 250 million people. See the table below for more details.

Drylands and Desertification

Land		Population	
Total area of drylands (and % of global land)	60.63 Mkm^2 (48%)	Total population in dryland (and % of global population)	2.13 billion (40%)
Desertified (GLASSOD)	10.52 Mkm^2 (17% of drylands, 7.8% of global)	Threatened by desertification	1 Billion
		Affected by desertification	250 Million
Not desertified	50.11Mkm^2 (52%)	Not affected or threatened	1.05 Billion

Desertification as Land Degradation

- The CCD (Convention to Combat Desertification) defines desertification as shorthand for land degradation in the drylands, yet the two terms are often used as if they are distinct

- The CCD also defines "land" according to its primary productivity service and "land degradation" as an implicit loss of provision of this service. With respect to the expression of land degradation - the relations between biological productivity and economic benefit depends on users' priorities - transforming woodland to cropland may decrease biological productivity, degrade the economic benefit of firewood production but increase the economic benefit of food production.

- With respect to the mechanisms of land degradation - changes in the properties of the land (soil, water, vegetation) do not correspond one-to-one to changes in productivity.

- Furthermore, a decline in both productivity and land qualities are insufficient evidence for land degradation because the decline in productivity may have been caused by changes in rainfall or in labour input more than by the decreased land qualities.

- Thus, a range of interacting variables that affect productivity should be addressed in order to assess objectively and unambiguously land degradation.

- Commonly considered degradation processes are vegetation degradation, water and wind erosion, salinization, soil compaction and crusting, and soil nutrient depletion. Pollution, acidification, alkalization, and water logging are often important locally.

- Field experiments, field measurements, field observations, remote sensing, and computer modeling are carried out to study these processes.

- The higher the aggregation level in each of these study approaches, the more problematic each of the methods becomes, either because of upscaling issues or because of questionable extrapolations and generalizations.

- **The Global Assessment of Soil Degradation focused on human-induced soil degradation but ignored climate-induced degradation and vegetation degradation.**

- **The data and maps of GLASOD were based on assessments by soil scientists, each judging the areas they knew best.**

- **These data formed the basis for the World Atlas of Desertification. Re-interpretation of existing data and attempts to consider the temporal and spatial dynamics of land processes, adaptive responses of land users and ground validation of remote sensing images and outputs of computer models improve perception of drylands' degradation.**

- **Indeed, tracking rainfall variability and land users' adaptive responses, it has been shown that desertification in the Sahel is less severe and widespread than earlier suggested.**

- **The Land Degradation Assessment in Drylands project (LADA) in which FAO, UNEP and other partners participate is intended to deliver up-to-date global assessments that take into account ecological, social, economic and technical information (see http://www.fao.org/ag/agl/agll/lada/default.stm).**

Agriculture and Cultivation in Drylands

Cultivation in Hyperarid and Arid Drylands

- **Most cultivation in the hyperarid and arid drylands (the desert biome) occurs in oases, where crops are irrigated by either fluvial, ground or local water sources (or a combination thereof).**

- **Since the middle of the last century, oases have borne increasing demographic and investment pressures. This has resulted in increased water removal and the annihilation of surrounding vegetation by overgrazing and firewood exploitation.**

- **Soil salinization has occurred either due to overexploitation of a groundwater-dependent oasis, or due to overexploitation of a fluvial-dependent oasis.**

- **The overexploitation of the Maghrebian oasis at the northern border of the Sahara was driven by population increase, policies to settle nomadic populations, investments generated by migrants working abroad and the transformation from self-sufficient to open-market economies in north-African countries.**

- **Pumping from deeper aquifers and expanding cultivated areas without drainage lead to spreading shallow water tables and subsequent soil salinization. In the Nile delta, traditional water management of the summer flood kept the delta water table 5 - 7 metres below surface during the low flow season.19th and 20th centuries' water management, including the construction of the Aswan dam, enabled year-round irrigation and out-of-season crops such as cotton. It also reduced water table depth, which resulted in soil salinization and a dramatic decline in crop yield.**

- In the Tarim basin of northwestern China, a combination of population increase and minor climatic fluctuations reduced the vegetation cover of dunes, resulting in sand movements.

  This led to losses of riparian woodlands in the oases due to sand encroachment, to doubling the area covered by shifting dunes, and to blocking downstream flood courses, leading to breakdown of the oases economy.

  This degradation of soil conservation service, caused by overexploitation of sand vegetation caused three large-scale crises since 2200 years BP. These crises have left behind several ruined cities and rendered out of service the southern branch of the Silk Road.

Cultivation in Semiarid Drylands

- In semiarid drylands, agricultural use of land is common and can be sustainable, particularly if runoff harvest designs are used.

- Commercial cropping irrigation is required for semiarid drylands, and therefore semiarid irrigation is widely associated with salinization hazards. For example, the accelerated population growth, agricultural encroachment since mid-20th century, and strong climatic fluctuation resulted in soil salinization in irrigated lands - especially in the fine-textured soils of Central Asia.

- The encroachment of agriculture into semiarid rangelands leads to decreasing yields due to progressive soil degradation in the newly occupied areas with poorer land quality

Cultivation in Dry Subhumid Drylands

- The dry subhumid drylands are exposed to freezing-thawing cycles and a relatively high recurrence of drought and strong winds. This leads to a high risk of topsoil loss.

- Once the topsoil is lost to wind, the underlying layers rich in calcium carbonate and poor in organic matter develop crusts that impede infiltration and foster further soil loss by gully erosion.

- Parallel to soil loss, there is also a decrease in water quality through larger sedimentation and non-point chemical pollution with salts, nutrients and pesticides

The traditional agricultural use of Mediterranean shrub lands and woodlands in the Mediterranean basin prevented soil loss through sophisticated terrace systems across hill slopes.

The rural population increase that started at the end of the 19th century occurred too fast to allow widespread land conditioning and triggered extensive soil losses.

The outcome was large upstream areas of exposed rock and accretion pulses in river deltas.

- **Comparing the mean annual loss of 0.07 ton soil per hectare by inter-rill and rill erosion of natural shrublands with rates of such erosion in shrublands converted to agriculture in Greece yielded a three-fold increase in erosion from wheat fields (P<0.001) and twenty fold in erosion from vineyards (P<0.02) during 1991-95 period of observations (Poesen & Hooke 1997, Kosmas et al. 1997).**

- **Such conversion also enhanced gully development Oostwoud et al. 2000 and gully initiation (Poesen et al. 2002): 39% of wheat fields on marls as compared to 8.2% of non-cultivated marl plots and 27% of almond groves on gravelly sand loams as compared to 6.2% of gravelly sandy loams plots, generated very active gully heads in south-east Spain (Oostwoud et al. 2000) .**

- **Population size in the northern Mediterranean countries stabilized and even declined during the second half of the 20th century, which brought about agricultural abandonment.**

- **However, soil and vegetation did not always recover. This is because rural populations maintained unstable structures (e.g. terraces, waterway networks) that slowly collapse after abandonment and these continue to deliver sediments.**

- **This erosion has often reduced soil depth beyond the threshold of vegetation recovery. Associated with soil erosion in Mediterranean ecosystems used as croplands, tree removal for agriculture increased storm flow peaks and flood risk, downstream sedimentation, landfill of water reservoir systems and decreasing water quality.**

Drylands and Anthropogenic Climate Change

Climate change affects dryland ecosystems in a number of critical areas

1. Decreased Grain and Forage Quality

- Possibly the most significant dryland ecosystem service to be affected by climate change is the provision of food and fibre. Modeling results show potential decreases in grain and forage quality, the latter being of particular interest to dryland ecosystems where pastoral management is key.

- Although plant productivity could increase under conditions of increased atmospheric carbon dioxide, such benefits may be offset by the adverse effects of higher than optimal temperatures. Increased air temperatures under climate change may reduce crop yields, which has significant implications for food security in countries with climate sensitive agricultural sectors and a high prevalence of drylands

- **Plant production, species distribution, disturbance regimes (e.g. frequency and extent of fire), insect/pest outbreaks, grassland/shrubland boundaries and non-intensive animal production would all be affected by climate change.**

- **For example, the IPCC (Intergovernmental Panel on Climate Change) Working Group 1 projected an increased frequency of extreme events. This could significantly impact on fire frequency and extent in fire-prone dryland ecosystems. Negative effects on the ecosystem provisioning services of previously benign anthropogenic burning regimes could increase**

Fire in the Savanna Grasslands of South Africa

Degraded Freshwater Quality

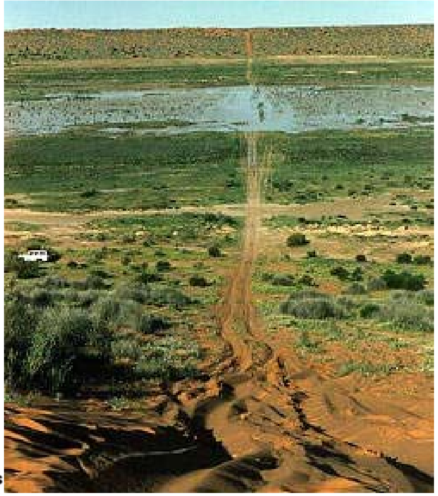
- A second critical dryland ecosystem service projected to be affected by climate change is freshwater. Dryland ecosystems are characterized by water deficits. Potential effects of climate change on water provisioning thus requires close attention.Under a changed climate, water quality would likely be degraded by increased water temperatures. Although this effect may be offset in areas where flows are projected to increase, water quality will degrade in areas where flows decrease.

Excessive Algae Growth

Changed Availability of Water Resources

- **Flood magnitude and frequency will increase in most regions, while low flows will decrease further in many dryland regions. The impact of climate change on water resource availability depends on changes in the volume, timing, and quality of stream flow and recharge as well as on human management factors such as:**
  - **system characteristics,**
  - **changing pressures on the system,**
  - **how the management of the system evolves, and**
  - **what adaptation measures are undertaken in the light of climate risk.**

- **It is conceivable then, that non-climatic stressors will have a greater impact on water resource availability than climate-change induced stress, reiterating the need for a continued focus on sustainable management of critical ecosystem services.**



Floodwater in Simpson Desert dunes, Australia

Increased Irrigation and Secondary Salinization

- Climate change may also substantially affect irrigation withdrawals. For example, increased frequency of dry spells might encourage agriculturalists in dryland areas to stabilize crop quality and yield through increased use of irrigation.

- Irrigation in semi-arid climates can be a major cause of secondary salinization. Although increased atmospheric carbon dioxide could reduce the effects of secondary salinization, any reduction may be offset by increased air temperatures.

Close up of Drip Irrigation and Salinization Around Cotton Plants

In dryland ecosystems overall, a changed climate might amplify the potential negative effects of an existing management regime (e.g. water, grazing) on the provisioning services of interest.

Such negative effects might result in the ecosystem becoming unstable and transitioning to a state of lower productivity with progressively higher costs of intervention and reversal.

Human Well-Being in Drylands

- **The elements of human well-being can be broadly categorized into five groups. Each of them can be further broken down into indicators and factors that are relevant for drylands.**

- **Security: Food security is an essential element of human well-being in drylands. Lack of food security is linked to socioeconomic marginalization, lack of proper infrastructure and social amenities, and often a lack of societal resilience. Prolonged droughts as well as floods can create insecurity in drylands.**

- **Basic materials for good life: Reduction of biological productivity due to water scarcity is the main limiting factor in the provision of basic materials for good life. Such a reduction also limits the livelihood opportunities in drylands and often leads to damaging practices, such as intensified cultivation.**

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- **Health**: **Nutrition and access to clean drinking water are the two main factors necessary to good health. In Asia, for example, the percentage of children under the age of 5 facing hunger is between 30 and 40%. This number is related to limitations in biological productivity and food security and reflects the overall nutritional condition in drylands.**

- **Good social relations**: **The quality of social relations can be gauged in terms of social strife (wars and political upheavals) and refugees. There are two types of refugees to consider:**
  - ***environmental refugees* - those who leave their homes due to environmental degradation and lack of viable livelihoods**
  - ***political refugees* - those who are displaced for political reasons but may impact availability of services in drylands where they are re-located.**

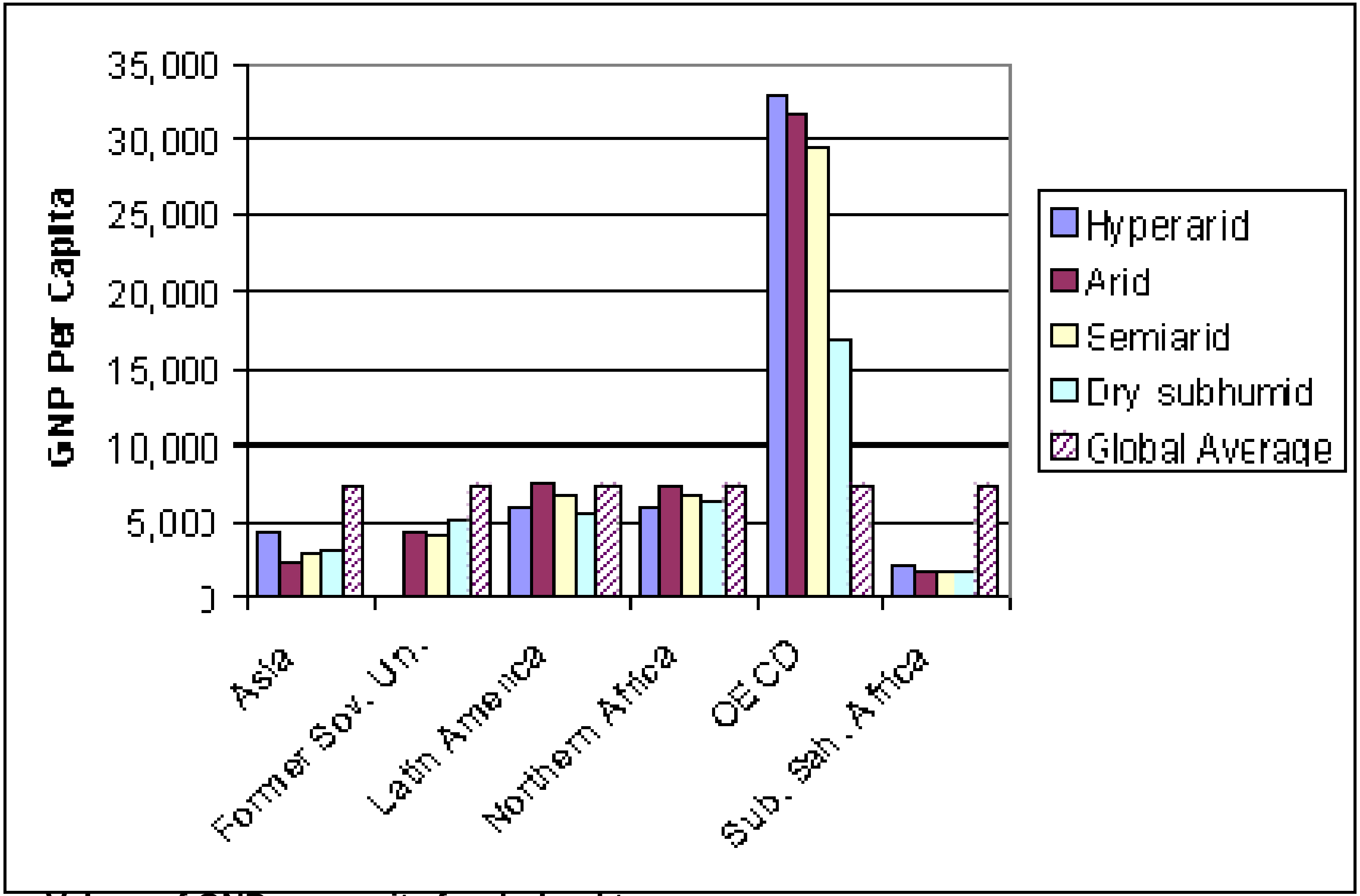
- **Freedoms and choice**: **With the exception of OECD countries, drylands peoples are mostly politically marginalized. In other words, their role in political decision-making processes is perceived as insignificant.**

- **Thus, *human well-being is directly or indirectly linked to the availability of ecosystem services, including provisioning, regulating, supporting, and cultural services.***

Relationship Between Ecosystem Conditions and the Basic Materials for a Good Life

- **Since sociopolitical drivers interfere with many of the elements of human well-being, it is difficult to fully explain the causal links between ecosystem conditions and services and human well-being. However, we can examine the links between the basic materials for a good life, such as food, fibre and energy, and ecosystem services, such as biological productivity, water and sanitation availability, floods/droughts, etc.**

- **The relationship between human well-being and level of aridity is explored here using two key indicators: *gross national product per capita* and *infant mortality rates*. This analysis is done at a regional level and is based on sub-national data developed for the Millennium Ecosystem Assessment process. The underlying assumption is that the level of aridity is directly correlated to the availability of ecosystem services as well as to the level of stress/degradations observed in drylands.**



Values of GNP per capita for dryland types

(Note: there are no hyper-arid drylands in the former Soviet Union region)

The graph above shows no strong trend between economic performance, measured as GNP per capita, and the level of aridity.

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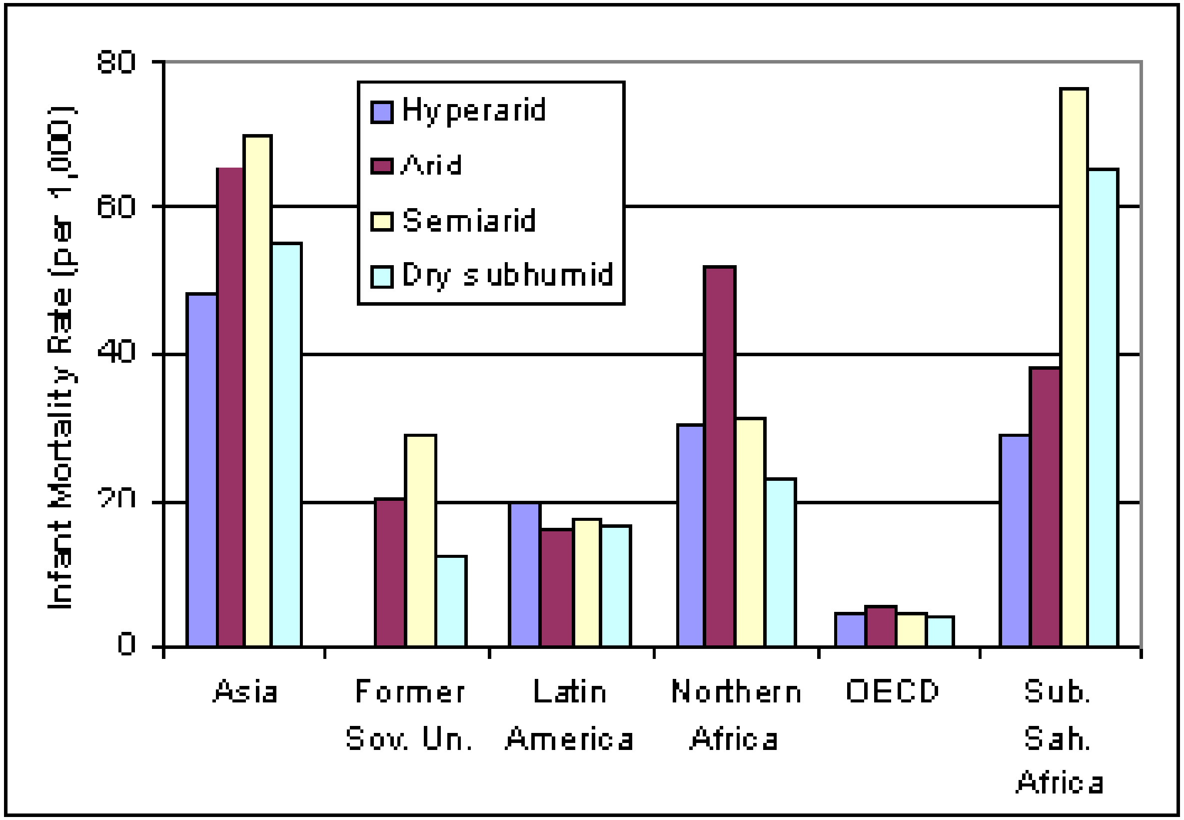


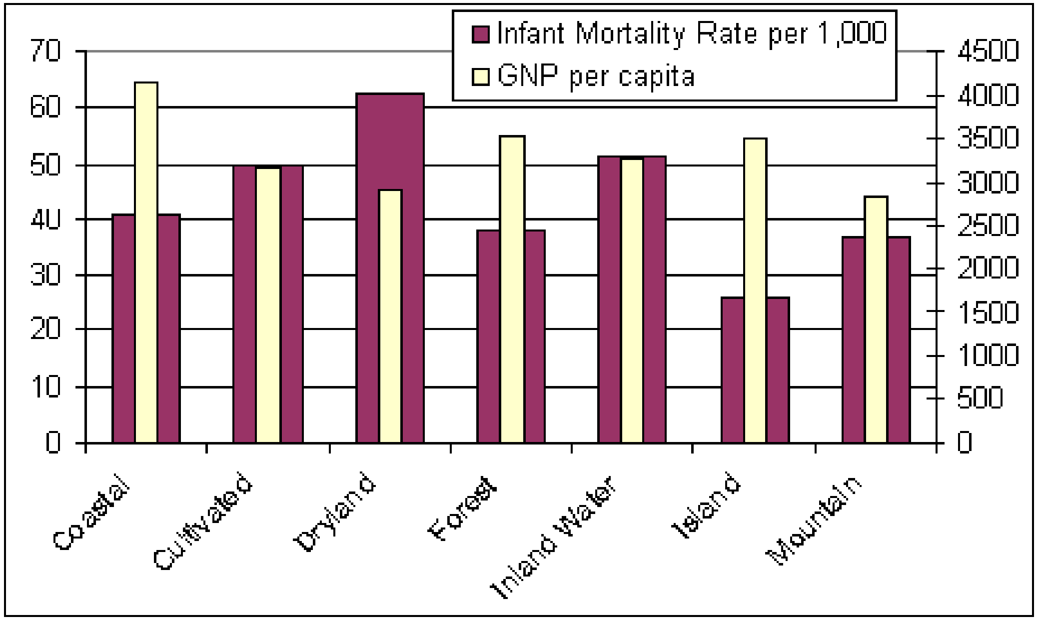
Infant mortality rates (per 1,000) in drylands.

The graph above shows the infant mortality rate in dryland sub-types, in which a consistent correlation between aridity and infant mortality rate is not apparent. The inter-regional differences are quite significant in OECD countries where infant mortality rates are lower than all the other regions. The situation is the worst in Asia and Africa, where arid and semi-arid regions suffer the most.

One may argue that infant mortality rates are also reflective of a complex set of factors like food and nutritional security, health provisioning infrastructure, and general economic conditions.

Thus, the potential relationship between infant mortality and the provisioning of ecosystem services is masked by other governance and structural factors, making it difficult to make definitive conclusions.

The fact that drylands people are under-privileged becomes evident when we undertake an intra-regional comparison of infant mortality rates and GNP, as shown in the graph below. Drylands people have the highest infant mortality rates, and their economic condition is the worst. Indeed, one may argue that the two factors are linked together



Comparison of infant mortality rates and GNP per capita

What drives the relative and absolute impoverished state of human well-being in drylands?

Two different, but not entirely distinct, explanations may be offered:

1. ***Biological productivity*** **is the most important drylands ecosystem service, providing people with food, fibre, and biomass energy.**

   Dryland people cultivate these commodities either for their own essential use, or for an income that in turn enables them to obtain items that are necessary to achieve and maintain their well-being. Therefore, the deteriorating condition of the services that support biological productivity, brought about by direct or indirect drivers, are detrimental to the well-being of dryland peoples.

   When biological products cannot be obtained within drylands, it adversely impacts the basic materials for good life as well as all other key components of well-being, including health, security, good social relations, and freedom of choice.

2. ***Water scarcity*** **in drylands is closely linked to reduced biological productivity. The impairment of water provisions – as a result of global climate change and increasing population stresses – leads to a decrease in biological productivity and an increase in human poverty.**

   Water scarcity also results in a greater number of people without access to clean drinking water and adequate sanitation, jeopardizing public health. By being impoverished, dryland people also become socially and politically marginalized.

   This marginalization leads to reduced human security and increased vulnerability to drivers of change.

Integrated Water Resource Management in Drylands

- In drylands, as in other regions, any water transfer in and between river basins affects communities along those basins. Thus, it is important to view water resources strategically at the river basin level, particularly when water transfer schemes cross national and international boundaries.

- Appropriate management and maintenance of existing irrigation systems is critical for long-term sustainability. It is also important to manage demand of water resources, rather than managing the supply alone.

While developing integrated water management approaches for drylands, the following must be considered:

- **Existing water management systems are often complex, with limited capacity for adoption of advanced technologies. Limited fiscal and human resources often affect the adequateness of the management practices. This is further exacerbated by a rapidly-increasing population in drylands.**

- **The bureaucratic mechanisms in place to oversee water management at the national level are also complex. In contrast, the international water management mechanisms are currently in their infancy and are undergoing evolution.**

- Currently, functional water distribution systems often result in the uneven distribution of water between end-users. Poor drainage systems lead to salinization of soils.

- Integrated water management approaches that account for all natural resources and have the full involvement of local communities have been successful. Another successful approach is the promotion of landscape architecture and the movement away from traditional, mono-cropping agricultural systems.

- Governments sometimes provide perverse subsidies to projects that over-utilize the existing water resources and are detrimental to the environment in general.

Innovative Water Management in Drylands

- A number of innovative approaches and solutions to water resource management in drylands are available. These water management approaches are multidisciplinary and multi-stakeholder. A key element of successful water and resource management is building partnerships for joint action. These partnerships can be at the institutional or professional level and the scale can vary from local to international. It is most important to involve end-users, such as farmers, in the development and implementation of activities.

- Successful implementation of these approaches requires that scientifically-based policy guidelines be developed for governments. The long - and short-term evaluation of environmental and socioeconomic impacts of such policies should be a critical component of the policy development process. It is also important to consider demand management policies, rather than focus just on water supply side.

Innovative Water Management in Drylands

The Wadi Mousa Wastewater Treatment Plant in Jordan

Although their application requires caution and careful evaluation, several new and innovative approaches are available for water management.

- **Water productivity can be significantly improved through recently-developed methods of water harvesting, supplemental irrigation and deficit irrigation. These technologies have been quite successfully tested at a pilot scale and now require a broader implementation.**

Innovative Water Management in Drylands

- The chronic shortage of water in arid areas requires us to look for new and innovative solutions. One key option is to recycle and re-use as much of the available water as possible.

  This solution obviously requires development and implementation of wastewater treatment technologies as well as effective management of existing resources. Some of these methodologies have been evaluated at relatively small scale and require a more careful evaluation as broader-scale implementation schemes are developed.

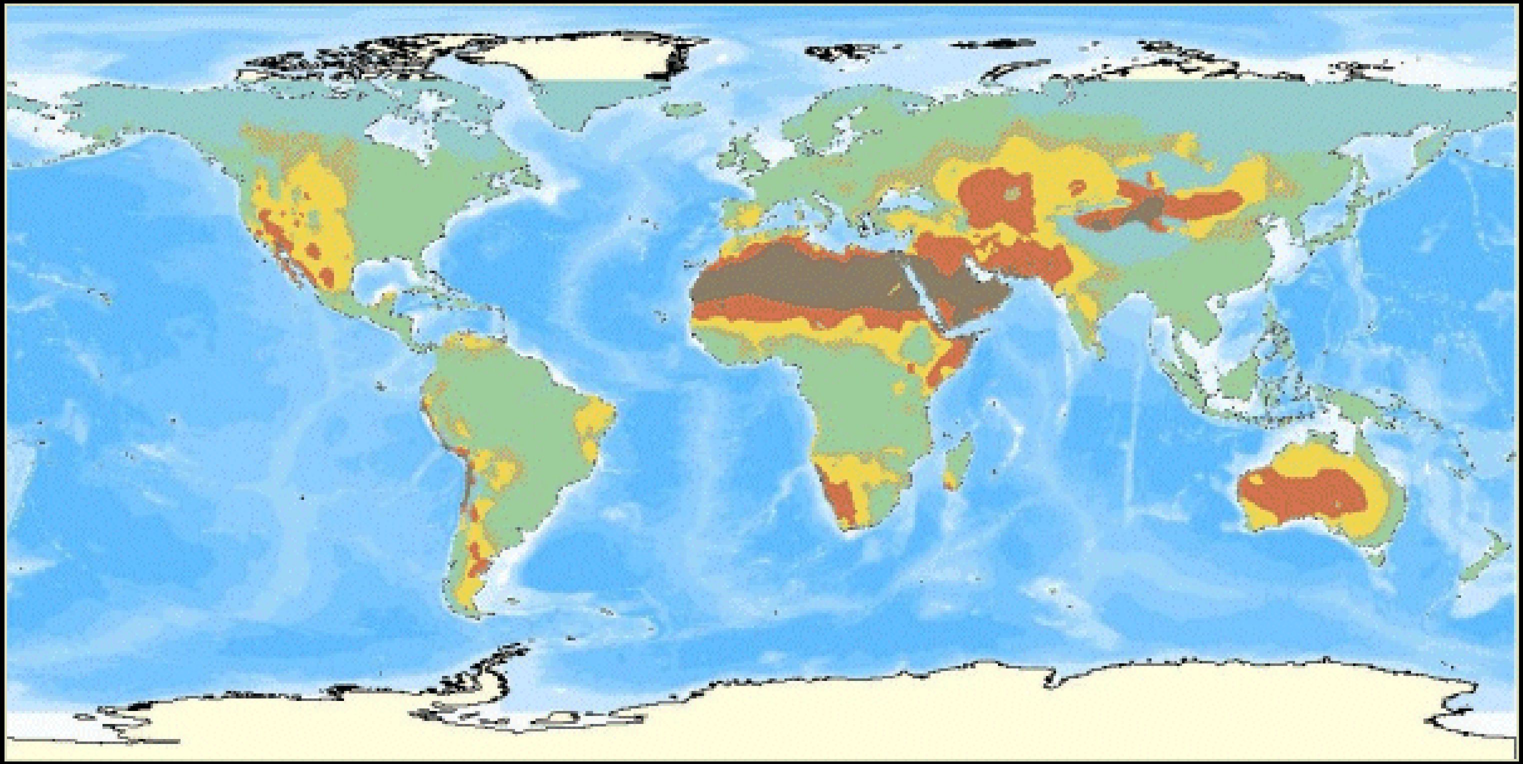
- Effectively managing and maximizing the productivity of existing water resources is critical in dry areas where water harvesting and supplemental irrigation can be useful.

  It is also important to keep in mind that often optimum crop production can be achieved by spreading supplemental irrigation over larger tracts of land. In other words, *water – not land – is the limiting factor in determining the crop productivity of drylands*

Innovative Water Management in Drylands

- For wastewater treatment technologies to be effective, they have to be relatively inexpensive and amenable to local production. In this respect, attention should be given to natural ecosystems as treatment processes, such as soil infiltration treatment and oxidation ponds.

- The long-term impacts of applying treated wastewater should be carefully evaluated. In particular, the long-term impact of heavy metals and other pathogenic pollutants commonly found in wastewater should be assessed. The impacts on both environment and human health deserve our attention. Sustained monitoring is necessary in areas where treated waters are applied. This monitoring can be further enhanced through modeling and simulations



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